



Fisheries and Oceans
Canada

Pêches et Océans
Canada

Science

Sciences

CSAS

Canadian Science Advisory Secretariat

SCCS

Secrétariat canadien de consultation scientifique

Research Document 2011/135

Document de recherche 2011/135

Pacific Region

Région du Pacifique

**Stock Assessment and Recovery
Potential Assessment for Quillback
Rockfish (*Sebastes maliger*) on the
Pacific Coast of Canada**

**Évaluation des stocks et évaluation du
potentiel de rétablissement du sébaste à
dos épineux (*Sebastes maliger*) dans les
eaux côtières canadiennes du Pacifique**

K. L. Yamanaka¹, M.K. McAllister², M.-P. Etienne³ and R. Flemming¹

¹Fisheries and Oceans Canada
Pacific Biological Station
Nanaimo, B.C. V9T 6N7, Canada

²University of British Columbia
Fisheries Centre
Aquatic Ecosystems Research Laboratory
Vancouver, B.C. V6T 1Z4, Canada

³AgroParistech /INRA UMR 518 MIA
16 rue Claude Bernard
F-75231 Paris Cedex 05, France

This series documents the scientific basis for the evaluation of aquatic resources and ecosystems in Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

La présente série documente les fondements scientifiques des évaluations des ressources et des écosystèmes aquatiques du Canada. Elle traite des problèmes courants selon les échéanciers dictés. Les documents qu'elle contient ne doivent pas être considérés comme des énoncés définitifs sur les sujets traités, mais plutôt comme des rapports d'étape sur les études en cours.

Research documents are produced in the official language in which they are provided to the Secretariat.

Les documents de recherche sont publiés dans la langue officielle utilisée dans le manuscrit envoyé au Secrétariat.

This document is available on the Internet at:

Ce document est disponible sur l'Internet à:

<http://www.dfo-mpo.gc.ca/csas-sccs>

ISSN 1499-3848 (Printed / Imprimé)

ISSN 1919-5044 (Online / En ligne)

© Her Majesty the Queen in Right of Canada, 2012

© Sa Majesté la Reine du Chef du Canada, 2012

Canada

TABLE OF CONTENTS

TABLE OF CONTENTS.....	III
LIST OF TABLES.....	IV
LIST OF FIGURES.....	V
ABSTRACT.....	VI
RÉSUMÉ.....	VII
1 INTRODUCTION.....	1
2 BACKGROUND BIOLOGY.....	2
2.1 RANGE.....	2
2.2 HABITAT.....	2
3 ASSESSMENT OF STATUS.....	2
3.1 STOCK ASSESSMENT METHODOLOGY.....	2
3.2 FISHERIES REFERENCE POINTS.....	3
4 INPUTS TO THE MODEL.....	3
4.1 LIFE HISTORY PARAMETERS.....	3
4.2 HISTORIC CATCH.....	4
4.3 ABUNDANCE TREND DATA.....	4
5 STOCK ASSESSMENT MODELLING.....	4
5.1 THE REFERENCE CASE.....	4
5.2 SENSITIVITY TESTS.....	5
6 SOURCES OF UNCERTAINTY.....	5
7 QUESTIONS AND ANSWERS.....	6
7.1 PHASE I: ASSESS CURRENT/RECENT SPECIES STATUS.....	6
7.2 PHASE II: SCOPE FOR MANAGEMENT TO FACILITATE RECOVERY.....	9
7.3 PHASE III: SCENARIOS FOR MITIGATION AND ALTERNATIVE TO ACTIVITIES..	10
8 CONCLUSIONS AND RECOMMENDATIONS.....	13
9. REFERENCES.....	14
10. TABLES.....	17
11. FIGURES.....	27
APPENDIX A. ASSESSMENT MODEL SPECIFICATION.....	33
APPENDIX B. BIOLOGICAL DATA ANALYSIS.....	48
APPENDIX C. COMMERCIAL CATCH 1918 TO 2010.....	60
APPENDIX D. RECREATIONAL CATCH.....	88
APPENDIX E. TREND DATA.....	96
APPENDIX F. MODEL RESULTS.....	131
APPENDIX G. SENSITIVITY ANALYSES.....	141
APPENDIX H. REQUEST FOR SCIENCE ADVICE.....	148

LIST OF TABLES

Table 1. Catch in tonnes by year for the years 1918 to 2010 used in the Quillback Rockfish- outside management unit stock assessment. Catches include landed, discarded and unreported catches.	17
Table 2. Catch in tonnes by year for the years 1918 to 2010 used in the Quillback Rockfish- inside management unit stock assessment. Catches include landed, discarded and unreported catches.	19
Table 3. Research surveys and catch records reviewed for use as stock trend data for Quillback Rockfish, by management unit (inside/outside), survey name, gear type, survey year span, number of surveys within the span, total number of samples (sets, tows, transects), number of sets that contained Quillback Rockfish, whether the data was used in the assessment and the most recent reference for the survey.	21
Table 4. Posterior mean, median, SD, and CV for parameters and stock status indicators for B.C. Quillback Rockfish – outside management unit. Posterior medians for C_{2011}/MSY , C_{2011}/R_{py2011} , B_{1918}/K , and all eight catchability parameters (q) were calculated using a lognormal approximation based on the posterior mean and SD. All other posterior medians were obtained directly from a resample from the importance draws.	22
Table 5. Posterior mean, median, SD, and CV for parameters and stock status indicators for B.C. Quillback Rockfish – inside management unit. Posterior medians for C_{2011}/MSY , C_{2011}/R_{py2011} , B_{1918}/K , and all eight catchability parameters (q) were calculated using a lognormal approximation based on the posterior mean and SD. All other posterior medians were obtained directly from a resample from the importance draws.	23
Table 6. BSP Posterior median estimates of three generations of population decline ($B_{fin}/$ B_{init}) for the years 1997-2010 for the Reference Case (Ref. 1) and under a number of the key alternative scenarios for the Outside Quillback rockfish populations.	24
Table 7. BSP Posterior median estimates of three generations of population decline ($B_{fin}/$ B_{init}) for the years 1997-2010 for the Reference Case (Ref. 1) and under a number of the key alternative scenarios for the Inside Quillback rockfish populations.	24
Table 8. Stock status indicators for Quillback Rockfish - outside management unit after 5, 15, 30 and 90 years. Policies are constant total fishing mortality (TFM) policies (tonnes). B_{FINAL} is the biomass in the final year of the projection (2016 for 5-year horizon, 2026 for 15-year horizon, 2041 for 30-year horizon, and 2101 for 90-year horizon). Probabilities (P) are presented for 4 stock status indicators: B_{FINAL} will be above: the Limit Reference Point (40% of B_{MSY}), the Upper Stock Reference (80% of B_{MSY}), the target biomass of B_{MSY} , and the current 2010 biomass (B_{2010}).	25
Table 9. Stock status indicators for Quillback Rockfish - inside management unit after 5, 15, 30 and 90 years. Policies are constant total fishing mortality (TFM) policies (tonnes). B_{FINAL} is the biomass in the final year of the projection (2016 for 5-year horizon, 2026 for 15-year horizon, 2041 for 30-year horizon, and 2101 for 90-year horizon). Probabilities (P) are presented for 4 stock status indicators: B_{FINAL} will be above: the Limit Reference Point (40% of B_{MSY}), the Upper Stock Reference (80% of B_{MSY}), the target biomass of B_{MSY} , and the current 2010 biomass (B_{2010}).	26

LIST OF FIGURES

Figure 1. Quillback Rockfish management units on the Pacific coast of Canada. Outside management unit is made up of the remainder of the coast (shaded in grey). Inside management unit extends along the protected waters south and east of Vancouver Island (shaded in black).....	27
Figure 2. Quillback Rockfish stock status for the outside and inside management units in B.C. Consistent with DFO's Precautionary Approach and Fisheries Reference Points stock status is presented as the median biomass in 2011 over the biomass at MSY with 95% confidence intervals.	28
Figure 3. Catch, and posterior median and 90% probability interval for stock biomass (t) of Quillback Rockfish - outside management unit, and the observed stock trend indices divided by their posterior median value for the catchability coefficient for years 1918 to 2010. Results are shown for the reference case.....	29
Figure 4. Catch, and posterior median and 90% probability interval for stock biomass (t) of Quillback Rockfish - inside management unit, and the observed stock trend indices divided by their posterior median value for the catchability coefficient for years 1918 to 2010. Results are shown for the reference case.....	29
Figure 5. Time series estimates for Quillback Rockfish – outside management unit of the ratio of posterior median F_y/F_{msy} to stock biomass relative to B_{msy} for the reference case BSP model. Trajectories start at the right and proceed to the left.....	30
Figure 6. Time series estimates for Quillback Rockfish – inside management unit of the ratio of posterior median F_y/F_{msy} to stock biomass relative to B_{msy} for the reference case BSP model. Trajectories start at the right and proceed to the left.....	30
Figure 7. Projections showing 90% probability intervals (dotted lines) and medians (solid lines) for outside quillback rockfish Reference Case given the following fixed total fishing mortality: a. 30 t, b. 60 t, c. 90 t, d. 120 t, e. 150 t.....	31
Figure 8. Projections showing 90% probability intervals (dotted lines) and medians (solid lines) for inside quillback rockfish Reference Case given the following fixed total fishing mortality: a. 0 t, b. 10 t, c. 20 t, d. 30 t, e. 40 t.....	32

Correct citation for this publication:

Yamanaka, K.L., McAllister, M.K., Etienne, M.-P., and Flemming, R. 2012. Stock Assessment and Recovery Potential Assessment for Quillback Rockfish (*Sebastes maliger*) on the Pacific Coast of Canada. DFO Can. Sci. Advis. Sec. Res. Doc. 2011/135. vii + 151 p.

ABSTRACT

The Committee On the Status of Endangered Wildlife In Canada (COSEWIC) designated Quillback Rockfish in British Columbia as threatened in November 2009. The rationale for this designation are their inherent low productivity due to longevity (95 years), late maturation (50% at 11 years), slow growth, and episodic recruitment that is dependent on ocean conditions, accessibility and vulnerability to commercial, recreational and Aboriginal fisheries, and the 50 to 75% decline in some survey indices since the mid-1980's.

This document provides background information and a coastwide stock assessment of Quillback Rockfish intended to support a Recovery Potential Assessment and Government decision making in 2011. Although COSEWIC recognizes only one coastwide designatable unit for Quillback Rockfish, this assessment is divided into two management units: inside and outside. Stock status is determined relative to fishery reference points consistent with DFO's decision making framework that incorporates the Precautionary Approach.

A Bayesian state space surplus production model is employed which requires a time series of annual catch biomass from each of the fisheries, abundance indices (CPUE) from research surveys, estimated parameters including carry capacity, intrinsic rate of population growth, biomass in the first year of the model, and catchability for each CPUE series. A Reference Case model is used for management advice and sensitivity analyses are performed to assess the influence of various inputs into the model on the stock outcomes. The model is then projected over three generations into the future to develop decision tables which are presented as probabilities for four stock status indicators given various fixed total fishing mortality harvest policies.

RÉSUMÉ

En novembre 2009, le Comité sur la situation des espèces en péril au Canada (COSEPAC) a désigné le sébaste à dos épineux en Colombie-Britannique comme étant une espèce menacée. La justification de cette désignation en est son faible taux inhérent de reproduction en raison de sa longévité (95 ans), sa maturation tardive (50 % à 11 ans), sa croissance lente, ainsi que les recrutements épisodiques selon les conditions de l'océan, l'accessibilité et la vulnérabilité à la pêche commerciale, récréative ou par les Autochtones, de même que le déclin de 50 à 75 % depuis le milieu des années 1980 d'après certains indices de relevés.

Ce document donne des renseignements généraux et une évaluation des stocks de sébaste à dos épineux pour l'ensemble de la côte, à l'appui d'une évaluation du potentiel de rétablissement et de la prise de décision du gouvernement en 2011. Même si le COSEPAC ne reconnaît qu'une seule unité désignable pour l'ensemble de la côte pour le sébaste à dos épineux, cette évaluation est divisée selon deux unités de gestion : intérieure et extérieure. L'état des stocks est déterminé par rapport à des points de référence de pêche conformes au cadre décisionnel du MPO intégrant l'approche de précaution.

On utilise un modèle bayésien de l'espace d'états de la production excédentaire qui nécessite une série chronologique de la biomasse des prises annuelles pour chacun des facteurs que sont les pêches, les indices d'abondance (CPUE) des levés de recherche, les paramètres estimés incluant la capacité biotique, le taux intrinsèque de croissance de la population, la biomasse au cours de la première année du modèle et la capturabilité pour chaque série de CPUE. Un modèle de scénario de référence est utilisé pour l'avis sur la gestion et des analyses de sensibilité sont effectuées afin d'évaluer l'influence des diverses données fournies au modèle sur les résultats concernant les stocks. Le modèle est ensuite projeté sur trois générations à venir afin de mettre au point des tables de décision qui sont présentées à titre de probabilités pour quatre indicateurs de situation des stocks en fonction de diverses politiques établies pour le total des captures et de la mortalité par la pêche.

1 INTRODUCTION

The purpose of this document is to assess Quillback Rockfish coastwide in British Columbia (B.C.) to determine stock status relative to fishery reference points within DFO's Precautionary Approach framework and estimate future stock outcomes given various fixed total fishing mortality harvest policies. This document provides information to support a Recovery Potential Assessment and Government decision making in 2011 (DFO 2009).

Quillback Rockfish (*Sebastes maliger*) from the Strait of Georgia, B.C., were initially assessed with other commercially exploited rockfish (*Sebastes spp.*) in 1986 (Richards 1986a). Since then, various coastwide assessments have been conducted (Yamanaka and Richards 1992, 1993a, 1994, 1995, Yamanaka 1995, unpublished manuscript, PSARC G95-11, Yamanaka and Kronlund 1997, Kronlund et al. 1999). The last coastwide stock assessment for the inshore rockfish complex (*Sebastes ruberrimus*, *S. maliger*, *S. caurinus*, *S. melanops*, *S. nigrocinctus*, and *S. nebulosus*) was presented in 2001 (Yamanaka and Lacko, 2001). The biology and distribution of Quillback Rockfish in B.C. was reviewed in Yamanaka et al. (2006). The Committee On the Status of Endangered Wildlife In Canada (COSEWIC) published a status report on Quillback Rockfish, based on this review, in 2009 (COSEWIC, 2009). COSEWIC considered this status report and designated Quillback Rockfish in B.C. as threatened¹ in November 2009.

The rationale for COSEWIC's threatened designation for Quillback Rockfish in B.C. are their inherent low productivity due to longevity (95 years), late maturation (50% at 11 years), slow growth, and episodic recruitment that is dependent on ocean conditions, accessibility and vulnerability to commercial, recreational and Aboriginal fisheries, and the 50 to 75% decline in some survey indices since the mid-1980's. (http://www.sararegistry.gc.ca/species/speciesDetails_e.cfm?sid=1062).

For this assessment, the B.C. coastwide Quillback Rockfish designatable unit is divided into two management units; inside (East side of Vancouver Island) and outside (remainder of the coast) (Figure 1). Although only one designatable unit for Quillback Rockfish is recognized by COSEWIC, fishery management for these two units have been separate and unique since the inception of the directed commercial fishery for hook and line rockfish in 1986. Stock status and projections are presented separately for these two management units.

Stock status is assessed using a Bayesian surplus production (BSP) assessment model recently used to assess the inside stock of yelloweye rockfish in B.C. (Yamanaka et al. 2012). The data required for more complex age structured models are not yet available for a coastwide assessment of Quillback Rockfish. Fishing is the primary source of mortality identified for Quillback Rockfish in the COSEWIC status report (2009). No other potential source of mortality is examined in this document. Future stock outcomes from a reference case BSP model are used to assess the recovery potential of the Quillback Rockfish stock under various fixed total fishery mortality harvest policies.

This document attempts to answer the 17 questions posed in the *Revised Protocol for Conducting Recovery Potential Assessments* (DFO 2009). The main document provides background information and briefly describes analyses conducted for the assessment and provides full details of these analyses in appendices.

¹a wildlife species likely to become endangered if limiting factors are not reversed (COSEWIC Definitions)

2 BACKGROUND BIOLOGY

2.1 RANGE

Quillback Rockfish range from Kodiak Island in the Gulf of Alaska (Mecklenburg et al. 2002) to Anacapa Passage in Southern California (Love and Lea 1997) and are common from Southeast Alaska to Northern California (Love et al. 2002). Quillback Rockfish are a common species coastwide in B.C.

Throughout their distribution range, Quillback Rockfish occupy a depth range from 2 metres (m) (Love et al. 2002) to 274 m (Phillips 1957). In B.C., based on 2.5 to 97.5 percentiles of fisheries catches, Quillback Rockfish occupy a depth range from 14 to 143 m (Yamanaka et al. 2006). Juvenile rockfish tend to settle onto benthic habitats at shallower depths than adults. Visual observations of Quillback Rockfish fish ≤ 20 and >20 centimetres in length occupy a median depth of 48 m and 60 m, respectively and a maximum depth of 159 m and 182 m, respectively (Yamanaka et al. 2006).

2.2 HABITAT

Quillback Rockfish are associated with rocky marine habitats throughout their distribution and depth range. In B.C. they are observed hovering near to or settled upon high relief rock ridges, reefs, cobbles and broken rock, and occupying crevices, cloud sponges and crinoid aggregations (Richards 1986b, Matthews 1990, Murie et al. 1994, Yamanaka et al. 2006). Temperature and salinity ranges for Quillback Rockfish observed *in situ* are 8.1 to 12.1° C and 28.2 to 35 parts per thousand, respectively (Yamanaka et al. 2006). Temperature and salinity limits for this species are unknown.

Young of the year Quillback Rockfish recruit to shallow rocks and detached plant material over sandy bottoms (Love 2002). Older juveniles move inshore to protected areas and are most abundant in low energy rock areas associated with bull kelp cover (Love et al. 2002). Like many rockfish, larger individuals occupy deeper habitats (Lea et al. 1999). This species exhibits movement within home ranges of 30 to 1500 m² and will home from displacements of 500 m (Matthews 1989). Residence requirements for this marine species are unknown and likely do not exist.

An estimate of habitat area occupied by Quillback Rockfish in B.C., derived from commercial fishing catch records, is approximately 27,000 km² (Yamanaka 2006). Potential habitat area for this species, based solely on 95 percentiles of their depth range (14 to 147 m) estimated coastwide in B.C. is 56,000 km². (Yamanaka et al. 2006). The actual habitat of Quillback Rockfish in B.C. is probably somewhere in-between these estimates as not all marine areas have been fished in B.C., hence occupied habitat is underestimated and not all potential habitat is rock bottom, hence potential habitat is overestimated. The marine habitat in B.C. has remained as it is today since the last glaciation (Thomson et al. 2008).

3 ASSESSMENT OF STATUS

3.1 STOCK ASSESSMENT METHODOLOGY

A Bayesian state space surplus production (BSP) model was employed, similar to those applied in the 2008 assessment of B.C. Bocaccio Rockfish (*Sebastes paucispinis*) and the 2011 assessments of the inside stock of Yelloweye Rockfish (*S. ruberrimus*), outside stocks of Lingcod (*Ophiodon elongatus*), and Atlantic Redfish (McAllister and Babcock 2006, Stanley et

al. 2009, Yamanaka et al. 2012, King et al. 2012, McAllister and Duplisea 2011). As is the case with these assessments, there are insufficient age data for Quillback Rockfish coastwide to employ more complex age-structured models. BSP model specifications are presented in Appendix A. The BSP assessment model attributes the source of interannual variations in Quillback Rockfish mortality to fisheries and changes in fishing effort. The model requires a time series of annual catch biomass from each of the fisheries and at least one abundance index of catch per unit of effort (CPUE) with coefficients of variation (CV). Estimated parameters include carrying capacity (K), the intrinsic rate of population growth (r), the biomass in the first modeled year defined as a ratio of K (p_0), variance parameters for each CPUE series, and catchability (q) for each CPUE series. Prior probability distributions (priors) are specified for all of the estimated parameters for this Bayesian estimation.

Output statistics computed from the BSP model are marginal posterior distributions for all model parameters (described above) and management quantities below;

MSY – maximum sustainable yield

B_{cur} – biomass in the current year

B_{cur}/K – ratio of current biomass to carrying capacity

B_{init} – biomass at the start of the model

B_{init}/K – ratio of biomass at the start of the model to carrying capacity

B_{cur}/B_{init} – ratio of current biomass to biomass at the start of the model

C_{cur}/MSY – ratio of current catch to maximum sustainable yield

F_{cur}/F_{msy} – ratio of current fishing mortality to that at maximum sustainable yield

B_{cur}/B_{msy} – ratio of current biomass to biomass at maximum sustainable yield

C_{cur}/Rep_y – ratio of current catch to replacement catch

B_{msy} – biomass at maximum sustainable yield

Rep_y – replacement yield

$Catch/Rep_y$ – ratio of catch to replacement yield

$P(B_{cur} > 0.4 B_{msy})$ – probability that the current biomass is greater than the Limit Reference Point (LRP – see Fishery Reference Points below)

$P(B_{cur} > 0.8 B_{msy})$ – probability that the current biomass is greater than the Upper Stock Reference (USR – see Fishery Reference Points below)

3.2 FISHERIES REFERENCE POINTS

Fisheries reference points consistent with DFO's decision making framework that incorporates the Precautionary Approach are presented in this assessment (DFO 2006). Surplus production models, commonly define B_{MSY} at $0.5 B_0$, or half of the unfished biomass. For the BSP assessment model, B_0 is defined as the carrying capacity parameter, K. A reference case BSP model which uses the most appropriate inputs will be used as a basis for management together with the following reference points:

$$\text{Limit Reference Point (LRP)} = 0.4 B_{MSY} = 0.2 K = 0.2 B_0$$

$$\text{Upper Stock Reference (USR)} = 0.8 B_{MSY} = 0.4 K = 0.4 B_0$$

$$\text{Target Reference Point (TRP)} = B_{MSY} = 0.5 K = 0.5 B_0$$

4 INPUTS TO THE MODEL

4.1 LIFE HISTORY PARAMETERS

In the Bayesian surplus production stock assessment model used for Quillback Rockfish, life history parameters are represented through a single growth parameter "r" which represents the

intrinsic rate of population growth which is estimated using von Bertalanffy growth parameters and maturity schedules derived from biological data collected during research surveys, natural mortality rates estimated from maximum ages using Hoenig's equation and an estimated stock-recruit steepness parameter. Biological data analyses are presented in Appendix B.

4.2 HISTORIC CATCH

Quillback Rockfish are caught in all groundfish commercial (trawl, halibut, sablefish, dogfish, lingcod and rockfish) and recreational fisheries, Pacific Salmon troll fisheries, as well as Spot Prawn trap and Shrimp trawl fisheries. The catch of Quillback Rockfish is assembled using available data for commercial and recreational fisheries from 1918 to 2010. Aboriginal catch and Shrimp trawl catch were not compiled for this assessment but are assumed to be small and accounted for within the model sensitivity tests for uncertainty in all catches (see below). Catch represents all mortality from fisheries including landed, discarded and unreported catches.

Landed and discarded catch for the commercial groundfish, Pacific Salmon troll and Spot Prawn trap fisheries are summarized in Appendix C. Unreported catch in the commercial groundfish fisheries are accounted for by doubling the commercial catch between 1986 and 2005 (industry representatives pers comm). This corresponds to a period when under-reporting of catch occurred due to single species license restrictions and fishery management regulations.

Landed and released catch from the recreational fisheries are detailed in Appendix D.

The total catch of Quillback Rockfish used in the stock assessment are presented from 1918 to 2010 in Table 1 for the inside management unit and Table 2 for the outside management unit.

4.3 ABUNDANCE TREND DATA

All available sources for Quillback Rockfish trend data are presented and reviewed for their use in the stock assessment. Research surveys and commercial catch records are listed with details on gear type, survey years and sampling rate together with their use in the stock assessment (Table 3). A detailed description of these data sources and a discussion of their use in the stock assessment are presented in Appendix E.

All longline gear and submersible surveys are used in the assessment where possible. Most of the jig gear surveys are also used with the exception of surveys which changed fishing methods or geographic coverage between surveys. Almost all the trawl gear surveys were included in the assessment with the exception of the West Coast Haida Gwaii and shrimp trawl surveys due to very low to nil sampling rates. Commercial catch records were not included as trend data for the stock assessment due to low sampling rates (trawl fisheries) and the influences of fisher behaviour in response to management or market demands (hook and line).

5 STOCK ASSESSMENT MODELLING

5.1 THE REFERENCE CASE

The reference case model runs utilize the best available data inputs from the most scientifically defensible sources and the output provides the basis for management advice. Details on priors are in Appendix A. The following list summarizes the key model settings for the reference case:

- Prior mean r formulated for each of the stocks using the Beverton-Holt steepness prior distribution and life history parameter estimates for each stock
- All stock trend indices used for each stock (see Table 3 and Appendix E)

- Schaefer surplus production function ($B_{MSY}/K=0.5$)
- Prior mean $B_{1918}/K = 1$ for outside and 0.9 for inside waters
- Uninformative priors for q
- Lag 1 autocorrelation with the autocorrelation coefficient, ρ , set at 0.5 starts in 2011 (see Stanley et al. 2009 for the equations)
- CVs for stock trend indices obtained by iterative reweighting, determined by fitting the BSP model to the data

5.2 SENSITIVITY TESTS

Sensitivity tests were conducted to evaluate the effect of stock assessment model assumptions on stock status and projection results. A summary of these analyses and a brief description of each analysis are provided below. Details of these sensitivity tests are presented in Appendix G.

Category code	Category description	Run number	Runs for both areas (Order of Areas: outside, inside)
Ref	Reference run	1-2	Reference case runs
A	r prior mean	1-2	prior for r centred over low values
		3-4	prior for r centred over high values
B	B_{1918}/K prior mean	1-2	prior mean centred over low values
		3-4	prior mean centred over high values
C	Uncertainty over historic catches	1-2	Historic catch values multiplied by 50% and 150%.
D	Effect of survey data	1	Johnstone Strait Jig survey
		2	Inside dogfish longline survey
		3	Inside rockfish longline surveys
		4	Strait of Georgia Sub and Jig surveys
		5	Hecate Strait assemblage & synoptic trawl surveys
		6	Synoptic trawl surveys
		7	IPHC longline surveys
		8	PHMA and Charter longline surveys
E	Prior for K	1-2	Uniform on K prior (500-50,000 tons)

6 SOURCES OF UNCERTAINTY

The sensitivity of model results to variations of model inputs have been addressed through the Sensitivity Tests in Appendix G. Other uncertainties not addressed in these sensitivity tests but that may affect model outcomes include possible effects from pinniped predation and trends in recruitment.

It is known that pinniped abundance has increased substantially and that rockfish are a component of their diets. For the Yelloweye Rockfish stock assessment for the inside management unit, pinniped consumption was treated like a fishery and included in an exploratory Pinniped Bayesian Surplus Production (PBSP) model (Yamanaka et al. 2012). If future research on pinniped diets and consumption rates yield species specific data and show

that pinniped mortality is significant for Quillback Rockfish, a PBSP model or other model that could account for this may be considered in a future assessment.

If there are trends in recruitment for Quillback Rockfish, this could increase uncertainty in the models used to assess this species. The model accounts for the intrinsic rate of increase of the stock with the r parameter but large trends (positive or negative) or variations in recruitment could have additional effects. Should a time series of appropriate age data become available, an age-structured assessment may be considered in the future for Quillback Rockfish.

7 QUESTIONS AND ANSWERS

7.1 PHASE I: ASSESS CURRENT/RECENT SPECIES STATUS

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

Present status for the Quillback Rockfish is determined through the Reference Case BSP model run in Table 4 (outside) and Table 5 (inside) which show that in 2011 median biomass (B_{2011}) for the outside management unit is 6,480 tonnes (CV 1.21) and for the inside management unit is 2,668 tonnes (CV 0.60). The median biomass at MSY (B_{msy}) is 9,307 tonnes (CV 0.60) for the outside management unit and 5,475 tonnes (CV 0.32) for the inside management unit. The median replacement yield in 2011 ($Repy_{2011}$) is 241 tonnes (CV 0.78) for the outside management unit and 100 tonnes (CV 0.47) for the inside management unit. Median B_{2011}/B_{msy} for the outside management unit is 0.736 (CV 0.57) and for the inside management unit is 0.493 (CV 0.41).

Figure 2. shows a graphical representation of the median biomass in 2011 (B_{cur}) relative to B_{msy} (95% confidence intervals) set within a precautionary framework showing $0.4 B_{msy}$ and $0.8 B_{msy}$ as examples of a lower stock and an upper stock reference, respectively.

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

Model reconstructions of the Quillback Rockfish biomass from 1918 to 2010 by management unit are shown in Figures 3 and 4, together with catch history and trend indices. The median biomass in 2011 is 37.7% (CV 0.65) of the biomass in 1918 (B_{1918}) for the outside management unit and 27.4% (CV 0.47) for the inside management unit.

Table 6 (outside) and Table 7 (inside) show the posterior median estimates of population decline over three generations between 1997 and 2010 given the Reference Case and under a number of key alternative scenarios. The outside population Reference Case in 1997 is estimated at 0.41 of the population three generations earlier and in 2010 is estimated at 0.35. There is a greater three generation population decline for the inside population compared with the outside population. For the inside population Reference Case in 1997 the three generation decline is estimated at 0.28 and in 2010 is estimated at 0.27.

The time series trajectory of the ratio of F_y/F_{msy} to B_y/B_{msy} (stock biomass relative to the stock size at MSY) for the two management units are shown in Figures 5 and 6. The biomass in 1989 for the inside management unit and in 1995 for the outside management unit equalled the biomass at MSY. Since these years, the stock has been below that at MSY.

-
3. Estimate, to the extent that information allows, the current or recent **life history parameters** for the species (total mortality [Z], natural mortality[m], fecundity, maturity, recruitment, etc.) or reasonable surrogates, and associated uncertainties for all parameters.

For the BSP assessment model, an r parameter is used to represent the intrinsic rate of increase of the population. An informative prior for r is developed from length at age, maturity schedules and length-weight relationships (details in Appendix B). The median priors for r for the outside and inside populations are 0.0881 (SD 0.057) and 0.0910 (SD 0.058), respectively.

7.1.1 Mortality

Total mortality (Z) has been estimated for the outside and inside management units of Quillback Rockfish using catch curve analyses in Yamanaka et al. (2006). The posterior mode of the Z distribution ranged from 0.059 to 0.135.

Natural mortality is estimated using Hoenig's equation for maximum ages of 95 and 80 years for the outside and inside management units, respectively (Hoenig 1983). M is 0.048 (CV 0.25) for the outside management unit and 0.057 (CV 0.25) for the inside (Yamanaka and Lacko 2001).

7.1.2 Fecundity

Quillback Rockfish were sampled from the Campbell River and Nanaimo areas on the inside management unit for fecundity studies. Fish between 30 and 40 cm in length ranged in fecundity from about 100,000 to 350,000 oocytes (Schnute and Richards 1990).

7.1.3 Maturity

In this assessment, maturity was estimated from research survey data and showed that the age of 50% maturity for females coastwide is 8.5 years and for males is 7.5 and 10.5 years on the outside and inside management units, respectively.

Samples of Quillback Rockfish from jig research surveys in 1992 within the inside management unit (PFMA 12) are used to estimate the size and age at which 50% of the females are sexually mature. 50% of females at 29.3 cm (95% CI 28.9 – 29.7 cm) and 11 years of age (95% CI 10 – 12 years) are sexually mature (Yamanaka and Richards 1993b). In California and Alaska, Quillback Rockfish mature at younger (7 years) and older (12 years) ages, respectively (Love et al. 2002).

7.1.4 Recruitment

Recruitment for Quillback Rockfish is generally unknown but exceptional year classes are assumed to be sporadic with the intervening 10 to 15 year periods of low to average recruitment. The last exceptional year class of Quillback Rockfish detected in the Johnstone Strait Nearshore Reef-fish Jig Survey was in 1985. In the 1992 survey, 28% of the Quillback Rockfish caught during the survey were from this age-class, and were caught as 7 year olds (Yamanaka and Richards 1993b). This cohort was also identified as 19 year olds in the 2004 survey (Yamanaka and Lacko 2008).

4. Address the separate terms of reference for describing and quantifying (to the extent possible) the **habitat requirements and habitat use patterns** of the species.

Quillback Rockfish are associated with rocky marine habitats throughout their distribution and depth range. In B.C. they are observed hovering near to or settled upon high relief rock ridges,

reefs, cobbles and broken rock, and occupying crevices, cloud sponges and crinoid aggregations (Richards 1986b, Matthews 1990, Murie et al. 1994, Yamanaka et al. 2006, 2012). Temperature and salinity ranges for Quillback Rockfish observed *in situ* are 8.1 to 12.1° C and 28.2 to 35 parts per thousand, respectively (Yamanaka et al. 2006). Temperature and salinity limits for this species are unknown.

Young of the year Quillback Rockfish recruit to shallow rocks and detached plant material over sandy bottoms (Love 2002). Older juveniles move inshore to protected areas and are most abundant in low energy rock areas associated with bull kelp cover (Love et al. 2002). Like many rockfish, larger individuals occupy deeper habitats (Lea et al. 1999). This species exhibits movement within home ranges of 30 to 1500 m² and will home from displacements of 500 m (Matthews 1989). Residence requirements for this marine species are unknown and likely do not exist.

5. Estimate expected **population and distribution targets** for recovery, according to DFO guidelines.

In discussion with DFO managers, population and distribution targets have not been set for this species. Quillback Rockfish are widely distributed in shallow coastal waters throughout B.C.. Although COSEWIC recognizes only one Designatable Unit (DU) for Quillback Rockfish, in this document targets are presented for two spatially explicit management units; outside and inside.

6. Project **expected population trajectories** over three generations (or other biologically reasonable time), and trajectories over **time to the recovery target** (if possible to achieve), given current population dynamics parameters and associated uncertainties using DFO guidelines on long-term projections.

Generation time for the outside and inside management units for Quillback Rockfish are estimated at 32 and 28.5 years, respectively. Future population projections from the model were estimated for 5, 15, 30 and 90 years to cover a 3-generation time frame. Expected population trajectories from the Reference Case model runs project over three generations for Quillback Rockfish given various fixed total fishing mortality. These are shown in Table 8 and Figure 7 for the outside management unit and Table 9 and Figure 8 for the inside management unit.

If the recovery target is stated as “95% probability of the population $>0.8 B_{msy}$ ”, this is expected to be achieved, for the outside management unit, in 90 years at a fixed total fishery mortality of about 60 tonnes, and for the inside management unit this is not expected to be achieved in 90 years with a harvest.

If the recovery target is stated as “95% probability of the population $>0.4 B_{msy}$ ”, for the outside management unit this is expected to be achieved in 15 years at a fixed total fishery mortality of 30 t and in 90 years with a fixed fishery mortality of about 90 t. For the inside management unit, this target will be achieved in 90 years with a fixed fishery mortality of about 30 tonnes.

7. Evaluate **residence requirements** for the species, if any.

Residence requirements for this marine species are unknown and likely do not exist.

7.2 PHASE II: SCOPE FOR MANAGEMENT TO FACILITATE RECOVERY.

8. Assess the **probability that the recovery targets can be achieved** under current rates of population dynamics parameters, and **how that probability would vary with different mortality (especially lower) and productivity (especially higher) parameters.**

Reference case model runs under various fixed total fishing mortality are shown with 90% probability intervals in Figures 7 and 8 for the outside and inside, respectively. Model sensitivity tests listed on page 6 are used to assess the probability of achieving the recovery targets given changes to various model inputs and parameters from the Reference Case. The productivity parameter r (intrinsic rate of growth) is included as runs A1 to A4 which are presented in Appendix G. The results are moderately sensitive to this prior even though the posterior means for r are quite different. In all instances when different hypotheses for r for outside quillback are considered, there was at least a 50% probability of the stock staying above B_{MSY} after fifteen years for fixed total fishing mortality policies of 120 tons and less. The results for inside Quillback Rockfish were similar and sensitive to alternative priors means for r and required much lower fixed total fishing mortality policies to achieve at least a 50% chance of exceeding $0.8 B_{MSY}$ in 30 years.

9. Quantify to the extent possible the **magnitude of each major potential source of mortality** identified in the pre-COSEWIC RAP and considering information in COSEWIC Status Report, from DFO sectors, and other sources.

The major sources of mortality for Quillback Rockfish in B.C. are from fisheries. The relative contribution of each of these fisheries to the total mortality is estimated from catches by fishery in 2010. These can be viewed in Table 1. For the outside management unit, the total mortality from all fisheries is 158.60 tonnes, of which 116.50 t was taken by the commercial groundfish fishery, 41.77 t by the recreational fishery, 0.28 t by the salmon troll fishery. For the inside management unit, the total mortality from all fisheries is 33.90 tonnes, of which 24.80 t was taken by the commercial groundfish fishery, 9.00 t by the recreational fishery, 0.06 t by the salmon troll fishery.

An estimate of the total rockfish (all species) coastwide catch (upper 95% CI) in the Spot Prawn fishery ranged from 22,792 rockfish in 2005 to 40,780 rockfish in 2002 (Rutherford et al. 2010). Quillback Rockfish accounted for the greatest proportion (62%) of all rockfish encounters, however, rockfish catch by species, on a coastwide basis could not be estimated due to small sample size and low encounter rates (Rutherford et al. 2010). Aboriginal fisheries and the recreational Spot Prawn trap fishery are likely to account for a small mortality. Mortality in the shrimp trawl fishery has been reported and mitigated by the implementation of exclusion devices in the trawls (Olsen et al. 2000). Illegal and unreported catches are unknown across all fisheries.

10. Quantify to the extent possible the **likelihood that the current quantity and quality of habitat is sufficient** to allow population increase, and would be sufficient to support a population that has reached its recovery targets (using the same methods as in step 4)

There are no data available to determine threats to Quillback Rockfish habitat quantity and quality. It is not possible to determine the likelihood that the current quantity and quality of habitat is sufficient for recovery of Quillback Rockfish in B.C. Quillback Rockfish habitat in B.C.

occurs between 14 and 147 m in depth and is estimated between 27,000 and 56,000 square kilometres. It is unlikely that the large extent of habitat occurring throughout B.C. marine waters is limiting to Quillback Rockfish recovery.

11. Assess to the extent possible the magnitude by which current **threats to habitats have reduced habitat quantity and quality**.

There are no data available to determine threats to Quillback Rockfish habitat quantity and quality. If there are any threats from the current fisheries, these may be mitigated within Rockfish Conservation Areas by the introduction of spatial management measures in the Rockfish Conservation Strategy (see below) whereby 20% and 30% of rockfish habitats on the outside and inside management units, respectively, have been closed to fishing (Yamanaka and Logan 2010). There are no habitat threats identified in the COSEWIC status report for Quillback Rockfish (COSEWIC 2009).

7.3 PHASE III: SCENARIOS FOR MITIGATION AND ALTERNATIVE TO ACTIVITIES

12. Using input from all DFO sectors and other sources as appropriate develop an **inventory of all feasible measures to minimize/mitigate** the impacts of activities that are threats to the species and its habitat (steps 9 and 11).

7.3.1 Rockfish Conservation Strategy

In the late 1990's DFO's conservation concerns over the inshore rockfish stocks resulted in the development of the Rockfish Conservation Strategy (Yamanaka and Logan 2010). This strategy included 4 components;

1. comprehensive catch monitoring,
2. dramatically reduced fishing mortality,
3. extensive fishery closed areas, and
4. improvements to stock assessment and monitoring.

In 2002, fishing mortality was reduced in the commercial and recreational sectors by 50% in the outside management unit and by 75% in the inside management unit. This was accomplished by total allowable catch (TAC) reductions in all commercial fisheries and bag limit reductions in the recreational fisheries. In addition, DFO began comprehensive consultations with all stakeholders and the public on the development of closed areas to fishing. These closed areas, or Rockfish Conservation Areas (RCAs), began to be implemented in 2002 and continued consultations over the next 5 years brought 167 RCAs into existence by 2007. These RCAs encompass 20% of the rockfish habitats in the outside management unit and 30% on the inside. Comprehensive catch monitoring was first piloted in 2006 and instituted in 2009 and stock assessment and monitoring programs have existed since 2003.

As outlined in the Rockfish Conservation Strategy, direct fisheries management measures to mitigate fishing mortality are reductions to fishery TACs for Quillback Rockfish and spatial management measures such as RCAs and the closure of areas to all fishing activities that may intercept Quillback Rockfish to protect a portion of the stocks within these areas (and perhaps habitats) from harvest activities. These measures have been implemented to the extent deemed necessary in 2001 and the benefits of these measures may take some time to be detected given the life history and generally low productivity of these inshore rockfish species. Threats to habitats are not well understood. The COSEWIC report did not identify any threats to habitat.

7.3.2 Species specific total allowable catches (TACs)

Inshore rockfish have been assessed in the past as a complex of nearshore, shallow water, rockfish that include Yelloweye Rockfish (*Sebastes ruberrimus*), Quillback Rockfish, Copper Rockfish (*S. caurinus*), China Rockfish (*S. nebulosus*), Tiger Rockfish (*S. negrocinctus*) and Black Rockfish (*S. melanops*). Quillback Rockfish has been managed in the commercial fishery since 1995 in an aggregate together with Copper Rockfish (Aggregate 1) and TAC management is for combined aggregates which also include, China Rockfish and Tiger Rockfish (Aggregate 2). One TAC is managed for Aggregates 1 and 2. Hence, there is a possibility that Quillback Rockfish (or any of the other species in the aggregate) could be over harvested if the TAC for the Aggregate is set at a higher level than that which is sustainable for Quillback Rockfish. Management of a species specific TAC for Quillback Rockfish may be considered and would mitigate the possibility of over harvesting this species.

In the recreational fishery, bag limits and catch caps are also managed for an inshore rockfish species aggregate which is comprised of six rockfish species. Similar to the commercial fishery, fishery managers may consider a species specific bag limit and catch cap for the recreational fishery.

7.3.3 Reductions to TACs

Fisheries are the only threat to the Quillback Rockfish addressed in this document. In addition to the Rockfish Conservation Strategy mitigation measures already implemented, additional reductions to fishery harvests may be considered.

13. Using input from all DFO sectors and other sources as appropriate, develop an inventory of all reasonable **alternatives to the activities** that are threats to the species and its habitat (steps 9 and 11), but with potential for less impact. (e.g. changing gear in fisheries causing bycatch mortality, relocation of activities harming habitat)

Under DFO's selective fishing policy (DFO 2001), selective fishing technology and practices are adopted for all Pacific fisheries. However, for all gear types and fisheries, it is difficult to selectively harvest Quillback Rockfish as they coexist with other rockfish species with similar habits.

Directed fisheries for Quillback Rockfish may be restricted by management measures such as relocating fishing activities to deeper depths (greater than 150 m) to avoid the catch of Quillback Rockfish but this is impractical for coastwide fisheries and may also affect other species of concern. Through the use of RCAs (closed areas) as a spatial management tool and reductions in fishing mortality, the primary threat has been reduced on inshore rockfish, including Quillback Rockfish (Yamanaka and Logan 2010).

Habitat impacts and threats are not well understood and management actions will be developed as more information arises.

14. Using input from all DFO sectors and other sources as appropriate develop an inventory of all **reasonable and feasible activities that could increase the productivity or survivorship parameters** (steps 3 and 8).

Significant fishery management activities to increase the Quillback Rockfish stocks in B.C. were implemented in the Rockfish Conservation Strategy which included large reductions in fishing mortality and the implementation of RCAs (areas closed to fishing) (Yamanaka and Logan

2010). Other measures to maintain a spawning stock size that does not compromise recovery could increase population productivity or survivorship. Attempts at rockfish aquaculture have not been successful and are impractical at this time for B.C.

15. Estimate, to the extent possible, the **reduction in mortality rate expected** by each of the mitigation measures in step 12 or alternatives in step 13 and **the increase in productivity or survivorship** associated with each measure in step 14.

Mitigation measures consist of reductions in total fishing mortality which has been presented in Tables 8 and 9 for the Reference case applied to the catch in all fisheries. Allocations to fishery by sector and fisheries within sectors are conducted by DFO managers. Reductions in mortality rate by fishery are directly related to the catch within the fishery. Table 1 and 2 show the catch by fishing sector and Appendix C details catch by fishery. Habitat impacts are not possible to assess at this time. Hence it is not possible to assess habitat associations with stock productivity or survivorship.

16. Project **expected population trajectory** (and uncertainties) over three generations (or other biologically reasonable time), and to the time of reaching recovery targets when recovery is feasible; given mortality rates and productivities from 15 that are **associated with specific scenarios** identified for exploration. Include scenarios which provide as high a probability of survivorship and recovery as possible for biologically realistic parameter values.

From the Reference Case model runs, expected population trajectories over 5, 15, 30 and 90 year horizons (approximately three generations) are shown with various fixed total fishing mortality harvest policies in Tables 8 and 9 and Figures 7 and 8.

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 key parameter values for population productivity include the posterior median values for the maximum intrinsic rate of increase (r) and the fishing mortality rate that is expected to result in maximum sustainable yield (F_{msy}). The maximum rate of increase provides the maximum possible value for the exploitation rate above which extinction could be expected to occur if fishing mortality rates were on average larger than this value. For outside waters quillback r and F_{msy} are 0.069 and 0.035, respectively. For inside waters quillback r and F_{msy} are 0.051 and 0.025, respectively.

The development of a spatially and age-structured population dynamics model and fishing fleet dynamics models could enable evaluation of the potential economic impacts of listing the species should area closures become a more extensively applied method of promoting stock recovery. See Appendix B for additional parameter values for population productivity and starting mortality rates.

8 CONCLUSIONS AND RECOMMENDATIONS

A stock assessment of Quillback Rockfish in B.C. was conducted using a Bayesian surplus production model applied over two management units; outside and inside (see Request for Science Advice in Appendix H). The model required fishery catch reconstructions to provide catch series from 1918 to 2010, as well as, abundance trends for the two management units. Reference Case model runs provided median biomass estimates for 2011 of 6,480 tonnes (CV 1.21) for the outside management unit and 2,668 tonnes (CV 0.60) for the inside management unit. B_{2010}/B_{msy} for the outside and inside is 0.736 (95%CI is 0.266 to 1.814) and 0.493 (95% CI is 0.252 to 0.945), respectively. The probability that the biomass of the outside Quillback Rockfish is above 0.4 B_{msy} is 81.2 % and above 0.8 B_{msy} is 45.6%. The probability that the biomass of the inside Quillback Rockfish is above 0.4 B_{msy} is 70.2% and above 0.8 B_{msy} is 11.5%. Stocks in both management areas appear to be within the cautious zone (DFO 2006).

There is a greater uncertainty around estimates from the assessment for the outside management unit than for the inside management unit. This is due to the high among year variability in stock trend indices as well as imprecise biomass estimates from some surveys. For the inside the stock trend indices had lower interannual variability and a more consistent decline in the indices between the 1980s and the 2000s.

Fishing mortality is the only threat addressed in this assessment. Historic coastwide catches of Quillback Rockfish peaked in the commercial groundfish fisheries at over 1280 tonnes in 1990 for the outside management area and almost 706 tonnes in 1986 for the inside management area. In 2002, subsequent to the implementation of the Rockfish Conservation Strategy which reduced fishing mortality by 50% outside and 75% inside, coastwide commercial catches were reduced to 406 tonnes and the coastwide recreational catches were estimated at 51 tonnes. In 2010, coastwide fishing mortality for the commercial groundfish fisheries is estimated at 141.3 tonnes, and for the Pacific Salmon troll fishery at 0.34 tonnes for a total coastwide commercial fishing mortality of about 142 tonnes. In 2010, the coastwide recreational fishery mortality is estimated at 51 tonnes.

Fishery management actions that may provide further protection for the Quillback Rockfish may be the development of species specific harvests (TACs, bag limits, catch caps) for the commercial and recreational fisheries. There is a possibility that over harvesting could occur if the aggregate quota management currently used for Quillback Rockfish (Aggregates 1 and 2) is larger than the specific quota for Quillback Rockfish.

The large reductions to fishing mortality accomplished under the Rockfish Conservation Strategy, in addition to the closure of fishing areas within Rockfish Conservation Areas (RCAs) for protection of 20% outside and 30% inside rockfish habitats was a major step toward the conservation of Quillback Rockfish. Given the life history and generally low productivity of Quillback Rockfish, benefits from these dramatic measures will take decades.

At current catches of slightly less than 160 tonnes outside and slightly more than 30 tonnes inside, for the Reference Case at the end of the 5 year horizon, there is about an 81% and 77% probability, respectively, of the $B_{final} > 0.4 B_{msy}$. The stock is projected to increase over time, hence over the longer time horizons the probabilities increase for $B_{final} > 0.4 B_{msy}$ and $B_{final} > 0.8 B_{msy}$ for Total Fishing Mortality policies of 120 tonnes or less for the outside management area and for policies of 60 tonnes or less for the inside management area.

9. REFERENCES

- COSEWIC. 2009. Assessment and Status Report on the Quillback Rockfish (*Sebastes maliger*) in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vii + 71pp. http://publications.gc.ca/collections/collection_2011/ec/CW69-14-589-2010-eng.pdf.
- DFO. 2006. A harvest strategy compliant with a precautionary approach. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2006/023.
- DFO. 2009. Revised protocol for conducting recovery potential assessments. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2007/039.
- Hoenig, J.M. 1983. Empirical use of longevity data to estimate mortality rates. Fish. Bull. Vol 82(1): 898-903.
- King, J.R., McAllister, M. K., Holt, K. R., and Starr, P.J. 2012. Lingcod (*Ophiodon elongatus*) stock assessment and yield advice for outside stocks in British Columbia. DFO Can. Sci. Advis. Sec. Res. Doc. 2011/124. vii + 176p.
- Kronlund, A.R., Yamanaka, K.L., and Workman, G. 1999. Inshore rockfish stock assessment for the West coast of Canada in 1998 and recommendations for 1999/2000. DFO Can. Sci. Advis. Sec. Res. Doc. 1999/58. 54 p.
- Lea, R. N., McAllister, R. D., and VenTresca, D.A. 1999. Biological aspects of nearshore rockfishes of the genus *Sebastes* from Central California. California Department of Fish and Game. Fish Bulletin 177. 109 p.
- Love, M.S., and Lea, R.N. 1997. Range Extension of the quillback rockfish, *Sebastes maliger*, to the southern California Bight. Calif. Fish Game 83(2):78-83.
- Love, M.S., Yoklavich, M.M., and Thorsteinson, L. 2002. The Rockfishes of the Northeast Pacific. University of California Press. Berkley and Los Angeles, California. 404p.
- Matthews, K.R. 1989. A telemetric study of the home ranges and homing routes of copper and Quillback Rockfishes on shallow rocky reefs. Can. J. Zool. 68: 2243-2250.
- Matthews, K. R. 1990. An experimental study of movement patterns and habitat preferences of copper, quillback, and brown rockfishes on three habitat types. Env. Biol. Fish. 29:161-178.
- McAllister, M.K., and Babcock, E.A. 2006. Bayesian surplus production model with the Sampling Importance Resampling algorithm (BSP): A user's guide. Available from: <http://www.sefsc.noaa.gov/library.jsp> (January 27, 2010).
- McAllister, M.K., and Duplisea, D. 2011. Production model fitting and projection for Atlantic redfish (*Sebastes fasciatus* and *Sebastes mentella*) to assess recovery potential and allowable harm. DFO Can. Sci. Advis. Sec. Res. Doc. 2011/057 vi + 75p.
- Mecklenburg, C., Mecklenburg, T., and Thorsteinson, L. 2002. Fishes of Alaska. American Fisheries Society. Bethesda, Maryland.

-
- Murie, D.J., Parkyn, D.C., Clapp, B.G., and Krause, G.G. 1994. Observations on the distribution and activities of rockfish, *Sebastes* spp., in Saanich Inlet, British Columbia, from the Pisces IV submersible. *Fish. Bull.* 92:313-323.
- Olsen, N., Boutillier, J.A., and Convey, L. 2000. Estimated bycatch in the British Columbia shrimp trawl fishery. *DFO Can. Sci. Advis. Sec. Res. Doc.* 2000/168. 54 p.
- Phillips, J. B. 1957. A review of the rockfishes of California. *Calif. Dept. Fish and Game, Fish Bull.* 104. Sacramento, California.
- Richards, L.J. 1986a. PSARC Working paper G86-1. 1986 assessment for commercially exploited rockfish stocks in the Strait of Georgia. *Can. Manuscr. Rep. Fish. Aquat. Sci.* 1885: 55p.
- Richards, L.J. 1986b. Depth and habitat distributions of three species of rockfish (*Sebastes*) in British Columbia: observations from the submersible PISCES IV. *Envr. Biol. of Fishes* 17(1): 13-21.
- Rutherford, D.T., Fong, K., and Nguyen, H. 2010. Rockfish Bycatch in the British Columbia commercial Prawn Trap Fishery. *DFO Can. Sci. Advis. Sec. Res. Doc.* 2009/109. iii + 25p.
- Schnute, J.T., and Richards, L.J. 1990. A unified approach to the analysis of fish growth, maturity, and survivorship data. *Can. J. Fish Aquat. Sci.* 43: 24-40.
- Stanley, R.D., McAllister, M., Starr, P., and Olsen, N. 2009. Stock assessment for bocaccio (*Sebastes paucispinis*) in British Columbia waters. *DFO Can. Sci. Advis. Sec. Res. Doc.* 2009/055: xiv + 200p.
- Thomson, R.E., Bornhold B.D., and Mazzotti, S. 2008. An examination of the factors affecting relative and absolute sea level in British Columbia. *Can. Tech. Rep. Hydr. Ocean Sci.* 260.
- Yamanaka, K.L., and Kronlund, A.R. 1997. Inshore rockfish stock assessments for the west coast of Canada in 1996 and recommended yield options for 1997. *Can. Tech. Rep. Fish. Aquat. Sci.* 2175: 80 p.
- Yamanaka, K.L., and Lacko, L.C. 2001. Inshore rockfish (*Sebastes ruberrimus*, *S. maliger*, *S. caurinus*, *S. melanops*, *S. nigrocinctus*, and *S. nebulosus*) stock assessment for the west coast of Canada and recommendations from management. *DFO Can. Sci. Advis. Sec. Res. Doc.* 2001/139. 102p.
- Yamanaka, K.L., and Lacko, L.C. 2008. 2004 Research catch and effort data on nearshore reef-fishes in British Columbia Statistical Area 12. *Can. Tech. Rep. Fish. Aquat. Sci.* 2803: ix + 45p.
- Yamanaka, K. L., and Logan, G. 2010. Developing British Columbia's Inshore Rockfish Conservation Strategy. *Marine and Coastal Fisheries: Dynamics, Management and Ecosystem Science* 2:28–46.

-
- Yamanaka, K.L., and Richards, L.J. 1992. Inshore Rockfish. p. 221-266 *In* Leaman, B.M. [Ed.]. Groundfish stock assessments for the west coast of Canada in 1991 and recommended yield options for 1992. Can. Tech. Rep. Fish. Aquat. Sci. 1866:304p.
- Yamanaka, K.L., and Richards, L.J. 1993a. Inshore Rockfish. p. 336-359 *In* Leaman, B.M. and M. Stocker [Eds.]. Groundfish stock assessments for the west coast of Canada in 1992 and recommended yield options for 1993. Can. Tech. Rep. Fish. Aquat. Sci. 1919:407p.
- Yamanaka, K.L., and Richards, L.J. 1993b. 1992 research catch and effort on nearshore reef-fishes in British Columbia Statistical Area 12. Can. Manuscr. Rep. Fish. Aquat. Sci. 2184: 77 p.
- Yamanaka, K.L., and Richards, L.J. 1994. Inshore Rockfish. p. 317-338 *In* Stocker, M. [Ed.]. Groundfish stock assessments for the west coast of Canada in 1993 and recommended yield options for 1994. Can. Tech. Rep. Fish. Aquat. Sci. 1975:352p.
- Yamanaka, K.L., and Richards, L.J. 1995. Inshore Rockfish. p. 394-422 *In* Stocker, M. and J. Fargo [Eds.]. Groundfish stock assessments for the west coast of Canada in 1994 and recommended yield options for 1995. Can. Tech. Rep. Fish. Aquat. Sci. 2069:440p.
- Yamanaka, K.L., Lacko, L.C., Miller-Saunders, K., Grandin, C., Lochead, J.K., Martin, J.C., Olsen, N., and Wallace, S.S. 2006. A review of Quillback Rockfish *Sebastes maliger* along the Pacific coast of Canada: biology, distribution and abundance trends. DFO Can. Sci. Advis. Sec. Res. Doc. 2006/077. 58p.
- Yamanaka, K.L., McAllister, M. K., Etienne, M.-P., Obradovich, S.G., and Haigh, R. 2012. Stock assessment for the inside population of yelloweye rockfish (*Sebastes ruberrimus*) in British Columbia, Canada for 2010. DFO Can. Sci. Adv. Sec. Res. Doc. 2011/129. xiv + 132 p.

10. TABLES

Table 1. Catch in tonnes by year for the years 1918 to 2010 used in the Quillback Rockfish- outside management unit stock assessment. Catches include landed, discarded and unreported catches.

Year	Commercial GF catch	Recreational catch	Salmon Troll catch	Total Catch
1918	28.2	0	3.36	31.5
1919	10.4	0	3.36	13.8
1920	8.8	0	3.36	12.1
1921	2.7	0	3.36	6.1
1922	5.4	0	3.36	8.8
1923	3.0	0	3.36	6.3
1924	3.7	0	3.36	7.0
1925	3.4	0	3.36	6.8
1926	6.8	0	3.36	10.2
1927	10.1	0	3.36	13.5
1928	8.1	0	3.36	11.5
1929	9.7	0	3.36	13.1
1930	5.8	0	3.36	9.2
1931	2.9	0	3.36	6.3
1932	1.6	0	3.36	5.0
1933	0.9	0	3.36	4.3
1934	1.2	0	3.36	4.6
1935	4.9	0	3.36	8.3
1936	8.0	0	3.36	11.4
1937	1.7	0	3.36	5.0
1938	8.1	0	3.36	11.5
1939	0.5	0	3.36	3.9
1940	0.6	0	3.36	3.9
1941	3.2	0	3.36	6.5
1942	3.6	0	3.36	6.9
1943	9.5	0	3.36	12.8
1944	12.6	0	3.36	16.0
1945	17.4	0	3.36	20.8
1946	22.9	0	3.36	26.2
1947	4.3	0	3.36	7.6
1948	6.5	0	3.36	9.9
1949	8.7	0	3.36	12.0
1950	3.9	0	3.36	7.3
1951	20.7	0	3.36	24.1
1952	12.5	0	3.36	15.9
1953	7.5	0	3.12	10.6
1954	7.8	0	2.82	10.6
1955	4.8	0	2.93	7.7
1956	4.3	0	2.78	7.1
1957	8.7	0	3.19	11.9
1958	4.1	0	3.44	7.5
1959	5.1	0	3.37	8.5
1960	10.3	0	3.42	13.7
1961	8.9	0	3.84	12.8
1962	17.1	0	3.46	20.6
1963	17.8	0	2.18	20.0
1964	6.9	0	2.62	9.6

Table 1. continued. Catch in tonnes by year for the years 1918 to 2010 used in the Quillback Rockfish-outside management unit stock assessment. Catches include landed, discarded and unreported catches.

Year	Commercial GF catch	Recreational catch	Salmon troll Catch	Total Catch
1965	9.9	0	2.77	12.7
1966	12.6	0	2.80	15.4
1967	14.5	0	2.82	17.3
1968	7.7	0	3.15	10.8
1969	24.1	0	2.87	26.9
1970	39.2	0	2.96	42.1
1971	29.9	0	3.03	33.0
1972	35.4	0	2.84	38.3
1973	25.9	0	2.71	28.6
1974	49.1	0	2.57	51.7
1975	56.1	0	2.49	58.6
1976	34.5	0	2.66	37.2
1977	46.7	0	2.97	49.7
1978	56.9	0	3.00	59.9
1979	68.5	0	3.33	71.9
1980	68.6	0	4.15	72.8
1981	50.0	0	3.63	53.6
1982	47.2	0.0	3.54	50.7
1983	53.5	0.0	3.62	57.1
1984	62.4	0.0	3.07	65.4
1985	128.5	0.0	2.71	131.2
1986	479.6	0.0	2.40	482.0
1987	628.7	0.0	1.93	630.7
1988	838.6	0.0	1.99	840.6
1989	757.4	0.0	1.69	759.1
1990	1281.3	0.0	2.05	1283.4
1991	1255.9	0.0	2.09	1258.0
1992	953.3	0.0	1.96	955.2
1993	1074.7	0.0	1.55	1076.3
1994	943.0	0.0	1.48	944.5
1995	675.1	0.0	1.10	676.2
1996	652.2	0.0	0.68	652.9
1997	662.2	0.0	0.38	662.6
1998	510.0	0.0	0.20	510.1
1999	437.6	0.0	0.13	437.8
2000	417.1	18.39	0.10	435.6
2001	358.0	49.57	0.15	407.7
2002	321.2	32.09	0.24	353.5
2003	240.7	28.29	0.23	269.2
2004	248.8	26.07	0.24	275.1
2005	233.4	43.12	0.28	276.8
2006	77.5	38.32	0.28	116.1
2007	89.4	37.13	0.23	126.8
2008	113.6	59.16	0.34	173.0
2009	116.0	39.19	0.46	155.4
2010	116.5	41.77	0.28	158.6

Table 2. Catch in tonnes by year for the years 1918 to 2010 used in the Quillback Rockfish- inside management unit stock assessment. Catches include landed, discarded and unreported catches.

Year	Commercial GF catch	Recreational catch	Salmon Troll catch	Total Catch
1918	29.1	0	0.13	29.2
1919	72.4	0	0.13	72.5
1920	36.2	0	0.13	36.3
1921	31.3	0	0.13	31.5
1922	39.1	0	0.13	39.2
1923	37.9	0	0.13	38.1
1924	43.1	0	0.13	43.2
1925	37.0	0	0.13	37.2
1926	42.4	0	0.13	42.5
1927	42.4	0	0.13	42.5
1928	43.6	0	0.13	43.7
1929	56.8	0	0.13	56.9
1930	51.3	0	0.13	51.4
1931	33.6	0	0.13	33.8
1932	38.2	0	0.13	38.3
1933	18.7	0	0.13	18.8
1934	22.1	0	0.13	22.2
1935	28.3	0	0.13	28.5
1936	30.8	0	0.13	30.9
1937	24.0	0	0.13	24.1
1938	81.0	0	0.13	81.1
1939	16.2	0	0.13	16.4
1940	17.7	0	0.13	17.8
1941	10.8	0	0.13	11.0
1942	25.1	0	0.13	25.3
1943	145.8	0	0.13	145.9
1944	217.2	0	0.13	217.3
1945	233.9	0	0.13	234.0
1946	156.6	0	0.13	156.7
1947	50.0	0	0.13	50.1
1948	76.0	0	0.13	76.1
1949	101.4	0	0.13	101.5
1950	43.1	0	0.13	43.2
1951	31.5	0	0.13	31.6
1952	24.0	0	0.13	24.1
1953	50.0	0	0.13	50.2
1954	33.0	0	0.12	33.1
1955	32.8	0	0.12	32.9
1956	30.2	0	0.11	30.3
1957	50.7	0	0.13	50.9
1958	73.6	0	0.15	73.7
1959	77.6	0	0.15	77.8
1960	63.9	0	0.16	64.0
1961	47.1	0	0.16	47.2
1962	74.8	0	0.14	75.0
1963	56.8	0	0.13	56.9
1964	35.7	0	0.13	35.8

Table 2. continued. Catch in tonnes by year for the years 1918 to 2010 used in the Quillback Rockfish-inside management unit stock assessment. Catches include landed, discarded and unreported catches.

Year	Commercial GF catch	Recreational catch	Salmon Troll catch	Total Catch
1965	31.5	0	0.11	31.6
1966	26.8	0	0.10	26.9
1967	38.5	0	0.08	38.6
1968	42.4	0	0.07	42.5
1969	49.0	0	0.08	49.1
1970	59.7	0	0.09	59.8
1971	50.0	0	0.06	50.1
1972	55.5	0	0.06	55.6
1973	67.5	0	0.06	67.6
1974	33.5	0	0.06	33.6
1975	27.0	0	0.07	27.1
1976	32.8	0	0.10	32.9
1977	91.0	0	0.09	91.1
1978	102.5	0	0.09	102.6
1979	164.4	0	0.09	164.5
1980	118.4	0	0.07	118.5
1981	140.2	73.3	0.06	213.6
1982	186.7	74.7	0.06	261.5
1983	197.9	56.4	0.02	254.3
1984	230.3	54.1	0.03	284.4
1985	289.1	49.1	0.02	338.2
1986	706.4	73.6	0.02	780.0
1987	570.7	73.6	0.02	644.3
1988	668.6	78.5	0.03	747.1
1989	618.5	61.7	0.03	680.2
1990	630.2	70.3	0.02	700.5
1991	641.7	55.8	0.02	697.5
1992	239.5	41.2	0.03	280.7
1993	267.8	63.7	0.04	331.5
1994	379.0	48.2	0.01	427.2
1995	132.2	47.4	0.00	179.6
1996	111.7	38.7	0.04	150.4
1997	86.5	39.4	0.01	125.9
1998	108.2	30.9	0.00	139.1
1999	125.8	39.9	0.00	165.7
2000	117.0	33.3	0.00	150.3
2001	163.4	19.0	0.00	182.4
2002	22.6	13.5	0.00	36.1
2003	84.6	10.9	0.00	95.5
2004	54.3	7.2	0.00	61.5
2005	49.9	9.2	0.00	59.1
2006	15.3	9.3	0.00	24.6
2007	20.2	8.5	0.00	28.7
2008	28.8	11.9	0.01	40.7
2009	20.0	9.0	0.00	29.0
2010	24.8	9.0	0.06	33.9

Table 3. Research surveys and catch records reviewed for use as stock trend data for Quillback Rockfish, by management unit (inside/outside), survey name, gear type, survey year span, number of surveys within the span, total number of samples (sets, tows, transects), number of sets that contained Quillback Rockfish, whether the data was used in the assessment and the most recent reference for the survey.

RESEARCH SURVEYS

location	Name	gear type	span of years	number surveys	total sets	species sets	data used	latest reference
inside	Pisces/Aquarius Submersible Surveys	submersible	1984 - 2003	2	58	53	yes	Yamanaka et al. 2004
inside	Strait of Georgia Nearshore Reef-fish Jig Survey	jig	1984 - 1985	2	285	237	no	Richards and Cass 1985
inside	Johnstone Strait Nearshore Reef-fish Jig Survey	jig	1986 - 2004	5	567	476	yes	Yamanaka and Lacko 2008
inside	Strait of Georgia Lingcod Jig Survey	jig	1985 - 2005	2 [^]	163	103	yes	Haggarty and King 2006
inside	Dogfish Longline Survey	longline	1986 - 2008	5	199	34	yes	King and McFarlane 2009
inside	Strait of Georgia Towed Camera Survey	towed camera	2003	1	40	16	yes	Martin and Yamanaka 2004
inside	Inshore Rockfish Longline Survey	longline	2003 - 2010	7	341	231	yes	Lochead and Yamanaka 2005
inside	Howe Sound Spot Prawn survey	prawn trap	1999 - 2010	12	856	156	no	Favaro et al. 2010
outside	Hecate Strait Multispecies Assemblage Survey	trawl	1984 - 2003	11	1046	125	yes	Choromanski et al. 2002
outside	Hecate Strait Synoptic survey	trawl	2005 - 2009	3	493	106	yes	Olsen et al. 2009a
outside	IPHC Standardized Stock Assessment Survey	longline	1996 - 2010	15	1359	216	yes	Obradovich et al. 2007
outside	Research Industry Charter Survey	longline	1997 - 2003	4	256	95	yes	Yamanaka et al. 2003
outside	Juan Perez Sound Submersible Survey	submersible	2005	1	29	26	yes	Yamanaka et al. 2004
outside	PHMA Longline Survey - northern	longline	2006 - 2010	3	584	331	yes	Obradovich et al. 2008
outside	PHMA Longline Survey - southern	longline	2007 - 2009	2	382	157	yes	Obradovich et al. 2008
outside	Queen Charlotte Sound Synoptic Survey	trawl	2003 - 2009	5	1177	53	yes	Olsen et al. 2009b
outside	West Coast Vancouver Island Synoptic Survey	trawl	2004 - 2010	4	873	37	yes	Olsen et al. 2009c
outside	West Coast Haida Gwaii Synoptic Survey	trawl	2004 - 2010	3	504	0	no	Olsen et al. 2008
outside	West Coast Vancouver Island Shrimp Survey	shrimp trawl	1975 - 1994	34	3494	3	no	Boutillier et al. 1998a
outside	Queen Charlotte Sound Shrimp Survey	shrimp trawl	1998 - 2010	13	1009	0	no	Boutillier et al. 1998b

CATCH RECORDS

coastwide	Hook and Line Rockfish Logbooks	jig, longline	1986 - 2010				no	Haigh and Richards 1997
coastwide	Trawl At-Sea Observer Program	trawl	1995 - 2004				no	
coastwide	Prawn Trap Observer Program	prawn trap	2002 - 2009				no	Rutherford et al. 2010

[^] seven surveys conducted, only 2 used for PFMA 18 and 19 due to changes in PFMA 18 and 19

Table 4. Posterior mean, median, SD, and CV for parameters and stock status indicators for B.C. Quillback Rockfish – outside management unit. Posterior medians for C_{2011}/MSY , $C_{2011}/Repy_{2011}$, B_{1918}/K , and all eight catchability parameters (q) were calculated using a lognormal approximation based on the posterior mean and SD. All other posterior medians were obtained directly from a resample from the importance draws.

Variable	Mean	Median	SD	CV
K	23437	18614	14145	0.60
r	0.080	0.069	0.05	0.59
MSY	462	321	539	1.17
B_{2011}	12148	6480	14690	1.21
B_{2011}/K	0.43	0.368	0.25	0.57
B_{1918}	25122	18766	14991	0.60
B_{1918}/K	1.09	1.06	0.24	0.22
B_{2011}/B_{1918}	0.42	0.377	0.28	0.65
C_{2011}/MSY	0.53	0.470	0.30	0.55
F_{2011}/F_{MSY}	1.00	0.779	0.91	0.91
B_{2011}/B_{MSY}	0.86	0.736	0.49	0.57
B_{MSY}	11718	9307	7073	0.60
$Repy_{2011}$	293	241	229	0.78
q_{HMSAS}	9.89×10^{-05}	8.73×10^{-05}	5.27×10^{-05}	0.53
q_{QCSSS}	2.32×10^{-04}	1.86×10^{-04}	1.73×10^{-04}	0.74
q_{HSSS}	4.71×10^{-04}	3.75×10^{-04}	3.57×10^{-04}	0.76
q_{WCVISS}	8.82×10^{-05}	7.04×10^{-05}	6.65×10^{-05}	0.75
q_{IPHIC}	1.56×10^{-03}	1.28×10^{-03}	1.08×10^{-03}	0.69
q_{PHMA_N}	5.80×10^{-04}	4.62×10^{-04}	4.42×10^{-04}	0.76
q_{PHMA_S}	3.29×10^{-04}	2.62×10^{-04}	2.50×10^{-04}	0.76
$q_{Charters}$	1.64×10^{-04}	1.37×10^{-04}	1.09×10^{-04}	0.66
g_{rec}	9.26×10^{-04}	7.36×10^{-04}	7.05×10^{-04}	0.76

Table 5. Posterior mean, median, SD, and CV for parameters and stock status indicators for B.C. Quillback Rockfish – inside management unit. Posterior medians for C_{2011}/MSY , $C_{2011}/Repy_{2011}$, B_{1918}/K , and all eight catchability parameters (q) were calculated using a lognormal approximation based on the posterior mean and SD. All other posterior medians were obtained directly from a resample from the importance draws.

Variable	Mean	Median	SD	CV
K	11484	10667	3632	0.32
r	0.050	0.051	0.020	0.45
MSY	144	140	50	0.35
B_{2011}	3016	2668	1813	0.60
B_{2011}/K	0.27	0.247	0.11	0.41
B_{1918}	11500	9686	4315	0.38
B_{1918}/K	1.00	0.98	0.22	0.22
B_{2011}/B_{1918}	0.28	0.274	0.13	0.47
C_{2011}/MSY	0.27	0.25	0.11	0.40
F_{2011}/F_{MSY}	0.60	0.498	0.40	0.66
B_{2011}/B_{MSY}	0.53	0.493	0.22	0.41
B_{MSY}	5742	5475	1816	0.32
$Repy_{2011}$	107	100	50	0.47
$q_{NI,jig}$	1.29×10^{-03}	1.25×10^{-03}	3.46×10^{-04}	0.27
$q_{dogfish}$	9.42×10^{-04}	9.01×10^{-04}	2.87×10^{-04}	0.31
$q_{RLL A12}$	1.53×10^{-03}	1.43×10^{-03}	5.68×10^{-04}	0.37
$q_{RLL A13}$	1.37×10^{-03}	1.29×10^{-03}	5.10×10^{-04}	0.37
$q_{RLL A14}$	6.89×10^{-04}	6.45×10^{-04}	2.59×10^{-04}	0.38
$q_{RLL A15}$	4.91×10^{-04}	4.60×10^{-04}	1.85×10^{-04}	0.38
$q_{RLL A16}$	2.85×10^{-04}	2.66×10^{-04}	1.07×10^{-04}	0.38
$q_{RLL A18}$	2.79×10^{-04}	2.61×10^{-04}	1.05×10^{-04}	0.38
$q_{RLL A28}$	4.31×10^{-04}	4.04×10^{-04}	1.62×10^{-04}	0.38
q_{sub}	6.79×10^{-03}	6.53×10^{-03}	1.92×10^{-03}	0.28
$q_{SOG,jig}$	7.34×10^{-04}	6.96×10^{-04}	2.48×10^{-04}	0.34
g_{rec}	1.83×10^{-03}	1.77×10^{-03}	4.80×10^{-04}	0.26

Table 6. BSP Posterior median estimates of three generations of population decline (B_{fir}/B_{init}) for the years 1997-2010 for the Reference Case (Ref. 1) and under a number of the key alternative scenarios for the Outside Quillback rockfish populations.

Bayesian Surplus Production model							
Year	Ref.1	Low r	High r	$B_{1918}/K=0.8$	$B_{1918}/K=1.2$	Low catch	High Catch
1997	0.41	0.41	0.43	0.50	0.35	0.37	0.42
1998	0.39	0.39	0.41	0.47	0.34	0.35	0.40
1999	0.38	0.37	0.40	0.45	0.33	0.34	0.38
2000	0.36	0.36	0.39	0.44	0.32	0.33	0.37
2001	0.36	0.35	0.38	0.42	0.32	0.32	0.36
2002	0.34	0.34	0.37	0.41	0.31	0.31	0.35
2003	0.34	0.33	0.36	0.40	0.31	0.31	0.35
2004	0.34	0.33	0.37	0.39	0.31	0.31	0.35
2005	0.34	0.32	0.37	0.39	0.31	0.31	0.35
2006	0.35	0.33	0.37	0.38	0.31	0.31	0.35
2007	0.35	0.33	0.38	0.39	0.32	0.32	0.35
2008	0.34	0.33	0.37	0.39	0.32	0.31	0.35
2009	0.35	0.33	0.37	0.39	0.32	0.31	0.35
2010	0.35	0.33	0.38	0.38	0.32	0.32	0.35

Table 7. BSP Posterior median estimates of three generations of population decline (B_{fir}/B_{init}) for the years 1997-2010 for the Reference Case (Ref. 1) and under a number of the key alternative scenarios for the Inside Quillback rockfish populations.

Bayesian Surplus Production model							
Year	Ref.1	Low r	High r	$B_{1918}/K=0.7$	$B_{1918}/K=1.1$	Low catch	High Catch
1997	0.28	0.28	0.28	0.34	0.23	0.25	0.28
1998	0.27	0.27	0.27	0.33	0.23	0.24	0.27
1999	0.26	0.26	0.27	0.32	0.23	0.24	0.27
2000	0.26	0.26	0.26	0.31	0.22	0.23	0.26
2001	0.24	0.24	0.25	0.29	0.22	0.22	0.25
2002	0.25	0.24	0.25	0.29	0.22	0.22	0.25
2003	0.25	0.24	0.25	0.29	0.22	0.22	0.25
2004	0.25	0.24	0.25	0.29	0.22	0.22	0.25
2005	0.25	0.24	0.25	0.29	0.22	0.22	0.25
2006	0.25	0.24	0.26	0.29	0.23	0.23	0.26
2007	0.26	0.24	0.27	0.29	0.23	0.23	0.26
2008	0.26	0.25	0.27	0.29	0.24	0.23	0.26
2009	0.27	0.25	0.27	0.30	0.24	0.24	0.27
2010	0.27	0.25	0.28	0.31	0.25	0.24	0.28

Table 8. Stock status indicators for Quillback Rockfish - outside management unit after 5, 15, 30 and 90 years. Policies are constant total fishing mortality (TFM) policies (tonnes). B_{FINAL} is the biomass in the final year of the projection (2016 for 5-year horizon, 2026 for 15-year horizon, 2041 for 30-year horizon, and 2101 for 90-year horizon). Probabilities (P) are presented for 4 stock status indicators: B_{FINAL} will be above: the Limit Reference Point (40% of B_{MSY}), the Upper Stock Reference (80% of B_{MSY}), the target biomass of B_{MSY} , and the current 2010 biomass (B_{2010}).

Horizon	TFM Policy (tonnes)	Median B_{FINAL}/B_{MSY}	P ($B_{FINAL} > 0.4 B_{MSY}$)	P ($B_{FINAL} > 0.8 B_{MSY}$)	P ($B_{FINAL} > B_{MSY}$)	P ($B_{FINAL} > B_{2010}$)
5 -year	0	0.86	0.88	0.54	0.41	0.78
	30	0.86	0.88	0.54	0.41	0.77
	60	0.84	0.87	0.53	0.41	0.73
	90	0.83	0.85	0.52	0.40	0.69
	120	0.81	0.83	0.51	0.39	0.64
	150	0.79	0.82	0.49	0.38	0.59
	180	0.78	0.80	0.48	0.37	0.54
	210	0.76	0.78	0.48	0.36	0.49
	240	0.75	0.77	0.47	0.36	0.44
	270	0.73	0.75	0.46	0.35	0.40
15 -year	0	1.19	0.96	0.75	0.62	0.88
	30	1.15	0.94	0.72	0.59	0.86
	60	1.10	0.92	0.69	0.56	0.83
	90	1.04	0.89	0.65	0.53	0.77
	120	0.99	0.85	0.61	0.49	0.71
	150	0.93	0.81	0.57	0.47	0.64
	180	0.88	0.77	0.54	0.44	0.57
	210	0.82	0.73	0.51	0.42	0.50
	240	0.77	0.69	0.49	0.39	0.44
	270	0.71	0.66	0.46	0.37	0.39
30 -year	0	1.55	0.99	0.90	0.82	0.92
	30	1.49	0.98	0.86	0.78	0.90
	60	1.41	0.95	0.82	0.73	0.87
	90	1.33	0.92	0.76	0.68	0.81
	120	1.24	0.86	0.71	0.62	0.74
	150	1.14	0.81	0.66	0.57	0.66
	180	1.03	0.75	0.60	0.51	0.58
	210	0.91	0.69	0.55	0.47	0.49
	240	0.78	0.63	0.49	0.43	0.42
	270	0.65	0.58	0.46	0.40	0.36
90 -year	0	1.88	1.00	0.98	0.96	0.94
	30	1.83	0.99	0.97	0.94	0.93
	60	1.76	0.97	0.94	0.90	0.90
	90	1.68	0.93	0.88	0.85	0.85
	120	1.59	0.86	0.81	0.77	0.77
	150	1.47	0.78	0.73	0.69	0.67
	180	1.31	0.70	0.65	0.61	0.58
	210	1.13	0.61	0.57	0.54	0.49
	240	0.82	0.54	0.50	0.47	0.41
	270	0.00	0.48	0.44	0.41	0.34

Table 9. Stock status indicators for Quillback Rockfish - inside management unit after 5, 15, 30 and 90 years. Policies are constant total fishing mortality (TFM) policies (tonnes). B_{FINAL} is the biomass in the final year of the projection (2016 for 5-year horizon, 2026 for 15-year horizon, 2041 for 30-year horizon, and 2101 for 90-year horizon). Probabilities (P) are presented for 4 stock status indicators: B_{FINAL} will be above: the Limit Reference Point (40% of B_{MSY}), the Upper Stock Reference (80% of B_{MSY}), the target biomass of B_{MSY} , and the current 2010 biomass (B_{2010}).

Horizon	TFM Policy (tonnes)	Median B_{FINAL}/B_{MSY}	P ($B_{FINAL} > 0.4 B_{MSY}$)	P ($B_{FINAL} > 0.8 B_{MSY}$)	P ($B_{FINAL} > B_{MSY}$)	P ($B_{FINAL} > B_{2010}$)
5 -year	0	0.58	0.79	0.23	0.10	0.80
	10	0.58	0.79	0.24	0.10	0.80
	20	0.57	0.78	0.23	0.10	0.78
	30	0.56	0.77	0.22	0.10	0.74
	40	0.56	0.75	0.21	0.09	0.70
	50	0.55	0.74	0.21	0.09	0.67
	60	0.54	0.73	0.20	0.09	0.63
	70	0.53	0.71	0.19	0.08	0.60
	80	0.52	0.69	0.18	0.08	0.56
	90	0.51	0.68	0.18	0.08	0.52
15 -year	0	0.80	0.89	0.50	0.33	0.91
	10	0.78	0.88	0.48	0.32	0.89
	20	0.75	0.85	0.45	0.29	0.86
	30	0.72	0.82	0.42	0.27	0.83
	40	0.68	0.80	0.40	0.25	0.78
	50	0.65	0.77	0.37	0.23	0.73
	60	0.62	0.74	0.35	0.21	0.68
	70	0.59	0.70	0.32	0.19	0.62
	80	0.56	0.66	0.29	0.18	0.57
	90	0.53	0.63	0.27	0.17	0.52
30 -year	0	1.15	0.95	0.73	0.60	0.96
	10	1.10	0.93	0.70	0.57	0.94
	20	1.04	0.91	0.65	0.53	0.92
	30	0.98	0.88	0.61	0.48	0.87
	40	0.91	0.84	0.57	0.45	0.83
	50	0.84	0.81	0.52	0.41	0.77
	60	0.77	0.76	0.48	0.37	0.72
	70	0.70	0.70	0.44	0.34	0.65
	80	0.63	0.64	0.40	0.31	0.58
	90	0.55	0.59	0.37	0.28	0.52
90 -year	0	1.75	0.99	0.95	0.90	0.99
	10	1.70	0.98	0.92	0.87	0.98
	20	1.63	0.96	0.89	0.83	0.96
	30	1.56	0.93	0.85	0.78	0.92
	40	1.47	0.88	0.80	0.73	0.88
	50	1.37	0.83	0.74	0.67	0.81
	60	1.25	0.76	0.66	0.61	0.74
	70	1.10	0.68	0.59	0.54	0.66
	80	0.91	0.61	0.53	0.47	0.57
	90	0.59	0.53	0.46	0.41	0.50

11. FIGURES

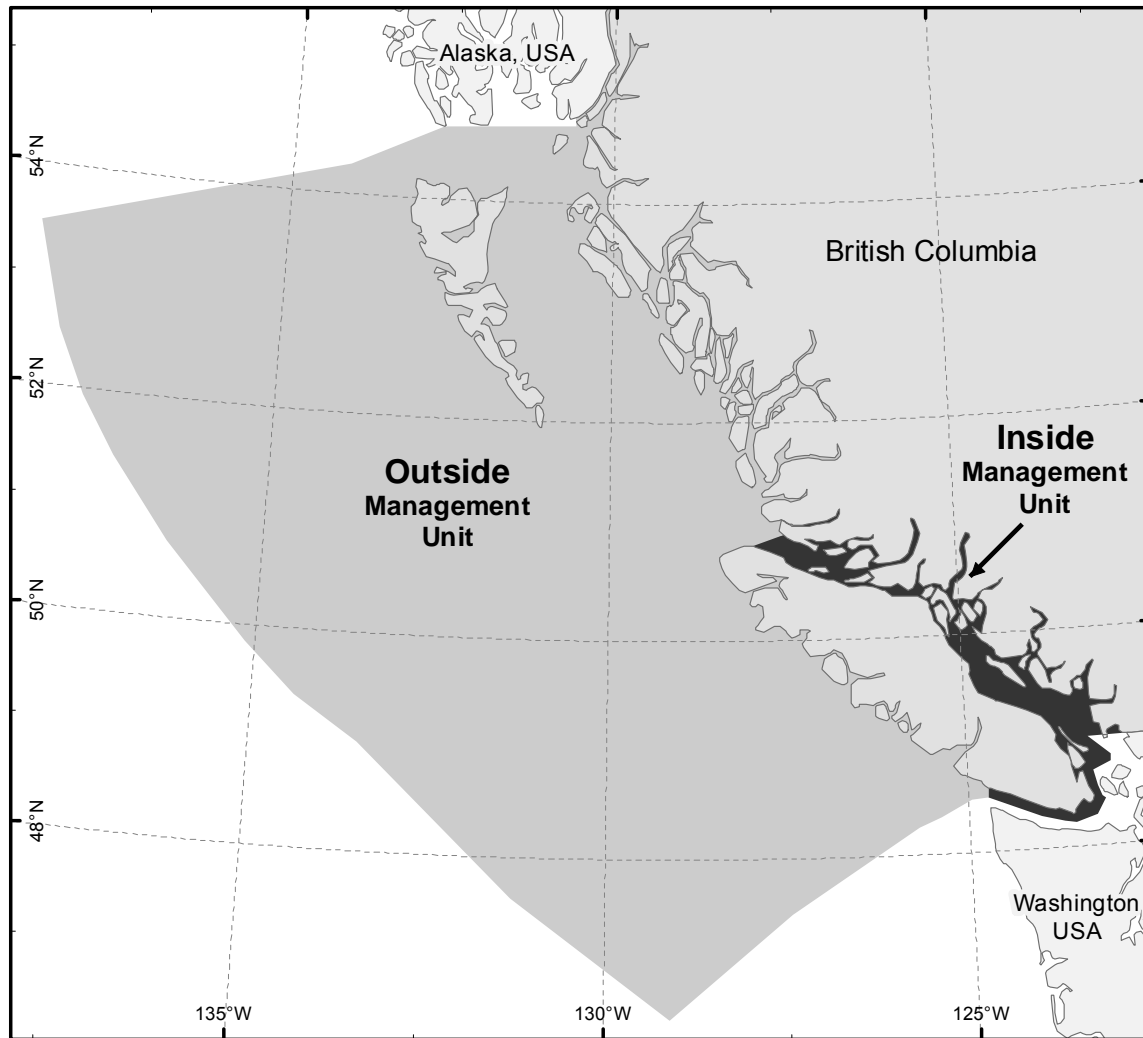


Figure 1. Quillback Rockfish management units on the Pacific coast of Canada. Outside management unit is made up of the remainder of the coast (shaded in grey). Inside management unit extends along the protected waters south and east of Vancouver Island (shaded in black).

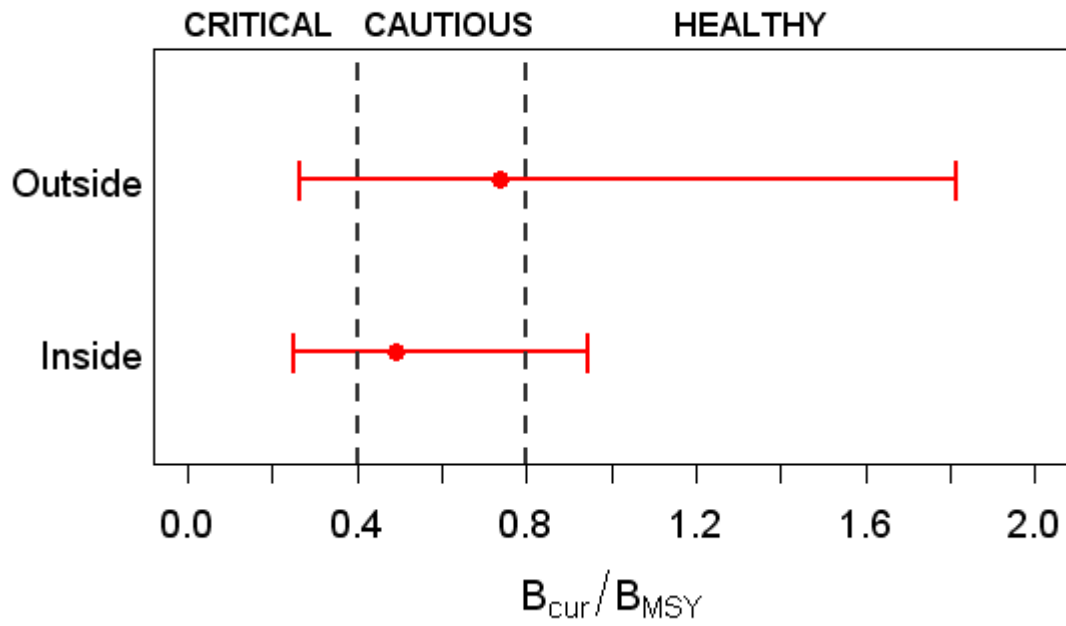


Figure 2. Quillback Rockfish stock status for the outside and inside management units in B.C. Consistent with DFO's Precautionary Approach and Fisheries Reference Points stock status is presented as the median biomass in 2011 over the biomass at MSY with 95% confidence intervals.

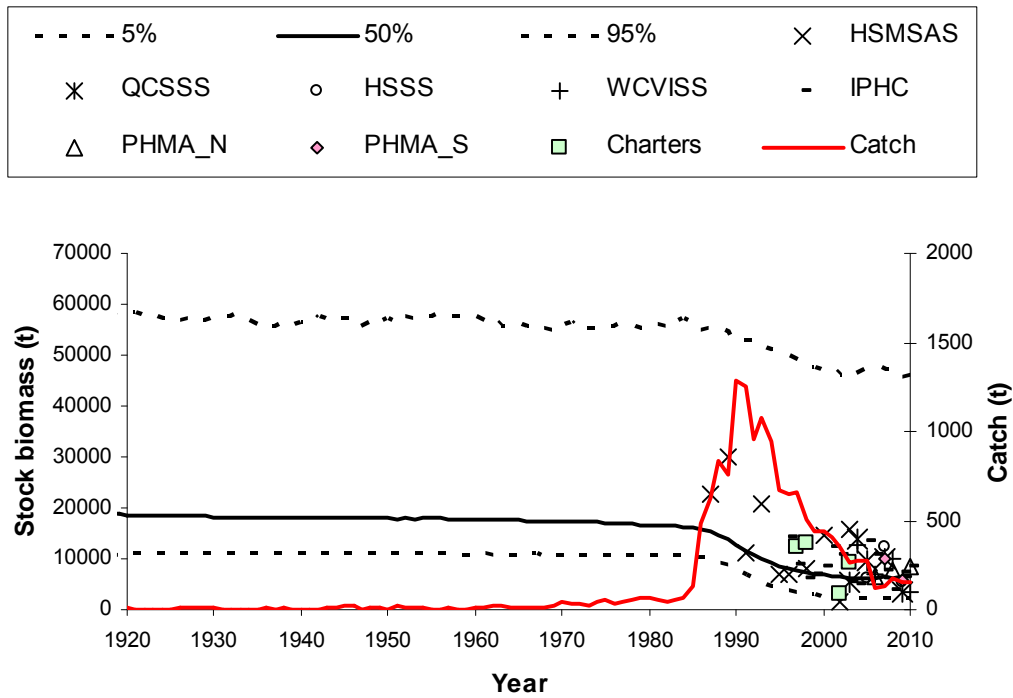


Figure 3. Catch, and posterior median and 90% probability interval for stock biomass (t) of Quillback Rockfish - outside management unit, and the observed stock trend indices divided by their posterior median value for the catchability coefficient for years 1918 to 2010. Results are shown for the reference case.

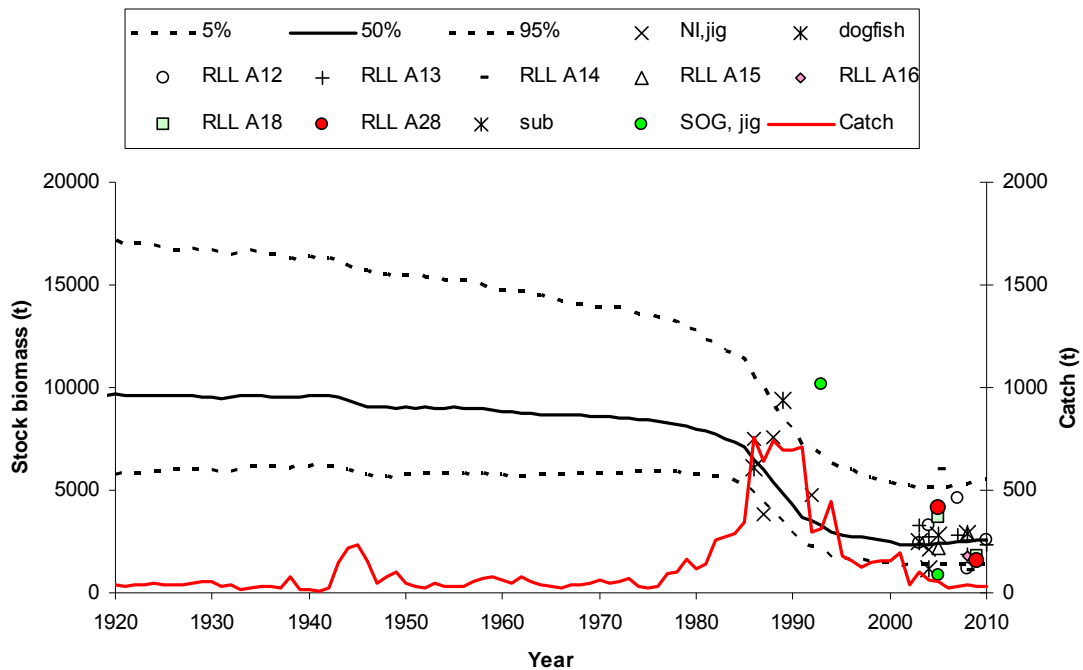


Figure 4. Catch, and posterior median and 90% probability interval for stock biomass (t) of Quillback Rockfish - inside management unit, and the observed stock trend indices divided by their posterior median value for the catchability coefficient for years 1918 to 2010. Results are shown for the reference case.

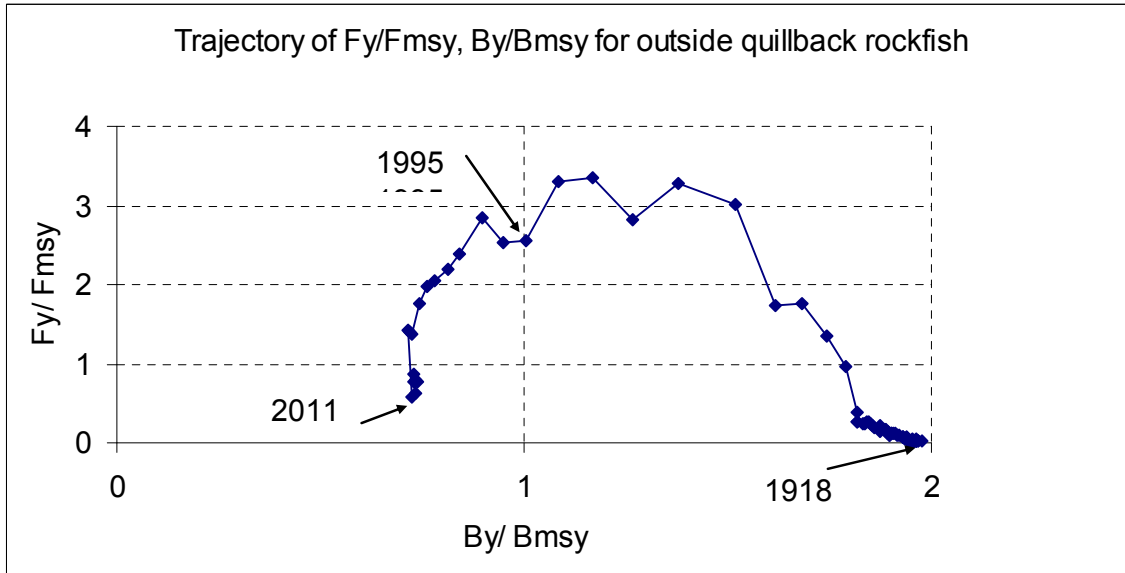


Figure 5. Time series estimates for Quillback Rockfish – outside management unit of the ratio of posterior median F_y/F_{msy} to stock biomass relative to B_{msy} for the reference case BSP model. Trajectories start at the right and proceed to the left.

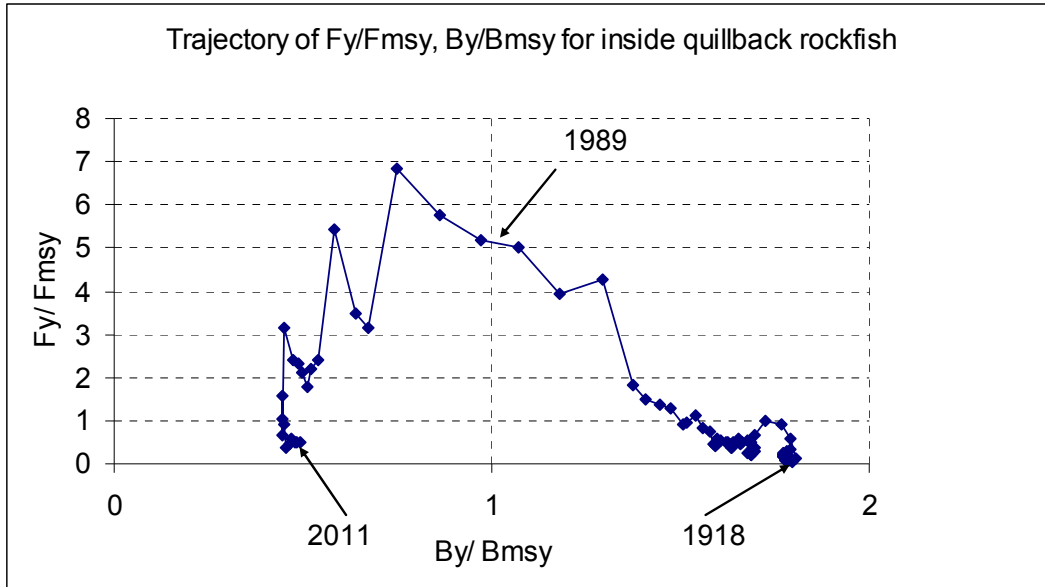


Figure 6. Time series estimates for Quillback Rockfish – inside management unit of the ratio of posterior median F_y/F_{msy} to stock biomass relative to B_{msy} for the reference case BSP model. Trajectories start at the right and proceed to the left.

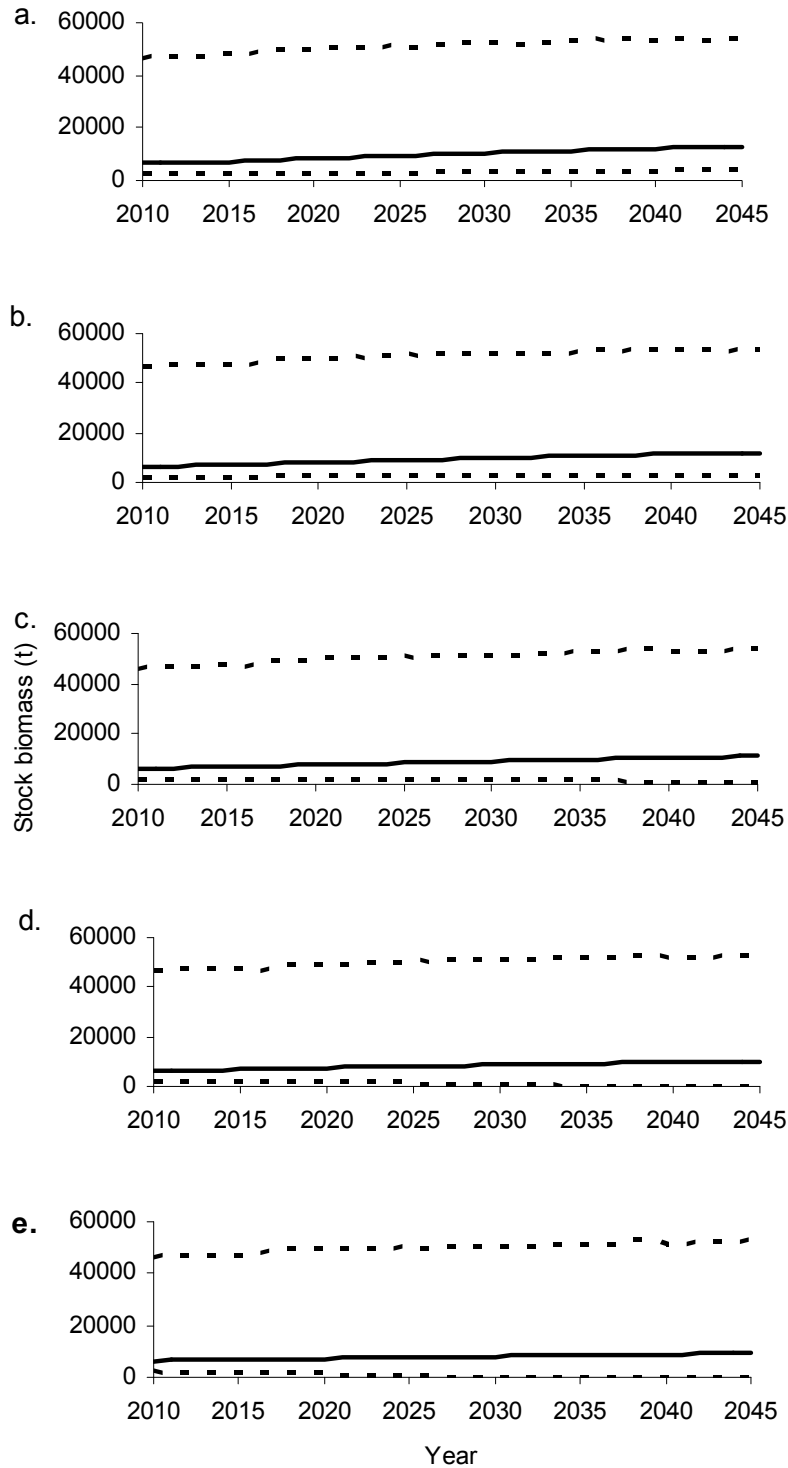


Figure 7. Projections showing 90% probability intervals (dotted lines) and medians (solid lines) for outside quillback rockfish Reference Case given the following fixed total fishing mortality: a. 30 t, b. 60 t, c. 90 t, d. 120 t, e. 150 t.

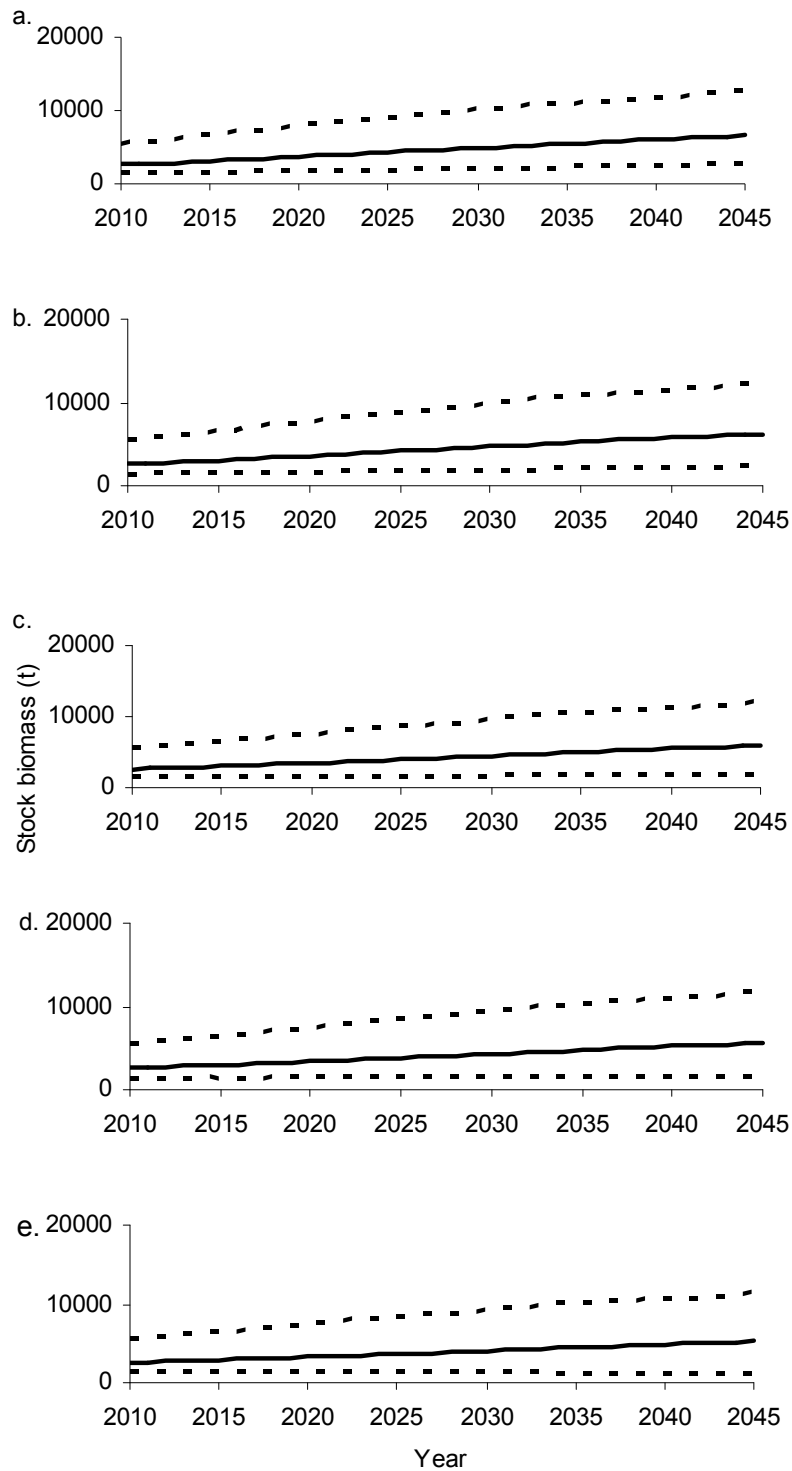


Figure 8. Projections showing 90% probability intervals (dotted lines) and medians (solid lines) for inside quillback rockfish Reference Case given the following fixed total fishing mortality: a. 0 t, b. 10 t, c. 20 t, d. 30 t, e. 40 t.

APPENDIX A. ASSESSMENT MODEL SPECIFICATION

SURPLUS PRODUCTION MODEL EQUATIONS.....	34
Deterministic Model Components.....	34
Stochastic Model Components.....	34
PRIOR DISTRIBUTIONS	37
Intrinsic Rate of Increase (r)	37
Carrying Capacity (K)	40
Ratio of Initial Biomass to Carrying Capacity (p_0).....	41
Process Error Variance.....	41
Observation Error Variance	41
Catchability (q).....	41
POSTERIOR APPROXIMATION	43
DEFINITION OF REFERENCE CASE	43
SENSITIVITY ANALYSES.....	44
Evaluation of Credibility of Sensitivity Analysis Scenarios.....	45
REFERENCES.....	46
Table A1. Summary of estimated parameters.	36
Table A2. Summary of derived management parameters of interest for the Schaefer model. ...	37
Table A3. Prior distributions for surplus production model parameters.	37
Table A4. Prior distributions for female natural mortality (M) and steepness (h) parameters used in demographic analysis for inside and outside quillback.	38
Table A5. Mean, SD and CV of r prior for each area.	40
Table A6. Square root of the average variance of the observation error for each abundance indices j , $\sigma_{obs,j}$, per area, obtained from the preliminary analysis and used in the assessment models.	41
Table A7. Definition of the subscripts for the stock trend indices in Table A6.	42
Table A8. Summary of the sensitivity runs applied. The values of the mean and SD of prior distributions for low r and high r scenarios are provided in Table A9.....	44
Table A9. The alternative prior medians of r for each area. The prior SD in the logarithm of r (0.25) remains constant.	45
Table A10. The alternative prior medians of r for each area. The prior SD in the logarithm of r (0.25) remains constant.	45
Figure A1. Prior distributions for r for each Area.....	40

SURPLUS PRODUCTION MODEL EQUATIONS

We applied a Bayesian surplus production model that utilized Sampling Importance Resampling to assess quillback stock status within each of the two assessment areas. Analyses were conducted using a previously developed Bayesian Surplus Production model program (BSP; McAllister and Babcock 2006). Required inputs for the program were catch and at least one catch rate (CPUE) index of abundance with coefficients of variation (CV). Estimated parameters included carrying capacity (K), the intrinsic rate of population growth (r), the biomass in the first modeled year defined as a ratio of K (p_0), variance parameters for each CPUE series, and catchability (q) for each CPUE series. Prior probability distributions (priors) were specified for all of the estimated parameters for this Bayesian estimation.

DETERMINISTIC MODEL COMPONENTS

The surplus production model used is Prager's instantaneous F version of the Schaefer production model (Schaefer 1954; Prager 1994). This version of an SPM has been applied in other recent assessments in the Pacific Region for British Columbia bocaccio rockfish and yelloweye rockfish (Stanley et al. 2009; King et al. 2012; Yamanaka et al. 2012) and in a recent recovery potential analysis of Canadian east coast redfish (*Sebastes mentella* and *S. fasciatus*) (McAllister and Duplisea 2011). State dynamics are modelled by assuming that biomass in a given year is a function of biomass in the previous year, the instantaneous fishing mortality rate, and two parameters that describe the impact of earlier biomass in growth, r and K :

$$(A1) \quad B_{y+1} = B_y + rB_y \left(1 - \frac{B_y}{K} \right) - F_y B_y$$

where y is the year, B_y the stock biomass at the start of year y , r the intrinsic rate of increase, K the carrying capacity and F_y the instantaneous fishing mortality rate during year y . For the initial year, an additional parameter, p_0 , is estimated which gives the ratio of initial stock biomass to carrying capacity ($p_0 = B_{1918}/K$).

Abundance indices are assumed to be directly proportional to stock biomass. The deterministic observation equation is:

$$(A2) \quad E(I_{j,y}) = q_j B_y$$

where q_j is the constant of proportionality for the abundance index j , $I_{j,y}$ the observed abundance index j in year y and $E(I_{j,y})$ is the model predicted value for $I_{j,y}$.

STOCHASTIC MODEL COMPONENTS

The state-space approach allows for deviations from model predictions (i.e., random variability) in both (i) the data (e.g., relative biomass indices) and (ii) the unobserved state of the system of interest (e.g., annual population biomass) (Millar and Meyer, 2000). These two components of the system are modelled within a single probabilistic framework that can be highly flexible (Rivot et al., 2004). Fisheries modellers tend to choose multiplicative lognormal errors (Millar and Meyer, 2000), which is what we use in our model. The abundance index data are assumed to be lognormally distributed:

$$(A3) \quad I_{j,y} \sim \text{lognormal}\left(\ln(E(I_{j,y})), \sigma_{\text{obs},j,y}^2\right)$$

where $I_{j,y}$ is the observed index of abundance for series j in year y , q_j is the constant of proportionality for series j and $\sigma_{\text{obs},j,y}$ is the standard deviation in the error deviation between the log predicted index and the log observed index j in year y .

The full log likelihood function for a given management area is as follows:

$$(A4) \quad \text{Log}(L_a) = c - \sum_{j=1}^{n_a} \sum_{y=i_j}^{f_j} \frac{\ln\left(\frac{I_{j,y}}{E(I_{j,y})}\right)^2}{2\sigma_{\text{obs},j,y}^2}$$

where c is a constant, n_a is the number of stock trend indices for area a , i_j is the initial year for stock trend index j , f_j is the final year for stock trend index j ,

The stochastic form equation A1 (i.e., the process equation) is:

$$(A5) \quad \log(B_{y+1}) = \log\left(B_y + rB_y\left(1 - \frac{B_y}{K}\right) - F_y B_y\right) + \varepsilon_{\text{process},y}$$

where the prior density for $\varepsilon_{\text{process},y}$ is given by, $\varepsilon_{\text{process},y} \sim \text{Normal}(0, \sigma_{\text{process}}^2)$.

In each year the value for F_y is solved numerically given the total recorded catch, C_y , where the total catch is available. However, where recreational catch records are missing, we use the imputed recreational fishing effort in each year, E_y , as a covariate for the partial fishing mortality rate due to recreational fishing:

$$(A6) \quad F_{y,r} = gE_y$$

where g is the catchability coefficient for recreational fishing, E_y is the total recreational fishing effort in year y and $F_{y,r}$ is the imputed recreational fishing mortality rate in year y . In years with missing recreational catch records, the biomass dynamic equation becomes:

$$(A7) \quad \log(B_{y+1}) = \log\left(\left(B_y + rB_y\left(1 - \frac{B_y}{K}\right) - F_y B_y\right) \exp(-F_{r,y})\right) + \varepsilon_{\text{process},y}$$

$$(A8) \quad C_{r,y} = \left(B_y + rB_y\left(1 - \frac{B_y}{K}\right) - F_y B_y\right) (1 - \exp(-F_{r,y}))$$

We estimated g by predicting the average recreational catch for the years 2000-2010 where we have records of both recreational catch and recreational effort.

$$(A9) \quad \text{Log}(L_b) = c - \frac{\left(\log\left(\frac{\bar{C}_r}{\hat{C}_r}\right) \right)^2}{2\sigma_r^2}$$

Where L_b is the likelihood function of the average recreational catch data \bar{C}_r , for the years in which records are available (2000-2010) (see Appendix D), c is a likelihood function constant, \hat{C}_r is the average of the predicted recreational catch for these same years with the predicted catches given by eq.

The stochastic form of equation A2 (i.e., the observation equation) is:

$$(A10) \quad \log(I_{j,y}) = \log(q_j) + \log(B_y) + \varepsilon_{obs,j,y}$$

where $\varepsilon_{obs,j} \sim \text{Normal}(0, \sigma_{obs,j}^2)$.

The $\varepsilon_{process}$ are i.i.d. random variables in all modelled years up to 2010. As shown above, they have the same prior density function (eq. A5) but should information be available in the data, there may be updates to the priors in the computation of their posterior distributions. Up to 2010, all $\varepsilon_{obs,j,y}$ are considered to be independent and have the same variances between years. For each future year in the projections, we have modelled the $\varepsilon_{process}$ random variables to be positively autocorrelated with a correlation coefficient, ρ (see Stanley et al. (2009) for details on the autocorrelation equations). There were too few years in which it was possible to estimate the autocorrelation in process error deviates (ρ) because estimates only became non-zero after 2000. We therefore applied the commonly applied default value for ρ of 0.5.

A summary of key parameters estimated by the surplus production model is provided in Table A1. A summary of derived management parameters is provided in Table A2.

Table A1. Summary of estimated parameters.

Parameter	Description
r	Intrinsic rate of increase
K	Carrying Capacity
p_0	Ratio of initial stock biomass in first year to carrying capacity
$\{q_{j=1}, q_{j=2}, \dots, q_{j=J}\}$	Vector of catchability parameters for J abundance indices (where, J is Area-specific as described in Table 1 of main document)

Table A2. Summary of derived management parameters of interest for the Schaefer model.

Maximum Sustainable Yield (MSY)	$rK/4$
Stock size for MSY	$K/2$
Rate of exploitation at MSY	$r/2$
Maximum rate of exploitation	r

PRIOR DISTRIBUTIONS

A summary of prior distributions for estimated parameters is given in Table A3. A more detailed description of the methods used to determine each prior is provided below.

Table A3. Prior distributions for surplus production model parameters.

Parameter	Prior density function
log(K) for outside quillback	Uniform(log(100),log(100000))
log(K) for inside quillback	Uniform(log(100),log(50000))
$\ln(q_i)$	Uniform(-20,20)
p_o for inside quillback	Lognormal(log(0.9),0.2 ²)
p_o for outside quillback	Lognormal(log(1.0),0.2 ²)
r (outside)	LogNormal(log(0.0881),0.604 ²)
r (inside)	LogNormal(log(0.091),0.595 ²)
$\varepsilon_{process,y}$	Normal(0, 0.05 ²)

INTRINSIC RATE OF INCREASE (R)

For each assessment area, an informative prior distribution for the intrinsic rate of increase, r , was approximated with the Euler-Lotka demographic method. This method was first defined in McAllister et al. (2001) and reformulated in McAllister and Babcock (2006) and Stanley et al. (2009). This demographic method has recently been applied to Pacific Region stock assessments for British Columbia bocaccio rockfish (Stanley et al. 2009) and yelloweye rockfish (Yamanaka et al. 2012). We provide an overview of the steps taken by Yamanaka et al. (2009) in this section.

Demographic Model Applied to Quillback

The input data for the demographic model used to develop a prior distribution for r includes the posterior distributions obtained from the biological data analysis (Appendix B), as well as probability density functions that describe uncertainty in natural mortality and steepness parameters (Table A4).

Table A4. Prior distributions for female natural mortality (M) and steepness (h) parameters used in demographic analysis for inside and outside quillback.

Parameter	Prior density function	Other details
M (year^{-1}) outside quillback	Lognormal(0.048, 0.25 ²)	Minimum = 0.02, maximum = 0.12
M (year^{-1}) inside quillback	Lognormal(0.057, 0.25 ²)	Minimum = 0.02, maximum = 0.12
Beverton-Holt steepness (h)	$h \sim 0.2 + 0.8 * h'$	Mean(h) = 0.67, SD(h) = 0.17
h' ($h' \in [0;1]$)	$h' \sim \text{Beta}(2.6, 1.8)$	
from Forrest et al. (2010)		

Prior distributions for M and h

The median of the lognormal probability distribution used to describe M was 0.048 yr^{-1} for outside female quillback rockfish and 0.057 yr^{-1} for inside female quillback rockfish. The standard deviation of the logarithm of M was set at 0.25 to thoroughly account for uncertainty in this parameter. Minimum and maximum values were set at 0.02 and 0.12 to exclude implausibly low or implausibly high values. M was assumed equal for all age classes starting with one year olds.

The steepness parameter, h , used in equation A14 (below) is defined as the ratio of recruitment at 20% of the unexploited stock biomass to recruitment in the unfished state (Hilborn and Liermann 1998; Myers et al. 1999). Spawner recruitment data were not available for British Columbia quillback stocks, which made it necessary to construct a distribution for h from the literature. A Beverton-Holt recruitment function was selected for the current assessment because quillback have not been observed to display cannibalistic behaviour. Because it is benthic, dwells mainly in rocky habitats and limited in terms of the number of hiding places from predators, this suggests a Beverton-Holt-shaped recruitment curve.

We used Forrest et al.'s (2010) published meta-analyses of rockfish stock-recruit data from which to obtain an informative prior for a Beverton-Holt steepness parameter for quillback

Demographic equations

The Lotka equation is numerically solved for r with the integration over ages starting at age 0. Assuming that there is no reproduction in the first year, a computation in which the integration starts at age 1 is analytically equivalent to an integration starting at age 0 (McAllister et al. 1994):

$$(A11) \quad 1 = \sum_{t=1}^{t_p} l_t m_t e^{-tr}$$

where l_t is the survivorship at age t (i.e., the fraction of animals surviving from age 1 to age t), m_t the number of age 1 recruits expected to be produced by adult females of age t , r the intrinsic rate of increase, and t_p the age of the plus group, which was set at 84 years for quillback. At this age only about 1-2% of individuals are still alive.

Survivorship for equation A11 was computed with the following equation:

$$(A12) \quad l_t = l_1 \exp\left(-\sum_{i=1}^{t-1} M_i\right)$$

where l_1 is set to 1 and M is the natural mortality rate for quillback. The number of age 1 recruits expected to be produced by adult females of age t (m_t in equation A11) is the product of the number of age 1 recruits produced per ton of spawners when spawner abundance approaches zero (R_s), the weight at age t (W_t), and the fraction mature at age t ($fmat_t$):

$$(A13) \quad m_t = R_s W_t fmat_t$$

Probability distributions for W_t and $fmat_t$ were taken from the posterior distributions obtained from the biological data analysis (Appendix B). Specific details of the methods used to obtain marginal posterior distributions for these parameters are available in Cuif et al. (2009). The R_s in equation A13 can be expressed as a function of spawner biomass produced per single age-1 recruit (S) and recruitment steepness (h), as shown in equations A14 – A15. In the case of a Beverton-Holt stock-recruitment relationship,

$$(A14) \quad R_s = \frac{4h}{S(1-h)} \quad (\text{Michielsens and McAllister 2004}).$$

The S parameter in equation A14 (spawner biomass per single age-1 recruit) is defined as:

$$(A15) \quad S = \left(\sum_{t=1}^{t_p-1} (W_t fmat_t e^{-tM}) \right) + W_{t_p} fmat_{t_p} \frac{e^{-t_p M}}{1 - e^{-M}}$$

where t_p is the age of the plus group and W_{t_p} the expected weight of animals in the plus group. The weight of animals in the plus group (W_{t_p}) was computed from the relative number ($nagep$) and weight (W) of animals in ages above the plus group. For quillback populations in which we assume the plus group extends from $t = 85$ to 90 years,

$$(A16) \quad nagep_t = \frac{e^{-M(t-16)}}{\sum_{i=85}^{90} e^{-M(i-16)}}$$

$$(A17) \quad W_{t_p} = \sum_{t=85}^{90} nagep_t W_t$$

1

Formulation of r prior

Three candidate probability density functions (*pdf*) were considered to represent the frequency distribution of r values drawn from the Monte Carlo method when creating a prior for r : lognormal, normal, and gamma. Model selection analysis was applied to results to determine which *pdf* best described the Monte Carlo frequency distribution. The sum of squares of the

deviations between the Monte Carlo frequency and the predicted frequency was minimized in each case so that the best fit was obtained for each distribution. The normal *pdf* had the lowest sums of squares, and was thus used to represent prior distributions for the two assessment areas. A more thorough description of this analysis is available in Cuif et al. (2009).

The prior distributions for r that were used as inputs to the SPM were similar for the two areas (Table A5, Figure A1).

Table A5. Mean, SD and CV of r prior for each area.

	Outside	Inside
Median (r)	0.0881	0.0910
SD(r)	0.057	0.058
SD(log(r))	0.604	0.595

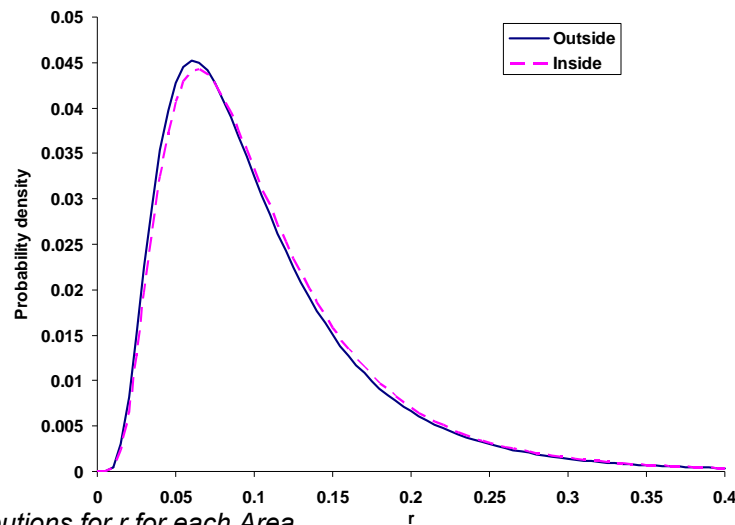


Figure A1. Prior distributions for r for each Area.

CARRYING CAPACITY (K)

The prior for K in each assessment area was first assumed uniform over a large range of values between 100 tonnes and 50,000 tons for inside and 100 tonnes and 100000 tonnes for outside. This was to enable equal credibility for small and large possible values for K . However, this uniform prior on K appeared unsuitable because posterior distributions for some key quantities (e.g., the ratio of current stock size to B_{msy}) at least for the outside population were quite flat. This problem, resulting mainly from large interannual variability in stock trend indices, has previously been noted by Millar and Meyer (2000) and recently in King et al. 2012. We therefore chose an alternative approach in which we applied a uniform prior over the natural logarithm of K with the same upper and lower bounds. This alternative tended to reduce the very fat tail in posteriors for K and initial stock size, but had relatively little influence on posterior median results. The uniform prior over the log of K was used in the reference case.

Ratio of Initial Biomass to Carrying Capacity (p_0)

The first year of the total catch time series considered is 1918. Our prior distribution suggested that the outside quillback stock biomass in 1918 (B_{1918}) was at unfished conditions since the offshore trawl and hook and line fishery was not widely developed at this time. However, in inside waters, even by 1918, there had been moderate amounts of hook and line fishing. The prior for p_0 was assumed to be log-normal with a mean of $\log(1)$ for outside quillback and $\log(0.9)$ for inside quillback and a SD in the natural logarithm of p_0 of 0.2.

Process Error Variance

The prior standard deviation of $\varepsilon_{process}$, $\sigma_{process}$, was set at 0.05. This was to account for interannual variability in stock biomass due to variability in stock dynamics processes that were not explicitly modeled (e.g. interannual variation in movement between areas, recruitment, growth). The value for the prior SD was the same as that applied in the inside yelloweye rockfish assessment (Yamanaka 2012) and the recent Atlantic redfish recovery potential analysis (McAllister and Duplisea 2011).

Observation Error Variance

Values for $\sigma_{obs,j}$ (i.e., the standard deviation of $\varepsilon_{obs,j}$, from equation A10) were obtained by iterative reweighting for each model run. Even then, the values obtained tended to be quite stable across different model runs for the same stock (Table A6 for reference case values). We presumed the same constant values for $\sigma_{obs,j}^2$ for all values in a given stock trend index. Thus in the iterative reweighting, the values for $\sigma_{ind,j}^2$ were adjusted to match (rounding up to the nearest 0.05 or 0.1) the values for $\sigma_{obs,j}^2$ that were outputted from the stock assessment model.

Catchability (q)

The prior *pdf* for q_j is uniform over the log of q_j over the interval [-20,20]. This prior is the same for each abundance index j .

Table A6. Square root of the average variance of the observation error for each abundance indices j , $\sigma_{obs,j}$, per area, obtained from the preliminary analysis and used in the assessment models.

Inside	$\sigma_{NI,jig}$	$\sigma_{dogfish}$	σ_{RLLA12}	σ_{RLLA13}	σ_{RLLA14}	σ_{RLLA15}	σ_{RLLA16}	σ_{RLLA18}	σ_{RLLA28}	σ_{sub}	$\sigma_{SOG,jig}$
	0.35	0.5	0.55	0.55	1.3	0.5	0.55	0.6	0.75	0.2	1.6
Outside	σ_{HMSAS}	σ_{QCSSS}	σ_{HSSS}	σ_{WCVISS}	σ_{IPHC}	σ_{PHMA_N}	σ_{PHMA_S}	$\sigma_{Charters}$			
	0.85	0.60	0.45	0.55	0.4	0.2	0.4	0.6			

Table A7. Definition of the subscripts for the stock trend indices in Table A6.

Inside waters			
Index	Survey	Time period	Number of years
NI,jig	Northern inside waters jig.	1986-2004	5
dogfish	Inside dogfish longline	1986-2008	5
RLL A##	Inside rockfish longline Area ##	2003-2010	8
sub	Strait of Georgia submersible	1984-2003	2
SOG, jig	Strait of Georgia lingcod jig	1993-2005	2
Outside waters			
Index	Survey	Time period	Number of years
HSMSAS	Hecate Strait Multispecies Assemblage	1984-2003	11
QCSSS	Queen Charlotte Sound Synoptic Trawl	2003-2009	5
HSSS	Hecate Strait Synoptic Trawl	2005-2009	3
WCVISS	WCVI shrimp survey	2004-2010	4
IPHC	International Pacific Halibut Commission Longline	1996-2010	15
PHMA_N	Pacific Halibut Management Association - southern waters	2006-2010	3
PHMA_S	Pacific Halibut Management Association - northern waters	2007-2009	2
Charters	Research Charter Survey for Yelloweye Rockfish	1997-2003	4

The total objective function or log of Bayes rule, i.e., the log the prior density function and log likelihood function for each area a is thus given by:

(A18)

$$\begin{aligned} \log(\text{Bayes rule}_a) = & \log(L_a) + \log(L_b) + \sum_{j=1}^{n_a} \log(\text{prior}(q_{j,a})) + \log(\text{prior}(K_a)) + \log(\text{prior}(r_a)) \\ & + \log(\text{prior}(p_{o,a})) + \sum_{y=1918}^{2010} \log(\text{prior}(\varepsilon_y)) \end{aligned}$$

where n_a is the number of abundance indices in area a .

POSTERIOR APPROXIMATION

The SIR algorithm was used to compute marginal posterior distributions for BSP model parameters and quantities of interest (McAllister et al. 1994; Stanley et al. 2009). The key output statistics computed include marginal posterior distributions of current stock biomass (B_{2011}), current stock biomass to carrying capacity (B_{2011}/K), the ratio of current stock biomass to stock biomass at MSY (B_{2011}/B_{MSY}), the replacement yield in 2011 ($RepY_{2011}$), the ratio of the replacement yield in 2011 to the catch biomass in 2011 ($RepY_{2011}/C_{2011}$), and the ratio of fishing mortality rate in 2011 to fishing mortality rate at MSY (F_{2011}/F_{MSY}).

Sampling was quite efficient and runs of 1-2 million draws from the importance function were sufficient (approximately 1/2 - 1 hour of computing on 2 GHz IBM PCs). The marginal posteriors for the quantities of interest were reliably estimated with the maximum importance ratio for any one draw taking no more than about 0.2% in each of the runs conducted. Runs using alternative importance functions, (e.g., with different variances in the key parameters), yielded practically identical marginal posterior estimates. The marginal prior and posterior *pdfs* of r and K are plotted in Appendix F to show the extent to which priors have been updated.

DEFINITION OF REFERENCE CASE

We develop and present results for each of the two assessment areas using a reference case set of inputs and assumptions. For the reference case runs, all inputs, assumptions and settings were formulated based on the best available information and scientific judgment. Prior distributions used in the reference case have been described above. The following list summarizes the key settings:

- Prior mean r formulated for each of the two stocks using the Beverton-Holt steepness prior distribution and life history parameter estimates for each stock
- All stock trend indices used for each stock, except for the commercial catch rate indices
- Schaefer surplus production function ($B_{MSY}/K=0.5$)
- Prior mean $B_{1918}/K = 1$ for outside and 0.9 for inside waters
- Uninformative priors for q
- Lag 1 autocorrelation with the autocorrelation coefficient, ρ , set at 0.5 starts in 2011 (see Stanley et al. 2009 for the equations)
- CVs for stock trend indices obtained by iterative reweighting, determined by fitting the BSP model to the data

We allowed for the possibility of updating the reference case settings based on results obtained after fitting the model to the data in the different sensitivity analyses. We applied conservative criteria for updating the reference case settings to reduce the possibility of making excessively frequent and numerous changes or poorly justified changes that could result from random variation in the data when reference case settings are actually better approximations than the alternative settings. We would consider revising reference case settings only if there was a very strong weight of evidence (e.g., a Bayes factor of less than 1/10) against the reference case setting compared to the most credible alternative setting for some model component) in the posterior results and this held for the two stocks.

SENSITIVITY ANALYSES

Sensitivity tests were conducted to evaluate the effect of stock assessment model assumptions on stock status and projection results. A summary of these analyses is provided in Table A8, and a brief description of each analysis is provided below.

Table A8. Summary of the sensitivity runs applied. The values of the mean and SD of prior distributions for low r and high r scenarios are provided in Table A9.

Category code	Category description	Run number	Runs for all two areas (Order of Areas: outside, inside)
Ref	Reference run	1-2	Reference case runs
A	r prior mean	1-2	prior for r centred over low values
		3-4	prior for r centred over high values
B	B_{1918} / K prior mean	1-2	prior mean centred over low values
		3-4	prior mean centred over high values
C	Uncertainty over historic catches	1-2	Historic catch values multiplied by 50% and 150%.
D	Effect of survey data	1	Johnstone Strait Jig survey
		2	Inside dogfish longline survey
		3	Inside rockfish longline surveys
		4	Strait of Georgia Sub and Jig surveys
		5	Hecate Strait assemblage & synoptic trawl surveys
		6	Synoptic trawl surveys
		7	IPHC longline surveys
		8	PHMA and Charter longline surveys
E	Prior for K	1-2	Uniform on K prior (500-50,000 tons)

Prior distribution on r - To evaluate the sensitivity of model results to the informative prior distribution for r , two additional runs were conducted for each of the two assessment areas: one with high r and one with low r (Table A9). The low prior r median was one third less than the reference case and the high prior r median was one third higher than the reference case prior r median.

Table A9. The alternative prior medians of r for each area. The prior SD in the logarithm of r (0.25) remains constant.

1.1.1. Area	1.1.2. low r mean	1.1.3. reference r mean	1.1.4. high r mean
1.1.5. Outside	1.1.6. 0.059	1.1.7. 0.0881	1.1.8. 0.117
1.1.9. Inside	1.1.10. 0.061	1.1.11. 0.0910	1.1.12. 0.121

B_{1918}/K prior mean – To evaluate the sensitivity of the model to alternative priors for the ratio of initial stock size to average unfished stock size (B_{1918}/K) prior means lower and higher than the reference case were applied for both areas (Table A10).

Table A10. The alternative prior medians of r for each area. The prior SD in the logarithm of r (0.25) remains constant.

1.1.13. Area	1.1.14. low B_{1918}/K mean	1.1.15. reference B_{1918}/K mean	1.1.16. high B_{1918}/K mean
1.1.17. Outside	1.1.18. 0.8	1.1.19. 1	1.1.20. 1.2
1.1.21. Inside	1.1.22. 0.7	1.1.23. 0.9	1.1.24. 1.1

Prior for K – An alternative to the reference case prior for K is presented as a sensitivity analysis for both areas. The alternative formulation uses a uniform distribution between 5,000 tonnes and 50,000 tonnes for inside and uniform over 5,000 tonnes to 100,000 tonnes for outside. As described in Appendix A, this prior was originally considered for both assessment areas; however the reference case was switched to the log of K with the same upper and lower bounds due to flat posterior distributions particularly for the outside area. We include the original formulation in sensitivity analyses for comparison purposes.

Effect of including different survey data - We evaluated the sensitivity of results to including different sets of survey data for the two areas. This was accomplished by rerunning the BSP model with each different set of survey data removed one at a time. We did not rerun the models with each single dataset removed one at a time due to time and space constraints. Even so this created multiple additional runs to report on and gives a rigorous evaluation of the sensitivity of results to the different sources of data.

Evaluation of Credibility of Sensitivity Analysis Scenarios

To compare the credibility of each model given the data in sensitivity analyses, we computed Bayes factors (Kass and Raftery 1995) for the reference case and for each of the related sensitivity runs. Bayes factors account for both the relative goodness of fit of the model to the data and the parsimony for each of the alternative models. They are calculated as the ratio of the marginal probability of the data for one model to that for another model. We used the mean value for the importance weights from a given model run as an approximation of the probability of the data given the model (Kass and Raftery 1995; McAllister and Kirchner 2002). This is known to be a numerically stable approximation for the probability of the data given the model and approximations obtained through importance sampling were obtained with high precision (i.e., the CV in the natural logarithm in the mean weight was less than 0.05 after several million

draws from the importance function). In all instances we referenced Bayes factors to our reference case model settings, i.e., the probability of the data for the reference case model was placed in the denominator and that for the model to which it was compared in the numerator. It is commonly held that nothing should be made of Bayes factor unless the value for it departs substantially from 1. Even fairly large or small Bayes factors can come from random chance in the data and possible misspecification of probability models for the data, e.g., treating errors for each observed index value as independent when they may not be independent. Thus, while a factor of 1/10 may appear to provide strong evidence against a model, the difference in fits of the model to the data could still have resulted from random chance in the data. Intermediate values for Bayes factor (e.g., between about 1/100 and 100) should be interpreted with restraint. Models with Bayes factors of between about 1/10 and 1/100 could be interpreted as unlikely but not discredited. When Bayes factor is less than 1/1000, the model with lower credibility can be viewed as highly unlikely relative to the other.

REFERENCES

- Cuif, M., McAllister, M., and King, J.R. 2009. Development of a surplus production model applicable to British Columbia offshore stocks of quillback (*Ophiodon elongatus*). Canadian Technical Report of Fisheries and Aquatic Sciences 2861: xii+72 p. Available at <http://www.dfo-mpo.gc.ca/Library/340571.pdf> (January 27, 2010).
- Forrest, E., McAllister, M.K., Dorn, M., Martell, S., and Stanley, R.D. 2010. Hierarchical Bayesian estimation of recruitment parameters and reference points for Pacific rockfishes (*Sebastes* spp.) under alternative assumptions about the stock-recruit function. *Can. J. Fish. Aquat. Sci.* 67: 1611-1634.
- Kass, R.E., and Raftery, A.E. 1995. Bayes factors. *J. Am. Stat. Assoc.* 90: 773–795.
- King, J.R., McAllister, M.K., Holt, K.R., and Starr, P. 2012. Lingcod (*Ophiodon elongatus*) stock assessment and yield advice for outside stocks in British Columbia. DFO Can. Sci. Advis. Sec. Res. Doc. 2011/124. vii + 176p.
- McAllister, M.K., and Babcock, E.A. 2006. Bayesian surplus production model with the Sampling Importance Resampling algorithm (BSP): A user's guide. Available from: <http://www.sefsc.noaa.gov/library.jsp> (January 27, 2010).
- McAllister, M.K., and Duplisea, D. 2011. Production model fitting and projection for Atlantic redfish (*Sebastes fasciatus* and *Sebastes mentella*) to assess recovery potential and allowable harm. DFO Can. Sci. Advis. Sec. Res. Doc. 2011/057 vi + 75p.
- McAllister, M.K. and Kirchner, C.H. 2002. Accounting for structural uncertainty to facilitate precautionary fishery management: illustration with Namibian orange roughy. *In* Targets, Thresholds, and the Burden of Proof in Fisheries Management, Mangel, M. (Ed.) *Bull. Mar. Sci.* 70(2):499-540.
- McAllister, M.K., Pikitch, E.K., and Babcock, E.A. 2001. Using demographic methods to construct Bayesian priors for the intrinsic rate of increase in the Schaefer model and implications for stock rebuilding. *Can. J. Fish. Aquat. Sci.* 58: 1871–1890
- McAllister, M.K., Pikitch, E.K., Punt, A.E., and Hilborn, R. 1994. A Bayesian approach to stock assessment and harvest decisions using the sampling/importance resampling algorithm. *Can. J. Fish. Aquat. Sci.* 51: 2673-2687.

-
- Michielsens, C. and McAllister, M.K. 2004. A Bayesian hierarchical meta-analysis of stock-recruitment functions for Atlantic salmon: quantifying structural and parameter uncertainties. *Can. J. Fish. Aquat. Sci.* 61:1032-1047.
- Millar, R.B., and Meyer, R. 2000. Non-linear state space modeling of fisheries biomass dynamics by using Hastings–Metropolis within-Gibbs sampling. *Appl. Stat.*, 49: 327–342.
- Myers, R.A., Bowen, K.G., and Barrowman, N.J. 1999. Maximum reproductive rate of fish at low population sizes. *Can. J. Fish. Aquat. Sci.*, 56: 2404–2419.
- Prager, M. H. 1994. A suite of extensions to a nonequilibrium surplus-production model. *Fish. Bull. (U.S.)* 92: 374–389.
- Rivot, E., Prévost, E., Parent, E., and Baglinière, J.L. 2004. A Bayesian state-space modelling framework for fitting a salmon stage-structured population dynamic model to multiple time series of field data. *Ecological Modelling.*, 179: 463–485.
- Schaefer, M.B. 1954. Some aspects of the dynamics of populations important to the management of commercial marine fisheries. *Bulletin of the Inter-American Tropical Tuna Commission*, 1: 27-56.
- Stanley, R. D., McAllister, M., Starr, P., and Olsen, N. 2009. Stock assessment for bocaccio (*Sebastes paucispinis*) in British Columbia waters. DFO Can. Sci. Advis. Res. Doc. 2009/055. xiv + 200p.
- Yamanaka, K.L., McAllister, M.M, Etienne, M.-P., Obradovich, S., and Haigh, R. 2012. *Stock assessment for the inside population of yelloweye rockfish (Sebastes ruberrimus) in British Columbia, Canada for 2010*. DFO Can. Sci. Advis. Sec. Res. Doc. 2011/129. xiv + 132p.

APPENDIX B. BIOLOGICAL DATA ANALYSIS

Approximations of the rates of natural mortality rates for inside and outside female quillback rockfish were obtained from the application of the Hoenig (1983) method to the oldest aged fished found in research survey samples, 80 years for the inside and 95 years for the outside (Table B1).

Table B1. Values applied for the rate of natural mortality for female quillback rockfish in inside and outside waters.

	Units	Value	CV	Minimum	Maximum
Natural mortality rate for inside quillback	yr ⁻¹	0.057	0.25	0.02	0.12
Natural mortality rate for outside quillback	yr ⁻¹	0.048	0.25	0.02	0.12

Three types of biological analysis are presented in this appendix: (i) estimation of growth parameters based on length-at-age data, (ii) estimation of a maturity function, and (iii) estimation of a length-weight relationship. Outputs from these analyses were used to develop informative prior distributions for productivity parameters in the Bayesian surplus production model (Appendix F).

Biological samples were collected from research surveys between 1984 and 2010. Samples were obtained from a variety of gear types, including bottom trawl, longline, and jig. Ageing was conducted using break and burn methodology (Chilton and Beamish 1982). Annual sample sizes for age data are shown in Table B2. Samples for ageing taken from the commercial fishery are unlikely to reflect the stock as a whole due to specific size requirements for the live-fish market.

Table B2. Number of quillback rockfish aged in the two management units (inside/outside) from jig, longline and trawl research surveys from 1980 to 2008.

year	inside	outside	year	inside	outside
1980		63	1995		
1981			1996		
1982			1997		
1983	180		1998	341	
1984	450		1999		
1985	472		2000	100	
1986	518		2001		17
1987	463		2002		21
1988	887		2003	472	360
1989			2004	558	299
1990			2005	274	744
1991			2006	108	1810
1992	572		2007	612	808
1993	177		2008	151	1954
1994					

A Bayesian approach to parameter estimation was used for all three biological analyses. Marginal posterior distributions for biological parameters were obtained using importance sampling (SIR). The SIR algorithm used was based on McAllister and Ianelli (1997). Its application to the current quillback analysis is described in Cuif et al. (2009). All sampling was determined to be efficient based on the maximum importance ratio. For all model runs, the maximum weight for a single draw (expressed as a percentage of the total cumulative posterior weight) dropped below 0.40% within one million draws from the importance function.

GROWTH PARAMETERS

The growth of individual quillback was estimated by fitting a Bayesian version of the Von Bertalanffy growth model to individual length-at-age observations for male and female quillback. The Von Bertalanffy model is based on three parameters: L_{∞} is the mean asymptotic length of old fish, k is the growth rate coefficient, and t_0 is the theoretical age at length zero. A normal probability density function was used to represent the probability of the observation given the model prediction of the length at age t , L_t :

$$L_t \sim \text{Normal} \left(L_{\infty} \left(1 - e^{-k(t-t_0)} \right), \sigma_g^2 \right)$$

Relatively uninformative priors were placed on k , L_{∞} and t_0 for all areas (Table B3).

Table B3. Prior distributions for Von Bertalanffy growth parameters.

Parameter	Prior density function
k (year ⁻¹)	Normal(0.5,10 ²)
L_{∞} (mm)	Normal(500,1000 ²)
t_o (year)	Normal(0,100 ²)
σ_g	Uniform(log(0.000001),log(100))

Results provided for females show slightly lower growth rates and higher asymptotic length, L_{∞} , than males in both areas (Table B4, Figures B1 to B4). The results for the female and male growth and L_{∞} parameters are slightly higher for the outside area. Estimates for all parameters are quite precise (i.e., have low CVs). Only female growth parameter estimates were used to develop the r prior for input into the assessment model.

Table B4 Posterior means and CVs for the Von Bertalanffy growth parameters for each sex and each area.

	Outside		Inside	
	mean	CV	mean	CV
Female				
<i>Sample size</i>	2827		3122	
L_{∞} (mm)	407.36	0.004	402.54	0.005
k (year ⁻¹)	0.0987	0.005	0.0848	0.004
t_o (year)	-5.01	0.13	-5.06	0.075
Male				
<i>Sample size</i>	3225		3186	
L_{∞} (mm)	397.73	0.003	391.75	0.006
k (year ⁻¹)	0.1095	0.005	0.1005	0.003
t_o (year)	-4.70	0.13	-3.85	0.11

Outside female quillback rockfish growth curve

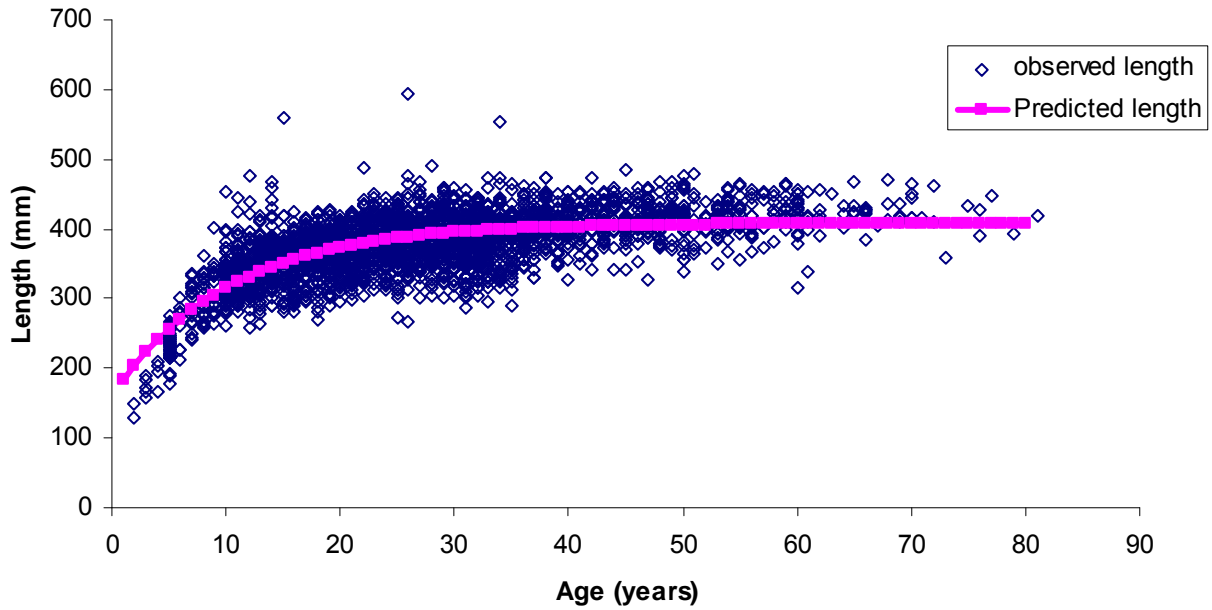


Figure B1. Plots of the observed length at age for females and predicted values from the Von Bertalanffy curve fitted to data for outside quillback rockfish.

Outside male quillback rockfish growth curve

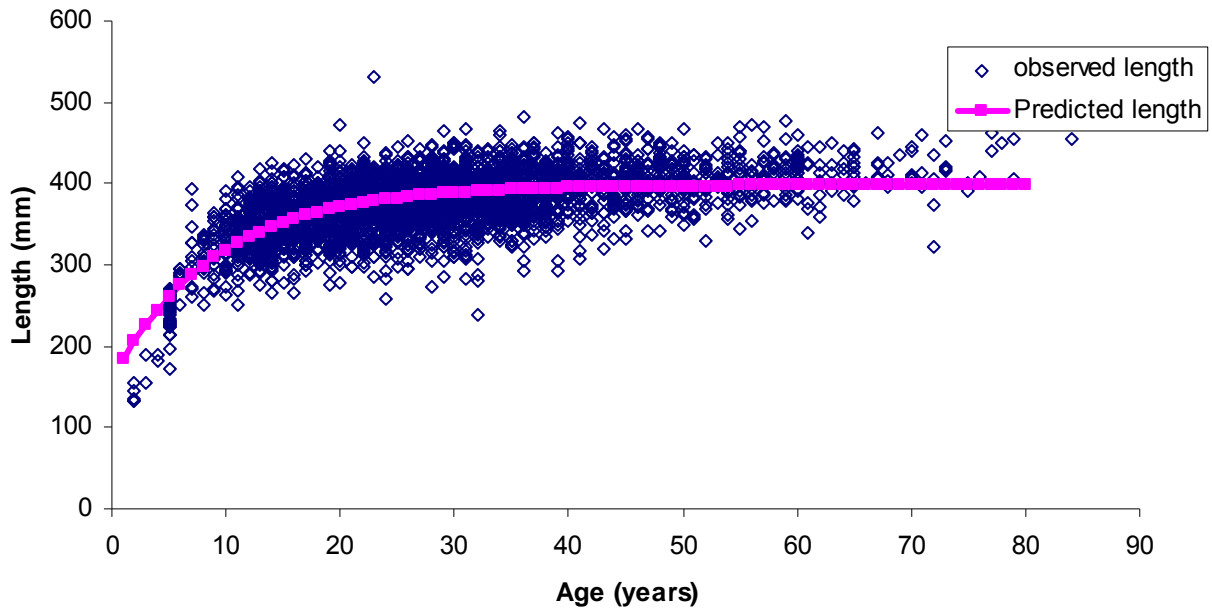


Figure B2. Plots of the observed length at age for males and predicted values from the Von Bertalanffy curve fitted to data for outside quillback rockfish.

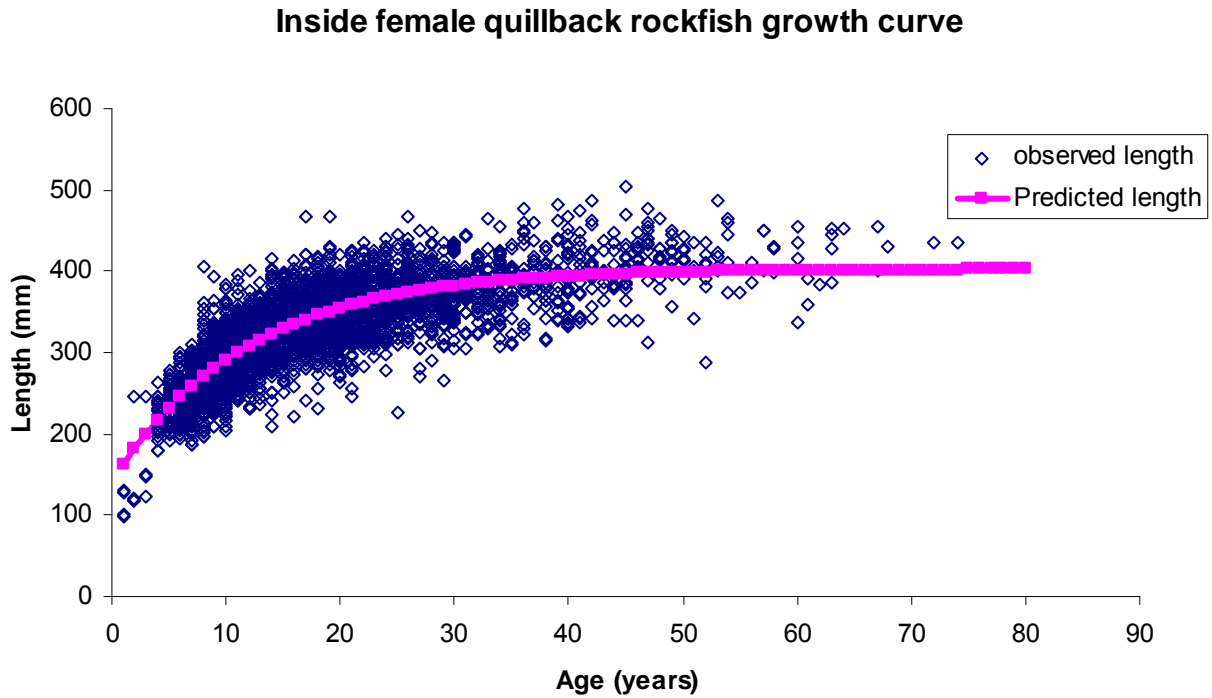


Figure B3. Plots of the observed length at age for females and predicted values from the Von Bertalanffy curve fitted to data for inside quillback rockfish.

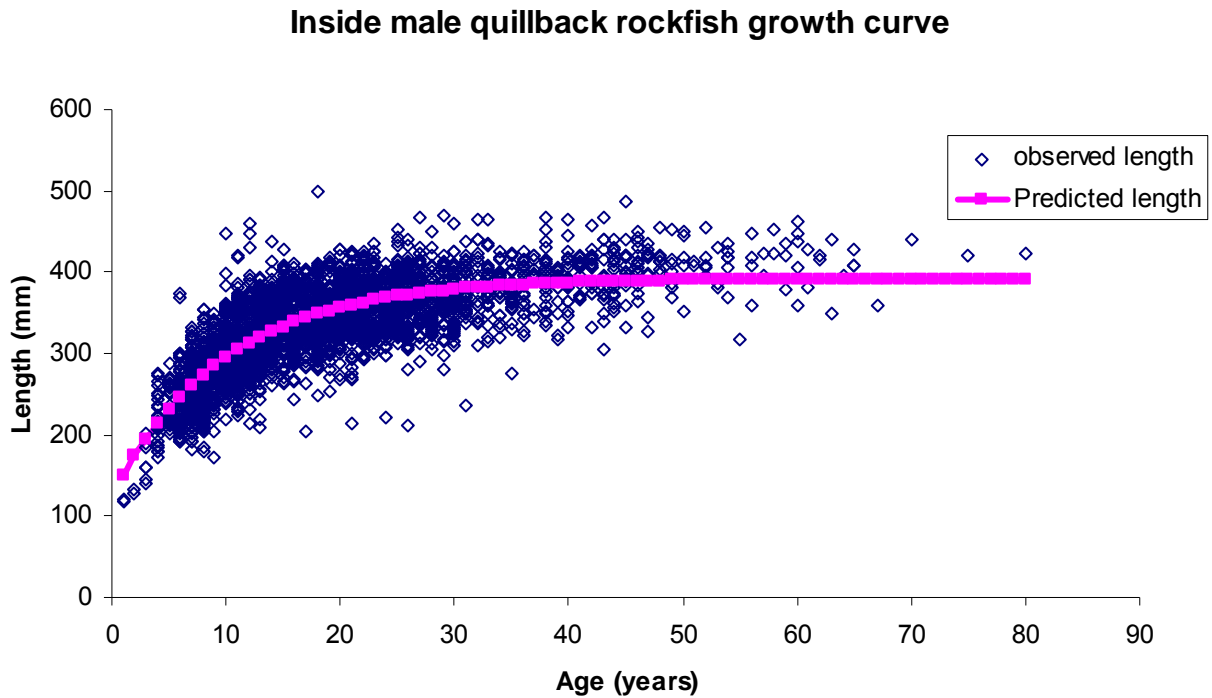


Figure B4. Plots of the observed length at age for males and predicted values from the Von Bertalanffy curve fitted to data for inside quillback rockfish.

MATURITY PARAMETERS

The proportion mature at age was modelled using a normalized and discretized cumulative lognormal density function. Initial analyses indicated that this form of a maturity function provided a better fit to proportion mature at age data than a logistic function. The maturity function includes two parameters: the median age mature (*med_age*) and the standard deviation in the log fraction maturing at age (σ_{mat}). Uninformative prior distributions were used for both parameters (Table B5).

Table B5. Prior distributions for maturity parameters.

Parameter	Prior density function
<i>Med_age</i> (year)	Uniform(0,20)
σ_{mat}	Uniform(log(0.000001),log(100))

The posterior mode for median age of maturity for females and males ranged from about 7.5 to 8.5 years and 7.5 to 10.5 years, respectively (Table B6).

Table B6 Posterior modes and standard deviation of the maturity parameters for each sex and each area.

	Outside		Inside	
Female	mode	CV	mode	CV
<i>Sample size</i>	2823		2807	
<i>med_age</i> (yr)	8.5	NA	8.5	NA
<i>min_age_mat</i> (yr)	6	NA	6	NA
θ_{mat} (yr)	3.05	0.45	3.33	0.32
σ_{mat}	0.95	0.13	1.03	0.10
Male	mode	CV	mode	CV
<i>Sample size</i>	3223		2948	
<i>med_age</i> (yr)	7.5	NA	10.5	NA
<i>min_age_mat</i> (yr)	6	NA	5	NA
<i>med_age</i> (year)	1.1E-07	>10	10.53	0.02
σ_{mat}	3.28	0.74	0.48	0.04

Fraction mature at age for outside female quillback rockfish

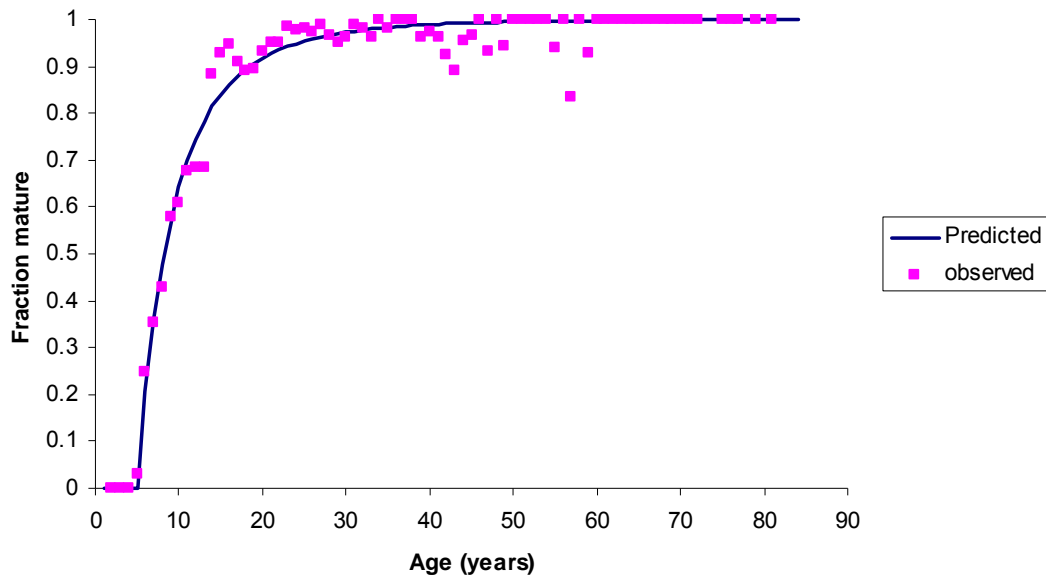


Figure B6. Plots of the observed and estimated fraction mature for outside female quillback rockfish.

Fraction mature at age for outside male quillback rockfish

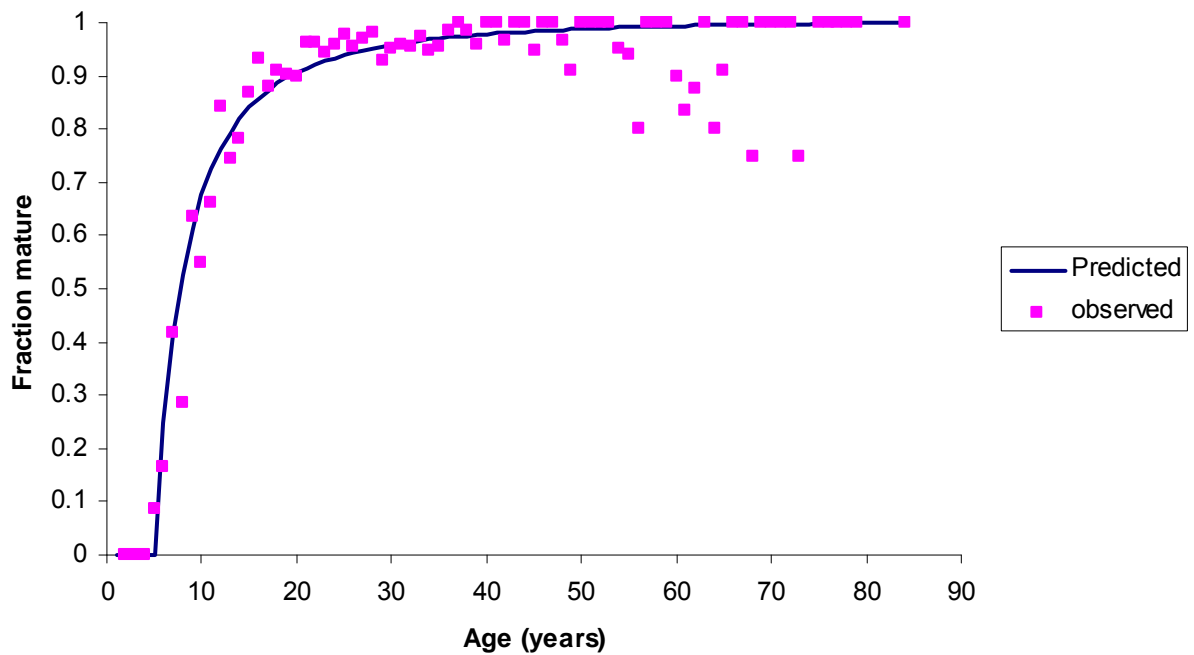


Figure B7. Plots of the observed and estimated fraction mature for outside male quillback rockfish.

Fraction mature at age for outside female quillback rockfish

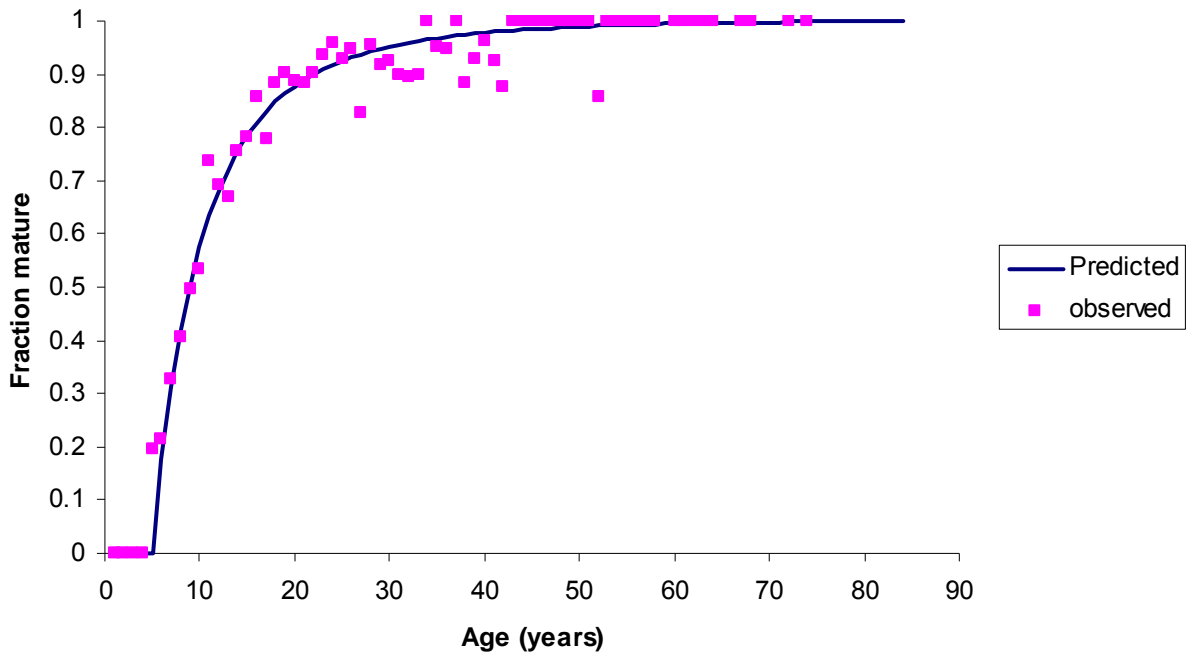


Figure B8. Plots of the observed and estimated fraction mature for inside female quillback rockfish.

Fraction mature at age for inside male quillback rockfish

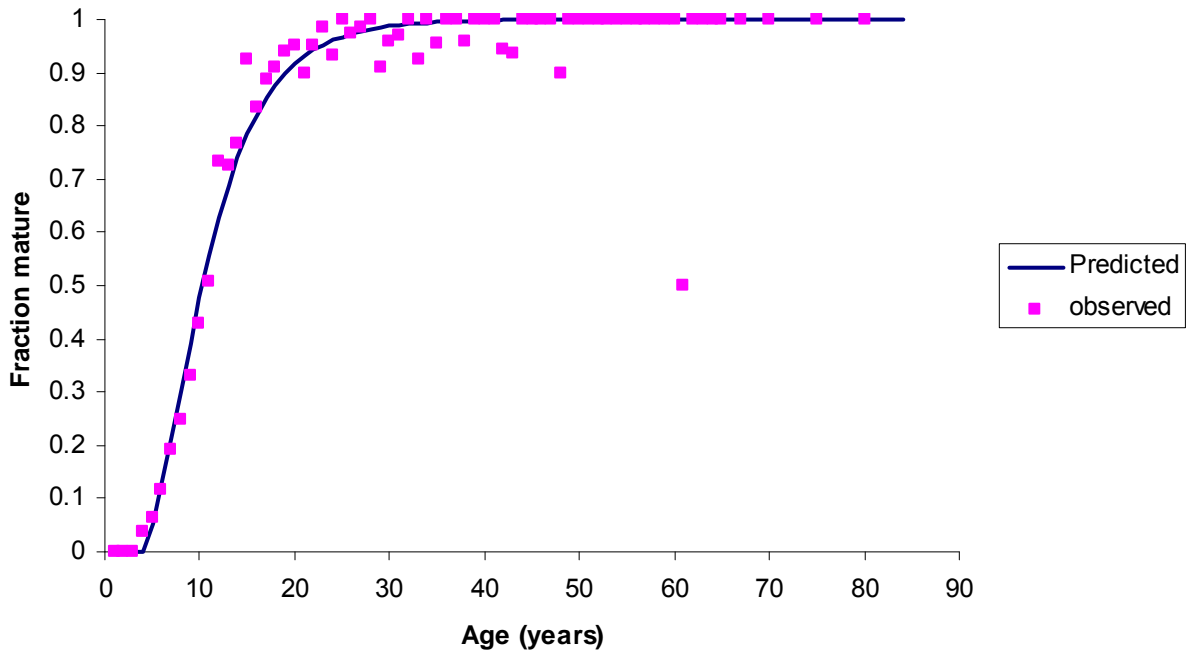


Figure B9. Plots of the observed and estimated fraction mature for inside male quillback rockfish.

LENGTH-WEIGHT RELATIONSHIP

The relationship between length and weight was described using a power function with two parameters, a and b . The Bayesian analysis assumed that the probability of observing a fish with log weight at age, $\log(W_i)$, followed the normal probability density function:

$$\log(W_i) \sim \text{Normal}(\log(a) + b \log(L_i), \sigma_{ab}^2)$$

where, a is the intercept or proportionality constant and b is the length exponent. Uninformative prior distributions were used for all parameters (TableB7).

TableB7. Prior distributions for parameters of the length-weight relationship.

Parameter	Prior density function
$\log(a)$	Normal(0,100 ³)
b	Normal(0,100 ²)
σ_{ab}	Uniform(log(0.000001),log(10))

Estimated posterior models for length-weight parameters were similar among areas for both males and females (Table B8, Figure B10 to Figure B13Error! Reference source not found.).

TableB8. Posterior modes and SD of the length (mm) to weight (g) conversion parameters for each sex and each area.

	Outside		Inside	
Female	mode	SD	mode	SD
<i>Sample size</i>	379		2579	
$\log(a)$	-19.09	0.14	-18.28	0.064
a	5.11E-06	-	1.15E-05	-
b	3.232	0.023	3.086	0.011
Male	mode	SD	mode	SD
<i>Sample size</i>	375		2640	
$\log(a)$	-19.11	0.126	-18.01	0.06
a	4.98E-06	-	1.50E-06	-
b	3.236	0.0215	3.037	0.0106

Outside female quillback length to weight relationship

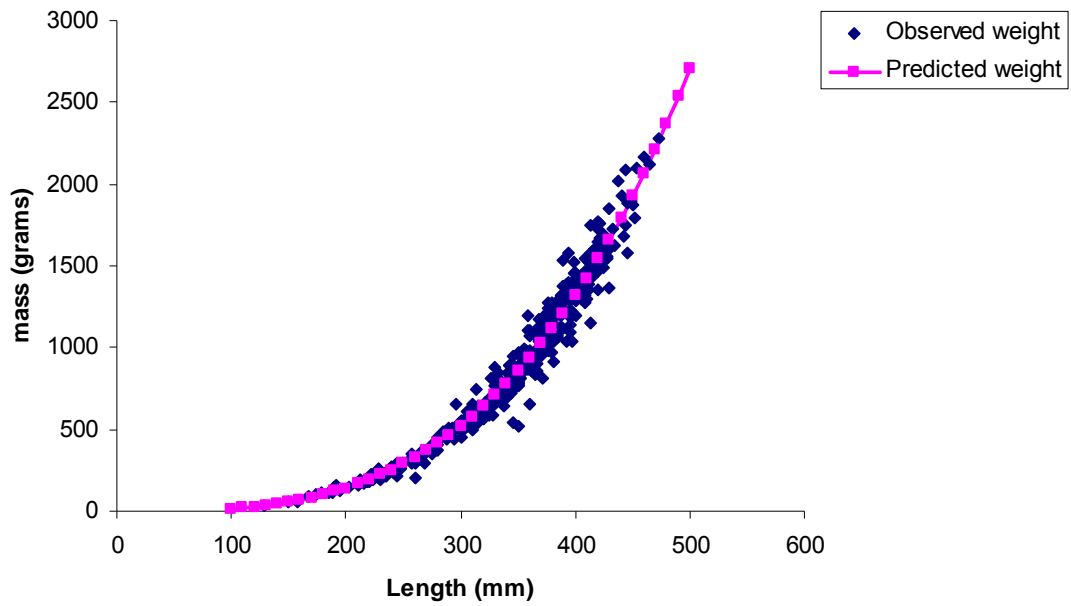


Figure B10. Plot of mass versus weight, predicted and observed for outside female quillback rockfish.

Outside male quillback length to weight relationship

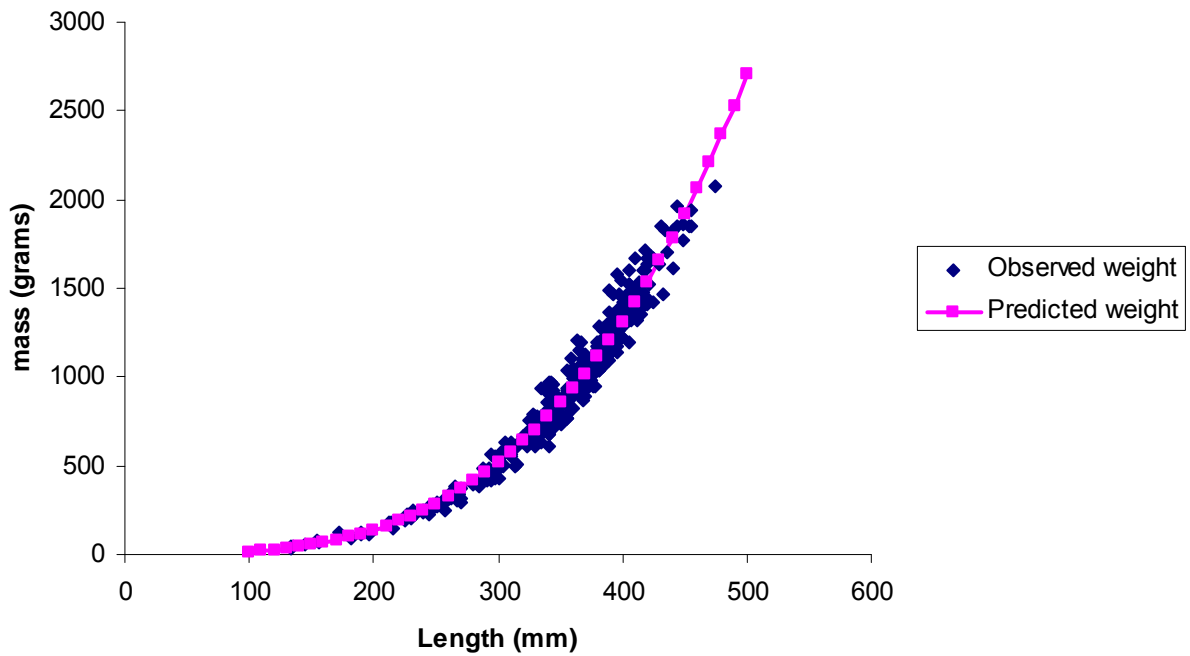


Figure B11. Plot of mass versus weight, predicted and observed for outside male quillback rockfish.

Inside female quillback length to weight relationship

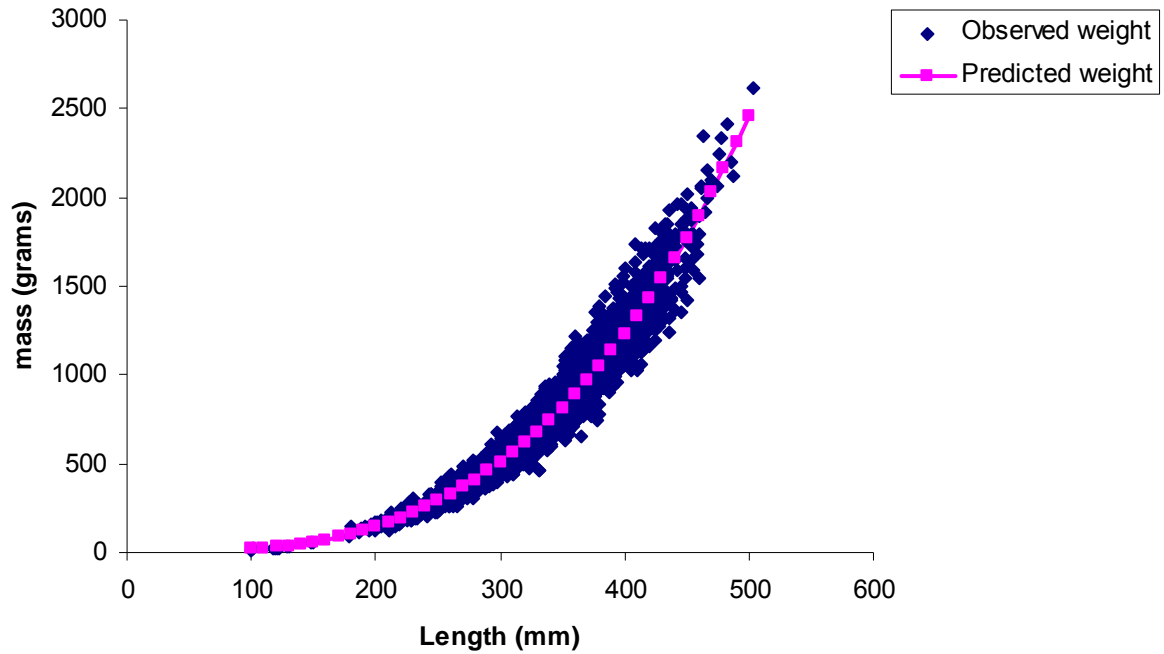


Figure B12. Plot of mass versus weight, predicted and observed for inside female quillback rockfish.

Inside male quillback length to weight relationship

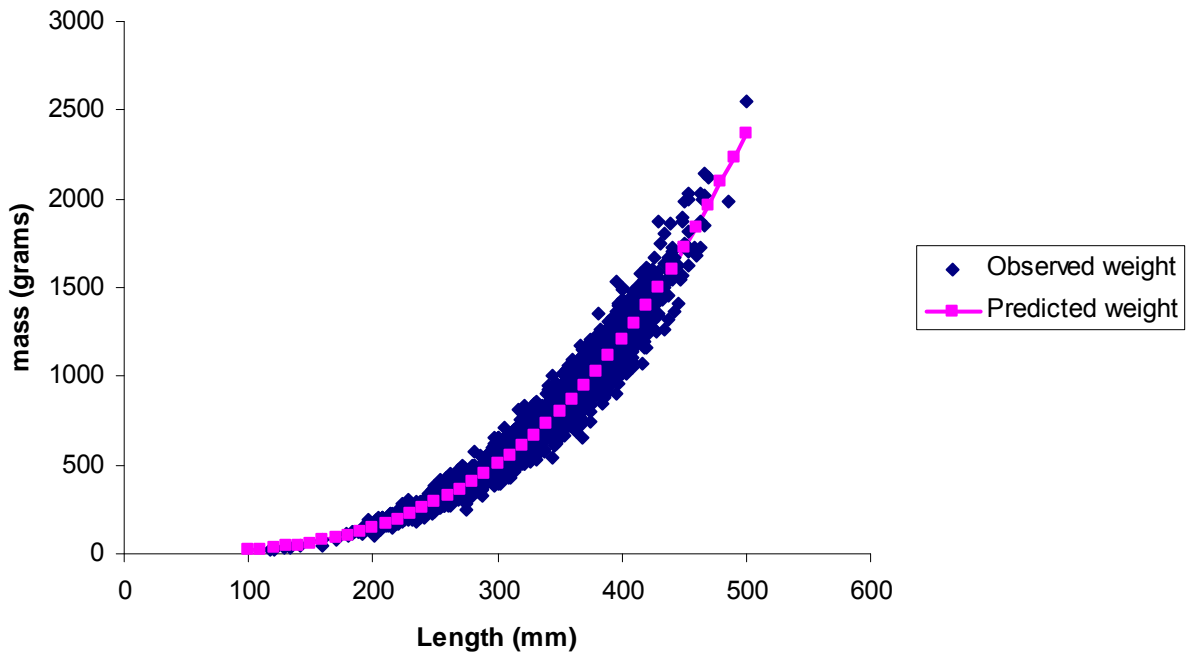


Figure B13. Plot of mass versus weight, predicted and observed for inside male quillback rockfish.

REFERENCES

- Chilton, D.E., and Beamish, R.J. 1982. Age determination methods for fishes studied by the Groundfish Program at the Pacific Biological Station. Can. Spec. Publ. Fish. Aquat. Sci. 60: 102 p.
- Cuif, M., McAllister, M., and King, J.R. 2009. Development of a surplus production model applicable to British Columbia offshore stocks of quillback (*Ophiodon elongatus*). Can. Tech. Rep. Fish. Aquat. Sci. 2861: xii+72 p.
- Hoenig, J.M. 1983. Empirical use of longevity data to estimate mortality rates. Fish. Bull. Vol 82(1): 898-903.
- McAllister, M.K., and Ianelli, J.N. 1997. Bayesian stock assessment using catch-age data and the sampling – importance – resampling algorithm. Can. J. Fish. Aquat. Sci. 54: 284-300.
- von Bertalanffy, L. 1938. A quantitative theory of organic growth. Hum. Biol. 10: 181-213.

APPENDIX C. COMMERCIAL CATCH 1918 TO 2010.

INTRODUCTION	61
COMMERCIAL GROUND FISH TRAWL AND HOOK AND LINE CATCH.....	61
1. COMMERCIAL GROUND FISH CATCH RECONSTRUCTION ALGORITHM (FROM HAIGH AND YAMANAKA 2011).....	61
A. Compile the historical catches of POP, ORF and TRF	62
B. Gather the principal species catches (landed and discarded).....	62
C. Calculate ratios	63
D. Reconstruct the catch of the principal species.....	65
2. HISTORIC LANDINGS OF ROCKFISH	65
1918 – 1950: Landings (Canada Dominion Bureau of Statistics).....	65
1930 – 1964: US landings from BC waters (Stewart, pers. comm.)	66
1945 – 1953: Table C3_Catch_Pre54 (Thomson & Yates 1960-61).....	66
1950 – 1975: Canadian and US landings from BC waters (Ketchen 1976).....	66
1951 – 1981: Sales slip data for red fish and rockfish (Obradovich)	66
1954 – 1995: Logbooks and landings (GFCatch).....	67
1965 – 1976: Russian and Japanese catch in BC waters (Ketchen 1980).....	67
1982 – 1994: Sales slip data (PacHarv3)	67
3. MODERN CATCH OF ROCKFISH.....	67
1982-1995: Sales slip data (PacHarv3).....	67
1954 – 1995: Logbooks and landings (GFCatch).....	68
1996 – 2007: Observer trawl data (PacHarvest)	68
1986-1995: Hook and line fisher log data (PacHarvHL)	68
1995-2006: Hook and line dockside monitoring data (PacHarvHL).....	68
2006 – 2009: Fishery Operations System data (GFFOS).....	68
4. CALCULATED RATIOS	69
5. RECONSTRUCTION RESULTS	69
REFERENCES.....	69
COMMERCIAL PACIFIC SALMON TROLL CATCH	86
COMMERCIAL SPOT PRAWN CATCH	87
Table C1. Reconstructed catch history for Quillback Rockfish from the Trawl Fishery, by PMFC for the years 1918 to 2010 in tonnes.	71
Table C2. Reconstructed catch history for Quillback Rockfish from the Halibut Fishery, by PFMC for the years 1918 to 2010 in tonnes.	73
Table C3. Reconstructed catch history for Quillback Rockfish from the Sablefish (K) Fishery, by PFMC for the years 1918 to 2010 in tonnes.....	75
Table C4. Reconstructed catch history for Quillback Rockfish from the Spiny Dogfish and Lingcod (Schedule II) Fishery, by PFMC for the years 1918 to 2010 in tonnes.....	77
Table C5. Reconstructed catch history for Quillback Rockfish from the Rockfish Hook and Line (ZN) Fishery, by PFMC for the years 1918 to 2010 in tonnes.....	79

Table C6. Reconstructed catch history for Quillback Rockfish from all Fisheries Combined, by PFMC and Total Outside Management Area, for the years 1918 to 2010 in tonnes.....	81
Table C7. Commercial Pacific Salmon troll catch in tonnes of Quillback Rockfish for the years 1952 to 2010 by management unit (inside and outside).	86
Figure C1. Quillback Rockfish catch reconstruction for the Trawl Fishery, by PFMC and year from 1918 to 2010 in tonnes.	83
Figure C2. Quillback Rockfish catch reconstruction for the Halibut Fishery, by PFMC and year from 1918 to 2010 in tonnes.	83
Figure C3. Quillback rockfish catch reconstruction for the Sablefish Fishery, by PFMC and year from 1918 to 2010 in tonnes.	84
Figure C4. Quillback Rockfish catch reconstruction for the Dogfish and Lingcod (Schedule II) Fishery, by PFMC and year from 1918 to 2010 in tonnes.....	84
Figure C5. Quillback Rockfish catch reconstruction for the Rockfish Hook and Line (ZN) Fishery, by PFMC and year from 1918 to 2010 in tonnes.....	85
Figure C6. Quillback Rockfish catch reconstruction for all Fisheries Combined, by PFMC and year from 1918 to 2010 in tonnes.	85

INTRODUCTION

The catch of Quillback Rockfish in the commercial groundfish trawl and hook and line fisheries, Pacific Salmon Troll fishery and the Spot Prawn fishery are discussed and presented in this appendix.

COMMERCIAL GROUND FISH TRAWL AND HOOK AND LINE CATCH

Commercial catch reconstructions were undertaken for Quillback Rockfish following the methodology for Yelloweye Rockfish in Haigh and Yamanaka (2011) and Yamanaka et al. (2012). A general description of this process is given below.

1. COMMERCIAL GROUND FISH CATCH RECONSTRUCTION ALGORITHM (FROM HAIGH AND YAMANAKA 2011)

In general for an individual rockfish species, the reconstruction algorithm for annual catch (landed + discarded) uses historical landings of broad catch categories and estimates a proportion of them by major area and fishery. The more recent data sources contain catch information by individual rockfish species, which negates the need to estimate from a general catch category. The same is true for reported discards - earlier years require estimation, later years report them.

The reconstruction executes a complex series of rules using SQL queries combined with R code to derive an annual catch series for five fisheries (trawl, halibut, sablefish, dogfish-lingcod, hook and line rockfish) in BC's eight PMFC areas (4B, 3C, 3D, 5A, 5B, 5C, 5D, 5E). This yields 40 annual series (48 when fisheries are combined).

The landings estimation procedure uses observations from modern (assumed complete) data sources to calculate catch ratios of individual rockfish species to a general group that was historically reported – total rockfish (TRF), other rockfish (ORF) excluding Pacific ocean perch (POP), or POP, where $TRF = ORF + POP$. These ratios are then applied to historical landings

of the group to estimate landings of a specific rockfish species. The assumption that modern catch ratios are the same as those in past is probably violated (primarily introducing bias), but these are the data we have, and we make this assumption.

The estimation of discard rates also uses modern data, but restricts the records to those observed by an independent source. The assumption is that modern discard rates reflect those in past where management restrictions fostered discarding.

A. Compile the historical catches of POP, ORF and TRF

The first step in the reconstruction is to pull together the historical data for POP, ORF, and TRF. In earlier data sources, there is little information on fishery types as we know them today. For this reason we consolidate the information into four basic gear categories = (h&l, trap, trawl, combined). The latter is reserved for catch where no information exists on gear type used.

The data are also sorted into groups:

- (i) additive – where the catch data are unique and therefore additive, and
- (ii) redundant – where the catch data may be redundant to or overlap other sources.

An example of the latter occurs when Ketchen's (1976) trawl data usually (if not always) exceeds the values reported in GFCatch. When data sources are flagged to be redundant, we use the maximum value by year.

Once we've identified purely additive data, including the maxima of redundant sources, we sum the landings to derive the historical rockfish dataset.

B. Gather the principal species catches (landed and discarded)

Annual species catches (landed and discarded) are extracted from various databases (Table 1). Starting in 2006 for the hook and line (H&L) fisheries and in 2007 for the trawl fishery, all catch information flows into the centralized Fishery Operations System (FOS). Additionally, species are managed through an 'integrated fisheries management' plan, which sometime blurs the distinction among the various fisheries. Despite the appearance that traditional fisheries no longer exist, we prefer to retain some semblance of order in our assessments.

Table 1. Catch information sources for the five main groundfish fisheries. FID = Fishery identification number; DMP = dockside monitoring program.

FID	Fishery	Years	Database	Catch Information
1	trawl	1956-1995	Ketchen/GFCatch	Mixture (sales slips, validation recs)
		1996-2006	PacHarvest	Merged (DMP, observer/fisher logs)
		2007-2009	GFFOS	Mixture (DMP, observer/fisher logs)
2	halibut	1982-1995	PacHarv3	Sales slips
		1996-2005	PacHarvHL	DMP
		2006-2009	GFFOS	Mixture (DMP, observer/fisher logs)
3	sablefish	1982-2002	PacHarv3	Mixture (sales slips, validation recs)
		2003-2005	PacHarvSable	DMP
		2006-2009	GFFOS	Mixture (DMP, observer/fisher logs)
4	dogfish/ lingcod	1982-1995	PacHarv3	Sales slips
		1996-2005	PacHarvHL	DMP
		2006-2009	GFFOS	Mixture (DMP, observer/fisher logs)
5	rockfish (H&L)	1979-1985	GFCatch	Mixture (sales slips, validation recs)
		1986-1994	PacHarvHL	Fisher logs
		1995-2005	PacHarvHL	DMP
		2006-2009	GFFOS	Mixture (DMP, observer/fisher logs)

Our collection of catch information also includes the landings of prominent groups:

POP = Pacific ocean perch (redundant in the case when the principal species is POP),

ORF = Rockfish species other than POP,

TRF = Total rockfish (ORF + POP),

TAR = Target group of species that might represent the fishery.

These groups are used later for calculating various ratios that adjust historical or incomplete catch series. The TAR groups for the H&L fisheries are fairly clear:

halibut	Pacific halibut <i>Hippoglossus stenolepis</i> ;
sablefish	sablefish <i>Anoplopoma fimbria</i> ;
dogfish-lingcod	spiny dogfish <i>Squalus acanthias</i> and/or lingcod <i>Ophiodon elongatus</i> ;
rockfish (H&L)	quillback rockfish <i>Sebastes maliger</i> + copper rockfish <i>S. caurinus</i> + china rockfish <i>S. nebulosus</i> + tiger rockfish <i>S. nigrocinctus</i> + yelloweye rockfish <i>S. ruberrimus</i> .

The TAR group for trawl is nebulous because this fishery has so many potential targets depending on quota holdings. We don't use the trawl TAR group for any calculation; however, for convenience we simply set the trawl TAR to TRF.

Often we get annual landings where the PMFC area is not known or not specified (major code = 0). Rather than discard these landings (which can be substantial) we allocate them to the BC PMFC areas based on observed proportions of landings in the BC PMFC areas by year.

C. Calculate ratios

We calculate various ratios (to facilitate the rebuilding of historical catch) from modern catch statistics using reference years that reflect periods when information knowledge is high and/or stable. For most rockfish species, we choose a starting reference year of 1997, which coincides with observer trawl coverage and the initiation of the IVQ program. The latter year 2005 is the last full calendar year that appears in the PacHarvest database.

alpha – Proportion rockfish (in this case, Quillback) caught in a major area by each fishery. For each fishery, we use to define the proportion of the principal species landed in a major area.

beta – Proportion rockfish caught in H&L fisheries for each major area. As the historical hook and line catch series do not specify the various fisheries we have today, we derive a ratio for each major area that gives the proportion of H&L catch taken by the halibut, dogfish-lingcod, and the H&L rockfish fisheries.

gamma – Ratio of rockfish to a prominent group (e.g., other rockfish). This ratio calculates the landed catch of the principal species to catch of a prominent group of species (e.g., D = ORF, E = TRF, F = TAR). For minor rockfish, the prominent group is usually ORF, whereas for a predominant principal species like POP we would use TRF.

delta – Discard rate of rockfish per category from observer logs. Discard rate calculations must use observer records because these records are the only ones that consistently report discarding. Modern observer trawl data comprise chiefly onboard observer records from 1996 to 2006 and so discards are well known for this period. For the non-trawl fisheries, at-sea observer data were collected between 2000 and 2004 and include discarded catch.

For non-quota species that are rarely retained, we often need to use the landings of some other group as the denominator of a discard ratio. That is, we calculate the amount of discarded principal species per landings of a target species or group of species. This is especially true for fisheries other than trawl and H&L rockfish. For instance, a halibut fishing vessel traditionally would not retain *Sebastes* species so that rockfish caught were discarded without any record. Consequently, a discard rate expressed as principal rockfish discarded (0 t) per principal rockfish landed (0 t) yields no information. Even observer records with positive discards of rockfish would report landed rockfish catch of 0 t.

lambda – Proportion of early catch by general gear type. The very early time series of rockfish catch (1918-1950) only cover three districts (I, II, and III) along the BC coast, which we assign to PMFC areas. This early catch has no gear type specified. In past reconstructions, the catch with unknown gear type was split into general categories ('h&l', 'trap', and 'trawl') using the empirical gear ratios from sales slip data. This reconstruction assumes that the catch prior to World War II (1918-1938) was taken primarily by the hook and line fisheries (90% H&L, 10% trawl). During and after the war, the estimated gear distribution is calculated from the sales slip landings in 1951 and 1952 (Table 2).

Table 2. Gear ratios by PMFC major area based on sales slip landings (compiled into PacHarvHL tables by Shannon Obradovich) from 1951-52.

majorj	h&l	gear	
		trap	trawl
1	0.47418	0.01680	0.50902
3	0.07301	0	0.92699
4	0.90450	0	0.09550
5	0.63728	0	0.36272
6	0.47760	0	0.52240
7	0.53184	0	0.46816
8	0.32667	0	0.67333
9	1.00000	0	0

D. Reconstruct the catch of the principal species

Historical data other than those from the Dominion Bureau specify gear type . These data generally start in 1930 and run until 1995. To estimate landings of the principal species from historical landings of a larger group (e.g., ORF or TRF), we use Table 1.

The final step adds discarded catch, which can come from catch records or calculations. In the early years without regulations, discarding was deemed negligible, that is, they kept what they caught. Table 3 reports the various discarding regimes we use in the catch reconstruction.

Table 3. Discard regimes by fishery where 'negligible' assumes discarding was minimal, 'calculated' derives mean discard rates (step 3 above), and 'reported' indicates that actual discards appear in the catch records.

fid	fishery	negligible	calculated	reported
1	trawl	1918-1953	1954-1995	1996-2010
2	halibut	1918-1978	1979-2005	2006-2010
3	sablefish	1918-1985	1986-2005	2006-2010
4	dogfish-lingcod	1918-1985	1986-2005	2006-2010
5	rockfish (h&l)	1918-1985	1986-2005	2006-2010

2. HISTORIC LANDINGS OF ROCKFISH

1918 – 1950: Landings (Canada Dominion Bureau of Statistics)

In British Columbia, the earliest rockfish catch records are those compiled by the Canada Dominion Bureau of Statistics (1918–1950). Landings were reported in three districts (Table 4) that roughly include the following areas: District I – the Vancouver area, District II – the area north of Cape Caution, and District III – the remainder of the province. Yamanaka et al. (2010) extracted the rockfish records and noted the following. The category of fish varied slightly from year to year and included 'red cod, etc.' (1918-1930), 'red and rock cod' (1931-1943, 1945, 1946), 'red cod' (1944), and 'rockfish' (1947-1950). Fishing gear was not specified in the records. Landings were originally recorded in short hundredweights (centum weights 'cwt', defined as 100 lbs). We convert these to lbs for the historical catch database.

Using 1951-52 sales slip data for red fish and rockfish (see section below on data compiled by Obradovich), we estimate the proportion of district catch caught in PMFC areas – D1: 4B (p=1.0); D2: 5A (0.003), 5B (0.390), 5C (0.165), 5D (0.321), 5E (0.121); D3: 4B (0.610), 3C (0.207), 3D (0.167), 5A (0.016) – and allocate the district catch accordingly.

1930 – 1964: US landings from BC waters (Stewart, pers. comm.)

Ian J. Stewart (National Marine Fisheries Service, Northwest Fisheries Science Center, 2725 Montlake Blvd. E., Seattle WA, 98112) very kindly sent us his spreadsheet on historical landings (lbs) of rockfish in Washington, Oregon, and California that he used for the most recent assessment of canary rockfish (*Sebastes pinniger*) in US Pacific waters (Stewart 2009). In particular, we use his Washington landings of rockfish from 1942 to 1964 collected from Pacific Coast States Fisheries bulletins (Dept. of the Interior) housed at the NW Fisheries Science Center. Stanley et al. (2009) also used these data (but only to 1949), and estimated the proportion of Washington landings coming from BC waters to be 0.715. Further, Stanley et al. (2009) allocated the BC removals to PMFC areas using observed proportions by area of US catch from Ketchen (1976) for the years 1950 to 1953: 3C (0.220), 3D (0.163), 5A (0.209), 5B (0.387), 5C (0.003), and 5D (0.018). We adopt this allocation scheme here.

Additionally, Ian Stewart compiled Pacific Fisherman yearbooks for Washington landings from 1930 to 1964. Stanley et al. (2009) only used the 1930-1941 data and the same allocation ratios mentioned above to estimate catch from BC's PMFC areas. We follow Stanley's allocation scheme but use all of Stewart's data.

1945 – 1953: Table B3 Catch Pre54 (Thomson & Yates 1960-61)

The data table B3_Catch_Pre54 in the DFO database GFCatch on the server SVBCPBSGFIIS provides rolled-up trawl catch data for predominant species/groups. These landings appear in two Fisheries Research Board of Canada statistical circular series (Thomson & Yates 1960, Thomson & Yates 1961).

1950 – 1975: Canadian and US landings from BC waters (Ketchen 1976)

During the period 1950 to 1975, American fishing vessels were actively trawling the waters off BC's coast and accounted for the majority of catch. Ketchen (1976) provides annual summaries of landings (thousands of lbs) by PMFC area for thirteen predominant fish species/groups, including 'other rockfish'.

For individual rockfish species, estimated landings can be calculated as a proportion of 'other rockfish' landed.

1951 – 1981: Sales slip data for red fish and rockfish (Obradovich)

Shannon Obradovich (Pacific Biological Station, Nanaimo, BC) compiled sales slip data from 'BC Commercial Catch Statistics: Pacific Region', and the results are available as tables:

B21_Historic_Year_Details and
B22_Historic_Area_Catch in the DFO database PacHarvHL (server SVBCPBSGFIIS).

These historic sale slips report landings by Pacific Fisheries Management (PFM) areas (a.k.a. DFO statistical areas, which we convert to PMFC areas), hook and line gear type (longline, handline, and troll), and categories of "red and rock cod" (1951-1975) and "rockfish" (1976-1981). The hook and line fisheries and the trawl fishery account for most of the catch, with minor amounts recorded by the trap fisheries.

1954 – 1995: Logbooks and landings (GFCatch)

Rutherford (1999) provides a good summary of the GFCatch database (server SVBCPBSGFIIS) and its history. In brief, this database contains catch and effort data from three sources: logbooks (skippers, onboard observers), landing records (sales slips or validation records), and anecdotal information. The logbooks provide good information on areas fished and amount of effort but only estimates of catch. Species composition is usually limited to dominant retained species. Conversely, sales slips and validation records provide accurate estimates of weight unloaded at the dock but very little information on the areas fished or effort expended. The accuracy of species composition is variable. Anecdotal information (viewing offloads, interviewing vessel crews) often provides information that supplements or sometimes supersedes data provided by the other two sources. Annual catch summaries of rockfish other than POP are presented for hook and line gear, for trap gear, and for trawl gear.

1965 – 1976: Russian and Japanese catch in BC waters (Ketchen 1980)

For a decade along the BC coast, the U.S.S.R. and Japan harvested very large amounts of rockfish (primarily Pacific ocean perch). Ketchen (1980) attempts to estimate these foreign catches using whatever catch records he could get from the two nations. The Russians tended to use large sweeping areas to record catch while the Japanese provided more methodical summaries by geo-referenced blocks. Neither of these standards conform to the PMFC areas that Canada and the US had agreed to use. Additionally, the Russians tended to use the term ‘perches’ for all rockfish, while the Japanese terminology of ‘Pacific ocean perch’ included all rockfish. Ketchen’s methodology for estimating rockfish catch produces three estimates (minimum, intermediate, and maximum). Catch reconstructions years later tend to use the intermediate estimates, and we follow this tradition. Ketchen estimated ‘other rockfish’ caught by the Russian and Japanese fleets and Pacific ocean perch caught by the two fleets.

1982 – 1994: Sales slip data (PacHarv3)

Sales slip data from landings records provide catch by trip. The Oracle database generally known as PacHarv3 but actually called HARVEST_V2_0 on the ORAPROD server is complicated. Luckily there is a CATCH_SUMMARY table that provides a rollup from various other tables. We extract annual catches from this summary table by PFM areas converted to PMFC areas. Below, we report ‘other rockfish’ landings by three gear types: hook and line, trap, and trawl.

3. MODERN CATCH OF ROCKFISH

Modern catch statistics for BC rockfish are currently housed in a variety of DFO databases. These can be accessed through Microsoft front-end shells located at (<http://SVBCPBSGFIIS/sql/>). However, we have automated the catch reconstruction as much as possible using SQL queries launched from the R statistical platform using the packages RODBC and PBSfishery. Some of the data sources below for catch of individual rockfish species have already been described in the previous section that describes historical landings of rockfish groups (POP and ORF). We repeat the descriptions for convenience. Importantly for PacHarv3 there are substantial differences in grouping by gear code for prominent group vs. grouping by fishery for principal species.

1982-1995: Sales slip data (PacHarv3)

Sales slip data from landings records provide catch by trip. The Oracle database generally known as PacHarv3 but actually called HARVEST_V2_0 on the ORAPROD server is complicated. Luckily there is a CATCH_SUMMARY table that provides a rollup from various

other tables. From this summary table we can extract annual catches by PFM areas that we convert to PMFC areas.

1954 – 1995: Logbooks and landings (GFCatch)

Rutherford (1999) provides a good summary of the GFCatch database (server SVBCPBSGFIIS) and its history. Species composition is usually limited to dominant retained species. Sales slips and validation records provide accurate estimates of weight unloaded at the dock but very little information on the areas fished or effort expended. The accuracy of species composition is variable. Anecdotal information (viewing offloads, interviewing vessel crews) often provides information that supplements or sometimes supersedes data provided by the other two sources.

1996 – 2007: Observer trawl data (PacHarvest)

The PacHarvest database (server SVBCPBSGFIIS) houses observer trawl catch and effort information for most fishing events (net hauls) from 1996 to 2006 (with some residual information in 2007). Details and history of PacHarvest can be found in Schnute et al. (1999). In 1996, a mandatory observer program for most Option A trips (bottom trawl) and some Option B trips became an important new data source for the groundfish fishery. Captains of vessels not covered by the observer log program (Options A for hake and pollock, B, and C) submit their own logbook records. There is never redundancy in the records, i.e., each fishing event is represented by either an observer log or a fisher log.

1986-1995: Hook and line fisher log data (PacHarvHL)

The rockfish hook and line fishing license (ZN) was introduced in 1986 along with a voluntary fishing logbook program. The logbooks became a license requirement in the early 1990s. Logbook records remained the only source of species specific rockfish catch records until the institution of the dockside monitoring program. The format of the ZN logbook has changed over time but the basic catch and effort by location data have been maintained in databases (Haigh and Richards 1997).

1995-2006: Hook and line dockside monitoring data (PacHarvHL)

The user-pay hook and line dockside monitoring program was instituted in 1995. This program provided timely species specific catch monitoring that replaced the sale slip system for quota and fishery management. The dockside monitoring program is conducted by contractors (Archipelago Marine Research Ltd.) who meet hook and line vessels at the dock and validate their catches as they are offloaded. From 1995 to 2006 the contractors also keypunched this information and sent it to DFO monthly for uploading into PacHarvHL.

2006 – 2009: Fishery Operations System data (GFFOS)

FOS (Fishery Operations System) is a computer information system containing a central data repository and software tools to input, output, and manage the data needed to support, operate, and manage fisheries. FOS began in 2000 as a collaborative project between commercial and aboriginal salmon to produce a common catch database. It has since grown to include other fisheries, data, and functions. The most recent groundfish catch and effort data are housed in the database GFFOS, which contains 'Views' (queries) to tables in the main DFO fisheries database FOS, on the Oracle server ORADEV. The groundfish section recently set up a mirror for GFFOS on the Oracle server GFSH. This latter server might eventually become the sole repository of the GFFOS views of the primary FOS database. Catch data appear complete for the hook and line fisheries from April 1, 2006 on and for the groundfish trawl fishery from April 1, 2007 on.

Quillback Rockfish landings and discards

Landed catch and reported discards for Quillback Rockfish are available from the modern catch databases by fishery. For most rockfish species, landed catch is only known with some degree of certainty from 1996 on. Prior to this, landings are estimated from ratios to ORF calculated using data observed from 1997 to 2005. For Quillback Rockfish, landings from the dogfish-lingcod and H&L rockfish fisheries (only) are relatively well known from 1982 on, so the catch reconstruction uses these rather than estimating them. Where annual landings from various databases overlap, the maximum value is used. Annual landings/discards from unknown PMFC areas are allocated to each of the known PMFC areas proportionally by catch weight. Entries marked '---' indicate no catch reported or calculated; values of 0 indicate positive catch less than 0.05 t. Note: the 2010 data are not complete.

4. CALCULATED RATIOS

The ratios calculated for Quillback Rockfish are presented as proportion of rockfish A landed in major area by fishery, proportion of rockfish A caught in major area by H&L fishery, ratio of rockfish A to prominent group (POP/TRF, YYR/ORF) in major area by fishery, discard rate (discard / landed) in major area by fishery, discard rate (discard / TAR) in major area by fishery, and relative proportions of 1918-1950 rockfish catch in major areas by gear type. Note that the ratio is not used in the reconstruction. Its calculation offers a matrix where each column (fishery) could disaggregate a single coastal catch number from that fishery into catches by major area. Fortunately, catches back to 1918 specify some area information that can be used or disaggregated by other means.

5. RECONSTRUCTION RESULTS

The reconstructed total removals for Quillback Rockfish are presented by fishery – trawl (Table C1, Figure C1), halibut (Table C2, Figure C2), sablefish (Table C3, Figure C3), dogfish-lingcod (Table C4, Figure C4), H&L rockfish (Table C5, Figure C5), and all fisheries combined (Table C6, Figure C6).

REFERENCES

- Canada Dominion Bureau of Statistics, 1918–1950. Fisheries Statistics of Canada (British Columbia). Ottawa, Ontario.
- Haigh, R., and Richards, L.J. 1997. A relational database for hook and line rockfish logbook data. Can. Manuscr. Rep. Fish. Aquat. Sci. 2408, 46 p.
- Haigh, R. and Yamanaka, K.L. 2011. Catch history reconstruction for rockfish (*Sebastes spp.*) caught in British Columbia coastal waters. Can. Tech. Rep. Fish. Aquat. Sci. viii + 124p.
- Ketchen, K.S. 1976. Catch and effort statistics of the Canadian and United States trawl fisheries in waters adjacent to the British Columbia coast 1950-1975. Fisheries and Marine Service, Data Record No. 6. Nanaimo, BC, May 1976.
- Ketchen, K.S. 1980. Reconstruction of Pacific ocean perch (*Sebastes alutus*) stock history in Queen Charlotte Sound. Part I. Estimation of foreign catches, 1965-1976. Can. Manuscr. Rep. Fish. Aquat. Sci. 1570, iv + 46 pp.

-
- 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, v + 66pp.
- Schnute, J.T., Olsen, N., and Haigh, R. 1999. Slope rockfish assessment for the west coast of Canada in 1998. CSAS Res. Doc. 1999/184, 104 p.
- Stanley, R.D., Starr, P., Olsen, N. 2009. Stock assessment for Canary rockfish (*Sebastes pinniger*) in British Columbia waters. DFO Can. Sci. Advis. Sec. Res. Doc. 2009/013, xxi + 200 pp.
- Stewart, I.J. 2009. Status of the U.S. canary rockfish resource in 2009 (Update of 2007 assessment model). Agenda Item E.6.a Attachment 6 June 2009. National Marine Fisheries Service, Seattle WA.
- Thomson, J.A. and Yates, A.N. 1960. British Columbia landings of trawl-caught groundfish by month, by major statistical area. Volume 1, 1945-1949. Fisheries Research Board of Canada, Statistical Circular Series No. CNS 1.
- Thomson, J.A. and Yates, A.N. 1961. British Columbia landings of trawl-caught groundfish by month, by major statistical area. Volume 2, 1950-1954. Fisheries Research Board of Canada, Statistical Circular Series No. CNS 2.
- Yamanaka, K.L., McAllister, M.M., Etienne, M.-P., Obradovich, S. and Haigh, R. 2012. Stock assessment for the inside population of yelloweye rockfish (*Sebastes ruberrimus*) in British Columbia, Canada for 2010. DFO Can. Sci. Advis. Sec. Res. Doc. 2011/129 xiv + 132p.

Table C1. Reconstructed catch history for Quillback Rockfish from the Trawl Fishery, by PMFC for the years 1918 to 2010 in tonnes.

Trawl year	Inside 4B	Outside 3C	Outside 3D	Outside 5A	Outside 5B	Outside 5C	Outside 5D	Outside 5E	
1918	0.067	0.000	0.000	0.000	0.000	0.000	0.000	0.005	0.000
1919	0.167	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000
1920	0.084	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000
1921	0.072	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1922	0.090	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1923	0.088	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1924	0.099	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1925	0.086	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1926	0.098	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000
1927	0.098	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000
1928	0.101	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000
1929	0.131	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000
1930	0.118	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000
1931	0.078	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1932	0.088	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1933	0.043	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1934	0.051	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1935	0.065	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000
1936	0.071	0.001	0.000	0.000	0.001	0.000	0.000	0.002	0.000
1937	0.055	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000
1938	0.187	0.001	0.000	0.001	0.001	0.001	0.000	0.001	0.000
1939	0.356	0.001	0.000	0.001	0.001	0.001	0.000	0.002	0.000
1940	0.387	0.002	0.000	0.002	0.001	0.001	0.000	0.003	0.000
1941	0.237	0.001	0.000	0.001	0.001	0.001	0.000	0.009	0.000
1942	0.550	0.012	0.000	0.012	0.010	0.001	0.018	0.000	0.000
1943	3.190	0.037	0.001	0.040	0.031	0.002	0.053	0.000	0.000
1944	4.753	0.020	0.000	0.017	0.014	0.002	0.040	0.000	0.000
1945	5.669	0.147	0.004	0.177	0.137	0.006	0.191	0.000	0.000
1946	3.778	0.076	0.002	0.089	0.070	0.005	0.134	0.000	0.000
1947	1.334	0.038	0.001	0.046	0.036	0.001	0.049	0.000	0.000
1948	1.791	0.063	0.002	0.075	0.058	0.002	0.079	0.000	0.000
1949	2.354	0.076	0.002	0.092	0.071	0.003	0.097	0.000	0.000
1950	1.168	0.074	0.002	0.106	0.067	0.003	0.148	0.000	0.000
1951	0.764	0.073	0.002	0.074	0.080	0.003	0.081	0.000	0.000
1952	0.588	0.083	0.002	0.072	0.069	0.002	0.095	0.000	0.000
1953	0.727	0.046	0.001	0.056	0.039	0.001	0.057	0.000	0.000
1954	2.203	0.059	0.002	0.077	0.057	0.002	0.071	0.000	0.000
1955	2.393	0.056	0.002	0.117	0.053	0.002	0.108	0.000	0.000
1956	1.306	0.039	0.002	0.122	0.025	0.003	0.033	0.000	0.000
1957	0.788	0.051	0.002	0.058	0.042	0.004	0.109	0.000	0.000
1958	0.978	0.056	0.001	0.079	0.053	0.003	0.063	0.000	0.000
1959	2.916	0.140	0.002	0.099	0.060	0.002	0.102	0.000	0.000
1960	3.223	0.141	0.002	0.074	0.054	0.002	0.161	0.000	0.000
1961	1.895	0.144	0.003	0.088	0.064	0.002	0.183	0.000	0.000
1962	1.694	0.177	0.005	0.122	0.089	0.003	0.277	0.000	0.000
1963	0.938	0.079	0.004	0.106	0.072	0.004	0.085	0.000	0.000

Table C1 continued

1964	2.072	0.075	0.002	0.109	0.053	0.005	0.145	0.000
1965	1.166	0.087	0.002	0.669	0.108	0.009	2.398	0.008
1966	2.481	0.469	0.021	1.475	0.181	0.001	3.615	0.012
1967	0.895	0.103	0.006	0.837	0.137	0.001	0.621	0.002
1968	1.812	0.164	0.008	0.679	0.123	0.003	0.749	0.002
1969	1.815	0.086	0.006	7.544	0.173	0.005	0.272	0.000
1970	1.847	0.100	0.007	0.520	0.132	0.003	0.397	0.000
1971	0.616	0.112	0.005	0.334	0.121	0.004	0.396	0.000
1972	0.828	0.068	0.005	0.613	0.171	0.008	0.732	0.000
1973	0.449	0.043	0.004	1.051	0.177	0.005	0.434	0.000
1974	0.397	0.021	0.004	1.785	0.114	0.007	0.549	0.000
1975	0.533	0.043	0.003	0.815	0.102	0.010	0.393	0.000
1976	0.645	0.112	0.001	0.464	0.156	0.036	0.925	0.000
1977	0.562	0.069	0.001	0.155	0.143	0.067	1.214	0.772
1978	1.101	0.023	0.001	0.555	0.223	0.484	1.295	0.014
1979	2.293	0.062	0.001	1.030	0.210	0.709	1.970	0.005
1980	1.211	0.375	0.410	5.339	0.240	0.722	1.564	0.006
1981	1.040	0.064	0.001	0.076	0.207	2.010	1.265	0.006
1982	0.883	1.313	0.002	2.573	0.093	0.161	1.378	0.004
1983	0.582	0.070	0.350	1.296	0.095	0.337	2.855	1.359
1984	0.784	0.094	0.059	3.068	0.154	0.483	1.753	0.037
1985	0.650	0.107	0.012	0.413	0.126	0.356	2.587	0.063
1986	0.712	0.188	0.024	0.302	0.135	0.251	4.325	0.349
1987	0.712	0.126	0.022	0.529	0.215	0.343	4.177	0.008
1988	0.638	0.268	0.022	0.414	0.266	0.518	2.184	0.009
1989	0.920	0.252	0.060	1.448	0.247	0.490	4.962	0.007
1990	0.694	0.152	0.019	2.186	0.369	0.486	6.832	0.008
1991	0.036	0.708	3.226	2.181	3.388	3.833	15.758	0.004
1992	0.366	2.489	0.260	17.930	2.630	9.089	16.320	0.007
1993	0.201	0.549	0.446	15.795	2.723	5.003	23.523	0.009
1994	0.092	1.742	0.252	23.554	2.261	4.985	13.383	0.008
1995	0.032	4.450	1.036	15.197	2.180	4.180	8.183	0.048
1996	0.178	0.071	0.105	4.175	0.583	5.056	3.921	0.018
1997	0.032	0.047	0.000	3.435	1.219	1.459	2.616	0.021
1998	0.022	0.422	0.060	4.328	0.685	1.023	2.387	0.000
1999	0.000	0.405	0.098	1.717	0.954	1.360	1.869	0.000
2000	0.002	0.908	0.001	1.684	0.968	0.686	1.349	0.000
2001	0.004	0.256	0.061	1.243	0.538	0.741	0.501	0.000
2002	0.003	0.437	0.108	3.232	0.488	0.791	0.388	0.000
2003	0.004	0.565	0.019	2.104	0.900	1.164	0.701	0.000
2004	0.002	0.326	0.011	1.219	0.245	0.606	0.212	0.000
2005	0.003	0.186	0.000	0.718	0.428	0.126	0.604	0.000
2006	0.009	0.044	0.015	0.283	0.377	0.676	0.072	0.000
2007	0.000	0.112	0.000	0.364	0.354	0.219	0.114	0.000
2008	0.016	0.103	0.002	0.282	0.397	0.037	0.104	0.000
2009	0.016	0.166	0.019	0.144	0.400	0.169	0.102	0.000
2010	0.002	0.081	0.005	0.568	0.355	0.094	0.193	0.000

Table C10. Reconstructed catch history for Quillback Rockfish from the Halibut Fishery, by PFMC for the years 1918 to 2010 in tonnes.

Halibut year	Inside 4B	Outside 3C	Outside 3D	Outside 5A	Outside 5B	Outside 5C	Outside 5D	Outside 5E
1918	0.012	0.010	0.036	0.000	0.054	0.014	0.234	0.088
1919	0.030	0.018	0.068	0.001	0.007	0.002	0.031	0.012
1920	0.015	0.011	0.039	0.000	0.010	0.003	0.044	0.017
1921	0.013	0.006	0.024	0.000	0.000	0.000	0.002	0.001
1922	0.016	0.014	0.050	0.000	0.000	0.000	0.001	0.000
1923	0.016	0.006	0.023	0.000	0.001	0.000	0.005	0.002
1924	0.018	0.006	0.023	0.000	0.003	0.001	0.012	0.004
1925	0.016	0.004	0.015	0.000	0.004	0.001	0.018	0.007
1926	0.018	0.007	0.027	0.000	0.009	0.002	0.038	0.014
1927	0.018	0.010	0.037	0.000	0.013	0.004	0.059	0.022
1928	0.018	0.009	0.035	0.000	0.010	0.003	0.043	0.016
1929	0.024	0.008	0.029	0.000	0.014	0.004	0.063	0.024
1930	0.021	0.006	0.021	0.000	0.008	0.002	0.034	0.013
1931	0.014	0.006	0.022	0.000	0.001	0.000	0.006	0.002
1932	0.016	0.003	0.012	0.000	0.001	0.000	0.004	0.001
1933	0.008	0.002	0.008	0.000	0.000	0.000	0.001	0.000
1934	0.009	0.002	0.008	0.000	0.001	0.000	0.004	0.002
1935	0.012	0.003	0.009	0.000	0.009	0.002	0.038	0.014
1936	0.013	0.005	0.019	0.000	0.013	0.003	0.057	0.022
1937	0.010	0.001	0.005	0.000	0.002	0.001	0.011	0.004
1938	0.034	0.019	0.071	0.001	0.001	0.000	0.005	0.002
1939	0.007	0.000	0.008	0.000	0.001	0.000	0.002	0.003
1940	0.007	0.000	0.005	0.000	0.001	0.000	0.003	0.004
1941	0.004	0.000	0.019	0.000	0.007	0.002	0.020	0.023
1942	0.010	0.001	0.048	0.000	0.006	0.002	0.018	0.020
1943	0.060	0.003	0.126	0.001	0.016	0.005	0.047	0.054
1944	0.089	0.004	0.167	0.001	0.021	0.006	0.063	0.073
1945	0.096	0.003	0.130	0.001	0.034	0.010	0.101	0.117
1946	0.064	0.002	0.114	0.001	0.049	0.014	0.146	0.169
1947	0.020	0.001	0.036	0.000	0.008	0.002	0.024	0.028
1948	0.031	0.001	0.055	0.000	0.012	0.004	0.036	0.042
1949	0.042	0.002	0.074	0.000	0.016	0.005	0.048	0.056
1950	0.018	0.001	0.031	0.000	0.007	0.002	0.021	0.024
1951	0.013	0.003	0.102	0.000	0.037	0.015	0.140	0.147
1952	0.010	0.001	0.075	0.001	0.034	0.006	0.070	0.098
1953	0.021	0.002	0.065	0.002	0.015	0.003	0.037	0.020
1954	0.013	0.002	0.080	0.001	0.015	0.002	0.052	0.037
1955	0.013	0.001	0.093	0.000	0.003	0.003	0.022	0.046
1956	0.012	0.003	0.088	0.001	0.006	0.001	0.004	0.012
1957	0.021	0.010	0.135	0.000	0.014	0.001	0.013	0.063
1958	0.030	0.003	0.134	0.000	0.003	0.000	0.002	0.004
1959	0.031	0.005	0.144	0.000	0.005	0.000	0.001	0.006
1960	0.025	0.005	0.161	0.002	0.008	0.006	0.033	0.018
1961	0.019	0.006	0.209	0.001	0.012	0.002	0.014	0.020
1962	0.031	0.015	0.243	0.002	0.012	0.014	0.002	0.017
1963	0.023	0.010	0.156	0.002	0.052	0.007	0.026	0.083

Table C2 continued.

1964	0.014	0.004	0.112	0.000	0.016	0.003	0.003	0.007
1965	0.013	0.003	0.093	0.000	0.007	0.006	0.010	0.053
1966	0.010	0.002	0.111	0.001	0.011	0.003	0.028	0.027
1967	0.016	0.005	0.150	0.001	0.009	0.009	0.073	0.031
1968	0.017	0.004	0.122	0.000	0.011	0.001	0.014	0.004
1969	0.020	0.009	0.124	0.002	0.032	0.014	0.006	0.002
1970	0.024	0.018	0.148	0.001	0.063	0.041	0.101	0.002
1971	0.021	0.011	0.042	0.002	0.040	0.033	0.109	0.010
1972	0.023	0.021	0.231	0.003	0.047	0.023	0.149	0.018
1973	0.028	0.015	0.098	0.003	0.016	0.020	0.137	0.026
1974	0.014	0.034	0.117	0.003	0.012	0.055	0.205	0.004
1975	0.011	0.026	0.099	0.002	0.038	0.073	0.203	0.040
1976	0.014	0.024	0.108	0.002	0.051	0.021	0.149	0.040
1977	0.038	0.031	0.124	0.011	0.052	0.036	0.145	0.032
1978	0.043	0.026	0.115	0.006	0.047	0.048	0.342	0.123
1979	0.068	0.047	0.242	0.012	0.040	0.056	0.276	0.229
1980	0.049	0.040	0.234	0.009	0.030	0.042	0.395	0.282
1981	0.058	0.036	0.162	0.007	0.021	0.032	0.287	0.187
1982	0.141	0.507	0.147	0.027	0.092	3.768	1.101	0.197
1983	0.104	0.407	0.224	0.035	0.078	4.116	1.720	0.182
1984	0.147	0.788	0.377	0.045	0.062	7.080	2.836	0.834
1985	0.207	0.561	0.512	0.049	0.250	12.222	4.208	0.550
1986	0.285	0.234	1.379	0.079	0.173	11.173	3.440	0.954
1987	0.232	0.825	1.338	0.112	0.335	14.282	5.083	0.585
1988	0.271	0.425	0.882	0.137	0.388	13.026	6.598	1.095
1989	0.264	0.527	1.229	0.156	0.341	6.920	5.646	1.320
1990	0.168	0.412	1.218	0.173	0.422	6.707	5.649	1.585
1991	0.254	0.642	1.523	0.146	0.658	3.051	6.003	1.018
1992	0.143	0.353	0.881	0.145	0.518	3.185	5.381	2.885
1993	0.096	0.499	2.460	0.141	0.526	5.505	7.320	3.346
1994	0.106	0.438	1.866	0.161	0.647	6.613	6.662	3.239
1995	0.062	0.996	0.264	0.394	0.414	6.276	5.994	0.144
1996	0.898	1.195	1.463	1.363	1.835	8.348	15.625	0.859
1997	0.353	1.735	0.386	0.576	1.163	9.596	13.334	0.410
1998	0.425	2.131	0.715	1.067	1.662	12.351	13.771	0.469
1999	0.171	1.491	0.441	0.335	1.214	9.317	12.035	0.497
2000	0.080	2.079	1.685	0.470	3.074	8.630	12.607	4.519
2001	0.234	1.843	1.937	0.448	2.557	8.784	11.116	5.346
2002	0.093	2.208	4.312	0.638	2.156	14.079	12.906	7.604
2003	0.016	2.187	4.295	0.237	2.276	9.773	8.281	7.005
2004	0.048	1.948	3.950	0.065	2.048	9.612	8.515	6.749
2005	0.040	2.593	3.565	0.067	1.592	9.609	8.740	6.713
2006	0.413	2.444	0.792	6.581	2.649	10.402	4.017	1.948
2007	0.512	1.253	0.910	5.892	4.679	9.378	5.773	1.981
2008	0.731	7.399	2.635	8.972	3.150	11.649	4.949	3.947
2009	0.542	5.458	2.643	7.709	3.968	10.681	5.030	5.209
2010	0.321	10.163	1.549	5.804	3.392	11.891	3.449	2.155

Table C3. Reconstructed catch history for Quillback Rockfish from the Sablefish (K) Fishery, by PFMC for the years 1918 to 2010 in tonnes.

Sablefish year	Inside 4B	Outside 3C	Outside 3D	Outside 5A	Outside 5B	Outside 5C	Outside 5D	Outside 5E
1918	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1919	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1920	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1921	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1922	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1923	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1924	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1925	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1926	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1927	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1928	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1929	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1930	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1931	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1932	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1933	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1934	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1935	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1936	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1937	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1938	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1939	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1940	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1941	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1942	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1943	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1944	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1945	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1946	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1947	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1948	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1949	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1950	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1951	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1952	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1953	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1954	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1955	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1956	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1957	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1958	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1959	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1960	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1961	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1962	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1963	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table C3 continued.

1964	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1965	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1966	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1967	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1968	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1969	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1970	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1971	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1972	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000
1973	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1974	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1975	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000
1976	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1977	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1978	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1979	0.000	0.000	0.005	0.000	0.000	0.008	0.000	0.000
1980	0.000	0.000	0.001	0.000	0.000	0.002	0.000	0.000
1981	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000
1982	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1983	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000
1984	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1985	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1986	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1987	0.000	0.000	0.214	0.000	0.000	0.000	0.000	0.000
1988	0.000	0.000	0.044	0.000	0.000	0.000	0.000	0.000
1989	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1990	0.000	0.010	0.012	0.000	0.000	0.000	0.000	0.000
1991	0.000	0.001	0.015	0.000	0.000	0.006	0.000	0.000
1992	0.000	0.000	0.006	0.000	0.000	0.000	0.000	0.000
1993	0.000	0.001	0.016	0.000	0.000	0.000	0.000	0.000
1994	0.000	0.016	0.005	0.000	0.000	0.020	0.000	0.000
1995	0.000	0.005	0.006	0.000	0.000	0.000	0.000	0.002
1996	0.000	0.000	0.233	0.000	0.000	0.000	0.000	0.036
1997	0.000	0.046	0.012	0.000	0.000	0.000	0.000	0.000
1998	0.000	0.052	0.000	0.000	0.000	0.000	0.000	0.000
1999	0.000	0.000	0.082	0.000	0.000	0.000	0.000	0.000
2000	0.000	0.133	0.062	0.000	0.000	0.112	0.000	0.000
2001	0.000	0.026	0.039	0.000	0.002	0.000	0.000	0.000
2002	0.000	0.022	0.086	0.000	0.000	0.000	0.000	0.003
2003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2005	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2006	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2007	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2008	0.000	0.000	0.000	0.171	0.000	0.000	0.000	0.152
2009	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2010	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table C4. Reconstructed catch history for Quillback Rockfish from the Spiny Dogfish and Lingcod (Schedule II) Fishery, by PFMC for the years 1918 to 2010 in tonnes.

Dogfish- Lingcod year	Inside 4B	Outside 3C	Outside 3D	Outside 5A	Outside 5B	Outside 5C	Outside 5D	Outside 5E
1918	0.026	0.015	0.006	0.001	0.038	0.007	0.004	0.000
1919	0.065	0.028	0.011	0.001	0.005	0.001	0.001	0.000
1920	0.032	0.016	0.006	0.001	0.007	0.001	0.001	0.000
1921	0.028	0.010	0.004	0.000	0.000	0.000	0.000	0.000
1922	0.035	0.021	0.008	0.001	0.000	0.000	0.000	0.000
1923	0.034	0.010	0.004	0.000	0.001	0.000	0.000	0.000
1924	0.039	0.009	0.004	0.000	0.002	0.000	0.000	0.000
1925	0.033	0.006	0.002	0.000	0.003	0.001	0.000	0.000
1926	0.038	0.011	0.004	0.001	0.006	0.001	0.001	0.000
1927	0.038	0.016	0.006	0.001	0.009	0.002	0.001	0.000
1928	0.039	0.014	0.006	0.001	0.007	0.001	0.001	0.000
1929	0.051	0.012	0.005	0.001	0.010	0.002	0.001	0.000
1930	0.046	0.009	0.003	0.000	0.005	0.001	0.001	0.000
1931	0.030	0.009	0.004	0.000	0.001	0.000	0.000	0.000
1932	0.034	0.005	0.002	0.000	0.001	0.000	0.000	0.000
1933	0.017	0.003	0.001	0.000	0.000	0.000	0.000	0.000
1934	0.020	0.003	0.001	0.000	0.001	0.000	0.000	0.000
1935	0.025	0.004	0.002	0.000	0.006	0.001	0.001	0.000
1936	0.028	0.008	0.003	0.000	0.009	0.002	0.001	0.000
1937	0.022	0.002	0.001	0.000	0.002	0.000	0.000	0.000
1938	0.073	0.030	0.012	0.001	0.001	0.000	0.000	0.000
1939	0.014	0.000	0.001	0.000	0.001	0.000	0.000	0.000
1940	0.016	0.000	0.001	0.000	0.001	0.000	0.000	0.000
1941	0.010	0.001	0.003	0.000	0.005	0.001	0.000	0.000
1942	0.022	0.002	0.008	0.001	0.004	0.001	0.000	0.000
1943	0.128	0.004	0.021	0.002	0.011	0.002	0.001	0.000
1944	0.191	0.005	0.027	0.002	0.015	0.003	0.001	0.000
1945	0.205	0.004	0.021	0.002	0.024	0.005	0.002	0.000
1946	0.137	0.004	0.019	0.002	0.034	0.007	0.003	0.000
1947	0.044	0.001	0.006	0.001	0.006	0.001	0.000	0.000
1948	0.067	0.002	0.009	0.001	0.009	0.002	0.001	0.000
1949	0.089	0.002	0.012	0.001	0.011	0.002	0.001	0.000
1950	0.038	0.001	0.005	0.000	0.005	0.001	0.000	0.000
1951	0.028	0.004	0.017	0.001	0.026	0.007	0.002	0.000
1952	0.021	0.002	0.012	0.002	0.023	0.003	0.001	0.000
1953	0.044	0.003	0.011	0.006	0.010	0.001	0.001	0.000
1954	0.028	0.003	0.013	0.003	0.010	0.001	0.001	0.000
1955	0.027	0.002	0.015	0.001	0.002	0.001	0.000	0.000
1956	0.026	0.005	0.014	0.001	0.004	0.000	0.000	0.000
1957	0.045	0.015	0.022	0.000	0.010	0.001	0.000	0.000
1958	0.065	0.005	0.022	0.000	0.002	0.000	0.000	0.000
1959	0.067	0.008	0.024	0.001	0.003	0.000	0.000	0.000
1960	0.054	0.008	0.026	0.005	0.005	0.003	0.001	0.000
1961	0.041	0.008	0.034	0.003	0.009	0.001	0.000	0.000
1962	0.066	0.022	0.040	0.005	0.009	0.007	0.000	0.000
1963	0.050	0.015	0.025	0.006	0.036	0.003	0.000	0.000

Table C4 continued.

1964	0.030	0.006	0.018	0.001	0.011	0.001	0.000	0.000
1965	0.027	0.005	0.015	0.001	0.005	0.003	0.000	0.000
1966	0.022	0.004	0.018	0.003	0.008	0.001	0.000	0.000
1967	0.034	0.008	0.024	0.002	0.006	0.005	0.001	0.000
1968	0.037	0.006	0.020	0.000	0.008	0.001	0.000	0.000
1969	0.042	0.014	0.020	0.006	0.022	0.007	0.000	0.000
1970	0.052	0.027	0.024	0.002	0.044	0.020	0.002	0.000
1971	0.044	0.017	0.007	0.006	0.028	0.017	0.002	0.000
1972	0.049	0.031	0.038	0.007	0.033	0.011	0.003	0.000
1973	0.060	0.022	0.016	0.009	0.011	0.010	0.002	0.000
1974	0.030	0.051	0.019	0.007	0.008	0.027	0.004	0.000
1975	0.024	0.040	0.016	0.006	0.026	0.036	0.003	0.000
1976	0.029	0.037	0.018	0.005	0.036	0.010	0.003	0.000
1977	0.081	0.047	0.020	0.030	0.036	0.018	0.002	0.000
1978	0.091	0.039	0.019	0.015	0.033	0.024	0.006	0.000
1979	0.146	0.071	0.040	0.033	0.028	0.028	0.005	0.001
1980	0.105	0.061	0.038	0.024	0.021	0.021	0.007	0.001
1981	0.125	0.055	0.026	0.019	0.015	0.016	0.005	0.000
1982	0.167	0.046	0.023	0.015	0.010	0.016	0.003	0.000
1983	0.177	0.041	0.036	0.016	0.012	0.016	0.004	0.000
1984	0.206	0.035	0.061	0.021	0.013	0.015	0.005	0.001
1985	0.259	0.045	0.083	0.043	0.043	0.058	0.011	0.001
1986	3.181	11.486	0.562	0.076	4.066	0.292	0.018	0.013
1987	4.578	9.459	0.784	0.154	0.302	0.430	0.038	0.019
1988	4.968	15.929	0.694	0.174	0.318	0.602	0.039	0.053
1989	3.499	9.707	0.578	0.222	0.569	0.185	0.039	0.019
1990	3.341	13.950	0.841	0.368	2.030	0.171	0.055	0.018
1991	2.394	13.762	0.763	0.259	2.022	0.410	0.058	0.019
1992	1.603	8.583	0.571	0.244	0.997	0.863	0.043	0.026
1993	1.997	6.947	1.020	0.144	0.319	0.366	0.049	0.020
1994	3.832	4.706	1.530	0.187	0.387	0.201	0.041	0.036
1995	7.180	5.047	1.502	0.007	0.203	0.244	0.013	0.004
1996	0.476	0.111	0.080	0.026	0.058	0.007	0.014	0.006
1997	4.250	1.274	0.875	0.045	0.943	0.116	0.022	0.096
1998	5.043	1.585	1.085	0.507	0.184	0.424	0.178	0.031
1999	5.827	5.104	0.365	0.488	0.825	0.531	0.214	0.050
2000	3.510	3.386	0.526	0.004	0.080	0.236	0.098	0.134
2001	7.640	7.519	1.888	0.004	0.130	0.214	0.083	0.067
2002	10.056	3.729	2.670	0.004	0.147	0.384	0.100	0.024
2003	13.290	4.617	3.311	0.084	0.270	0.525	0.031	0.132
2004	10.208	7.627	2.677	0.287	0.690	0.519	0.095	0.068
2005	8.699	7.350	2.232	0.153	0.293	0.339	0.255	0.078
2006	0.139	1.761	0.790	0.022	0.000	0.021	0.031	0.014
2007	0.400	4.186	1.477	0.195	0.614	0.021	0.033	0.055
2008	0.369	5.224	0.171	0.669	0.343	0.057	0.055	0.010
2009	0.543	6.896	1.131	0.435	0.125	0.267	2.617	0.025
2010	0.549	3.658	0.252	0.662	0.717	0.163	1.871	0.024

Table C5. Reconstructed catch history for Quillback Rockfish from the Rockfish Hook and Line (ZN) Fishery, by PFMC for the years 1918 to 2010 in tonnes.

Rockfish (H&L) year	Inside 4B	Outside 3C	Outside 3D	Outside 5A	Outside 5B	Outside 5C	Outside 5D	Outside 5E
1918	28.972	3.169	0.499	0.121	7.301	5.552	10.988	0.030
1919	72.099	5.976	0.942	0.179	0.964	0.733	1.451	0.004
1920	36.056	3.466	0.546	0.107	1.371	1.043	2.064	0.006
1921	31.203	2.078	0.327	0.061	0.065	0.050	0.098	0.000
1922	38.967	4.406	0.694	0.129	0.022	0.017	0.034	0.000
1923	37.799	2.068	0.326	0.061	0.148	0.112	0.222	0.001
1924	42.915	2.004	0.316	0.060	0.369	0.281	0.555	0.002
1925	36.899	1.315	0.207	0.041	0.552	0.420	0.830	0.002
1926	42.230	2.360	0.372	0.074	1.196	0.909	1.800	0.005
1927	42.217	3.313	0.522	0.104	1.828	1.390	2.751	0.007
1928	43.438	3.067	0.483	0.095	1.330	1.011	2.001	0.005
1929	56.549	2.607	0.411	0.084	1.968	1.497	2.962	0.008
1930	51.075	1.892	0.298	0.060	1.054	0.801	1.586	0.004
1931	33.494	1.933	0.305	0.057	0.174	0.133	0.262	0.001
1932	38.036	1.017	0.160	0.030	0.110	0.084	0.166	0.000
1933	18.632	0.687	0.108	0.020	0.020	0.015	0.030	0.000
1934	21.981	0.684	0.108	0.021	0.125	0.095	0.188	0.001
1935	28.237	0.821	0.129	0.029	1.173	0.892	1.765	0.005
1936	30.646	1.711	0.270	0.057	1.782	1.355	2.681	0.007
1937	23.914	0.448	0.071	0.014	0.336	0.255	0.505	0.001
1938	80.694	6.300	0.993	0.185	0.154	0.117	0.231	0.001
1939	15.873	0.057	0.113	0.015	0.111	0.094	0.114	0.001
1940	17.288	0.036	0.071	0.010	0.143	0.121	0.147	0.001
1941	10.585	0.133	0.264	0.039	0.918	0.778	0.943	0.008
1942	24.566	0.337	0.669	0.092	0.803	0.681	0.825	0.007
1943	142.410	0.887	1.760	0.241	2.128	1.804	2.185	0.018
1944	212.177	1.170	2.321	0.319	2.895	2.454	2.973	0.025
1945	227.929	0.916	1.817	0.262	4.619	3.915	4.742	0.039
1946	152.602	0.803	1.593	0.243	6.687	5.668	6.866	0.057
1947	48.582	0.255	0.506	0.072	1.088	0.923	1.118	0.009
1948	74.116	0.389	0.772	0.110	1.661	1.407	1.705	0.014
1949	98.871	0.519	1.030	0.146	2.215	1.877	2.275	0.019
1950	41.875	0.220	0.436	0.062	0.938	0.795	0.963	0.008
1951	30.652	0.896	1.423	0.097	5.037	5.861	6.563	0.049
1952	23.395	0.339	1.045	0.276	4.569	2.284	3.306	0.033
1953	49.239	0.623	0.904	0.812	2.010	1.021	1.727	0.007
1954	30.707	0.675	1.114	0.391	1.989	0.662	2.456	0.013
1955	30.318	0.363	1.298	0.128	0.352	1.049	1.055	0.015
1956	28.837	1.116	1.224	0.192	0.857	0.350	0.168	0.004
1957	49.882	3.290	1.886	0.000	1.928	0.405	0.616	0.021
1958	72.483	1.064	1.861	0.000	0.474	0.166	0.084	0.001
1959	74.592	1.713	2.003	0.082	0.627	0.046	0.056	0.002
1960	60.547	1.778	2.240	0.646	1.046	2.300	1.541	0.006
1961	45.126	1.791	2.909	0.455	1.683	0.653	0.644	0.007
1962	73.036	4.749	3.381	0.649	1.658	5.510	0.103	0.006
1963	55.775	3.134	2.167	0.810	7.039	2.613	1.233	0.028

Table C5 continued.

1964	33.564	1.350	1.559	0.174	2.178	0.984	0.131	0.002
1965	30.273	1.116	1.295	0.089	1.000	2.456	0.476	0.018
1966	24.320	0.805	1.551	0.383	1.495	1.021	1.335	0.009
1967	37.602	1.739	2.086	0.250	1.234	3.707	3.445	0.010
1968	40.579	1.369	1.703	0.061	1.530	0.442	0.635	0.001
1969	47.109	2.952	1.733	0.830	4.341	5.575	0.280	0.001
1970	57.825	5.820	2.058	0.258	8.519	16.127	4.743	0.001
1971	49.299	3.627	0.582	0.828	5.397	13.109	5.108	0.003
1972	54.564	6.709	3.215	0.953	6.361	8.969	6.994	0.006
1973	67.008	4.736	1.362	1.201	2.193	7.820	6.443	0.009
1974	33.055	10.900	1.629	0.894	1.581	21.435	9.617	0.001
1975	26.474	8.435	1.374	0.843	5.152	28.794	9.524	0.013
1976	32.158	7.851	1.502	0.715	6.937	8.280	7.003	0.013
1977	90.342	9.927	1.731	3.959	7.090	14.167	6.816	0.011
1978	101.232	8.296	1.599	1.971	6.410	19.064	16.056	0.042
1979	161.906	15.162	3.367	4.393	5.398	21.904	12.969	0.235
1980	117.060	13.017	3.254	3.210	4.048	16.631	18.527	0.095
1981	139.021	11.786	2.256	2.568	2.901	12.412	13.463	0.063
1982	185.510	9.827	2.002	2.020	1.950	12.613	7.242	0.040
1983	197.038	8.796	3.075	2.172	2.260	12.552	11.349	0.023
1984	229.144	7.404	5.210	2.832	2.531	11.709	14.668	0.192
1985	287.936	9.659	7.032	5.768	8.367	45.615	29.641	0.098
1986	349.021	52.565	19.193	7.578	9.219	81.544	29.927	0.272
1987	279.852	57.741	18.675	18.129	13.304	99.779	67.239	0.129
1988	328.431	175.626	12.336	21.527	25.082	67.643	72.757	0.250
1989	304.547	67.629	66.133	26.238	41.229	60.734	81.528	0.289
1990	310.872	118.239	157.399	43.036	40.748	82.366	126.946	28.263
1991	318.142	63.054	99.071	89.650	71.918	83.718	136.768	24.332
1992	117.632	25.586	36.525	109.482	51.782	75.777	97.104	6.965
1993	131.622	18.886	72.338	101.380	52.034	76.749	115.365	23.883
1994	185.450	14.695	26.036	102.076	62.087	80.292	103.128	10.249
1995	58.840	5.235	17.242	60.513	45.041	81.186	55.896	15.660
1996	54.283	11.601	25.998	56.731	46.559	70.088	56.683	13.265
1997	38.615	9.067	28.910	51.112	32.936	84.512	75.136	10.004
1998	48.596	16.898	20.767	60.970	28.384	51.215	21.503	10.122
1999	56.906	12.414	14.552	21.207	35.485	65.771	26.036	3.966
2000	54.908	23.413	18.753	18.593	44.399	33.113	21.140	5.700
2001	73.840	23.950	9.414	13.191	32.122	28.496	24.347	2.114
2002	1.162	7.040	5.963	11.276	22.087	41.075	15.336	1.309
2003	28.973	7.562	3.383	18.663	20.698	13.108	8.436	0.000
2004	16.879	2.970	3.565	20.501	21.376	19.550	8.833	0.136
2005	16.209	2.998	2.178	18.713	16.494	22.740	7.869	0.060
2006	14.770	1.196	0.651	5.457	7.106	25.569	3.973	0.634
2007	19.287	3.748	0.779	16.482	14.307	12.848	3.487	0.142
2008	27.683	3.864	1.592	16.366	17.382	19.891	3.657	0.392
2009	18.903	2.271	0.526	15.222	18.357	21.728	4.331	0.396
2010	23.907	3.047	0.523	19.038	20.234	23.390	2.950	0.285

Table C6. Reconstructed catch history for Quillback Rockfish from all Fisheries Combined, by PFMC and Total Outside Management Area, for the years 1918 to 2010 in tonnes.

Combined Fisheries - QUILLBACK ROCKFISH

year	Inside 4B	Outside 3C	Outside 3D	Outside 5A	Outside 5B	Outside 5C	Outside 5D	Outside 5E	Total - Outside
1918	29.078	3.194	0.541	0.122	7.392	5.573	11.231	0.118	28.171
1919	72.361	6.023	1.021	0.181	0.976	0.736	1.483	0.016	10.436
1920	36.187	3.493	0.592	0.108	1.389	1.047	2.110	0.022	8.761
1921	31.316	2.094	0.355	0.062	0.066	0.050	0.100	0.001	2.728
1922	39.109	4.440	0.752	0.131	0.023	0.017	0.034	0.000	5.397
1923	37.937	2.084	0.353	0.062	0.149	0.113	0.227	0.002	2.990
1924	43.071	2.020	0.342	0.061	0.374	0.282	0.568	0.006	3.651
1925	37.033	1.325	0.225	0.041	0.559	0.421	0.849	0.009	3.428
1926	42.383	2.378	0.403	0.075	1.211	0.913	1.840	0.019	6.839
1927	42.371	3.339	0.566	0.105	1.851	1.395	2.812	0.030	10.097
1928	43.596	3.091	0.524	0.096	1.346	1.015	2.045	0.022	8.139
1929	56.754	2.627	0.445	0.085	1.993	1.502	3.028	0.032	9.712
1930	51.261	1.907	0.323	0.060	1.067	0.805	1.621	0.017	5.800
1931	33.616	1.948	0.330	0.058	0.177	0.133	0.268	0.003	2.917
1932	38.175	1.025	0.174	0.031	0.112	0.084	0.170	0.002	1.597
1933	18.700	0.692	0.117	0.020	0.020	0.015	0.031	0.000	0.897
1934	22.061	0.689	0.117	0.021	0.126	0.095	0.192	0.002	1.243
1935	28.340	0.827	0.140	0.029	1.188	0.895	1.805	0.019	4.904
1936	30.757	1.725	0.292	0.058	1.804	1.360	2.741	0.029	8.009
1937	24.001	0.452	0.076	0.015	0.340	0.256	0.517	0.005	1.662
1938	80.987	6.350	1.076	0.188	0.156	0.117	0.237	0.002	8.127
1939	16.249	0.058	0.122	0.016	0.113	0.095	0.118	0.004	0.526
1940	17.698	0.038	0.077	0.012	0.146	0.122	0.153	0.005	0.552
1941	10.836	0.135	0.286	0.040	0.931	0.782	0.972	0.031	3.178
1942	25.149	0.352	0.725	0.105	0.823	0.684	0.860	0.027	3.576
1943	145.788	0.932	1.908	0.284	2.186	1.813	2.286	0.072	9.481
1944	217.211	1.199	2.515	0.339	2.945	2.465	3.077	0.098	12.639
1945	233.899	1.070	1.973	0.442	4.813	3.935	5.036	0.157	17.426
1946	156.581	0.885	1.727	0.334	6.840	5.694	7.149	0.227	22.857
1947	49.981	0.296	0.549	0.119	1.138	0.928	1.191	0.037	4.257
1948	76.005	0.455	0.838	0.186	1.739	1.415	1.821	0.056	6.510
1949	101.355	0.600	1.118	0.240	2.313	1.888	2.421	0.075	8.654
1950	43.098	0.296	0.475	0.169	1.017	0.801	1.132	0.032	3.922
1951	31.456	0.976	1.544	0.171	5.180	5.886	6.786	0.196	20.740
1952	24.015	0.425	1.134	0.351	4.695	2.294	3.472	0.131	12.502
1953	50.031	0.673	0.980	0.876	2.074	1.026	1.821	0.027	7.478
1954	32.950	0.739	1.208	0.472	2.071	0.667	2.580	0.050	7.788
1955	32.751	0.422	1.408	0.246	0.410	1.054	1.186	0.061	4.787
1956	30.182	1.164	1.328	0.315	0.893	0.354	0.205	0.017	4.276
1957	50.736	3.366	2.045	0.058	1.994	0.410	0.739	0.085	8.698
1958	73.556	1.128	2.017	0.079	0.534	0.169	0.149	0.006	4.082
1959	77.606	1.866	2.172	0.182	0.695	0.049	0.159	0.008	5.131
1960	63.850	1.932	2.429	0.727	1.113	2.310	1.735	0.024	10.270
1961	47.081	1.949	3.155	0.547	1.768	0.657	0.841	0.027	8.946

Table C6 continued.

1962	74.826	4.963	3.669	0.778	1.768	5.534	0.382	0.022	17.116
1963	56.787	3.237	2.352	0.924	7.199	2.626	1.344	0.112	17.795
1964	35.680	1.435	1.691	0.285	2.258	0.993	0.279	0.009	6.950
1965	31.480	1.212	1.406	0.760	1.120	2.474	2.884	0.080	9.936
1966	26.834	1.280	1.702	1.862	1.694	1.026	4.980	0.048	12.591
1967	38.548	1.855	2.266	1.090	1.387	3.723	4.141	0.043	14.505
1968	42.445	1.544	1.853	0.741	1.673	0.446	1.398	0.008	7.662
1969	48.986	3.061	1.884	8.382	4.569	5.601	0.558	0.002	24.058
1970	59.748	5.965	2.237	0.781	8.756	16.191	5.243	0.002	39.175
1971	49.980	3.767	0.635	1.170	5.586	13.163	5.614	0.013	29.949
1972	55.464	6.830	3.488	1.576	6.611	9.012	7.877	0.025	35.418
1973	67.546	4.816	1.479	2.264	2.397	7.855	7.016	0.035	25.862
1974	33.496	11.006	1.769	2.688	1.715	21.524	10.375	0.005	49.082
1975	27.042	8.543	1.493	1.666	5.319	28.914	10.124	0.053	56.113
1976	32.845	8.024	1.628	1.186	7.180	8.347	8.080	0.054	34.499
1977	91.022	10.073	1.876	4.156	7.322	14.288	8.178	0.815	46.707
1978	102.467	8.384	1.734	2.546	6.713	19.621	17.700	0.179	56.876
1979	164.412	15.342	3.654	5.468	5.675	22.703	15.220	0.470	68.531
1980	118.425	13.493	3.938	8.582	4.339	17.418	20.493	0.383	68.645
1981	140.245	11.942	2.447	2.670	3.144	14.470	15.020	0.257	49.950
1982	186.701	11.693	2.174	4.635	2.145	16.559	9.724	0.241	47.172
1983	197.901	9.314	3.685	3.519	2.445	17.022	15.928	1.565	53.478
1984	230.281	8.321	5.707	5.965	2.759	19.287	19.262	1.064	62.365
1985	289.052	10.372	7.638	6.273	8.786	58.250	36.447	0.712	128.478
1986	353.198	64.472	21.158	8.035	13.593	93.260	37.710	1.588	239.816
1987	285.373	68.150	21.033	18.923	14.157	114.834	76.536	0.741	314.374
1988	334.308	192.247	13.978	22.252	26.055	81.788	81.577	1.407	419.304
1989	309.230	78.115	68.000	28.064	42.386	68.330	92.174	1.636	378.705
1990	315.076	132.764	159.489	45.762	43.570	89.730	139.482	29.874	640.671
1991	320.825	78.166	104.598	92.235	77.985	91.019	158.587	25.374	627.964
1992	119.743	37.013	38.243	127.801	55.927	88.915	118.849	9.884	476.631
1993	133.916	26.882	76.279	117.460	55.602	87.623	146.256	27.257	537.359
1994	189.481	21.597	29.690	125.978	65.383	92.110	123.214	13.532	471.503
1995	66.114	15.732	20.049	76.111	47.838	91.885	70.085	15.857	337.558
1996	55.835	12.978	27.879	62.295	49.035	83.499	76.243	14.184	326.114
1997	43.252	12.169	30.183	55.169	36.261	95.683	91.108	10.531	331.104
1998	54.086	21.089	22.627	66.872	30.914	65.013	37.838	10.622	254.976
1999	62.903	19.414	15.538	23.747	38.478	76.978	40.154	4.513	218.823
2000	58.500	29.919	21.028	20.751	48.521	42.777	35.193	10.354	208.543
2001	81.718	33.594	13.339	14.886	35.349	38.235	36.047	7.527	178.977
2002	11.313	13.436	13.138	15.151	24.879	56.329	28.730	8.940	160.604
2003	42.283	14.930	11.009	21.088	24.145	24.570	17.449	7.136	120.327
2004	27.137	12.870	10.204	22.072	24.359	30.287	17.654	6.953	124.401
2005	24.951	13.127	7.976	19.650	18.807	32.814	17.468	6.851	116.694
2006	15.331	5.446	2.248	12.342	10.132	36.668	8.093	2.596	77.525
2007	20.199	9.299	3.167	22.932	19.955	22.465	9.408	2.179	89.404
2008	28.799	16.590	4.400	26.460	21.273	31.633	8.765	4.500	113.621
2009	20.005	14.792	4.319	23.509	22.850	32.845	12.080	5.630	116.025
2010	24.778	16.949	2.329	26.072	24.699	35.538	8.464	2.464	116.515

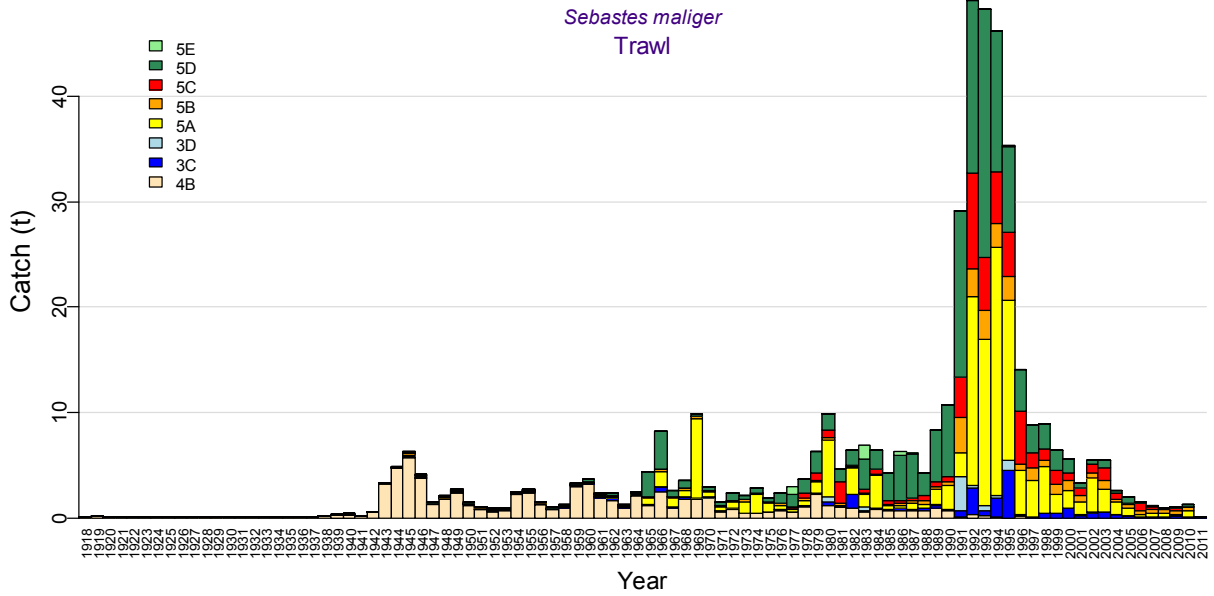


Figure C1. Quillback Rockfish catch reconstruction for the Trawl Fishery, by PFMC and year from 1918 to 2010 in tonnes.

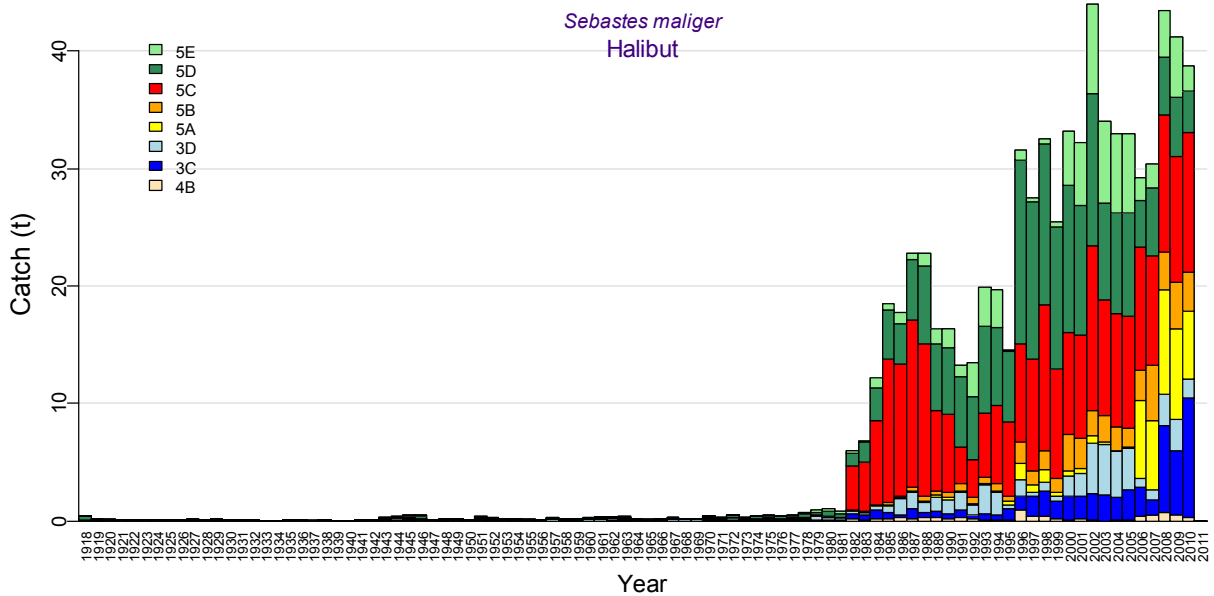


Figure C2. Quillback Rockfish catch reconstruction for the Halibut Fishery, by PFMC and year from 1918 to 2010 in tonnes.

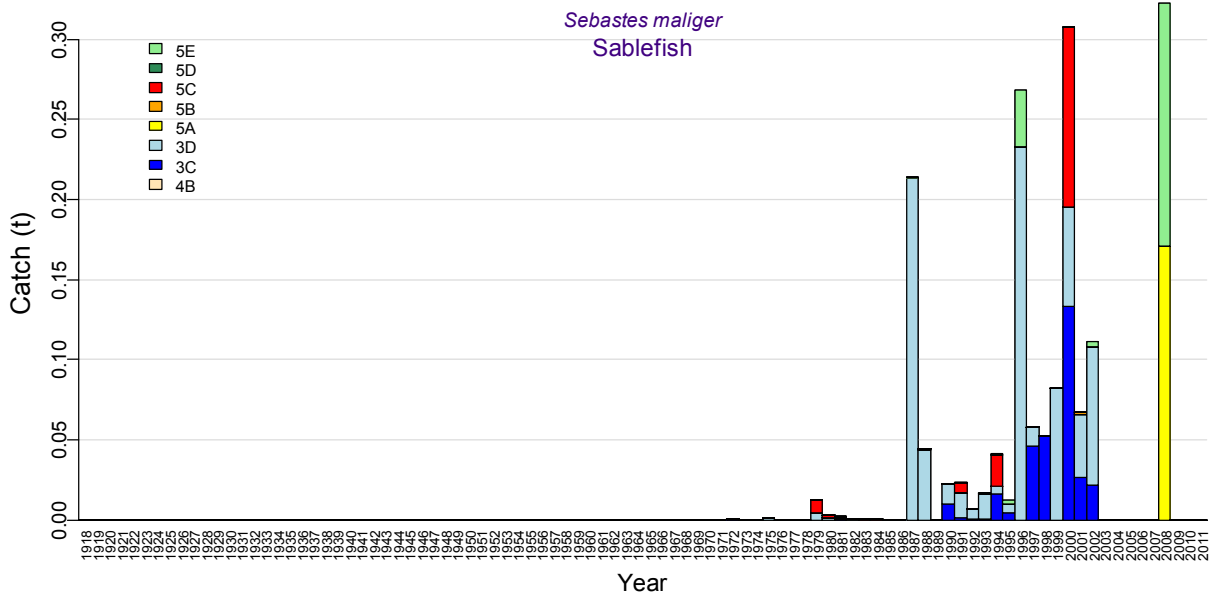


Figure C3. Quillback rockfish catch reconstruction for the Sablefish Fishery, by PFMC and year from 1918 to 2010 in tonnes.

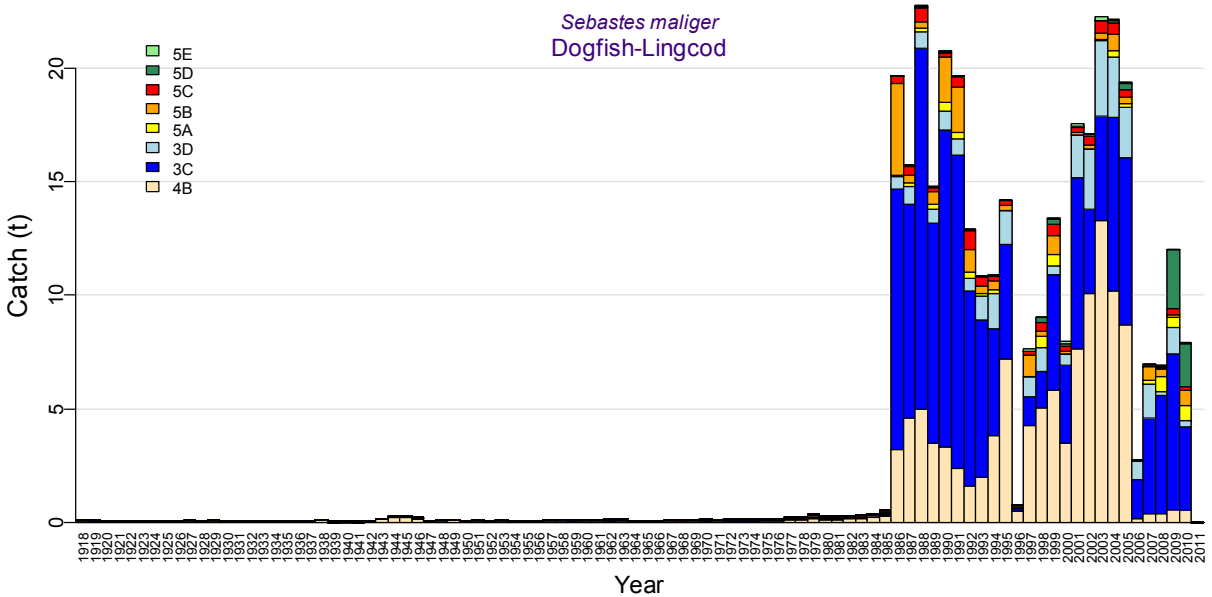


Figure C4. Quillback Rockfish catch reconstruction for the Dogfish and Lingcod (Schedule II) Fishery, by PFMC and year from 1918 to 2010 in tonnes.

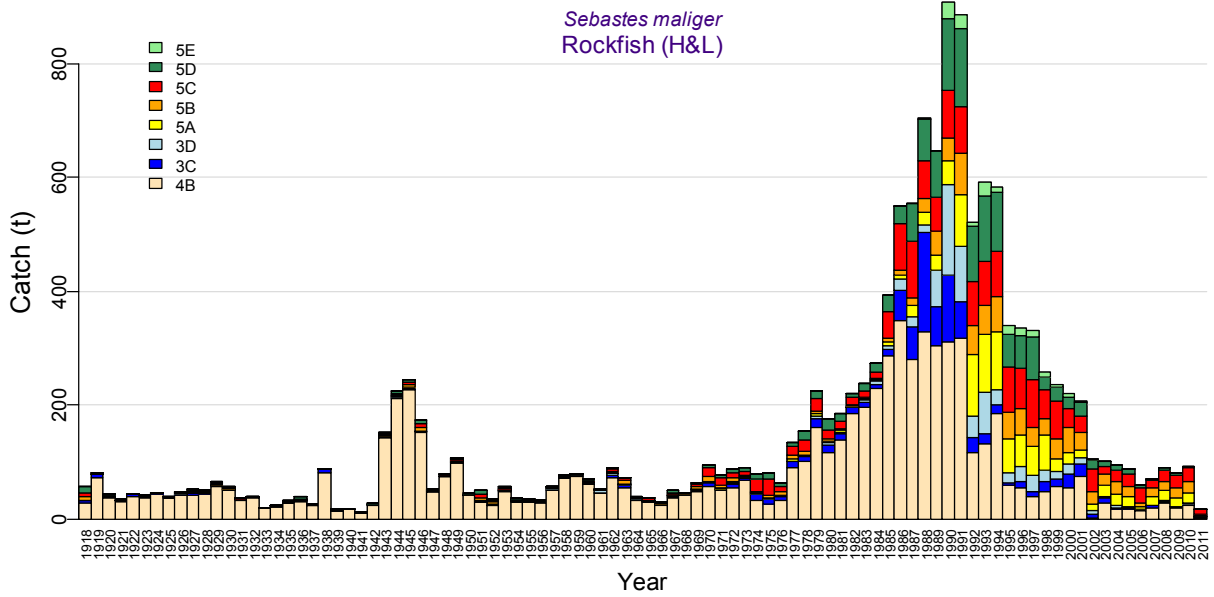


Figure C5. Quillback Rockfish catch reconstruction for the Rockfish Hook and Line (ZN) Fishery, by PFMC and year from 1918 to 2010 in tonnes.

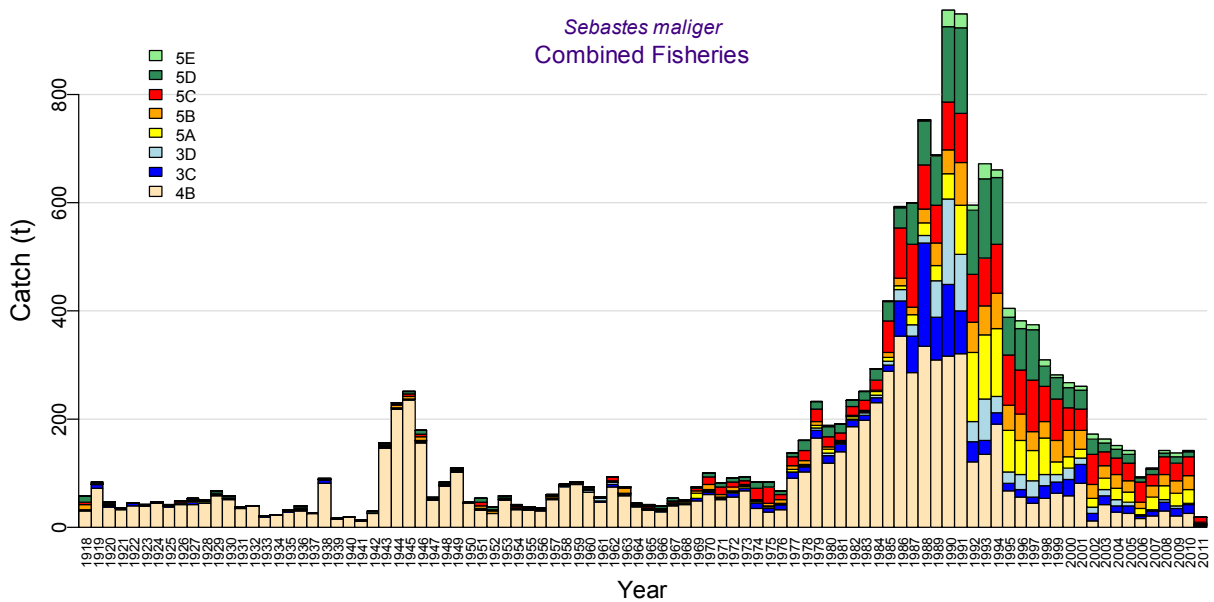


Figure C6. Quillback Rockfish catch reconstruction for all Fisheries Combined, by PFMC and year from 1918 to 2010 in tonnes.

COMMERCIAL PACIFIC SALMON TROLL CATCH

The commercial salmon troll catch of Quillback Rockfish is reconstructed using recent observer records for the inside and outside management areas to obtain a median catch in pieces of Quillback Rockfish per troll day. This observer catch rate is converted to weight (0.94 kg from the recreational creel sampling program) then applied to the total troll effort in days for the inside and outside fisheries. Data used were obtained from Bruce Patten, Salmon Assessment Biologist, Salmon And Freshwater Ecosystems, DFO. Catches are shown in Table C7.

Catches were fixed from 1918 to 1951 to the catch in 1952 for each management unit.

Table C7. Commercial Pacific Salmon troll catch in tonnes of Quillback Rockfish for the years 1952 to 2010 by management unit (inside and outside).

Year	Quillback Rockfish		Year	Quillback Rockfish	
	inside	outside		inside	outside
	biomass in tonnes			biomass in tonnes	
1952	0.13	3.36	1982	0.06	3.54
1953	0.13	3.12	1983	0.06	3.62
1954	0.12	2.82	1984	0.02	3.07
1955	0.12	2.93	1985	0.03	2.71
1956	0.11	2.78	1986	0.02	2.40
1957	0.13	3.19	1987	0.02	1.93
1958	0.15	3.44	1988	0.02	1.99
1959	0.15	3.37	1989	0.03	1.69
1960	0.16	3.42	1990	0.03	2.05
1961	0.16	3.84	1991	0.02	2.09
1962	0.14	3.46	1992	0.02	1.96
1963	0.13	2.18	1993	0.03	1.55
1964	0.13	2.62	1994	0.04	1.48
1965	0.10	2.77	1995	0.01	1.10
1966	0.11	2.80	1996	0.00	0.68
1967	0.10	2.82	1997	0.04	0.38
1968	0.08	3.15	1998	0.01	0.20
1969	0.07	2.87	1999	0.00	0.13
1970	0.08	2.96	2000	0.00	0.10
1971	0.09	3.03	2001	0.00	0.15
1972	0.06	2.84	2002	0.00	0.24
1973	0.06	2.71	2003	0.00	0.23
1974	0.06	2.57	2004	0.00	0.24
1975	0.06	2.49	2005	0.00	0.28
1976	0.07	2.66	2006	0.00	0.28
1977	0.10	2.97	2007	0.00	0.23
1978	0.09	3.00	2008	0.01	0.34
1979	0.09	3.33	2009	0.00	0.46
1980	0.09	4.15	2010	0.06	0.28
1981	0.07	3.63			

COMMERCIAL SPOT PRAWN CATCH

The catch of rockfish in the commercial Spot Prawn trap fishery is a rare and random event that follows a Poisson distribution (Rutherford et al. 2009). The annual coastwide rockfish catch (all species) is estimated to range from a low of 13, 900 pieces in 2005 to a high of 20,000 pieces in 2002. The majority (approximately 80%) of this catch is from in the inside management unit.

Quillback rockfish is the most frequently encountered rockfish in this fishery and make up 62% of the rockfish catch. The average size of Quillback Rockfish caught is estimated at 0.233 kg and are immature fish of approximately 4 years of age. There is insufficient information to estimate a total coastwide catch of Quillback Rockfish from the commercial Spot Prawn trap fishery (Rutherford et al. 2009).

Rutherford, D.T., Fong, K., and Nguyen, H. 2009 Rockfish bycatch in the British Columbia commercial Prawn trap fishery. DFO Can. Sci. Advis. Sec. Res. Doc. 2009/109. iii + 25 p.

APPENDIX D. RECREATIONAL CATCH

Quillback are captured by the recreational fishery throughout British Columbia waters. There are two sources of recreational catch data compiled by Fisheries and Oceans Canada: the Strait of Georgia Sport Fishery Creel Survey (Creel) (Hardie et al. 2001) and the Survey of Recreational Fishing in Canada (Recreational) (DFO). Creel survey programs do not have complete geographic or seasonal coverage and both of these also vary by year (Hardie 2001, Lewis 2004). The National survey provides coastwide coverage by region of fishing effort and occurs every five years from 1975 to 2005 (DFO 2005).

INSIDE MANAGEMENT UNIT

For the inside fishery, the Creel survey is used to estimate the recreational catch between 1982 and 2010 and anecdotal information from local experts is used to profile effort back to World War II when we assume that the recreational fishery began to develop (Yamanaka et al. 2012).

Strait of Georgia Creel Survey 1982 - 2008

The Strait of Georgia Creel survey catch estimates were obtained between 1982 and 2010 from the South Coast Creel Database (David O'Brian, Salmon Biologist, South Coast Division, DFO). Catch in numbers of rockfish are recorded for kept fish between 1982 and 1998 and kept and released fish between 1999 and 2008. These catch estimates are in numbers of rockfish (all species) in PFMAs 13 to 20, 28 and 29 for the years 1982 to 1999 and for Quillback Rockfish in PFMAs 12 to 20, 28 and 29 for the years 2000 to 2008.

Using proportions of Quillback Rockfish to rockfish (all species) by PFMA in 2000, the number of Quillback Rockfish caught by PFMA are estimated from the rockfish (all species) catch estimates. Using proportions of Quillback Rockfish catch in PFMA12 to the rest of the Strait of Georgia in 2000 and 2001 estimates of PFMA 12 Quillback Rockfish catches are made. To estimate the weight in tonnes of the Quillback Rockfish catch, the average weight of Quillback Rockfish, 0.94 kg, determined from weights collected during the creel survey between 2000 and 2008, is applied to the total number of fish. These estimates are not corrected for missing survey months and could be considered biased low by 5% (Bill Shaw pers. comm.). The estimate of the inside Quillback Rockfish catch by recreational anglers is shown for the inside management unit by PFMA in Table D1 and summarized for the inside unit in Table D2.

Estimated recreational catch 1945 – 1981 (from Yamanaka et al. 2012)

Recreational catches prior to the creel survey were reconstructed by formulating a time series of hypothesized recreational fishing effort prior to the creel survey. It is known that Quillback Rockfish have been captured by recreational anglers since the late 1800's with recreational angling effort increasing after World War II (George Bates, Bill Otway, Wayne Seto pers. comm.). The reconstruction of fishing effort in the recreational fishery is based on a family run recreational fishing resort history; Bates Beach. George Bates supplied the following information.

“You could consider the start of the recreational fishery right after WWII, with the fleet characterized by “putter” boats – at this time Bates Beach fleet size = 10 boats

Recreational fishing effort increased steadily from WWII up to the early 1960s, at which time outboard motors became popular and allowed movement out to rock reefs further offshore.

The herring population collapsed and so did the salmon fishing so people switched to groundfish, primarily lingcod and rockfish. Generally during this time there was a lull in the fishing effort – Bates Beach sold the business in 1965 fleet size = 10.

In the early 1970’s the herring population came back and so did the salmon, effort on groundfish decreased – Bates Beach reopened second resort around 1971 – original Bates Beach still operating until 2006 with a slow decline in the original fleet to <3 boats.

In the 1980’s there was good salmon fishing, effort peaked in the recreational fishery in the mid-late 1980’s – Bates Beach fleet size = 17 boats during this peak.

Steady decline in effort began around 1998 to the present. During 1992 – 96 coho fishing declined and effort switched back to groundfish. Bates beach fleet size in 2009 = 3 boats.”

Based on this, trend lines were formulated for historic recreational fishing effort up to 1981. Applying the Bayesian imputation method in Stanley et al. (2009), using the average recreational catch per unit effort from 1982 -1986 and the historical hypothesized fishing effort, catches were probabilistically imputed up to 1981. These data are similar to effort data in Puget Sound with increases in recreational fishing effort from 1970 to a peak in 1983 followed by declines with minor peaks in 1991-92 and 1997 (Williams et al. 2010).

OUTSIDE MANAGEMENT UNIT

West Coast Vancouver Island Creel Survey 2000 – 2010 and 1984 to 2001

For the outside fishery, the West Coast Vancouver Island (WCVI) Creel survey catch estimates were obtained for the years 2000 to 2010 from Brenda Wright, Salmon Stock Assessment, South Coast Division, DFO. Numbers of Quillback Rockfish kept and released and effort in boat trips are shown in Table D3. These fish numbers were converted to biomass using 0.94 kgs per fish from the Strait of Georgia Creel Sampling program (Table D4). To extend this time series back further, effort data was used from 1984 to 2001 from Table 2. in Lewis (2004) and shown in Table D5. These data show more interannual variability than the annual estimated obtained for 2000 to 2010. These values are normalized so that the mean value for 2000 for this series was the same as that for the 2000 to 2010 series to produce a time series from 1984 to 2010.

Survey of Recreational Fishing in Canada 1975 - 2005

The National Survey on Recreational fishing in Canada offered estimates of total fishing effort and total rockfish catch in inside waters, WCVI and all outside Canadian waters once every five years from 1975 to 2005. The proportion of Quillback Rockfish catch to rockfish catch estimated from the WCVI creel survey was used to convert rockfish catch in the National survey to species specific catches. The total catch for WCVI waters from the creel survey for 2000 to

2010 were scaled up by the mean ratio of the WCVI catch from the National Survey to the catch from the WCVI creel survey for years 2000 and 2005. This ratio was applied to bias correct the WCVI creel survey catch values from 2000 to 2010. This multiplier was about 8.1. The average body mass was presumed to be 0.94 kg from the Strait of Georgia creel sampling program. From the National survey the average percentage of the total outside management unit catch taken on the WCVI was about 51% (Table D6). The total outside management unit catch was thus computed from the adjusted creel survey catches for WCVI using this percentage.

The imputed recreational effort series for inside waters from 1918 to 1981 is used to impute the effort series for these years for outside waters.

Table D1. Estimated Quillback Rockfish (*Sebastes maliger*) recreational catch in pieces of fish from the inside management area Strait of Georgia Creel Survey by year and PFMA and for the total inside management unit (Total) for the years 1982 to 2010.

year	12	13	14	15	16	17	18	19	20	28	29	Total
1982	8871	12229	4721	2357	31398	3881	4285	5008	339	2311	2538	77939
1983	9328	22826	4702	2424	21444	4104	3895	3660	1469	2815	2798	79465
1984	7984	14181	3989	2774	9372	8032	3860	3392	1085	2376	2936	59982
1985	6748	8994	3422	1107	22414	4742	2308	3211	591	1590	2407	57534
1986	6857	10208	6266	1920	11976	5226	2834	3497	1150	932	1338	52203
1987	9768	15321	8156	1800	22234	6925	3260	4197	1506	1314	3868	78349
1988	9768	15321	8156	1800	22234	6925	3260	4197	1506	1314	3868	78349
1989	10008	11714	8789	2010	28181	7423	3789	6919	0	1310	3321	83464
1990	7555	11504	6318	1601	24750	3576	1351	3851	941	1382	2820	65649
1991	8454	10616	6484	1407	27690	4621	1256	2819	394	2417	8601	74758
1992	6722	9105	3845	817	25337	4061	1777	3175	498	1590	2480	59405
1993	5234	9859	2564	809	12179	3411	1027	3358	602	1214	3584	43843
1994	7787	17549	6863	1832	17050	4472	1017	3284	511	2673	4696	67735
1995	5651	12104	3514	1437	17085	3451	1075	2313	381	1176	3044	51231
1996	5146	14566	1463	1219	19185	1538	587	2970	387	1505	1880	50447
1997	4400	12424	1709	1466	12488	2281	937	1616	308	1556	1935	41119
1998	4239	18783	1013	1422	10340	2075	637	1942	552	504	451	41957
1999	3251	13564	683	371	10265	1237	244	1475	282	1103	363	32838
2000	5269	10077	1168	781	17022	2832	429	1583	943	1373	950	42427
2001	2017	8880	4266	921	7891	6130	1062	3160	556	104	461	35447
2002	201	3291	2067	1147	4526	4530	538	1708	1692	262	279	20240
2003	1538	1260	1135	654	3278	4125	783	900	505	87	100	14363
2004	1817	792	289	528	1722	3104	1034	1140	1030	43	82	11581
2005	2005	578	22	60	1693	1061	363	605	1183	17	41	7627
2006	3584	585	94	476	723	1128	974	1557	610	24	11	9766
2007	2504	1363	18	248	1876	1780	564	545	942	66	9	9914
2008	2070	226	77	476	3996	584	154	412	748	191	80	9013
2009	2849	1263	153	658	1962	2131	470	1112	2033	0	3	12634
2010	2289	196	159	135	3391	535	350	859	1662	0	0	9577

¹numbers of fish converted to weight using 0.94 kg (average weight of Quillback Rockfish in the creel survey 2000-2008)

Table D2. Total biomass in tonnes of Quillback Rockfish from the inside management unit recreational fishery. Numbers of fish from Table D1 are converted to biomass using a mean weight of 0.94 kgs.

Quillback rockfish
estimates
Recreational creel
survey - inside

Year	tonnes
1982	73.3
1983	74.7
1984	56.4
1985	54.1
1986	49.1
1987	73.6
1988	73.6
1989	78.5
1990	61.7
1991	70.3
1992	55.8
1993	41.2
1994	63.7
1995	48.2
1996	47.4
1997	38.7
1998	39.4
1999	30.9
2000	39.9
2001	33.3
2002	19.0
2003	13.5
2004	10.9
2005	7.2
2006	9.2
2007	9.3
2008	8.5
2009	11.9
2010	9.0

Table D3. West Coast Vancouver Island Creel Survey boat trips, kept and released catch (in numbers of fish) of Quillback Rockfish by PFMA and year.

Sum of Boat Trips PFMA		YEAR										
		2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
20		6497	5827	4460	6617	5208	6203	7795	7556	9040	8139	8742
21		982	511	140	1276	618	712	483	385	678	410	943
22				676	496							
23		33310	26540	44805	52665	51601	46143	39323	25403	25294	34632	31639
24		4152	2722	3144	3128	3422	1753	2090	1843	1714	1287	998
25		8815	12106	10661	11254	10621	10864	11883	14016	10155	7992	9244
26		581	423	856	1531	1874	535	1704	905	475	448	299
27			5964		2132		1740	1719	2260	3525	4457	3702
121		241	735	1991	1574	1555	3084	2552	3040	2108	1854	913
123		4856	6843	7785	8711	7904	10505	10984	9183	9628	8078	7168
124		1399	845	3542	917	3489	2016	1851	2084	3307	3578	3368
125			3604	203	206	85	812	1556	1707	3375	3148	1736
126		248	517	1068	232	653	624	1318	610	1449	1595	1590
127							403	3937	1958	3820	3091	3570
Grand Total		61080	66638	79333	90738	87028	85395	87195	70951	74568	78709	73913
Sum of Quillback Kept PFMA		YEAR										
		2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
20		54	53	2	3	6	7	10	26	100	70	53
21		0				1	4		34	12		
22												
23		556	217	238	428	381	546	355	379	392	592	239
24		167	28	79	39		23	86	145	358	10	
25		227	45	852	172	251	673	314	279	245	248	315
26				7		1			1			
27			2054		84		13	63	100	220	240	115
121		0	28		52	19	415	147	329	147	26	79
123			16	96	127	64	443	849	524	790	303	919
124			179	238	76	196	211	211	168	398	317	229
125			455			16	70	51	153	605	280	221
126					1		11					
127								153	99	146	263	335
Grand Total		1004	3074	1513	981	937	2417	2240	2235	3413	2349	2505
Sum of Quillback Released PFMA		YEAR										
		2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
20									5		11	4
21									12			
22												
23		185	84	403	470	101	116	143	58	141	8	26
24				27	35	17		63	27	28	10	
25		43	44	100	394	545	97	83	85		6	12
26							2					
27							4	3	18	26	154	65
121								4	3	25		4
123				2	13		12	23	15	34		66
124			4	104		74	206	7	9	86	29	23
125			114		2	71	29	1	20	59	8	32
126						1	4					
127										150	50	60
Grand Total		227	246	636	914	809	471	327	252	548	275	293

Table D4. Recreational catch of Quillback Rockfish by year, effort in number of boat trips, number of fish and biomass in tonnes from the West Coast Vancouver Island Creel Survey. Numbers of fish were converted to biomass using an average weight of 0.94 kg.

WCVI CREEL SURVEY		number	Biomass
year	boat trips	quillback	tonnes
2000	61080	1232	1.2
2001	66638	3320	3.1
2002	79333	2149	2.0
2003	90738	1895	1.8
2004	87028	1746	1.6
2005	85395	2887	2.7
2006	87195	2566	2.4
2007	70951	2487	2.3
2008	74568	3962	3.7
2009	78709	2624	2.5
2010	73913	2797	2.6

Table D5. Tidal effort estimates in number of boat days for the West coast Vancouver Island 1984 to 2001. From Table 2. in Lewis (2004).

year	effort boat days
1984	62311
1985	57966
1986	32555
1987	59958
1988	44822
1989	69241
1990	75804
1991	87779
1992	115078
1993	84591
1994	102845
1995	72676
1996	29297
1997	75068
1998	86632
1999	90798
2000	62710
2001	76240

Table D6. National Survey of recreational fishing in Canada, effort in boat days coastwide, by management unit (inside/outside) and West Coast Vancouver Island.

year	coastwide	inside	outside	WCVI
2000	385156	249809	135347	69392
2005	248152	148231	99921	50699

REFERENCES

- DFO. 2005. Survey of Recreational Fishing in Canada 2005, 2000, 1995, 1990, 1985, 1980, 1975. Economic Analysis and Statistics, Policy Sector, Fisheries and Oceans Canada, Ottawa.
- Hardie, D.C., Nagtegaal, D. A., and Nagy, L. 2001. Strait of Georgia and Northern Vancouver Island sport fishery creel survey statistics for salmon and groundfish, 1999. Can. Manuscr. Rep. Fish. Aquat. Sci. 2553: 111 p.
- Lewis, D.M. 2004. West Coast Vancouver Island sport fishery creel survey statistics 2001 and historical data 1984-2000. Can. Manuscr. Rep. Fish. Aquat. Sci. 2639: 66 p.
- Stanley, R. D., M. McAllister, P. Starr and N. Olsen, 2009. Stock assessment for bocaccio (*Sebastes paucispinis*) in British Columbia waters. DFO Can. Sci. Advis. Sec. Res. Doc. 2009/ 055: xiv + 200 p.
- Williams, G.D., Levin, P.S. and Palsson, W. A. 2010. Rockfish in Puget Sound: An ecological history of exploitation. Marine Policy (2010), doi:10.1016/j.marpol.2010.02.008
- Yamanaka, K.L., McAllister, M.M., Etienne, M.-P., Obradovich, S. and Haigh, R. 2012. Stock assessment for the inside population of yelloweye rockfish (*Sebastes ruberrimus*) in British Columbia, Canada for 2010. DFO Can. Sci. Advis. Sec. Res. Doc. 2011/129 xiv + 132p.

APPENDIX E. TREND DATA

Introduction	97
1. RESEARCH SURVEYS	99
1.1 INSIDE MANAGEMENT UNIT	99
1.1.1 HOOK AND LINE GEAR – JIG	99
1.1.1.1 Strait of Georgia Nearshore Reef-fish Jig Survey (PFMAs 15 and 16)	99
1.1.1.2 Johnstone Strait Nearshore Reef-fish Jig Survey (PFMAs 12 and 13)	99
1.1.1.3 Strait of Georgia Lingcod Jig Surveys	100
1.1.2 HOOK AND LINE GEAR – LONGLINE	101
Methods for computing abundance indices from reearch longline surveys taking interspecific competition for hooks and the return of empty hooks into account	101
A. Introduction	101
B. Relative abundance indices using information on empty hooks	102
C. Relative abundance indices with missing information on empty hooks	103
1.1.2.1 Inshore Rockfish Longline Survey	104
1.1.2.2 Strait of Georgia Dogfish Longline Survey	105
1.1.3 VISUAL SURVEYS	106
1.1.3.1 Pisces/Aquarius Submersible Surveys	106
1.1.3.2 Strait of Georgia Towed Camera Survey	107
1.1.4 SPOT PRAWN TRAP GEAR	108
1.1.4.1 Howe Sound Spot Prawn Survey	108
1.2 OUTSIDE MANAGEMENT UNIT	109
1.2.1 HOOK AND LINE GEAR – LONGLINE	109
1.2.1.1 IPHC Standardized Stock Assessment Survey	109
1.2.1.2 Research Industry Charter Survey	110
1.2.1.3 PHMA Longline Survey – northern	111
1.2.1.4 PHMA Longline Survey – southern	112
1.2.2 VISUAL SURVEYS	113
1.2.2.1 Juan Perez Sound Submersible Survey	113
1.2.3 GROUND FISH TRAWL GEAR	113
Methods for the estimation of biomass from Groundfish trawl surveys	113
1.2.3.1 Hecate Strait Multispecies Assemblage Survey	116
1.2.3.2 Hecate Strait Synoptic survey	116
1.2.3.3 Queen Charlotte Sound Synoptic Survey	116
1.2.3.4 West Coast Queen Charlotte Islands Synoptic Survey	116
1.2.3.5 West Coast Vancouver Island Synoptic Survey	116
1.2.4 SHRIMP TRAWL GEAR	116
1.2.4.1 West Coast Vancouver Island Shrimp Survey and Queen Charlotte Sound Shrimp Survey	116
2. COMMERCIAL CATCH AND EFFORT	117
2.1 COASTWIDE	117
2.1.1 ROCKFISH HOOK AND LINE (ZN) FISHERY	117
Methods of CPUE derived delta lognormal abundance index from ZN logbook data	118
Data	118
Model	119
Results	121
2.1.2 GROUND FISH TRAWL OBSERVER PROGRAM	124
2.1.3 PACIFIC SALMON TROLL FISHERY OBSERVER RECORDS	124
2.1.4 SPOT PRAWN TRAP FISHERY OBSERVER PROGRAM	124

INTRODUCTION

This appendix is an attempt to identify all available data sources for Quillback Rockfish and evaluate their utility as abundance indices for the stock assessment. Data include research survey and commercial catch data where Quillback Rockfish are recorded as catch. Where there are time series of comparable surveys, with sufficient data, abundance indices are constructed and used within the Bayesian surplus production model for the assessment of Quillback Rockfish. Methods used to develop indices are also described in the appropriate sections. For some of the visual surveys, single surveys are used to estimate a biomass for the management unit. Quillback Rockfish data sources (research surveys and catch records) are shown in Table E1 and discussed individually below.

Reasons for not using some research survey data in the stock assessment are largely due to their very low sampling rate for Quillback Rockfish and hence would not reliability track stock abundance. Similarly, for the commercial catch CPUE series for the trawl and trap fisheries were not used due to very low sampling rates. Furthermore, for the Spot Prawn trap fishery, the very small fish size and recent short time span would not be representative of the stock as a whole and perhaps more suited as a pre-recruit index. The hook and line CPUE series were relatively stable during the period of large catches which raised suspicions that these were not reliable as abundance indices. Reasons for the stability of the CPUE series include; fleet movements to maintain high catch rates, subtle influence of fishery management actions coupled with live market demands such as lowered trip limits to prolong the fishery to maintain a constant but limited supply of live fish to the market. Despite breaking the CPUE series into segments within which fishery management remained constant and accounting for gear type and depth in the analyses, the commercial hook and line CPUE data were not used in the stock assessment.

Table E1. Research surveys and catch records reviewed for use as stock trend data for Quillback Rockfish, by management unit (inside/outside), survey name, gear type, survey year span, number of surveys within the span, total number of samples (sets, tows, transects), number of sets that contained Quillback Rockfish, whether the data was used in the assessment and the most recent reference for the survey.

RESEARCH SURVEYS

location	name	gear type	span of years	number surveys	total sets	species sets	data used	latest reference
inside	Pisces/Aquarius Submersible Surveys	submersible	1984 - 2003	2	58	53	yes	Yamanaka et al. 2004
inside	Strait of Georgia Nearshore Reef-fish Jig Survey	jig	1984 - 1985	2	285	237	no	Richards and Cass 1985a
inside	Johnstone Strait Nearshore Reef-fish Jig Survey	jig	1986 - 2004	5	567	476	yes	Yamanaka and Lacko 2008
inside	Strait of Georgia Lingcod Jig Survey	jig	1985 - 2005	2 [^]	163	103	yes	Haggarty and King 2006
inside	Dogfish Longline Survey	longline	1986 - 2008	5	199	34	yes	King and McFarlane 2009
inside	Strait of Georgia Towed Camera Survey	towed camera	2003	1	40	16	yes	Martin and Yamanaka 2004
inside	Inshore Rockfish Longline Survey	longline	2003 - 2010	7	341	231	yes	Lochead and Yamanaka 2007
inside	Howe Sound Spot Prawn survey	prawn trap	1999 - 2010	12	856	156	no	Favaro et al. 2010
outside	Hecate Strait Multispecies Assemblage Survey	trawl	1984 - 2003	11	1046	125	yes	Choromanski et al. 2005
5outside	Hecate Strait Synoptic survey	trawl	2005 - 2009	3	493	106	yes	Olsen et al. 2009a
outside	IPHC Standardized Stock Assessment Survey	longline	1996 - 2010	15	1359	216	yes	Obradovich et al. 2007
outside	Research Industry Charter Survey	longline	1997 - 2003	4	256	95	yes	Yamanaka et al. 2004
outside	Juan Perez Sound Submersible Survey	submersible	2005	1	29	26	yes	Yamanaka et al. 2004
outside	PHMA Longline Survey - northern	longline	2006 - 2010	3	584	331	yes	Obradovich et al. 2008
outside	PHMA Longline Survey - southern	longline	2007 - 2009	2	382	157	yes	Obradovich et al. 2008
outside	Queen Charlotte Sound Synoptic Survey	trawl	2003 - 2009	5	1177	53	yes	Olsen et al. 2009b
outside	West Coast Vancouver Island Synoptic Survey	trawl	2004 - 2010	4	873	37	yes	Olsen et al. 2009c
outside	West Coast Haida Gwaii Synoptic Survey	trawl	2004 - 2010	3	504	0	no	Olsen et al. 2008
outside	West Coast Vancouver Island Shrimp Survey	shrimp trawl	1975 - 1994	34	3494	3	no	Boutillier et al. 1998a
outside	Queen Charlotte Sound Shrimp Survey	shrimp trawl	1998 - 2010	13	1009	0	no	Boutillier et al. 1998b

CATCH RECORDS

coastwide	Hook and Line Rockfish Logbooks	jig, longline	1986 - 2010				no	Haigh and Richards 1997
coastwide	Trawl At-Sea Observer Program	trawl	1995 - 2004				no	Kate Rutherford pers comm
coastwide	Prawn Trap Observer Program	prawn trap	2002 - 2009				no	Rutherford et al. 2010

[^] seven surveys conducted, only 2 used for PFMA's 18 and 19 due to changes in PFMA's fished

1. RESEARCH SURVEYS

Directed fisheries for Quillback Rockfish conduct their operations using hook and line gears; single or multiple artificial jigs or baited hooks and demersal longlines. These gears are efficient at catching Quillback Rockfish because they can be fished in hard bottom habitats. All surveys using longline gear were used in the assessment. Only some of the jig surveys were used in the assessment due to changes in fishing gear from artificial lures in 1984/5 to herring bait from 1986 to 2004, changes in the PFMA's fished and also to a lesser extent, the lack of electronic accessibility of some of the jig data in GFBio. For the visual surveys, there is one survey that conducted sampling in two years and this was used in the assessment. For other visual surveys where only a single survey carried out and these were not used. Although Quillback Rockfish do not typically occur over trawlable areas, some trawl surveys do catch these rockfish and in some areas these surveys do provide useable data for the assessment.

1.1. INSIDE MANAGEMENT UNIT

1.1.1. Hook And Line Gear – Jig

1.1.1.1 Strait of Georgia Nearshore Reef-fish Jig Survey (PFMA's 15 and 16)

An assessment program for nearshore reef-fishes was initiated in 1984. As part of this program hook and line jig fishing surveys were developed to monitor fish catch rate and population parameters in nearshore reef habitats. Several trips were conducted in 1984 during which various fishing methods were tested and developed (Richards et. al., 1985). Standardized methods were accepted by 1985 (Richards and Cass 1985a). Electronic data from these surveys is maintained in the DFO database GFBio at the Pacific Biological Station under the trip_ids : 44090 to 44094 (1984), and 44111 (1985)

As there is only 1 year in the series for this area, this data was not used in the stock assessment.

1.1.1.2 Johnstone Strait Nearshore Reef-fish Jig Survey (PFMA's 12 and 13)

As part of an assessment program for nearshore reef-fishes initiated in 1984, hook and line jig fishing surveys were developed to monitor fish catch rate and population parameters in nearshore reef habitats. Since 1986, ten research sites in Statistical Area 12 have been surveyed, in June of 1986, 1987, 1988, 1992 and 2004, with standardized jig fishing gear and methods. Within each site, three depth intervals (5 - 40m, 41-70 m and 71-100 m), if available, were fished. (Richards and Cass 1987, Richards and Hand 1987, Richards et al. 1988, Yamanaka and Richards 1993, Yamanaka and Lacko, 2008). This survey series is used in the assessment.

Electronic data from these surveys is maintained in the DFO database GFBio at the Pacific Biological Station under the trip_ids: 44114 to 44124, 55242 and 55243.

Data are retained only for sites fished in all years. The 2004 data are stored differently than in previous years – a 'parent' fishing event is recorded for each time the boat stopped to fish a particular site and depth stratum, as well as a separate record for each time a fisher puts a hook in the water; whereas in previous years only a single record was recorded for each stop. Data are summarized to the Parent Fishing Event id. The duration of each fishing event is recorded in minutes. Catch counts are recorded in the "Samples" table and weights for individual fish are recorded in the "Specimens" table. A number of records without recorded weights are excluded

from the weight based CPUE calculation. CPUE is calculated as grams per minute, by year and depth class and are shown in Table E2.

Table E2. Quillback Rockfish catch per unit of effort (grams per minute) in the Johnstone Strait nearshore reef-fish jig surveys by year and depth class, showing median, mean, standard deviation (std dev), coefficient of variation (Cv), number of sets conducted (#sets) and the number of zero catches (#zero catches). Total number of sets and total number of zero catches for the survey series are also shown.

Quillback CPUE, GRAMS per Minute (includes zero catches)

Year	Depth Class	median	mean	std dev	Cv	# sets	# zero catches
1986		101.553	191.095	212.337	111.116	44	8
1987		59.091	74.157	72.275	97.463	47	4
1988		75.324	126.616	198.725	156.951	28	3
1992		68.646	117.839	142.807	121.188	36	5
2004	[5,40]	27.680	41.027	45.344	110.521	40	11
1986		217.611	262.145	240.799	91.857	42	7
1987		80.275	103.769	94.974	91.525	42	10
1988		202.800	214.841	143.741	66.906	29	2
1992		91.818	115.248	77.197	66.984	33	1
2004	(40,70]	33.415	51.438	61.752	120.053	35	12
1986		146.250	257.198	309.675	120.403	25	8
1987		97.083	104.454	103.870	99.441	29	9
1988		189.167	190.312	115.827	60.861	15	1
1992	(70,100]	136.000	181.710	252.215	138.801	27	3
1986	[5,40]	101.553	191.095	212.337	111.116	44	8
						567	91

1.1.1.3 Strait of Georgia Lingcod Jig Surveys

As part of a research program for lingcod, three hook and line surveys were conducted in the southern portion of the Strait of Georgia (statistical areas 18 and 19) in June, August and October 1993 (Yamanaka and Murie. 1995), and again in June of 2005 (Haggarty and King, 2006). Using the research fishing methods developed in Richards *et al.* (1985) and Richards and Cass (1985a), two depth intervals (0-25m, 25-50m) and up to twenty sites were fished with trolling rods and frozen herring bait. Sites where at least two fishing sets were completed in each survey were included in the CPUE analysis. Catch Rate was reported in fish per hour. These data were used in the stock assessment and are shown in Table E3.

Electronic data from the 1993 surveys is maintained in the DFO database GFBio at the Pacific Biological Station under the trip_ids: 470000 to 470002, but not for the 2005 survey.

Table E3. Descriptive statistics for catch rate were extracted from Table 23 in Yamanaka et al. 2006.

Table 23 from Yamanaka et al. 2006. Quillback rockfish descriptive statistics for catch rate during the lingcod jig surveys (Yamanaka and Murie 1995, Haggarty and King 2005).

Quillback CPUE	Shallow (1-25 m)		Deep (25-50 m)	
	1993	2005	1993	2005
N	52	16	52	18
LO_95%_CI	2.4629	0	6.9844	0.1943
MEAN	4.335	0	9.645	1.1111
UP_95%_CI	6.2071	0	12.306	2.0279
SD	6.7245	0	9.5566	1.8436
C.V.	155.12	99.083	165.92	
Minimum	0	0	0	0
Median	2.795	0	6.16	0
Maximum	37.5	0	46.15	6

A third, potentially comparable survey was completed in 2003 in statistical areas 17, 18, and 19 (Haggarty and King, 2004). Data from this survey is not maintained in electronic format in GFBio, and was not included in this assessment.

Three similar Lingcod jig surveys were conducted in statistical Area 17 in 1985, 1987, 1988, and 2003 (Cass and Richards 1987, Hand and Richards 1987, Hand and Richards 1989). A fourth Lingcod jig survey conducted in 2004 (Haggarty and King, 2005) covered statistical areas 13 to 16. Data from these surveys was not included in this assessment due to their limited geographic range and lack of available electronic data.

Hook And Line Gear – Longline

Methods for computing abundance indices from reearch longline surveys taking interspecific competition for hooks and the return of empty hooks into account

A. Introduction

This note describes how the relative abundance indices have been defined and computed. There are two different situations, depending on whether or not the empty hooks, i.e. hook-by-hook data, have been recorded.

Empty hooks have been recorded for:

- Inshore Rockfish Longline Survey - Inside Management Area - North and South
- PHMA Longline Survey - Outside Management Area - North and South
- IPHC – Outside Management Area

Five relative abundances indices have been derived from those datasets using the methodology described in section B.

Regarding the Dogfish Longline Survey historic dataset (Inside) and the Research Charter dataset (Outside), the information on empty hooks is not available and has to be reconstructed. Furthermore, the gear used in the Dogfish survey changed in 2004 and the relative abundance indices have to account for this change. The methodology proposed to produce relative abundance indices for these datasets is developed in section C.

B. Relative abundance indices using information on empty hooks

For all data set available, the same methodology was used to obtain abundance indices. We used the model proposed by Etienne & al, [1] called Multinomial Exponential Model (MEM). This model takes empty hooks and competition into account to produce robust abundance indices. Let us define for one longline set

N_T the number of quillback caught,
 N_{NT} the number of other individuals caught,
 N_E the number of hooks with bitten or no remaining bait,
 N_B the number of baited hooks at the end of the soaktime,
 N the total number of observed hooks.

MEM assumes that the vector (N_B, N_T, N_{NT}, N_E) has a multinomial distribution, $M(N, a)$, with:

$$\begin{aligned} a &= (a_1, a_2, a_3, a_4) \\ \text{and} \\ a_1 &= e^{-\lambda S} \\ a_2 &= (1 - e^{-\lambda S}) \lambda_T / \lambda (1 - p_T) \\ a_3 &= (1 - e^{-\lambda S}) \lambda_{NT} / \lambda (1 - p_{NT}) \\ a_4 &= (1 - e^{-\lambda S}) (\lambda_T p_T + \lambda_{NT} p_{NT}) / \lambda. \end{aligned}$$

$\lambda = \lambda_T + \lambda_{NT}$, is the total relative abundance, λ_T is the relative abundance of quillback, λ_{NT} is the relative abundance of all competitors on the hooks, p_T is the probability for a quillback to escape from the hook, and p_{NT} is the same probability for an individual from another species.

This form of the model is not identifiable, we use the version called MEM1 in the paper which assumes $p_{NT} = p_T = p$. This assumption means that all species have the same capacity to escape. In this version, the expression of MEM1 is simpler.

(N_B, N_T, N_{NT}, N_E) has a multinomial distribution, $M(N, a)$, with:

$$\begin{aligned} a &= (a_1, a_2, a_3, a_4) \\ \text{and} \\ a_1 &= e^{-\lambda S}, \\ a_2 &= (1 - e^{-\lambda S}) \lambda_T / \lambda (1 - p) \\ a_3 &= (1 - e^{-\lambda S}) \lambda_{NT} / \lambda (1 - p) \\ a_4 &= (1 - e^{-\lambda S}) p \end{aligned}$$

Since the estimation of this MEM1 is lead within a Bayesian framework, prior distributions on the parameters have to be specified:

$$\lambda_{NT} \sim \text{Gamma}(0.01, 0.01), \lambda_T \sim \text{Gamma}(0.01, 0.01) \text{ and } p \sim \text{Beta}(0.5, 0.5).$$

The posterior distribution of λ_T is the posterior distribution of the relative abundance of quillback. The posterior mean is used as the relative index; posterior standard deviation and coefficient of variation are given as information on the precision on this relative index.

One index is defined per dataset and per year of survey. For one dataset, the probability of escape is assumed to be constant over year to produce more precise estimate of this probability. This assumption is reasonable since the survey procedure is the same over year, there is no reason to expect very different capacity of escape from one year to another.

C. Relative abundance indices with missing information on empty hooks

The procedure described in this section is not published at this moment but has already been used to produce relative indices for other species (yelloweye rockfish). This procedure aims at reconstructing the empty hooks missing in the dogfish dataset and dealing with the change of gear.

Reconstruction of the empty hooks

Since the number of empty hooks is unknown, it has to be reconstructed. Using the posterior distribution of a similar experiment, some very precise information on the probability of escape is available. For instance, the posterior distribution of p using the inside water dataset can be modeled by a beta distribution $\text{Beta}(27000, 76900)$. To allow more flexibility in our model, we relax the distribution, keeping the same mean but increasing the variance, and the chosen prior distribution on p is $\text{Beta}(2700, 7690)$. This choice of distribution is important since this parameter drives the reconstruction on empty hooks.

Considering the number of empty hooks as unknown in the MEM1 model, in the Bayesian framework, with a very precise distribution on the probability of escape p will produce some relative abundance indices which incorporate the uncertainty given by this lack of information on the empty hooks.

Change of gear

During the first year of the dogfish survey (1986 to 1989) the J hooks were used on the longlines. In 2004, it has been decided to change for C hooks. To account for this change of gear a double survey has been conducted in 2004, using on the same longline J hooks and C hooks. In 2005 and 2008, the C hooks have been deployed.

The idea of changing from J hooks to C hooks was that it is easier to steal the bait (and then produce an empty hook) from a J hook than a C hook. This suggests that the model would allow two different probabilities of escape p_J and p_C . This approach would have been preferred if we had information on empty hooks, without this information we have to use a probability of escape estimated from the C hooks on the other survey to reconstruct the information. Therefore it is not possible to define different probability of escape for each gear. An alternative is to assume that the relative abundance indices produced by an experiment using J hooks is proportional to the relative abundance indices produced with a C hooks experiment. Using year 2004, it should be possible to estimate this proportionality constant and then translate the abundance indices produced with J hooks in the same scale than the abundance indices computed from C hooks experiment. Since there is very few quillback caught in 2004, we assume that this proportionality constant is shared by all rockfish species.

To compute this coefficient of proportionality we use the following model:

$$\begin{aligned} (N_B^g, N_T^g, N_{NT}^g, N_E^g) &\text{ has a multinomial distribution, } M(N^g, a^g), \text{ with } a^g = (a_1^g, a_2^g, a_3^g, a_4^g), \\ &\text{ where the upperscript } g=C \text{ or } J \text{ depending on the gear used in the experiment} \\ &\text{ and} \\ a_1^g &= \exp(-\lambda^g S), \\ a_2^g &= (1 - \exp(-\lambda^g S)) \lambda_{NT}^g / \lambda^g (1-p) \\ a_3^g &= (1 - \exp(-\lambda^g S)) \lambda_T^g / \lambda^g (1-p) \\ a_4^g &= (1 - \exp(-\lambda^g S)) p, \end{aligned}$$

then the constraints of proportionality are added in the model using the following equalities:

$$\lambda^J_T = \alpha_T \lambda^C_T \text{ and } \lambda^J_{NT} = \alpha_{NT} \lambda^C_{NT}.$$

The parameters in the model are then λ^C_{NT} , λ^C_T , p , α_T and α_{NT} . Their prior distribution are set to

$$\alpha_T \sim \text{Gamma}(0.01, 0.01), \alpha_{NT} \sim \text{Gamma}(0.01, 0.01), \lambda^C_T \sim \text{Gamma}(0.01, 0.01), \\ \lambda^C_{NT} \sim \text{Gamma}(0.01, 0.01), p \sim \text{Beta}(2700, 7690).$$

p is assumed to be constant over years. All the rockfish caught in 2004 are used to estimate α_T , and all non rockfish catch are used to estimate α_{NT} . One λ^C_T and one λ^C_{NT} are estimated per year, using the correction factor for years using the C hooks.

1.1.2.1 Inshore Rockfish Longline Survey

Since 2003, an area and depth stratified random longline survey has been conducted in portions of the inside waters between Vancouver Island and the mainland, referred to as the Strait of Georgia Management region (statistical areas 12 to 20, 28 and 29), to provide catch rate indices and associated biological data for the assessment of inshore rockfish (Lochead and Yamanaka 2007). The northern portion of the survey grid was surveyed in 2003, 2004, 2007, and 2010, the southern half in 2005, the central third in 2008, and the southernmost third in 2009. The number of sets in each statistical area by year is shown in the Table E4.

Table E4. Strait of Georgia (SG) rockfish longline survey sets conducted by survey year and Pacific Fishery Management Area (PFMA). Total number of sets for all surveys = 471.

Year	PFMA											
	11	12	13	14	15	16	17	18	19	20	28	29
2003	1	55	23	1	5		2					
2004	1	47	17									
2005			1	9	20	14	11	9	6	13	7	6
2007	2	42	20									
2008		7	11	6	18	10	5					
2009							9	7	5	6	6	5
2010		35	29									

Electronic data from these surveys is maintained in the DFO database GFBio at the Pacific Biological Station under the trip_ids: 50080, 55980, 60506, 63746, 66007, 68487, 69948, and 61306.

Blocks judged unfishable and blocks that fell mainly within a Rockfish Conservation Area (RCA) have been removed from the survey grid over the years. A major adjustment made for 2010 was the removal of areas north and south of the boundaries of the Inside waters designatable unit of Yelloweye Rockfish. Only sets that remain in the 2010 grid and that are not more than 25% within an RCA are included for analysis (Table E5).

Table E5. Strait of Georgia rockfish longline survey sets remaining within the survey grid after the removal of sets within the Rockfish Conservation Areas (RCAs), by year and PFMA. Total number of sets for all surveys = 341.

Year	PFMAs									
	12	13	14	15	16	17	18	19	28	29
2003	35	19	1	1		1				
2004	27	13								
2005		1	6	17	9	7	6	3	7	4
2007	25	19								
2008	7	11	6	16	8	4				
2009						7	6	3	3	5
2010	35	29								

The data are formatted for input into the abundance index method that accounts for hook competition and unbaited hooks, as described in detail above (Etienne et al.¹).

Abundance index values derived for the Inshore Rockfish Longline Surveys are shown below in Table E6.

Table E6. Inshore Rockfish longline survey abundance indices derived using methods by Etienne et al.¹, by area and survey year.

	Area 12	Area 13	Area 14	Area 15	Area 16	Area 18	Area 28
2003	3.47	4.16					
2004	4.65	3.52					
2005	-1000	-1000	3.83	1.01	0.96	0.96	1.65
2006	-1000	-1000	-1000	-1000	-1000	-1000	-1000
2007	6.51	3.57	-1000	-1000	-1000	-1000	-1000
2008	1.67	2.4	0.69	1.33	0.47	-1000	-1000
2009	-1000	-1000				0.46	0.64
2010	3.61	2.96					

1.1.2.2 Strait of Georgia Dogfish Longline Survey

Five surveys have been conducted in the Strait of Georgia to measure Dogfish abundance. In four surveys, three depth strata were sampled at each of ten sites: 56-110m, 111-165 m and 166-220 m. In 1986 and 1989, J-hook gear were used, and in 2005 and 2008 circle hook gear were used. In 2004, a calibration survey was conducted to compare catch rates by depth strata between these two gear types. (Gallucci et. al, 2011, King and MacFarlane 2009).

Tables of electronic data with recorded counts by species and soak times per set. CPUE is calculated using a modeling method that accounts for hook competition and unbaited hooks. Data on empty hooks is reconstructed and the effects of hook type changes type are estimated as described in detail below above (Etienne et al.¹).

Abundance index values derived for the Dogfish Longline Surveys are shown below in Table E7 and Figure E1.

¹ Etienne, M.-P., Obradovich, S., Yamanaka, K.L., and McAllister, M.K. unpublished manuscript. Extracting abundance indices from longline surveys: method to account for hook competition and unbaited hooks.

Table E7. Relative abundance index for Quillback Rockfish derived from the dogfish longline survey using methods by Etienne et al.¹.

	Year	lambdaT	SDlambdaT	CVlambdaT	lambdaNT	SDlambdaNT
Dogfish	1986	5.46E-005	2.78E-005	5.09E-001	6.46E-003	2.22E-004
Dogfish	1989	8.40E-005	4.05E-005	4.82E-001	1.01E-002	3.46E-004
Dogfish	2004	1.05E-005	3.94E-006	3.76E-001	3.53E-003	9.21E-005
Dogfish	2005	2.50E-005	5.04E-006	2.01E-001	1.50E-002	3.64E-004
Dogfish	2008	2.62E-005	5.13E-006	1.96E-001	8.69E-003	1.60E-004

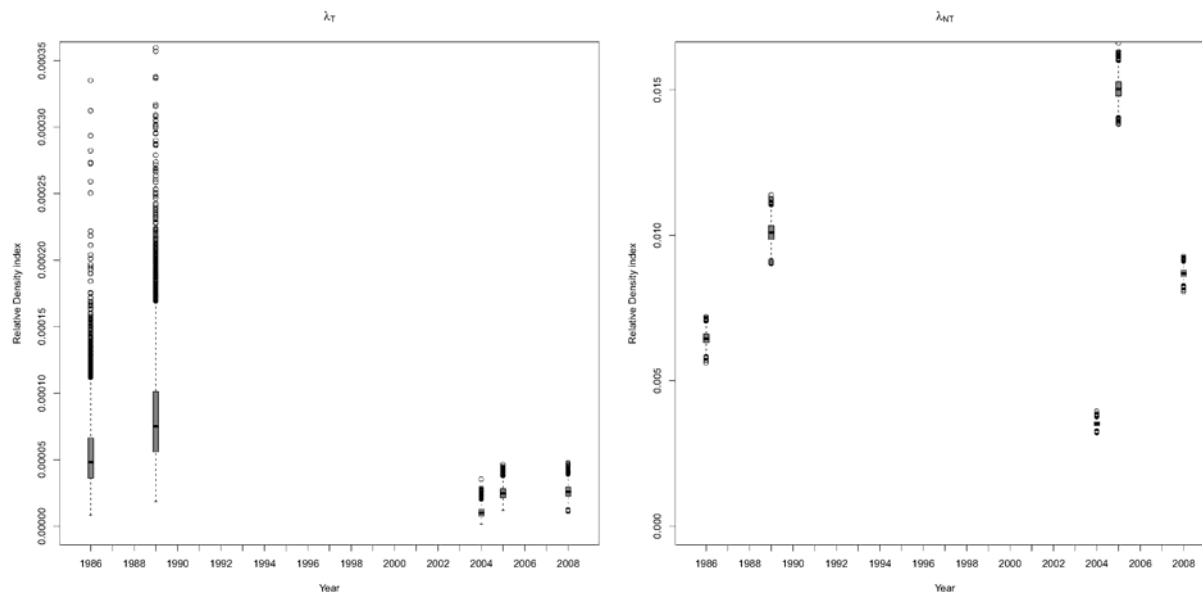


Figure E1. Relative abundance index for Quillback Rockfish derived from the Dogfish Longline Survey using methods by Etienne et al.¹.

Visual Surveys

1.1.3.1 Pisces/Aquarius Submersible Surveys

Two manned submersible surveys were conducted in 1984 and 2003 in the Southern Strait of Georgia and Desolation Sound to index the abundance of Inshore Rockfish. The 2003 survey attempted to repeat the dive transects conducted in 1984 (Richards and Cass 1985b, Yamanaka et al. 2004).

Descriptive statistics are taken from Table 21 in Yamanaka et al. (2006) (Table E8 and Figure E2).

¹ Etienne, M.-P., Obradovich, S., Yamanaka, K.L., and McAllister, M.K. unpublished manuscript. Extracting abundance indices from longline surveys: method to account for hook competition and unbaited hooks.

Table E8. Summary statistics for Quillback Rockfish visual counts per transect during the 1984 and 2004 submersible surveys (Yamanaka et al. 2004).

Counts per transect	Quillback	
	1984	2003
Mean	47.4	16.7
Standard Error	10.79	3.36
Median	38	11.5
Standard Deviation	49.44	15.01
Sample Variance	2443.95	225.19
Range	232	59
Minimum	9	0
Maximum	241	59
Confidence Level (95%)	22.5	7.02

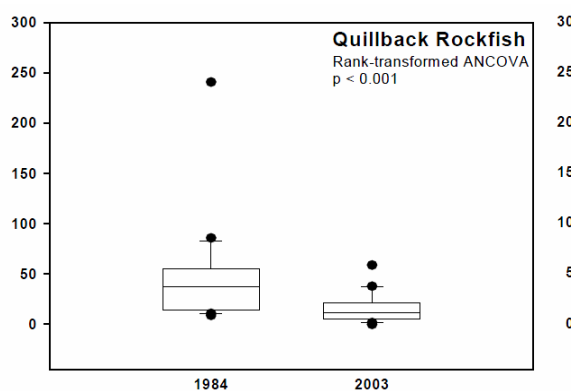


Figure E2. Visual counts (boxplots) of Quillback Rockfish per transect during submersible survey dives conducted in 1984 and 2003 in the Strait of Georgia (Yamanaka et al. 2004).

1.1.3.2 Strait of Georgia Towed Camera Survey

A video survey was conducted in 2003, in the Strait of Georgia statistical areas 17, 18 and 19. A depth-stratified random design was employed where the survey area was divided into two depth strata of 10-50 m and 51-100 m and overlain with a 1 km² grid (Martin and Yamanaka 2004). Twenty-two blocks were randomly selected from each depth strata. Transects within the block were targeted in areas of hard bottom and/or high slope. Quillback rockfish densities are estimated from visual fish counts using area swept methods. Descriptive statistics for densities over all habitat types were extracted from Table 17 in Yamanaka et al. (2006) (Table E9). These data were not used in the stock assessment.

Table E9. Quillback rockfish densities (number of fish per square kilometer) estimated from visual fish counts using a Remotely Operated Vehicle (ROV) in the Strait of Georgia in 2003.

Density # per km ²	Bedrock	Boulder	Cobble	Mixed Coarse	Sand	All Habitat Types
Mean	12,283	7,632	252	405	5,506	4,226
Std Error	6,239	2610	252	110	5,506	1,364
Median	0	0	0	146	0	0
Std Dev	24,163	14,059	758	594	18,264	8,521
Range	69,988	50,789	2275	2370	60,576	45,902
Minimum	0	0	0	3	0	0
Maximum	69,988	50,789	2,275	2,373	60,576	45,902
95% CI	13,381	5,348	582	226	12,270	2,762

SPOT PRAWN TRAP GEAR

1.1.4.1 Howe Sound Spot Prawn Survey

Catch of Quillback Rockfish was observed in a 10-year (1999–2008) fishery-independent research survey that employed traps that are similar to the traps used in the commercial Spot Prawn fishery. During each sampling period, 39–65 strings of 20 prawn traps were deployed throughout Howe Sound, near Vancouver (Favaro et al. 2010).

The Howe Sound Spot Prawn trap survey is not used in the assessment due to the very small average fish size (0.15 ± 0.09 kg) taken in this survey, coupled with the relatively short time series (Favaro et al. 2010). These small fish will not recruit to the fishery for another 6 to 10 years and the survey has only only 10 data points. This survey may prove to be a good indicator of incoming recruitment for Quillback Rockfish (Figure E3).

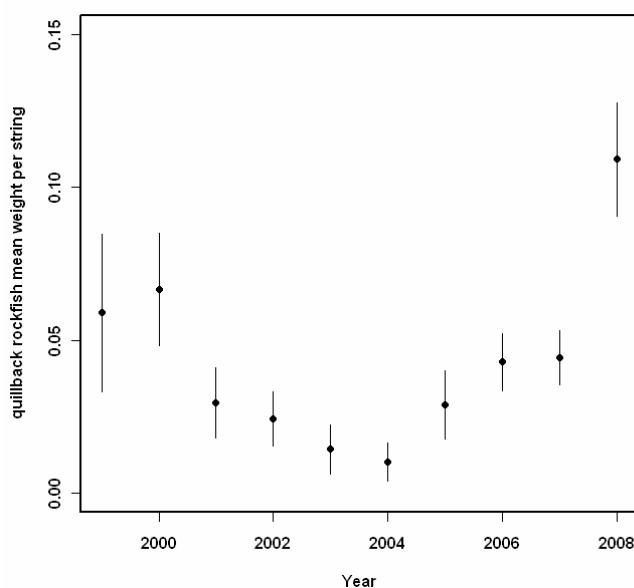


Figure E3. Catch of Quillback Rockfish (mean weight per string of traps) in Spot Prawn research survey traps deployed in Howe Sound, British Columbia, from 1999 to 2008. Data from Favaro et al. 2010, Favaro pers comm.

1.2. OUTSIDE MANAGEMENT UNIT

1.2.1 Hook And Line Gear – Longline

1.2.1.1 IPHC Standardized Stock Assessment Survey

Since 2003, a third observer has been deployed on the International Pacific Halibut Commission's (IPHC) Standardized Stock Assessment (SSA) survey in British Columbia. This survey samples fixed stations within the IPHC regulatory area 2B which corresponds to the Outside management unit. During the survey, an onboard technician identifies the catch to species on a hook-by-hook basis and collects biological samples from rockfish (Obradovich *et al.* 2008).

Electronic tabular data for the 1996 to 2002 surveys was received from the IPHC for the purposes of this assessment. Data from the surveys after 2002 is maintained in the DFO database GFBio at the Pacific Biological Station under the trip_ids: 52040, 52041, 56913, 56914, 56915, 60247, 60248, 60249, 62006, 62007, 62008, 64846, 64847, 67357, 67358, 69047, 69048, 70627, and 70628.

The data are formatted for input into the abundance index method that accounts for hook competition and unbaited hooks, using methods developed by Etienne *et al.*¹. The results are shown in Table E10 and Figure E4. These data make up the longest time series of relative abundance for the outside management area and are used in the stock assessment.

*Table E10. Relative abundance index for Quillback Rockfish derived from the IPHC SSA longline survey using methods by Etienne *et al.*¹.*

	Year	lambdaT	SDlambdaT	CVlambdaT	lambdaNT	SDlambdaNT	CVlambdaNT
IPHC	1996	1.63E-005	1.35E-006	8.31E-002	5.51E-003	3.37E-005	6.10E-003
IPHC	1997	1.01E-005	1.78E-006	1.76E-001	3.69E-003	3.89E-005	1.05E-002
IPHC	1998	6.94E-006	1.41E-006	2.03E-001	5.14E-003	4.61E-005	8.98E-003
IPHC	1999	7.87E-006	1.20E-006	1.52E-001	3.70E-003	2.84E-005	7.68E-003
IPHC	2000	9.61E-006	1.79E-006	1.86E-001	5.17E-003	5.04E-005	9.74E-003
IPHC	2001	1.39E-005	2.23E-006	1.60E-001	5.22E-003	5.32E-005	1.02E-002
IPHC	2002	1.24E-005	2.22E-006	1.79E-001	6.33E-003	6.98E-005	1.10E-002
IPHC	2003	6.30E-006	5.05E-007	8.01E-002	4.69E-003	1.64E-005	3.50E-003
IPHC	2004	5.63E-006	4.86E-007	8.64E-002	4.67E-003	1.64E-005	3.50E-003
IPHC	2005	1.52E-005	8.80E-007	5.78E-002	5.49E-003	2.17E-005	3.96E-003
IPHC	2006	1.24E-005	8.97E-007	7.23E-002	5.88E-003	2.58E-005	4.39E-003
IPHC	2007	8.75E-006	7.89E-007	9.02E-002	5.54E-003	2.64E-005	4.76E-003
IPHC	2008	4.24E-006	4.44E-007	1.05E-001	3.10E-003	1.36E-005	4.38E-003
IPHC	2009	8.33E-006	6.21E-007	7.46E-002	4.76E-003	1.78E-005	3.74E-003
IPHC	2010	9.54E-006	6.12E-007	6.41E-002	4.55E-003	1.59E-005	3.50E-003

¹ Etienne, M.-P., Obradovich, S., Yamanaka, K.L., and McAllister, M.K. unpublished manuscript. Extracting abundance indices from longline surveys: method to account for hook competition and unbaited hooks.

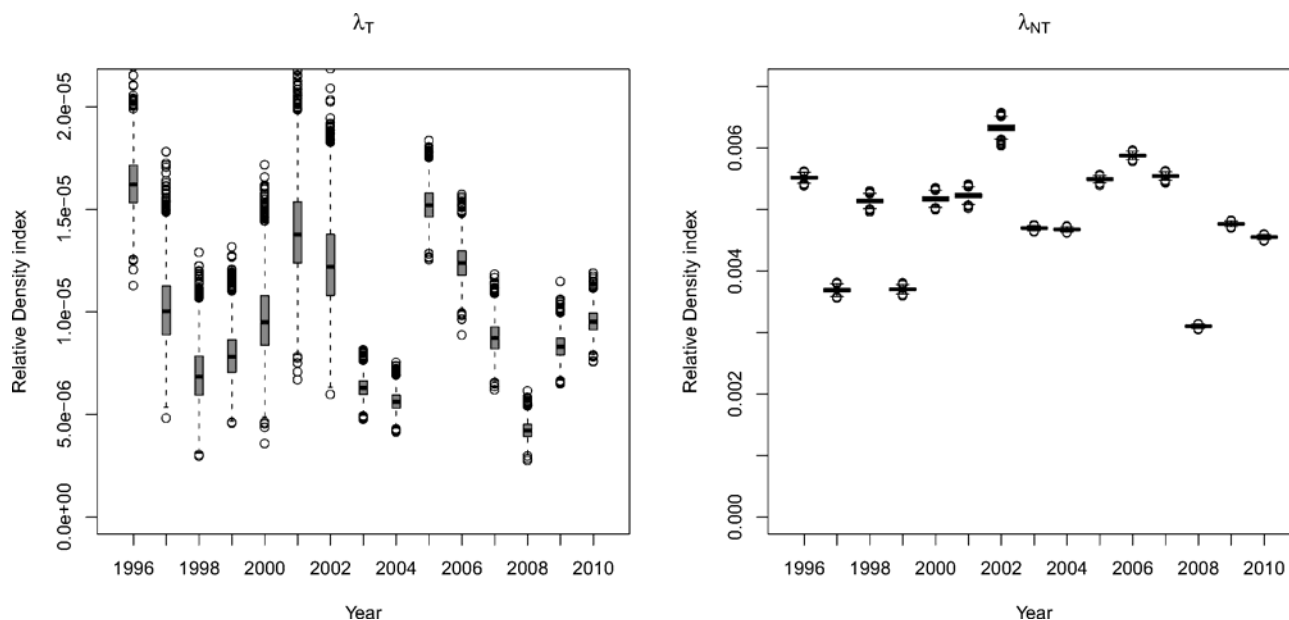


Figure E4. Relative abundance index for Quillback Rockfish derived from the IPHC SSA survey using methods by Etienne et al.¹.

1.2.1.2 Research Industry Charter Survey

Four surveys were undertaken jointly with the rockfish hook and line (ZN licensed) industry in September 1997, May 1998, and five years later in September 2002 and May 2003, to assess rockfish status in a northern and southern area of the coast and at specific sites that fishers identified as heavily and lightly fished; Tasu and Skuung Gwaii on the west side of Haida Gwaii and Triangle and Top Knot on the upper west coast of Vancouver Island. (Kronlund and Yamanaka 2001, Yamanaka et al 2004). Data from these surveys are used in a relative abundance index for Quillback Rockfish and included in the stock assessment.

Electronic data from these surveys are maintained in the DFO database GFBio at the Pacific Biological Station under the trip_ids 25748, 25749, 25750, 25751, 25898, 25899, 25900, 45556, 45557, 48420, and 48421.

The data are formatted for input into the abundance index method that accounts for hook competition and unbaited hooks (Etienne et al.¹) (Table E11 and Figure E5).

Table E11. Relative abundance index for Quillback Rockfish derived from the research industry charter longline survey using methods by Etienne et al.¹.

	Year	lambdaT	SDlambdaT	CVlambdaT	lambdaNT	SDlambdaNT	CVlambdaNT
Charters	1997	1.53E-004	9.44E-006	6.16E-002	4.97E-003	1.08E-004	2.17E-002
Charters	1998	1.63E-004	8.53E-006	5.23E-002	4.32E-003	8.83E-005	2.05E-002
Charters	2002	3.98E-005	4.60E-006	1.16E-001	4.37E-003	9.46E-005	2.17E-002
Charters	2003	1.14E-004	8.16E-006	7.14E-002	6.14E-003	1.32E-004	2.14E-002

¹ Etienne, M.-P., Obradovich, S., Yamanaka, K.L., and McAllister, M.K. unpublished manuscript. Extracting abundance indices from longline surveys: method to account for hook competition and unbaited hooks.

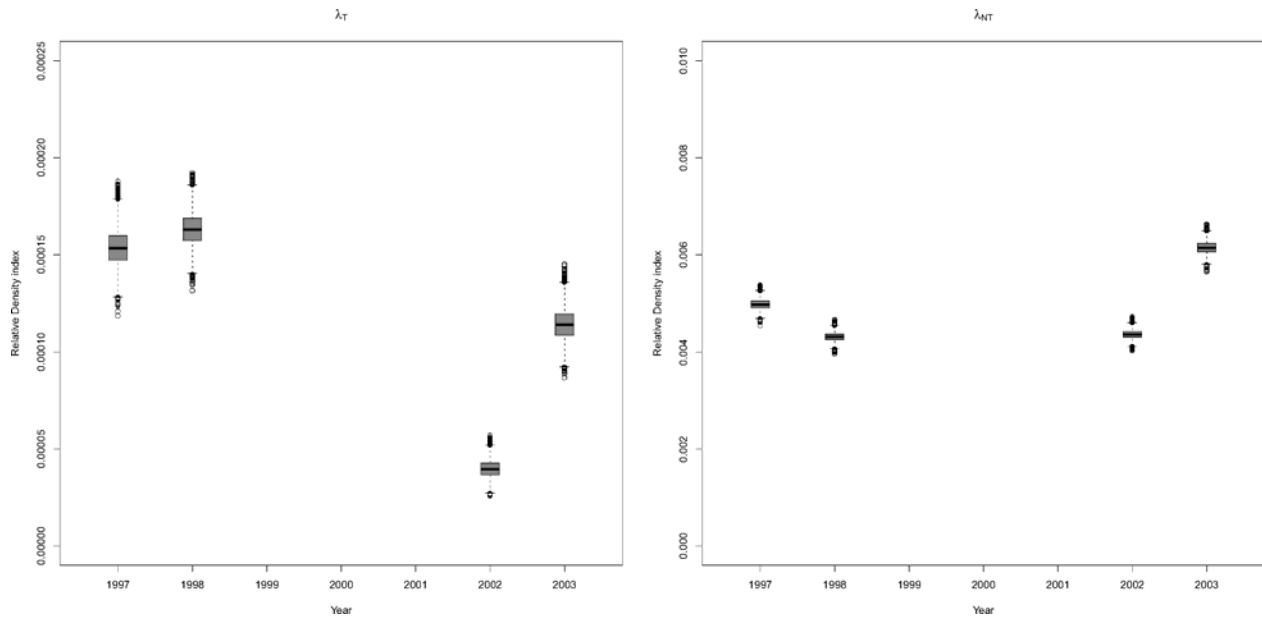


Figure E5. Relative abundance index for Quillback Rockfish derived from the research industry charter longline survey using methods by Etienne et al.¹.

1.2.1.3 PHMA Longline Survey – northern

Together with industry, Pacific Halibut Management Association (PHMA), the Department of Fisheries and Oceans (DFO) initiated a depth stratified, random design research longline survey in August 2006. These research charters obtained catch rates of all species and biological samples of rockfish, using standardized longline gear. Although a relatively recent survey, the abundance indices from these surveys have been included in the stock assessment.

The survey alternates annually between northern and southern portions of coastal British Columbia. The current survey design has a “target” of 200 research sets distributed across three depth strata (20 to 70m, 71 to 150m, and 151 to 260m). Three surveys have been conducted in the northern area, which comprises statistical areas 5C, 5D, 5E and that portion of 5B off the shores of Haida Gwaii, in 2006, 2008, 2010 (Yamanaka, unpublished data). These data are used in the stock assessment.

Electronic data from these surveys is maintained in the DFO database GFBio at the Pacific Biological Station under the trip_ids: 62746, 62747, 62748, 66587, 66588, 66589, 70647, 70648, 70649

The data are formatted for input into the abundance index method that accounts for hook competition and unbaited hooks Etienne et al.¹ A total of 4 sets fell within RCAs and were excluded from the analysis. Data for the northern surveys are shown in Table E12 and Figure E6.

¹ Etienne, M.-P., Obradovich, S., Yamanaka, K.L., and McAllister, M.K. unpublished manuscript. Extracting abundance indices from longline surveys: method to account for hook competition and unbaited hooks.

Table E12. Relative abundance index for Quillback Rockfish derived from the Northern portion of the PHMA longline survey using methods by Etienne et al.¹.

	Year	lambdaT	SDlambdaT	CVlambdaT	lambdaNT	SDlambdaNT	CVlambdaNT
PHMA_North	2006	2.70E-004	5.95E-006	2.20E-002	7.12E-003	3.12E-005	4.38E-003
PHMA_North	2008	3.18E-004	6.53E-006	2.06E-002	5.96E-003	2.90E-005	4.87E-003
PHMA_North	2010	3.38E-004	6.69E-006	1.98E-002	5.53E-003	2.83E-005	5.11E-003
				pe	4.97E-001	1.35E-003	2.71E-003

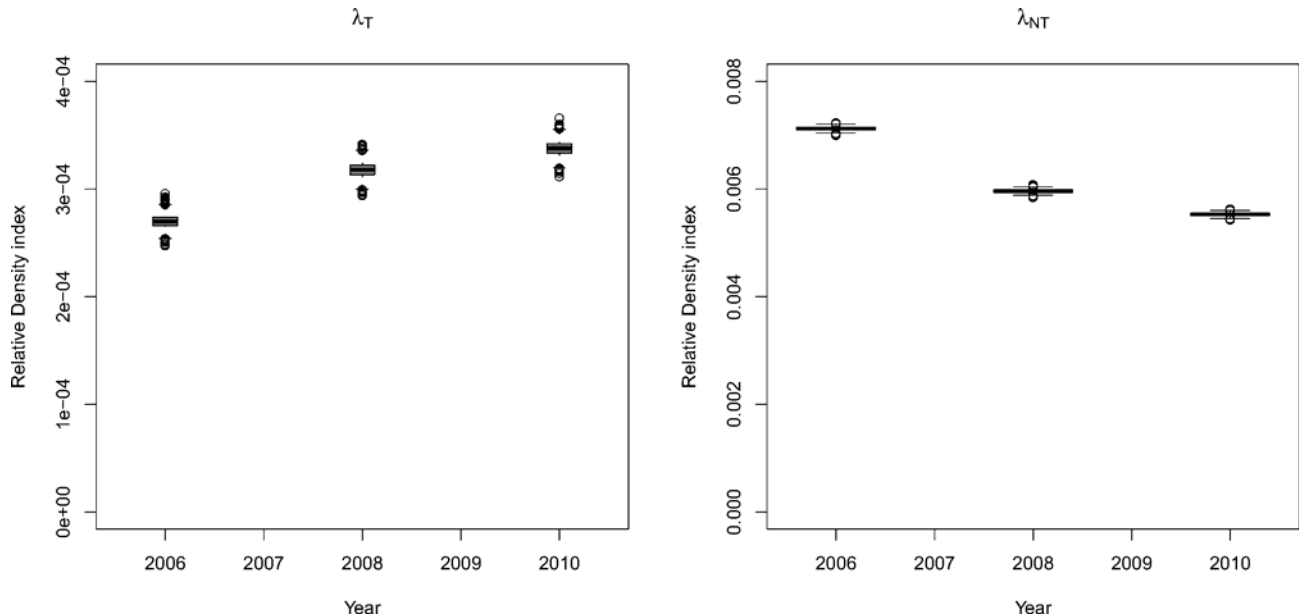


Figure E6. Relative abundance index for Quillback Rockfish derived from the Northern portion of the PHMA survey using methods by Etienne et al.¹

1.2.1.4 PHMA Longline Survey – southern

Two of the PHMA surveys (see PHMA Longline Survey – northern, above) have been completed in the southern area, which comprises statistical areas 3C, 3D, 5A and a portion of 5B, in 2007 and 2009 (Yamanaka, unpublished data).

Electronic data from these surveys is maintained in the DFO database GFBio at the Pacific Biological Station under the trip_ids: 64926, 64927, 64928, 69287, 69288, 69289

The data are formatted for input into the abundance index method that accounts for hook competition and unbaited hooks (Etienne et al.¹).

The results are shown in Table E13 and Figure E7.

Table E13. Relative abundance index for Quillback Rockfish derived from the Southern portion of the PHMA survey using methods by Etienne et al.¹.

	Year	lambdaT	SDlambdaT	CVlambdaT	lambdaNT	SDlambdaNT	CVlambdaNT
PHMA_South	2007	2.29E-004	5.66E-006	2.47E-002	7.18E-003	3.34E-005	4.65E-003
PHMA_South	2009	1.33E-004	4.30E-006	3.23E-002	5.42E-003	2.80E-005	5.17E-003
				pe	4.93E-001	1.66E-003	3.36E-003

¹ Etienne, M.-P., Obradovich, S., Yamanaka, K.L., and McAllister, M.K. unpublished manuscript. Extracting abundance indices from longline surveys: method to account for hook competition and unbaited hooks.

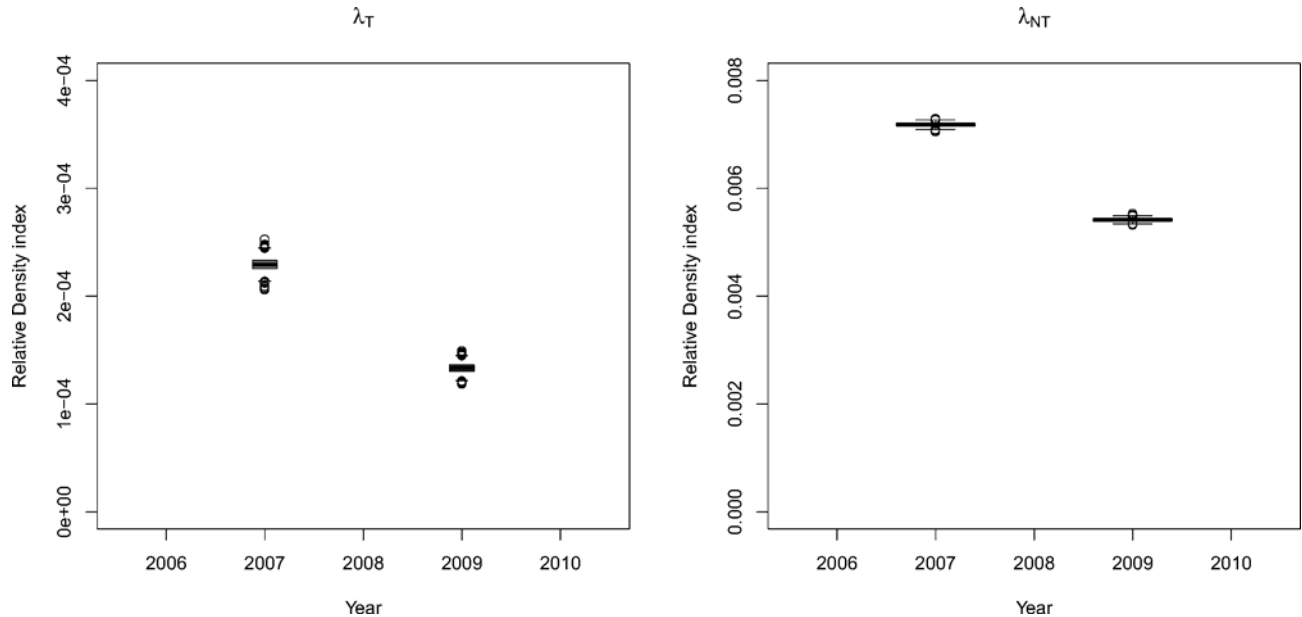


Figure E7. Relative abundance index for Quillback Rockfish derived from the Southern portion of the PHMA survey using methods by Etienne et al.¹.

Visual Surveys

1.2.2.1 Juan Perez Sound Submersible Survey

A submersible survey was conducted in Juan Perez Sound on the East side of the Queen Charlotte Islands in May 2005. Dive transects were conducted within a habitat stratified randomly selected survey grid. Probability density functions (PDF) are constructed from fish observations and used in conjunction with estimates of line length to estimate the density of Quillback Rockfish populations by habitat type for the survey area (Yamanaka et al. 2006). These data were not used in the stock assessment.

Groundfish TRAWL GEAR

Biomass estimates derived from the groundfish trawl surveys are summarized by survey and year in Table E14.

Methods for the estimation of biomass from Groundfish trawl surveys

Quillback Rockfish are incidentally caught by trawl gear in the shallower depth strata of the groundfish research surveys. The Queen Charlotte Sound, West Coast Vancouver Island and West Coast Haida Gwaii Synoptic Surveys are not used in the assessment due to the very low and intermittent sampling rate. These surveys are primarily conducted in water deeper than Quillback Rockfish depths over soft substrates. In contrast to these, the Hecate Strait Surveys are in shallower water and cover a wider range of substrates, including gravel. The Hecate Strait Surveys are included in the assessment.

¹ Etienne, M.-P., Obradovich, S., Yamanaka, K.L., and McAllister, M.K. unpublished manuscript. Extracting abundance indices from longline surveys: method to account for hook competition and unbaited hooks.

All data were retrieved from GFBio and the following algorithm used to estimate biomass from tow data (N. Olsen pers comm). The bocaccio biomass in any year y was obtained by summing the product of the CPUE and the area surveyed across the surveyed strata i :

$$B_y = \sum_{i=1}^k C_{y_i} A_i = \sum_{i=1}^k B_{y_i} \quad \text{Eq. 1}$$

where C_{y_i} = mean CPUE density (kg/km²) of Quillback Rockfish in stratum i
 A_i = area of stratum i (km²), and
 B_{y_i} = biomass of bocaccio in stratum i for year y .
 k = number of strata

CPUE (C_{y_i}) for bocaccio in stratum i for year y was calculated as a density in kg/km² by

$$C_{y_i} = \frac{\sum_{j=1}^{n_{y_i}} \left(\frac{W_{y_i j}}{D_{y_i j} w_{y_i j}} \right)}{n_{y_i}} \quad \text{Eq. 2}$$

where $W_{y_i j}$ = catch weight (kg) for bocaccio in stratum i for year y and tow j
 $D_{y_i j}$ = distance travelled (km) by tow j in stratum i for year y
 $w_{y_i j}$ = net opening (doorspread; km) by tow j in stratum i for year y
 n_{y_i} = number of tows in stratum i

One thousand bootstrap replicates with replacement were made on the survey data to estimate bias corrected 95% confidence regions and relative error for each survey year (Efron 1982).

Table E14. Biomass estimates in kilograms (median bootstrap estimate, lower and upper 95% CI) (kg) for Quillback Rockfish by trawl survey and year. The total catch of Quillback Rockfish in kilograms, the number of sets in the survey and the number of sets with Quillback Rockfish are also shown by survey and year. Table from N. Olsen, DFO pers comm.

Trawl Survey	Year	Total Catch of Quillback RF (kg)	Number of Sets in Survey	Number of Sets With Quillback RF	Quillback RF Biomass Estimate (kg)	Median Bootstrap Estimate (kg)	Lower 95% CI	Upper 95% CI
Queen Charlotte Sound Synoptic	2003	61.8	233	5	85,502	81,671	12,886	265,498
Queen Charlotte Sound Synoptic	2004	221.2	230	13	230,539	212,597	64,348	814,722
Queen Charlotte Sound Synoptic	2005	107.3	224	12	159,531	155,685	36,588	416,566
Queen Charlotte Sound Synoptic	2007	193.1	257	13	165,857	161,066	42,325	557,443
Queen Charlotte Sound Synoptic	2009	43.0	233	10	57,153	54,087	24,237	127,187
Hecate Strait Multispecies Assemblage	1984	26.0	82	9	44,820	44,377	12,025	121,194
Hecate Strait Multispecies Assemblage	1987	115.0	90	11	208,091	197,299	62,959	573,919
Hecate Strait Multispecies Assemblage	1989	149.0	95	12	276,592	259,379	71,371	807,440
Hecate Strait Multispecies Assemblage	1991	147.0	99	14	103,668	97,578	31,915	293,944
Hecate Strait Multispecies Assemblage	1993	143.0	94	10	192,021	175,735	49,179	722,401
Hecate Strait Multispecies Assemblage	1995	69.0	102	13	62,239	58,523	28,387	137,831
Hecate Strait Multispecies Assemblage	1996	113.0	105	11	65,102	63,710	30,676	132,466
Hecate Strait Multispecies Assemblage	1998	77.0	86	9	74,873	71,746	26,013	174,359
Hecate Strait Multispecies Assemblage	2000	114.0	106	11	134,262	121,157	41,512	482,274
Hecate Strait Multispecies Assemblage	2002	34.0	91	8	13,602	13,091	5,038	30,685
Hecate Strait Multispecies Assemblage	2003	100.0	96	17	146,411	137,770	54,760	371,123
Hecate Strait Synoptic	2005	374.3	203	45	206,152	205,375	121,871	328,200
Hecate Strait Synoptic	2007	359.5	134	33	410,682	384,208	198,936	1,018,297
Hecate Strait Synoptic	2009	160.9	156	28	183,434	177,960	83,187	450,752
West Coast Vancouver Island Synoptic	2004	48.6	90	8	79,141	76,070	29,039	197,678
West Coast Vancouver Island Synoptic	2006	44.7	166	8	43,459	39,821	17,220	127,346
West Coast Vancouver Island Synoptic	2008	59.2	163	8	62,420	58,987	24,665	151,577
West Coast Vancouver Island Synoptic	2010	44.7	138	10	22,696	22,163	8,770	58,899
West Coast Vancouver Island Shrimp	1977	0.25	140	1	77	77	0	231
West Coast Vancouver Island Shrimp	1992	5	81	1	2,459	2,459	0	7,376
West Coast Vancouver Island Shrimp	1994	3	95	1	1,509	1,509	0	4,526

1.2.3.1 Hecate Strait Multispecies Assemblage Survey

The Hecate Strait multispecies groundfish bottom trawl survey, initiated in April 1984 and conducted usually every 2 years, provides the longest running time series of fisheries independent groundfish surveys on the west coast. Surveys have been conducted in 1984, 1986, 1987, 1989, 1991, 1993, 1995, 1996, 1998, 2000, and 2002. Although secondary objectives varied with the survey years, the primary, long term objective of the Hecate Strait survey was to conduct ecosystem - based research for multispecies stock assessment and management of groundfish in the Hecate Strait region (Choromanski et al. 2005). The Hecate Strait survey area is shallower and includes harder gravel bottom types than the other trawl surveys. This trawl survey, unlike the others, does catch Quillback Rockfish frequently therefore this index is included in the stock assessment.

The method for estimation of biomass from this survey are described above and shown in Table E14.

1.2.3.2 Hecate Strait Synoptic survey

A depth stratified random design bottom trawl survey of Hecate Strait was conducted in 2005, 2007, and 2009. These surveys are part of a long-term survey series, coordinated with other area-specific surveys, described below, that together cover the continental shelf and upper slope of most of the British Columbia coast. The objective of these surveys is to provide fishery independent abundance indices of all demersal fish species available to bottom trawling, as well as to collect biological samples of selected species (Olsen et al. 2009a). The abundance index from this survey, for the same reasons as the Hecate Strait Multispecies Assemblage survey, is included in the stock assessment.

The method for estimation of biomass from this survey are described above and shown in Table E14.

1.2.3.3 Queen Charlotte Sound Synoptic Survey

Five surveys were conducted in Queen Charlotte Sound in 2003, 2004, 2005, 2007 and 2009 as part of the survey series covering the British Columbia coast described above. These surveys are used in the assessment for the outside management unit. (Olsen et al. 2009b)

1.2.3.4 West Coast Haida Gwaii Synoptic Survey

Three surveys were conducted in 2006, 2007, 2008 as part of the survey series covering the British Columbia coast described above. These surveys are not used in the assessment as no Quillback were observed in the catches. (Olsen et al. 2009b)

1.2.3.5 West Coast Vancouver Island Synoptic Survey

Three surveys were conducted on the West Coast of Vancouver Island in 2004, 2008, 2010. These surveys are used in the assessment for the outside management unit. (Olsen et al. 2009c)

Shrimp Trawl Gear

1.2.4.1 West Coast Vancouver Island Shrimp Survey and Queen Charlotte Sound Shrimp Survey

Since 1973, there have been a series of systematic area swept trawl surveys conducted on the West Coast of Vancouver Island in PFMA's 124 and 125. Surveys were generally completed in the spring for each area, on a more or less annual basis.. In addition to the annual spring surveys, in 1977 and 1978 post-fishery fall (September) surveys were also completed. Following large catches in 1995, the survey was expanded into Areas 121 and 123 in 1996. (Boutillier et al. 1998a)

An area-swept shrimp trawl survey was undertaken in Queen Charlotte Sound in July 1998. Five volunteer commercial shrimp vessels were used to complete the survey, which covered portions of Pacific Fisheries Management Areas 7,9, 10, 107, 108, 109, and 110 (Boutillier et al. 1998b).

Electronic data from these surveys is maintained in the DFO database GFBio at the Pacific Biological Station.

Data from these surveys is not used in the assessment as Quillback Rockfish have been observed only 3 times on the WCVI survey and not at all on the QCS survey.

2. COMMERCIAL CATCH AND EFFORT

2.1 COASTWIDE

2.1.1 Rockfish Hook And Line (Zn) Fishery

Hook and line rockfish logbooks from the ZN licensed fishery are available from 1986 to 2010. The abundance index for Quillback Rockfish was derived using methods described in Yamanaka et al. (2011) Appendix E and redescribed in “Methods of CPUE derived Delta Lognormal abundance index from ZN logbook data” below.

The data from 1986 to 2005 was extracted through the MS Access front-end to the DFO database of logbook records, called PACHarvHL, in a 3 step process.

1. Make a table of all relevant Fishing Events.

The criteria for selecting events from the table “B3_Fishing_Events” are that the Log type = “Fisherlog”, as opposed to Observer logs; the Fishery ID = 5 = ZN; the Target Species is NOT “044” (Dogfish) or “614” (Halibut) or “042” (Dogfish sharks) or “106” (Salmonids); the Fishing Year < 2006; and the Duration (in minutes) is not 0. A number of other Target Species are recorded, for example Rougheye rockfish, Thornyheads, or Sablefish, that may indicate fishing events not likely to capture Quillback – these have been retained in the initial data preparation on the assumption that selection by depth will account for them. A second fishery type of K/ZN, which is a combination of Sablefish and Hook and Line, was not included, on the assumption that this fishing would happen consistently below depths where Quillback Rockfish occur.

Trip types are also recorded in this database. Non-quota trips, Permit trips (i.e. trips to Seamounts), Research Charters, and FOS Experimental trips are excluded.

The gear types represented by this data are Handline, which includes ‘Other HL Gear, Rod and Reel, and Troll, and Longline. Unknown gear types are later separated into Handline if maximum depth is less than 50 meters or ‘null’ and Longline if depth is greater than 50 meters.

2. Make a table of all Quillback catches (counts).

The criteria for selecting records from the table “B4_Catches” are that again the Log type = “Fisherlog”; and the Species Code = “424” (Quillback Rockfish). The records are grouped by Hail in Number and Set Number, and Weights and Counts are summed. Counts for those records with only a weight recorded are updated based on an average weight per piece of 0.88 kg, which is calculated based on records with both nonzero weights and counts.

3. Join these tables on Hail in Number and Set Number.

Some corrections to derived data in the database were also made. About 2000 records had reasonable spatial coordinates, but no Statistical Area code; these were updated with a spatial join. Fishing depth is not updated for all possible records, nor is it correct in all cases. This value is re-calculated to equal $(\text{max} + \text{min}) / 2$ where both values exist, or either max or min where only one value is recorded.

The data from 2006 to 2010 was extracted through the MS Access front-end to the Fisheries Operations System (FOS) database called GFFOS. The table "GF_D_OFFICIAL_FE_CATCH" contains derived data that provides the best landed catch estimate by fishing episode is used in the following queries.

Two tables were created, one for Gear type Hook and Line, and one for Gear type Longline. The criteria for selecting records are that the Year is from 2006 to 2010 (2006 data may not be complete, the 1st record occurs in June); Duration in minutes is between 15 and 2000, the Data source code = 105 (Fishing Log); the Fishery Sector is Rockfish Inside or Rockfish Outside; Depths are not null (the minimum and maximum depth is selected accordingly from Start and End depth (converted from Fathoms to Meters ($*1.8288$))); and the Target species is not "044", '614', or "051" (Dogfish, Halibut, Skates).

Quillback Rockfish catch counts are recorded in the Official Catch table across a number of fields, in categories such as sublegal, legal, liced, released, retained. Counts are summed for each event.

Hook counts are taken from the GF_FE_LONGLINE_GEAR_SPECS table, and are calculated for Longline sets by 'Number of Gear Set' minus 'Number of Gear Lost' multiplied by 'Hooks per Skate'. The criteria for a Longline Hook count record to be considered valid was determined to be 'Number of Gear Set' less than 26 and 'Hooks per Skate' greater than 59. (A number of records are 'lost' due to obvious errors in data entry, for example the Fisher records 200 hooks per skate for most sets, but 20 for some.)

Hook counts for Hook and Line records seem for the most part unusable and have not been calculated; but, the original data are included in the table.

During processing for the GLM analyses, the data from these two databases are combined and then separated into Inside (PFMAs 12 to 19, 28 and 29) and Outside (remainder of the coast).

Methods of CPUE derived delta lognormal abundance index from ZN logbook data

Data

The commercial catch data for Quillback Rockfish were derived from logbook records from the directed hook and line rockfish fishery (ZN licences) in British Columbia inside (Strait of Georgia) and outside (remainder of the coast) management regions. The hook and line fishery includes both longline gear and gear classified as handline, including rod and reel, troll and other handline gear. As the logbook program for the hook and line rockfish (Sebastes) fishery began in 1986 (see Kronlund and Yamanaka 1997 and Yamanaka and Kronlund 1997 for further details), data are available from 1986 to 2010. Due to management changes during this time period the data are split into five time series. For the inside 1986-1990, 1992-1994, 1995-2001, 2003-2005, 2006-2010 and 2002 is not included in the time series due to a large reduction in effort by the fleet that year in protest of the total allowable catch reductions. For the outside 1986-1990, 1993-

1994, 1995-2005, 2006-2010, 1991, 1992 and 2002 were not included in the series due to management changes in adjacent years which resulted in a single year for the index.

Catch data for Quillback Rockfish are recorded as piece counts and/or weights and are available by year, area (PFMA), gear type, and set. Where only weights were provided the count was imputed using a weight to count conversion based on all catch records available. Counts were summed for all utilization codes (retained or discarded). Data for sets where non-reef species (e.g. dogfish (*Squalus acanthius*), Pacific halibut (*Hippoglossus stenolepis*) were targeted and/or duration was zero were excluded. Sets with unknown gear type were assigned to a gear category based on their maximum depth, where those with a maximum depth greater than 50 m were longline and all others were handline. Data from areas where no yelloweye were caught during the time series were discarded from all models.

Model

Catch per unit effort (CPUE) is a commonly used metric for abundance. It is calculated as:

$$(E1) \quad CPUE_i = \frac{C_i}{E_i}$$

where C is the count of yelloweye and E is the duration (in hours) the gear was deployed during set i. In earlier years all catch is recorded as one entry per day and should be considered as a daily measure, thus differing from later time periods.

Often CPUE time series are standardized using generalized linear models (GLM) where the year effects are assumed to closely follow the abundance trends. Here, I follow the methodology of Babcock and McAllister (2002) in employing a Bayesian delta lognormal model with the explanatory variables (factors) year, area, and gear type. Three models using a combination of these factors were produced: year, year/gear, and year/gear/depth. No interactions are considered. The delta lognormal model has two components, a binomial density function to model the number of positive catches of Quillback Rockfish (a binomial abundance index) and a lognormal density function to model the sets with positive catches (a lognormal abundance index) (Babcock and McAllister 2002). All effects are estimated relative to the reference year, area, and gear. Here that is the first year, first area, first gear and is noted as b_0 for the number of positive catches and a_0 for the positive CPUE observations.

The binomial portion of the delta lognormal model employs a logit link to linearize the binomial probabilities and takes the form:

$$(E2) \quad \log\left(\frac{py_{y,a,g}}{1 - py_{y,a,g}}\right) = b_0 + by_y + ba_a + bg_g = \beta_{y,a,g}$$

where $py_{y,a,g}$ (the binomial abundance index) is the probability of a successful (non-zero) catch in year y and gear a with depth g and the b terms are the respective effects with b_0 representing the mean for the reference year, gear and depth. The mean of the lognormal portion of the delta lognormal model uses a log link and takes the form:

$$(E3) \quad \log(a.mu_{y,a,g}) = a_0 + ay_y + aa_a + ag_g = \alpha_{y,a,g}$$

where $a.\mu_{y,a,g}$ (the lognormal abundance index) is the mean of the lognormal density function for year y and gear a with depth g and the a terms are the respective effects with a_0 representing the mean for the reference year, gear and depth.

The joint posterior probability density function (pdf) for the GLM model is the product of the binomial and lognormal portions of the model and the priors for the vectors of the parameters a , b , and the constant CPUE variance σ . The joint posterior pdf for the delta lognormal model is:

$$\begin{aligned}
 p(\sigma, \underline{a}, \underline{b} | \underline{z}, \underline{k}, \underline{w}) &\propto p(\sigma) \cdot p(b_0) \cdot p(a_0) \\
 &\cdot \left(\prod_{y=2}^{n_y} p(a_{y_y}) p(b_{y_y}) \right) \cdot \left(\prod_{a=2}^{n_a} p(a_{a_a}) p(b_{a_a}) \right) \cdot \left(\prod_{g=2}^{n_g} p(a_{g_g}) p(b_{g_g}) \right) \\
 \text{(E4)} \\
 &\cdot \prod_{y=1}^{n_y} \prod_{a=1}^{n_a} \prod_{g=1}^{n_g} \binom{n_{y,a,g}}{w_{y,a,g}} \left(\frac{\exp(\beta_{y,a,g})}{1 + \exp(\beta_{y,a,g})} \right)^{w_{y,a,g}} \left(\frac{1}{1 + \exp(\beta_{y,a,g})} \right)^{(n_{y,a,g} - w_{y,a,g})} \\
 &\cdot \prod_{s=1}^{n_{y,a,g}} \left(\frac{1}{z_{y,a,g,s} \sigma \sqrt{2\pi}} \exp \left(- \frac{(\log(z_{y,a,g,s}) - \alpha_{y,a,g})^2}{2\sigma^2} \right) \right)^{k_i}
 \end{aligned}$$

where z is the CPUE observation, k is a value of 0 or 1 dependent on whether the catch is zero or non-zero respectively, w is the number of positive catches, and n is the number of sets. Further details on the derivation of the joint pdf can be found in Babcock and McAllister (2002). The priors for the \underline{a} terms, \underline{b} terms, and σ are non-informative and defined with mean and standard deviation as:

$$\text{(E5)} \quad ax \sim N(0, 1.0E - 6) \quad bx \sim N(0, 1.0E - 6) \quad \sigma \sim \log N(\log(0.5), 1.2)$$

where x represents the particular year (y), gear (a) or depth (g) effect. As the first year, first gear, and first depth are treated as references in the respective models, $ax[1]$ and $bx[1]$ are set to zero.

Year effects with the gear and depth effects removed were obtained by integrating the joint posterior pdf to compute the marginal probability distributions. These integrated year effects represent the delta lognormal abundance indices. Posterior means and standard deviations are provided to summarize the central tendencies and spread in the year effects of the CPUE data.

The joint posterior pdf is estimated using the WinBUGS software (Lunn et al. 2000), employing Markov Chain Monte Carlo (MCMC). These algorithms require a stationary distribution and tests for convergence are necessary to check whether the stationary distribution has been achieved. Two Markov chains with different initial values were run for each model to allow tests for convergence on the posterior distribution. The Gelman-Rubin convergence statistic (BGR) approaches 1.0 when the pooled chain and within chain variances are similar and convergence is achieved (McCarthy 2007). Visual diagnostics for the chains were also examined to ensure that the chains were well-mixed. All models had a "burn-in" period of 2000 to 5000 iterations prior to convergence on the posterior distribution. The "burn-in" was discarded before posterior statistics

were calculated. After removal of the "burn-in", the posterior mean and standard deviation of the first 10% and last 10% of the chains were examined to ensure that they were relatively equal. To remove autocorrelation in the chains and ensure that each draw from the posterior distribution was independent, the chains were thinned and one in every 20 draws was kept. The chains were run until 10000 samples from the posterior distribution were produced. The deviance information criterion (DIC), given by:

$$(E6) \quad DIC = \hat{D} + 2p_D$$

where \hat{D} is the deviance and p_D is the effective number of estimated parameters, was used to assess model fit and select the best model for use in the stock assessment (McCarthy 2007). A lower DIC values indicates the model which provides the best fit, while minimizing the number of parameters in the model. WinBUGS was called using the R package R2WinBUGS, while convergence diagnostics were assessed with the package coda (Ihaka and Gentleman 1996).

Results

Posterior means, standard deviations and coefficients of variation (CVs) for the model year/gear/depth are presented in Table E15 and Figure E8. There is little contrast in the data within the year segments for both management units. There appears to be no stock response to the peak catches from the mid 1980's to 1991 which has raised concerns over whether this data series can be used as a reliable abundance index.

The lack of contrast (hyperstability) in the indices may be a result of fishery management actions, fleet movements and/or market demands. Fishery management has varied dramatically through the years and although the time series has been divided into segments within which fishery management was relatively stable, there could have been subtle changes that influenced catch rates within these time periods which we could not account for. Systematic movement of fishermen between areas over time could lead to biases in this model that does not account for this behaviour (Carruthers et al. 2010). Unlike the Yelloweye Rockfish analyses, area is not accounted for in the model (Yamanaka et al. 2012). This source of bias on estimates of time trends in abundance using standardized commercial catch per unit effort data are expected to be relatively minor because of the short time segments, however, the effects could be large enough to limit contrast in the indices despite large catches. Quillback Rockfish are the target species for the hook and line fishery, particularly for the inside management area and their catch rates would tend to drive fishermen behaviour. There is perhaps variation in catch rates between areas for Quillback Rockfish and thus an incentive for movement of fishermen between areas which would lead to a hyperstability of the overall stock trend in the standardized indices. Quillback Rockfish are also the primary rockfish sold in a very lucrative but relatively small "live" fish market. This "live" market must also have some influence on fishermen behaviour with its demands of live fish in a small and constant supply to avoid "flooding" the market with fish so the prices remain high.

For both the Yelloweye Rockfish analysis and the current models for Quillback Rockfish, important variables including competition for hooks from non-target species (e.g. a dogfish abundance covariate) could not be accounted for due to the structure of the logbook data in the early years.

These abundance indices from the hook and line rockfish fishery (ZN) are not used in the stock assessment. For the many reasons explained earlier, these data were deemed unreliable for an abundance index.

Table E15. Hook and line rockfish logbook (ZN) delta lognormal abundance index (year effects) means, standard deviations (SD) and coefficients of variation (CVs) by management unit. Double lines indicate breaks in the index due to changes in management for the fishery.

INSIDE MANAGEMENT UNIT				
Year	Posterior Mean of CPUE	posterior SD CPUE	posterior CV CPUE	
1986	3.03E+000	1.06E-001	3.50E-002	
1987	3.17E+000	1.21E-001	3.82E-002	
1988	3.24E+000	1.19E-001	3.66E-002	
1989	3.02E+000	1.05E-001	3.48E-002	
1990	2.81E+000	9.87E-002	3.51E-002	
1992	4.99E+000	3.71E-001	7.44E-002	
993	4.87E+000	3.58E-001	7.36E-002	
1994	4.95E+000	3.57E-001	7.22E-002	
1995	1.23E+000	5.85E-002	4.76E-002	
1996	1.04E+000	4.89E-002	4.71E-002	
1997	1.18E+000	5.09E-002	4.30E-002	
1998	1.14E+000	5.81E-002	5.08E-002	
1999	1.04E+000	5.08E-002	4.89E-002	
2000	1.03E+000	5.39E-002	5.24E-002	
2001	1.03E+000	4.68E-002	4.53E-002	
2003	2.54E+000	1.91E-001	7.51E-002	
2004	2.83E+000	1.88E-001	6.63E-002	
2005	2.39E+000	1.50E-001	6.30E-002	
2006	1.44E+000	1.50E-001	1.04E-001	
2007	1.25E+000	1.34E-001	1.08E-001	
2008	1.14E+000	1.29E-001	1.13E-001	
2009	1.32E+000	1.55E-001	1.17E-001	
2010	2.39E+000	2.41E-001	1.01E-001	
OUTSIDE MANAGEMENT UNIT				
Year	Posterior Mean of CPUE	posterior SD CPUE	posterior CV CPUE	
1986	1.00E+000	1.33E-001	1.33E-001	
1987	6.65E-001	8.38E-002	1.26E-001	
1988	1.74E+000	2.12E-001	1.22E-001	
1989	1.94E+000	2.47E-001	1.27E-001	
1990	1.57E+000	1.80E-001	1.14E-001	
1993	4.50E+000	1.13E+000	2.52E-001	
1994	4.51E+000	1.10E+000	2.44E-001	
1995	1.45E+000	1.15E-001	7.97E-002	
1996	1.41E+000	1.01E-001	7.21E-002	
1997	1.63E+000	1.19E-001	7.32E-002	
1998	1.70E+000	1.28E-001	7.55E-002	
1999	1.28E+000	1.01E-001	7.92E-002	
2000	1.55E+000	1.24E-001	8.04E-002	
2001	9.83E-001	8.37E-002	8.51E-002	
2002	2.60E+000	1.14E-001	4.40E-002	
2003	2.21E+000	9.20E-002	4.16E-002	
2004	2.44E+000	9.77E-002	4.01E-002	
2005	1.94E+000	9.16E-002	4.73E-002	
2006	1.63E+000	1.19E-001	7.29E-002	
2007	1.93E+000	1.20E-001	6.20E-002	
2008	2.10E+000	1.26E-001	6.02E-002	
2009	1.86E+000	1.10E-001	5.89E-002	
2010	2.50E+000	1.48E-001	5.91E-002	

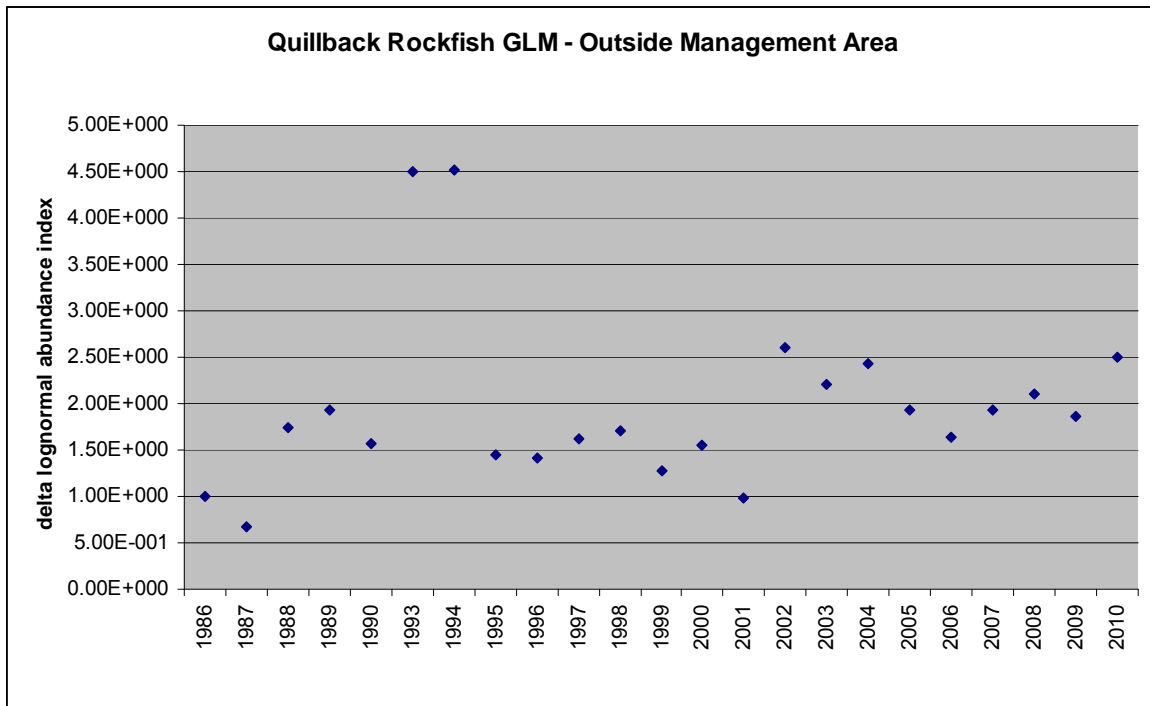
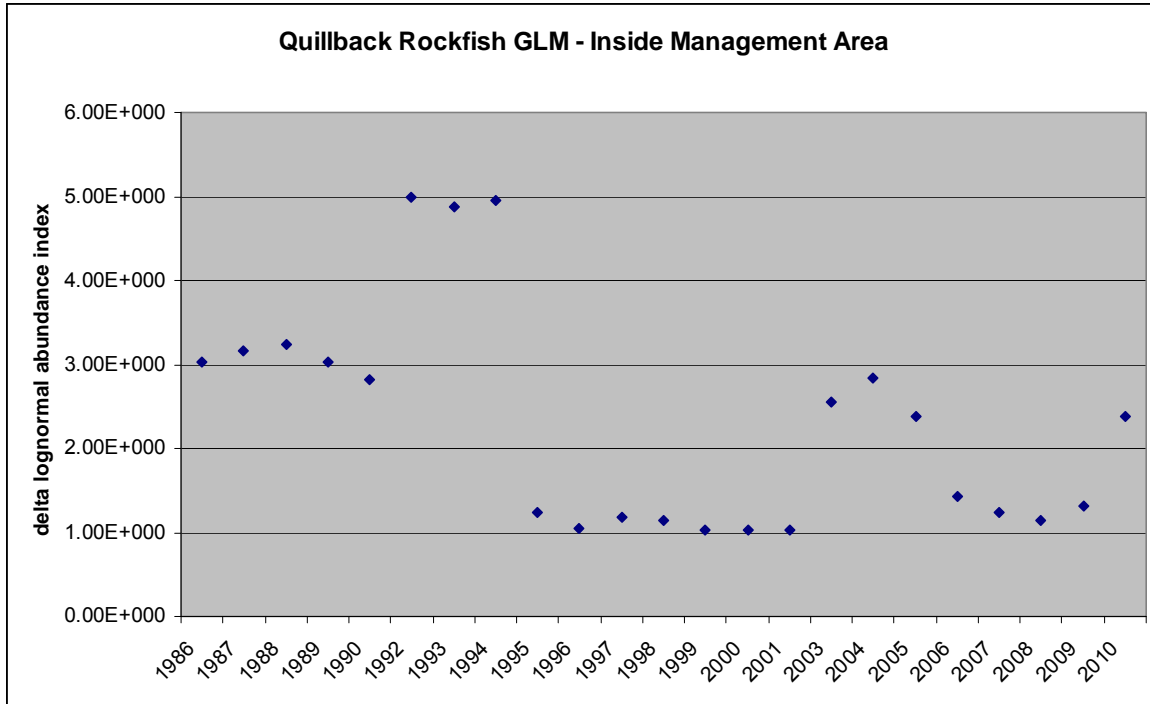


Figure E8. Quillback Rockfish abundance indices derived from the commercial hook and line rockfish fishery (ZN licensed) logbook records from the inside (top) and outside (bottom) management units. Segments for the inside were 1986-1990, 1992-1994, 1995-2001, 2003-2005, 2006-2010. Segments for the outside were 1986-1990, 1993-1994, 1995-2005, 2006-2010, 1991, 1992. 2002 was left out of the analyses.

2.1.2 Groundfish Trawl Observer Program

The groundfish trawl at-sea observer program was initiated in 1995 and recorded catches of Quillback Rockfish in small quantities (<.004 kg/hr). As with the hook and line fishery for Quillback Rockfish, catch rates are highly influenced by management measures and with declining TACs confounding the interpretation of abundance trends. Figure E9 from Yamanaka et al (2006) shows the abundance trend which does not vary much over time. Groundfish trawl observer records are not used in the stock assessment.

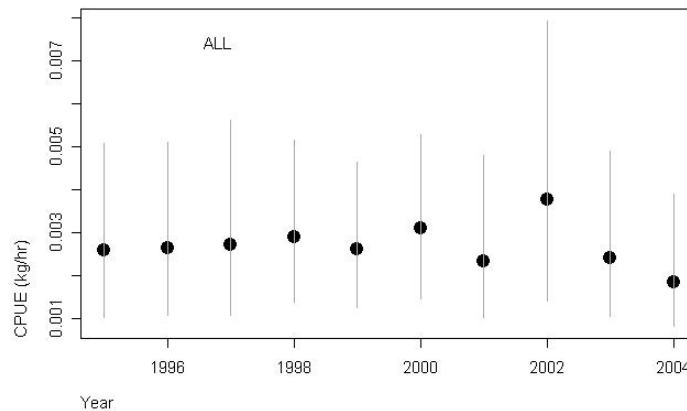


Figure E9. Commercial trawl observer recorded quillback rockfish cpue (kg/hr) by year. Figure from Yamanaka et al. 2006.

2.1.3 Pacific Salmon Troll Fishery Observer Records

Observers were deployed on the Pacific Salmon troll fishery intermittently from 1998. Records of rockfish were recorded in the earlier years and in the most recent years rockfish have been identified to species. These species specific records were reviewed but the catch of Quillback Rockfish is too infrequent to provide a reliable abundance index. See commercial catch from the Pacific Salmon troll fishery in Appendix C.

2.1.4 Spot Prawn Trap Fishery Observer Program

A sampling program to estimate rockfish bycatch in the British Columbia commercial prawn trap fishery was initiated in 2002. For the rockfish bycatch program, on-ground monitors sample a sub-set of traps in PFMA areas 2 to 29, and record rockfish encounters to the species level. Rockfish encounters in the commercial prawn fishery are a rare and random event and follow a Poisson distribution (Rutherford et al. 2010).

Electronic tables of data were made available for analysis. Encounter rates by PFMA area (outside and inside) and for all areas combined were redeveloped based on the methods used by Rutherford (2010) and are shown in Figures E10, E11 and E12.

The Spot Prawn trap observer data are not used in the assessment due to the small average fish size (0.233kg) and approximate age of 4 (Rutherford et al. 2010). This survey may prove to be a good indicator of incoming recruitment for Quillback Rockfish.

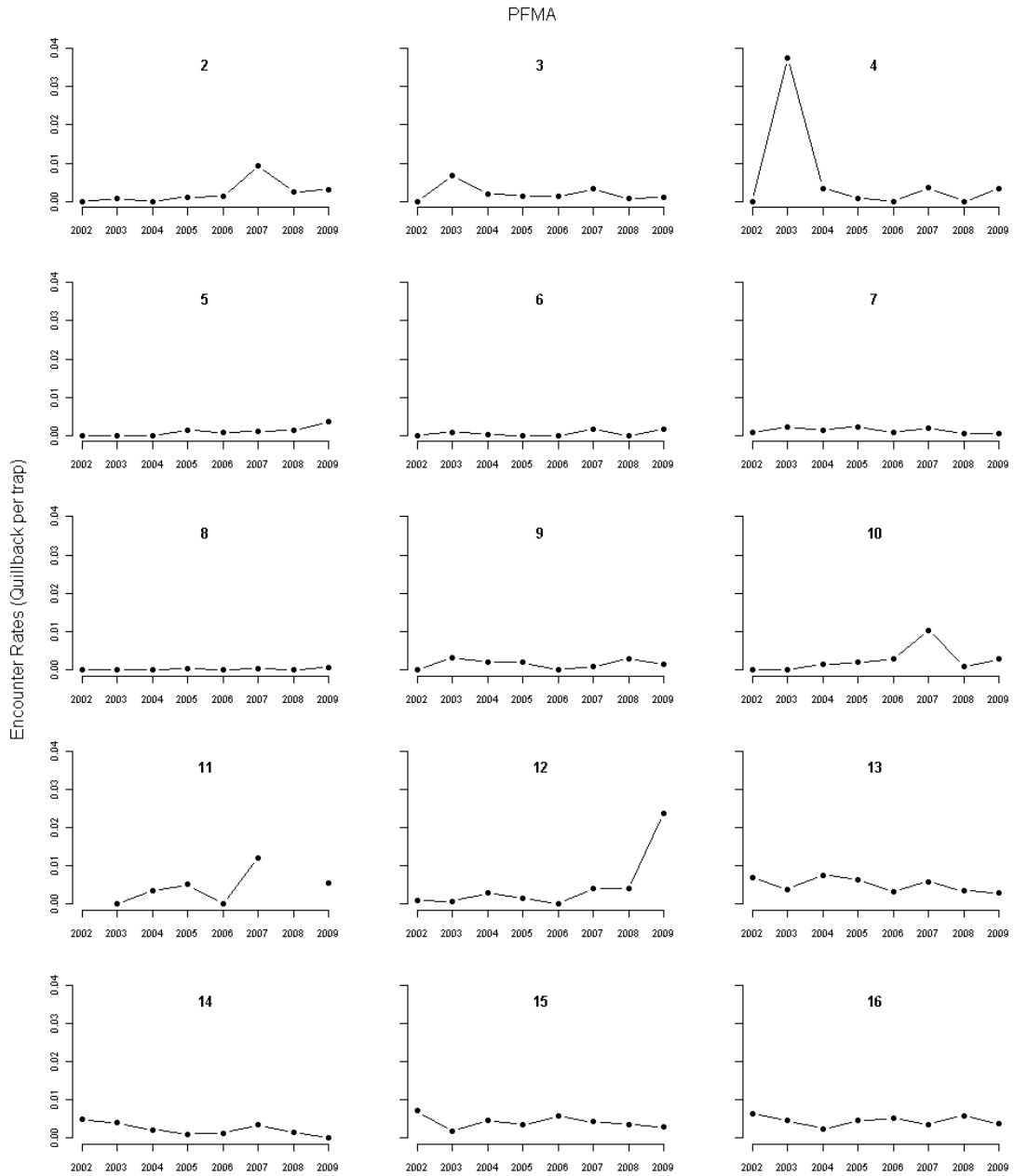


Figure E10. Encounter rate (number of fish per trap) index for Quillback Rockfish in the outside management unit commercial Spot Prawn observer program, by PFMA (2 to 16) and year.

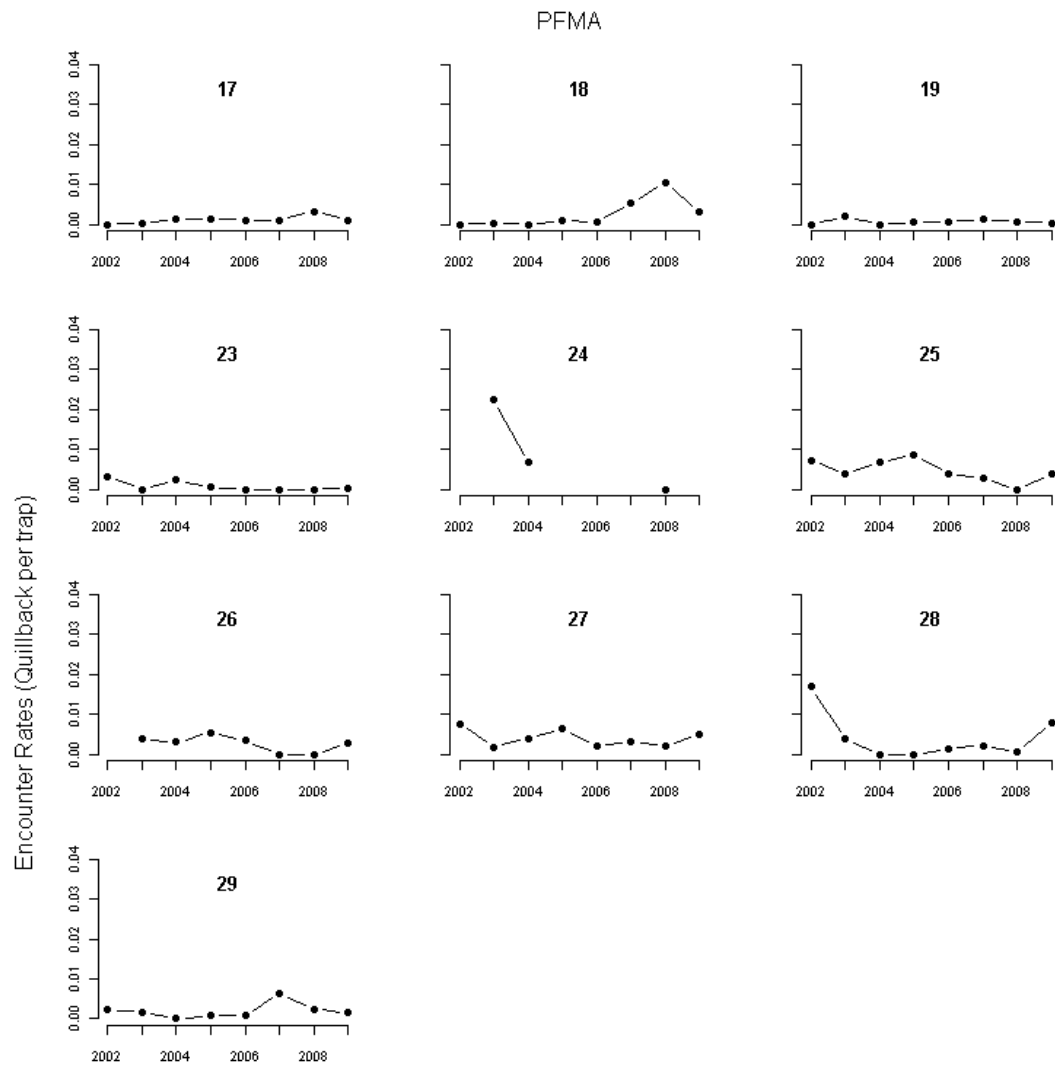


Figure E11. Encounter rate (number of fish per trap) index for Quillback Rockfish in the inside management unit commercial Spot Prawn observer program, by PFMA (17 to 29) and year.

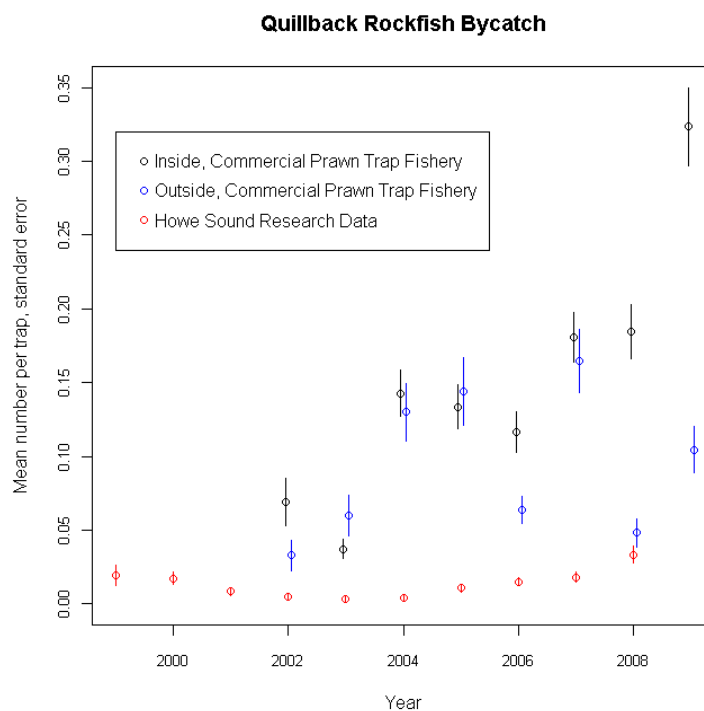


Figure E12. Encounter rate index for Quillback Rockfish in the commercial Spot Prawn trap fishery for all PFMA's sampled by management unit (inside and outside), with Howe Sound research survey data for comparison.

REFERENCES

- Babcock, E.A. and McAllister, M.K. 2002. Bayesian generalized linear models for standardizing catch rate indices of abundance. Col. Vol. Sci. Pap. ICCAT, 54(5): 1641-1670.
- Boutillier, J.A., Bond, I.A., Nguyen, H., and Harbo, R.M. 1998a. Shrimp survey off the west coast of Vancouver Island and resulting management actions - May 1998. Can. Manuscr. Rep. Fish. Aquat. Sci. 2461: 110 p.
- Boutillier, J.A., Bond, I.A., Nguyen, H., and Harbo, R.M. 1998b. Queen Charlotte Sound shrimp survey and resulting management actions, July 1998. Can. Manuscr. Rep. Fish. Aquat. Sci. 2462: 47 p.
- Carruthers, T., McAllister, M.K., and Ahrens, R. 2010. Simulating spatial dynamics to evaluate methods of deriving abundance indices for tropical tunas. Can. J. Fish. Aquat. Sci. 67: 1409-1427
- Cass, A.J., and Richards, L.J. 1987. Lingcod Hook and Line Survey in the Gulf Islands Region (Statistical Area 17) of the Strait of Georgia, October-December 1985. Can. Man. Rep. Fish. Aquat. Sci. 1934: 65 p.

-
- Choromanski, E.M., Workman, G.D., and Fargo, J. 2005. Hecate Strait multispecies bottom trawl survey, CCGS W.E. Ricker, May 19 to June 7, 2003. Can. Data Rep. Fish. Aquat. Sci. 1169: viii + 85 p.
- Efron, B. 1982. The Jackknife, the Bootstrap and Other Resampling Plans. CBMS-NSF Regional Conference Series in Applied Mathematics, Monograph 38, SIAM, Philadelphia.
- Favaro, B, Rutherford, D.T., Duff, S.D., and Cote, I.M. 2010. Bycatch of rockfish and other species in British Columbia spot prawn traps: Preliminary assessment using research traps. Fisheries Research Volume 102, Issues 1-2, February 2010, Pages 199-206, ISSN 0165-7836, DOI: 10.1016/j.fishres.2009.11.013.
- Gallucci, V., Taylor, I., King, J., McFarlane, G., and McPhie, R. 2011. Spiny Dogfish (*Squalus Acanthias*) Assessment and Catch Recommendations for 2010. DFO Can. Sci. Advis. Sec. Res. Doc. 2011/034. xii + 69p.
- Haggarty, D.R., and King, J.R. 2004. Hook and line survey of Lingcod (*Ophiodon elongatus*) and Rockfish (*Sebastes sp.*) stocks in southern Strait of Georgia (statistical areas 17, 18 and 19) October 2003. Can. Tech. Rep. Fish. Aquat. Sci. 2533: 38p.
- Haggarty, D.R., and King, J.R. 2005. Hook and line survey of Lingcod (*Ophiodon elongatus*) and Rockfish (*Sebastes spp.*) in northern Strait of Georgia (statistical areas 13, 14, 15 and 16) June 14 - July 9, 2004. Can. Tech. Rep. Fish. Aquat. Sci. 2590: 57 p.
- Haggarty, D.R., and King, J.R. 2006. Hook and line survey of Lingcod (*Ophiodon elongatus*) and Rockfish (*Sebastes spp.*) in northern Strait of Georgia (statistical areas 18 and 19) June 19 - 29, 2005. Can. Tech. Rep. Fish. Aquat. Sci. 2623: vii + 44p.
- Haigh, R., and Richards, L.J. 1997. A relational database for hook and line rockfish logbook data. Can. Manuscr. Rep. Fish. Aquat. Sci. 2408: 46 p.
- Hand, C.M. and Richards, L.J. 1987. Hook and Line Survey of Lingcod (*Ophiodon elongatus*) and Rockfish (*Sebastes spp.*) Stocks in the Gulf Islands Region (MSA 17) of the Strait of Georgia, January and February, 1987. Can. Manuscr. Rep. Fish. Aquat. Sci. 1957: 57 p.
- Hand, C.M. and Richards, L.J. 1989. Hook and Line Survey of Lingcod (*Ophiodon elongatus*) Stocks in the Gulf Islands Region (MSA 17) of the Strait of Georgia, 1985 to 1988. Can. Manuscr. Rep. Fish. Aquat. Sci. 2043: 45 p.
- Ihaka, R. and Gentleman, R. 1996. R: A Language for Data Analysis and Graphics. Journal of Computational and Graphical Statistics, 5(3): 299-314.
- International Pacific Halibut Commission, Stock Assessment Surveys, Online information available at: <http://www.iphc.washington.edu/research/surveys.html> (May 16, 2011)
- King, J. R., and McFarlane, G.A. 2009. Trends in abundance of spiny dogfish in the Strait of Georgia, 1980–2005. Pages 89–100 in V. F. Gallucci, G. A. McFarlane, and G. G. argmann, editors. Biology and management of spiny dogfish sharks. American Fisheries Society, Bethesda, Maryland.

-
- Kronlund, A.R., and Yamanaka, K.L. 1997. Analysis of ZN hook and line logbook data: Strait of Georgia Management Region. DFO Can. Sci. Advis. Sec. Res. Doc. 1997/135. 44 p.
- Kronlund, A. R., and Yamanaka, K. L. 2001. Yelloweye rockfish (*Sebastes ruberrimus*) life history parameters assessed from areas with contrasting fishing histories. Spatial Processes and Management of Marine Populations. *Alaska Sea Grant College Program AK-SG-01-02* , pp. 257-280.
- Lochead, J.K., and Yamanaka, K.L. 2007. Summary report for the inshore rockfish (*Sebastes* spp.) longline survey conducted in Statistical Areas 14 to 20, 28 and 29, from August 11 to September 6, 2005. Can. Tech. Rep. Fish. Aquat. Sci. 2690: ix + 53 p.
- Lunn, D.J., Thomas, A., Best, N., and Spiegelhalter, D. 2000. WinBUGS -- a Bayesian modelling framework: concepts, structure, and extensibility. *Statistics and Computing*, 10: 325-337.
- Martin, J.C., and Yamanaka, K.L. 2004. A visual survey of inshore rockfish abundance and habitat in the southern Strait of Georgia using a shallow-water towed video system. Can. Tech. Rep. Fish. Aquat. Sci. 2566: ix + 52 p.
- McCarthy, M.A. 2007. *Bayesian Methods for Ecology*. Cambridge University Press, New York. 296 p.
- Obradovich, S.G., Yamanaka, K.L., Cooke, K., Lacko, L.C., and Dykstra, C. 2008. Summary of Non-Halibut Catch from the Standardized Stock Assessment Survey Conducted by the International Pacific Halibut Commission in British Columbia from June 4 to July 7, 2007. Can. Tech. Rep. Fish. Aquat. Sci. 2807: x + 83 p.
- Olsen, N., Rutherford, K.L., and Stanley, R.D. 2008. West Coast Queen Charlotte Islands groundfish bottom trawl survey, August 25th to September 21st, 2008. Can. Manuscr. Rep. Fish. Aquat. Sci. 2858: vii + 50 p.
- Olsen, N., Rutherford, K.L., Stanley, R.D., and Wyeth, M.R. 2009a. Hecate Strait groundfish bottom trawl survey, May 26th to June 21st, 2009. Can. Manuscr. Rep. Fish. Aquat. Sci. 2901: vi + 49 p.
- Olsen, N., Rutherford, K.L., Stanley, R.D., and Wyeth, M.R. 2009b. Queen Charlotte Sound groundfish bottom trawl survey, July 7th to August 8th, 2009. Can. Manuscr. Rep. Fish. Aquat. Sci. 2899: vi + 61 p.
- Olsen, N., Rutherford, K.L., Stanley, R.D., and Wyeth, M.R. 2009c. West coast Vancouver Island groundfish bottom trawl survey, May 26th to June 22nd, 2008. Can. Manuscr. Rep. Fish. Aquat. Sci. 2902: vi + 50 p.
- Richards, L.J., and Cass, A.J. 1985a. 1985 research catch and effort data on Nearshore reef-fishes in the Strait of Georgia B.C. (statistical area 15 and 16). Can. Manuscr. Rep. Fish. Aquat. Sci. 1851: 68 p.
- Richards, L.J., and Cass, A.J. 1985b. Transect counts of rockfish in the Strait of Georgia from the submersible Pisces IV, October & November 1984. Can. Data Rep. Fish. Aquat. Sci. 511: 99p.

-
- Richards, L.J., and Cass, A.J. 1987. 1986 research catch and effort data on nearshore reef-fishes in British Columbia statistical areas 12, 13 and 16. Can. Manuscr. Rep. Fish. Aquat. Sci. 1903: 119 p.
- Richards, L.J., and Hand, C.M. 1987. 1987 Research catch and effort data on nearshore reef-fishes in British Columbia statistical areas 12 and 13. Can. Manscr. Rep. Fish. Aquat. Sci. 1958: 59p.
- Richards, L.J., Hand, C.M, and Candy, J.R. 1988. 1988 Research catch and effort data on nearshore reef-fishes in British Columbia Statistical Areas 12 and 13. Can. Manscr. Rep. Fish. Aquat. Sci. 2000: 89p.
- Richards, L.J., Cass, A.J., Selsby, J. R., van den Broek, R., and Loynachan, S.D. 1985. A Summary of Research Catch and Effort Data for Nearshore Reef-Fishes Collected during 1984 in MSA 15 and 16 of the Strait of Georgia. Can. Manuscr. Rep. Fish. Aquat. Sci. 1833: 69 p.
- Rutherford, D.T., Fong, K., and Nguyen, H. 2010. Rockfish Bycatch in the British Columbia Commercial Prawn Trap Fishery. DFO Can. Sci. Advis. Sec. Res. Doc. 2009/109. iii + 25p.
- Yamanaka, K.L. and Kronlund, A.R. 1997. Analysis of longline logbook data for the west coast Vancouver Island Yelloweye Rockfish fishery. DFO Can. Sci. Advis. Sec. Res. Doc. 1997/134. 41 p.
- Yamanaka, K.L., and Lacko, L.C. 2008. 2004 Research catch and effort data on nearshore reef-fishes in British Columbia Statistical Area 12. Can. Tech. Rep. Fish. Aquat. Sci. 2803: ix + 45 p.
- Yamanaka, K.L., and Murie, D.J. 1995. Hook and line surveys. Pp. 69-76. In Groundfish Stock Assessments for the West Coast of Canada in 1994 and Recommended Yield Options for 1995. M. Stocker and J. Fargo[eds.]. Can. Tech. Rep. Fish. Aquat. Sci. 2069: 440p.
- Yamanaka, K.L., and Richards, L.J. 1993. 1992 research catch and effort data on nearshore reef-fishes in British Columbia Statistical Area 12. Can. Manuscr. Rep. Fish. Aquat. Sci. 2184: 77p.
- Yamanaka, K.L., Lacko, L.C., Lochead, J.K., Martin, J., Haigh, R., Grandin, C., and West, K. 2004. Stock Assessment Framework For Inshore Rockfish. DFO Can. Sci. Advis. Sec. Res. Doc. 2004/068. 63p.
- Yamanaka, K.L., Lacko, L.C., Miller-Saunders, K., Grandin, C., Lochead, J. K., Martin, J.C., Olsen, N., and Wallace, S.S. 2006. A review of quillback rockfish *Sebastes maliger* along the Pacific coast of Canada: biology, distribution and abundance trends. Can. Sci. Advis. Sec. Res. Doc. 2006/077: 54 p.

APPENDIX F. MODEL RESULTS

QUILLBACK ROCKFISH STOCK STATUS IN 2011

OUTSIDE MANAGEMENT UNIT

Results for the full suite of parameters estimated from the reference case run for outside waters are summarized in Table F1. Predicted posterior median biomass levels from the surplus production model between 1918 and 2010, as well as catch and observed stock trend indices, are shown in Figures 2 and 3 of the main assessment document for the outside and inside management units, respectively.

Posterior distributions for most quantities of interest are imprecise (Table F1, Figures F1 and F2). This result is likely due to high among-year variability in stock trend indices, as well as imprecise biomass estimates from some surveys (Appendix E and Figures 3 and 4 in the main document). The posterior median for the intrinsic rate of increase r (0.134) was lower than the prior median (0.255). Catchability coefficients for stock trend indices (q_j) all had fairly large posterior CVs (0.52-0.98). This is mainly due to the high interannual variation in the standardized trawl fishery CPUE indices.

Estimates of process error terms for the outside management unit were zero up to the year 2000 but were updated to deviate from zero for most years since 2000 (Figure F3). In the last few years, process error deviate estimates are negative.

Table F1. Posterior mean, median, SD, and CV for parameters and stock status indicators for B.C. Quillback Rockfish – outside management unit. Posterior medians for C_{2011}/MSY , $C_{2011}/Repy_{2011}$, B_{1918}/K , and all eight catchability parameters (q) were calculated using a lognormal approximation based on the posterior mean and SD. All other posterior medians were obtained directly from a resample from the importance draws.

Variable	Mean	Median	SD	CV
K	23437	18614	14145	0.60
r	0.080	0.069	0.05	0.59
MSY	462	321	539	1.17
B_{2011}	12148	6480	14690	1.21
B_{2011}/K	0.43	0.368	0.25	0.57
B_{1918}	25122	18766	14991	0.60
B_{1918}/K	1.09	1.06	0.24	0.22
B_{2011}/B_{1918}	0.42	0.377	0.28	0.65
C_{2011}/MSY	0.53	0.470	0.30	0.55
F_{2011}/F_{MSY}	1.00	0.779	0.91	0.91
B_{2011}/B_{MSY}	0.86	0.736	0.49	0.57
B_{MSY}	11718	9307	7073	0.60
$Repy_{2011}$	293	241	229	0.78
q_{HMSAS}	9.89E-05	8.73E-05	5.27E-05	0.53
q_{QCSSS}	2.32E-04	1.86E-04	1.73E-04	0.74
q_{HSSS}	4.71E-04	3.75E-04	3.57E-04	0.76
q_{WCVISS}	8.82E-05	7.04E-05	6.65E-05	0.75
q_{IPHC}	1.56E-03	1.28E-03	1.08E-03	0.69
q_{PHMA_N}	5.80E-04	4.62E-04	4.42E-04	0.76
q_{PHMA_S}	3.29E-04	2.62E-04	2.50E-04	0.76
$q_{charters}$	1.64E-04	1.37E-04	1.09E-04	0.66
q_{rec}	9.26E-04	7.36E-04	7.05E-04	0.76

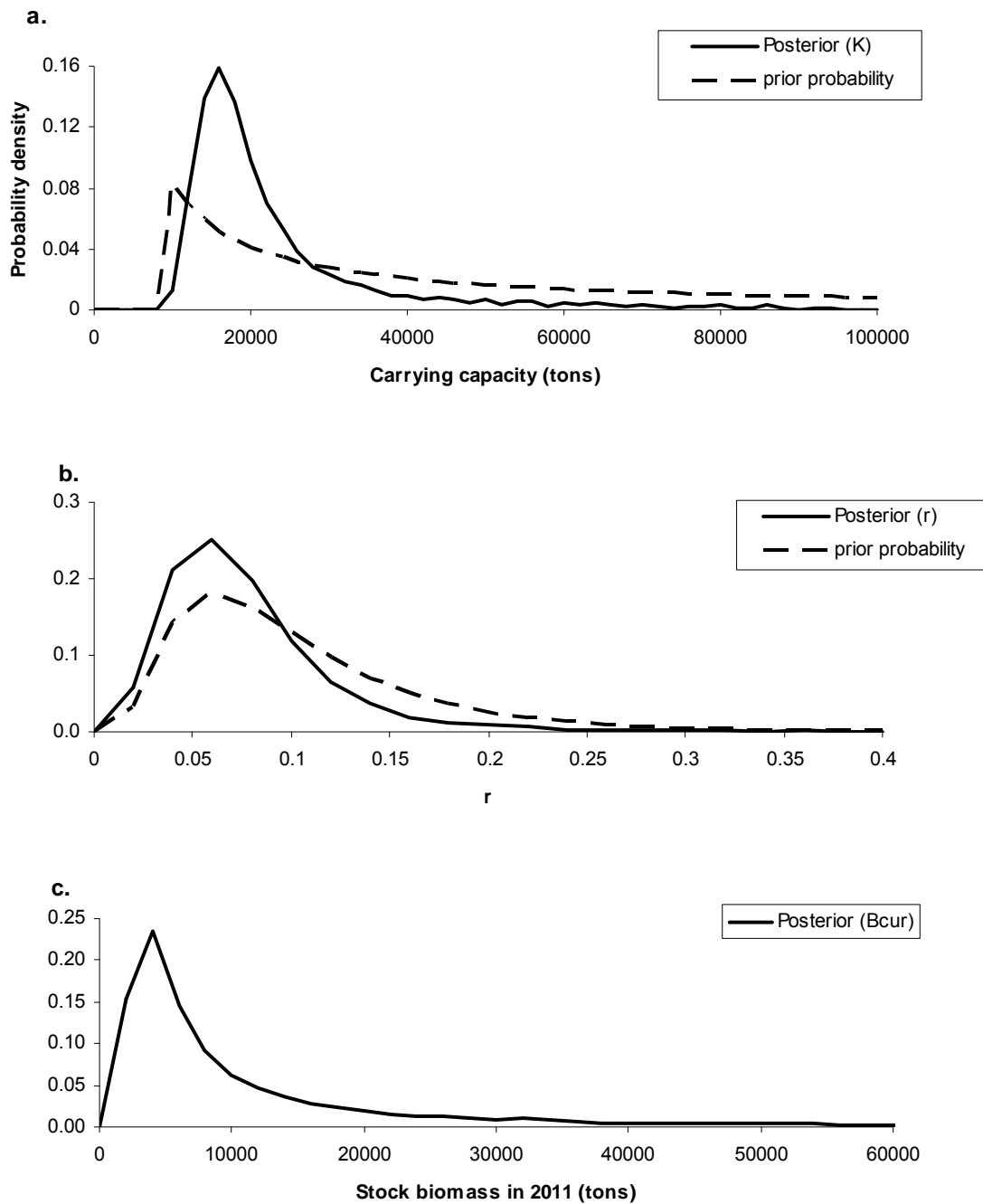


Figure F1. Reference case posterior distributions for (a) carrying capacity, (b) the maximum rate of increase, and (c) stock biomass in 2011 for Quillback Rockfish – outside management unit.

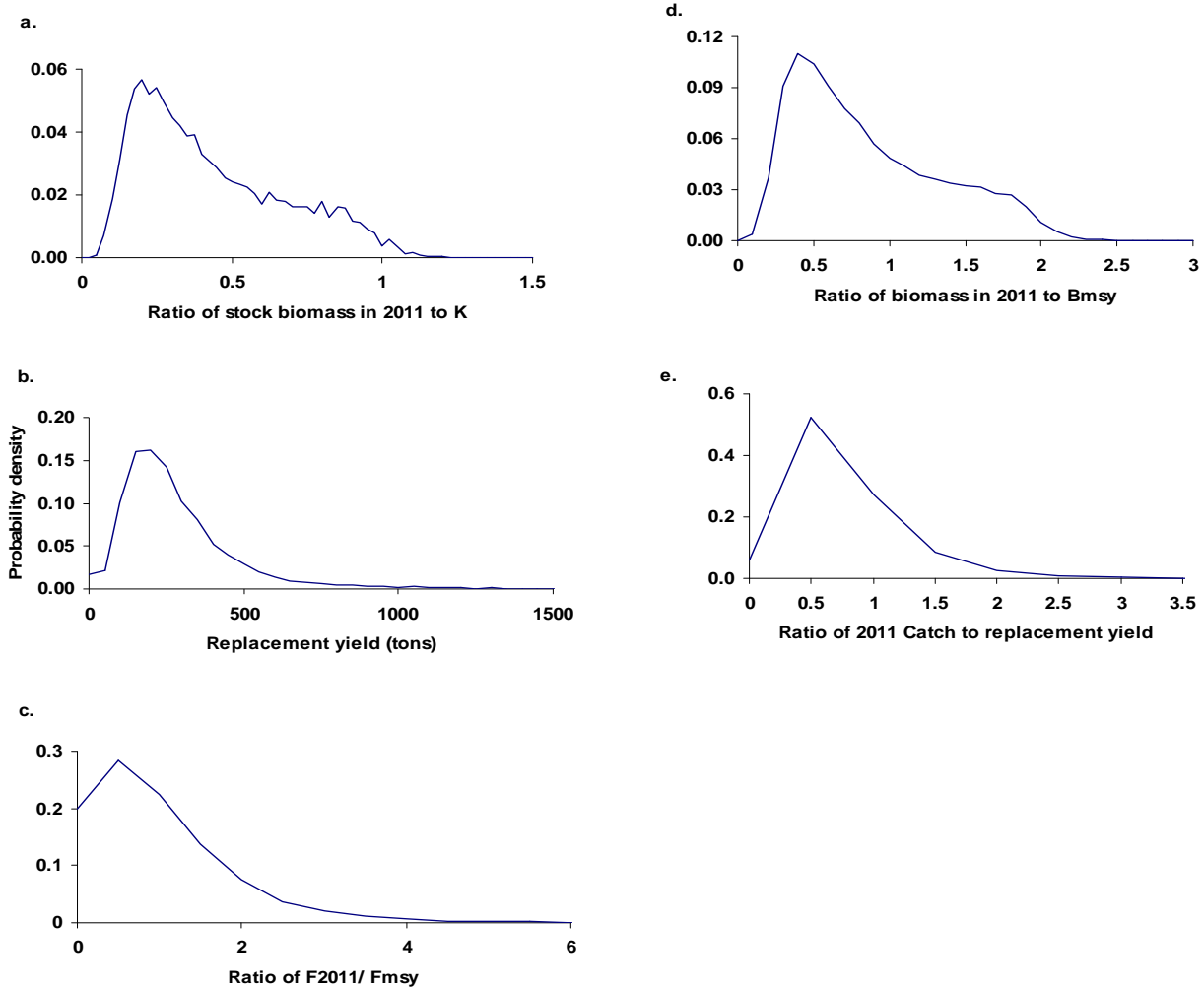


Figure F2. Posterior distributions for Quillback Rockfish – outside management unit for (a) ratio of stock biomass in 2011 to unfished stock size, (b) replacement yield in 2011, (c) ratio of fishing mortality rate in 2011 to that under F_{MSY} , (d) ratio of stock biomass in 2011 to B_{MSY} , and (e) catch in 2011 to replacement yield.

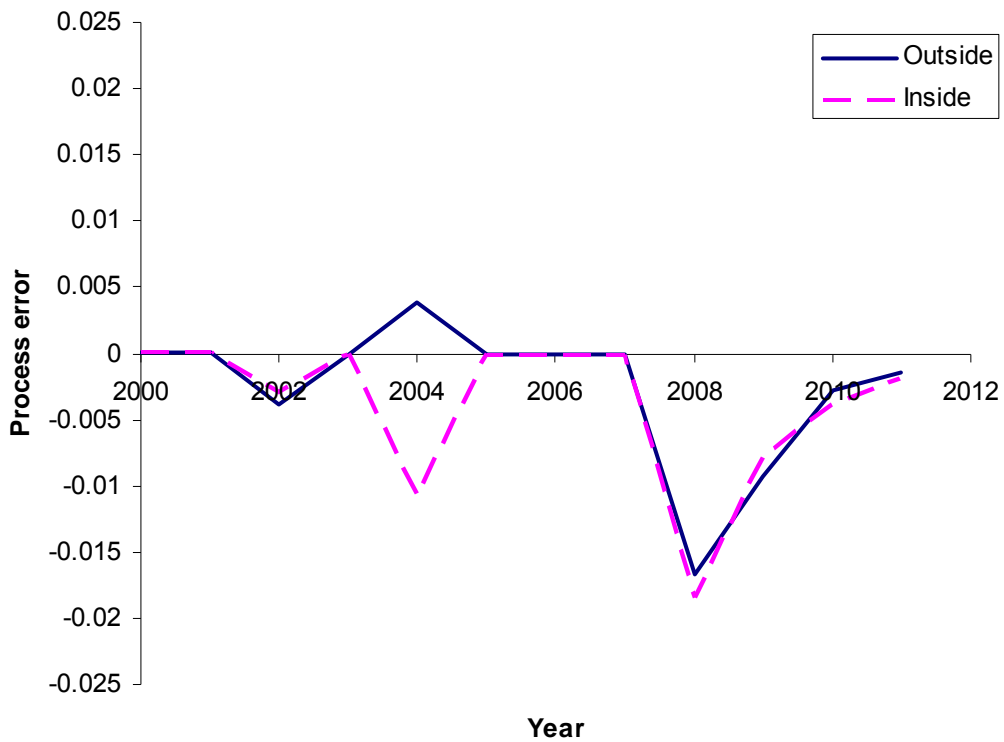


Figure F3. Posterior modal estimates of process error terms for the years 2000 to 2011 for each of the two assessment areas. Results were produced using reference case settings for each run. The posterior means for the process errors prior to 2001 were estimated to be zero. The BSP model still accounted for uncertainty in process errors in all years including these ones. Due to the large observation errors in the abundance index time series and there being fewer overlapping time series in earlier years, the data did not enable updating of the prior for years up to 2001. Thus the posterior distributions for process error terms before 2001 were no different from the prior distribution with a posterior mean of zero and posterior SD of 0.075 and the posterior modes are not shown for years prior to 2000.

INSIDE MANAGEMENT UNIT

Results for the full suite of parameters estimated from the reference case run for inside quillback are summarized in Table F2. Predicted posterior median biomass levels from the surplus production model between 1918 and 2011, as well as catch and observed stock trend indices, are shown in Figure 3 of the main assessment document.

The posterior distributions for carrying capacity (K), stock biomass in 2011, and most other quantities of interest are more precise for inside quillback (Table F2, Figures F4 and F5). This is mainly due to the lower interannual variability in some of the stock trend indices for inside quillback and the more consistent decline seen in most of the indices between the 1980s and the 2000s.

As with the outside, estimates of process error terms for the inside management unit were zero up to the year 2001 but were updated to deviate from zero for most years since 2001 (Figure F3). In the last few years, process error deviate estimates are negative and very similar to those for the outside.

Table F2. Posterior mean, Median, SD, and CV for key parameters and stock status indicators for B.C. Quillback/Rockfish- inside management unit. Posterior medians for C_{2011}/MSY , $C_{2011}/Repy_{2011}$, B_{1918}/K , and all 6 catchability parameters (q) were calculated using a lognormal approximation based on the posterior mean and SD. All other posterior medians were obtained directly from a resample from the importance draws.

Variable	Mean	Median	SD	CV
K	11484	10667	3632	0.32
r	0.050	0.051	0.020	0.45
MSY	144	140	50	0.35
B_{2011}	3016	2668	1813	0.60
B_{2011}/K	0.27	0.247	0.11	0.41
B_{1918}	11500	9686	4315	0.38
B_{1918}/K	1.00	0.98	0.22	0.22
B_{2011}/B_{1918}	0.28	0.274	0.13	0.47
C_{2011}/MSY	0.27	0.25	0.11	0.40
F_{2011}/F_{MSY}	0.60	0.498	0.40	0.66
B_{2011}/B_{MSY}	0.53	0.493	0.22	0.41
B_{MSY}	5742	5475	1816	0.32
$Repy_{2011}$	107	100	50	0.47
$q_{NI,jig}$	1.29E-03	1.25E-03	3.46E-04	0.27
$q_{dogfish}$	9.42E-04	9.01E-04	2.87E-04	0.31
$q_{RLL A12}$	1.53E-03	1.43E-03	5.68E-04	0.37
$q_{RLL A13}$	1.37E-03	1.29E-03	5.10E-04	0.37
$q_{RLL A14}$	6.89E-04	6.45E-04	2.59E-04	0.38
$q_{RLL A15}$	4.91E-04	4.60E-04	1.85E-04	0.38
$q_{RLL A16}$	2.85E-04	2.66E-04	1.07E-04	0.38
$q_{RLL A18}$	2.79E-04	2.61E-04	1.05E-04	0.38
$q_{RLL A28}$	4.31E-04	4.04E-04	1.62E-04	0.38
q_{sub}	6.79E-03	6.53E-03	1.92E-03	0.28
$q_{SOG,jig}$	7.34E-04	6.96E-04	2.48E-04	0.34
g_{rec}	1.83E-03	1.77E-03	4.80E-04	0.26

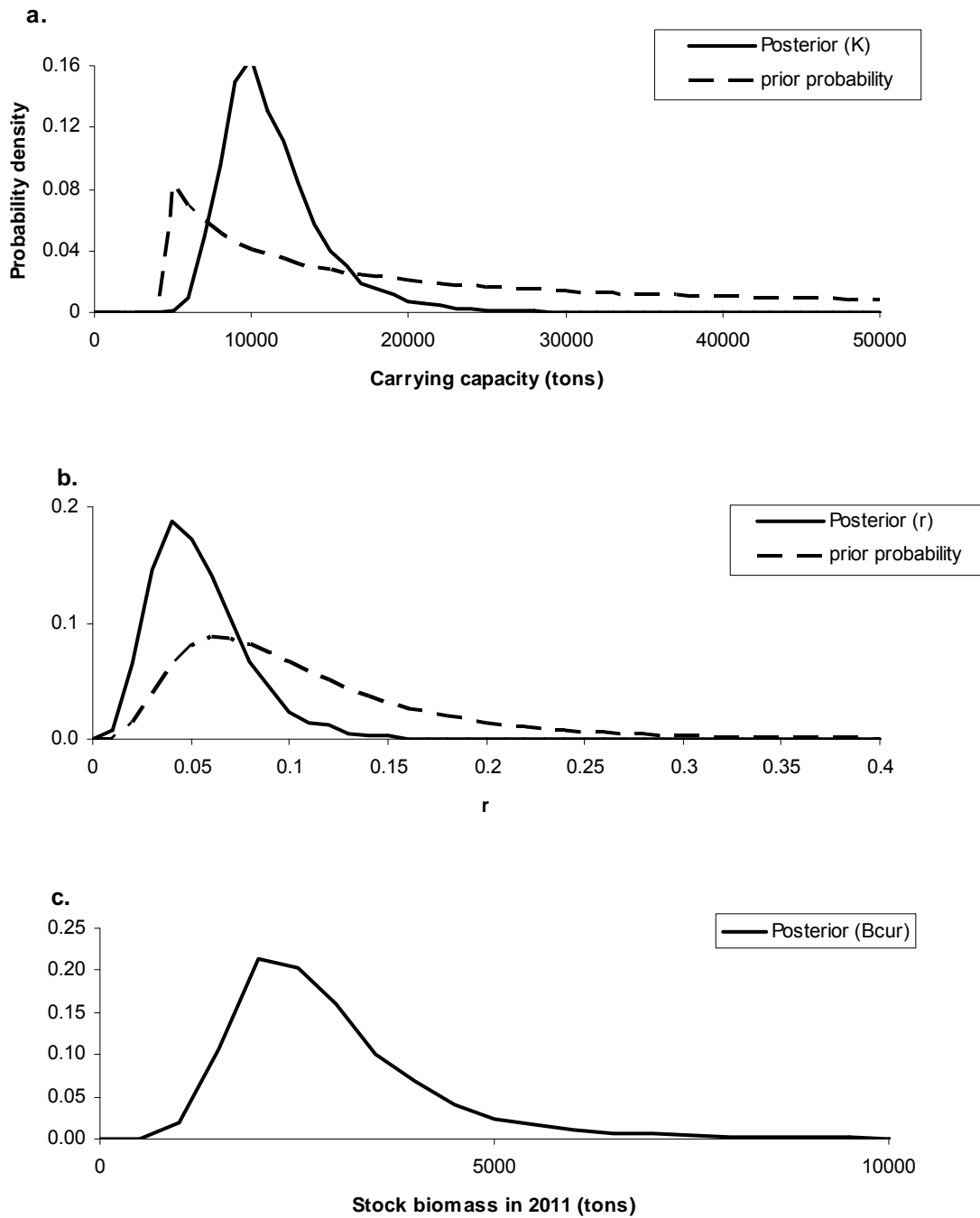


Figure F4. Reference case posterior distributions for (a) carrying capacity, (b) the maximum rate of increase and (c) stock biomass in 2011 for Quillback Rockfish – inside management unit.

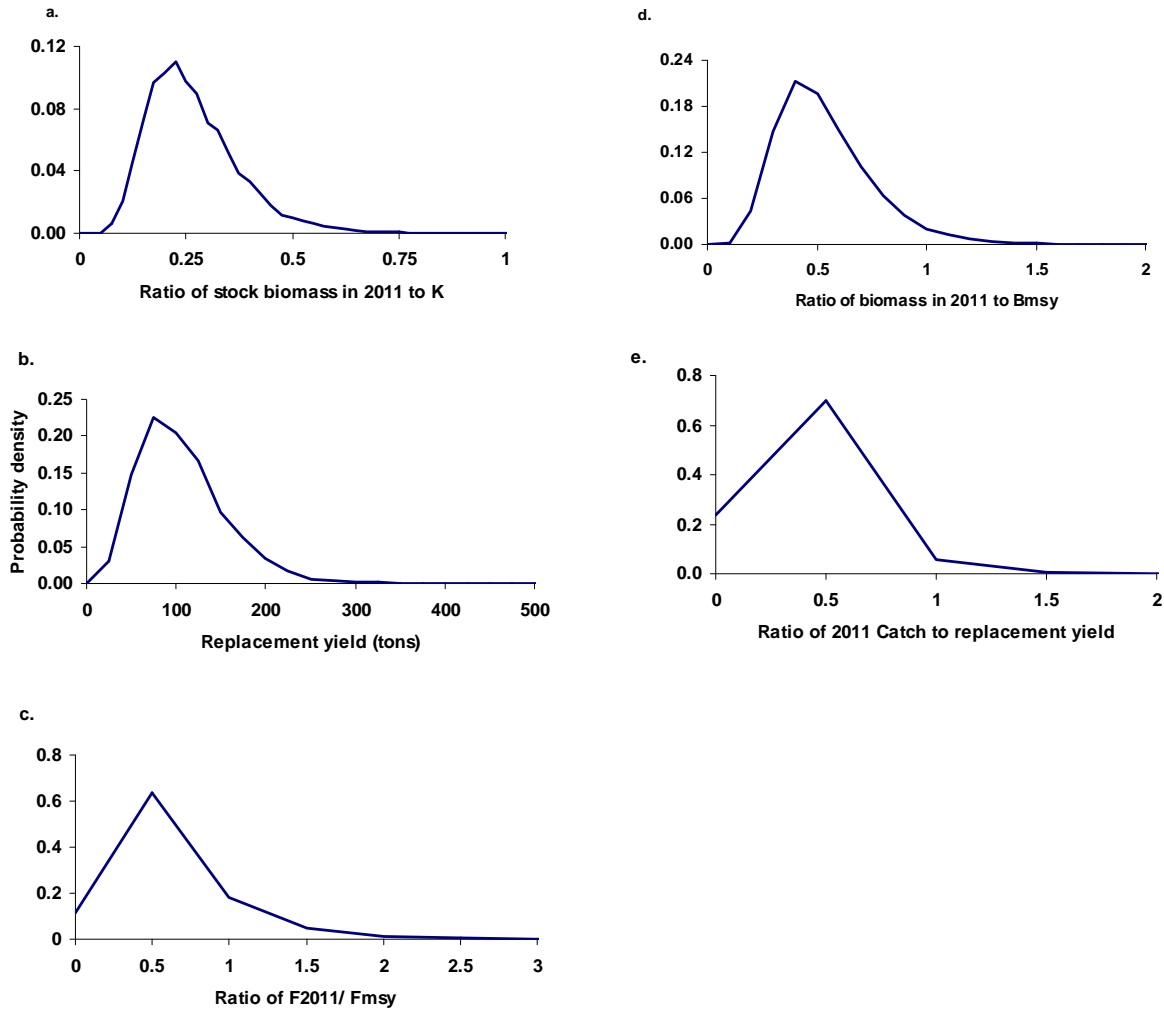


Figure F5. Posterior distributions for Quillback Rockfish – inside management unit for (a) ratio of stock biomass in 2011 to unfished stock size, (b) replacement yield in 2011, (c) ratio of fishing mortality rate in 2011 to that under F_{MSY} and tech, (d) ratio of stock biomass in 2011 to B_{MSY} , and (e) catch in 2011 to replacement yield.

STOCK PROJECTIONS FOR YIELD ADVICE

Decision tables for constant total fishing mortality (TFM) policies based on 5, 15, 30 and 90 year projections are summarized by assessment area in Table F3 and F4. The range of constant total fishing mortality (TFM) policies considered ranged from 30 to 270 tons for the outside management unit and 10 to 90 tons for the inside management unit. For both areas, upward median trajectories of B_{FINAL}/B_{MSY} occur for all policy options evaluated for TFMs of 1000 tonnes and lower.

Table F 3. Stock status indicators for Quillback Rockfish - outside management unit after 5, 15, 30 and 90 years. Policies are constant total fishing mortality (TFM) policies (tonnes). B_{FINAL} is the biomass in the final year of the projection (2016 for 5-year horizon, 2026 for 15-year horizon, 2041 for 30-year horizon, and 2101 for 90-year horizon). Probabilities (P) are presented for 3 stock status indicators: B_{FINAL} will be above the Limit Reference Point (40% of B_{MSY}), B_{FINAL} will be above the target biomass of B_{MSY} , and B_{FINAL} will be above the current 2010 biomass (B_{2010}).

Horizon	TFM Policy (tonnes)	B_{FINAL}/B_{MSY}	P ($B_{FINAL} > 0.4 B_{MSY}$)	P ($B_{FINAL} > 0.8 B_{MSY}$)	P ($B_{FINAL} > B_{MSY}$)	P ($B_{FINAL} > B_{2010}$)
5 -year	0	0.86	0.88	0.54	0.41	0.78
	30	0.86	0.88	0.54	0.41	0.77
	60	0.84	0.87	0.53	0.41	0.73
	90	0.83	0.85	0.52	0.40	0.69
	120	0.81	0.83	0.51	0.39	0.64
	150	0.79	0.82	0.49	0.38	0.59
	180	0.78	0.80	0.48	0.37	0.54
	210	0.76	0.78	0.48	0.36	0.49
	240	0.75	0.77	0.47	0.36	0.44
	270	0.73	0.75	0.46	0.35	0.40
15 -year	0	1.19	0.96	0.75	0.62	0.88
	30	1.15	0.94	0.72	0.59	0.86
	60	1.10	0.92	0.69	0.56	0.83
	90	1.04	0.89	0.65	0.53	0.77
	120	0.99	0.85	0.61	0.49	0.71
	150	0.93	0.81	0.57	0.47	0.64
	180	0.88	0.77	0.54	0.44	0.57
	210	0.82	0.73	0.51	0.42	0.50
	240	0.77	0.69	0.49	0.39	0.44
	270	0.71	0.66	0.46	0.37	0.39
30 -year	0	1.55	0.99	0.90	0.82	0.92
	30	1.49	0.98	0.86	0.78	0.90
	60	1.41	0.95	0.82	0.73	0.87
	90	1.33	0.92	0.76	0.68	0.81
	120	1.24	0.86	0.71	0.62	0.74
	150	1.14	0.81	0.66	0.57	0.66
	180	1.03	0.75	0.60	0.51	0.58
	210	0.91	0.69	0.55	0.47	0.49
	240	0.78	0.63	0.49	0.43	0.42
	270	0.65	0.58	0.46	0.40	0.36
90 -year	0	1.88	1.00	0.98	0.96	0.94
	30	1.83	0.99	0.97	0.94	0.93
	60	1.76	0.97	0.94	0.90	0.90
	90	1.68	0.93	0.88	0.85	0.85
	120	1.59	0.86	0.81	0.77	0.77
	150	1.47	0.78	0.73	0.69	0.67
	180	1.31	0.70	0.65	0.61	0.58
	210	1.13	0.61	0.57	0.54	0.49
	240	0.82	0.54	0.50	0.47	0.41
	270	0.00	0.48	0.44	0.41	0.34

Table F4. Stock status indicators for Quillback Rockfish - inside management unit after 5, 15, 30 and 90 years. Policies are constant total fishing mortality (TFM) policies (tonnes). B_{FINAL} is the biomass in the final year of the projection (2016 for 5-year horizon, 2026 for 15-year horizon, 2041 for 30-year horizon, and 2101 for 90-year horizon). Probabilities (P) are presented for 3 stock status indicators: B_{FINAL} will be above the Limit Reference Point (40% of B_{MSY}), B_{FINAL} will be above the target biomass of B_{MSY} , and B_{FINAL} will be above the current 2010 biomass (B_{2010}).

Horizon	TFM Policy (t)	B_{FINAL}/B_{MSY}	P ($B_{FINAL} > 0.4 B_{MSY}$)	P ($B_{FINAL} > 0.8 B_{MSY}$)	P ($B_{FINAL} > B_{MSY}$)	P ($B_{FINAL} > B_{2010}$)
5 -year	0	0.58	0.79	0.23	0.10	0.80
	10	0.58	0.79	0.24	0.10	0.80
	20	0.57	0.78	0.23	0.10	0.78
	30	0.56	0.77	0.22	0.10	0.74
	40	0.56	0.75	0.21	0.09	0.70
	50	0.55	0.74	0.21	0.09	0.67
	60	0.54	0.73	0.20	0.09	0.63
	70	0.53	0.71	0.19	0.08	0.60
	80	0.52	0.69	0.18	0.08	0.56
	90	0.51	0.68	0.18	0.08	0.52
15 -year	0	0.80	0.89	0.50	0.33	0.91
	10	0.78	0.88	0.48	0.32	0.89
	20	0.75	0.85	0.45	0.29	0.86
	30	0.72	0.82	0.42	0.27	0.83
	40	0.68	0.80	0.40	0.25	0.78
	50	0.65	0.77	0.37	0.23	0.73
	60	0.62	0.74	0.35	0.21	0.68
	70	0.59	0.70	0.32	0.19	0.62
	80	0.56	0.66	0.29	0.18	0.57
	90	0.53	0.63	0.27	0.17	0.52
30 -year	0	1.15	0.95	0.73	0.60	0.96
	10	1.10	0.93	0.70	0.57	0.94
	20	1.04	0.91	0.65	0.53	0.92
	30	0.98	0.88	0.61	0.48	0.87
	40	0.91	0.84	0.57	0.45	0.83
	50	0.84	0.81	0.52	0.41	0.77
	60	0.77	0.76	0.48	0.37	0.72
	70	0.70	0.70	0.44	0.34	0.65
	80	0.63	0.64	0.40	0.31	0.58
	90	0.55	0.59	0.37	0.28	0.52
90 -year	0	1.75	0.99	0.95	0.90	0.99
	10	1.70	0.98	0.92	0.87	0.98
	20	1.63	0.96	0.89	0.83	0.96
	30	1.56	0.93	0.85	0.78	0.92
	40	1.47	0.88	0.80	0.73	0.88
	50	1.37	0.83	0.74	0.67	0.81
	60	1.25	0.76	0.66	0.61	0.74
	70	1.10	0.68	0.59	0.54	0.66
	80	0.91	0.61	0.53	0.47	0.57
	90	0.59	0.53	0.46	0.41	0.50

APPENDIX G. SENSITIVITY ANALYSES

MODEL ASSUMPTIONS AND INPUT DATA

Parameter estimates from sensitivity runs for each assessment area are provided in Table G1 and Table G2.

For the two stocks, the estimates of stock status were affected to varying extents by the use of lower and higher prior means for the parameter r . For example, the posterior median for B_{2011}/B_{MSY} decreased from 0.74 to 0.68 going from the reference case to the low prior mean for r and increased to 0.8 for the high prior mean for r for the outside (Table G1). However, the posterior median for F_{2011}/F_{MSY} was about 25% -30% higher under the low r prior mean for the outside and inside stocks (Table G1 and G2).

For the two stocks, the alternative priors for the initial stock size had relatively little impact on stock status and productivity (Tables G1 and G2).

Considering the low and high alternative catch scenarios gave fairly similar stock status results for both stocks (Tables G1 and G2). However the estimates of current stock size and B_{msy} were scaled down and up considerably with the catch multipliers.

For the outside, the removal of the synoptic survey data and the removal of the IPHC data caused the stock status results to be slightly less optimistic for some of the stock status indicators including F_{2010}/F_{msy} and $Catch_{2010}/Repy$ (Table G1). This was due to the lower current stock size estimates obtained when these data were removed. In contrast, the results for inside quillback were relatively insensitive to the removals of the different sets of stock trend indices (Table G2). The removal of the Strait of Georgia Jig and Sub count indices resulted in slightly less optimistic stock status indicators, due to the lower estimate of final stock size. Applying a uniform on K prior also had relatively little impact on stock status indicators (Tables G1 and G2). Under this alternative prior, results were slightly more optimistic only for the outside population where the posterior distributions were less informed by the data than for the inside population.

For the two assessment areas, the prior for r was updated slightly with posterior medians less than the prior medians by up to about one third. Even though the abundance index data show high interannual variability, they generally showed a decline over the period when the largest catches were taken in the 1970s and 1980s. Most of the indices show decreases in the last five years when catches are also decreasing in the two areas. This continued lack of increase and then a decrease in the abundance indices when catches are low and then decreasing is the cause of the update in the prior for r in the different areas and the lower value for the posterior median for r compared to the prior median. This same pattern of continued low values in abundance indices after catches have declined substantially since the 1980s was also the cause of similar updates in the priors for r for British Columbia bocaccio (Stanley et al. 2009), inside yelloweye rockfish (Yamanaka et al. in prep.) and offshore lingcod (King et al. 2009).

EVALUATION OF CREDIBILITY OF SENSITIVITY ANALYSIS SCENARIOS

To evaluate the relative credibility of the alternative BSP model settings against the data, Bayes Factors were computed for some alternative sets of BSP stock assessment models and results are shown in Table 3. We have a slightly more liberal interpretation than Kass and Raftery (1995), to account for the relatively tight priors placed on some parameters. In our interpretation, ratios of marginal posterior probabilities of more than 1000: 1 could be taken as strong evidence against a particular model. Ratios of between 100:1 and 1000: 1 could be taken as moderate

evidence against the less likely model. Ratios of 50:1 could be taken as weak evidence against the less likely model. In all instances the prior probabilities for the alternative models were held constant. The Bayes factors in nearly all instances were quite similar across the alternative models. For example, for outside quillback the Bayes factors for models with alternative priors for r were quite similar ranging from 1.3 to 0.8 indicating that each of the models with the alternative priors for r remain credible and none is more credible than any of the others with differences easily due to random patterns in the data. For both areas the different priors for the initial stock size all had the same Bayes factor. For both areas the lowest historic catch scenario had slightly higher Bayes factors than the higher catch scenarios. These latter differences could also easily be explained by random patterns in the data.

DECISION ANALYSIS

We show decision analysis results across two additional axes of uncertainty for inside and outside quillback rockfish (Tables G3 to G7). Table G3 shows decision analysis results for outside quillback rockfish where the low, reference case and high priors for the parameter r were applied. The results are moderately sensitive to this prior even though the posterior means for r are quite different. In all instances when different hypotheses for r for outside quillback are considered, there was at least a 50% probability of the stock staying above $0.8 B_{MSY}$ after fifteen years for fixed total fishing mortality policies of 120 tons and less. The results for inside quillback rockfish were similar sensitive to alternative priors means for r and required much lower for fixed total fishing mortality policies to achieve at least a 50% chance of exceeding $0.8 B_{MSY}$ in 30 years (Table G4). Results were slightly more sensitive to the alternative scenarios for historic catch (Tables G6 and G7). In all instances Bayes factor was not sufficiently low for the reference case compared to some other case such that we would consider rejecting our reference case settings for the reference case.

Table G1. Stock assessment results for alternative settings to the Bayesian surplus production (BSP) stock assessment model for Quillback Rockfish – outside management unit. B_{2011} refers to the stock size in 2011, $RepY_{2011}$ refers to the replacement yield in 2011. F_{2011} refers to the fishing mortality rate in 2011. All biomass values are in tonnes. The posterior 5th, 50th (median) and 95th percentiles are shown for each estimated quantity. See Table G3 for a description of each sensitivity run.

Code	<i>r</i>			<i>B_{msy}</i>			<i>B₂₀₁₁</i>			<i>RepY₂₀₁₁</i>			<i>B₂₀₁₁/B_{msy}</i>			<i>F₂₀₁₁/F_{msy}</i>			<i>Catch₂₀₁₁/RepY₂₀₁₁</i>			
	5%	50%	95%	5%	50%	95%	5%	50%	95%	5%	50%	95%	5%	50%	95%	5%	50%	95%	5%	50%	95%	
Ref.1	Reference run																					
	0.029	0.069	0.157	6110	9307	28482	2131	6480	46916	86.96	240.8	687.5	0.266	0.736	1.814	0.071	0.779	2.621	0.199	0.646	1.664	
	r prior mean 33% lower and 33% higher																					
A.1.1	0.02	0.051	0.113	6454	9971	26208	2208	6351	38385	69.81	196.7	546.6	0.258	0.681	1.657	0.126	1.011	3.396	0.28	0.798	2.134	
A.1.2	0.036	0.083	0.2	5874	8949	27638	2020	6845	47793	90.45	275.2	788.4	0.268	0.803	1.879	0.049	0.624	2.295	0.154	0.558	1.45	
	Initial stock size, 0.8 K and 1.2 K																					
B.1.1	0.028	0.069	0.156	6095	9524	30723	2046	6386	50098	81.42	242.6	773.2	0.261	0.718	1.823	0.059	0.78	2.64	0.168	0.639	1.693	
B.1.2	0.029	0.068	0.159	6134	9154	26803	2125	6269	42114	88.66	241.5	712.4	0.268	0.717	1.759	0.078	0.784	2.581	0.187	0.649	1.659	
	Catches half or 50% higher																					
C.1.1	0.027	0.066	0.149	3453	5368	18182	1083	3296	30540	42.44	125.1	403.6	0.213	0.685	1.825	0.057	0.779	2.708	0.185	0.623	1.687	
C.1.2	0.029	0.066	0.15	8736	13505	35405	3000	9145	53990	134.3	345.9	934.5	0.272	0.72	1.732	0.098	0.827	2.651	0.239	0.675	1.674	
	Effect of removing different data sets																					
D.1.1	0.03	0.071	0.167	5941	9324	29094	1824	6102	47429	74.78	236.9	675	0.236	0.701	1.86	0.064	0.796	2.792	0.202	0.647	1.768	
D.1.2	0.032	0.077	0.167	3214	5177	17752	1143	3816	30777	58.82	154.9	357.5	0.278	0.79	1.869	0.112	1.146	3.628	0.381	1.001	2.33	
D.1.3	0.031	0.077	0.192	3224	5162	14813	751	3214	23457	37.6	140.8	350.4	0.159	0.684	1.826	0.135	1.337	6.414	0.397	1.092	3.517	
D.1.4	0.028	0.068	0.185	6274	9938	30651	2211	7962	49313	74.39	250.3	774	0.27	0.836	1.844	0.06	0.656	2.565	0.155	0.615	1.741	
	Uniform on K prior																					
E.1.1	0.026	0.065	0.177	6534	11671	37285	2348	10328	65995	61.02	262.7	935.3	0.282	0.949	1.94	0.044	0.537	2.477	0.095	0.562	1.633	

Table G2. Stock assessment results for alternative settings to the Bayesian surplus production (BSP) stock assessment model for Quillback Rockfish – inside management unit. B_{2011} refers to the stock size in 2011, $RepY_{2011}$ refers to the replacement yield in 2011. F_{2011} refers to the fishing mortality rate in 2011. All biomass values are in tons. The posterior 5th, 50th (median) and 95th percentiles are shown for each estimated quantity. See Sensitivity tests on page 6 of the main document for a description of each sensitivity run.

Code	<i>r</i>			<i>B_{msy}</i>			<i>B₂₀₁₁</i>			<i>RepY₂₀₁₁</i>			<i>B₂₀₁₁/B_{msy}</i>			<i>F₂₀₁₁/F_{msy}</i>			<i>Catch₂₀₁₁/RepY₂₀₁₁</i>			
	5%	50%	95%	5%	50%	95%	5%	50%	95%	5%	50%	95%	5%	50%	95%	5%	50%	95%	5%	50%	95%	
Ref.2	Reference run																					
	0.023	0.051	0.102	3663	5334	9134	1453	2668	5675	41.53	100.3	198.2	0.252	0.493	0.945	0.189	0.498	1.373	0.171	0.337	0.813	
	r prior mean 33% lower and 33% higher																					
A.2.1	0.018	0.039	0.081	3968	5820	9915	1449	2662	5920	32.92	80.5	171.8	0.233	0.451	0.898	0.234	0.644	1.745	0.197	0.42	1.027	
A.2.2	0.027	0.059	0.108	3514	5077	8333	1461	2645	5289	49.91	110.7	202.7	0.269	0.517	0.943	0.18	0.444	1.141	0.167	0.305	0.677	
	Initial stock size, 0.8 K and 1.2 K																					
B.2.1	0.022	0.051	0.1	3704	5514	9253	1439	2615	5651	42.82	96.6	193.9	0.242	0.477	0.924	0.198	0.519	1.336	0.174	0.35	0.789	
B.2.2	0.023	0.049	0.098	3756	5415	8613	1488	2711	5629	42.48	94.5	189.9	0.265	0.497	0.916	0.206	0.521	1.318	0.178	0.357	0.795	
	Catches half or 50% higher																					
C.2.1	0.022	0.05	0.099	1980	2999	4942	708	1312	2744	20.92	50.4	98.7	0.213	0.443	0.858	0.202	0.514	1.387	0.171	0.335	0.802	
C.2.2	0.023	0.05	0.095	5492	7826	12841	2189	3963	8378	65.03	147.7	285.5	0.263	0.503	0.95	0.2	0.504	1.312	0.178	0.343	0.78	
	Effect of removing different data sets																					
D.2.1	0.024	0.054	0.112	3583	5302	8786	1422	2803	6362	44.73	108.8	220.2	0.251	0.526	1.062	0.151	0.452	1.286	0.153	0.311	0.753	
D.2.2	0.024	0.053	0.105	3690	5470	9658	1578	3089	7532	45.87	114.1	230.3	0.279	0.571	1.126	0.14	0.418	1.207	0.146	0.296	0.732	
D.2.3	0.027	0.062	0.137	3273	4973	8221	1628	2843	5535	53.53	121.3	226.9	0.291	0.56	1.017	0.152	0.392	1.033	0.149	0.279	0.631	
D.2.4	0.023	0.052	0.106	3710	5353	9823	1009	2394	9741	34.21	90.4	221.3	0.184	0.444	1.235	0.123	0.575	1.755	0.151	0.373	0.985	
	Uniform on K prior																					
E.2.1	0.02	0.046	0.095	3890	5770	10160	1467	2741	6262	39.1	95.1	195.2	0.226	0.468	0.958	0.191	0.539	1.484	0.173	0.355	0.864	

Table G3. Bayes factors for alternative BSP stock assessment models. In each of these comparisons, the prior probability on each model alternative is set to be equal across the alternative models. The hypothesis can be considered highly unlikely based on the definition that a Bayes Factor ≤ 0.01 is highly unlikely. See Sensitivity Testson page 6 of the main document for a description of each sensitivity run.

Category Description	Code	Run Description	Bayes Factor
A.1 <i>r</i> prior mean outside	A.1.1	low <i>r</i>	1.3
	Ref.1	Reference run BSP	1.0
	A.1.2	high <i>r</i>	0.8
A.2 <i>r</i> prior mean inside	A.2.1	low <i>r</i>	1.9
	Ref.2	Reference run BSP	1.0
	A.2.2	high <i>r</i>	0.6
B.1 Alternative initial stock sizes outside	B.1.1	low <i>alpha</i>	1.0
	Ref.1	Reference run BSP	1.0
	B.1.2	high <i>alpha</i>	1.0
B.2. Alternative initial stock sizes inside	B.2.1	low <i>alpha</i>	1.0
	Ref.2	Reference run BSP	1.0
	B.2.2	high <i>alpha</i>	1.0
C.1 Uncertainty in catches outside	C.1.1	low <i>catch</i>	1.5
	Ref.1	Reference run BSP	1.0
	C.1.2	high <i>catch</i>	0.8
C.2 Uncertainty in catches inside	C.2.1	low <i>catch</i>	1.4
	Ref.2	Reference run BSP	1.0
	C.2.2	high <i>catch</i>	0.9

Table G4. Summary decision table for Quillback Rockfish – outside management unit. The probability that stock biomass exceeds $0.8 B_{MSY}$ after 15 years under each alternative constant total fishing mortality (TFM) policy and under each alternative hypothesized prior mean value for the parameter for the maximum intrinsic rate of increase, r .

	Hypothesized prior mean r		
	Low r	Reference r	High r
Prior median	0.059	0.0881	0.117
Posterior mean	0.050	0.067	0.083
Bayes factor	1.3	1.0	0.8
TFM Policy			
0	0.65	0.75	0.81
30	0.62	0.72	0.79
60	0.59	0.69	0.75
90	0.55	0.65	0.72
120	0.52	0.61	0.68
150	0.49	0.57	0.65
180	0.46	0.54	0.63
210	0.43	0.51	0.59
240	0.42	0.49	0.56
270	0.39	0.46	0.53

Table G5. Summary decision table for Quillback Rockfish – inside management unit. The probability that stock biomass exceeds $0.8 B_{MSY}$ after 15 years under each alternative constant total fishing mortality (TFM) policy and under each alternative hypothesized prior mean value for the parameter for the maximum intrinsic rate of increase, r .

	Hypothesized prior mean r		
	Low r	Reference r	High r
Prior median	0.061	0.0910	0.121
Posterior mean	0.043	0.054	0.063
Bayes factor	1.9	1.0	0.6
TFM Policy			
0	0.37	0.50	0.57
10	0.35	0.48	0.56
20	0.33	0.45	0.54
30	0.31	0.42	0.51
40	0.28	0.40	0.47
50	0.26	0.37	0.44
60	0.24	0.35	0.41
70	0.22	0.32	0.38
80	0.20	0.29	0.35
90	0.18	0.27	0.33

Table G6. Summary decision table for Quillback Rockfish – outside management unit. The probability that stock biomass exceeds $0.8 B_{MSY}$ after 15 years under each alternative constant total fishing mortality (TFM) policy and under alternative scenarios for total historic catch.

Bayes factor	Historic catch scenario		
	Low catch	Reference case	High catch
	1.5	1.0	0.8
TFM Policy			
0	0.70	0.75	0.76
30	0.64	0.72	0.73
60	0.58	0.69	0.71
90	0.52	0.65	0.69
120	0.47	0.61	0.65
150	0.42	0.57	0.63
180	0.38	0.54	0.60
210	0.35	0.51	0.57
240	0.33	0.49	0.54
270	0.31	0.46	0.51

Table G7. Summary decision table for Quillback Rockfish – inside management unit. The probability that stock biomass exceeds $0.8 B_{MSY}$ after 15 years under each alternative constant total fishing mortality (TFM) policy and under alternative scenarios for total historic catch.

Bayes factor	Historic catch scenario		
	Low catch	Reference case	High catch
	1.4	1.0	0.9
TFM Policy			
0	0.44	0.50	0.52
10	0.40	0.48	0.51
20	0.35	0.45	0.49
30	0.30	0.42	0.47
40	0.25	0.40	0.46
50	0.21	0.37	0.44
60	0.18	0.35	0.42
70	0.15	0.32	0.41
80	0.13	0.29	0.39
90	0.11	0.27	0.37

APPENDIX H. REQUEST FOR SCIENCE INFORMATION AND/OR ADVICE

PART 1: DESCRIPTION OF THE REQUEST – TO BE FILLED BY THE CLIENT REQUESTING THE INFORMATION/ADVICE

Date (when initial client's submission is sent to Science): 24/11/2010

Directorate, Branch or group initiating the request and category of request	
Directorate/Branch/Group	Category of Request
<input checked="" type="checkbox"/> Fisheries and Aquaculture Management	<input checked="" type="checkbox"/> Stock Assessment
<input checked="" type="checkbox"/> Oceans & Habitat Management and SARA	<input checked="" type="checkbox"/> Species at Risk
<input type="checkbox"/> Policy	<input type="checkbox"/> Human impacts on Fish Habitat/ Ecosystem components
<input type="checkbox"/> Science	<input type="checkbox"/> Aquaculture
<input type="checkbox"/> Other (please specify):	<input type="checkbox"/> Ocean issues
	<input type="checkbox"/> Invasive Species
	<input type="checkbox"/> Other (please specify):

Initiating Branch Contact:	
Name: Tamee Mawani/ Karen Calla	Telephone Number: 604-666-9033 604-666-0395
Email: Tameezan.mawani@dfo-mpo.gc.ca	Fax Number:
Karen.calla@dfo-mpo.gc.ca	

Issue Requiring Science Advice (i.e., "the question"):
<i>Issue posed as a question for Science response.</i>
<p>Compilation of a research document (which will be the RPA) that will include the required information as stated in the revised protocol for conducting recovery potential assessments (revised in 2009). The RPA provides scientific background, identification of threats and probability of recovery of a species, or population, that is deemed to be at risk.</p> <p>In July 2004, the ADM Fisheries and Aquaculture Management agreed to work towards integrating the Precautionary Approach (PA) into Fisheries Management Renewal on groundfish fisheries. To this end staff were instructed to ensure all future Science assessments begin to include candidate Limit Reference Points for groundfish and pelagic fisheries. In this context is it appropriate to recommend candidate Limit Reference Points (LRP), an Upper Stock Reference Point (USR) and target reference point (TRP) for the quillback rockfish (coastwide)? IF so what would the candidate points be (include biological considerations and rationale used to form these recommended candidate points.)</p> <p>What is the current status of the quillback rockfish stock (coastwide) relative to the DFO Precautionary Approach harvest default reference points? Provide rationale for if the LRP, USR and TRP candidates differ from the PA default reference points and include decision tables which forecast the impact of varying harvest levels on future population trends.</p> <p>Any assessment should give consideration to recreational and food, social, ceremonial harvest of quillback. In addition, quillback catch within the commercial prawn by trap fishery should be considered.</p>

Rationale for Advice Request:
<i>What is the issue, what will it address, importance, scope and breadth of interest, etc.?</i>
This species has been designated as threatened by COSEWIC and the completion of a RPA is a mandated requirement in the listing decision process for species at risk.

Possibility of integrating this request with other requests in your sector or other sector's needs?

n/a

Intended Uses of the Advice, Potential Impacts of Advice within DFO, and on the Public:

Who will be the end user of the advice (e.g. DFO, another government agency or Industry?). What impact could the advice have on other sectors? Who from the Public will be impacted by the advice and to what extent?

This advice will be used in the Species at Risk Act legal listing decision for quillback rockfish and any management actions could possibly be included in the 2012/2013 groundfish IFMP.

Date Advice Required:

Latest possible date to receive Science advice: May 2011.

Funding:

Specific funds may already have been identified to cover a given issue (e.g. SARCEP, Ocean Action Plan, etc.)

Source of funding: SARCEP

Expected amount:

Initiating Branch's Approval:

Approved by Initiating Director:

Date:

Name of initiating Director: Sue Farlinger

Send form via email attachment following instructions below:

Regional request: Depending on the region, the coordinator of the Regional Centre for Science Advice or the Regional Director of Science will be the first contact person. Please contact the coordinator in your region to confirm the approach.

National request: At HQ, the Director of the Canadian Science Advisory Secretariat (Ghislain.Chouinard@dfo-mpo.gc.ca) AND the Director General of the Ecosystem Science Directorate (Sylvain.Paradis@dfo-mpo.gc.ca) will be the first contact persons.

PART 2: RESPONSE FROM SCIENCE

In the regions: to be filled by the Regional Centre for Science Advice.

At HQ: to be filled by the Canadian Science Advisory Secretariat in collaboration with the Directors of the Science program(s) of concern.

<p>Criteria characterising the request:</p> <p><input type="checkbox"/> Science advice is requested (rather than just information)</p> <p><input type="checkbox"/> A sound basis of peer-reviewed information and advisory precedent already exists.</p> <p><input type="checkbox"/> Inclusiveness is an issue</p> <p><input type="checkbox"/> Advice on this specific issue has been provided in the past.</p> <p><input type="checkbox"/> Urgent request.</p> <p><input type="checkbox"/> DFO is not the final advisory body.</p> <p style="padding-left: 20px;"><input type="checkbox"/> CEAA process</p> <p style="padding-left: 20px;"><input type="checkbox"/> COSEWIC process</p> <p style="padding-left: 20px;"><input type="checkbox"/> Other:</p>	<p>Constraints regarding the planning of a standard peer review/Workshop:</p> <p><input type="checkbox"/> External expertise required</p> <p><input type="checkbox"/> This is a scientifically controversial issue, i.e., consensus does <i>not</i> currently exist within DFO science.</p> <p><input type="checkbox"/> Extensive preparatory work is required.</p> <p><input type="checkbox"/> Determination of information availability is required (prior to provision of advice).</p> <p><input type="checkbox"/> Resources supporting this process are not available.</p> <p><input type="checkbox"/> Expected time needed for the preparatory work:</p> <p><input type="checkbox"/> Other (please specify):</p>	<p>Other criteria that could affect the choice of the process, the timelines, or the scale of the meeting:</p> <p><input type="checkbox"/> The response provided could be considered as a precedent that will affect other regions.</p> <p><input type="checkbox"/> The response corresponds to a new framework or will affect the framework currently in place.</p> <p><input type="checkbox"/> Expertise from other DFO regions is necessary.</p> <p><input type="checkbox"/> Other (please specify):</p>
<p>Recommendation regarding the advisory process and the timelines:</p>		
<p><input type="checkbox"/> Science Special Response Process (SSRP)</p>	<p><input type="checkbox"/> Workshop</p>	<p><input type="checkbox"/> Peer Review Meeting</p>
<p>Rationale justifying the choice of process:</p> <p>Types of publications expected and if already known, number of report for each series:</p> <p><input type="checkbox"/> Science Advisory Report (●) <input type="checkbox"/> Research Document (●)</p> <p><input type="checkbox"/> Proceeding (●) <input type="checkbox"/> Science Response Report (●)</p> <p><input type="checkbox"/> Other:</p>		
<p>Date Advice to be Provided:</p> <p><input type="checkbox"/> Date specified can be met.</p> <p><input type="checkbox"/> Date specified can NOT be met.</p> <p>Alternate date, as agreed to by client Branch lead and Science lead:</p>		

OR

No Formal Response to be Provided by Science

Rationale:

- DFO Science Region does not have the expertise required.
- DFO Science Region does not have resources available at this time.
- The deadline can not be met.
- Not a natural science issue (e.g. socio-economic)
- Response to a similar question has been provided elsewhere:
Reference:

Additional explanation:

Science Branch Lead:

Name:

Telephone Number:

Email:

* Please contact Science Branch lead for additional details on this request.

Science Branch Approval:

Approved by Regional Director, Science (or their delegate authority):

Date:

Name of the person who approved the request:

Once part 2 completed, the form is sent via email attachment to the initiating Branch contact person.

PART 3: PLANNING OF THE ADVISORY PROCESS

Science Branch Approval:

Coordinator of the event:

Potential chair(s):

Suggested date / period for the meeting:

Need a preparatory meeting:

Leader of the Steering Committee: