Chapter 13: Assessment of the Rougheye and Blackspotted Rockfish stock in the Gulf of Alaska (Executive Summary)

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Introduction

Rockfish are assessed on a biennial stock assessment schedule to coincide with the availability of new survey data. We use a separable age-structured model as the primary assessment tool for Gulf of Alaska rougheye and blackspotted rockfish (RE/BS complex). The model consists of an assessment, which uses survey and fishery data to generate a historical time series of population estimates, and a projection which uses results from the assessment model to predict future population estimates and recommended harvest levels. The model was constructed with AD Model Builder software and allows for size composition data that is adaptable to several rockfish species. For Gulf of Alaska rockfish in alternate (even) years we present an executive summary to recommend harvest levels for the next (odd) year. For this off-cycle year, we only updated the 2009 projection model estimates with revised catch data for 2009 and a new catch estimate for 2010. Please refer to last year's full stock assessment, which is available online, (Shotwell et al., 2009 http://www.afsc.noaa.gov/REFM/docs/2009/GOArougheye.pdf) for further information regarding the assessment model. A full stock assessment document with updated assessment and projection model results will be presented in next year's SAFE report.

Updated ABC, OFL, Catch and Projection

New information for this year's projection is updated 2009 catch at 280 t and the October 2 estimate of the 2010 catch at 445 t. Catch estimates used in last year's model were 278 t and 400 t for 2009 and 2010, respectively. For the 2011 fishery, we recommend the maximum allowable ABC of 1,312 t from the updated projection. This ABC is very similar to last year's ABC of 1,302 t. The corresponding reference values for the RE/BS complex are summarized in the following table, with the recommended ABC and OFL values in bold. The stock is not overfished, nor is it approaching overfishing status.

Quantity/Status	Last Year (2009)		This Year	
	2010	2011	**2011**	2012
M (natural mortality)	0.034	0.034	0.034	0.034
Specified/recommended Tier	3a	3a	3a	3a
Projected biomass (ages 3+)	45,751	45,935	45,907	46,154
Female spawning biomass (t)				
Projected	13,638	13,729	13,720	13,684
$B_{100\%}$	25,463	25,463	25,463	25,463
$B_{40\%}$	10,185	10,185	10,185	10,185
$B_{35\%}$	8,912	8,912	8,912	8,912
F_{OFL}	0.048	0.048	0.048	0.048
$maxF_{ABC}$ (maximum allowable = $F_{40\%}$)	0.040	0.040	0.040	0.040
Specified/recommended F_{ABC}	0.040	0.040	0.040	0.040
Specified/recommended OFL (t)	1,568	1,581	**1,579**	1,579
Specified/recommended ABC (t)	1,302	1,313	**1,312**	1,312
Is the stock being subjected to overfishing?	No	No	No	No
Is the stock currently overfished?	No	No	No	No
Is the stock approaching a condition of being overfished?	No	No	No	No

*Projected ABCs and OFLs for 2012 are derived using an expected catch value of 368 t for 2011 based on recent ratios of catch to ABC. This calculation is in response to management requests to obtain a more accurate one-year projection.

Area Apportionment

The apportionment percentages are identical to last year, because there is no new survey information. The following table shows the recommended apportionment for 2011. Please refer to last year's SAFE report for information regarding the apportionment rational for rougheye and blackspotted rockfish.

	Western	Central	Eastern	Total
Area Apportionment	6.16%	66.18%	27.65%	100%
Area ABC (t)	**81**	**868**	**363**	**1,312**
OFL (t)				**1,579**

Responses to Council, SSC, and Plan Team Comments

The GOA Plan Team 2009 minutes included the following comments concerning all stock assessments:

"That the AFSC coordinate with the Regional Office a source for catch data to ensure that authors use the same set of reports for recent years (e.g., for the current and previous year). This also applies for prohibited species catch (PSC) tables as well as non-target species catch."

A coordinated effort between Fisheries Monitoring and Assessment (FMA) division, the Alaska Regional Office (AKRO) and the Pacific States Marine Fisheries Commission (PSMFC) was initiated in 2009 to utilize the Alaska Fisheries Information Network (AKFIN) as a data warehouse for Alaska Fisheries Science Center (AFSC) economists and stock assessment scientists. A workshop was held in February 2010 at the Auke Bay Laboratories (ABL) where FMA, AKRO, AKFIN, and ABL staff discussed the types of fishery data required each year for the stock assessments and SAFE reports. Included in this workshop was an introduction to the new AKFIN Answers Dashboard site and newly added North Pacific Observer (NORPAC) database tables. The AKFIN site is a coordinated effort between AKRO, FMA, and AKFIN to house and distribute fishery data. The new NORPAC tables maintain continuity of the observer data across the entire historical time series. Following this workshop a reports committee consisting of AFSC and AKFIN staff was developed to produce standardized catch reports available through the AKFIN Answers site. These reports are in the testing phase and will be available for assessments in 2011.

"For fisheries where bycatch in halibut fisheries apply, authors are requested to coordinate with the Regional Office or other appropriate agency to account for these removals."

The issues of unobserved incidental catch in the IFQ halibut fishery is of increasing concern in the management of many GOA species, and the SSC has specifically requested catch estimates for rougheye rockfish, sharks and skates. A working group was formed in 2010 to examine quantitative methods to estimate the incidental catch of non-target species. The working group presented multiple approaches to the Joint Groundfish Plan Team at the September 2010 meeting and will present catch estimates of four example species for review at the November 2010 Plan Team meeting. After the SSC reviews the methods and determines the most appropriate, the working group will prepare time series estimates of catch for all non-target species. This data will be available to assessment authors for the 2011 stock assessment cycle.

The SSC December 2009 minutes included the following comments concerning all stock assessments:

"The SSC suggests that description of the apportionment rationale in each SAFE chapter of area-apportioned species would be helpful to the reader."

The apportionment rationale for the RE/BS complex is explained in the *Area Allocation of Harvests* section of the 2009 full SAFE report under *Projections and Harvest Alternatives*. Apportionment is determined based on the geographic distribution of rougheye and blackspotted rockfish biomass in the trawl surveys. This distribution has been computed as a weighted average of the percent biomass distribution for each area in the three most recent trawl surveys. Each successive survey is given a progressively heavier weighting using factors of 4, 6, and 9, respectively.

The GOA Plan Team 2009 minutes included the following comments concerning all rockfish:

"Some rockfish assessments may have revised maturity estimates and the Team would like to review comparisons of these studies in September 2010. In particular, locations and timing of samples, and recommendations from assessment authors for approaches to modifying assessments."

A report on estimating rockfish maturity in the Gulf of Alaska was prepared and presented by ABL rockfish staff for the September 2010 Plan Team meeting. The GOA rockfish assessment authors will investigate methods for incorporating new maturity information into the assessment for 2011. Allowing for uncertainty of maturity estimates within the assessment is a possibility, but further exploration of such methods is needed.

The GOA Plan Team 2009 minutes included the following comments concerning rougheye and blackspotted rockfish:

"Plan Team recommendations for the next assessment:

1.) *Go through the stock structure template for rougheye and blackspotted species*
2.) *Evaluate to what extent bycatch in the halibut fishery is an issue in terms of total removals. Note to coordinate with other authors regarding appropriate methodology for estimating bycatch from this fishery.*
3.) *Note that a research priority should be to analyze genetic samples from the 2009 trawl survey."*

Response to Comment 1:
Please refer to Appendix A of this document for a thorough evaluation of research regarding GOA rougheye and blackspotted rockfish stock structure. We follow the stock structure template recommended by the Stock Structure Working Group (SSWG) to the Plan Teams in 2009 and elaborate on each category within this template. Also included are discussions on distribution, speciation, misidentification, and implications for management. Given this evaluation, we recommend continuing the current management of area-specific ABCs and gulf-wide OFLs for rougheye and blackspotted rockfish.

Response to Comment 2:
Please refer to our previous response regarding bycatch in the halibut fisheries in GOA Plan Team 2009 minutes section concerning all stock assessments. We intend to include estimates of rougheye and blackspotted rockfish bycatch in the halibut fishery in the 2011 full assessment SAFE report.

Response to Comment 3:
Please refer to the section on *Distribution, Speciation, and Misidentification* in Appendix A of this document for a summary of the special project initiated on the 2009 GOA trawl survey. The goal of this study was to collect relevant biological and genetic data to improve at-sea identification and examine differences in life history characteristics between rougheye and blackspotted rockfish. This project was designated a priority for otolith requests and genetic identification of samples. During the summer of

2010, otolith samples for this study were aged by the AFSC Age and Growth Lab and the genetic samples were analyzed by scientists at Auke Bay Laboratories.

The SSC December 2009 minutes included the following comments concerning rougheye and blackspotted rockfish:

"The SSC repeats its earlier request that the assessment authors bring forward separate models for the two rockfish species. The SSC recognizes that a key step towards the development of a split species model is the improvement in the accuracy of species identification by NMFS survey scientists and observers. A high priority should be placed on improving species identifications for rougheye and blackspotted rockfish through improvements in observer training and field identification guides (e.g., continued refinement of the species ID pamphlet that came out of Orr and Hawkins 2008 work)."

In December 2007 the SSC requested that the GOA rougheye and blackspotted rockfish authors "*work to bring forward a rationale for decisions regarding assessment of mixed species groups with attention to the potential for overfishing the weaker stock.*" In December 2008 the SSC endorsed the preparation of a new field identification pamphlet and stated that "*identification of rockfish to species is a high research priority*". We responded to the 2007 comment in the *Responses to Council, SSC, and Plan Team Comments* section of the 2008 GOA Rougheye and Blackspotted Rockfish Executive Summary. We elaborated on this response in the 2009 GOA Rougheye and Blackspotted Rockfish SAFE report in the *Evidence of Stock Structure* section of the *Introduction*. This section included a summary of the recent studies on the genetic and phenotypic differences between rougheye and blackspotted rockfish and a discussion of the current research regarding high at-sea misidentification rates and understanding species specific life history characteristics. We additionally include a complete stock structure evaluation of rougheye and blackspotted rockfish in Appendix A of this document. Preliminary results of the identification studies on the 2009 GOA trawl survey are included in the *Distribution, Speciation, and Misidentification* section of Appendix A.

At present, the high misidentification rates preclude the development of separate models for rougheye and blackspotted rockfish in the GOA. The special project on the 2009 GOA trawl survey will enhance training and field identification guides, allow for accurately specifying misidentification rates, and begin estimating biological parameters such as growth and distribution by species. In the future, we plan to extend this sampling to commercial fisheries as a special project requested of the Observer Program. When combined with accurate species-specific catch and survey data, such information will help determine the utility of a separate species models for examining if one species is a weaker stock and may be at greater risk of overfishing.

"The SSC agrees that currently using a mixed species model does not pose a conservation concern because directed fisheries are prohibited, and the incidental catch of rougheye and blackspotted rockfish remains well below the recommended ABC. However, the catch should be monitored to prevent overfishing. In particular, the authors should monitor the bycatch trends in the sablefish, halibut longline fisheries, and look for evidence of "topping off" in the POP fishery."

Under ACL management in 2011, catch accounting of total removals is required in groundfish stock assessments. A multi-agency effort is underway to identify all sources of mortality and determine appropriate methods of bycatch estimation and weight calculations. An example is the halibut bycatch working group discussed in the GOA Plan Team comments concerning all stock assessments. Summaries of these efforts were presented to the Plan Teams in September 2010. When available, we intend to utilize the potential single source database (e.g. AKFIN as discussed previously) to monitor and report all sources of rougheye and blackspotted rockfish catch.

"The SSC notes that the MCMC estimate of trawl survey q for the rougheye complex (0.381 Model 2) is considerably different than the q for dusky rockfish (0.911 Model 2). It would be useful to compare the model estimates of q for different species of rockfish and consider whether the estimates are reasonable."

The MCMC estimate of trawl survey *q* for GOA rougheye and blackspotted rockfish is 1.528, while the Hessian estimate is 1.478 (Table 13-13, 2009 GOA RE/BS SAFE). The contribution of the prior distribution imposed on the trawl survey *q* to the likelihood was 0.381 (Table 13-12, 2009 GOA RE/BS SAFE). However, the MCMC and Hessian estimates of GOA rougheye and blackspotted *q* are different from the dusky rockfish *q* (0.911 Model 2). We intend to compare the estimates of *q* for different rockfish species and results will be presented in the 2011 full assessment SAFE report.

"As noted in the assessment, the rockfish pilot project may allow improved utilization of the rockfish quotas. The authors should continue to consider the impact of the rockfish pilot program on catch."

We continue to monitor the rockfish pilot program and intend to include an update of the program in the 2011 full assessment SAFE report.

Research Priorities

It is critically important to rockfish stock assessments that the GOA trawl surveys continue and that they extend into deeper waters (>300m) in order to cover the range of primary habitat for rockfish, especially the rougheye rockfish complex. There is little information on larval, post-larval, or early juvenile stages of rockfish. Habitat requirements for these stages are mostly unknown. Research on early life history parameters and essential habitat for these early life stages is vital to effective management of rockfish.

Summaries for Plan Team

Species	Year	Biomass[1]	OFL	ABC	TAC	Catch[2]
RE/BS complex	2009	46,385	1,545	1,284	1,284	280
	2010	45,751	1,568	1,302	1,302	445
	2011	45,907	1,579	1,312		
	2012	46,154	1,579	1,312		

[1]Total biomass from the age-structured model

Stock/ Assemblage	Area	2010 OFL	2010 ABC	2010 TAC	2010 Catch[2]	2011 OFL	2011 ABC	2012 OFL	2012 ABC
RE/BS complex	W		80	80	94		81		81
	C		862	862	211		868		868
	E		360	360	140		363		363
	Total	1,568	1,302	1,302	445	1,579	1,312	1,579	1,312

[2]Current as of October 2, 2010 (http://www.fakr.noaa.gov/2010/2010.htm)

Appendix A: Stock structure evaluation for the Gulf of Alaska rougheye and blackspotted rockfish complex

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Executive Summary

We present various types of information on Gulf of Alaska (GOA) rougheye and blackspotted rockfish to evaluate potential stock structure within this species complex. Recently, the presence of two species, rougheye rockfish (*Sebastes aleutianus*) and blackspotted rockfish (*S. melanostictus*), was formally verified in what was once considered a single variable species with light and dark color morphs. Since 2007, assessment authors have been requested to develop a rationale for decisions regarding mixed stock species groups with attention to overfishing the weaker stock. Currently, there is no information on whether the two species have significantly different life history traits (e.g. age of maturity, growth). An attempt to separate data by species has occurred for several years on the Alaska Fisheries Science Center (AFSC) bottom trawl survey. However, several special projects with include genetic identification have shown high rates of misidentification in the field. Scientists and observers are currently evaluating new techniques to determine whether rapid and accurate field identification can occur. Until observers and survey biologists can reliably identify both species, we must continue to manage rougheye and blackspotted as a complex.

We, therefore, present the available stock structure data for the two species as a complex and refer to this as the rougheye/blackspotted rockfish complex or RE/BS rockfish. We follow the stock structure template recommended by the Stock Structure Working Group (SSWG) and elaborate on each category within this framework. Both non-genetic and genetic information are consistent with population structure by large management areas of eastern, central, and western GOA defined by fishery and survey sampling. This is evident in the non-genetic data as opposite trajectories for population trends by area, significantly different age, length, and growth parameters by area, and significant differences in parasite prevalence and intensity by area. Genetic studies have generally been focused on the speciation of the RE/BS complex; however, consistencies between the two species also suggest population structure by management area. Tests of homogeneity and adjacency show genetic structure consistent with a neighborhood model of dispersion. Dispersal distance for blackspotted rockfish in the GOA was consistent with management areas while rougheye rockfish in the eastern GOA may exhibit finer scale population structure.

Currently, GOA RE/BS rockfish is managed as a Tier 3a species with area-specific Acceptable Biological Catch (ABC) and gulf-wide Overfishing Level (OFL). Given the multiple layers of precaution instituted with relatively low Maximum Retained Allowance (MRA) percentages, a bycatch only fishery status, and the on average low area-specific harvest rates, we continue to recommend the current management specifications for RE/BS rockfish.

Introduction

The Stock Structure Working Group (SSWG) was formed in 2009 to develop a set of guidelines to assist stock assessment authors in providing recommendations on stock structure for Alaska stocks. The framework was presented at the September 2009 joint Groundfish Plan Team and a report was drafted shortly thereafter that included a template for presenting various scientific data for inferring stock structure (Table A1). The document was subsequently updated for the September 2010 joint Groundfish Plan Team (Spencer et al. 2010) and scheduled discussion will include the application of the template to specific cases developed in the report. One case is the Bering Sea/Aleutian Islands (BSAI) blackspotted and rougheye rockfish complex.

In this document, we extend the BSAI case to the Gulf of Alaska (GOA) rougheye and blackspotted rockfish complex. This completes the stock structure evaluation for rougheye and blackspotted rockfish in Alaska and allows for comparison of author recommendations and management implications between the two documents. In the first section of this document we provide general information on rougheye and blackspotted rockfish distribution and life history from the current GOA stock assessment and fishery evaluation report (SAFE) (Shotwell et al. 2009). We include a summary of genetic analyses determining the two species, and recent issues with misidentification in the GOA surveys. These topics are not specifically addressed in the stock structure template; however, this information is relevant for interpreting recent survey data. In the second section, we apply the stock structure template (Table A1) and elaborate on each category. Finally, we provide a summary of the stock structure information followed by author recommendations and management implications.

Distribution, Speciation, and Misidentification

Rougheye and blackspotted rockfish inhabit the outer continental shelf and upper continental slope of the northeastern Pacific. Their distribution extends around the arc of the North Pacific from Japan to Point Conception, California and includes the Bering Sea (Kramer and O'Connell 1988). The center of abundance appears to be Alaskan waters, particularly the eastern GOA. Adults in the GOA inhabit a narrow band along the upper continental slope at depths of 300-500 m; outside of this depth interval, abundance decreases considerably (Ito, 1999). Though relatively little is known about their biology and life history, rougheye and blackspotted rockfish have relatively high fecundity, late maturation, slow growth, extreme longevity, and low natural mortality. These species often co-occur with shortraker rockfish (*Sebastes borealis*) in trawl or longline hauls.

Recent studies on the genetic differences between the observed types of rougheye rockfish indicate two distinct species (Gharrett et al. 2005, Hawkins et al. 2005). The proposed speciation was initiated by Tsuyuki and Westrheim (1970) after electrophoretic studies of hemoglobin resolved distinct banding patterns in rougheye rockfish. Subsequent allozyme-based studies demonstrated clear isolation in samples (Seeb 1986) and five distinguishable loci for an Aleutian and Southeast type (Hawkins et al. 1997). A later extended allozyme study found the two types occurred in sympatry (overlapping distribution without interbreeding), and samples with depth information demonstrated a significantly deeper depth for the Aleutian type rougheye (Hawkins et al. 2005). Additional studies analyzed the variation in mitochondrial DNA and microsatellite loci and determined the two distinct types with relatively little hybridization (Gharrett et al. 2005). Please refer to Shotwell et al. (2009) for more detail on these genetic studies.

In 2008, Orr and Hawkins formally verified the two species as rougheye rockfish (*Sebastes aleutianus*) and blackspotted rockfish (*S. melanostictus*). They used combined genetic analyses of 339 specimens from Oregon to Alaska to identify the two species and formulated general distribution and morphological characteristics for each. Rougheye rockfish is typically pale with spots absent from the spinous dorsal fin and potential mottling on the body. Blackspotted rockfish is darker with spotting almost always present on the dorsal fin and body. The two species occur in sympatric distribution with rougheye extending farther south along the Pacific Rim and blackspotted extending into the western Aleutian Islands. The overlap is quite extensive (Gharrett et al. 2005, 2006).

At present there is difficulty in accurate at-sea field identification between the two species. In 2005 and 2006, the AFSC longline survey conducted two-day sampling experiments in the eastern GOA near Yakutat Bay. Approximately 250 samples were collected across a depth range of 200-400 m. Three identification methods were performed on each sample: at-sea identification of the fresh fish, expert (J. Orr) identification based on photographs of the fresh fish, and genetic identification in the laboratory to positively determine the species. Initially, misidentification rates in the field and by the expert were 46% and 29%, respectively. Following the Orr and Hawkins (2008) paper, several other morphological features were deemed important for blackspotted rockfish identification. Upon re-examination, the expert misidentification rate was reduced to 9%.

The results from these identification exercises led AFSC scientists to be concerned about their ability to accurately distinguish between the two species during surveys. In December 2007, the Science and Statistical Committee requested rougheye assessment authors develop a rationale for decisions regarding mixed stock species groups with attention to overfishing the weaker stock. There is no information on whether the two species have significantly different life history traits (e.g. age of maturity, growth). If differences in growth and maturity exist, disproportionate harvest rates could result. In the GOA, there is a large degree of overlap between the two species. Gulf-wide OFLs for this species complex may result in bycatch consisting of a large proportion of one species or the other.

In response to these concerns, a special project was initiated during the 2009 AFSC GOA bottom trawl survey. The goal of this study is to collect relevant biological and genetic data to improve at-sea identification and examine differences in life history characteristics between the two species. Field scientists collected length, weight, and muscle tissue from all rougheye and blackspotted rockfish being sampled for otoliths. Additionally, all unknown rougheye/blackspotted specimens were sampled for otoliths. For the whole survey, 934 otoliths and tissue samples were collected. Of these 420 were blackspotted, 495 were rougheye, and 19 were unidentified blackspotted/rougheye. During the summer of 2010, otolith samples for this study were aged by the AFSC Age and Growth Lab and the genetic samples were analyzed by scientists at Auke Bay Laboratories. Preliminary analysis of these samples suggested similar misidentification rates to the previous exercises on the longline survey (J. Heifetz, *personal communication*).

The special project on the 2009 GOA trawl survey will enhance training and field identification guides, allow for accurately specifying misidentification rates, and begin estimating biological parameters such as growth and distribution by species. In the future, we plan to extend this sampling to commercial fisheries as a special project requested of the Observer Program. When combined with accurate species-specific catch and survey data, such information will help determine whether one species is a weaker stock and may be at greater risk of overfishing.

Application of Stock Structure Template

Since the formal verification of the two species has only recently occurred, most data on rougheye and blackspotted rockfish is for both species combined. For the purpose of this stock structure evaluation, we generally refer to the two species together as the rougheye/blackspotted rockfish complex or RE/BS rockfish. We utilize the example framework for defining spatial management units (Spencer et al. 2009) to evaluate stock structure for RE/BS rockfish (Table A1). In the following sections, we elaborate on the available information for each category within this template.

Harvest and Trends

We present information on fishery and survey trends from the current SAFE for GOA rougheye and blackspotted rockfish (Shotwell et al. 2009). This information determines whether fishing mortality is large enough such that disproportionate harvests by area may be a conservation concern and to identify population trends by area that may indicate additional precautionary measures. We then examine the spatial overlap between fishery and survey data to determine if fishing pressure is on the same spatial scale as the surveyed population. This information is presented qualitatively with a series of spatial distribution maps and overlays.

Fishery (Shotwell et al. 2009)

Rougheye and blackspotted rockfish have been managed as a "bycatch" only species since 1991 when the North Pacific Fishery Management Council (NPFMC) separated the shortraker/rougheye rockfish management subgroup from the slope rockfish assemblage. This subgroup was classified into Tier 4 and assessment was based primarily on survey biomass estimates rather than age-structured modeling. In 2004, shortraker rockfish and rougheye rockfish were divided into separate subgroups to protect from possible overfishing. In 2005, an age-structured model was accepted for determining ABC (Acceptable Biological Catch) of rougheye rockfish and status was moved to Tier 3. Following the formal verification of the two rougheye species in 2008, rougheye rockfish was renamed the rougheye and blackspotted rockfish complex (RE/BS rockfish). ABC and TAC (Total Allowable Catch) are currently calculated for the two species as a complex and are apportioned to the three management areas of the GOA (western, central, and eastern). This apportionment is based on a weighted average of recent trawl survey estimates.

In 2006, NMFS issued a final rule on Amendment 68 to implement the Central Gulf of Alaska Rockfish Pilot Program, a five year rationalization program (2007-2011) that establishes cooperatives among trawl vessels and processors which receive exclusive harvest privileges for rockfish management groups. The intention of the Rockfish Pilot Program is to enhance resource conservation and improve economic efficiency for harvesters and processors who participate in the rockfish fishery. The program may affect the spatial distribution of fishing effort within the Central GOA since the extended fishing season lasts from May 1 through November 15 instead of an approximate two week fishery in July that had existed previously. The fishery should essentially spread out in space and time, allowing for improved product prices and reduced fishing pressure. The program should also improve at-sea and plant observer coverage for vessels participating in the rockfish fishery and result in higher potential to harvest 100% of the TAC in the Central GOA region.

Historically, gulf-wide catches of RE/BS rockfish have been between 130 t and 2,418 t (Figure A1a) and have generally been well below the available TAC since 1991. RE/BS rockfish are caught in either bottom trawls or with longline gear, and about half came from each gear type in 2009. Fully selected fishing mortality increased in the late 1980s and early 1990s and returned to relatively low levels from 1993 to present (Figure A1b). The spike may be due to the management of RE/BS rockfish in the slope rockfish complex prior to 1991 and the disproportionate harvest on shortraker due to their high value. Rougheye would also be caught as they often co-occur with shortraker. Since 2005, when separate catch accounting for RE/BS rockfish was implemented, total catch has been well below available TAC. Recent catch by management region suggest different spatial trends. Catch in the western GOA has been slowly increasing over time. Catch in central GOA has been highly variable over time and currently above average. Catch in the eastern GOA was increasing steadily until 2007 then decreased dramatically and only increased in the most recent year to slightly above average. Additionally, catches in the western GOA are closer to maximum of F_{ABC}, particularly in the most recent year (2010 estimated catch in the western GOA as of September 3 = 76 t with TAC set at 80 t, from www.fakr.noaa.gov). Catch in the eastern and central GOA have been well below maximum of F_{ABC} since 2008. These differences in fishing pressure by area may reflect changes due to the implementation of the Rockfish Pilot Program and vessel differences by area.

Survey (Shotwell et al. 2009)

Standard bottom trawl and longline surveys conducted by the AFSC provide much information on rougheye and blackspotted rockfish. Each survey captures a different element of the RE/BS rockfish population. The trawl survey stations cover the entire GOA from the nearshore to the shelf break (500-

1000 m) and are distributed based on a stratified random sampling design. The longline survey stations are systematically distributed near the shelf break and in various gullies throughout the GOA. Therefore, both surveys sample different parts of the RE/BS rockfish population. The trawl survey is not typically capable of sampling the deeper depths and high relief habitat of rougheye and blackspotted rockfish, while the longline survey can sample a large variety of habitats. Gear may also play a role. Juvenile fish are not susceptible to longline gear; consequently, the longline survey does not provide much information on recruitment. The trawl survey may be limited in sampling particular habitats, but does capture juveniles. We consider the trends in both surveys for understanding spatial and temporal patterns of RE/BS rockfish.

Bottom trawl surveys were conducted on a triennial basis in the Gulf of Alaska in 1984, 1987, 1990, 1993, 1996, and 1999. These surveys became biennial starting in 2001. The surveys provide an abundance index, age composition, and growth characteristics. The biomass estimates for rougheye and blackspotted rockfish have been relatively constant among the surveys, with the possible exception of 1993 and 2007 (Figure A2a). Compared with other species of *Sebastes*, the biomass estimates for rougheye and blackspotted rockfish show relatively tight confidence intervals and low coefficients of variation (CV), ranging between 11% and 23%. The low CVs are an indication of the rather uniform distribution for this species complex. Historically estimates by region suggested that the western and eastern GOA time series of biomass tended to be in opposite phase. Since 2003, the central and eastern GOA estimates have increased, while the western GOA has decreased and remained relatively low.

Since 1990, the longline survey has collected catch, effort, and length data annually for RE/BS rockfish. Longline data were expressed as a relative population weight (RPW) and the standard deviation of the time series is used to approximate the standard error of the individual estimates. We use 20% as the CV for this index. Longline survey RPW estimates for rougheye have been relatively constant since 1990, with the exception of large increases in 1997 and again in 2000 (Figure A2b). A sharp decline occurred in 2005 and estimates increased until 2007, declined by 2 % in 2008 and 17 % in 2009. The present value is approximately 5% below average.

In 2007, the GOA bottom trawl survey began separating rougheye rockfish from blackspotted rockfish using a species key developed by J. Orr (Orr and Hawkins, 2006). Biomass estimates by region of the two species somewhat support the broad southern and northern distribution of the two species in that blackspotted estimates were higher in the western GOA and rougheye estimates were higher in the eastern GOA (Figure A3). However, both species were identified in all regions, implying some overlap throughout the GOA. Over all areas, more blackspotted rockfish were identified than rougheye in 2007 (56% versus 44%), while in 2009 the reverse occurred (36% versus 64%). This was primarily due to the central GOA which contains the majority of the biomass for both species (Figure A3). Given the preliminary results from current research of high at-sea misidentification rates between the two species, and the clear overlap in all areas, we continue to combine all survey data for both species.

Spatial Overlap of Fishery and Survey

We utilized the above sources of fishery and survey data to generate a series of spatial distribution maps of RE/BS rockfish concentrations. We first developed maps of mean conditions to identify long-term patterns in RE/BS distribution (Figure A4). In order to compare different surveys and the fishery data on the same map, we created an interpolated raster image of the trawl survey data (Figure A4a). The trawl survey provided the most complete spatial coverage and weight estimates were available by haul. This data was also the most spatially comparable to the observed fishery data. We then considered the spatial distribution of RE/BS numbers from the longline survey and catch from the observed fishery relative to mean trawl survey conditions. The spatial overlay shows that on average the trawl survey tends to catch more RE/BS rockfish in the central GOA, while the longline survey catches more RE/BS rockfish in the eastern and western GOA (Figure A4b). In general, the mean catches for the fishery are distributed similarly to the trawl survey (Figure A4c). However, the shelf area of the Amatuli Gully region (broad shallow gully southwest of Prince William Sound) is an area of moderate trawl survey catch with very little fishery influence. This area may act as a nursery for smaller, potentially immature rougheye which would typically inhabit these shallower depths. Additionally, a comparison of the weight versus numbers for the trawl survey suggests high numbers and low weight in the Amatuli Gully area supporting the concept of smaller rougheye in this area.

Barriers and Phenotypic Characters

Generation Time and Maturity

We estimated generation time for RE/BS rockfish at 52 years following the methods described in Restrepo et al. 1998. Due to their longevity rockfish may be expected to have large generation times. However, this is particularly high even for rockfish and is likely due to the low natural mortality and late maturity for RE/BS rockfish (Spencer et al. 2010). Additionally, size at 50% maturity has been determined for 430 specimens of rougheye and blackspotted rockfish (McDermott 1994). This was converted to age at 50% maturity using the size-age matrix from the most recent stock assessment (Shotwell et al. 2009). Estimated age at 50% maturity for the rougheye and blackspotted complex is 19 years. This information suggests that RE/BS rockfish are particularly vulnerable to overfishing.

Recently, a total of 413 samples from the McDermott (1994) maturity study were aged with 104 from the GOA. A preliminary analysis of this data estimated age at 50% maturity of 37 years, which is dramatically different from the current estimate. The discrepancy may have resulted from low sample size for ages and potential for high age error from these very old rockfish. A dedicated rockfish maturity study would be required to generate enough maturity samples to investigate spatially explicit estimates.

Physical Barriers

The larval, post-larval, and young-of-the-year stages for RE/BS rockfish appear to be pelagic (Matarese et al. 1989, Gharrett et al. 2002). However, larval studies are hindered because the rockfish larvae at present can only be positively identified by genetic analysis, which is both expensive and labor-intensive. Genetic techniques have been used recently to identify a few post-larval RE/BS rockfish from samples collected in epipelagic waters far offshore in the GOA, which is the only documentation of habitat preference for this life stage. There is no information on when juvenile fish become demersal. Juvenile rougheye and blackspotted rockfish (15- to 30-cm fork length) have been frequently taken in GOA bottom trawl surveys, implying the use of low relief, trawlable bottom substrates. They are generally found at shallower, more inshore areas than adults and have been taken in variety of locations, ranging from inshore fiords to offshore waters of the continental shelf. Studies using manned submersibles have found that large numbers of small, juvenile rockfish are frequently associated with rocky habitat on both the shallow and deep shelf of the GOA (Carlson and Straty 1981, Straty 1987, Krieger 1993).

General circulation in the GOA is dominated by two major current systems: the northward flowing Alaska Current which narrows and intensifies near Prince William Sound to become the westward flowing Alaskan Stream and the narrow, counter-clockwise flowing Alaska Coastal Current (Wiengartner et al. 2009). Bathymetry is highly complex in the GOA, with a wide central and narrow east/west continental shelf that is highly incised by large gullies and canyons (Ladd et al. 2005). Marine species such as RE/BS rockfish with pelagic larval stages have potential for high dispersal due to the dominant current systems; however, actual extent of dispersal is unknown (Gharrett et al. 2007). Interaction with high relief bathymetric features such as submarine canyons during the demersal settlement stage may cause dispersal to be more localized.

Age and Growth

Rougheye and blackspotted rockfish appear to be among the longest-lived of all *Sebastes* species (Chilton and Beamish 1982); therefore, interpretation of annuli on otoliths is extremely difficult. However, in 2005, scientists from the AFSC Age and Growth lab moved RE/BS rockfish aging into production mode using the break-and-burn method (Chilton and Beamish 1982). Otolith samples from the fishery are taken by observers aboard fishing vessels and at onshore processing facilities. Only a few years have been aged for RE/BS rockfish and sampling is fishery dependent; therefore, we do not evaluate these samples for determining spatial differences in age. Otoliths are also taken on the GOA bottom trawl survey and RE/BS rockfish samples have been aged for all survey years except 2001 (Table A2). These ages are taken on a length-stratified system in which several fish are taken from each length category. An age-length key for the area and year are then applied to get the correct estimate of proportion-at-age for the survey area. Age samples are distributed across the three major management areas as follows:

Area	Western GOA	Central GOA	Eastern GOA
Sample size	541	2,375	1,683

Although rougheye and blackspotted rockfish have been reported to be greater than 200 years old (Munk 2001), the highest age collected over these survey years was 132 (AFSC 2006). The average age ranged from 15 to 23 over all survey years available. Age samples for 2007 were split by rougheye and blackspotted rockfish. Rougheye compositions tend to be spread evenly across ages, while blackspotted tend to be much older, with a mean age of 15 and 24 for rougheye and blackspotted, respectively. This may be due to a high at-sea misidentification rate or a true difference in age distribution between species (Shotwell et al. 2009).

Size composition of the RE/BS commercial catch is available; however samples are limited from 1993 through 2001. Additionally, as “bycatch” only species, distribution of the RE/BS sizes would be target and gear dependent and not representative of the true spatial distribution across the GOA. Therefore, as with the fishery ages, we did not evaluate these samples for spatial structure. Size compositions are available from the GOA bottom trawl survey for the RE/BS complex for all survey years (Table A2). These lengths are approximately randomly distributed and proportionate to survey catch in the three major management areas in the GOA:

Area	Western GOA	Central GOA	Eastern GOA
Sample size	5,236	27,061	11,818

In general, survey size compositions are skewed to the right with a mode of 43-45 cm. The average length has steadily decreased over time, ranging from 41 to 34 cm. In the 2007 and 2009 survey blackspotted and rougheye rockfish lengths were split. Rougheye had an average length of 34 cm while blackspotted had an average of 40 cm. Rougheye tend to have a much broader range of lengths from 15-53 cm, while blackspotted tend to be more confined to the 37-50 cm range. Again, this may be indicative of species misidentification or a true difference in size distribution between species (Shotwell et al. 2009).

Large subsamples of RE/BS lengths were collected on the AFSC longline survey from 1990 through 2005 and lengths for nearly all RE/BS caught are taken in recent surveys. Size compositions for all years were normally distributed with a mode between 45 and 47 cm in length (Shotwell et al. 2009). However, as mentioned previously, the longline survey is a systematic design primarily on the shelf break and compositions show that small fish were rarely caught. We, therefore, did not evaluate these size samples for understanding spatial size structure by management area.

To evaluate the GOA trawl survey information, we fit von Bertalanffy growth curves to the mean length-at-age data by area. This showed significantly different growth curves by management area (Figure A5a). The growth curves by area were then tested against each other using likelihood ratio tests at an alpha=0.05. Models sharing parameters were tested against the full model where all parameters were estimated for each area. Table A3 shows the parameters that were significantly different between areas using these tests. The optimum model fits for the area comparisons are shown in Figure A5b, A5c, and A5d. All three growth parameters in the eastern GOA (EGOA) were significantly different than both the central and western GOA (CGOA and WGOA, respectively). The CGOA and WGOA only had a significantly different *k* parameter.

Mean length and age differences were tested using the Tukey Honest Significant Differences test to account for multiple testing between areas. Mean age and mean size differed significantly by area with the largest and oldest fish in the western GOA with a cline toward smaller and younger fish toward the east. Significance of proportions was tested against a two-sided null hypothesis of 0.5 of the binomial distribution. The sex ratio was not significantly different than 0.50 in 2 of 3 areas. The western GOA has significantly more males, but unlikely enough to be biologically important (Table A3). The proportion of rougheye as identified by the GOA trawl survey was significantly different between all areas with a high proportion of blackspotted rockfish identified in the western GOA. The observed spatial differences are potentially due to stock structure, variable harvest levels by management area, true species specific life history characteristics, or a combination of all three.

Morphometrics and Meristics (Shotwell et al. 2009)

Within species differences in field identifiable characters is unknown. However, several studies have considered phenotypic differences between rougheye and blackspotted rockfish. Gharrett et al. 2006 compared meristic characters and morphometric dimensions (35 reported) to genetically determined species. Samples were analyzed from eight of the 84 locations described in Gharrett et al. (2005) where coloration was recorded. Distributions of all the phenotypic parameters overlapped; however, Type II rougheye (likely rougheye rockfish) had slightly fewer and shorter gill rakers and deeper bodies. Upon examination of coloration, Type II were predominantly light colored, while Type I (likely blackspotted rockfish) fish were either light or dark and the proportion of either color varied geographically. Orr and Hawkins (2006) discuss preliminary results of a fairly extensive study on the recognition, identification, and nomenclature of the two types of rougheye rockfish. The blackspotted rockfish was distinguished primarily by a darker body color, discrete spotting on the dorsal fin and body, longer fin spines, longer gill rakers, and a narrower body depth at the anal-fin origin; although the morphometric differences were slight.

Behavior and Movement

Spawning (Shotwell et al. 2009)

As with other *Sebastes* species, RE/BS rockfish are presumed to be viviparous, where fertilization and incubation of eggs is internal and embryos receive at least some maternal nourishment. There have been no studies on fecundity of RE/BS in Alaska. One study on their reproductive biology indicated that rougheye and blackspotted rockfish had protracted reproductive periods, and that parturition (larval release) may take place in December through April (McDermott 1994). There is no information as to when males inseminate females or if migrations for spawning/breeding occur.

Mark-Recapture Data

Barotrauma induced by traditional mark-recapture studies does not allow for survival of physoclistic species such as RE/BS rockfish (Moles et al. 1998). Therefore, tagging data for RE/BS rockfish is not available. However, preliminary results from a recent experimental study suggest that portable pressure tanks may be utilized immediately after capture to reduce or completely reverse the physical signs of barotrauma in RE/BS rockfish. In July 2010, six RE/BS rockfish were caught on longline gear near Little Port Walter, Alaska and brought to the surface from ~700 m. Fish were immediately repressurized in portable tanks on board and signs of barotrauma (e.g. bulging eyes and everted esophagi) were reversed within minutes. The fish were then slowly brought to surface pressure over time and monitored in a live tank. Four of the six fish survived barotrauma effects, and two continued to survive until released in an aquarium for long-term monitoring. For two of the four barotrauma survivors, equipment malfunctions resulted in oxygen-depleted tank water and caused mortality. These results suggest potential for future mark-recapture studies of RE/BS rockfish (C. Lunsford and P. Malecha, *personal communication*).

Natural Tags

Alternatives to human-implanted tags are often considered when traditional mark-recapture techniques are not feasible due to high mortality from severe barotrauma during capture (Moles et al. 1998). Parasites are a source of naturally occurring tags for stock discrimination in marine fish. Essentially, fish become infected with a parasite when they swim within the endemic region of that parasite. Biological parameters of the parasite (e.g. life span, suitable conditions) are used to infer past movements of the infected fish (MacKenzie and Abaunza 1998). In a 1998 study on shortraker and RE/BS rockfish, Moles et al. examined 100 rougheye specimens from 21 stations around the GOA for prevalence (proportion of fish with a given parasite) and intensity of metazoan parasites. Their results identified two gill copepod parasites (*Neobrachiella robusta*, and *Trochopus trituba*) and one internal parasite (*Corynosoma* sp.) that exhibited significant differences between INPFC management areas, particularly for the Southeast rougheye rockfish (Moles et al. 1998). In a multi-year study on genetic variation in shortraker and rougheye rockfish, Hawkins et al. 2005 opportunistically sampled these same three parasites in their 2001 GOA rougheye samples. Their objective was to determine if depth or species subtype (essentially rougheye versus blackspotted rockfish) factored into the geographic separation noted by Moles et al. 1998. Their results indicated the samples that were likely blackspotted rockfish had significantly higher prevalence of the two gill copepod parasites than the samples that were likely rougheye rockfish. The significant differences by area may be due to stock structure on the scale of management areas or species specific habitat preferences (Moles et al. 1998, Hawkins et al. 2005).

<u>Genetics</u>

There have been several studies investigating the genetic variation of the RE/BS rockfish complex (e.g. Gharrett et al. 2005, Hawkins et al. 2005). In general, results presented from these studies concentrate on the delineation of the two genetically distinct species, rougheye versus blackspotted, rather than the complex as a whole. However, information on genetic population structure is available by each species and information for the RE/BS complex may be inferred by comparisons between the two.

Isolation and Dispersal by Distance:

In a comprehensive genetic study, Gharrett et al. (2007) analyzed 1,220 samples of RE/BS rockfish collected between 1994 and 2003 throughout the total range for these species. The two species were distinguished using diagnostic mtDNA and microsatellite markers, 710 of Type I (likely blackspotted) and 510 of Type II (likely rougheye). Values for the fixation index, F_{ST}, for both species were very low indicating very little divergence existed among populations and a test of isolation by distance was also not significant for both species (Gharrett et al. 2007). These tests were for the entire species range from the Queen Charlotte Islands to the Aleutian Islands and Bering Sea. An additional G-statistic-based test of homogeneity was significant for both species suggesting that divergence was significantly positive (Gharrett et al. 2007). These results suggest that an overarching pattern does not exist for the entire species range but that geographic structure may exist on a smaller scale (Spencer et al. 2010).

In order to understand the geographic scale of the observed divergence, Gharrett et al. (2007) conducted homogeneity tests of adjacent populations and groups of adjacent populations. This analysis resolved distinct populations for both types of RE/BS rockfish throughout the total range, four for Type I (likely blackspotted) and six for Type II (likely rougheye). Additionally, divergence for Type II fish was stronger than Type I fish, indicating more limited dispersal. These results suggest that Type II (likely rougheye) and Type I (likely blackspotted) rockfish have population structure on the scale of the INPFC management areas. Additionally, Type II (likely rougheye) rockfish in the eastern GOA may exhibit finer population structure (Gharrett et al. 2007).

Summary, Recommendation, and Implications

Since 2007, the Scientific and Statistical Committee (SSC) has requested that rougheye/blackspotted assessment authors develop a rationale for decisions regarding mixed stock species groups with attention to overfishing the weaker stock. There is no information on whether the two species have significantly different life history traits (e.g. age of maturity, growth). If differences in growth and maturity exist, disproportionate harvest rates could result. Scientists and observers are currently evaluating new techniques to determine whether rapid and accurate field identification can occur. The 2009 AFSC GOA bottom trawl survey identification project is a first step in addressing some of these concerns. Until observers and survey biologists can reliably identify both species, we must continue to manage rougheye and blackspotted as a complex.

We summarize the available information on stock structure for the GOA rougheye and blackspotted rockfish complex in Table A4. Non-genetic information suggests population structure by large management areas of eastern, central, and western GOA. This is evident in opposite trajectories for population trends by area, significantly different age, length, and growth parameters by area, and significant differences in parasite prevalence and intensity by area. Genetic studies have generally been focused on the speciation of the RE/BS complex; however, consistencies between the two species also suggest population structure by management area. Tests of homogeneity and adjacency show genetic structure consistent with a neighborhood model of dispersion. Dispersal distance for rougheye (Type II) and blackspotted (Type I) was consistent with management areas; however, rougheye (Type II) in the eastern GOA may exhibit finer scale population structure (Gharrett et al. 2007).

Currently, the rougheye and blackspotted rockfish complex is managed as a Tier 3a stock with area-apportioned ABCs. Given the evidence for stock structure supported by both genetic and non-genetic data, the current level of spatial management for RE/BS rockfish seems well founded. Potential for finer scale population structure may exist for rougheye rockfish in the eastern GOA. However, the current issues with high at-sea misidentification rates for the two species and insufficient data at smaller scales do not support management at finer levels. Additionally, catches of RE/BS rockfish have been well below TAC since shortraker and rougheye were separated into different subgroups in 2004. We recommend the current level of spatial management with potential for area-specific OFLs as a higher level of precaution for the GOA RE/BS rockfish complex.

A risk evaluation for implementing area-specific OFLs would involve considering the implications on stock sustainability and current fishing practices. The stock structure evaluation exercise suggests that GOA RE/BS rockfish structure is consistent with large management areas. A potential concern for the stock is that if disproportionate harvest occurs within any management area, fish may not be replenished quickly from adjacent discrete areas. The current management approach of area-specific ABCs combined with relatively low Maximum Retained Allowance (MRA) levels and “bycatch only” fishery status generally results in area-specific harvests well below TAC. Only for the most recent year in the western GOA have catches even been close to TAC. Additionally, once an area-specific ABC is reached, retention of rougheye or blackspotted rockfish is prohibited. A reallocation of fishing effort to areas with lower rates of bycatch may also occur. Given the multiple levels of precaution through area-specific ABCs, there may be no added benefit to the stock by initiating area-specific OFLs. However, the potential cost to the fishery likely outweighs the potential benefit to the stock. Any fleet within an area that could potentially harvest RE/BS rockfish could be closed should an area-specific OFL be reached. Given the multiple layers of precautionary management built into the current TAC setting levels for RE/BS rockfish and the on-average low area-specific harvest rates, we recommend continuing the current management of area-specific ABCs and gulf-wide OFLs.

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Table A1: Example framework for defining spatial management units (from Spencer et al. 2010).

Factor and criterion	**Justification**
	Harvest and Trends
Fishing mortality (5-year average percent of F_{max})	If this value is low, then conservation concern is low
Spatial concentration of fishery relative to abundance (Fishing is focused in areas << management areas)	If fishing is focused on very small areas due to patchiness or convenience, localized depletion could be a problem.
Population trends (Different areas show different trend directions)	Could be caused by different productivities, because of adaptive selection, differing fishing pressure, or better recruitment conditions
	Barriers and phenotypic characters
Generation time (e.g., >10 years)	If generation time is long, population recovery from overharvest will be outside of management timeframe.
Physical limitations (Clear physical inhibitors to movement)	Sessile organism; physical barriers to dispersal such as strong oceanographic currents or fjord stocks
Growth differences (Significantly different LAA, WAA, or LW parameters)	Differences in growth could be a result of either short term genetic selection from fishing, local environmental influences, or longer-term adaptive genetic change.
Age/size-structure (Significantly different size/age compositions)	Differing recruitment by area could manifest in different age/size compositions. This could be caused by different spawning times, local conditions, or a phenotypic response to genetic adaptation.
Spawning time differences (Significantly different mean time of spawning)	Differences in spawning time could be a result of local environmental conditions, but indicate isolated spawning stocks.
Maturity-at-age/length differences (Significantly different mean maturity-at-age/ length)	Differences in maturity-at-age could be a result of fishing mortality, environmental conditions, or adaptive genetic change.
Morphometrics (Field identifiable characters)	Identifiable physical attributes may indicate underlying genotypic variation or adaptive selection. Mixed stocks w/ different reproductive timing would need to be field identified to quantify abundance and catch
Meristics (Minimally overlapping differences in counts)	Differences in counts such as gillrakers may indicate adaptive selection to local prey conditions.
	Behavior & movement
Spawning site fidelity (Spawning individuals occur in same location consistently)	Primary indicator of limited dispersal or homing
Mark-recapture data (Tagging data may show limited movement)	If tag returns indicate large movements of spawning fish among spawning grounds, this would suggest panmixia
Natural tags (Acquired tags may show movement smaller than management areas)	Otolith microchemistry and parasites can indicate natal origins, showing amount of dispersal
	Genetics
Isolation by distance (Significant regression)	Primary indicator of limited dispersal
Dispersal distance (<<Management areas)	Genetic data can be used to corroborate or refute movement from tagging data. If conflicting, resolution between sources is needed.
Pairwise genetic differences (Significant differences between geographically distinct collections)	Indicates reproductive isolation.

Table A2: Age and length samples sizes for RE/BS rockfish from AFSC GOA bottom trawl survey.

Year	Age Samples	Length Samples
1984	369	4,701
1987	348	3,994
1990	216	3,522
1993	876	5,818
1996	770	4,402
1999	650	3,945
2001		2,191
2003	510	3,030
2005	425	4,092
2007	435	4,253
2009		4,167
Total	4,599	44,115

Table A3: Significant differences between growth parameters and areas estimated from AFSC GOA bottom trawl survey data on RE/BS rockfish.

Parameter	WGOA	CGOA	EGOA	p-value*
L_inf	EG	EG	WG,CG	
K	EG,CG	EG,WG	WG,CG	
t_o	EG	EG	WG,CG	
Mean length (mm)	415	382	356	<0.001
Mean age	27.3	17.1	15.0	WGOA, <0.001
Proportion Male	***0.52***	0.50	0.50	WGOA, =0.001
Proportion Rougheye	***0.17***	***0.66***	***0.57***	<0.001

*p-value column refers to the between area comparisons. Proportions in bold refer to proportions that were significantly different than 0.5

Table A4: Summary of available data on stock structure for GOA rougheye and blackspotted rockfish.

Factor and criterion	**Available information**
Harvest and trends	
Fishing mortality (5-year average percent of F_{max})	Recent catch in the Western GOA are near F_{max}, and far below F_{max} in the Central and Eastern GOA
Spatial concentration of fishery relative to abundance (Fishing is focused in areas << management areas)	Catches are distributed similarly to survey abundance, except for a potential nursery area in Amatuli Gully region
Population trends (Different areas show different trend directions)	Population trend is stable for overall Gulf of Alaska, declining toward the Western GOA, and increasing toward the Eastern GOA
Barriers and phenotypic characters	
Generation time (e.g., >10 years)	The generation time is > 19 years
Physical limitations (Clear physical inhibitors to movement)	No known physical barriers; predominant current patterns move from east to west, potential restriction in gullies and canyons
Growth differences (Significantly different LAA, WAA, or LW parameters)	Significantly different growth curves and length-at-age relationships between the Western GOA, Central GOA, and Eastern GOA.
Age/size-structure (Significantly different size/age compositions)	Mean length is significantly higher in WGOA, mean age is significantly higher in WGOA
Spawning time differences (Significantly different mean time of spawning)	Unknown
Maturity-at-age/length differences (Significantly different mean maturity-at-age/ length)	Unknown
Morphometrics (Field identifiable characters)	Unknown within species, hypothesized pigmentation differences between species (Gharrett et al. 2006, Orr and Hawkins 2008)
Meristics (Minimally overlapping differences in counts)	Unknown within species, significantly different means of dorsal spines and gill rakers (Gharrett et al. 2006)
Behavior & movement	
Spawning site fidelity (Spawning individuals occur in same location consistently)	Unknown
Mark-recapture data (Tagging data may show limited movement)	Mark-recapture data not available, but potential to reduce barotrauma with new pressure tanks
Natural tags (Acquired tags may show movement smaller than management areas)	Parasite analysis shows structure by INPFC management area and between species (Moles et al. 1998, Hawkins et al. 2005)
Genetics	
Isolation by distance (Significant regression)	No significant isolation by distance for Type I or Type II rougheye (likely blackspotted and rougheye, respectively) (Gharrett et al. 2007)
Dispersal distance (<<Management areas)	Low, but significant F_{st} for both types indicates some limits to dispersal (Gharrett et al. 2007)
Pairwise genetic differences (Significant differences between geographically distinct collections)	Adjacency analysis suggests genetic structure on scale of INPFC management areas for Type I (blackspotted) and potentially finer scale structure for Type II (rougheye) (Gharrett et al. 2007)

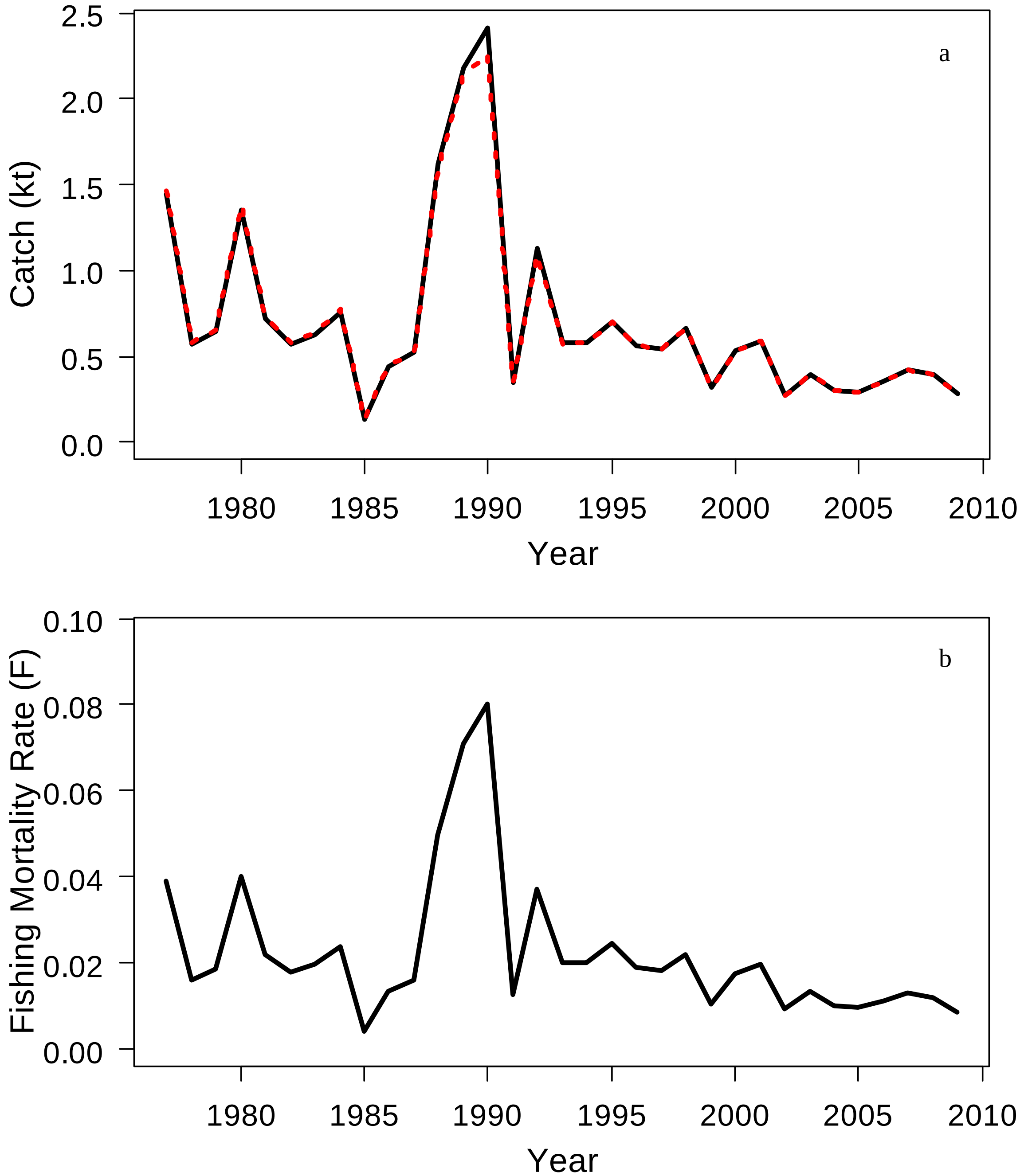

Figure A1: Commercial catch (a) and estimated fully selected fishing mortality (b) for Gulf of Alaska RE/BS rockfish (from Shotwell et al. 2009).

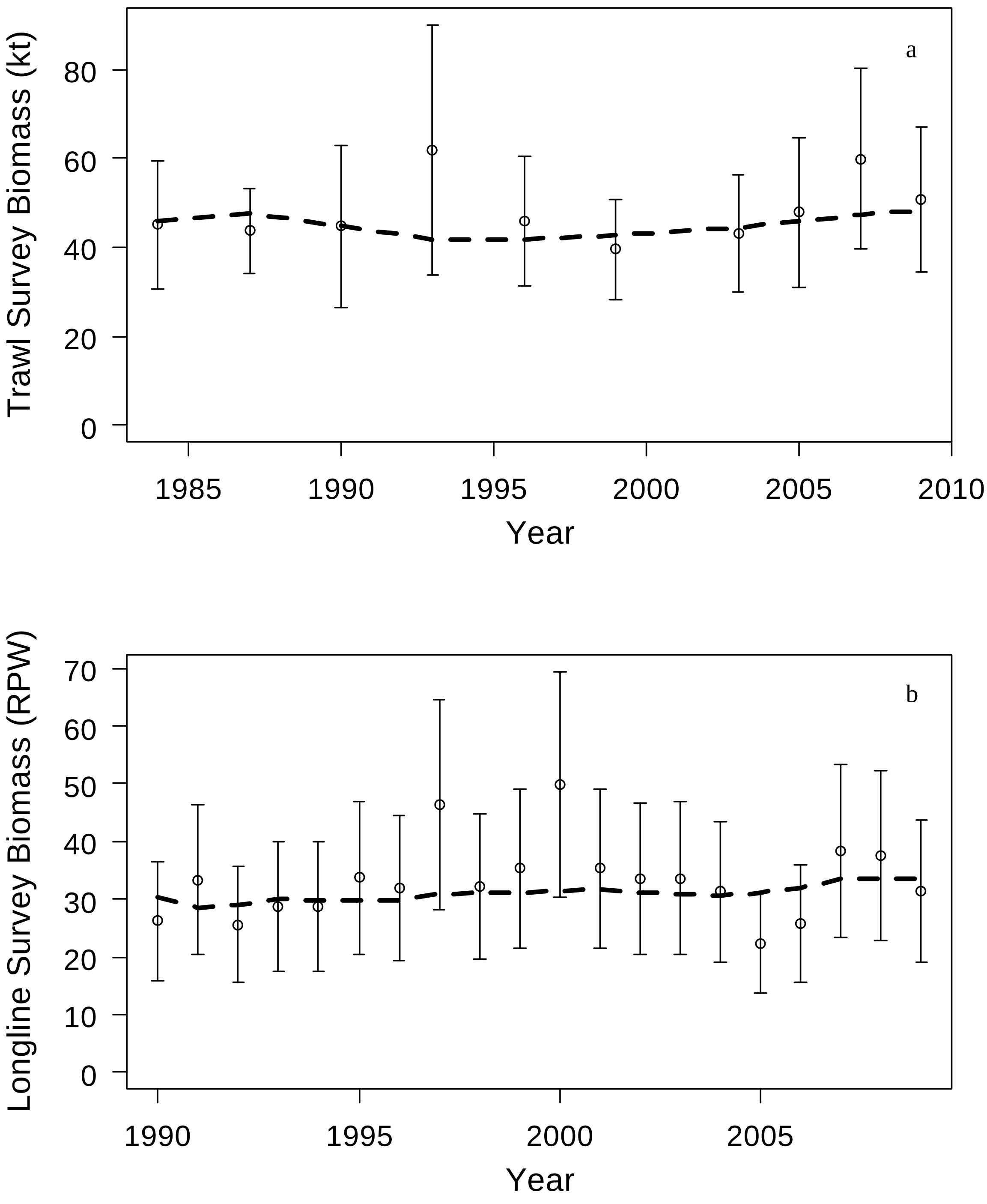

Figure A2: Observed (open circles) and model predicted (dashed line) biomass (kilotons) from AFSC bottom trawl survey (a) and relative population weight (RPW in thousands) from AFSC longline survey (b) for Gulf of Alaska RE/BS rockfish with 95% confidence intervals (from Shotwell et al. 2009).

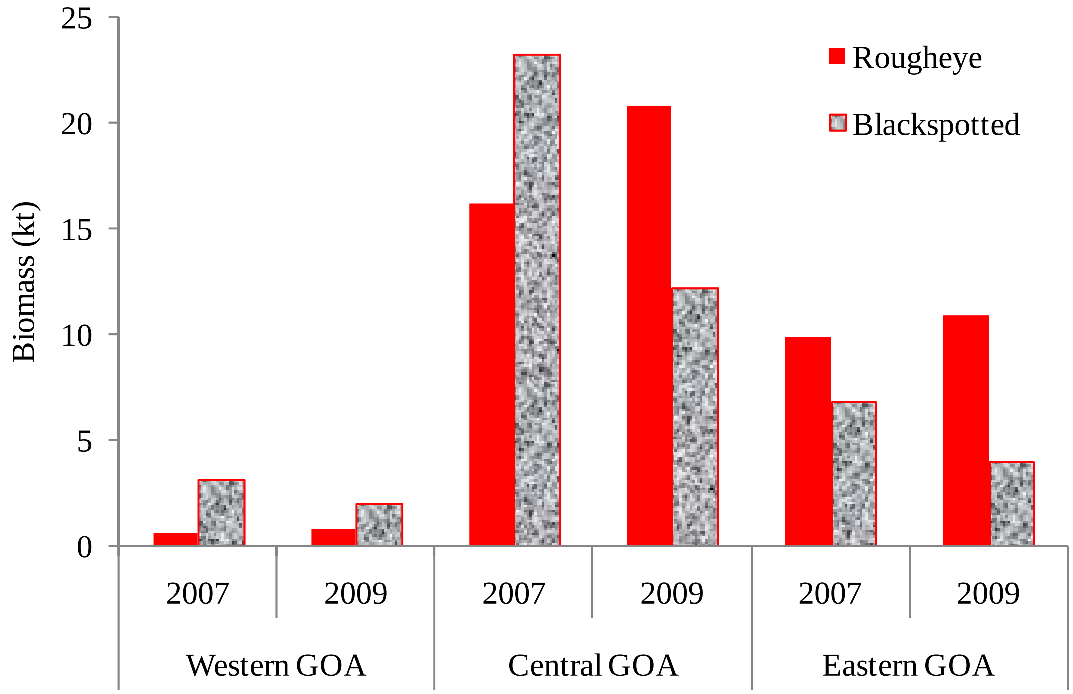

Figure A3: Biomass (kt) estimates by region for rougheye (red bars) and blackspotted (gray bars) rockfish from the 2007 and 2009 AFSC GOA bottom trawl surveys. These estimates should be considered with caution given the preliminary results from current research of high at-sea misidentification rates in the 2009 GOA trawl survey.

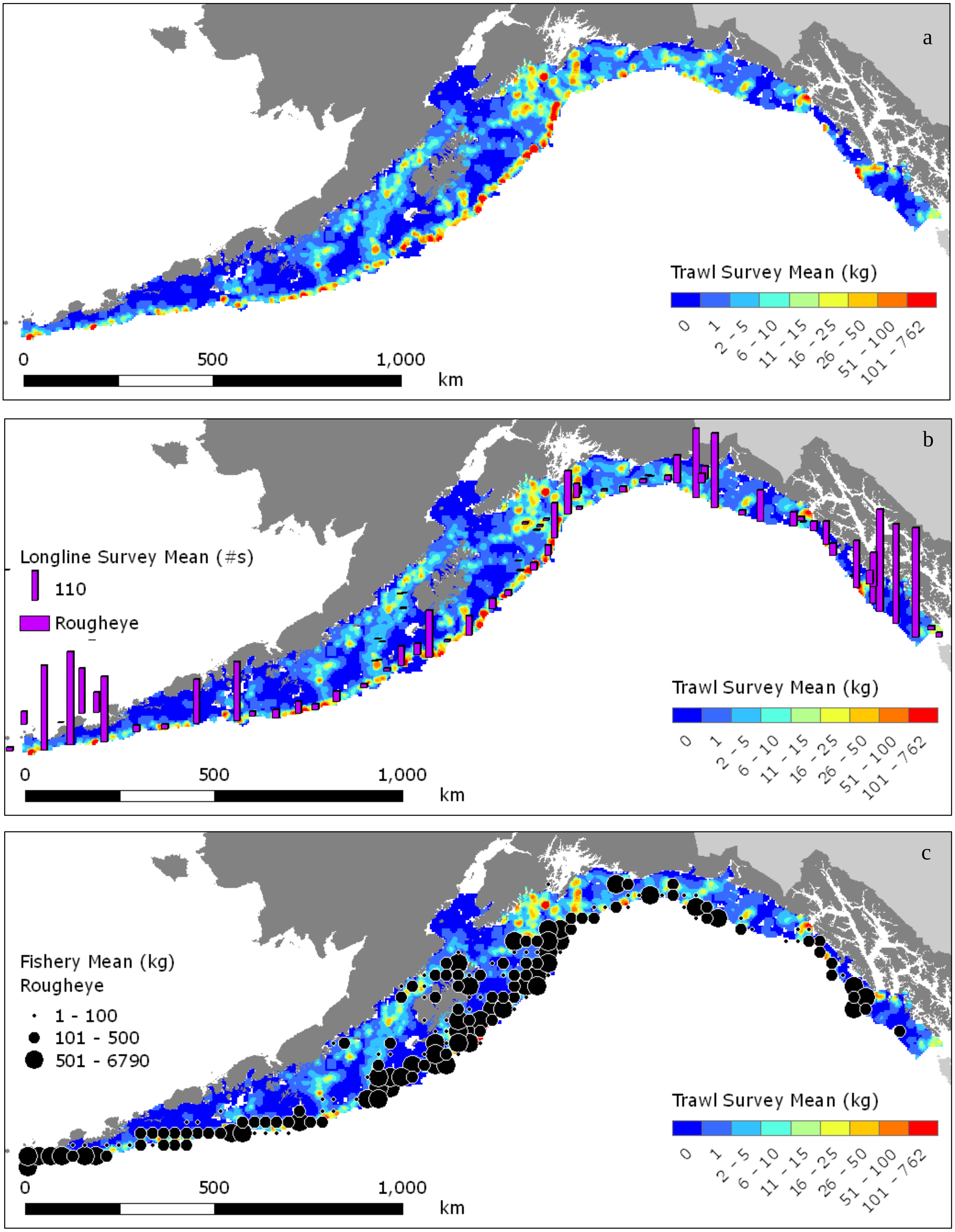

Figure A4: Distribution maps of RE/BS rockfish for trawl survey mean conditions from 1984-2009 (a), longline survey station means (2001-2009) with trawl survey mean conditions (b), and fishery catch mean (1993-2009) with trawl survey mean conditions (c).

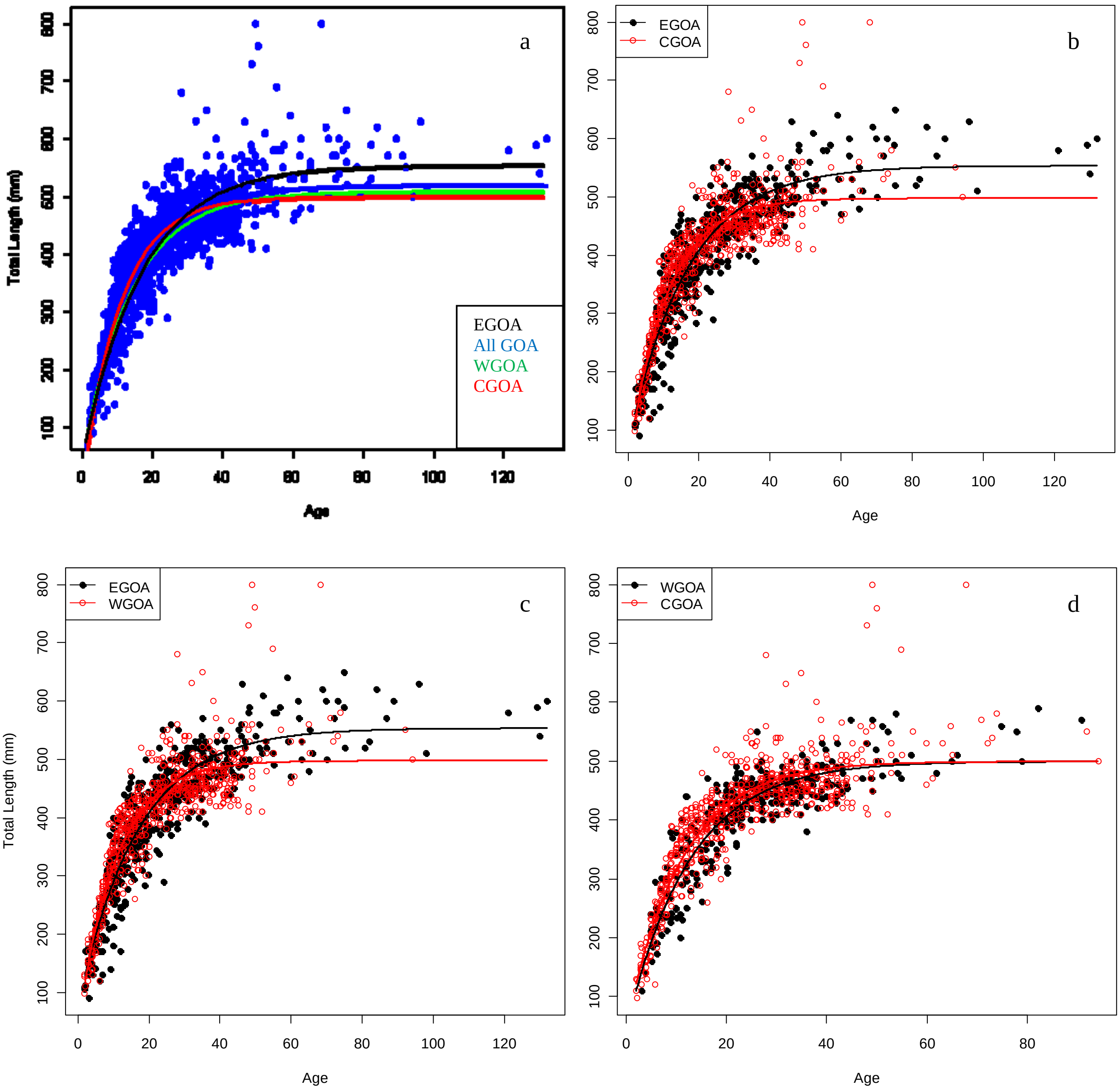

Figure A5: Mean length-at-age and fitted von Bertalanffy growth curves for RE/BS rockfish using AFSC bottom trawl survey data for all GOA (a), EGOA versus CGOA (b), EGOA versus WGOA (c), and CGOA versus WGOA (d).