9. Assessment of the Pacific ocean perch stock in the Gulf of Alaska

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Executive Summary

Rockfish are assessed on a biennial stock assessment schedule to coincide with the availability of new survey data. For Gulf of Alaska rockfish in on-cycle (odd) years, we present a full stock assessment document with updated assessment and projection model results. However, due to the 2013 government shutdown we did not present alternative model configurations in the 2013 assessment. As requested, we are providing a full assessment in 2014 in order to present an alternative model that incorporates new maturity information.

We use a statistical age-structured model as the primary assessment tool for Gulf of Alaska Pacific ocean perch which qualifies as a Tier 3 stock. This assessment consists of a population model, which uses survey and fishery data to generate a historical time series of population estimates, and a projection model, which uses results from the population model to predict future population estimates and recommended harvest levels. For this year, we update the 2013 assessment model estimates with new data collected since the last full assessment.

Summary of Changes in Assessment Inputs

Changes in the input data: The new data included are updated weight-at-age and an updated size-at-age transition matrix, a final catch estimate for 2013 and a new catch estimate for 2014-2016 (see *Specified catch estimation* section).

Changes in the assessment methodology: The recommended model incorporates new maturity information and fits the available maturity data within the assessment model to incorporate uncertainty in maturity within uncertainty estimates of other model parameters and estimates.

Summary of Results

For the 2015 fishery, we recommend the maximum allowable ABC of **21,012** t from the updated model. This ABC is a 9% increase from the 2014 ABC of 19,309 t. The increase is attributed to updating weight-at-age and the size-age transition matrix as well as incorporating new maturity information that decreases the age at 50% maturity. This also resulted in a 6% higher ABC than the 2015 ABC projected last year. The corresponding reference values for Pacific ocean perch are summarized in the following table, with the recommended ABC and OFL values in bold. Overfishing is not occurring, the stock is not overfished, and it is not approaching an overfished condition.

Quantity	As estimated or specified *last* year for: 2014	2015	As estimated or recommended *this* year for: 2015	2016[1]
M (natural mortality)	0.061	0.061	0.061	0.061
Tier	3a	3a	3a	3a
Projected total (age 2+) biomass (t)	410,712	408,839	416,140	412,351
Projected Female spawning biomass	120,356	121,939	142,029	144,974
$B_{100\%}$	257,697	257,697	283,315	283,315
$B_{40\%}$	103,079	103,079	113,326	113,326
$B_{35\%}$	90,194	90,194	99,160	99,160
F_{OFL}	0.132	0.132	0.139	0.139
$maxF_{ABC}$	0.113	0.113	0.119	0.119
F_{ABC}	0.113	0.113	0.119	0.119
OFL (t)	**22,319**	22,849	**24,360**	24,849
maxABC (t)	19,309	19,764	**21,012**	21,436
ABC (t)	**19,309**	19,764	**21,012**	21,436
Status	As determined *last* year for: 2012	2013	As determined *this* year for: 2013	2014
Overfishing	No	n/a	No	n/a
Overfished	n/a	No	n/a	No
Approaching overfished	n/a	No	n/a	No

[1]Projected ABCs and OFLs for 2015 and 2016 are derived using estimated catch of 17,716 for 2014, and projected catches of 17,665 t and 17,797 t for 2015 and 2016 based on realized catches from 2011-2013. This calculation is in response to management requests to obtain more accurate projections.

Area Apportionment

We concur with the Plan Team and SSC recommendation to use the random effects model, rather than the weighted survey average approach for apportionment. The apportionment percentages have changed with the use of the random effects model to fit to area-specific survey biomass, in 2013 with the original 4:6:9 weighted average approach the apportionments were 11% for the Western area, 69% for the Central area, and 20% for the Eastern area. The following table shows the recommended apportionment for 2015 and 2016 from the random effects model.

Area Apportionment	Western	Central	Eastern	Total
	11.0%	75.5%	13.5%	100%
2015 Area ABC (t)	**2,302**	**15,873**	**2,837**	**21,012**
2016 Area ABC (t)	**2,358**	**16,184**	**2,894**	**21,436**

Amendment 41 prohibited trawling in the Eastern area east of 140° W longitude. The ratio of biomass still obtainable in the W. Yakutat area (between 147° W and 140° W) is higher than the 2011 assessment at 0.71, a large increase from 0.48. Note that the random effects model was not applied for the WYAK and EYAK/SEO split (explained below in the response to SSC and Pan Team comments) and the weighting method of using upper 95% confidence of the ratio in biomass between these two areas used in previous assessments was continued. This results in the following apportionment of the Eastern Gulf area:

	W. Yakutat	E. Yakutat/Southeast	Total
2015 Area ABC (t)	**2,014**	**823**	**2,837**
2016 Area ABC (t)	**2,055**	**839**	**2,894**

In 2012, the Plan Team and SSC recommended combined OFLs for the Western, Central, and West Yakutat areas (W/C/WYK) because the original rationale of an overfished stock no longer applied. However, because of concerns over stock structure, the OFL for SEO remained separate to ensure this unharvested OFL was not utilized in another area. The Council adopted these recommendations. This results in the following apportionment for the W/C/WYK area:

	Western/Central/W. Yakutat	E. Yakutat/Southeast	Total
2015 Area OFL (t)	**23,406**	**954**	**24,360**
2016 Area OFL (t)	**23,876**	**973**	**24,849**

Summaries for Plan Team

Species	Year	Biomass[1]	OFL	ABC	TAC	Catch[2]
Pacific ocean perch	2013	345,260	18,919	16,412	16,412	13,183
	2014	410,712	22,319	19,309	19,309	14,863
	2015	416,140	24,360	21,012		
	2016	412,351	24,849	21,436		

[1]Total biomass from the age-structured model

Stock/ Assemblage	Area	2014 OFL	ABC	TAC	Catch[2]	2015 OFL	ABC	2016 OFL	ABC
Pacific ocean perch	W		2,399	2,399	104		2,302		2,349
	C		12,855	12,855	12,887		15,873		16,193
	WYAK		1,931	1,931	1,872		2,014		2,055
	SEO	1,303	2,124	2,124	0	954	823	973	839
	W/C/WYK	21,016				23,406		23,876	
	Total	22,319	19,309	19,309	14,863	24,360	21,012	24,849	21,436

[2]Current as of October 1, 2014, Source: NMFS Alaska Regional Office via the Alaska Fisheries Information Network (AKFIN).

SSC and Plan Team Comments on Assessments in General

"The SSC is pleased to see that many assessment authors have examined retrospective bias in the assessment and encourages the authors and Plan Teams to determine guidelines for how to best evaluate and present retrospective patterns associated with estimates of biomass and recruitment. We recommend that all assessment authors (Tier 3 and higher) bring retrospective analyses forward in next year's assessments." (SSC, December 2011)

"For the November 2012 SAFE report, the Teams recommend that authors conduct a retrospective analysis back 10 years (thus, back to 2002 for the 2012 assessments), and show the patterns for spawning biomass (both the time series of estimates and the time series of proportional changes relative to the 2012

run). This is consistent with a December 2011 NPFMC SSC request for stock assessment authors to conduct a retrospective analysis. The base model used for the retrospective analysis should be the author's recommended model, even if it differs from the accepted model from previous years." (Plan Team, September 2012)

In response to both of these comments, this year's assessment includes discussion of a retrospective analysis performed on the recommended model within 'Time series results' section. This retrospective analysis section will become a standard section in future assessments.

"The SSC concurs with the Plan Teams' recommendation that the authors consider issues for sablefish where there may be overlap between the catch-in-areas and halibut fishery incidental catch estimation (HFICE) estimates. In general, for all species, it would be good to understand the unaccounted for catches and the degree of overlap between the CAS and HFICE estimates, and to discuss these at the Plan Team meetings next September." (SSC, December 2011)

The degree of overlap between catch-in-areas and the HFICE estimates are negligible for POP, as shown in Table 9A-2 of Appendix 9A.

"The Teams recommend that authors continue to include other removals in an appendix for 2013. Authors may apply those removals in estimating ABC and OFL; however, if this is done, results based on the approach used in the previous assessment must also be presented. The Teams recommend that the "other" removals data set continue to be compiled, and expanded to include all sources of removal." (Plan Team, September 2012)

"The Teams recommend that the whole time series of each category of 'other' catches be made available on the NMFS "dashboard," so that they may be listed in all SAFE chapters." (Plan Team, November 2012)

In response to these two comments, other removals are available on the dashboard. These removals have been included in Table 9A-1 of Appendix 9A and will continue to be included in future assessments.

"The SSC recommends that the authors consider whether it is possible to estimate M with at least two significant digits in all future stock assessments to increase validity of the estimated OFL." (SSC, December 2012)

Because *M* is estimated inside the Pacific ocean perch assessment model, *M* is estimated with more than two significant digits.

"The Teams recommended that each stock assessment model incorporate the best possible estimate of the current year's removals. The Teams plan to inventory how their respective authors address and calculate total current year removals. Following analysis of this inventory, the Teams will provide advice to authors on the appropriate methodology for calculating current year removals to ensure consistency across assessments and FMPs." (Plan Team, September 2013)

We estimated current year's removals by multiplying the official catch as of October 1, 2014, by an expansion factor, which represents the average additional catch taken after October 1 and through December 31 in the last three complete years (2011-2013). Further description is provided in the 'Specified catch estimation' section below.

"For the GOA age-structured rockfish assessments, if length composition data are withheld, the Team recommends exploratory model runs to test sensitivity. This should include any year of fishery or survey length composition data which could serve as a proxy for the age composition, not simply the most recent survey year." (Plan Team, November 2013)

A sensitivity analysis of including the most recent year's survey length composition has been performed and is included in Appendix 9B. The fishery selectivity in recent years (post-1997) primarily selects ages between around age-9 to age-17 (ages with selectivity greater than 50%). The variability in length-at-age for these ages is such that there is very little distinction in age-at-length in the fishery, thus, little information is contained in the fishery length composition data to inform age. Evaluations of including the fishery length data in years without fishery age data into the assessment model post-1997 has shown that the model is essentially invariant to including the recent fishery length composition data as a proxy for age data. See Appendix 9B for further details regarding the use of the most recent length composition data from the survey.

"For assessments involving age-structured models, this year's CIE review of BSAI and GOA rockfish assessments included three main recommendations for future research: Authors should consider: (1) development of alternative survey estimators, (2) evaluating selectivity and fits to the plus group, and (3) re-evaluating natural mortality rates. The SSC recommends that authors address the CIE review during full assessment updates scheduled in 2014." (SSC, December 2013)

Because of the Government shutdown in 2013, comments were not fully addressed in last year's assessment. Full assessment updates for all the GOA rockfish stocks will be completed in 2015 and CIE review comments will be addressed at that time. Please refer to the Summary and response to the 2013 CIE review of the AFSC rockfish document presented to the September 2013 Plan Team (http://www.afsc.noaa.gov/REFM/stocks/Plan_Team/2013/Sept/2013_Rockfish_CIE_Response.pdf).

"During public testimony, it was proposed that assessment authors should consider projecting the reference points for the future two years (e.g., 2014 and 2015) on the phase diagrams. It was suggested that this forecast would be useful to the public. The SSC agrees. The SSC appreciated this suggestion and asks the assessment authors to do so in the next assessment." (SSC December 2013)

In this year's phase plane diagram the 2-year projections (2015 and 2016) are shown (Figure 9-16). The two year projections will be standard in the phase plan plot's of future assessments.

SSC and Plan Team Comments Specific to this Assessment

"The Team asks the [rockfish] authors to investigate whether the conversion matrix has changed over time. Additionally, the Team requests that the criteria for omitting data in stock assessment models be based upon the quality of the data (e.g. bias, sampling methods, information content, redundancy with other data, etc.) rather than the effect of the data on modeled quantities." (Plan Team, November 2011)

The size-age transition matrix and weight-at-age have been updated in this year's assessment. Many of the issues regarding temporal changes in the conversion and error matrices are similar across the age-structured rockfish assessments. In order to properly address this comment we plan to conduct an investigation on developing methods for updating conversion and error matrices for these long-lived species as a group and to perform sensitivity analyses on the timeliness of updates. We anticipate this future investigation to begin next year and will incorporate relevant results into the Pacific ocean perch model following further review. As mentioned above, an analysis evaluating the omission of the most recent year's survey length composition is provided in Appendix 9B.

"Future research will take another look at growth data, and similar to other rockfish assessments, another examination of the age and length bins – particularly in the plus age group. The author also intends to look at fishery spatial patterns. The [GOA Plan] Team supported these activities." (Plan Team, November 2011)

Age and length bins will be investigated for all the GOA rockfish stocks in the 2015 assessments, including new methods for incorporating ageing error, which will have an influence on the results of alternative age and length binning.

"The SSC looks forward to a review of the stock structure template applied to POP in the GOA, as well as an examination of growth data, age and length bins (including the plus group), and fishery spatial patterns during the next assessment cycle." (SSC, December 2011)

In 2012, the POP assessment completed the stock structure template that summarized the body of knowledge on stock structure and spatial management (Hanselman et al. 2012a).

"The Plan Team generally recommends that as part of the CIE review, authors focus on aspects of the assessment model that affect estimates of survey catchability." (Plan Team, November 2012)

During the CIE review estimates of catchability for the BSAI and GOA rockfish stocks were reviewed. Please refer to the Summary and response to the 2013 CIE review of the AFSC rockfish document presented to the September 2013 Plan Team (http://www.afsc.noaa.gov/REFM/stocks/Plan_Team/2013/Sept/2013_Rockfish_CIE_Response.pdf).

"The Plan Team recommends maintaining area specific ABCs but apportioning OFLs across the area currently open to bottom trawling (Western, Central, WYAK) and the area closed to bottom trawling (EYAK/SEO)." (Plan Team, November 2012)

"The SSC also accepts the Plan Team's recommended apportionment of ABCs among Western, Central, West Yakutat, and SEO areas in 2013-2014 with revised OFLs for the fished (W/C/WYAK) and lightly fished (SEO) areas (see table below in metric tons)." (SSC, December 2012)

In response to the previous two comments, since 2012 OFLs have been apportioned between the areas currently open to bottom trawling and the areas closed to bottom trawling.

"The Team recommends additional analyses with the survey length data for 2014 to evaluate effects on the 2006 recruitment estimate. Other contributing factors to the large uncertainty estimate for 2006 recruitment could be related to sample size specified of age data (max at 100)." (Plan Team, November 2013)

At the September 2014 Plan Team meeting analysis of the survey length composition data in relation to the 2006 year class was presented. Alternative input sample sizes for age composition will be investigated for all the GOA rockfish assessments in 2015.

"The survey averaging working group will continue to explore apportionment methods and the authors may consider incorporating their recommendations for apportionment contingent on the findings of this group." (Plan Team, November 2013)

In this year's assessment we are using the random effects model suggested by the survey averaging working group for apportionment among the Western, Central, and Eastern Gulf of Alaska. See the 'Area Apportionment of Harvests' section below for further details.

"The SSC agrees with the authors and Plan Team recommendations for OFL and ABC for 2014 and 2015. However, given concerns raised by the Plan Team on area apportionments, the SSC recommends using the 2011 apportionment to apportion ABCs among GOA areas." (SSC, December 2013)

Apportionment of the 2014 and 2015 ABCs and OFLs in 2013 was changed to use the 2011 apportionment values. In this year's assessment we are using the random effects model for apportionment. See the 'Area Apportionment of Harvests' section below for further details.

"The SSC recommends the following to the assessment authors:

- *Consider incorporating recommendations of the survey averaging working group for apportionment in 2014.*
- *Evaluate the effects of the survey length data on recruitment estimates.*
- *Evaluate the effect of sample size specified for age data.*
- *Bring forward an updated stock structure template for this stock in 2014 to evaluate the merits of continuing to separate OFLs.*
- *Evaluate new maturity data on POP that may be available.*
- *Address past recommendations by the CIE, Plan Team, and SSC."* (SSC, December 2013)

The recommendations of the survey averaging working group have been incorporated into this year's apportionment of ABC and OFL by using the random effects model to estimate the proportion of biomass by area. Appendix 9B contains analysis of the merits of including the most recent survey's length composition, which includes statistics that evaluate the effects on recruitment estimates as well as statistics investigating likelihoods and other model estimates. The effect of sample size specified for age data is an issue that pertains to not just the Pacific ocean perch assessment, but to any age-structured assessment. We plan to perform analyses in the coming year pertaining to the input sample size for the GOA rockfish age-structured assessments and the results of that analysis will be included in the 2015 assessments. However, such analyses should be conducted so that the method of determining input sample sizes are consistent across AFSC assessments, which is perhaps more appropriately evaluated by a Plan Team working group. As stated above, a stock structure template was completed in 2012 and no new information regarding stock structure since 2012 is available for update. The new maturity data available is incorporated into this year's assessment and is estimated conditionally within the model allowing for uncertainty in age-at-maturity to be incorporated into uncertainty for key model results such as ABC. We have addressed several of the past recommendations by the Plan Team and SSC above, and will continue to work on addressing CIE comments for inclusion into future assessments.

"The SSC recommends that this stock assessment be brought forward in the 2014 assessment cycle as a full assessment." (SSC, December 2013)

As per this recommendation by the SSC we are presenting a full assessment this year.

"The Team recommends using the random effects model, rather than the weighted survey average approach to the extent practical for POP and for rockfish in general [for apportionment]." (Plan Team, September 2014)

As stated in several of the previous responses, the random effects model was used in this year's assessment for apportionment of ABC and OFL among the Western, Central, and Eastern Gulf of Alaska.

However, the random effects model was not applied for the WYAK and EYAK/SEO split and the weighting method of using upper 95% confidence of the ratio in biomass between these two areas used in previous assessments was continued. There were two primary reasons for this: (1) uncertainty estimates for WYAK and EYAK/SEO survey biomass are not available at this time, thus, the random effects model cannot be used to fit the time-series of survey biomass in these two regions, and (2) use of the upper 95% confidence interval from WYAK to calculate the ratio between WYAK and EYAK/SEO was a policy decision that allowed for additional harvest of Pacific ocean perch in the WYAK area. Thus, any use of the random effects model to follow a similar method would also be a policy decision that would need to be made by the Plan Team and SSC. We request that the Plan Team and SSC provide a recommendation of how to use the random effects model to incorporate the 95% confidence interval for the WYAK apportionment.

"The Plan Team recommends evaluation of how the data weights given to the various fishery and survey age and length composition data affect the estimates of recruitment and age composition." (Plan Team, September 2014)

We plan to do a more thorough evaluation of weighting age and length data by performing a sensitivity analysis for all of the GOA rockfish assessments rather than just Pacific ocean perch. However, similar to the input sample size evaluation requested by the SSC, this is an issue that would be pertinent to any age-structured assessment performed by AFSC and should be conducted so that any weighting method developed is applicable across assessments. The results of this analysis for GOA rockfish will be presented in the 2015 assessments, although, this analysis may be more appropriately conducted by a Plan Team working group with a broader focus than just the GOA rockfish assessments.

"The Plan Team recommends the following test to evaluate the value of information contained in the survey length data and the transition matrix. Consider model estimates of age structure obtained when survey age composition is included as a standard for comparison. For each survey year, conduct two additional model runs: 1) without either the age or length composition data for that survey year; and 2) with the length composition from that survey year. Finally, evaluate which of these two runs comes closest to producing the age composition estimates obtained when the survey age composition are used. Evaluating this comparison across multiple survey years should provide a more general view of the effect of including survey length data." (Plan Team, September 2014)

This analysis has been provided in Appendix 9B. Overall, the results of this analysis suggest that the utility of using the most recent survey's length composition is case-specific. For Pacific ocean perch, the best case scenario results indicate no improvement to the model occurs by including the most recent year's length composition. At worst, there are unnecessary increases in the variability of modeled estimates when the most recent year's survey length composition is included. Thus, in this year's assessment we continue the convention of not fitting the most recent year of the survey length composition as a proxy for age composition and only fit the survey age composition data.

"Finally, the Plan Team recommends that the author consult with the Age and Growth Lab about the possibility of obtaining the most recent, additional POP age information to incorporate into the model, in order to supplement the survey length data. Additional age at length data for recent year classes would add to the model's accuracy." (Plan Team, September 2014)

We contacted the age and growth lab, but due to other assessment requests they were not able to complete the 2013 survey ages for POP in time to use in this year's assessment.

"The SSC received a presentation on two GOA rockfish species that included Pacific ocean perch (POP) and demersal shelf rockfish (DSR). In 2013, the POP authors conducted a full assessment, but were unable to include updated POP maturity data. At the request of the SSC, the authors will provide a full assessment in 2014 evaluating the effects of new maturity data, survey length data on recruitment estimates, and sample size specified for age data. The assessment author also provided an evaluation of an alternative approach using a random-effects model for area apportionment. The Plan Team recommended using the random effects model, rather than the weighted survey average approach to the extent practical for POP and for rockfish in general and the SSC agrees with this advice." (SSC, October 2014)

As stated in responses above, this year's assessment includes new maturity data, evaluates the utility of survey length composition (Appendix 9B), and uses the random effects model for apportionment. Input sample sizes for ages will be evaluated in the 2015 assessment.

Introduction

Biology and distribution

Pacific ocean perch (*Sebastes alutus,* POP) has a wide distribution in the North Pacific from southern California around the Pacific rim to northern Honshu Is., Japan, including the Bering Sea. The species appears to be most abundant in northern British Columbia, the Gulf of Alaska, and the Aleutian Islands (Allen and Smith 1988). Adults are found primarily offshore on the outer continental shelf and the upper continental slope in depths of 150-420 m. Seasonal differences in depth distribution have been noted by many investigators. In the summer, adults inhabit shallower depths, especially those between 150 and 300 m. In the fall, the fish apparently migrate farther offshore to depths of ~300-420 m. They reside in these deeper depths until about May, when they return to their shallower summer distribution (Love et al. 2002). This seasonal pattern is probably related to summer feeding and winter spawning. Although small numbers of Pacific ocean perch are dispersed throughout their preferred depth range on the continental shelf and slope, most of the population occurs in patchy, localized aggregations (Hanselman et al. 2001). Pacific ocean perch are generally considered to be semi-demersal but there can at times be a significant pelagic component to their distribution. Pacific ocean perch often move off-bottom during the day to feed, apparently following diel euphausiid migrations (Brodeur 2001). Commercial fishing data in the GOA since 1995 show that pelagic trawls fished off-bottom have accounted for as much as 31% of the annual harvest of this species.

There is much uncertainty about the life history of Pacific ocean perch, although generally more is known than for other rockfish species (Kendall and Lenarz 1986). The species appears to be viviparous (the eggs develop internally and receive at least some nourishment from the mother), with internal fertilization and the release of live young. Insemination occurs in the fall, and sperm are retained within the female until fertilization takes place ~2 months later. The eggs hatch internally, and parturition (release of larvae) occurs in April-May. Information on early life history is very sparse, especially for the first year of life. Pacific ocean perch larvae are thought to be pelagic and drift with the current, and oceanic conditions may sometimes cause advection to suboptimal areas (Ainley et al. 1993) resulting in high recruitment variability. However, larval studies of rockfish have been hindered by difficulties in species identification since many larval rockfish species share the same morphological characteristics (Kendall 2000). Genetic techniques using allozymes (Seeb and Kendall 1991) and mitochondrial DNA (Li 2004) are capable of identifying larvae and juveniles to species, but are expensive and time-consuming. Post-larval and early young-of-the-year Pacific ocean perch have been positively identified in offshore, surface waters of the GOA (Gharrett et al. 2002), which suggests this may be the preferred habitat of this life stage. Transformation to a demersal existence may take place within the first year (Carlson and Haight 1976). Small juveniles probably reside inshore in very rocky, high relief areas, and by age 3 begin to migrate to deeper offshore waters of the continental shelf (Carlson and Straty 1981). As they grow, they continue to migrate deeper, eventually reaching the continental slope where they attain adulthood.

Pacific ocean perch are mostly planktivorous (Carlson and Haight 1976; Yang 1993; 1996, Yang and Nelson 2000; Yang 2003; Yang et al. 2006). In a sample of 600 juvenile perch stomachs, Carlson and Haight (1976) found that juveniles fed on an equal mix of calanoid copepods and euphausiids. Larger juveniles and adults fed primarily on euphausiids, and to a lesser degree, copepods, amphipods and mysids (Yang and Nelson 2000). In the Aleutian Islands, myctophids have increasingly comprised a substantial portion of the Pacific ocean perch diet, which also compete for euphausiid prey (Yang 2003). Pacific ocean perch and walleye pollock (*Theragra chalcogramma*) probably compete for the same euphausiid prey as euphausiids make up about 50% of the pollock diet (Yang and Nelson 2000). Consequently, the large removals of Pacific ocean perch by foreign fishermen in the Gulf of Alaska in the 1960s may have allowed walleye pollock stocks to greatly expand in abundance.

Predators of adult Pacific ocean perch are likely sablefish, Pacific halibut, and sperm whales (Major and Shippen 1970). Juveniles are consumed by seabirds (Ainley et al. 1993), other rockfish (Hobson et al. 2001), salmon, lingcod, and other large demersal fish.

Pacific ocean perch is a slow growing species, with a low rate of natural mortality (estimated at 0.06), a relatively old age at 50% maturity (10.5 years for females in the Gulf of Alaska), and a very old maximum age of 98 years in Alaska (84 years maximum age in the Gulf of Alaska) (Hanselman et al. 2003). Age at 50% recruitment to the commercial fishery has been estimated to be between 7 and 8 years in the Gulf of Alaska. Despite their viviparous nature, they are relatively fecund with number of eggs/female in Alaska ranging from 10,000-300,000, depending upon size of the fish (Leaman 1991) Rockfish in general were found to be about half as fecund as warm water snappers with similar body shapes (Haldorson and Love 1991).

The evolutionary strategy of spreading reproductive output over many years is a way of ensuring some reproductive success through long periods of poor larval survival (Leaman and Beamish 1984). Fishing generally selectively removes the older and faster-growing portion of the population. If there is a distinct evolutionary advantage of retaining the oldest fish in the population, either because of higher fecundity or because of different spawning times, age-compression could be deleterious to a population with highly episodic recruitment like rockfish (Longhurst 2002). Research on black rockfish (*Sebastes melanops*) has shown that larval survival may be dramatically higher from older female spawners (Berkeley et al. 2004, Bobko and Berkeley 2004). The black rockfish population has shown a distinct downward trend in age-structure in recent fishery samples off the West Coast of North America, raising concerns about whether these are general results for most rockfish. de Bruin et al. (2004) examined Pacific ocean perch (*S. alutus*) and rougheye rockfish (*S. aleutianus*) for senescence in reproductive activity of older fish and found that oogenesis continues at advanced ages. Leaman (1991) showed that older individuals have slightly higher egg dry weight than their middle-aged counterparts. Such relationships have not yet been determined to exist for Pacific ocean perch or other rockfish in Alaska. Stock assessments for Alaska groundfish have assumed that the reproductive success of mature fish is independent of age. Spencer et al. (2007) showed that the effects of enhanced larval survival from older mothers decreased estimated F_{msy} (the fishing rate that produces maximum sustainable yield) by 3% to 9%, and larger decreases in stock productivity were associated at higher fishing mortality rates that produced reduced age compositions. Preliminary work at Oregon State University examined Pacific ocean perch of adult size by extruding larvae from harvested fish near Kodiak, and found no relationship between spawner age and larval quality (Heppell et al. 2009). However, older spawners tended to undergo parturition earlier in the spawning season than younger fish. These data are currently still being analyzed.

Evidence of stock structure

A few studies have been conducted on the stock structure of Pacific ocean perch. Based on allozyme variation, Seeb and Gunderson (1988) concluded that Pacific ocean perch are genetically quite similar throughout their range, and genetic exchange may be the result of dispersion at early life stages. In contrast, analysis using mitochondrial DNA techniques indicates that genetically distinct populations of Pacific ocean perch exist (Palof 2008). Palof et al. (2011) report that there is low, but significant genetic divergence (FST = 0.0123) and there is a significant isolation by distance pattern. They also suggest that there is a population break near the Yakutat area from conducting a principle component analysis. Withler et al. (2001) found distinct genetic populations on a small scale in British Columbia. Kamin et al (2013) examined genetic stock structure of young of the year Pacific ocean perch. The geographic genetic pattern they found was nearly identical to that observed in the adults by Palof et al. (2011). Currently, genetic studies are underway that should clarify the genetic stock structure of Pacific ocean perch and its relationship to population dynamics.

In a study on localized depletion of Alaskan rockfish, Hanselman et al. (2007) showed that Pacific ocean perch are sometimes highly depleted in areas 5,000-10,000 km^2 in size, but a similar amount of fish return in the following year. This result suggests that there is enough movement on an annual basis to prevent serial depletion and deleterious effects on stock structure.

In 2012, the POP assessment completed the stock structure template that summarized the body of knowledge on stock structure and spatial management (Hanselman et al. 2012a).

Fishery

Historical Background

A Pacific ocean perch trawl fishery by the U.S.S.R. and Japan began in the Gulf of Alaska in the early 1960s. This fishery developed rapidly, with massive efforts by the Soviet and Japanese fleets. Catches peaked in 1965, when a total of nearly 350,000 metric tons (t) was caught. This apparent overfishing resulted in a precipitous decline in catches in the late 1960s. Catches continued to decline in the 1970s, and by 1978 catches were only 8,000 t (Figure 9-1). Foreign fishing dominated the fishery from 1977 to 1984, and catches generally declined during this period. Most of the catch was taken by Japan (Carlson et al. 1986). Catches reached a minimum in 1985, after foreign trawling in the Gulf of Alaska was prohibited.

The domestic fishery first became important in 1985 and expanded each year until 1991 (Figure 9-1b). Much of the expansion of the domestic fishery was apparently related to increasing annual quotas; quotas increased from 3,702 t in 1986 to 20,000 t in 1989. In the years 1991-95, overall catches of slope rockfish diminished as a result of the more restrictive management policies enacted during this period. The restrictions included: (1) establishment of the management subgroups, which limited harvest of the more desired species; (2) reduction of total allowable catch (TAC) to promote rebuilding of Pacific ocean perch stocks; and (3) conservative in-season management practices in which fisheries were sometimes closed even though substantial unharvested TAC remained. These closures were necessary because, given the large fishing power of the rockfish trawl fleet, there was substantial risk of exceeding the TAC if the fishery were to remain open. Since 1996, catches of Pacific ocean perch have increased again, as good recruitment and increasing biomass for this species have resulted in larger TAC's. In recent years, the TAC's for Pacific ocean perch have usually been fully taken (or nearly so) in each management area except Southeast Outside. (The prohibition of trawling in Southeast Outside during these years has resulted in almost no catch of Pacific ocean perch in this area). In 2013, approximately 21% of the TAC was taken in the Western GOA. NMFS did not open directed fishing for Pacific ocean perch in this area because the catch potential from the expected l effort (15 catcher/processors) for a one day fishery (shortest allowed) exceeded the available TAC. Depending on management measures adopted in this area, future harvest levels are uncertain.

Detailed catch information for Pacific ocean perch in the years since 1977 is listed in Table 9-2. The reader is cautioned that actual catches of Pacific ocean perch in the commercial fishery are only shown for 1988-2012; for previous years, the catches listed are for the Pacific ocean perch complex (a former management grouping consisting of Pacific ocean perch and four other rockfish species), Pacific ocean perch alone, or all *Sebastes* rockfish, depending upon the year (see Footnote in Table 9-2). Pacific ocean perch make up the majority of catches from this complex. The acceptable biological catches and quotas in Table 9-2 are Gulf-wide values, but in actual practice the NPFMC has divided these into separate, annual apportionments for each of the three regulatory areas of the Gulf of Alaska.

Historically, bottom trawls have accounted for nearly all the commercial harvest of Pacific ocean perch. In recent years, however, a sizable portion of the Pacific ocean perch catch has been taken by pelagic trawls. The percentage of the Pacific ocean perch Gulf-wide catch taken in pelagic trawls increased from 2-8% during 1990-95 to 14-20% during 1996-98. By 2008, the amount caught in pelagic trawls was even higher at 31%.

Before 1996, most of the Pacific ocean perch trawl catch (>90%) was taken by large factory-trawlers that processed the fish at sea. A significant change occurred in 1996, however, when smaller shore-based trawlers began taking a sizeable portion of the catch in the Central area for delivery to processing plants in Kodiak. These vessels averaged about 50% of the catch in the Central Gulf area since 1998. By 2008, catcher vessels were taking 60% of the catch in the Central Gulf area and 35% in the West Yakutat area. Factory trawlers continue to take nearly all the catch in the Western Gulf area.

In 2007, the Central Gulf of Alaska Rockfish Program was implemented to enhance resource conservation and improve economic efficiency for harvesters and processors who participate in the Central Gulf of Alaska rockfish fishery. This rationalization program establishes cooperatives among trawl vessels and processors which receive exclusive harvest privileges for rockfish management groups. The primary rockfish management groups are northern rockfish, Pacific ocean perch, and pelagic shelf rockfish. Potential effects of this program on Pacific ocean perch include: 1) extended fishing season lasting from May 1 – November 15, 2) changes in spatial distribution of fishing effort within the Central GOA (e.g. Figure 9-21), 3) improved at-sea and plant observer coverage for vessels participating in the rockfish fishery, 4) and a higher potential to harvest 100% of the TAC in the Central GOA region. Recent data show that the Pilot project has resulted in much higher observer coverage of catch in the Central Gulf.

Hanselman et al. (2009) showed evidence that the fishery has changed over time and is more focused on younger fish and smaller boats. In response to this evidence it was suggested that we examine fishery age compositions by year, depth, and vessel size. We examine both the mean and the median because the presence of very old fish has consequences to modeling the plus group selectivity. Mean age has declined substantially from the first few years of fishery ages collected, while the median has remained steady because fewer very old fish are showing up in the catch (Figure 9-2a). This was also true in the bottom trawl survey age composition (Figure 9-2b). There is a clear cline toward older fish starting with NMFS area 620 (Chirikof) toward NMFS area 650 (Southeast Alaska) which has been closed to trawling since 1998 (Figure 9-2c). In the trawl survey data, this cline is not apparent in mean age from west to east (Figure 9-2d). A small increase in mean age with depth resulted in both the fishery and trawl survey age composition data (Figure 9-2e and f).

Overall, it would appear that there are trends in the data to support that the fishery is more focused on middle-aged fish, rather than older fish in recent years. Also as described in 2009, the fishery is focusing on shallower depths where younger fish are. As mean fishery age has declined, the mean survey age has steadily been increasing (Figure 9-2f, using 25+ group). The hypothesis that moving to smaller boats has caused a change in selectivity is not supported by this analysis, and we do not have age data far enough back to examine the very large catches of the foreign fleet. Further analysis would be to do some comparisons of the catch-at-age of other slope rockfish and to further examine length compositions from the foreign fleet.

Nominal catch rates (kg/minutes) have increased substantially since 1991 in the Gulf of Alaska. However, when compared to a measure of exploitable biomass (Age 6+), the increases in catch rate are coincident with a tripling of biomass during the same period. Increases in catch rates appear to be leveling off along with biomass estimates in recent years (Figure 9-3a). We also compared exploitation rate with CPUE and it shows that exploitation rate has slowly risen since the 1994 and is now leveling off near around 4 or 5% (Figure 9-3b).

Management measures/units

In 1991, the NPFMC divided the slope assemblage in the Gulf of Alaska into three management subgroups: Pacific ocean perch, shortraker/rougheye rockfish, and all other species of slope rockfish. In 1993, a fourth management subgroup, northern rockfish, was also created. In 2004, shortraker rockfish and rougheye rockfish were divided into separate subgroups. These subgroups were established to protect Pacific ocean perch, shortraker rockfish, rougheye rockfish, and northern rockfish (the four most soughtafter commercial species in the assemblage) from possible overfishing. Each subgroup is now assigned an individual ABC (acceptable biological catch) and TAC (total allowable catch), whereas prior to 1991, an ABC and TAC was assigned to the entire assemblage. Each subgroup ABC and TAC is apportioned to the three management areas of the Gulf of Alaska (Western, Central, and Eastern) based on distribution of survey biomass.

Amendment 32, which took effect in 1994, established a rebuilding plan for POP. The amendment stated that "*stocks will be considered to be rebuilt when the total biomass of mature females is equal to or greater than* B_{MSY}" (Federal Register: April 15, 1994, http://alaskafisheries.noaa.gov/prules/noa_18103.pdf). Prior to Amendment 32, overfishing levels had been defined GOA-wide. Under Amendment 32, "*the overfishing level would be distributed among the eastern, central, and western areas in the same proportions as POP biomass occurs in those areas. This measure would avoid localized depletion of POP and would rebuild POP at equal rates in all regulatory areas of the GOA.*" This measure established management area OFLs for Pacific ocean perch.

Amendment 41, which took effect in 2000, prohibited trawling in the Eastern area east of 140 degrees W. longitude. Since most slope rockfish, especially Pacific ocean perch, are caught exclusively with trawl gear, this amendment could have concentrated fishing effort for slope rockfish in the Eastern area in the relatively small area between 140 degrees and 147 degrees W. longitude that remained open to trawling. To ensure that such a geographic over-concentration of harvest would not occur, since 1999 the NPFMC has divided the Eastern area into two smaller management areas: West Yakutat (area between 147 and 140 degrees W. longitude) and East Yakutat/Southeast Outside (area east of 140 degrees W. longitude). Separate ABC's and TAC's are now assigned to each of these smaller areas for Pacific ocean perch, while separate OFLs have remained for the Western, Central, and Eastern GOA management areas.

In November, 2006, NMFS issued a final rule to implement Amendment 68 of the GOA groundfish Fishery Management Plan for 2007 through 2011. This action implemented the Central GOA Rockfish Program (formerly the Rockfish Pilot Program or RPP). The intention of this program is to enhance resource conservation and improve economic efficiency for harvesters and processors in the rockfish fishery. This should spread out the fishery in time and space, allowing for better prices for product and reducing the pressure of what was an approximately two week fishery in July. In a comparison of catches in the four years before the program to the four years after, it appears some effort has shifted to area 620 (Chirikof) from area 630 (Kodiak) (Figure 9-21). The authors will pay close attention to the benefits and consequences of this action.

Since the original establishment of separate OFLs by management areas for POP in the rebuilding plan (Amendment 32) in 1994, the spawning stock biomass has tripled. The rebuilding plan required that female spawning biomass be greater than B_{msy} and the stock is now 35% higher than B_{msy}. Management has prosecuted harvest accurately within major management areas using ABC apportionments. While evidence of stock structure exists in the Gulf of Alaska, it does appear to be along an isolation by distance cline, not sympatric groups (Palof et al. 2011; Kamin et al. 2013)). Palof et al. (2011) also suggest that the Eastern GOA might be distinct genetically, but this area is already its own management unit, and has additional protection with the no trawl zone. Hanselman et al. (2007) showed that POP are reasonably resilient to serial localized depletions (areas replenish on an annual basis). The NPFMC stock structure template was completed for Gulf of Alaska POP in 2012 (Hanselman et al. (2012a). Recommendations from this exercise were to continue to allocate ABCs by management area or smaller. However, the original rationale for area-specific OFLs from the rebuilding plan no longer exists because the overall population is above target levels and is less vulnerable to occasional overages. Therefore, in terms of rebuilding the stock, management area OFLs are no longer a necessity for the Gulf of Alaska POP stock.

Management measures since the break out of Pacific ocean perch from slope rockfish are summarized in Table 9-1.

Bycatch and discards

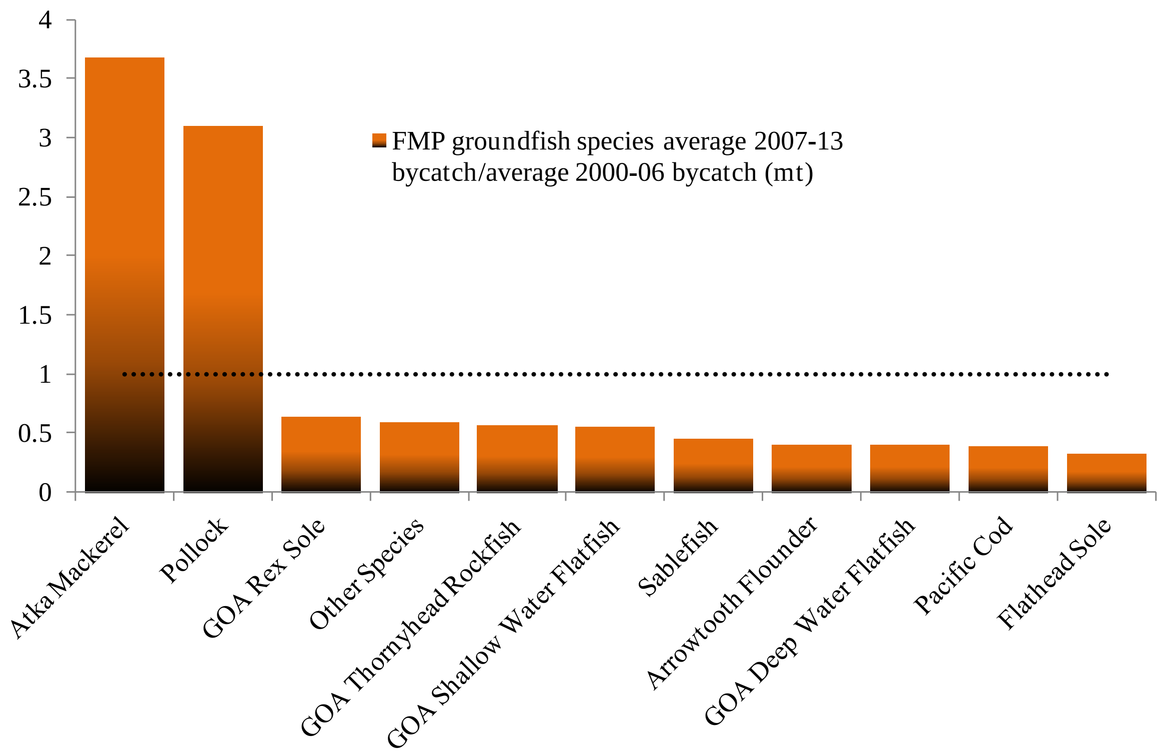
Gulf-wide discard rates[2] (% discarded) for Pacific ocean perch in the commercial fishery for 2000-2013 are listed as follows:

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
% Discard	11.3	8.6	7.3	15.1	8.2	5.7	7.8	3.7	4.1	6.8	4.2

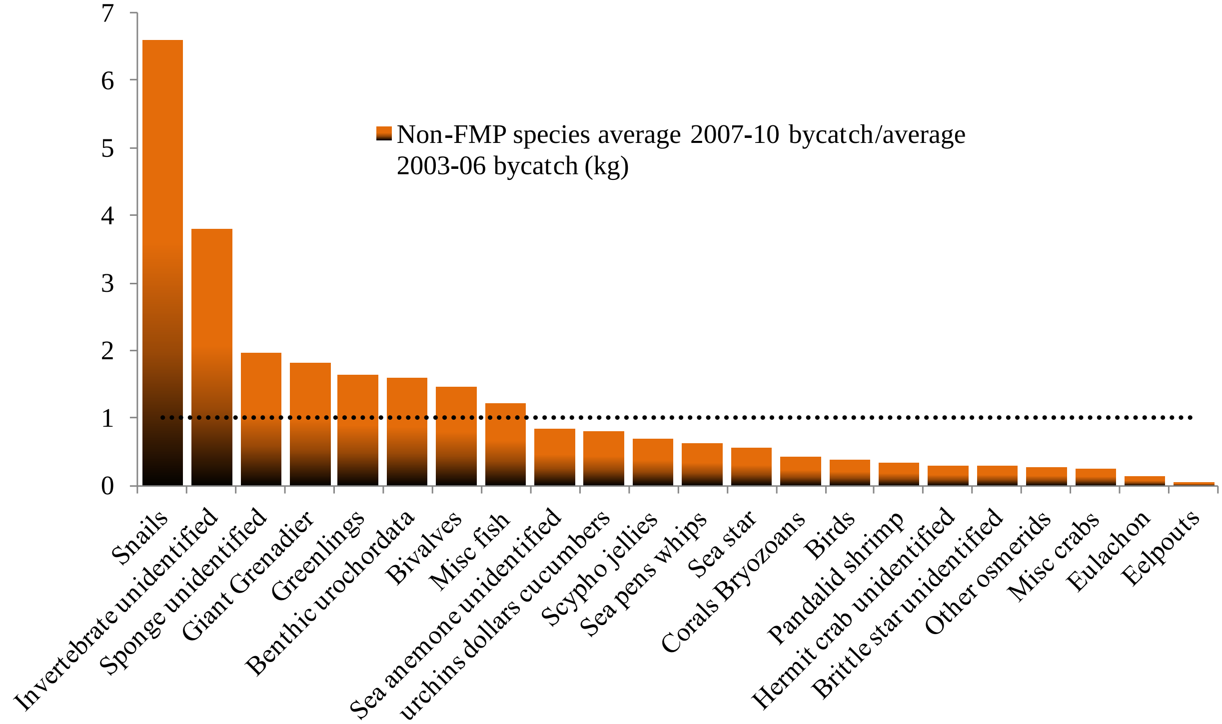
Year	2011	2012	2013
% Discard	6.5	4.8	7.6

Total FMP groundfish catch estimates in the GOA rockfish targeted fisheries from 2008-2013 are shown in Table 9-3. For the GOA rockfish fishery during 2008-2013, the largest non-rockfish bycatch groups are Atka mackerel (1,591 t/year), pollock (818 t/year), arrowtooth flounder (581 t/year), and Pacific cod (558 t/year). Catch of Pacific ocean perch in other Gulf of Alaska fisheries is mainly in the rex sole (326 t/year average) and arrowtooth (272 t/year) targeted fishing (Table 9-4).

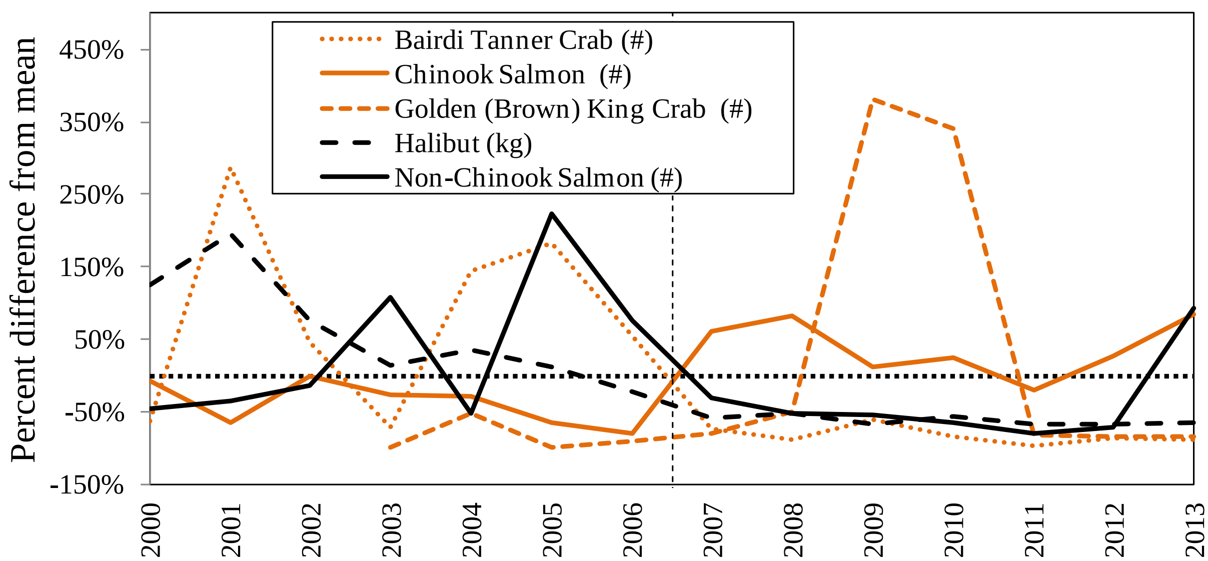
We compared bycatch from pre-2006 and post-2007 in the central GOA for the combined rockfish fisheries to determine impact of the Central GOA Rockfish Program implementation. We divided the average post-2006 bycatch (2007-2013) by the average pre-2007 bycatch (2000-2006) for non-rockfish species that had available information in both time periods. For the majority of FMP groundfish species, bycatch in the central GOA has been reduced since 2007, with the exception of Atka mackerel (414 t/year pre-2006 compared to 1,520 t/year post-2007) and walleye pollock (234 t/year pre-2006 compared to 722 t/year post-2007, see figure below):



Non-FMP species catch in the rockfish target fisheries is dominated by giant grenadier, miscellaneous fish, and ocassionally dark rockfish (recently removed from FMP to state management) (Table 9-5). 8 of 22 nontarget species resulted in an increase in bycatch post-2007 compared to pre-2006 (see figure below):



Prohibited species catch in the GOA rockfish fishery has been lower than average since 2011 for most major species. In 2013 only chinook and non-chinook salmon bycatch was larger than average. The catch of golden king crab drecreased dramatically from over 3,000 animals in 2009 and 2010, to just over 100 in 2011 – 2013. (Table 9-6). Catch of prohibited species in the combined rockfish trawl fisheries has decreased, on average, since 2006 for most groups, with the exception of chinook salmon:



Data

The following table summarizes the data used for this assessment:

Source	Data	Years
NMFS Groundfish survey	Survey biomass	1984-1999 (triennial), 2001-2013 (biennial)
	Age Composition	1984, 1987, 1990, 1993, 1996, 1999, 2003, 2005, 2007, 2009, 2011
U.S. trawl fisheries	Catch	1961-2014
	Age Composition	1990,1998-2002, 2004, 2005, 2006, 2008, 2010, 2012
	Length Composition	1963-1977, 1991-1997

Fishery

Catch

Catches range from 2,500 t to 350,000 t from 1961 to 2014. Detailed catch information for Pacific ocean perch is listed in Table 9-2 and shown graphically in Figure 9-1. This is the commercial catch history used in the assessment model. In response to Annual Catch Limits (ACLs) requirements, assessments now document all removals including catch that is not associated with a directed fishery. Research catches of Pacific ocean perch have been reported in previous stock assessments (Hanselman et al. 2009). Estimates of all removals not associated with a directed fishery including research catches are available and are presented in Appendix 9-A. In summary, research removals have typically been less than 100 t and very little is taken in recreational or halibut fisheries. These levels likely do not pose a significant risk to the Pacific ocean perch stock in the GOA.

Age and Size composition

Observers aboard fishing vessels and at onshore processing facilities have provided data on size and age composition of the commercial catch of Pacific ocean perch. Ages were determined from the break-and-burn method (Chilton and Beamish 1982). Table 9-7 summarizes the length compositions from 1995-2012. Table 9-8 summarizes age compositions from 1990, 1998-2002, 2004-2006, 2008, 2010, and 2012 for the fishery. Figures 9-4 and 9-5 show the distributions graphically. The age compositions in all years of the fishery data show strong 1986 and 1987 year classes. These year classes were also strong in age compositions from the 1990-1999 trawl surveys. The 2004-2006 fishery data show the presence of strong 1994 and 1995 year classes. These two year classes are also the highest proportion of the 2003 survey age composition. The 2012 fishery age composition shows a relatively high number of older fish in the plus group (25 years and older).

Survey

Biomass Estimates from Trawl Surveys

Bottom trawl surveys were conducted on a triennial basis in the Gulf of Alaska in 1984, 1987, 1990, 1993, 1996, and a biennial survey schedule has been used since the 1999 survey. The surveys provide much information on Pacific ocean perch, including an abundance index, age composition, and growth characteristics. The surveys are theoretically an estimate of absolute biomass, but we treat them as an index in the stock assessment. The surveys covered all areas of the Gulf of Alaska out to a depth of 500 m (in some surveys to 1,000 m), but the 2001 survey did not sample the eastern Gulf of Alaska. Summaries of biomass estimates from 1984 to 2013 surveys are provided in Table 9-9.

Comparison of Trawl Surveys in 1984-2013

Gulf-wide biomass estimates for Pacific ocean perch are shown in Table 9-9. Gulf-wide biomass estimates for 1984-2013 and 95% confidence intervals are shown in Figure 9-6. The 1984 survey results should be treated with some caution, as a different survey design was used in the eastern Gulf of Alaska. In addition, much of the survey effort in 1984 and 1987 was by Japanese vessels that used a very different net design than what has been the standard used by U.S. vessels throughout the surveys. To deal with this problem, fishing power comparisons of rockfish catches have been done for the various vessels used in the surveys (for a discussion see Heifetz et al. 1994). Results of these comparisons have been incorporated into the biomass estimates listed here, and the estimates are believed to be the best available. Even so, the use of Japanese vessels in 1984 and 1987 does introduce an element of uncertainty as to the standardization of these two surveys.

The biomass estimates for Pacific ocean perch were generally more imprecise between 1996-2001 than after 2003 (Figure 9-6). Although more precise, a fluctuation in biomass of 60% in two surveys (e.g. 2003 to 2005) does not seem reasonable given the slow growth and low natural mortality rates of Pacific ocean perch. Large catches of an aggregated species like Pacific ocean perch in just a few individual hauls can greatly influence biomass estimates and may be a source of much variability. Anomalously large catches have especially affected the biomass estimates for Pacific ocean perch in the 1999 and 2001 surveys. While there are still several large catches, the distribution of Pacific ocean perch is becoming more uniform with more medium-sized catches in more places compared to previous surveys (for example compare 2009 and 2011 with 1999 Figures 9-7a, b). In past SAFE reports, we have speculated that a change in availability of rockfish to the survey, caused by unknown behavioral or environmental factors, may explain some of the observed variation in biomass. We repeat this speculation here and acknowledge that until more is known about rockfish behavior, the actual cause of changes in biomass estimates will remain the subject of conjecture. Previous research has focused on improving rockfish survey biomass estimates using alternate sampling designs (Quinn et al. 1999, Hanselman et al. 2001, Hanselman et al. 2003). Research on the utility of hydroacoustics in gaining survey precision was completed in 2011 (Hanselman et al. 2012b, Spencer et al. 2012) which confirmed again that there are ways to improve the precision, but all of them require more sampling effort in high POP density strata. In addition, there is a study underway exploring the density of fish in untrawlable grounds that are currently assumed to have an equal density of fish compared to trawlable grounds.

Biomass estimates of Pacific ocean perch were relatively low in 1984 to 1990, increased markedly in both 1993 and 1996, and became substantially higher in 1999 and 2001 with much uncertainty. Biomass estimates in 2003 have less sampling error with a total similar to the 1993 estimate indicating that the large estimates from 1996-2001 may have been a result of a few anomalous catches. However, in 2005 the estimate was similar to 1996-2001, but was more precise. To examine these changes in more detail, the biomass estimates for Pacific ocean perch in each statistical area, along with Gulf-wide 95% confidence intervals, are presented in Table 9-9. The large rise in 1993, which the confidence intervals indicate was statistically significant compared with 1990, was primarily the result of big increases in biomass in the Central and Western Gulf of Alaska. The Kodiak area increased greater than ten-fold, from 15,765 t in 1990 to 153,262 t in 1993. The 1996 survey showed continued biomass increases in all areas, especially Kodiak, which more than doubled compared with 1993. In 1999, there was a substantial decline in biomass in all areas except Chirikof, where a single large catch resulted in a very large biomass estimate (Figure 9-7a). In 2001, the biomass estimates in both the Shumagin and Kodiak areas were the highest of all the surveys. In particular, the biomass in Shumagin was much greater than in previous years; as discussed previously, the increased biomass here can be attributed to very large catches in two hauls. In 2003 the estimated biomass in all areas except for Chirikof decreased, where Chirikof returned from a decade low to a more average value. The rise in biomass in 2005 can be attributed to large increases in the Shumagin and Kodiak areas. In 2007, the biomass dropped about 10% from 2005, with the bulk of that drop in the Shumagin area. Pacific ocean perch continued to be more uniformly distributed than in the past (Figure 9-7b). In 2009, total biomass was similar to 2007, and is the fourth survey in a row with relatively high precision. The biomass in the Western Gulf dropped severely, while the Chirikof and Eastern Gulf areas increased. It also appeared some of the biomass was consolidating around Kodiak Island (Figure 9-7b). In 2011, total biomass increased from 2009, but was quite similar to the mean of the last decade. The biomass estimate for 2013 was an all-time high and is one of the most precise of the survey time series. The 2013 survey design consisted of fewer stations than average, but the effect of this reduction in effort on POP survey catch was not apparent. The 2013 survey biomass increased in the Western, Central, and Easter Gulf. The Eastern gulf biomass had large uncertainty associated with it in comparison to the Western and Central Gulf.

Age Compositions

Ages were determined from the break-and-burn method (Chilton and Beamish 1982). The survey age compositions from 1984-2011 surveys showed that although the fish ranged in age up to 84 years, most of the population was relatively young; mean survey age was 10.2 years in 1996 and 11.4 years in 2009 (Table 9-10). The first four surveys identified a relatively strong 1976 year class and also showed a period of very weak year classes prior to 1976 (Figure 9-8). The weak year classes of the early 1970's may have delayed recovery of Pacific ocean perch populations after they were depleted by the foreign fishery. The survey age data from 1990-1999 suggested that there was a period of large year classes from 1986-1989. In 1990-1993, the 1986 year class looked very strong. Beginning in 1996 and continuing in 1999 survey ages, the 1987 and 1988 year classes also became prominent. Rockfish are difficult to age, especially as they grow older, and perhaps some of the fish have been categorized into adjacent age classes between surveys. Alternately, these year classes were not available to the survey until much later than the 1986 year class. Recruitment of the stronger year classes from the late 1980s probably has accounted for much of the increase in the estimated biomass for Pacific ocean perch in recent surveys. The 2003 survey age data indicate that 1994-1995 may also have been strong year classes. The 2005 and 2007 survey age compositions suggest that 1998 is a large year class. Indications from the 2009 and 2011 survey and the 2010 fishery age compositions suggest that the 2006 year class may be particularly strong.

Survey Size Compositions

Gulf-wide population size compositions for Pacific ocean perch are shown in Figure 9-9. The size composition for Pacific ocean perch in 2001 was bimodal, which differed from the unimodal compositions in 1993, 1996, and 1999. The 2001 survey showed a large number of relatively small fish, ~32 cm fork length which may indicate recruitment in the early 1990s, together with another mode at ~38 cm. Compared to the previous survey years, both 2001 and 2003 show a much higher proportion of small fish compared to the amount of fish in the pooled class of 39+ cm. This could be from good recruitment or from fishing down of larger fish. Survey size data are used in constructing the age-length transition matrix, but not used as data to be fitted in the stock assessment model. Size compositions from 2005-2007 returned to the same patterns as the 1996-1999 surveys, where the biomass was mainly adults. In 2009, there is indication of an incoming recent year class with an increase in the 18-20 cm range. In 2011, there are two modes of smaller fish at 20 and 25 cm likely showing potentially above-average 2006 and 2004 year classes, respectively. In 2013, these modes are less evident indicating the majority of the population is greater than 24cm.

In response to the groundfish Plan Team’s request we performed analysis of the utility of including the most recent year’s survey length composition into the assessment model (Appendix 9B). We recommend that the Pacific ocean perch assessment continue to not fit the most recent survey length composition as there was no improvement for most statistics evaluated, and for others, using the most recent year’s length composition induced unnecessary variability in model estimates.

Maturity

In previous assessments female age and size at 50% maturity were estimated for Pacific ocean perch from a study in the Gulf of Alaska that is based on the currently accepted break-and-burn method of determining age from otoliths (Lunsford 1999). A recent study of Pacific ocean perch maturity was undertaken by Conrath and Knoth (2013) which indicated a younger age at 50% maturity than the previous study. Using the same method as Hulson et al. (2011), in this year's assessment, we fit the data for both studies simultaneously within the assessment model so that uncertainty in maturity is reflected in the uncertainty of other model estimates.

Analytic Approach

Model Structure

We present results for Pacific ocean perch based on an age-structured model using AD Model Builder software (Fournier et al. 2012). Prior to 2001, the stock assessment was based on an age-structured model using stock synthesis (Methot 1990). The assessment model used for Pacific ocean perch is based on a generic rockfish model described in Courtney et al. (2007).

The parameters, population dynamics, and equations of the model are described in Box 1. Since its initial adaptation in 2001, the models' attributes have been explored and changes have been made to the template to adapt to Pacific ocean perch and other species. For 2009, further modifications were made to accommodate MCMC projections that use a pre-specified proportion of ABC for annual catch. Additionally in 2009, a change in selectivity curves was accepted to allow for time blocks and the dome-shaped gamma selectivity function.

Parameters Estimated Outside the Assessment Model

In previous assessments a von Bertalanffy growth curve was fitted to survey size at age data from 1984-1999 (Malecha et al. 2007). A second size to age transition matrix was adopted in 2003 to represent a lower density-dependent growth rate in the 1960s and 1970s (Hanselman et al. 2003), thus, there are two size to age transition matrices used in the model (pre- and post-1980). In this year's assessment the size at age data was updated through the 2011 survey. Sexes were combined. The size to age transition matrix for the recent period was then constructed by adding normal error with a standard deviation equal to the survey data for the probability of different ages for each size class. The estimated parameters for the growth curve are shown below:

L_∞=41.3 cm κ=0.19 t_0=-0.40 n=12,305

The previous assessments growth curve parameters were:

L_∞=41.4 cm κ=0.19 t_0=-0.47 n=9,336

Weight-at-age was constructed with weight at age data from the same data set as the length at age. The estimated growth parameters are shown below. A correction of $(W_\infty\text{-}W_{25})/2$ was used for the weight of the pooled ages (Schnute et al. 2001).

W_∞=1023 g a=0.00001 b=3.05 n=7,673

The previous assessments weight-at-age parameters were:

W_∞=984 g a=0.0004 b=2.45 n=3,592

Aging error matrices were constructed by assuming that the break-and-burn ages were unbiased but had a given amount of normal error around each age based on percent agreement tests conducted at the AFSC Age and Growth lab.

Parameters Estimated Inside the Assessment Model

The estimates of natural mortality (*M*), catchability (*q*) and recruitment deviations (σ_r) are estimated with the use of prior distributions as penalties. The prior mean for natural mortality is based on catch curve analysis to determine *Z*. Estimates of *Z* could be considered as an upper bound for *M*. Estimates of *Z* for Pacific ocean perch from Archibald et al. (1981) were from populations considered to be lightly exploited and thus are considered reasonable estimates of *M*, yielding a value of ~0.05. Natural mortality is a notoriously difficult parameter to estimate within the model so we assign a relatively precise prior CV of 10% (Figure 9-10). Catchability is a parameter that is somewhat unknown for rockfish, so while we assign it a prior mean of 1 (assuming all fish in the area swept are captured and there is no herding of fish from outside the area swept, and that there is no effect of untrawlable grounds), we assign it a less precise CV of 45% (Figure 9-11). This allows the parameter more freedom than that allowed to natural mortality. Recruitment deviation is the amount of variability that the model allows for recruitment estimates. Rockfish are thought to have highly variable recruitment, so we assign a high prior mean to this parameter of 1.7 with a CV of 20% (Figure 9-11).

Selectivity

In 2009, we presented empirical evidence that the fishery has changed its fishing practices over the time period (Hanselman et al. 2009). We noted that the fishery selectivity, which at that time was a nonparametric selectivity by age was drifting toward a dome shape. The fishery was catching a much higher proportion of older fish than the survey in the “eighties,” whereas in the “noughties” the fishery was catching a lower proportion of older fish than that found in the survey. Older POP generally are in the deepest water (Figure 9.2), and the trend since 1995 has been about a 50 meter decrease in catch-weighted average fishing depth (see figure below). This evidence led us to recommend allowing the fishery selectivity to become more dome-shaped and blocking fishery selectivity into three time periods:

1) 1961-1976: This period represented the massive catches and overexploitation by the foreign fisheries which slowed considerably by 1976. We do not have age data from this period to examine, but we can assume the near pristine age-structure was much older than now, and that at the high rate of exploitation, all vulnerable age-classes were being harvested. For these reasons we chose to only consider asymptotic (logistic) selectivity.
2) 1977-1995: This period represents the change-over from the foreign fleet to a domestic fleet, but was still dominated by large factory trawlers, which generally would tow deeper and further from port.
3) 1996-Present: During this period we have noted the emergence of smaller catcher-boats, semi-pelagic trawling and fishing cooperatives. The length of the fishing season has also been recently greatly expanded.

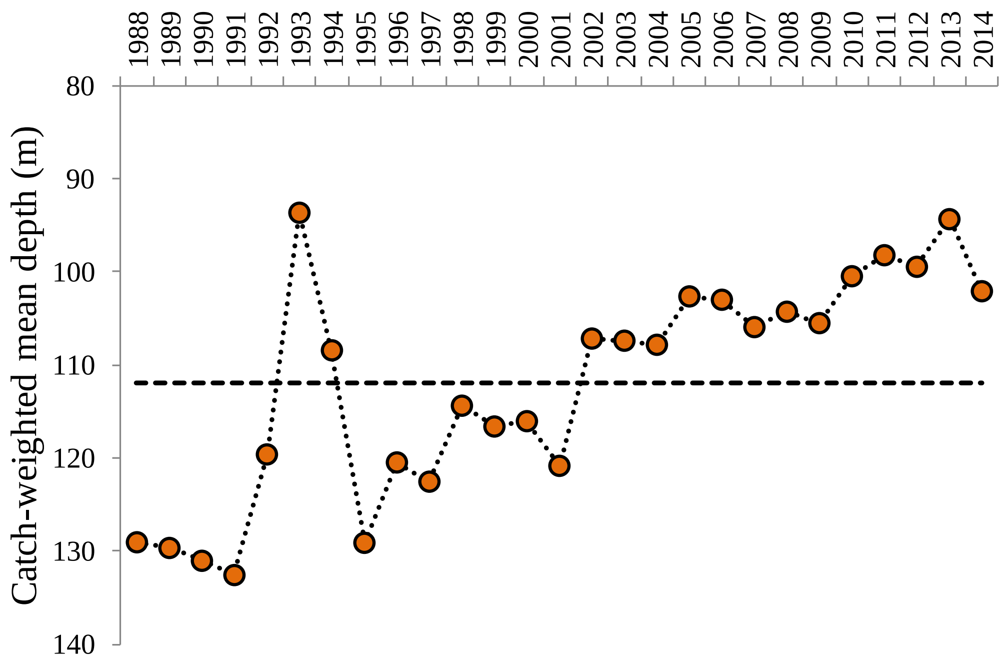
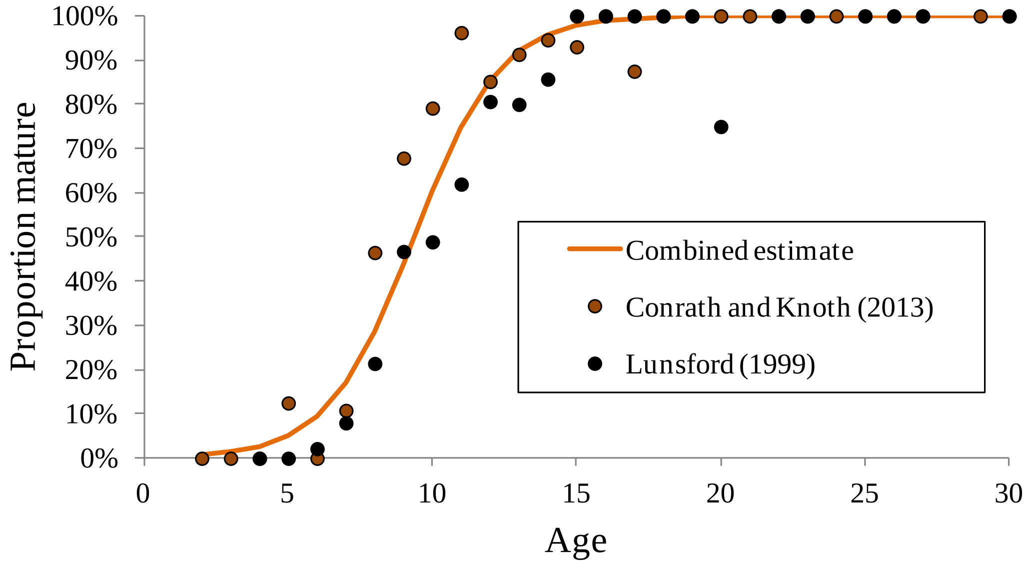


Figure. Change in catch-weighted mean depth of the Gulf of Alaska POP fishery over time (horizontal dashed line is average from 1988-2014).

We continue to recommend a model that transitions into dome-shaped selectivity for the fishery in the three time blocks described previously. We fitted a logistic curve for the first block, an averaged logistic-gamma in the 2nd block, and a gamma function for the 3rd block. In 2009 we also switched to fitting survey selectivity with the logistic curve (it was already very similar to the logistic) to be consistent. This accomplished a reduction of nine parameters that were used in the original non-parametric selectivities used between 2001-2007.

Maturity

Maturity-at-age is modeled with the logistic function, similar to selectivity-at-age for the survey and early-period fishery. In this year's assessment the recommended model estimates logistic parameters for maturity-at-age conditionally following the method presented in Hulson et al. (2011). Parameter estimates for maturity-at-age are obtained by fitting both datasets collected on female Pacific ocean perch maturity from Lunsford (1999) and Conrath and Knoth (2013). The binomial likelihood is used in the assessment model as an additional component to the joint likelihood function to fit the combined observations of female Pacific ocean perch maturity (e.g., Quinn and Deriso 1999). Parameters for the logistic function describing maturity-at-age are estimated conditionally in the model so that uncertainty in model results (e.g., ABC) can be linked to uncertainty in maturity parameter estimates through the Markov Chain Monte Carlo (MCMC) procedure described below in the *Uncertainty approach* section. The fit to the combined observations of maturity-at-age obtained in the recommended assessment model is shown below.



Identical maturity-at-age parameter estimates are obtained whether fitting the maturity data independently or conditionally, this is also true for the all the other parameters estimated in the model. Estimating maturity-at-age parameters conditionally influences the model only through the evaluation of uncertainty, as the MCMC procedure includes variability in the maturity parameters in conjunction with variability in all other parameters, rather than assuming the maturity parameters are fixed.

Other parameters estimated conditionally include, but are not limited to: mean recruitment, fishing mortality, and spawners per recruit levels. The numbers of estimated parameters for the recommended model are shown below. Other derived parameters are described in Box 1.

Parameter name	Symbol	Number
Natural mortality	M	1
Catchability	q	1
Log-mean-recruitment	μ_r	1
Recruitment variability	σ_r	1
Spawners-per-recruit levels	F_{35}, F_{40}, F_{50}	3
Recruitment deviations	τ_y	76
Average fishing mortality	μ_f	1
Fishing mortality deviations	ϕ_y	54
Fishery selectivity coefficients	fs_a	4
Survey selectivity coefficients	ss_a	2
Maturity-at-age coefficients	m_a	2
Total		146

Uncertainty approach

Evaluation of model uncertainty has recently become an integral part of the “precautionary approach” in fisheries management (Hilborn et al. 2001). In complex stock assessment models, evaluating the level of uncertainty is difficult. One way is to examine the standard errors of parameter estimates from the

Maximum Likelihood (ML) approach derived from the Hessian matrix. While these standard errors give some measure of variability of individual parameters, they often underestimate their variance and assume that the joint distribution is multivariate normal. An alternative approach is to examine parameter distributions through Markov Chain Monte Carlo (MCMC) methods (Gelman et al. 1995). When treated this way, our stock assessment is a large Bayesian model, which includes informative (e.g., lognormal natural mortality with a small CV) and noninformative (or nearly so, such as a parameter bounded between 0 and 10) prior distributions. In the model presented in this SAFE report, the number of parameters estimated is 142. In a low-dimensional model, an analytical solution might be possible, but in one with this many parameters, an analytical solution is intractable. Therefore, we use MCMC methods to estimate the Bayesian posterior distribution for these parameters. The basic premise is to use a Markov chain to simulate a random walk through the parameter space which will eventually converge to a stationary distribution which approximates the posterior distribution. Determining whether a particular chain has converged to this stationary distribution can be complicated, but generally if allowed to run long enough, it will converge. The “burn-in” is a set of iterations removed at the beginning of the chain. In our simulations we removed the first 1,000,000 iterations out of 10,000,000 and “thinned” the chain to one value out of every two thousand, leaving a sample distribution of 4,500. Further assurance that the chain had converged was to compare the mean of the first half of the chain with the second half after removing the “burn-in” and “thinning”. Because these two values were similar we concluded that convergence had been attained. We use these MCMC methods to provide further evaluation of uncertainty in the results below including 95% credible intervals for some parameters.

BOX 1. AD Model Builder POP Model Description

Parameter definitions	
y	Year
a	Age classes
l	Length classes
w_a	Vector of estimated weight at age, $a_0 \rightarrow a_+$
m_a	Vector of estimated maturity at age, $a_0 \rightarrow a_+$
a_0	Age it first recruitment
a_+	Age when age classes are pooled
μ_r	Average annual recruitment, log-scale estimation
μ_f	Average fishing mortality
ϕ_y	Annual fishing mortality deviation
τ_y	Annual recruitment deviation
σ_r	Recruitment standard deviation
fs_a	Vector of selectivities at age for fishery, $a_0 \rightarrow a_+$
ss_a	Vector of selectivities at age for survey, $a_0 \rightarrow a_+$
M	Natural mortality, log-scale estimation
$F_{y,a}$	Fishing mortality for year y and age class a ($fs_a \mu_f e^{\varepsilon}$)
$Z_{y,a}$	Total mortality for year y and age class a ($=F_{y,a}+M$)
$\varepsilon_{y,a}$	Residuals from year to year mortality fluctuations
$T_{a,a'}$	Aging error matrix
$T_{a,l}$	Age to length transition matrix
q	Survey catchability coefficient
SB_y	Spawning biomass in year y, ($=m_a\ w_a\ N_{y,a}$)
M_{prior}	Prior mean for natural mortality
q_{prior}	Prior mean for catchability coefficient
$\sigma_{r(prior)}$	Prior mean for recruitment variance
σ_M^2	Prior CV for natural mortality
σ_q^2	Prior CV for catchability coefficient
$\sigma_{\sigma_r}^2$	Prior CV for recruitment deviations

BOX 1 (Continued)

Equations describing the observed data

$$\hat{C}_y = \sum_a \frac{N_{y,a} * F_{y,a} * \left(1 - e^{-Z_{y,a}}\right)}{Z_{y,a}} * w_a$$

Catch equation

$$\hat{I}_y = q \ * \sum_a N_{y,a} * \frac{ss_a}{\max\left(ss_a\right)} * w_a$$

Survey biomass index (t)

$$\hat{P}_{y,a'} = \sum_a \left(\frac{N_{y,a} * ss_a}{\sum_a N_{y,a} * ss_a} \right) * T_{a,a'}$$

Survey age distribution
Proportion at age

$$\hat{P}_{y,l} = \sum_a \left(\frac{N_{y,a} * ss_a}{\sum_a N_{y,a} * ss_a} \right) * T_{a,l}$$

Survey length distribution
Proportion at length

$$\hat{P}_{y,a'} = \sum_a \left(\frac{\hat{C}_{y,a}}{\sum_a \hat{C}_{y,a}} \right) * T_{a,a'}$$

Fishery age composition
Proportion at age

$$\hat{P}_{y,l} = \sum_a \left(\frac{\hat{C}_{y,a}}{\sum_a \hat{C}_{y,a}} \right) * T_{a,l}$$

Fishery length composition
Proportion at length

Equations describing population dynamics

Start year

$$N_a = \begin{cases} e^{\left(\mu_r + \tau_{styr-a_0-a-1}\right)}, & a = a_0 \\ e^{\left(\mu_r + \tau_{styr-a_0-a-1}\right)} e^{-(a-a_0)M}, & a_0 < a < a_+ \\ \dfrac{e^{\left(\mu_r\right)} e^{-(a-a_0)M}}{\left(1 - e^{-M}\right)}, & a = a_+ \end{cases}$$

Number at age of recruitment

Number at ages between recruitment and pooled age class

Number in pooled age class

Subsequent years

$$N_{y,a} = \begin{cases} e^{\left(\mu_r + \tau_y\right)}, & a = a_0 \\ N_{y-1,a-1} * e^{-Z_{y-1,a-1}}, & a_0 < a < a_+ \\ N_{y-1,a-1} * e^{-Z_{y-1,a-1}} + N_{y-1,a} * e^{-Z_{y-1,a}}, & a = a_+ \end{cases}$$

Number at age of recruitment

Number at ages between recruitment and pooled age class

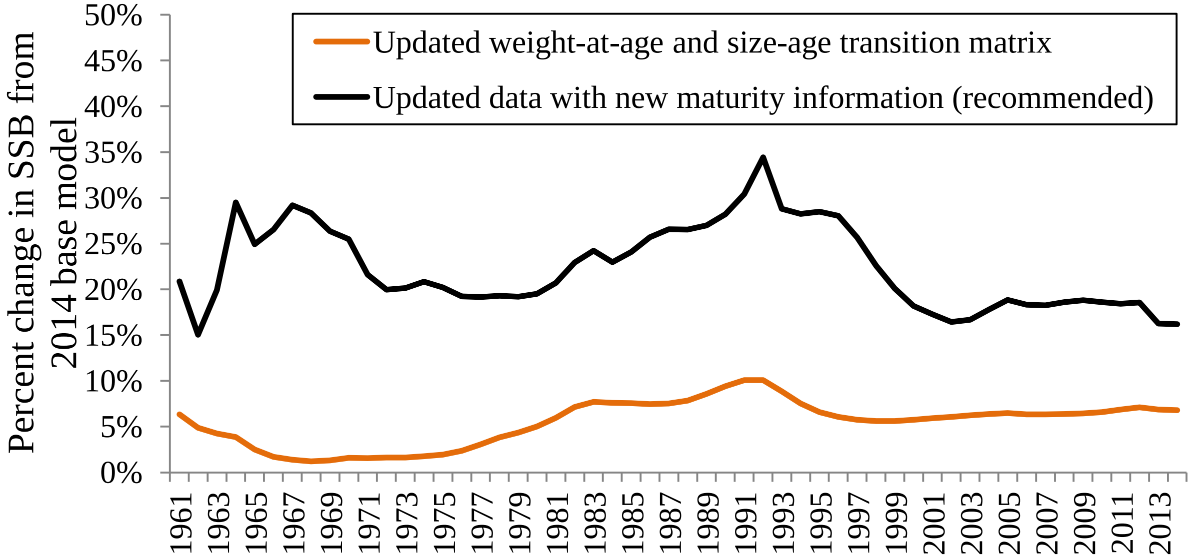
Number in pooled age class

Formulae for likelihood components	**BOX 1 (Continued)**
$L_1 = \lambda_1 \sum_y \left(\ln\left[\frac{C_y + 0.01}{\hat{C}_y + 0.01} \right] \right)^2$	Catch likelihood
$L_2 = \lambda_2 \sum_y \frac{\left(I_y - \hat{I}_y\right)^2}{2 * \hat{\sigma}^2 \left(I_y\right)}$	Survey biomass index likelihood
$L_3 = \lambda_3 \sum_{styr}^{endyr} -n^*{}_y \sum_a^{a+} \left(P_{y,a} + 0.001\right) * \ln\left(\hat{P}_{y,a} + 0.001\right)$	Fishery age composition likelihood ($n^*{}_y$ =sample size, standardized to maximum of 100)
$L_4 = \lambda_4 \sum_{styr}^{endyr} -n^*{}_y \sum_l^{l+} \left(P_{y,l} + 0.001\right) * \ln\left(\hat{P}_{y,l} + 0.001\right)$	Fishery length composition likelihood
$L_5 = \lambda_5 \sum_{styr}^{endyr} -n^*{}_y \sum_a^{a+} \left(P_{y,a} + 0.001\right) * \ln\left(\hat{P}_{y,a} + 0.001\right)$	Survey age composition likelihood
$L_6 = \lambda_6 \sum_{styr}^{endyr} -n^*{}_y \sum_l^{l+} \left(P_{y,l} + 0.001\right) * \ln\left(\hat{P}_{y,l} + 0.001\right)$	Survey size composition likelihood
$L_7 = \frac{1}{2\sigma_M^2} \left(\ln\left(M / M_{prior} \right) \right)^2$	Penalty on deviation from prior distribution of natural mortality
$L_8 = \frac{1}{2\sigma_q^2} \left(\ln\left(q / q_{prior} \right) \right)^2$	Penalty on deviation from prior distribution of catchability coefficient
$L_9 = \frac{1}{2\sigma_{\sigma_r}^2} \left(\ln\left(\sigma_r / \sigma_{r(prior)} \right) \right)^2$	Penalty on deviation from prior distribution of recruitment deviations
$L_{10} = \lambda_{10} \left[\frac{1}{2 * \sigma_r^2} \sum_y \tau_y^2 + n_y * \ln\left(\sigma_r\right) \right]$	Penalty on recruitment deviations
$L_{11} = \lambda_{11} \sum_y \varepsilon_y^2$	Fishing mortality regularity penalty
Selectivity equations	
$s_{a,s}^g = \left(1 + e^{\left(-\delta_{g,s}\left(a - a_{50\%,g,s}\right)\right)}\right)^{-1}$	Logistic selectivity
$s_{a,s}^g = \left(\frac{a}{a_{\max}} \right)^{a_{\max,g,s}/p} e^{\left(a_{\max,g,s} - a\right)/p}$ $p = 0.5\left[\sqrt{a_{\max,g,s}{}^2 + 4\delta_{g,s}{}^2} - a_{\max,g,s} \right]$	Reparameterized gamma distribution

Results

Model Evaluation

This model is identical in all aspects to the model accepted in 2013 except for inclusion of updated weight-at-age, an updated size-at-age transition matrix, and new maturity data. When we present alternative model configurations, our usual criteria for choosing a superior model are: (1) the best overall fit to the data (in terms of negative log-likelihood), (2) biologically reasonable patterns of estimated recruitment, catchabilities, and selectivities, (3) a good visual fit to length and age compositions, and (4) parsimony. In the following figure the percent change in spawning biomass from the 2014 base model (the same model as 2013 with only catch updated in 2014) compared to a model that updated growth data and the 2014 recommended model that updated both growth data and included new maturity information is shown.



Overall, including the updated growth data resulted in a 5% increase in spawning biomass on average compared to the base model. Including updated growth data with new maturity data resulted in a larger increase in spawning biomass, on average about 22%, which is expected given the decrease in the age at 50% maturity when including the new maturity information. The parameter estimates and likelihoods are also similar between the three models and are shown in Table 9-12.

The 2014 recommended model generally produces good visual fits to the data, and biologically reasonable patterns of recruitment, abundance, and selectivities. This model does not fit the 2013 survey estimate well, likely due to the large increase in this estimate compared to previous years that is difficult to explain in a long-lived species with our current model configuration. The 2014 recommended model update shows recent recruitment stabilizing and an increase in spawning and total biomass from previous projections. Therefore the, 2014 recommended model is utilizing the new information effectively, and we use it to recommend 2015 ABC and OFL.

Time Series Results

Key results have been summarized in Tables 9-12 to 9-15. Model predictions generally fitted the data well (Figures 9-1, 9-4, 9-5, 9-6, and 9-8) and most parameter estimates have remained similar to the last several years using this model.

Definitions

Spawning biomass is the biomass estimate of mature females. Total biomass is the biomass estimate of all Pacific ocean perch age two and greater. Recruitment is measured as the number of age two Pacific ocean perch. Fishing mortality is the mortality at the age the fishery has fully selected the fish.

Biomass and exploitation trends

Estimated total biomass gradually increased from a low near 85,000 t in 1980 to over 400,000 t for 2014 (Figure 9-12). MCMC credible intervals indicate that the historic low is reasonably certain while recent increases are not quite as certain. These intervals also suggest that current biomass is likely between around 270,000 and 780,000 t. Spawning biomass shows a similar trend, but is not as smooth as the estimates of total biomass (Figure 9-13). This is likely due to large year classes crossing a steep maturity curve. Spawning biomass estimates show a rapid increase between 1992 and 2000, and a slower increase (with considerable uncertainty) thereafter. Age of 50% selection is 5 and between 7 and 9 years for the survey and fishery, respectively (Figure 9-14). Fish are fully selected by both fishery and survey between 10 and 12. Current fishery selectivity is dome-shaped and matches well with the ages caught by the fishery. Catchability is slightly smaller (2.00) than that estimated in 2013 (2.09). The high catchability for POP is supported by several empirical studies using line transect densities counted from a submersible compared to trawl survey densities (Krieger 1993 [q=2.1], Krieger and Sigler 1996 [q=1.3], Hanselman et al. 2006[1] [q=2.1]).

Fully-selected fishing mortality shows that fishing mortality has decreased dramatically from historic rates and has leveled out in the last decade (Figure 9-15). Goodman et al. (2002) suggested that stock assessment authors use a “management path” graph as a way to evaluate management and assessment performance over time. We chose to plot a phase plane plot of fishing mortality to F_{OFL} ($F_{35\%}$) and the estimated spawning biomass relative to unfished spawning biomass ($B_{100\%}$). Harvest control rules based on $F_{35\%}$ and $F_{40\%}$ and the tier 3b adjustment are provided for reference. The management path for Pacific ocean perch has been above the $F_{35\%}$ adjusted limit for most of the historical time series (Figure 9-16). In addition, since 1999, Pacific ocean perch SSB has been above $B_{40\%}$ and fishing mortality has been below $F_{40\%}$.

Recruitment

Recruitment (as measured by age 2 fish) for Pacific ocean perch is highly variable and large recruitments comprise much of the biomass for future years (Figure 9-17). Recruitment has increased since the early 1970s, with the 1986 year class and potentially the 2006 year classes being the highest in recent history. The 1990s and 2000s are starting to show some steady higher than average recruitments. The addition of new survey age data and the large increase in 2013 survey biomass suggests that the 2006 year class may be above average (Figure 9-18). However, these recent recruitments are still highly uncertain as indicated by the MCMC credible intervals in Figure 9-17. Pacific ocean perch do not seem to exhibit much of a stock-recruitment relationship because large recruitments have occurred during periods of high and low biomass (Figure 9-17).

Uncertainty results

From the MCMC chains described in *Uncertainty approach*, we summarize the posterior densities of key parameters for the recommended model using histograms (Figure 9-19) and credible intervals (Table 9-13 and 9-15). We also use these posterior distributions to show uncertainty around time series estimates such as total biomass, spawning biomass, and recruitment (e.g. Figures 9-12, 9-13, 9-17, and 9-20).

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[1] Hanselman, D.H., S.K. Shotwell, J. Heifetz, and M. Wilkins. 2006. Catchability: Surveys, submarines and stock assessment. 2006 Western Groundfish Conference. Newport, OR. Presentation.

Table 9-13 shows the maximum likelihood estimate (MLE) of key parameters with their corresponding standard deviation derived from the Hessian matrix. Also shown are the MCMC, mean, median, standard deviation and the corresponding Bayesian 95% credible intervals (BCI). The Hessian and MCMC standard deviations are similar for q, M, and $F_{40\%}$, but the MCMC standard deviations are larger for the estimates of female spawning biomass and ABC. These larger standard deviations indicate that these parameters are more uncertain than indicated by the Hessian approximation. The distributions of these parameters with the exception of natural mortality are slightly skewed with higher means than medians for spawning biomass and ABC, indicating possibilities of higher biomass estimates (also see Figure 9-19).

Retrospective analysis

A within-model retrospective analysis of the recommended model was conducted for the last 10 years of the time-series by dropping data one year at a time. The revised Mohn's "rho" statistic (Hanselman et al. 2013) in female spawning biomass was -0.095, indicating that the model increases the estimate of female spawning biomass in recent years as data is added to the assessment. The retrospective female spawning biomass and the relative difference in female spawning biomass from the model in the terminal year are shown in Figure 9-22 (with 95% credible intervals from MCMC). In general the relative difference in female spawning biomass ranges from around -30% to 30%, with the largest differences occurring in the mid- to late-1970s, and early 1990's.

Harvest Recommendations

Amendment 56 Reference Points

Amendment 56 to the GOA Groundfish Fishery Management Plan defines the "overfishing level" (OFL), the fishing mortality rate used to set OFL (F_{OFL}), the maximum permissible ABC, and the fishing mortality rate used to set the maximum permissible ABC. The fishing mortality rate used to set ABC (F_{ABC}) may be less than this maximum permissible level, but not greater. Because reliable estimates of reference points related to maximum sustainable yield (MSY) are currently not available but reliable estimates of reference points related to spawning per recruit are available, Pacific ocean perch in the GOA are managed under Tier 3 of Amendment 56. Tier 3 uses the following reference points: $B_{40\%}$, equal to 40% of the equilibrium spawning biomass that would be obtained in the absence of fishing; $F_{35\%}$,,equal to the fishing mortality rate that reduces the equilibrium level of spawning per recruit to 35% of the level that would be obtained in the absence of fishing; and $F_{40\%}$, equal to the fishing mortality rate that reduces the equilibrium level of spawning per recruit to 40% of the level that would be obtained in the absence of fishing.

Estimation of the $B_{40\%}$ reference point requires an assumption regarding the equilibrium level of recruitment. In this assessment, it is assumed that the equilibrium level of recruitment is equal to the average of age-2 recruitments between 1979 and 2012 (i.e., the 1977 – 2010 year classes). Because of uncertainty in very recent recruitment estimates, we lag 2 years behind model estimates in our projection. Other useful biomass reference points which can be calculated using this assumption are $B_{100\%}$ and $B_{35\%}$, defined analogously to $B_{40\%}$. The 2014 estimates of these reference points are:

$B_{100\%}$	$B_{40\%}$	$B_{35\%}$	$F_{40\%}$	$F_{35\%}$
283,315	113,326	99,160	0.119	0.139

Specification of OFL and Maximum Permissible ABC

Female spawning biomass for 2015 is estimated at 142,029 t. This is above the $B_{40\%}$ value of 113,326 t. Under Amendment 56, Tier 3, the maximum permissible fishing mortality for ABC is $F_{40\%}$ and fishing mortality for OFL is $F_{35\%}$. Applying these fishing mortality rates for 2015, yields the following ABC and OFL:

$F_{40\%}$	0.119
ABC	**21,012**
$F_{35\%}$	0.139
OFL	**24,360**

Since 2009, our estimate of $F_{40\%}$ has been higher than past assessments and quite a bit higher than natural mortality. While it means that fishing will be taking place at a higher rate for a section of the population, fishing mortality is much lower in the older ages of the population due to the dome-shaped nature of the selectivity curve.

Projections and Status Determination

A standard set of projections is required for each stock managed under Tiers 1, 2, or 3 of Amendment 56. This set of projections encompasses seven harvest scenarios designed to satisfy the requirements of Amendment 56, the National Environmental Policy Act, and the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA).

For each scenario, the projections begin with the vector of 2014 numbers at age as estimated in the assessment. This vector is then projected forward to the beginning of 2015 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2014. In each subsequent year, the fishing mortality rate is prescribed on the basis of the spawning biomass in that year and the respective harvest scenario. In each year, recruitment is drawn from an inverse Gaussian distribution whose parameters consist of maximum likelihood estimates determined from recruitments estimated in the assessment. Spawning biomass is computed in each year based on the time of peak spawning and the maturity and weight schedules described in the assessment. Total catch after 2014 is assumed to equal the catch associated with the respective harvest scenario in all years. This projection scheme is run 1,000 times to obtain distributions of possible future stock sizes, fishing mortality rates, and catches.

Five of the seven standard scenarios will be used in an Environmental Assessment prepared in conjunction with the final SAFE. These five scenarios, which are designed to provide a range of harvest alternatives that are likely to bracket the final TAC for 2015, are as follow ("*max* F_{ABC}" refers to the maximum permissible value of F_{ABC} under Amendment 56):

> *Scenario 1*: In all future years, F is set equal to *max* F_{ABC}. (Rationale: Historically, TAC has been constrained by ABC, so this scenario provides a likely upper limit on future TACs.)
>
> *Scenario 2*: In 2015 and 2016, F is set equal to a constant fraction of *max* F_{ABC}, where this fraction is equal to the ratio of the realized catches in 2011-2013 to the ABC recommended in the assessment for each of those years. For the remainder of the future years, maximum permissible ABC is used. (Rationale: In many fisheries the ABC is routinely not fully utilized, so assuming an average ratio catch to ABC will yield more realistic projections.)
>
> *Scenario 3*: In all future years, F is set equal to 50% of max F_{ABC}. (Rationale: This scenario provides a likely lower bound on F_{ABC} that still allows future harvest rates to be adjusted downward when stocks fall below reference levels.)
>
> *Scenario 4*: In all future years, F is set equal to the 2009-2013 average F. (Rationale: For some stocks, TAC can be well below ABC, and recent average F may provide a better indicator of F_{TAC}

than F_{ABC}.)

Scenario 5: In all future years, F is set equal to zero. (Rationale: In extreme cases, TAC may be set at a level close to zero.)

Two other scenarios are needed to satisfy the MSFCMA's requirement to determine whether a stock is currently in an overfished condition or is approaching an overfished condition. These two scenarios are as follow (for Tier 3 stocks, the MSY level is defined as $B_{35\%}$):

Scenario 6: In all future years, F is set equal to F_{OFL}. (Rationale: This scenario determines whether a stock is overfished. If the stock is expected to be above 1) above its MSY level in 2014 or 2) above ½ of its MSY level in 2014 and above its MSY level in 2024 under this scenario, then the stock is not overfished.)

Scenario 7: In 2015 and 2016, F is set equal to *max* F_{ABC}, and in all subsequent years F is set equal to F_{OFL}. (Rationale: This scenario determines whether a stock is approaching an overfished condition. If the stock is 1) above its MSY level in 2016 or 2) above 1/2 of its MSY level in 2016 and expected to be above its MSY level in 2026 under this scenario, then the stock is not approaching an overfished condition.)

Spawning biomass, fishing mortality, and yield are tabulated for the seven standard projection scenarios (Table 9-16). The difference for this assessment for projections is in Scenario 2 (Author's F); we use pre-specified catches to increase accuracy of short-term projections in fisheries (such as POP) where the catch is usually less than the ABC. This was suggested to help management with setting preliminary ABCs and OFLs for two year ahead specifications. The methodology for determining these pre-specified catches is described below in ***Specified catch estimation.***

Status determination

In addition to the seven standard harvest scenarios, Amendments 48/48 to the BSAI and GOA Groundfish Fishery Management Plans require projections of the likely OFL two years into the future. While Scenario 6 gives the best estimate of OFL for 2015, it does not provide the best estimate of OFL for 2016, because the mean 2015 catch under Scenario 6 is predicated on the 2015 catch being equal to the 2015 OFL, whereas the actual 2015 catch will likely be less than the 2015 OFL. The executive summary contains the appropriate one- and two-year ahead projections for both ABC and OFL.

Under the MSFCMA, the Secretary of Commerce is required to report on the status of each U.S. fishery with respect to overfishing. This report involves the answers to three questions: 1) Is the stock being subjected to overfishing? 2) Is the stock currently overfished? 3) Is the stock approaching an overfished condition?

Is the stock being subjected to overfishing? The official catch estimate for the most recent complete year (2013) is 13,183 t. This is less than the 2013 OFL of 18,919 t. Therefore, the stock is not being subjected to overfishing.

Harvest Scenarios #6 and #7 are intended to permit determination of the status of a stock with respect to its minimum stock size threshold (MSST). Any stock that is below its MSST is defined to be *overfished*. Any stock that is expected to fall below its MSST in the next two years is defined to be *approaching* an overfished condition. Harvest Scenarios #6 and #7 are used in these determinations as follows:

Is the stock currently overfished? This depends on the stock's estimated spawning biomass in 2014:
a. If spawning biomass for 2014 is estimated to be below ½ $B_{35\%}$, the stock is below its MSST.
b. If spawning biomass for 2014 is estimated to be above $B_{35\%}$ the stock is above its MSST.

c. If spawning biomass for 2014 is estimated to be above ½ $B_{35\%}$ but below $B_{35\%}$, the stock's status relative to MSST is determined by referring to harvest Scenario #6 (Table 9-16). If the mean spawning biomass for 2024 is below $B_{35\%}$, the stock is below its MSST. Otherwise, the stock is above its MSST.

Is the stock approaching an overfished condition? This is determined by referring to harvest Scenario #7:
a. If the mean spawning biomass for 2016 is below 1/2 $B_{35\%}$, the stock is approaching an overfished condition.
b. If the mean spawning biomass for 2016 is above $B_{35\%}$, the stock is not approaching an overfished condition.
c. If the mean spawning biomass for 2016 is above 1/2 $B_{35\%}$ but below $B_{35\%}$, the determination depends on the mean spawning biomass for 2026. If the mean spawning biomass for 2026 is below $B_{35\%}$, the stock is approaching an overfished condition. Otherwise, the stock is not approaching an overfished condition.

Based on the above criteria and Table 9-16, the stock is not overfished and is not approaching an overfished condition.

Specified catch estimation

In response to Gulf of Alaska Plan Team minutes in 2010, we have established a consistent methodology for estimating current-year and future year catches in order to provide more accurate two-year projections of ABC and OFL to management. In the past, two standard approaches in rockfish models have been employed; assume the full TAC will be taken, or use a certain date prior to publication of assessments as a final estimate of catch for that year. Both methods have disadvantages. If the author assumes the full TAC is taken every year, but it rarely is, the ABC will consistently be underestimated. Conversely, if the author assumes that the catch taken by around October is the final catch, and substantial catch is taken thereafter, ABC will consistently be overestimated. Therefore, going forward in the Gulf of Alaska rockfish assessments, for current year catch, we are applying an expansion factor to the official catch on or near October 1 by the 3-year average of catch taken between October 1 and December 31 in the last three complete catch years (e.g. 2011-2013 for this year). For Pacific ocean perch, the expansion factor for 2014 catch is 1.06. Since the 2014 rockfish directed fishery did not occur in the Western Gulf until October 15 and those catches are not available at this time, an estimated 2,000 t of total catch in the Western Gulf was added to the 2014 total catch in the Central and Eastern Gulf to better reflect the 2014 estimated catch. The value of 2,000 t is based on the average recent catch in this area.

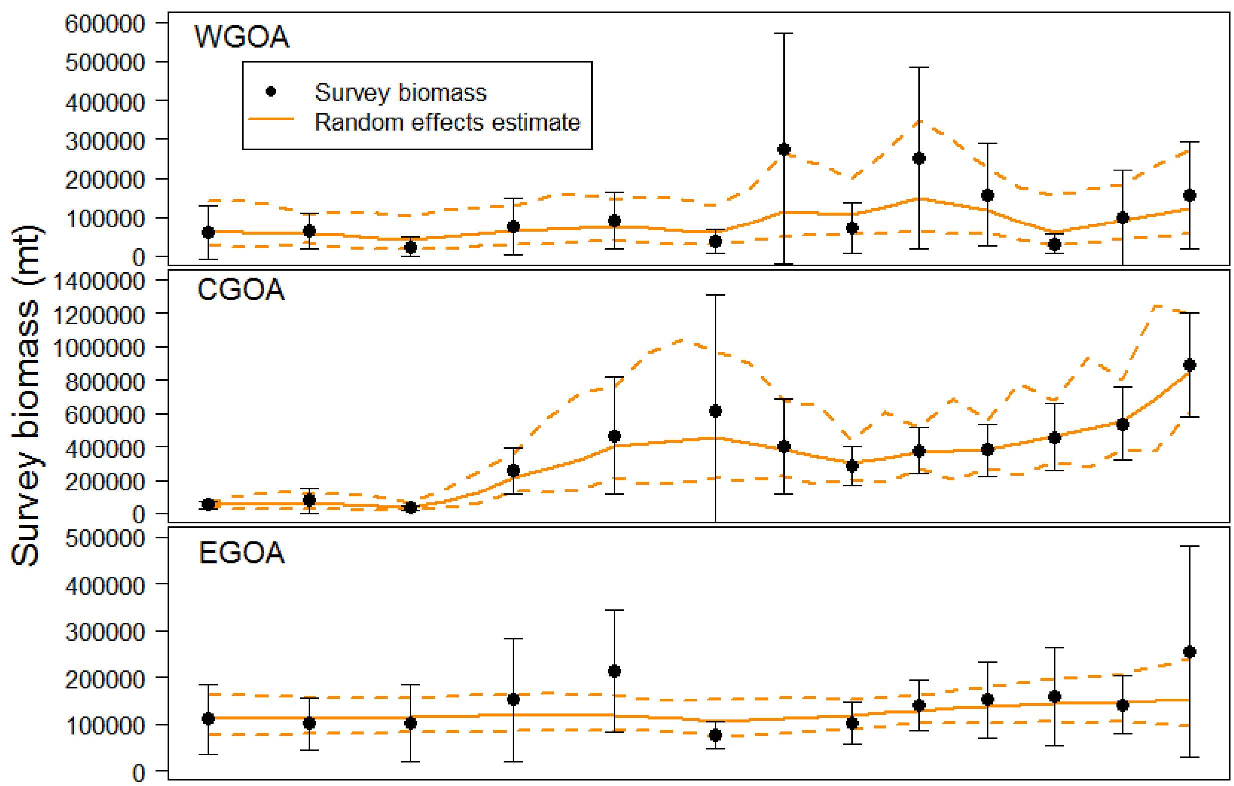
For catch projections into the next two years, we are using the ratio of the last three official catches to the last three TACs multiplied against the future two years' ABCs (if TAC is normally the same as ABC). This method results in slightly higher ABCs in each of the future two years of the projection, based on both the lower catch in the first year out, and based on the amount of catch taken before spawning in the projection two years out. To estimate future catches, we updated the yield ratio (0.84), which was the average of the ratio of catch to ABC for the last three complete catch years (2011-2013). This yield ratio was multiplied by the projected ABCs for 2015 and 2016 from the assessment model to generate catches for those years.

Alternate Projection

During the 2006 CIE review, it was suggested that projections should account for uncertainty in the entire assessment, not just recruitment from the endpoint of the assessment. We continue to present an alternative projection scenario using the uncertainty of the full assessment model, harvesting at maxABC (Alternative 1). This projection propagates uncertainty throughout the entire assessment procedure and is based on an MCMC chain of 10,000,000. The projection shows wide credibility intervals on future spawning biomass (Figure 9-20). The $B_{35\%}$ and $B_{40\%}$ reference points and future recruitments are based on the 1979-2012 age-2 recruitments, and this projection predicts that the median spawning biomass will eventually tend toward these reference points while at harvesting at $F_{40\%}$.

Area Apportionment of Harvests

Since 1996, apportionment of ABC and OFL among regulatory areas has been based on a method of weighting the prior 3 trawl survey biomass estimates. For this assessment the Plan Team and SSC requested that the random effects model proposed by the survey averaging working group be utilized for apportionment. The random effects model was fit to the survey biomass estimates (with associated variance) for the Western, Central, and Eastern Gulf of Alaska. The random effects model estimates a process error parameter (constraining the variability of the modeled estimates among years) and random effects parameters in each year modeled. The fit of the random effects model to survey biomass in each area is shown in the following figure. For illustration the 95% confidence intervals are shown for the survey biomass (error bars) and the random effects estimates of survey biomass (dashed lines).



In general the random effects model fits the area-specific survey biomass reasonably well. In the most recent survey, the random effects model fit the increases in biomass well within the Western and Central GOA, but did not fit the increase in the Eastern GOA well due to its large uncertainty. The previous weighting method resulted in apportionments of 11% for the Western area, 69% for the Central area, and 20% for the Eastern area. Using the random effects model estimates of survey biomass the apportionment results in 11.0% for the Western area, 75.5% for the Central area, and 13.5% for the Eastern area. This results in recommended ABC's of **2,302** t for the Western area, **15,873** t for the Central area, and **2,837** t for the Eastern area.

Amendment 41 prohibited trawling in the Eastern area east of 140° W longitude. In the past, the Plan Team has calculated an apportionment for the West Yakutat area that is still open to trawling (between 147°W and 140°W). We calculated this apportionment using the ratio of estimated biomass in the closed area and open area. This calculation was based on the team's previous recommendation that we use the weighted average of the upper 95% confidence interval for the W. Yakutat. We computed this interval this year using the weighted average of the ratio for 2009, 2011, and 2013. We calculated the approximate upper 95% confidence interval using the variance of a weighted mean for the 2009-2013 weighed mean ratio. This resulted in higher ratio of 0.71, up from 0.48 in 2011. This results in an ABC apportionment of **2,014** t to the W. Yakutat area which would leave **823** t unharvested in the Southeast/Outside area.

Overfishing Definition

Based on the definitions for overfishing in Amendment 44 in tier 3a (i.e., $F_{OFL} = F_{35\%}$=0.139), overfishing is set equal to 24,360 t for Pacific ocean perch. The overfishing level is apportioned by area for Pacific ocean perch and historically used the apportionment described above for setting area specific OFLs. However, in 2012, area OFLs were combined for the Western, Central, and West Yakutat (W/C/WYK) areas, while East Yakutat/Southeast (SEO) was separated to allow for concerns over stock structure. This results in overfishing levels for W/C/WYK area of **23,406** t and **954** t in the SEO area.

Ecosystem Considerations

In general, a determination of ecosystem considerations for Pacific ocean perch is hampered by the lack of biological and habitat information. A summary of the ecosystem considerations presented in this section is listed in Table 9-17.

Ecosystem Effects on the Stock

Prey availability/abundance trends: Similar to many other rockfish species, stock condition of Pacific ocean perch appears to be influenced by periodic abundant year classes. Availability of suitable zooplankton prey items in sufficient quantity for larval or post-larval Pacific ocean perch may be an important determining factor of year class strength. Unfortunately, there is no information on the food habits of larval or post-larval rockfish to help determine possible relationships between prey availability and year class strength; moreover, identification to the species level for field collected larval slope rockfish is difficult. Visual identification is not possible though genetic techniques allow identification to species level for larval slope rockfish (Gharrett et. al 2001). Some juvenile rockfish found in inshore habitat feed on shrimp, amphipods, and other crustaceans, as well as some mollusk and fish (Byerly 2001). Adult Pacific ocean perch feed primarily on euphausiids. Little if anything is known about abundance trends of likely rockfish prey items. Euphausiids are also a major item in the diet of walleye pollock. Recent declines in the biomass of walleye pollock, could lead to a corollary change in the availability of euphausiids, which would then have a positive impact on Pacific ocean perch abundance.

Predator population trends: Pacific ocean perch are preyed upon by a variety of other fish at all life stages, and to some extent marine mammals during late juvenile and adult stages. Whether the impact of any particular predator is significant or dominant is unknown. Predator effects would likely be more important on larval, post-larval, and small juvenile slope rockfish, but information on these life stages and their predators is scarce.

Changes in physical environment: Stronger year classes corresponding to the period around 1977 have been reported for many species of groundfish in the Gulf of Alaska, including Pacific ocean perch, northern rockfish, sablefish, and Pacific cod. Therefore, it appears that environmental conditions may have changed during this period in such a way that survival of young-of-the-year fish increased for many groundfish species, including slope rockfish. Pacific ocean perch appeared to have strong 1986-88 year classes, and these may be other years when environmental conditions were especially favorable for rockfish species. The environmental mechanism for this increased survival remains unknown. Changes in water temperature and currents could affect prey abundance and the survival of rockfish from the pelagic to demersal stage. Rockfish in early juvenile stage have been found in floating kelp patches which would be subject to ocean currents. Changes in bottom habitat due to natural or anthropogenic causes could alter survival rates by altering available shelter, prey, or other functions. Carlson and Straty (1981), Pearcy et al (1989), and Love et al (1991) have noted associations of juvenile rockfish with biotic and abiotic structure. Recent research by Rooper and Boldt (2005) found juvenile POP were positively correlated with sponge and coral.

The Essential Fish Habitat Environmental Impact Statement (EFH EIS) (NMFS 2005) concluded that the effects of commercial fishing on the habitat of groundfish is minimal or temporary. The continuing upward trend in abundance of Pacific ocean perch suggests that at current abundance and exploitation levels, habitat effects from fishing is not limiting this stock.

Effects of Pacific ocean perch Fishery on the Ecosystem

Fishery-specific contribution to bycatch of HAPC biota: In the Gulf of Alaska, bottom trawl fisheries for pollock, deepwater flatfish, and Pacific ocean perch account for most of the observed bycatch of coral, while rockfish fisheries account for little of the bycatch of sea anemones or of sea whips and sea pens. The bottom trawl fisheries for Pacific ocean perch and Pacific cod and the pot fishery for Pacific cod accounts for most of the observed bycatch of sponges (Table 9-5).

Fishery-specific concentration of target catch in space and time relative to predator needs in space and time (if known) and relative to spawning components: The directed slope rockfish trawl fisheries used to begin in July concentrated in known areas of abundance and typically lasted only a few weeks. The Rockfish Pilot project has spread the harvest throughout the year in the Central Gulf of Alaska. The recent annual exploitation rates on rockfish are thought to be quite low. Insemination is likely in the fall or winter, and parturition is likely mostly in the spring. Hence, reproductive activities are probably not directly affected by the commercial fishery. There is momentum for extending the rockfish fishery over a longer period, which could have minor effects on reproductive output.

Fishery-specific effects on amount of large size target fish: The proportion of older fish has declined since 1984, although it is unclear whether this is a result of fishing or large year-classes of younger fish coming into the population.

Fishery contribution to discards and offal production: Fishery discard rates for the whole rockfish trawl fishery has declined from 35% in 1997 to 25% in 2004. Arrowtooth flounder comprised 22-46% of these discards. Non-target discards are summarized in Table 9-5, with grenadiers (*Macrouridae sp.*) dominating the non-target discards.

Fishery-specific effects on age-at-maturity and fecundity of the target fishery: Research is under way to examine whether the loss of older fish is detrimental to spawning potential.

Fishery-specific effects on EFH non-living substrate: Effects on non-living substrate are unknown, but the heavy-duty “rockhopper” trawl gear commonly used in the fishery is suspected to move around rocks and boulders on the bottom. Table 9-5 shows the estimated bycatch of living structure such as benthic urochordates, corals, sponges, sea pens, and sea anemones by the GOA rockfish fisheries. The average bycatch of corals/bryozoans (0.78 t), and sponges (2.98 t) by rockfish fisheries are a large proportion of the catch of those species taken by all Gulf-wide fisheries.

Data Gaps and Research Priorities

There is little information on early life history of Pacific ocean perch and recruitment processes. A better understanding of juvenile distribution, habitat utilization, and species interactions would improve understanding of the processes that determine the productivity of the stock. Better estimation of recruitment and year class strength would improve assessment and management of the POP population. Studies to improve our understanding of POP density between trawlable and untrawlable grounds and other habitat associations would help in our determination of catchability parameters. Future assessment priorities include:

1) Respond to the various Plan Team and SSC requests that were not addressed in this year's assessment
2) Incorporate changes recommended by the 2013 CIE review (please refer to the Summary and response to the 2013 CIE review of AFSC rockfish document presented to the September 2013 Plan Team for further details)
3) Synthesize previous studies on rockfish catchability with submersibles into informative prior distributions on catchability in the model
4) Increase analysis of fishery spatial patterns and behavior

Summary

A summary of biomass levels, exploitation rates and recommended ABCs and OFLs for Pacific ocean perch is in the following table:

Quantity	As estimated or specified *last* year for: 2014	2015	As estimated or recommended *this* year for: 2015	2016[1]
M (natural mortality)	0.061	0.061	0.061	0.061
Tier	3a	3a	3a	3a
Projected total (age 2+) biomass (t)	410,712	408,839	416,140	412,351
Projected Female spawning biomass	120,356	121,939	142,029	144,974
$B_{100\%}$	257,697	257,697	283,315	283,315
$B_{40\%}$	103,079	103,079	113,326	113,326
$B_{35\%}$	90,194	90,194	99,160	99,160
F_{OFL}	0.132	0.132	0.139	0.139
$maxF_{ABC}$	0.113	0.113	0.119	0.119
F_{ABC}	0.113	0.113	0.119	0.119
OFL (t)	**22,319**	22,849	**24,360**	24,849
maxABC (t)	19,309	19,764	**21,012**	21,436
ABC (t)	**19,309**	19,764	**21,012**	21,436
Status	As determined *last* year for: 2012	2013	As determined *this* year for: 2013	2014
Overfishing	No	n/a	No	n/a
Overfished	n/a	No	n/a	No
Approaching overfished	n/a	No	n/a	No

[1]Projected ABCs and OFLs for 2015 and 2016 are derived using estimated catch of 17,716 for 2014, and projected catches of 17,665 t and 17,797 t for 2015 and 2016 based on realized catches from 2011-2013. This calculation is in response to management requests to obtain more accurate projections.

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Tables

Table 9-1. Management measures since the break out of Pacific ocean perch from slope rockfish are outlined in the following table:

Year	Catch (t)	ABC	TAC	OFL	Management Measures
1988	1,621	16,800	16,800		The slope rockfish assemblage, including POP, was one of three management groups for *Sebastes* implemented by the North Pacific Management Council. Previously, *Sebastes* in Alaska were managed as "Pacific ocean perch complex" or "other rockfish"
1989	19,003	20,000	20,000		
1990	21,140	17,700	17,700		
1991	6,542	5,800			Slope assemblage split into three management subgroups with separate ABCs and TACs: Pacific ocean perch, shortraker/rougheye rockfish, and all other slope species
1992	6,538	5,730	5,200		
1993	2,060	3,378	2,560		
1994	1,841	3,030	2,550	3,940	Amendment 32 establishes rebuilding plan Assessment done with an age structured model using stock synthesis
1995	5,741	6,530	5,630	8,232	
1996	8,378	8,060	6,959	10,165	
1997	9,519	12,990	9,190	19,760	
1998	8,908	12,820	10,776	18,090	
1999	10,473	13,120	12,590	18,490	Eastern Gulf divided into West Yakutat and East Yakutat/Southeast Outside and separate ABCs and TACs assigned
2000	10,146	13,020	13,020	15,390	Amendment 41 became effective which prohibited trawling in the Eastern Gulf east of 140 degrees W.
2001	10,817	13,510	13,510	15,960	Assessment is now done using an age structured model constructed with AD Model Builder software
2002	11,734	13,190	13,190	15,670	
2003	10,847	13,663	13,660	16,240	
2004	11,640	13,336	13,340	15,840	
2005	11,248	13,575	13,575	16,266	
2006	13,595	14,261	14,261	16,927	
2007	12,954	14,636	14,636	17,158	Amendment 68 created the Central Gulf Rockfish Pilot Project
2008	12,461	14,999	14,999	17,807	
2009	12,736	15,111	15,111	17,940	
2010	15,616	17,584	17,584	20,243	
2011	14,213	16,997	16,997	19,566	
2012	14,912	16,918	16,918	19,498	
2013	13,183	16,412	16,412	18,919	Area OFL for W/C/WYK combined, SEO separate
2014	14,863	19,309	19,309	22,319	

Table 9-2. Commercial catch[a] (t) of fish of Pacific ocean perch in the Gulf of Alaska, with Gulf-wide values of acceptable biological catch (ABC) and fishing quotas[b] (t), 1977-2013.

		Regulatory Area		Gulf-wide		Gulf-wide value	
Year	Fishery	Western	Central	Eastern	Total	ABC	Quota
1977	Foreign	6,282	6,166	10,993	23,441		
	U.S.	0	0	12	12		
	JV	-	-	-	-		
	Total	6,282	6,166	11,005	23,453	50,000	30,000
1978	Foreign	3,643	2,024	2,504	8,171		
	U.S.	0	0	5	5		
	JV	-	-	-	-		
	Total	3,643	2,024	2,509	8,176	50,000	25,000
1979	Foreign	944	2,371	6,434	9,749		
	U.S.	0	99	6	105		
	JV	1	31	35	67		
	Total	945	2,501	6,475	9,921	50,000	25,000
1980	Foreign	841	3,990	7,616	12,447		
	U.S.	0	2	2	4		
	JV	0	20	0	20		
	Total	841	4,012	7,618	12,471	50,000	25,000
1981	Foreign	1,233	4,268	6,675	12,176		
	U.S.	0	7	0	7		
	JV	1	0	0	1		
	Total	1,234	4,275	6,675	12,184	50,000	25,000
1982	Foreign	1,746	6,223	17	7,986		
	U.S.	0	2	0	2		
	JV	0	3	0	3		
	Total	1,746	6,228	17	7,991	50,000	11,475
1983	Foreign	671	4,726	18	5,415		
	U.S.	7	8	0	15		
	JV	1,934	41	0	1,975		
	Total	2,612	4,775	18	7,405	50,000	11,475
1984	Foreign	214	2,385	0	2,599		
	U.S.	116	0	3	119		
	JV	1,441	293	0	1,734		
	Total	1,771	2,678	3	4,452	50,000	11,475
1985	Foreign	6	2	0	8		
	U.S.	631	13	181	825		
	JV	211	43	0	254		
	Total	848	58	181	1,087	11,474	6,083
1986	Foreign	Tr	Tr	0	Tr		
	U.S.	642	394	1,908	2,944		
	JV	35	2	0	37		
	Total	677	396	1,908	2,981	10,500	3,702
1987	Foreign	0	0	0	0		
	U.S.	1,347	1,434	2,088	4,869		
	JV	108	4	0	112		
	Total	1,455	1,438	2,088	4,981	10,500	5,000
1988	Foreign	0	0	0	0		
	U.S.	2,586	6,467	4,718	13,771		
	JV	4	5	0	8		
	Total	2,590	6,471	4,718	13,779	16,800	16,800

Table 9-2. (continued)

		Regulatory Area				Gulf-wide value	
Year	Fishery	Western	Central	Eastern[1]	Total	ABC	Quota
1989	U.S.	4,339	8,315	6,348	19,003	20,000	20,000
1990	U.S.	5,203	9,973	5,938	21,140	17,700	17,700
1991	U.S.	1,758	2,638	2,147	6,542	5,800	5,800
1992	U.S.	1,316	2,994	2,228	6,538	5,730	5,200
1993	U.S.	477	1,140	443	2,060	3,378	2,560
1994	U.S.	166	909	767	1,841	3,030	2,550
1995	U.S.	1,422	2,597	1,721	5,741	6,530	5,630
1996	U.S.	987	5,145	2,247	8,378	8,060	6,959
1997	U.S.	1,832	6,709	978	9,519	12,990	9,190
1998	U.S.	846	8,062	Conf.	8,908	12,820	10,776
1999	U.S.	1,935	7,911	627	10,473	13,120	12,590
2000	U.S.	1,160	8,986	Conf.	10,146	13,020	13,020
2001	U.S.	945	9,872	Conf.	10,817	13,510	13,510
2002	U.S.	2,723	9,011	Conf.	11,734	13,190	13,190
2003	U.S.	2,124	8,117	606	10,847	13,663	13,660
2004	U.S.	2,196	8,567	877	11,640	13,336	13,340
2005	U.S.	2,338	8,064	846	11,248	13,575	13,580
2006	U.S.	4,051	8,285	1,259	13,595	14,261	14,261
2007	U.S.	4,430	7,282	1,242	12,954	14,636	14,635
2008	U.S.	3,679	7,682	1,100	12,461	14,999	14,999
2009	U.S.	3,141	10,550	1,926	12,736	15,111	15,111
2010	U.S.	3,682	7,677	1,040	15,616	17,584	17,584
2011	U.S.	1,819	10,523	1,871	14,213	16,997	16,997
2012	U.S.	2,452	10,777	1,683	14,912	16,918	16,918
2013	U.S.	447	11,199	1,537	13,183	16,412	16,412

Note: There were no foreign or joint venture catches after 1988. Catches prior to 1989 are landed catches only. Catches in 1989 and 1990 also include fish reported in weekly production reports as discarded by processors. Catches in 1991-2013 also include discarded fish, as determined through a "blend" of weekly production reports and information from the domestic observer program.

Definitions of terms: JV = Joint venture; Tr = Trace catches;

[a]Catch defined as follows: 1977, all Sebastes rockfish for Japanese catch, and Pacific ocean perch for catches of other nations; 1978, Pacific ocean perch only; 1979-87, the 5 species comprising the Pacific ocean perch complex; 1988-2013, Pacific ocean perch.

[b]Quota defined as follows: 1977-86, optimum yield; 1987, target quota; 1988-2013 total allowable catch.

Sources: Catch: 1977-84, Carlson et al. (1986); 1985-88, Pacific Fishery Information Network (PacFIN), Pacific Marine Fisheries Commission, 305 State Office Building, 1400 S.W. 5th Avenue, Portland, OR 97201; 1989-2005, National Marine Fisheries Service, Alaska Region, P.O. Box 21668, Juneau, AK 99802. ABC and Quota: 1977-1986 Karinen and Wing (1987); 1987-1990, Heifetz et al. (2000); 1991-2013, NMFS AKRO BLEND/Catch Accounting System via AKFIN database.

Table 9-3. FMP groundfish species caught in rockfish targeted fisheries in the Gulf of Alaska from 2008-2014. Conf. = Confidential because of less than three vessels or processors. Source: NMFS AKRO Blend/Catch Accounting System via AKFIN 10/28/2014.

	Estimated Catch (t)						
Group Name	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**
Pacific Ocean Perch	12135	12397	14974	13120	13953	11555	12972
Northern Rockfish	3805	3855	3833	3163	4883	4527	2784
Dusky Rockfish	-	-	-	-	3642	2870	2606
Pelagic Shelf Rockfish	3521	2956	2966	2324	-	-	-
Arrowtooth Flounder	517	497	706	340	764	766	1255
Pollock	390	1280	1046	813	574	829	856
Other Rockfish	632	736	737	657	889	488	626
Sablefish	503	404	388	440	470	495	484
Pacific Cod	445	631	734	560	404	584	441
Rougheye/Blackspotted Rockfish	104	97	180	286	219	274	348
Atka Mackerel	1744	1913	2148	1404	1173	1162	257
Shortraker Rockfish	231	247	133	239	303	290	198
Thornyhead Rockfish	248	177	106	161	130	104	187
Rex Sole	67	83	93	51	72	89	69
Deep Water Flatfish	29	30	48	57	54	37	68
Demersal Shelf Rockfish	45	77	34	27	111	136	38
Sculpin	-	-	-	39	55	70	28
Skate, Other	10	13	28	14	20	18	23
Skate, Longnose	12	17	12	25	23	23	21
Shallow Water Flatfish	71	53	47	48	65	27	17
Flathead Sole	19	32	24	13	16	26	16
Squid	-	-	-	12	15	10	16
Octopus	-	-	-	1	1	2	5
Skate, Big	4	4	14	8	13	2	3
Shark	-	-	-	5	5	93	1

Table 9-4 . Catch (t) of GOA Pacific ocean perch as bycatch in other fisheries from 2008-2014. Source: NMFS AKRO Blend/Catch Accounting System via AKFIN 10/28/2014.

Target	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**Average**
Arrowtooth Flounder	163	76	83	566	496	424	1318	447
Rex Sole	79	420	359	291	92	714	423	340
Pollock - midwater	37	4	24	48	224	133	285	108
Pollock - bottom	13	16	72	124	70	294	121	102
Pacific Cod	17	43	9	20	53	12	15	24
Shallow Water Flatfish	2	3	0	2	3	20	11	6
Flathead Sole	2	2	74	2	2	19	6	15
Sablefish	13	26	19	17	17	8	2	15
Deep Water Flatfish	-	-	-	-	-	1	1	1

Table 9-5. Non-FMP species bycatch estimates in tons for Gulf of Alaska rockfish targeted fisheries 2008 - 2014. Conf. = Confidential because of less than three vessels. Source: NMFS AKRO Blend/Catch Accounting System via AKFIN 10/28/2014.

Species Group Name	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**
Giant Grenadier	160.97	224.36	476.28	418.90	347.85	968.44	601.55
Misc fish	195.62	134.75	167.10	133.25	156.73	163.97	124.27
Dark Rockfish	17.86	46.98	112.04	12.82	59.03	42.16	13.35
Grenadier	2.82	3.11	34.94	110.49	89.67	39.11	6.33
Scypho jellies	0.11	0.70	1.87	0.00	0.16	0.50	6.05
Greenlings	14.73	8.10	9.52	7.91	9.05	7.25	2.96
Sea star	1.15	1.78	1.38	1.53	0.98	0.97	1.42
Sea anemone unidentified	0.69	3.24	1.56	4.10	6.33	4.20	1.11
Sponge unidentified	2.97	6.65	3.66	4.41	1.39	1.34	1.04
urchins dollars cucumbers	0.26	0.49	0.22	0.44	0.31	0.30	0.18
Corals Bryozoans	0.47	0.32	0.42	0.38	0.59	0.20	0.13
Pandalid shrimp	0.11	0.09	0.22	0.06	0.06	0.06	0.10
Eelpouts	0.35	0.00	0.05	Conf.	0.30	0.04	0.10
Sea pens whips	Conf.	0.01	0.01	0.04	-	0.05	0.07
Benthic urochordata	0.27	Conf.	0.08	Conf.	Conf.	Conf.	0.07
Snails	0.18	10.63	0.20	0.23	1.26	0.20	0.07
Brittle star unidentified	0.04	0.03	0.02	0.01	0.03	0.03	0.05
Hermit crab unidentified	0.01	0.01	0.01	0.02	Conf.	0.03	0.04
Misc crabs	0.07	0.10	0.07	0.04	0.05	0.01	0.04
Stichaeidae	-	0.01	-	-	-	Conf.	0.00
Invertebrate unidentified	0.23	0.30	5.05	0.36	3.86	0.18	0.00
Bivalves	0.00	Conf.	0.01	0.01	0.01	Conf.	Conf.
Eulachon	0.01	0.03	0.00	0.00	0.01	0.10	Conf.
Misc crustaceans	-	0.10	0.02	Conf.	-	Conf.	Conf.
Other osmerids	Conf.	0.16	0.00	-	Conf.	0.02	Conf.
Birds	Conf.	-	-	Conf.	Conf.	-	-
Capelin	-	0.00	-	-	-	0.02	-
Lanternfishes (myctophidae)	-	0.00	Conf.	-	-	Conf.	-
Misc deep fish	0.00	-	-	-	-	Conf.	-
Misc inverts (worms etc)	0.01	Conf.	-	Conf.	-	-	-
Pacific Sand lance	-	-	-	Conf.	-	-	-
Polychaete unidentified	-	-	-	-	-	Conf.	-

Table 9-6. Prohibited Species Catch (PSC) estimates reported in tons for halibut and herring, and thousands of animals for crab and salmon, by year, for the GOA rockfish fishery. Source: NMFS AKRO Blend/Catch Accounting System PSCNQ via AKFIN 10/28/2014.

Species Group Name	2008	2009	2010	2011	2012	2013	Average
Halibut	159	109	141	108	109	113	123
Chinook Salmon	2.28	1.39	1.57	1.02	1.60	2.32	1.70
Non-Chinook Salmon	0.50	0.47	0.37	0.21	0.31	2.02	0.65
Golden (Brown) King Crab	0.34	3.28	3.00	0.13	0.11	0.10	1.16
Bairdi Tanner Crab	0.06	0.24	0.10	0.03	0.09	0.07	0.10
Blue King Crab	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Herring	0.04	0.00	0.15	0.00	0.00	0.00	0.03
Opilio Tanner (Snow) Crab	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Red King Crab	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 9-7. Fishery length frequency data for Pacific ocean perch in the Gulf of Alaska.

Length (cm)	Year 1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
12	0	0	0	0	0	0	0	0	0	0
13-15	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0
20	0	0.001	0	0.001	0	0	0	0.001	0.001	0.001
21	0	0	0.001	0.001	0.001	0.001	0	0.001	0.001	0.001
22	0	0	0	0.002	0.001	0.001	0.001	0.002	0.001	0.002
23	0	0.001	0.001	0.001	0.002	0.001	0.001	0.003	0.001	0.003
24	0.001	0.003	0.001	0.001	0.002	0.001	0.002	0.002	0.003	0.004
25	0.002	0.003	0.002	0.002	0.006	0.002	0.003	0.004	0.003	0.004
26	0.003	0.004	0.004	0.002	0.006	0.002	0.004	0.006	0.005	0.006
27	0.002	0.004	0.007	0.003	0.006	0.004	0.003	0.005	0.007	0.009
28	0.003	0.004	0.007	0.005	0.007	0.007	0.006	0.01	0.01	0.009
29	0.005	0.008	0.01	0.007	0.008	0.008	0.014	0.011	0.015	0.014
30	0.005	0.006	0.009	0.01	0.009	0.008	0.018	0.018	0.022	0.015
31	0.008	0.009	0.014	0.012	0.011	0.012	0.013	0.026	0.03	0.026
32	0.012	0.015	0.014	0.018	0.019	0.015	0.018	0.035	0.057	0.041
33	0.021	0.032	0.023	0.033	0.038	0.024	0.026	0.045	0.075	0.068
34	0.053	0.068	0.057	0.052	0.067	0.057	0.042	0.063	0.091	0.099
35-38	0.64	0.583	0.581	0.556	0.503	0.519	0.514	0.495	0.425	0.475
>38	0.24	0.257	0.268	0.292	0.315	0.337	0.333	0.273	0.255	0.226
Total	18,724	5,126	7,027	5,750	6,156	7,112	6,140	5,563	6,094	9,784

Length (cm)	Year 2008	2009	2010	2011	2012	2013	2014
12	0	0	0	0	0	0	0
13-15	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0
18	0	0	0	0.001	0	0	0
19	0	0.001	0	0.001	0	0	0.001
20	0	0	0.002	0.001	0.001	0.001	0.001
21	0	0	0.001	0.001	0.003	0	0.002
22	0.001	0.001	0.003	0.001	0.005	0.001	0.003
23	0.002	0	0.005	0.002	0.008	0.003	0.003
24	0.002	0.001	0.004	0.002	0.008	0.004	0.003
25	0.003	0.002	0.003	0.003	0.010	0.008	0.002
26	0.003	0.003	0.003	0.003	0.015	0.013	0.002
27	0.003	0.005	0.004	0.003	0.014	0.014	0.003
28	0.008	0.006	0.005	0.005	0.010	0.015	0.004
29	0.012	0.008	0.006	0.007	0.009	0.019	0.007
30	0.016	0.013	0.008	0.010	0.009	0.020	0.011
31	0.025	0.023	0.014	0.012	0.012	0.022	0.015
32	0.04	0.042	0.025	0.020	0.021	0.014	0.019
33	0.063	0.071	0.042	0.033	0.031	0.017	0.024
34	0.093	0.099	0.074	0.060	0.051	0.032	0.043
35-38	0.473	0.498	0.551	0.551	0.521	0.328	0.343
>38	0.255	0.227	0.248	0.284	0.271	0.487	0.513
Total	8,154	8,898	11,174	9,800	12,882	10,767	10,427

Table 9-8. Fishery age compositions for GOA Pacific ocean perch 1999-2012.

Age Class	1999	2000	2001	2002	2004	2005	2006	2008	2010	2012
2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	0.000	0.000	0.002	0.000	0.000	0.001	0.000	0.000	0.000	0.000
4	0.000	0.005	0.004	0.003	0.002	0.001	0.001	0.005	0.013	0.018
5	0.003	0.015	0.002	0.014	0.007	0.012	0.003	0.005	0.005	0.026
6	0.016	0.037	0.017	0.016	0.051	0.021	0.045	0.021	0.013	0.020
7	0.024	0.026	0.040	0.035	0.040	0.085	0.089	0.031	0.019	0.023
8	0.029	0.056	0.029	0.097	0.049	0.085	0.114	0.102	0.070	0.028
9	0.043	0.064	0.058	0.078	0.166	0.103	0.108	0.103	0.071	0.046
10	0.051	0.057	0.060	0.108	0.177	0.142	0.084	0.161	0.120	0.092
11	0.178	0.054	0.060	0.105	0.067	0.114	0.106	0.108	0.149	0.105
12	0.191	0.132	0.063	0.051	0.075	0.074	0.087	0.048	0.122	0.116
13	0.130	0.127	0.131	0.070	0.069	0.047	0.061	0.090	0.074	0.093
14	0.088	0.110	0.146	0.108	0.036	0.044	0.037	0.051	0.057	0.093
15	0.120	0.104	0.084	0.086	0.036	0.021	0.035	0.043	0.051	0.051
16	0.061	0.060	0.092	0.065	0.049	0.032	0.026	0.023	0.041	0.045
17	0.021	0.052	0.061	0.054	0.050	0.050	0.027	0.026	0.040	0.049
18	0.019	0.031	0.071	0.038	0.041	0.041	0.035	0.011	0.021	0.033
19	0.003	0.025	0.040	0.035	0.030	0.032	0.038	0.026	0.014	0.025
20	0.003	0.008	0.015	0.011	0.021	0.026	0.027	0.028	0.014	0.021
21	0.000	0.010	0.012	0.003	0.009	0.028	0.025	0.026	0.016	0.015
22	0.008	0.011	0.002	0.005	0.007	0.011	0.010	0.026	0.032	0.016
23	0.003	0.004	0.006	0.003	0.005	0.008	0.015	0.020	0.011	0.011
24	0.000	0.001	0.000	0.003	0.006	0.007	0.010	0.015	0.006	0.006
25+	0.011	0.011	0.006	0.011	0.006	0.015	0.016	0.030	0.041	0.068
Sample size	376	734	521	370	802	727	734	609	631	1024

Table 9-9. Biomass estimates (t) and Gulf-wide confidence intervals for Pacific ocean perch in the Gulf of Alaska based on the 1984-2013 trawl surveys. (Biomass estimates and confidence intervals have been slightly revised from those listed in previous SAFE reports for Pacific ocean perch.)

	Western	**Central**		**Eastern**		**95 % Conf. Intervals**			
Year	Shumagin	Chirikof	Kodiak	Yakutat	Southeast	Total	Lower CI	Upper CI	CV
1984	60,666	9,584	39,766	76,601	34,055	220,672	110,732	330,613	25%
1987	64,403	19,440	56,820	47,269	53,274	241,206	133,712	348,699	23%
1990	24,543	15,309	15,765	53,337	48,341	157,295	64,922	249,669	30%
1993	75,416	103,224	153,262	50,048	101,532	483,482	270,548	696,416	22%
1996	92,618	140,479	326,281	50,394	161,641	771,413	372,447	1,170,378	26%
1999	37,980	402,293	209,675	32,749	44,367	727,064	-	1,488,653	53%
2001*	275,211	39,819	358,126	44,397	102,514	820,066	364,576	1,275,556	27%
2003	72,851	116,278	166,795	27,762	73,737	457,422	316,273	598,570	16%
2005	250,912	75,433	300,153	77,682	62,239	766,418	479,078	1,053,758	19%
2007	158,100	77,002	301,712	52,569	98,798	688,180	464,402	911,957	17%
2009	31,739	209,756	247,737	97,188	63,029	649,449	418,638	880,260	18%
2011	99,406	197,357	340,881	68,339	72,687	778,670	513,078	1,044,262	17%
2013	157,457	291,763	594,675	179,862	74,686	1,298,443	879,952	1,716,934	16%

*The 2001 survey did not sample the eastern Gulf of Alaska (the Yakutat and Southeastern areas). Substitute estimates of biomass for the Yakutat and Southeastern areas were obtained by averaging the biomass estimates for Pacific ocean perch in these areas in the 1993, 1996, and 1999 surveys, that portion of the variance was obtained by using a weighted average of the three prior surveys' variance.

Table 9-10. Survey age composition (% frequency) data for Pacific ocean perch in the Gulf of Alaska. Age compositions for are based on "break and burn" reading of otoliths.

Age	1984	1987	1990	1993	1996	1999	2003	2005	2007	2009	2011
2	0.003	0.019	0.005	0.006	0.006	0.006	0.016	0.001	0.003	0.005	0.001
3	0.002	0.101	0.043	0.018	0.016	0.020	0.057	0.034	0.020	0.087	0.030
4	0.058	0.092	0.155	0.021	0.036	0.045	0.053	0.050	0.018	0.044	0.046
5	0.029	0.066	0.124	0.044	0.043	0.052	0.071	0.077	0.044	0.049	0.124
6	0.079	0.091	0.117	0.088	0.063	0.026	0.040	0.073	0.041	0.025	0.042
7	0.151	0.146	0.089	0.125	0.038	0.041	0.054	0.119	0.056	0.096	0.036
8	0.399	0.056	0.065	0.129	0.088	0.059	0.107	0.069	0.089	0.065	0.024
9	0.050	0.061	0.054	0.166	0.145	0.095	0.115	0.087	0.125	0.106	0.071
10	0.026	0.087	0.055	0.092	0.185	0.054	0.057	0.092	0.094	0.047	0.073
11	0.010	0.096	0.036	0.045	0.110	0.114	0.053	0.063	0.063	0.053	0.105
12	0.016	0.018	0.024	0.052	0.080	0.144	0.044	0.035	0.064	0.079	0.073
13	0.015	0.011	0.028	0.038	0.034	0.086	0.036	0.027	0.050	0.035	0.065
14	0.019	0.011	0.072	0.025	0.036	0.067	0.057	0.031	0.030	0.039	0.047
15	0.005	0.009	0.017	0.026	0.028	0.046	0.048	0.039	0.026	0.047	0.037
16	0.003	0.011	0.011	0.011	0.006	0.040	0.042	0.022	0.013	0.013	0.024
17	0.008	0.013	0.005	0.036	0.013	0.023	0.032	0.027	0.018	0.006	0.015
18	0.004	0.007	0.008	0.007	0.009	0.013	0.029	0.036	0.039	0.015	0.024
19	0.002	0.005	0.004	0.003	0.014	0.003	0.016	0.024	0.028	0.005	0.024
20	0.000	0.005	0.006	0.002	0.013	0.012	0.015	0.021	0.043	0.012	0.023
21	0.003	0.004	0.004	0.002	0.003	0.007	0.010	0.013	0.024	0.032	0.018
22	0.003	0.003	0.002	0.004	0.004	0.008	0.005	0.018	0.022	0.062	0.009
23	0.002	0.002	0.002	0.002	0.003	0.012	0.006	0.004	0.016	0.013	0.018
24	0.003	0.002	0.006	0.004	0.000	0.004	0.007	0.008	0.018	0.022	0.019
25+	0.110	0.083	0.070	0.054	0.027	0.025	0.031	0.030	0.055	0.043	0.053
Total	1428	1824	1754	1378	641	898	985	1009	1177	418	794

Table 9-11. Estimated numbers (thousands) in 2014, fishery selectivity, and survey selectivity of Pacific ocean perch in the Gulf of Alaska. Also shown are schedules of age specific weight and female maturity.

Age	Numbers in 2014 (1000's)	Maturity (%)	Weight (g)	Fishery selectivity (%)	Survey selectivity (%)
2	49,318	0.7	42	0.0	4.5
3	46,456	1.3	91	0.0	11.0
4	43,995	2.5	155	0.2	24.6
5	39,662	4.7	227	1.6	46.3
6	41,681	8.8	304	6.1	69.5
7	43,845	15.8	381	15.3	85.8
8	168,021	26.9	455	29.9	94.1
9	33,210	41.8	525	48.3	97.7
10	24,581	58.4	589	67.4	99.1
11	20,181	73.3	647	83.9	99.7
12	21,428	84.3	698	95.2	99.9
13	21,620	91.3	744	100.0	100.0
14	24,033	95.3	784	98.5	100.0
15	45,394	97.6	818	91.9	100.0
16	20,517	98.7	849	81.8	100.0
17	12,546	99.3	875	69.9	100.0
18	13,329	99.7	897	57.6	100.0
19	18,836	99.8	916	46.0	100.0
20	9,330	99.9	932	35.6	100.0
21	6,336	100.0	946	27.0	100.0
22	5,348	100.0	958	19.9	100.0
23	4,838	100.0	968	14.4	100.0
24	4,809	100.0	977	10.2	100.0
25+	71,910	100.0	1004	7.1	100.0

Table 9-12. Summary of results from 2014 compared with 2013 results

	2013	**2014 base**	**2014 recommended**
Likelihoods			
Catch	0.12	0.12	0.12
Survey Biomass	10.06	10.09	10.26
Fishery Ages	26.99	27.02	27.06
Survey Ages	47.59	47.68	47.67
Fishery Sizes	55.71	55.76	54.28
Maturity	n/a	n/a	103.52
Data-Likelihood	140.5	140.7	242.91
Penalties/Priors			
Recruitment Devs	23.28	22.77	22.18
F Regularity	4.15	4.16	4.25
σ_r prior	4.76	4.93	5.03
q prior	1.36	1.34	1.21
M prior	2.00	2.05	2.15
Objective Fun Total	176.0	175.9	277.7
Parameter Ests.			
Active parameters	142	144	146
q	2.09	2.08	2.00
M	0.061	0.061	0.062
σ_r	0.92	0.91	0.90
Mean Recruitment (millions)	46.36	46.75	49.32
$F_{40\%}$	0.113	0.113	0.119
Total Biomass	410,712	406,112	416,140
$B_{CURRENT}$	120,356	121,599	142,029
$B_{100\%}$	257,697	255,708	283,315
$\mathbf{B_{40\%}}$	103,079	102,283	113,326
maxABC	19,309	19,661	**21,012**
$F_{35\%}$	0.132	0.132	0.139
$OFL_{F35\%}$	19,764	22,730	**24,360**

Table 9-13. Estimates of key parameters with Hessian estimates of standard deviation (σ), MCMC standard deviations (σ(MCMC)) and 95% Bayesian credible intervals (BCI) derived from MCMC simulations.

Parameter	μ	μ (MCMC)	Median (MCMC)	σ	σ(MCMC)	BCI-Lower	BCI-Upper
q	2.003	1.903	1.860	0.483	0.482	1.096	2.949
M	0.062	0.063	0.062	0.006	0.006	0.052	0.075
$F_{40\%}$	0.119	0.132	0.128	0.028	0.033	0.081	0.209
2014 SSB	142,029	161,723	155,085	39,749	47,604	88,395	270,182
2014 ABC	21,012	25,849	24,131	7,725	10,561	10,060	51,295

Table 9-14. Estimated time series of female spawning biomass, 6+ biomass (age 6 and greater), catch/6 + biomass, and number of age two recruits for Pacific ocean perch in the Gulf of Alaska. Estimates are shown for the current assessment and from the previous SAFE.

	Spawning biomass (t)		6+ Biomass (t)		Catch/6+ biomass		Age 2 recruits (1000's)	
Year	Previous	Current	Previous	Current	Previous	Current	Previous	Current
1977	27,585	32,872	93,797	94,879	0.229	0.227	17,282	18,820
1978	22,980	27,427	76,923	78,461	0.104	0.102	30,977	33,426
1979	22,669	27,039	73,310	75,301	0.114	0.111	54,603	59,379
1980	21,908	26,220	69,205	71,618	0.157	0.152	22,095	24,265
1981	19,829	23,990	63,185	65,909	0.168	0.161	18,347	20,104
1982	17,598	21,720	61,212	64,013	0.089	0.085	23,382	25,623
1983	17,493	21,849	71,566	74,359	0.040	0.038	26,625	29,303
1984	19,036	23,542	77,350	80,652	0.036	0.034	28,600	31,205
1985	20,815	25,991	81,946	85,860	0.010	0.009	45,072	47,698
1986	23,636	29,892	89,474	94,025	0.025	0.024	58,464	62,204
1987	26,450	33,679	96,154	101,375	0.047	0.045	44,613	49,982
1988	28,738	36,581	100,851	106,678	0.085	0.081	217,676	235,995
1989	29,459	37,647	105,712	111,647	0.113	0.107	66,294	58,052
1990	28,935	37,360	111,364	117,233	0.118	0.112	45,787	44,411
1991	28,305	37,196	113,157	119,805	0.058	0.055	40,462	43,268
1992	30,252	40,989	168,157	173,688	0.039	0.038	36,239	39,043
1993	36,055	46,788	189,965	193,393	0.011	0.011	34,717	37,125
1994	43,817	56,578	210,155	213,498	0.009	0.009	35,966	38,478
1995	53,077	68,622	227,268	231,740	0.025	0.025	39,240	42,353
1996	62,238	80,151	237,113	242,963	0.035	0.035	54,634	57,344
1997	70,871	89,560	241,798	248,970	0.039	0.038	99,952	105,296
1998	78,071	96,239	243,937	252,321	0.037	0.035	62,162	67,019
1999	83,542	100,883	246,287	255,829	0.043	0.041	52,189	56,122
2000	86,781	103,137	250,293	260,333	0.041	0.039	75,574	80,845
2001	88,792	104,702	266,813	276,525	0.041	0.039	149,929	156,280
2002	90,508	105,956	274,475	284,964	0.043	0.041	67,591	71,913
2003	91,575	107,436	278,379	289,777	0.039	0.037	53,094	56,160
2004	93,242	110,457	288,908	300,885	0.040	0.039	45,761	48,503
2005	95,623	114,271	318,916	329,585	0.035	0.034	37,571	40,164
2006	100,183	119,152	330,581	342,081	0.041	0.040	40,587	43,583
2007	104,120	123,774	334,968	347,558	0.039	0.037	49,172	53,275
2008	108,366	129,172	336,454	350,298	0.037	0.036	249,793	247,509
2009	112,814	134,664	334,567	349,807	0.039	0.037	56,816	60,006
2010	116,586	138,931	331,212	347,682	0.047	0.045	50,656	53,389
2011	118,372	140,821	326,607	344,277	0.043	0.041	44,992	47,712
2012	119,111	141,890	376,194	387,212	0.040	0.038	46,839	49,756
2013	118,145	142,586	381,472	392,662	0.032	0.034	46,457	49,404
2014		139,765		396,767		0.045		49,318

Table 9-15. Estimated time series of recruitment, female spawning biomass, and total biomass (2+) for Pacific ocean perch in the Gulf of Alaska. Columns headed with 2.5% and 97.5% represent the lower and upper 95% credible intervals from the MCMC estimated posterior distribution.

	Recruits (age-2)			Total Biomass			Spawning Biomass		
Year	Mean	2.5%	97.5%	Mean	2.5%	97.5%	Mean	2.5%	97.5%
1977	18,820	4,232	56,040	102,090	84,508	144,602	32,872	25,660	48,701
1978	33,426	6,878	101,406	86,393	68,985	129,994	27,427	20,160	43,438
1979	59,379	10,983	140,510	86,105	67,999	131,556	27,039	19,699	43,515
1980	24,265	5,232	76,617	85,829	67,164	135,468	26,220	18,888	43,208
1981	20,104	4,582	59,751	83,249	63,345	136,825	23,990	16,620	41,658
1982	25,623	5,243	69,829	81,327	59,771	139,671	21,720	14,392	39,888
1983	29,303	6,024	81,314	85,103	62,111	146,923	21,849	14,390	40,920
1984	31,205	6,497	91,829	91,759	67,082	157,964	23,542	15,762	43,658
1985	47,698	8,384	137,261	99,365	73,133	170,917	25,991	17,763	47,534
1986	62,204	10,235	173,681	110,501	82,235	188,276	29,892	20,918	53,523
1987	49,982	8,084	232,746	121,195	90,784	207,281	33,679	23,923	59,548
1988	235,990	18,398	470,276	138,309	103,104	236,262	36,581	25,996	64,558
1989	58,052	9,607	271,567	152,824	112,081	265,408	37,647	26,238	67,660
1990	44,411	7,145	145,902	165,744	119,389	293,239	37,360	25,284	69,597
1991	43,268	6,728	131,593	177,913	125,639	321,707	37,196	23,986	72,422
1992	39,043	6,773	116,890	196,054	138,847	352,623	40,989	26,251	79,881
1993	37,125	6,777	113,788	212,585	150,212	381,576	46,788	30,248	90,374
1994	38,478	6,554	123,838	231,793	165,167	410,222	56,578	37,884	106,571
1995	42,353	6,956	141,835	249,251	178,772	436,839	68,622	46,873	125,708
1996	57,344	8,509	196,514	261,252	187,539	456,576	80,151	55,195	145,893
1997	105,300	12,555	275,306	271,325	193,261	475,559	89,560	61,597	162,539
1998	67,019	9,185	252,806	279,961	198,862	493,102	96,239	65,940	174,708
1999	56,122	8,331	217,527	289,132	204,661	510,361	100,883	68,725	182,529
2000	80,845	9,018	308,661	297,568	211,055	527,237	103,137	69,808	188,071
2001	156,280	13,766	393,803	310,294	218,476	550,964	104,702	70,516	191,770
2002	71,913	10,367	294,507	322,981	227,249	577,693	105,956	71,073	194,363
2003	56,160	8,336	193,431	334,912	235,052	602,041	107,436	71,311	197,598
2004	48,503	7,865	164,266	347,081	243,619	625,294	110,457	73,045	203,847
2005	40,163	6,302	143,141	356,677	249,114	644,380	114,271	75,390	212,180
2006	43,583	7,435	163,654	364,579	253,408	658,493	119,152	78,532	220,310
2007	53,275	8,380	267,197	368,164	254,892	666,771	123,774	81,126	231,273
2008	247,510	15,288	667,117	378,723	259,080	684,123	129,172	84,678	242,200
2009	60,006	8,925	387,495	388,987	265,588	700,981	134,664	88,197	252,172
2010	53,389	7,655	270,694	398,943	271,512	715,009	138,931	90,786	260,028
2011	47,712	6,882	223,097	405,820	274,250	732,783	140,821	90,349	266,214
2012	49,756	7,112	271,787	412,006	277,798	752,097	141,890	90,715	268,729
2013	49,404	6,626	256,720	415,589	277,488	767,744	142,586	90,654	271,659
2014	49,318	6,987	260,266	418,867	278,973	781,772	139,765	87,682	267,460
2015	61,430	7,228	292,041	416,140	272,721	789,332	142,029	88,395	270,182
2016	61,430	6,822	305,980	412,351			144,974	91,310	270,084

Table 9-16. Set of projections of spawning biomass and yield for Pacific ocean perch in the Gulf of Alaska. This set of projections encompasses six harvest scenarios designed to satisfy the requirements of Amendment 56, the National Environmental Protection Act, and the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA). For a description of scenarios see ***Projections and Harvest Alternatives***. All units in t. $B_{40\%}$ = 113,326 t, $B_{35\%}$ = 99,160 t, $F_{40\%}$ = 0.119, and $F_{35\%}$ = 0.139.

Year	Maximum permissible F	Author's F* (prespecified catch)	Half maximum F	5-year average F	No fishing	Overfished	Approaching overfished
			Spawning biomass (t)				
2014	139,766	139,766	139,766	139,766	139,766	139,766	139,766
2015	141,569	142,029	142,972	142,360	144,396	141,105	141,569
2016	143,096	144,974	148,806	146,287	154,846	141,259	143,096
2017	143,592	146,442	153,772	149,230	164,985	140,403	143,110
2018	142,223	144,956	156,858	150,255	173,655	137,762	140,322
2019	139,335	141,893	158,112	149,545	180,577	133,767	136,131
2020	135,825	138,183	158,222	147,893	186,131	129,359	131,512
2021	132,386	134,541	157,823	145,976	190,753	125,223	127,169
2022	129,542	131,507	157,511	144,370	194,981	121,838	123,596
2023	127,476	129,273	157,601	143,343	199,163	119,331	120,926
2024	126,123	127,775	158,175	142,915	203,482	117,600	119,051
2025	125,104	126,626	158,907	142,735	207,646	116,272	117,581
2026	124,330	125,736	159,784	142,754	211,740	115,243	116,423
2027	123,710	125,011	160,733	142,888	215,736	114,407	115,470
			Fishing mortality				
2014	0.101	0.101	0.101	0.101	0.101	0.101	0.101
2015	0.119	0.099	0.060	0.085	-	0.139	0.139
2016	0.119	0.098	0.060	0.085	-	0.139	0.139
2017	0.119	0.119	0.060	0.085	-	0.139	0.139
2018	0.119	0.119	0.060	0.085	-	0.139	0.139
2019	0.119	0.119	0.060	0.085	-	0.139	0.139
2020	0.119	0.119	0.060	0.085	-	0.139	0.139
2021	0.119	0.119	0.060	0.085	-	0.139	0.139
2022	0.119	0.119	0.060	0.085	-	0.139	0.139
2023	0.119	0.119	0.060	0.085	-	0.139	0.139
2024	0.119	0.119	0.060	0.085	-	0.138	0.138
2025	0.119	0.119	0.060	0.085	-	0.137	0.137
2026	0.119	0.119	0.060	0.085	-	0.136	0.136
2027	0.119	0.119	0.060	0.085	-	0.135	0.135
			Yield (t)				
2014	17,716	17,716	17,716	17,716	17,716	17,716	17,716
2015	17,665	17,665	10,717	15,239	-	24,360	17,665
2016	21,169	17,797	11,221	15,690	-	24,232	21,169
2017	21,097	21,641	11,614	15,974	-	23,850	24,449
2018	20,586	21,076	11,770	15,922	-	22,986	23,517
2019	19,676	20,097	11,662	15,527	-	21,717	22,167
2020	18,575	18,922	11,358	14,913	-	20,305	20,670
2021	17,526	17,802	10,969	14,250	-	19,027	19,313
2022	16,679	16,892	10,591	13,665	-	18,039	18,257
2023	16,095	16,255	10,288	13,229	-	17,382	17,547
2024	15,763	15,881	10,087	12,959	-	16,957	17,116
2025	15,630	15,719	9,991	12,841	-	16,722	16,867
2026	15,601	15,672	9,965	12,814	-	16,633	16,752
2027	15,625	15,686	9,985	12,844	-	16,630	16,729

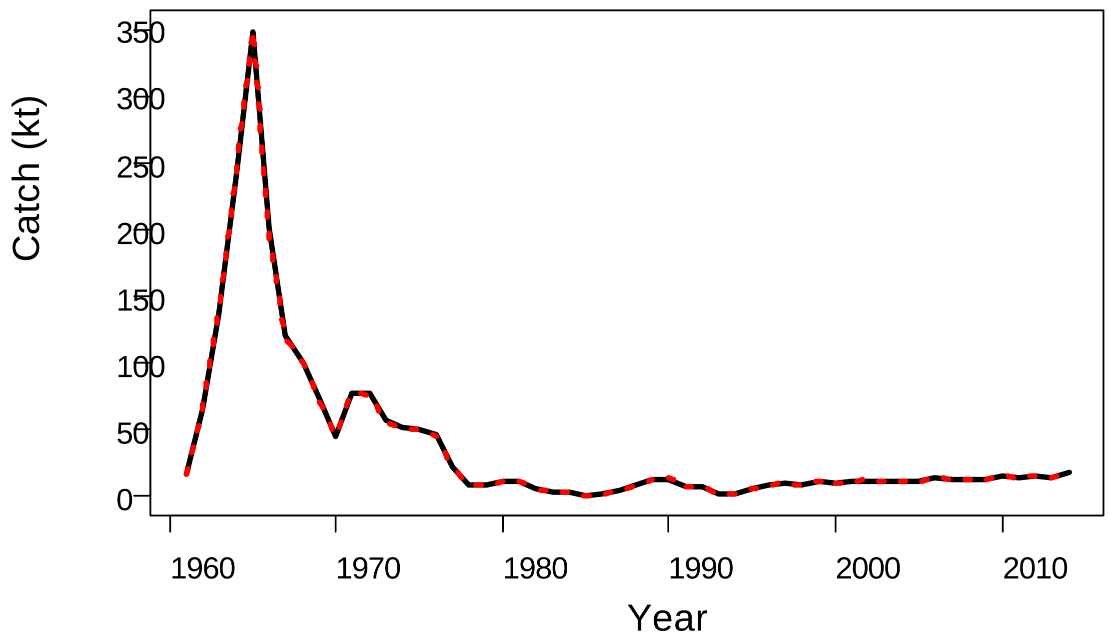
*Projected ABCs and OFLs for 2015 and 2016 are derived using estimated catch of 17,716 for 2014, and projected catches of 17,665 t and 17,797 t for 2015 and 2016 based on realized catches from 2011-2013. This calculation is in response to management requests to obtain more accurate projections.

Table 9-17. Summary of ecosystem considerations for Gulf of Alaska Pacific ocean perch.

Ecosystem effects on *GOA Pacific ocean perch*			
Indicator	Observation	Interpretation	Evaluation
Prey availability or abundance trends			
Phytoplankton and Zooplankton	Primary contents of stomach	Important for all life stages, no time series	Unknown
Predator population trends			
Marine mammals	Not commonly eaten by marine mammals	No effect	No concern
Birds	Stable, some increasing some decreasing	Affects young-of-year mortality	Probably no concern
Fish (Halibut, ling cod, rockfish, arrowtooth)	Arrowtooth have increased, others stable	More predation on juvenile rockfish	Possible concern
Changes in habitat quality			
Temperature regime	Higher recruitment after 1977 regime shift	Contributed to rapid stock recovery	No concern
Winter-spring environmental conditions	Affects pre-recruit survival	Different phytoplankton bloom timing	Causes natural variability, rockfish have varying larval release to compensate
Production	Relaxed downwelling in summer brings in nutrients to Gulf shelf	Some years are highly variable like El Nino 1998	Probably no concern, contributes to high variability of rockfish recruitment

***GOA POP* fishery effects on ecosystem**			
Indicator	Observation	Interpretation	Evaluation
Fishery contribution to bycatch			
Prohibited species	Stable, heavily monitored	Minor contribution to mortality	No concern
Forage (including herring, Atka mackerel, cod, and pollock)	Stable, heavily monitored (P. cod most common)	Bycatch levels small relative to forage biomass	No concern
HAPC biota	Medium bycatch levels of sponge and corals	Bycatch levels small relative to total HAPC biota, but can be large in specific areas	Probably no concern
Marine mammals and birds	Very minor take of marine mammals, trawlers overall cause some bird mortality	Rockfish fishery is short compared to other fisheries	No concern
Sensitive non-target species	Likely minor impact on non-target rockfish	Data limited, likely to be harvested in proportion to their abundance	Probably no concern
Fishery concentration in space and time	Duration is short and in patchy areas	Not a major prey species for marine mammals	No concern, fishery is being extended for several month starting 2007
Fishery effects on amount of large size target fish	Depends on highly variable year-class strength	Natural fluctuation	Probably no concern
Fishery contribution to discards and offal production	Decreasing	Improving, but data limited	Possible concern with non-targets rockfish
Fishery effects on age-at-maturity and fecundity	Black rockfish show older fish have more viable larvae	Inshore rockfish results may not apply to longer-lived slope rockfish	Definite concern, studies initiated in 2005 and ongoing

Figures



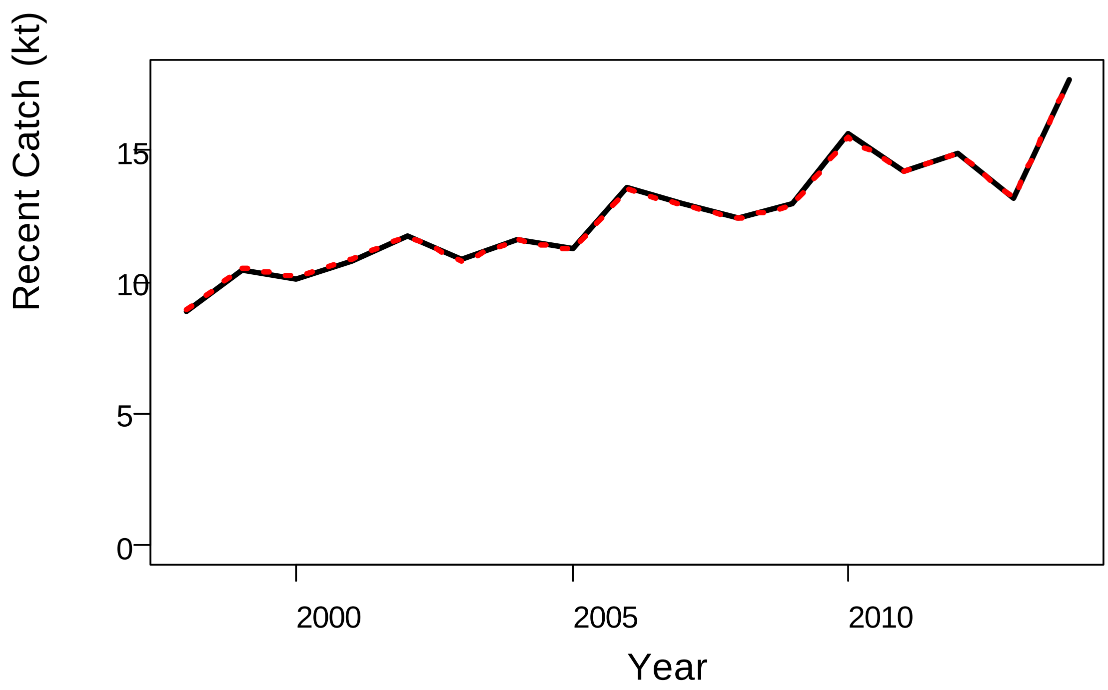


Figure 9-1. Estimated and observed long-term (top figure) and short-term (bottom figure) catch history for Gulf of Alaska Pacific ocean perch.

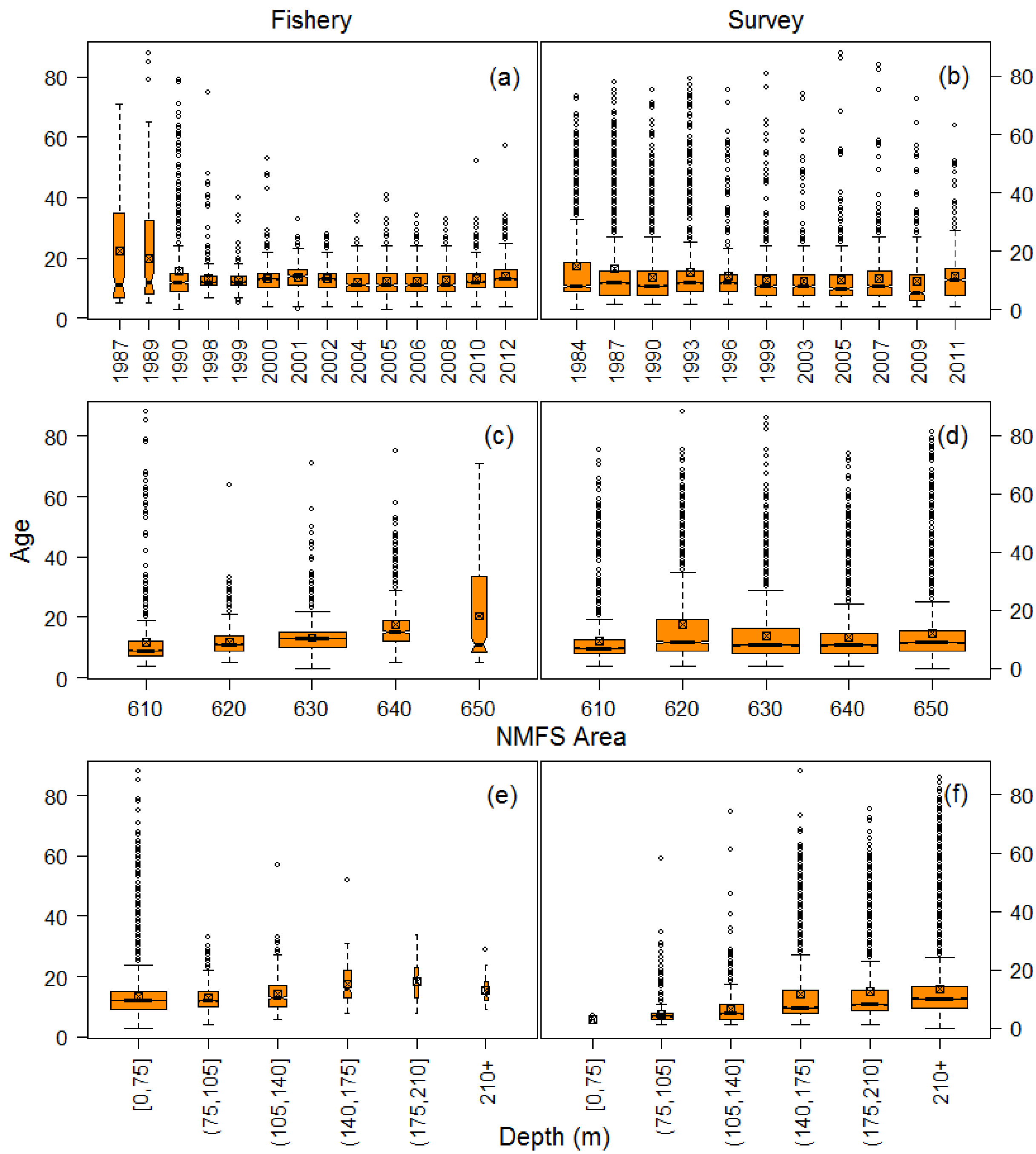


Figure 9-2. Comparisons of fishery and survey age compositions across time, depth, and NMFS area.

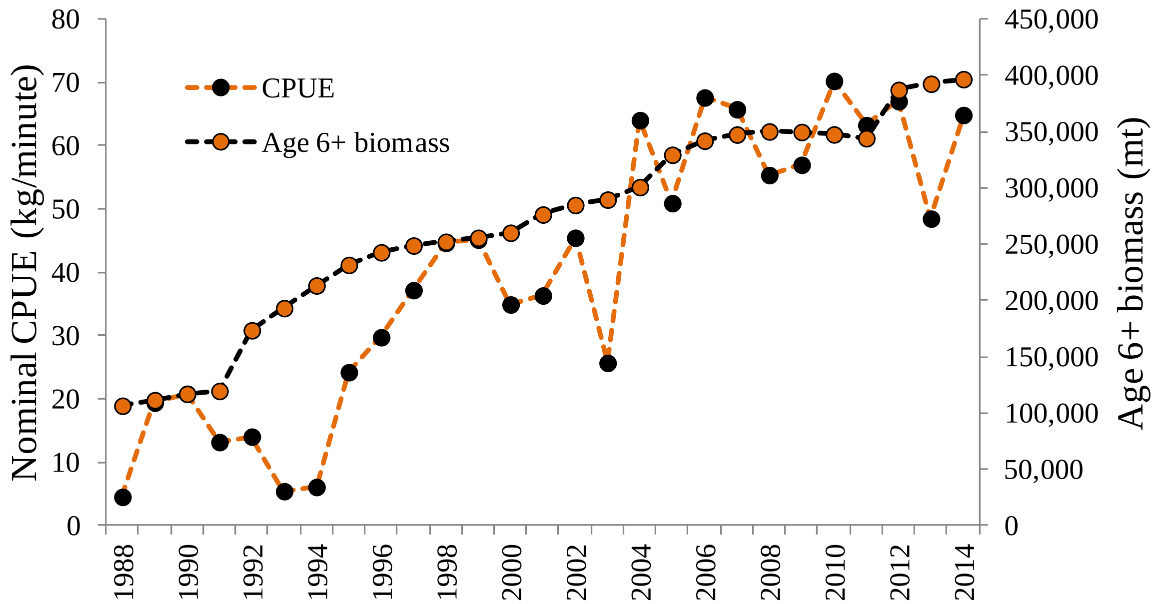


Figure 9-3a. Comparison of nominal catch-per-unit-effort (CPUE, kg/minute) and biomass (age 6+) in the Gulf of Alaska Pacific ocean perch fishery.

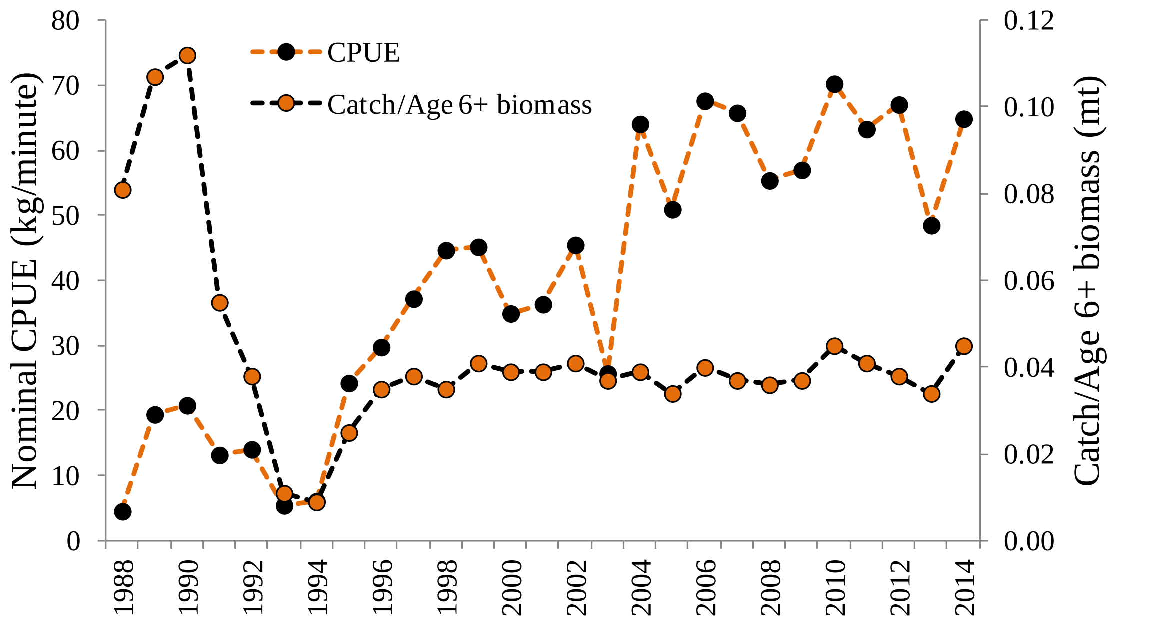


Figure 9-3b. Comparison of nominal catch-per-unit-effort (CPUE, kg/minute) and a proxy for exploitation rate (Catch/Age 6+ Biomass) for the Gulf of Alaska Pacific ocean perch fishery.

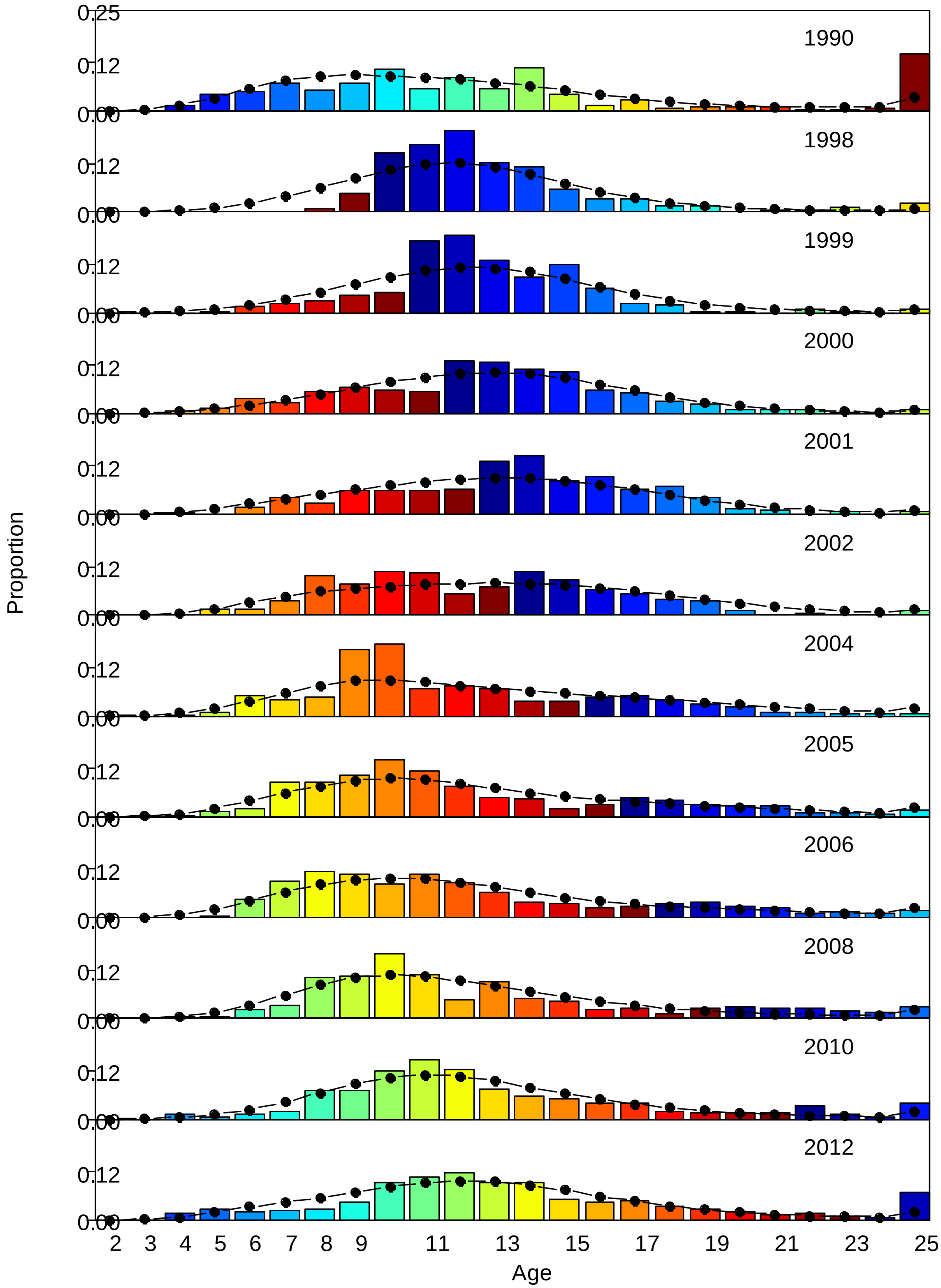


Figure 9-4. Fishery age compositions for GOA Pacific ocean perch. Observed = bars, predicted from author recommended model = line with circles. Colors follow cohorts.

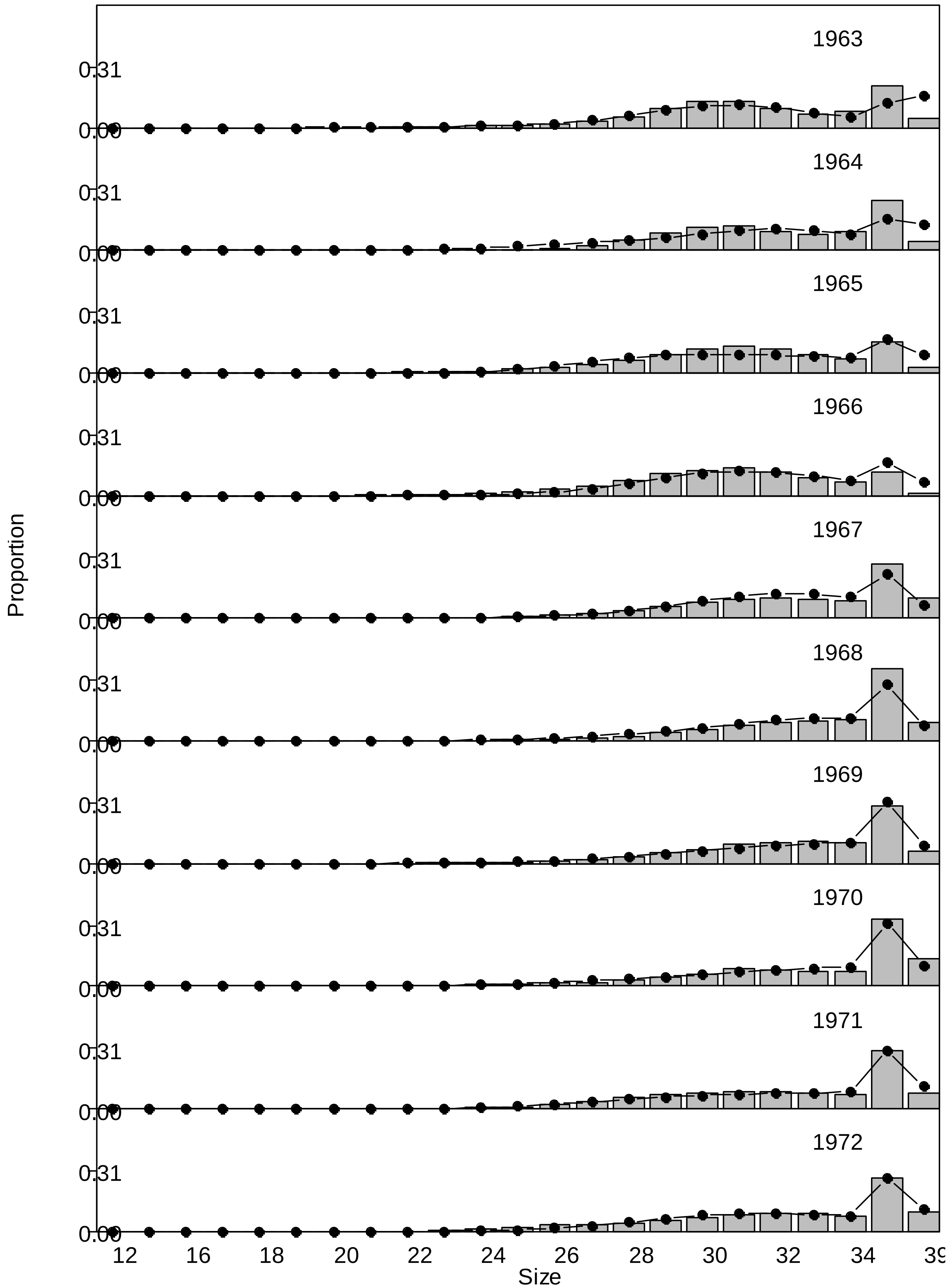


Figure 9-5. Fishery length (cm) compositions for GOA Pacific ocean perch. Observed = bars, predicted from author recommended model = line with circles.

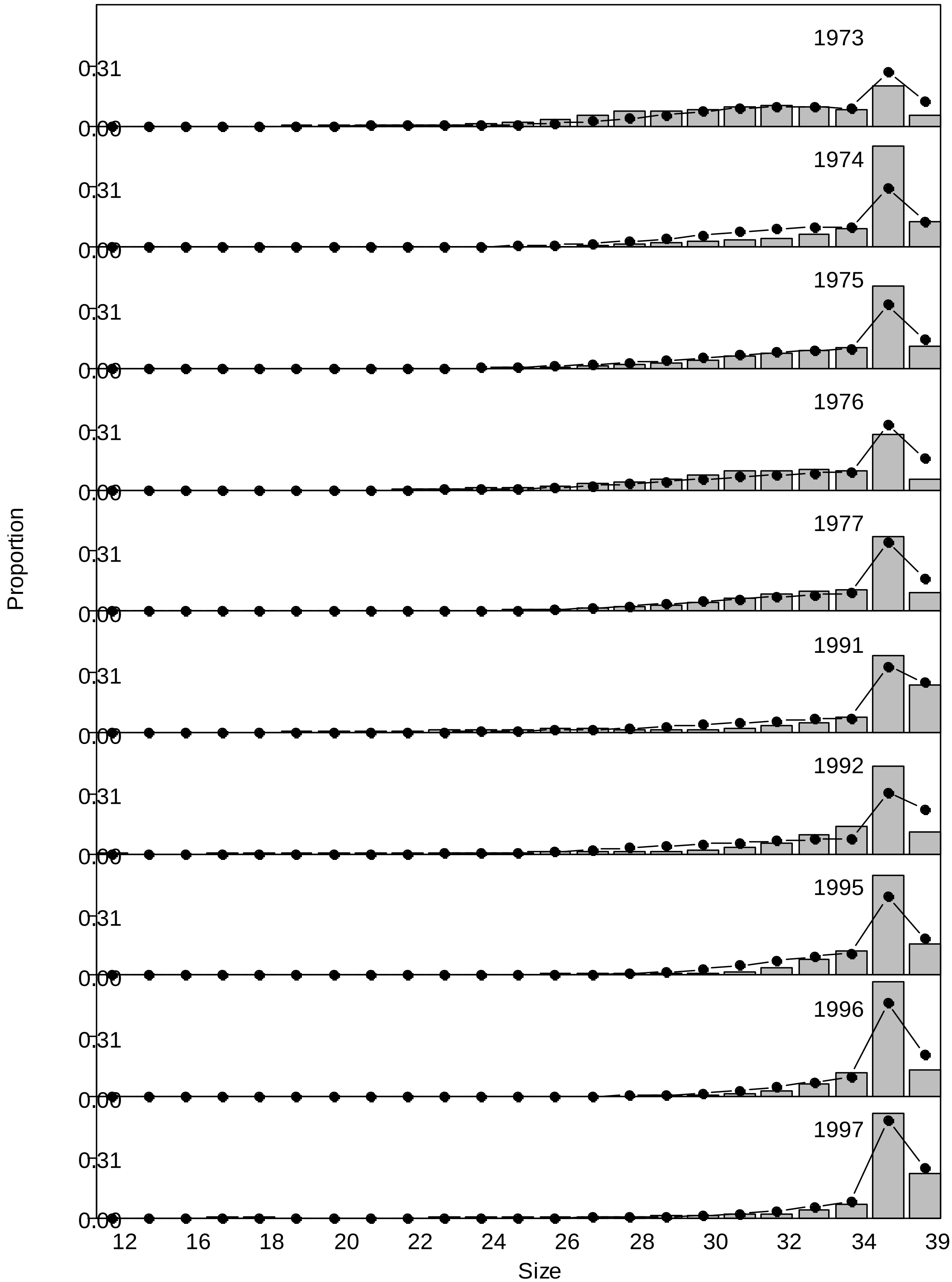


Figure 9-5. (continued) Fishery length (cm) compositions for GOA Pacific ocean perch. Observed = bars, predicted from author recommended model = line with circles.

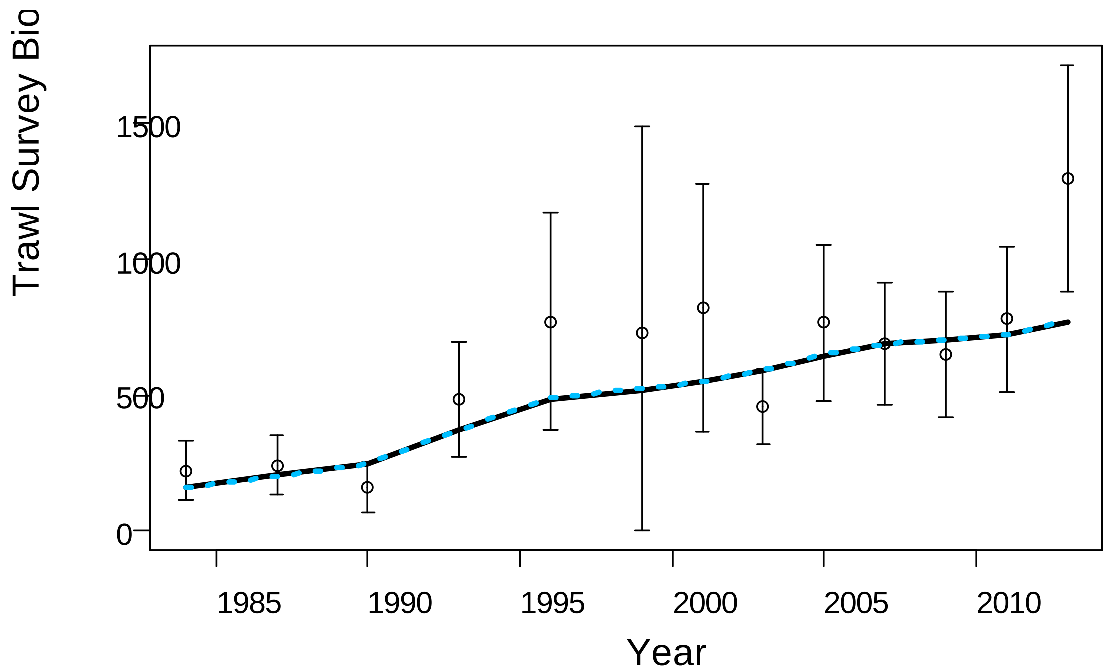


Figure 9-6. NMFS Groundfish Survey observed biomass estimates (open circles) with 95% sampling error confidence intervals for Gulf of Alaska Pacific ocean perch. Predicted estimates from the recommended model (black dashed line) compared with last year's model fit (blue dotted line).

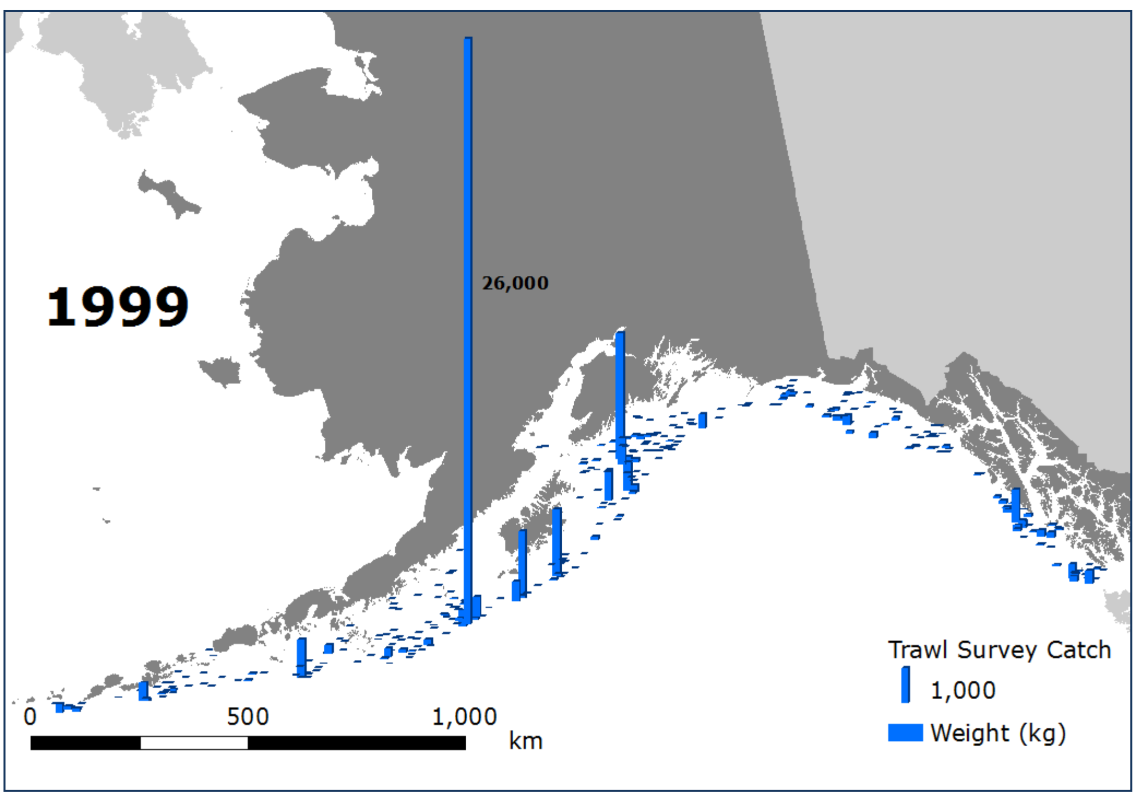


Figure 9-7a. Distribution of Gulf of Alaska Pacific ocean perch catches in the 1999 Gulf of Alaska groundfish survey.

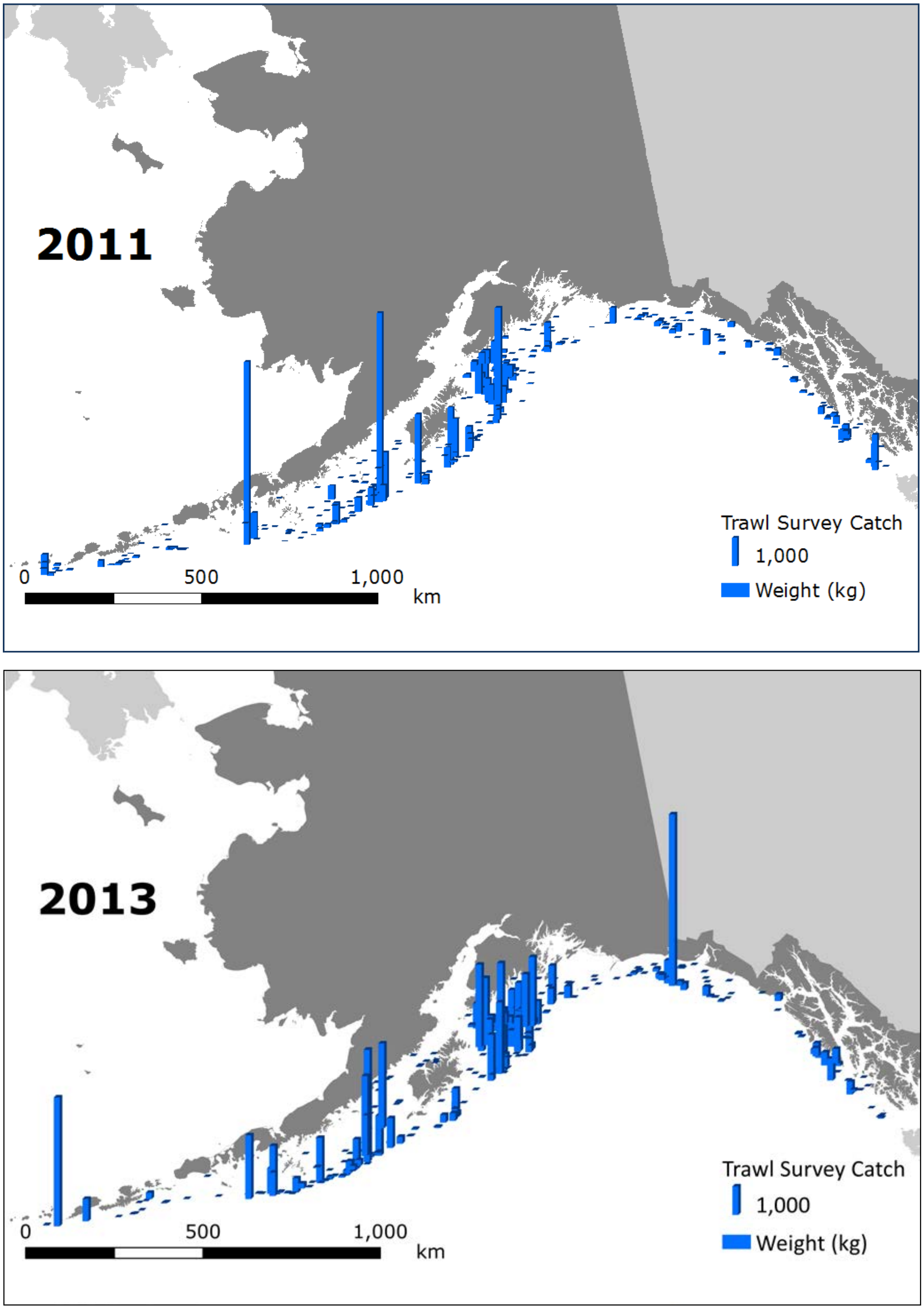


Figure 9-7b. Distribution of Gulf of Alaska Pacific ocean perch catches in the 2011 and 2013 Gulf of Alaska groundfish surveys.

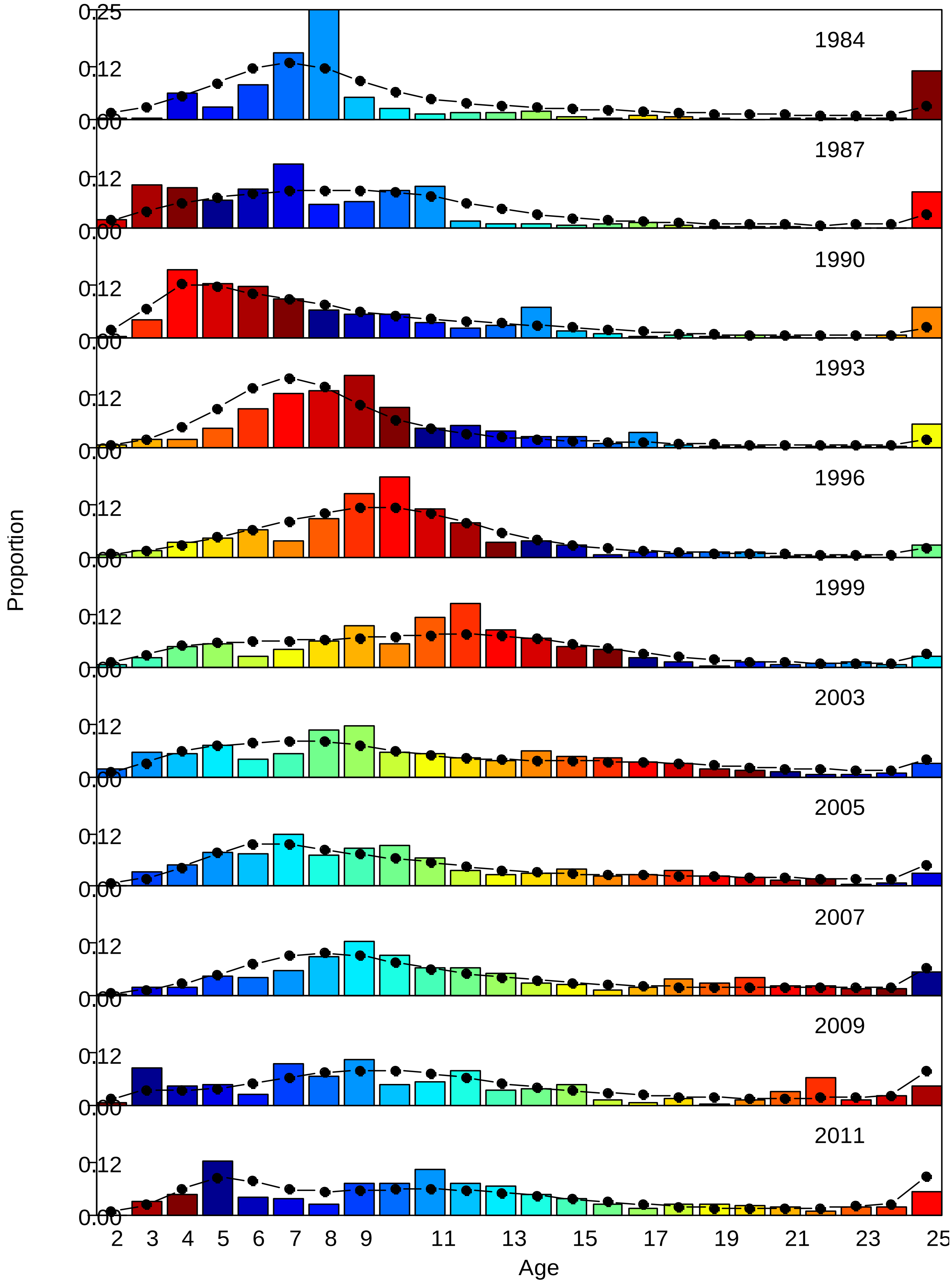


Figure 9-8. Groundfish survey age compositions for GOA Pacific ocean perch. Observed = bars, predicted from author recommended model = line with circles.

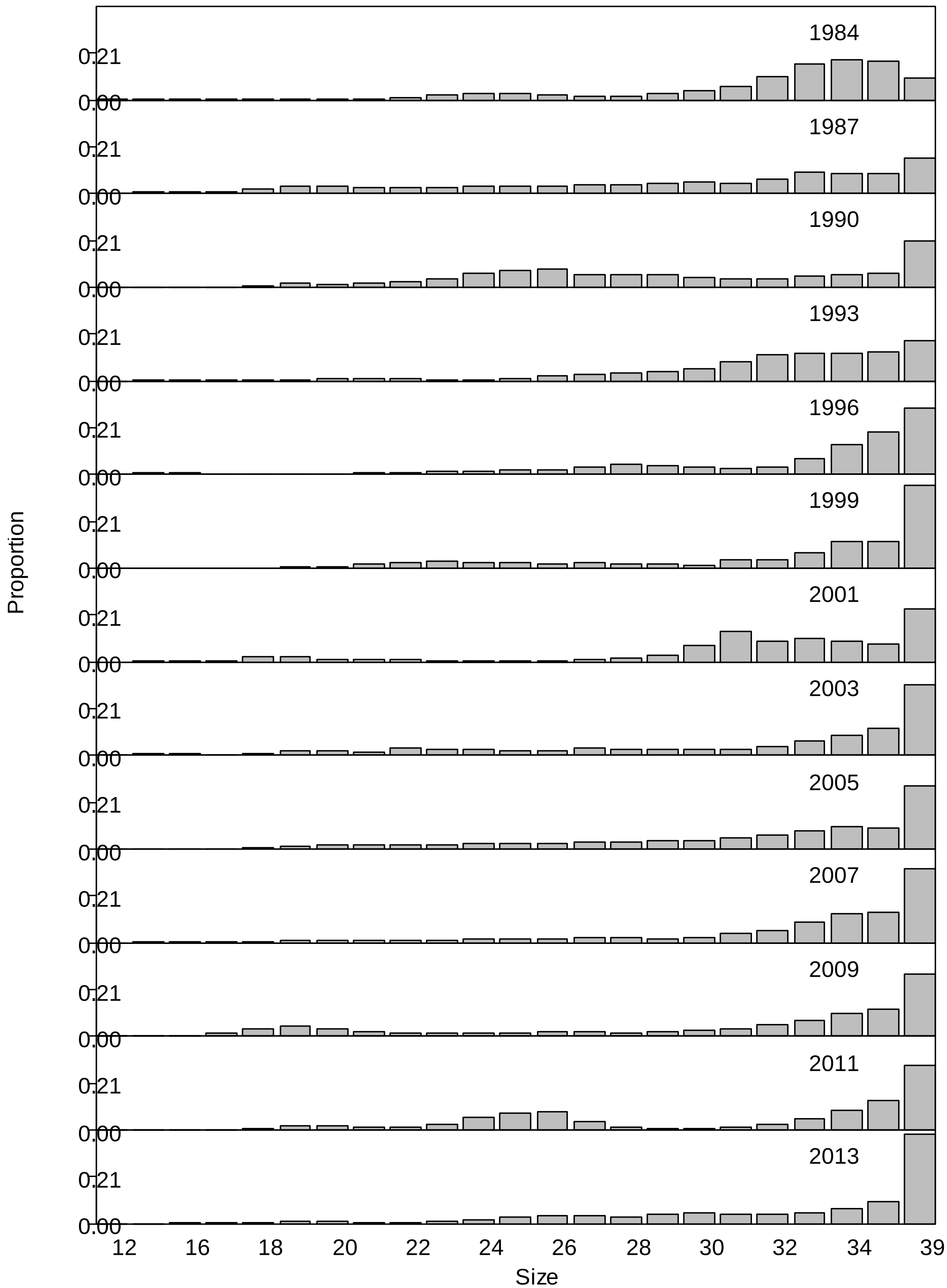


Figure 9-9. Groundfish survey length compositions for GOA Pacific ocean perch. Observed = bars. Survey size not used in Pacific ocean perch model because survey ages are available for these years.

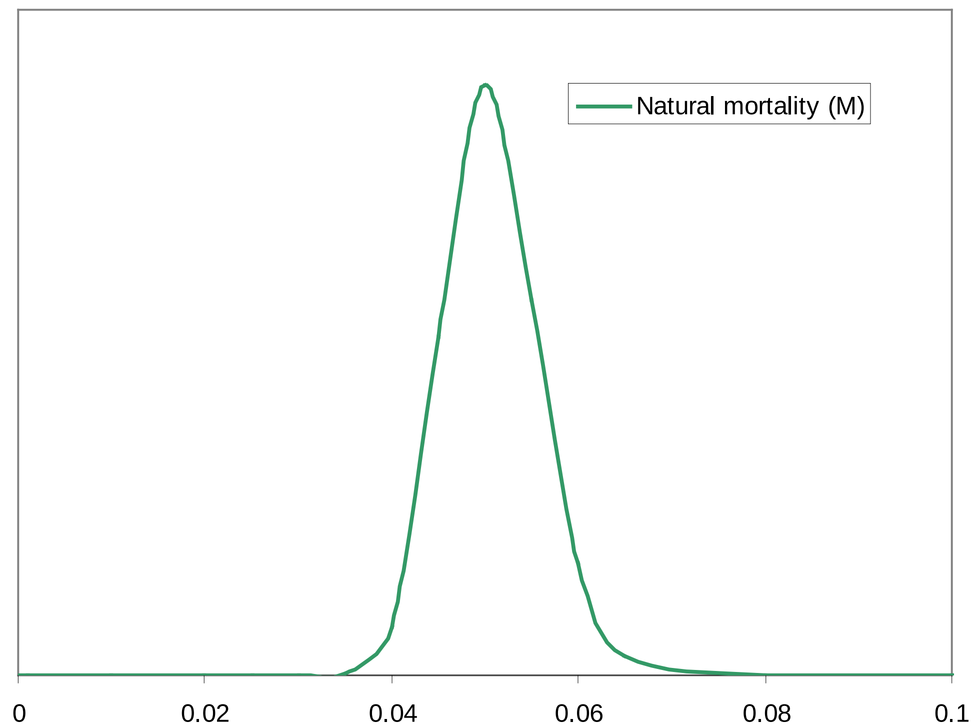


Figure 9-10. Prior distribution for natural mortality (*M*) of Pacific ocean perch, μ=0.05, CV=10%.

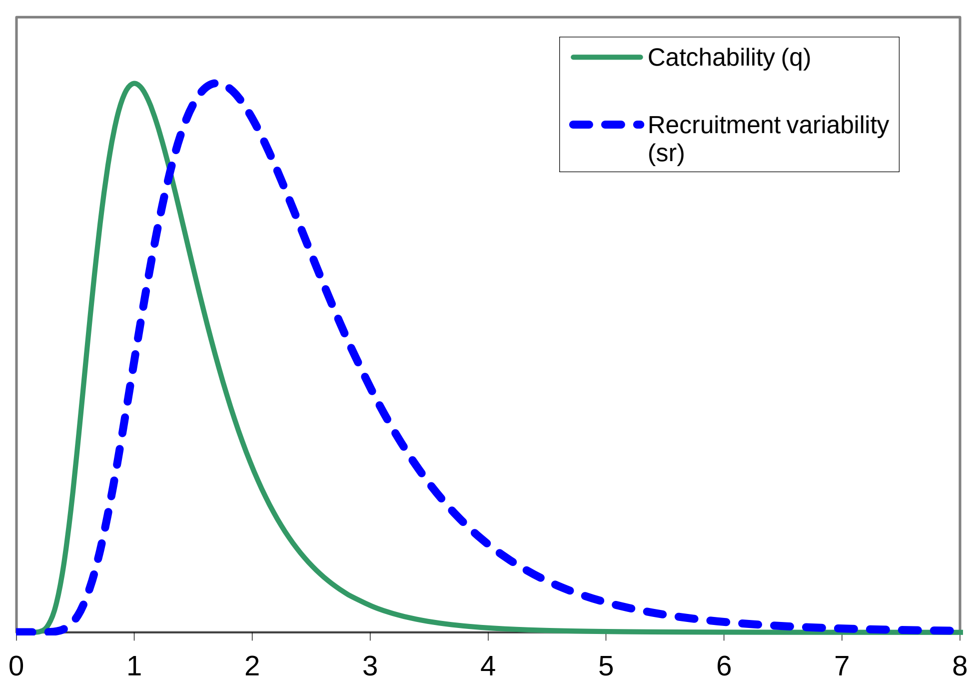


Figure 9-11. Lognormal prior distributions for catchability (*q*, μ=1, CV=45%) and recruitment variability (σ_r, μ=1.7, CV=20%) of Pacific ocean perch.

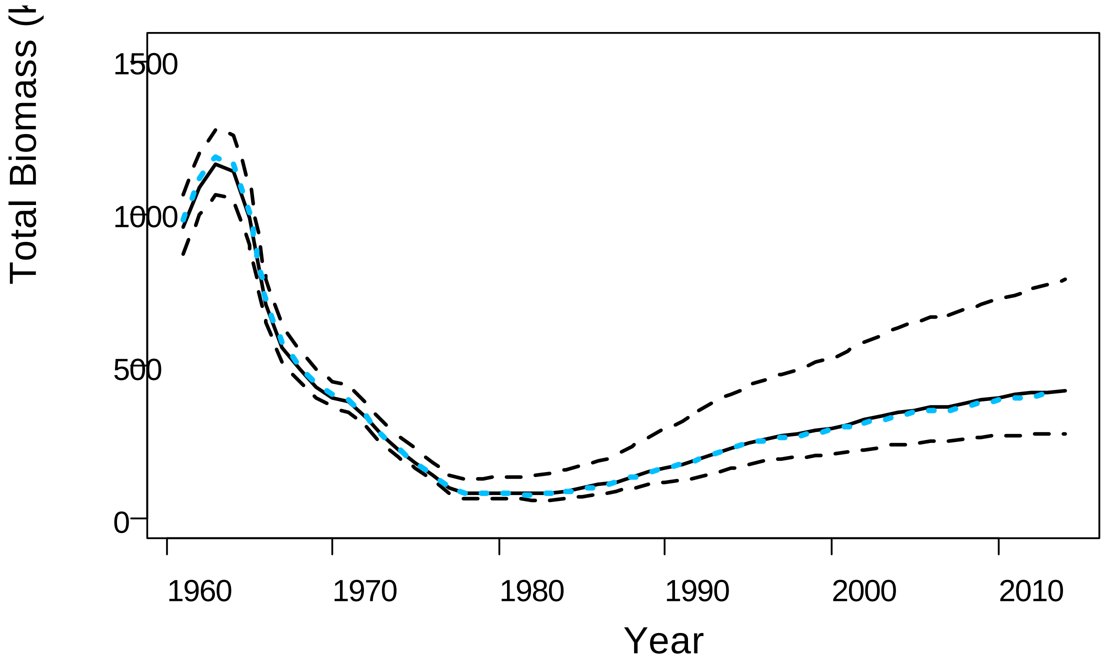


Figure 9-12. Model estimated total biomass (solid black line) with 95% credible intervals determined by MCMC (dashed line) for Gulf of Alaska Pacific ocean perch. Last year's model estimates included for comparison (dotted blue line).

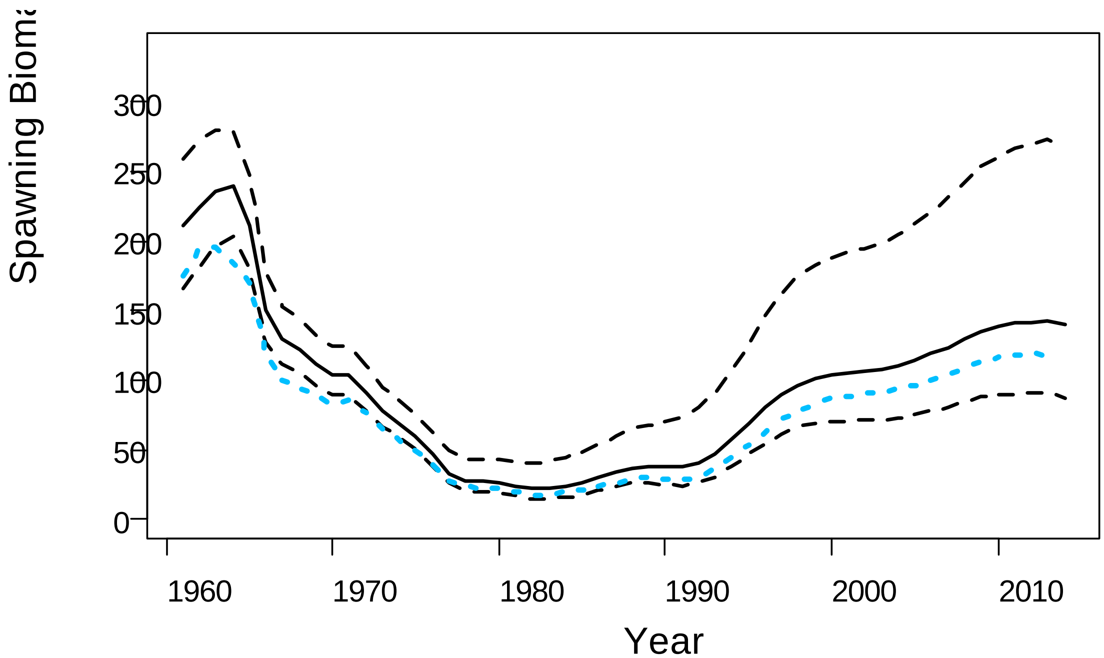


Figure 9-13. Model estimated spawning biomass (solid line) with 95% credible intervals determined by MCMC (dashed line) for Gulf of Alaska Pacific ocean perch. Last year's model estimates included for comparison (dotted blue line).

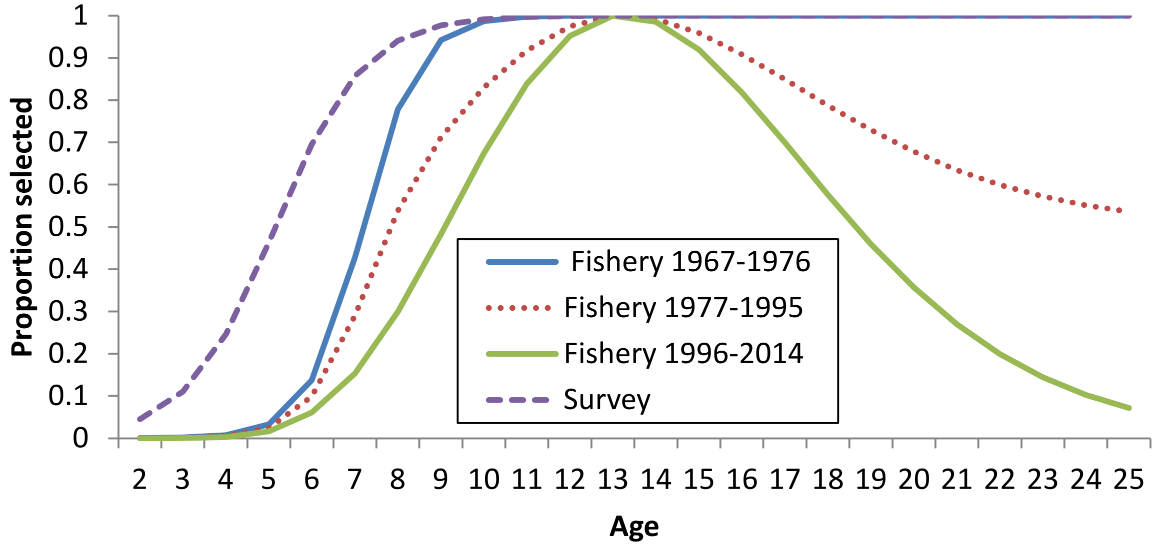


Figure 9-14. Estimated selectivities for the fishery for three periods and groundfish survey for Gulf of Alaska Pacific ocean perch.

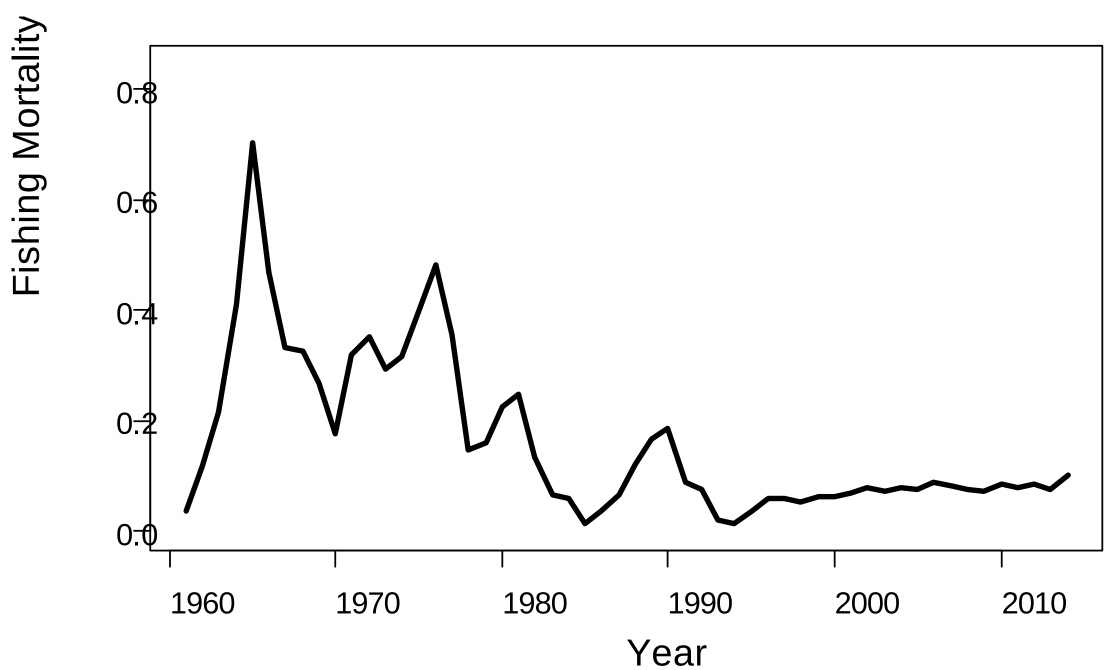


Figure 9-15. Estimated fully selected fishing mortality over time for GOA Pacific ocean perch.

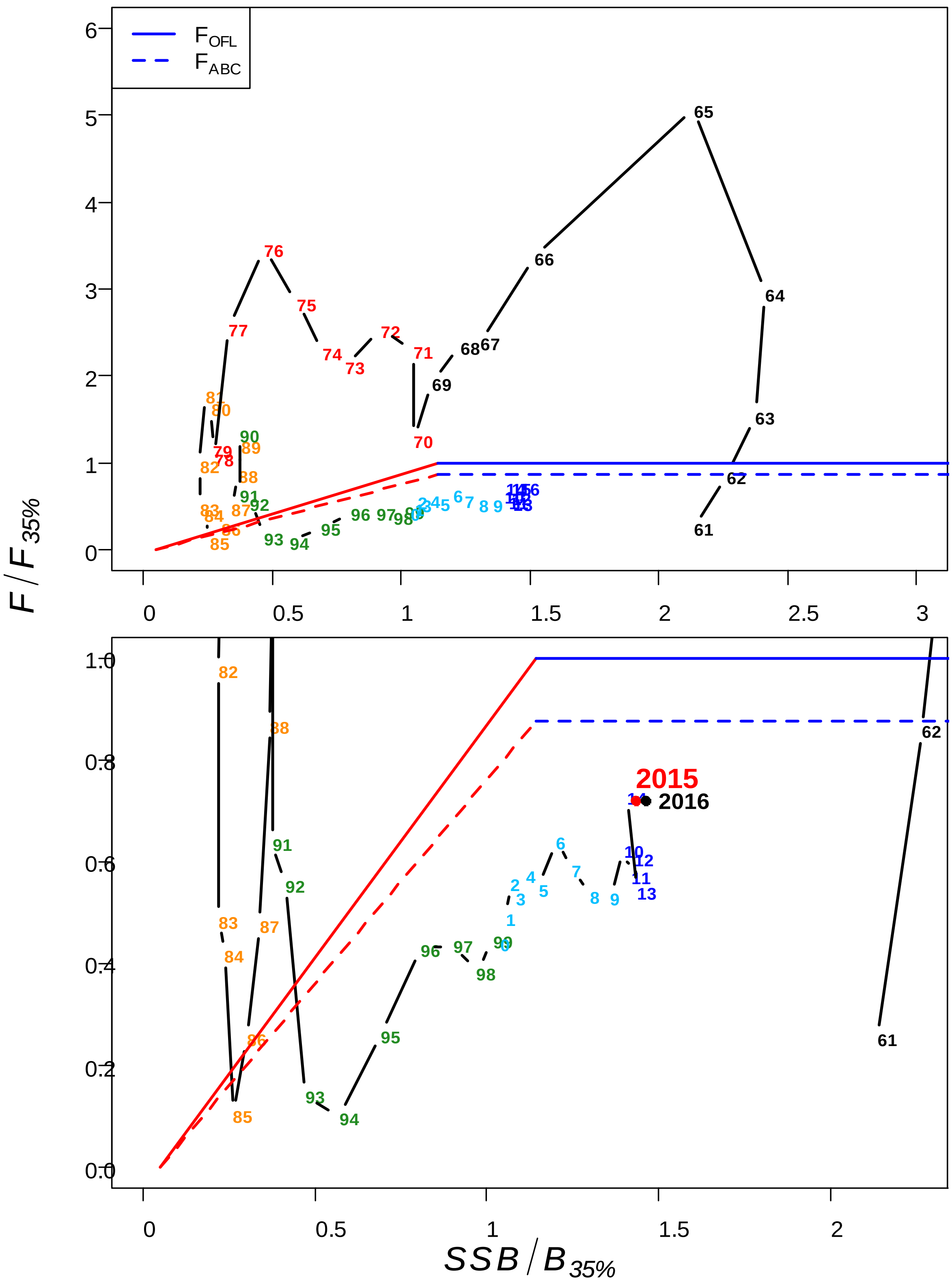


Figure 9-16. Time series of Pacific ocean perch estimated spawning biomass relative to the target level $B_{35\%}$ level and fishing mortality relative to $F_{35\%}$ for author recommended model. Top shows whole time series. Bottom shows close up on more recent management path.

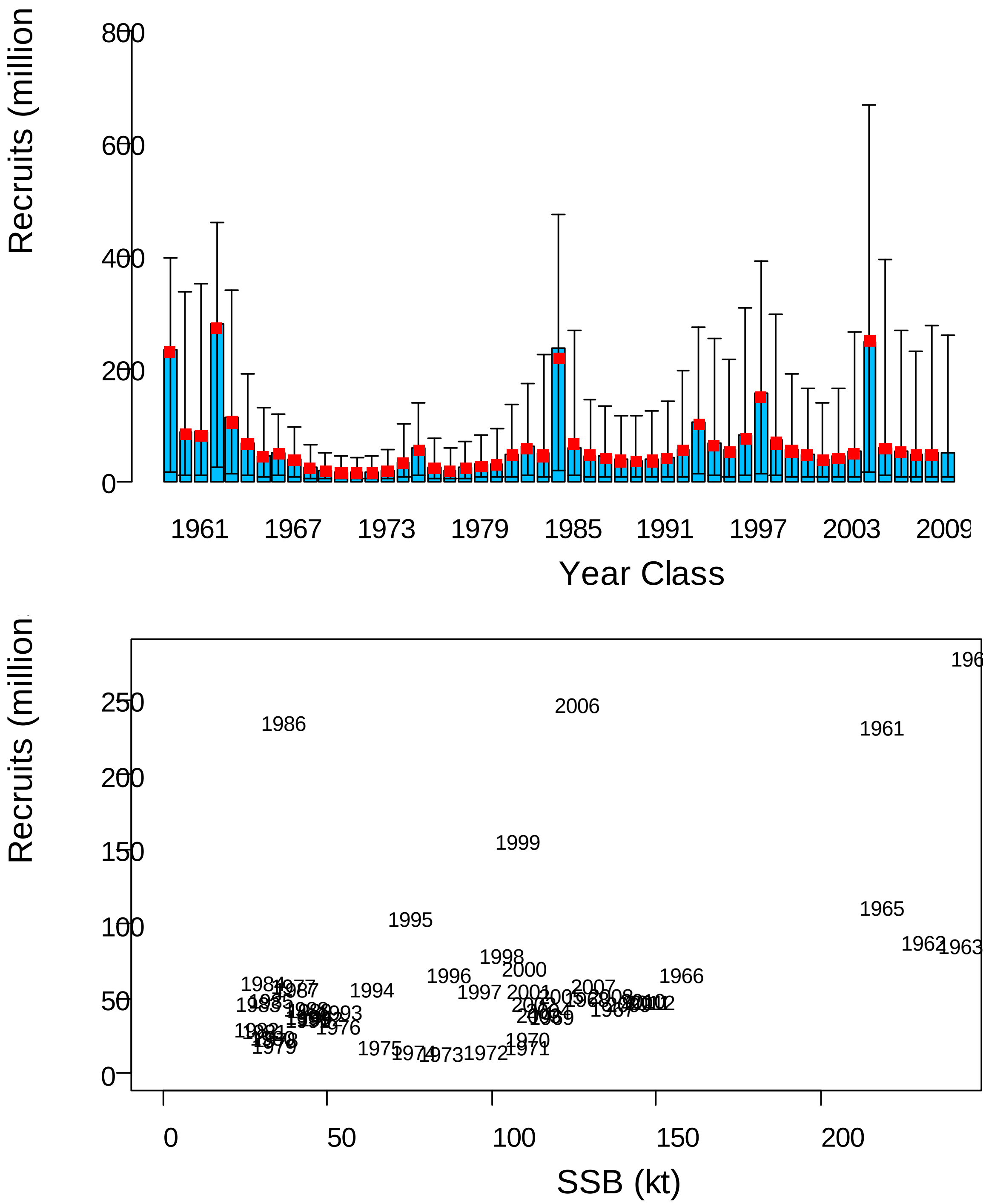


Figure 9-17. Estimated recruitment of Gulf of Alaska Pacific ocean perch (age 2) by year class with 95% credible intervals derived from MCMC (top). Estimated recruits per spawning stock biomass (bottom). Red square in top graph are last year's estimates for comparison.

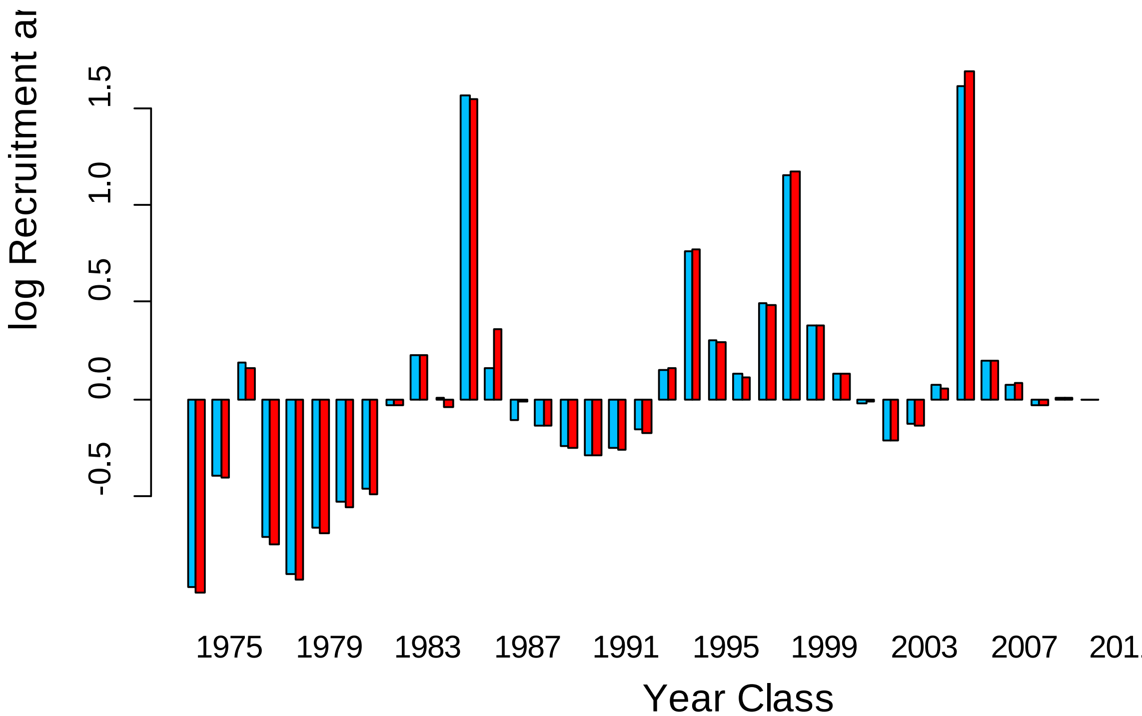


Figure 9-18. Recruitment deviations from average on the log-scale comparing last cycle's model (red) to current year recommended model (blue) for Gulf of Alaska Pacific ocean perch.

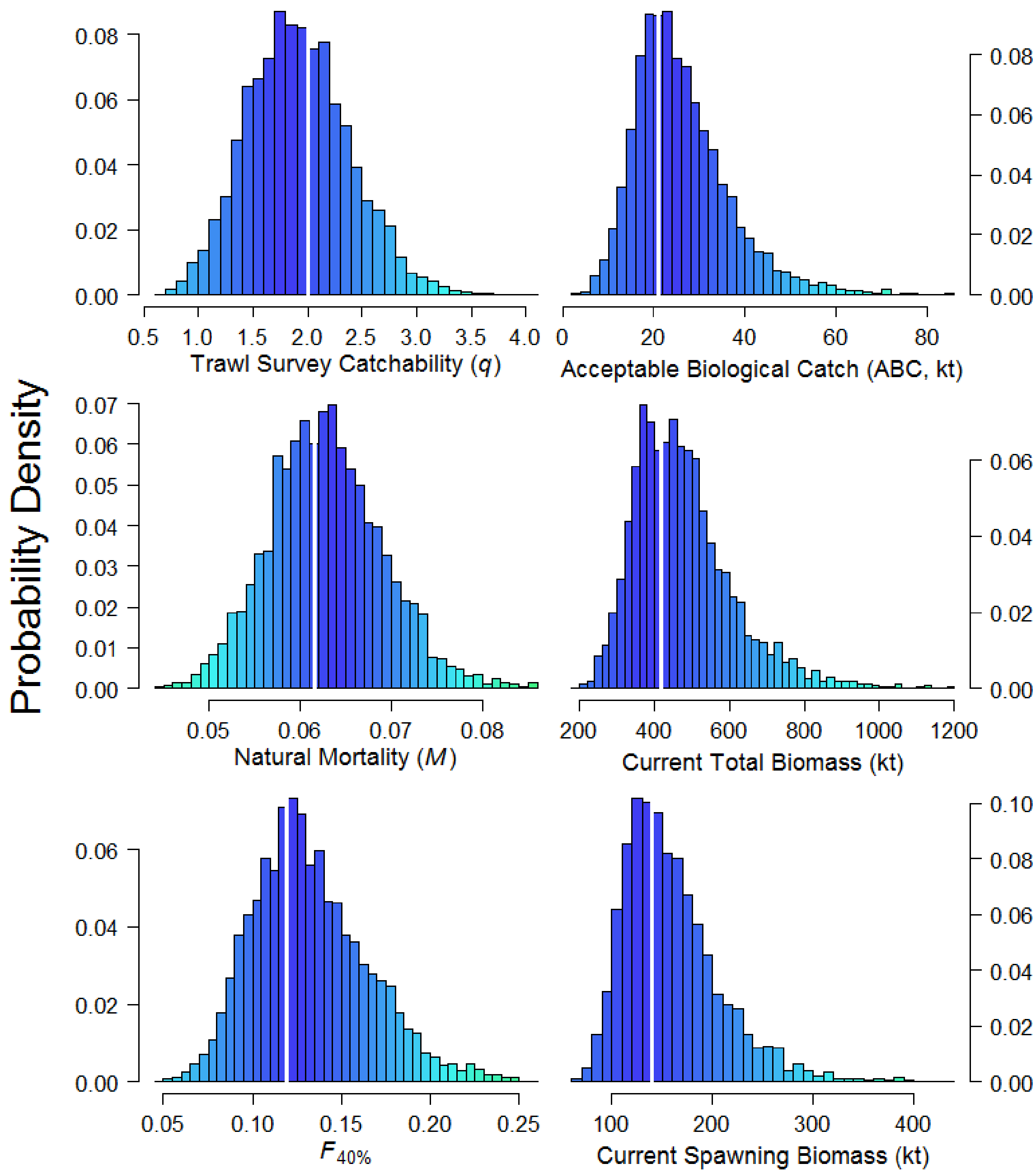


Figure 9-19. Histograms of estimated posterior distributions of key parameters derived from MCMC for Gulf of Alaska Pacific ocean perch. The vertical white lines are the recommended model estimates.

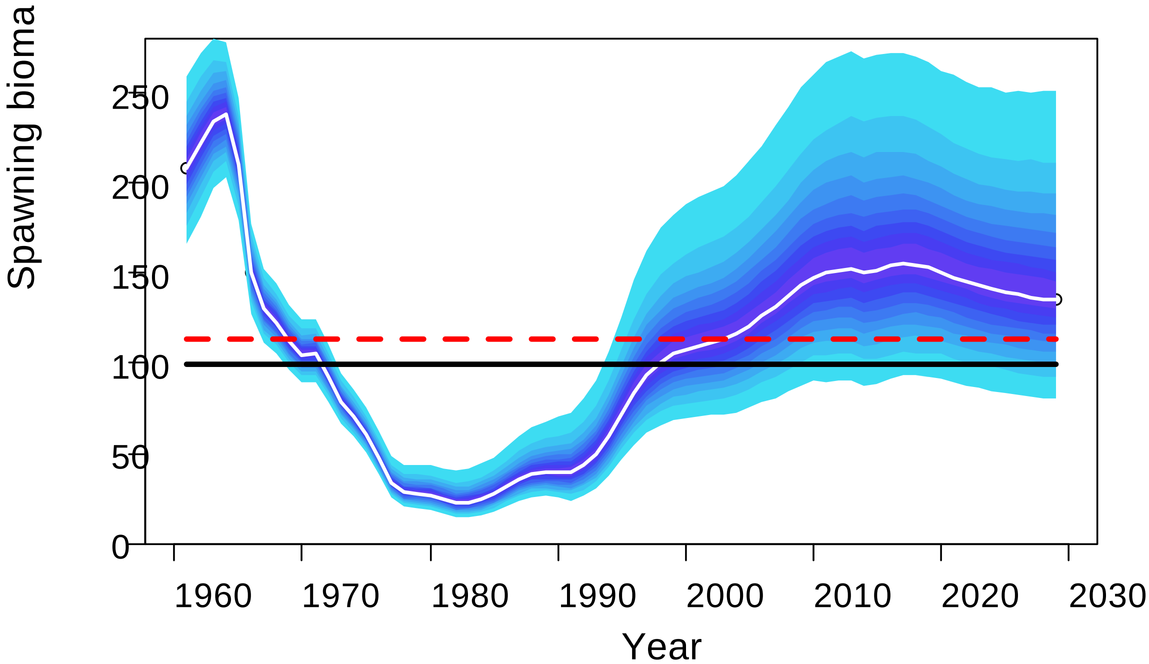


Figure 9-20. Bayesian credible intervals for entire spawning stock biomass series including projections through 2029. Red dashed line is $B_{40\%}$ and black solid line is $B_{35\%}$ based on recruitments from 1979-2012. The white line is the median of MCMC simulations. Each shade is 5% of the posterior distribution.

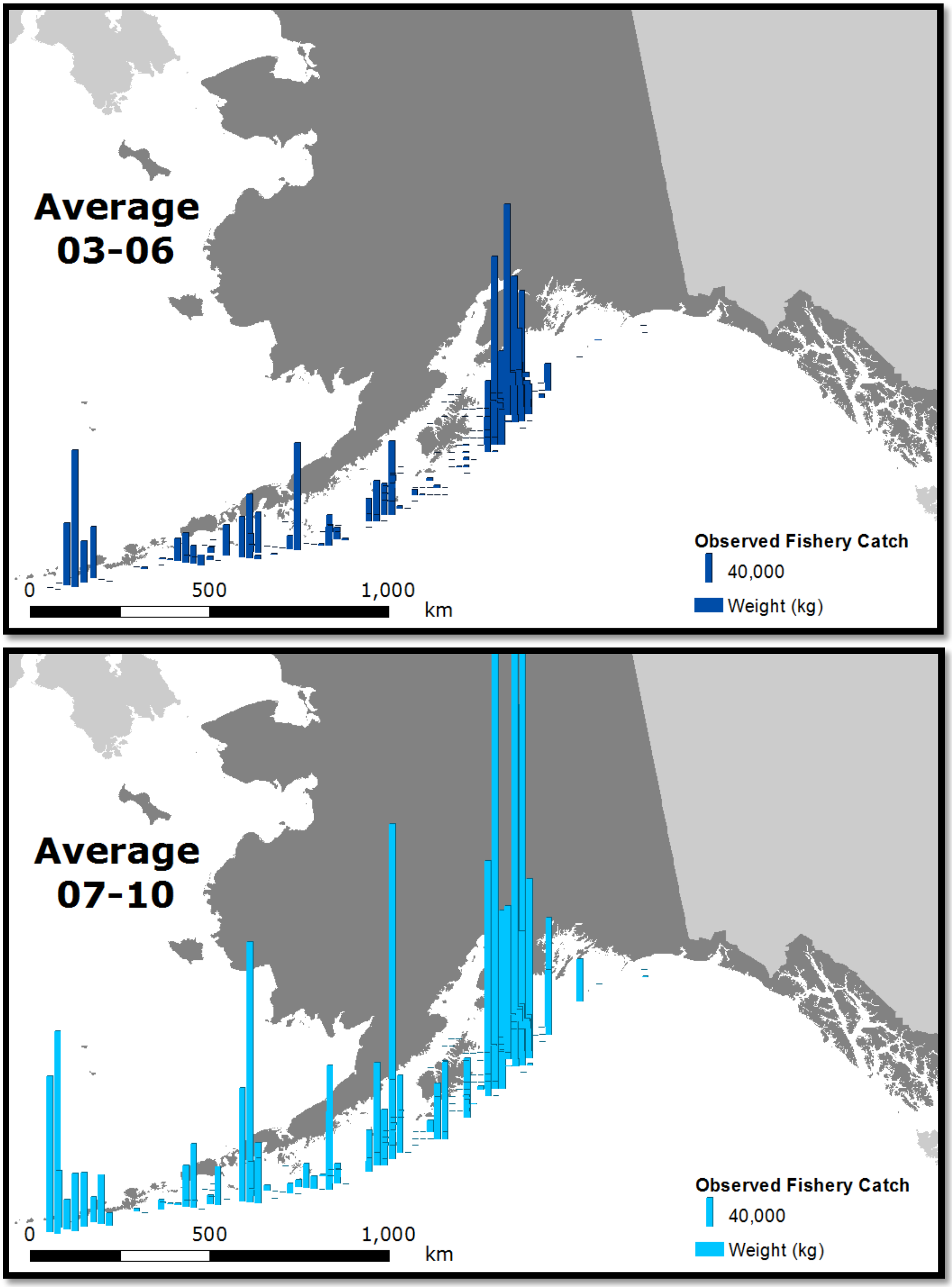


Figure 9-21. Maps of fishery catch based on observer data by 100 km^2 blocks for Pacific ocean perch from four years before and after the Rockfish Pilot Program.

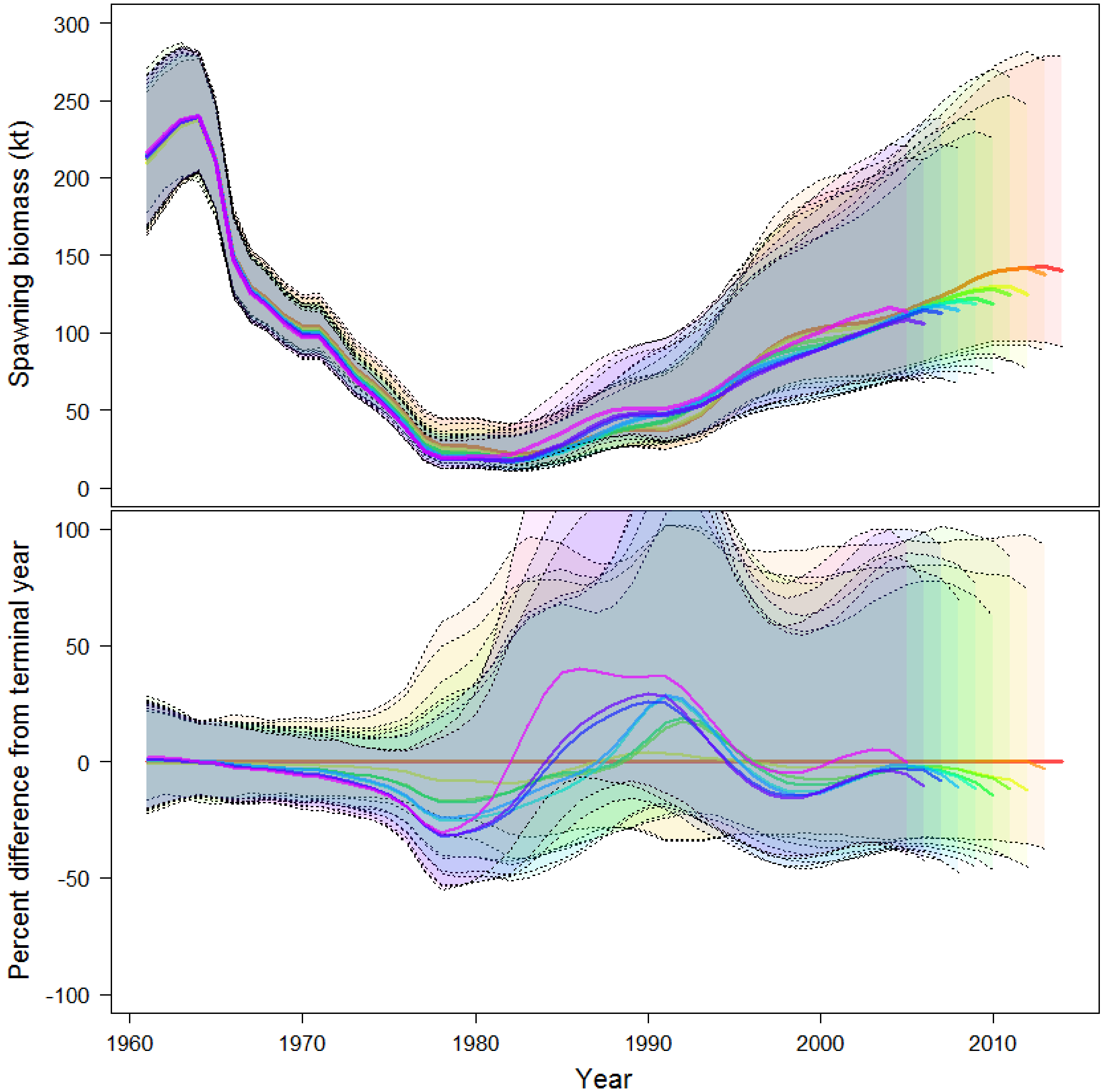


Figure 9-22. Retrospective peels of estimated female spawning biomass for the past 10 years from the recommended model with 95% credible intervals derived from MCMC (top), and the percent difference in female spawning biomass from the recommended model in the terminal year with 95% credible intervals from MCMC.

Appendix 9A.—Supplemental catch data

In order to comply with the Annual Catch Limit (ACL) requirements, two new datasets have been generated to help estimate total catch and removals from NMFS stocks in Alaska.

The first dataset, non-commercial removals, estimates total removals that do not occur during directed groundfish fishing activities. This includes removals incurred during research, subsistence, personal use, recreational, and exempted fishing permit activities, but does not include removals taken in fisheries other than those managed under the groundfish FMP. These estimates represent additional sources of removals to the existing Catch Accounting System estimates. For Gulf of Alaska (GOA) Pacific ocean perch, these estimates can be compared to the research removals reported in previous assessments (Hanselman et al. 2010) (Table 9A.1). Pacific ocean perch research removals are minimal relative to the fishery catch and compared to the research removals for many other species. The majority of removals are taken by the Alaska Fisheries Science Center's biennial bottom trawl survey which is the primary research survey used for assessing the population status of Pacific ocean perch in the GOA. Other research conducted using trawl gear catch minimal amounts of Pacific ocean perch. No reported recreational or subsistence catch of Pacific ocean perch occurs in the GOA. Total removals from activities other than directed fishery were near 3 tons in 2010. This is less than 0.02% of the 2011 recommended ABC of 19,309 t and represents a very low risk to the Pacific ocean perch stock. The removals for 2010 are lower than many other years. This is due to the biennial cycle of the bottom trawl survey in the GOA. However, since 2000 removals have been less than 100 t, and do not pose significant risk to the stock. For example, if these removals were accounted for in the stock assessment model, it would result in an increase in ABC 0f 0.1% for 2012.

The second dataset, Halibut Fishery Incidental Catch Estimation (HFICE), is an estimate of the incidental catch of groundfish in the halibut IFQ fishery in Alaska, which is currently unobserved. To estimate removals in the halibut fishery, methods were developed by the HFICE working group and approved by the Gulf of Alaska and Bering Sea/Aleutian Islands Plan Teams and the Scientific and Statistical Committee of the North Pacific Fishery Management Council. A detailed description of the methods is available in Tribuzio et al. (2011).

These estimates are for total catch of groundfish species in the halibut IFQ fishery and do not distinguish between "retained" or "discarded" catch. These estimates should be considered a separate time series from the current CAS estimates of total catch. Because of potential overlaps HFICE removals should not be added to the CAS produced catch estimates. The overlap will apply when groundfish are retained or discarded during an IFQ halibut trip. IFQ halibut landings that also include landed groundfish are recorded as retained in eLandings and a discard amount for all groundfish is estimated for such landings in CAS. Discard amounts for groundfish are not currently estimated for IFQ halibut landings that do not also include landed groundfish. For example, catch information for a trip that includes both landed IFQ halibut and sablefish would contain the total amount of sablefish landed (reported in eLandings) and an estimate of discard based on at-sea observer information. Further, because a groundfish species was landed during the trip, catch accounting would also estimate discard for all groundfish species based on available observer information and following methods described in Cahalan et al. (2010). The HFICE method estimates all groundfish caught during a halibut IFQ trip and thus is an estimate of groundfish caught whether landed or discarded. This prevents simply adding the CAS total with the HFICE estimate because it would be analogous to counting both retained and discarded groundfish species twice. Further, there are situations where the HFICE estimate includes groundfish caught in State waters and this would need to be considered with respect to ACLs (e.g. Chatham Strait sablefish fisheries). Therefore, the HFICE estimates should be considered preliminary estimates for what is caught in the IFQ halibut fishery. Improved estimates of groundfish catch in the halibut fishery may become available following restructuring of the Observer Program in 2013.

The HFICE estimates of GOA Pacific ocean perch catch are zero indicating the halibut fishery rarely if ever encounter Pacific ocean perch. (Table 9A.2). This is not unexpected as Pacific ocean perch are rarely encountered using hook and line gear and are primarily harvested using trawl gear. Therefore, due to the lack of Pacific ocean perch catch in the HFICE estimates, the impact of the halibut fishery on Pacific ocean perch stocks is negligible.

References:

Cahalan J., J. Mondragon., and J. Gasper. 2010. Catch Sampling and Estimation in the Federal Groundfish Fisheries off Alaska. NOAA Technical Memorandum NMFS-AFSC-205. 42 p.

Hanselman, D. H, S. K. Shotwell, J. Heifetz, and J. N. Ianelli. 2010. Assessment of the Pacific ocean perch stock in the Gulf of Alaska (executive summary). In Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska, p. 543-546. North Pacific Fishery Management Council, 605 W. 4th. Avenue, Suite 306, Anchorage, AK 99501.

Tribuzio, CA, S Gaichas, J Gasper, H Gilroy, T Kong, O Ormseth, J Cahalan, J DiCosimo, M Furuness, H Shen, K Green. 2011. Methods for the estimation of non-target species catch in the unobserved halibut IFQ fleet. August Plan Team document. Presented to the Joint Plan Teams of the North Pacific Fishery Management Council.

Table 9A-1 Total removals of Gulf of Alaska Pacific ocean perch (t) from activities not related to directed fishing, since 1977. Trawl survey sources are a combination of the NMFS echo-integration, small-mesh, and GOA bottom trawl surveys, and occasional short-term research projects. Other is recreational, personal use, and subsistence harvest.

Year	Source	Trawl	Other	Total
1977	Assessment of Pacific ocean perch in the Gulf of Alaska (Hanselman et al. 2010)	13		13
1978		6		6
1979		12		12
1980		13		13
1981		57		57
1982		15		15
1983		2		2
1984		77		77
1985		35		35
1986		14		14
1987		69		69
1988		0		0
1989		1		1
1990		26		26
1991		0		0
1992		0		0
1993		59		59
1994		0		0
1995		0		0
1996		81		81
1997		1		1
1998		305		305
1999		330		330
2000		0		0
2001		43		43
2002		60		60
2003		43		43
2004		0		0
2005		84		84
2006		0		0
2007		93		93
2008		0		0
2009		69		69
2010	AKRO	3	<1	3
2011		64	<1	64
2012		<1	<1	1
2013		87	<1	87

Table 9A-2. Estimates of Gulf of Alaska Pacific ocean perch catch (t) from the Halibut Fishery Incidental Catch Estimation (HFICE) working group. WGOA = Western Gulf of Alaska, CGOA = Central Gulf of Alaska, EGOA = Eastern Gulf of Alaska, PWS = Prince William Sound.

Area	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
WGOA	0	0	0	0	0	0	0	0	0	0
CGOA-Shumagin	0	0	0	0	0	0	0	0	0	0
CGOA-Kodiak/ PWS*	0	0	0	0	0	0	0	0	0	0
EGOA-Yakutat	0	0	0	0	0	0	0	0	0	0
EGOA-Southeast	0	0	0	0	0	0	0	0	0	0
Southeast Inside*	0	0	0	0	0	0	0	0	0	0
Total	0	0	0	0	0	0	0	0	0	0

*These areas include removals from the state of Alaska waters.

Appendix 9B.—Bottom Trawl Survey Length Composition Analysis

Introduction and Methods

An analysis of including the most recent year of the bottom trawl survey length composition data into the GOA POP assessment model was conducted in order to respond to the GOA Groundfish Plan Team's request from the September 2014 meeting. The primary issue investigated is that in any given full-assessment year the most recent bottom trawl survey age composition is unavailable, as the age and growth lab do not have time to process the otoliths prior to when assessments are conducted. In the absence of the most recent age composition, some assessments use the bottom trawl survey length composition (e.g., Spencer and Ianelli 2012, Dorn et al. 2013). The primary reason for including the length composition in the most recent year of the survey is that the assessment results would then reflect the most recent demographic information available. Alternatively, it has been argued that a reason for excluding the most recent length composition from the bottom trawl survey is that the potential benefits are offset by greater variability caused by sequentially adding and removing a single observation type (e.g. Hanselman et al. 2013, Hulson et al. 2013). It may also induce retrospective patterns. In either case, both methods replace the survey length data when age data becomes available. Consequently, a sensitivity analysis was designed to compare an 'ideal' case in which all years of the bottom trawl survey age composition data were included with the status quo and alternative cases:

Model case	Description
C0	Base case: all years of bottom trawl survey age composition are available and fitted by model
C1	Status quo: most recent bottom trawl survey age composition unavailable in the assessment year, survey length composition data excluded
C2	Alternative: most recent bottom trawl survey age composition unavailable in the assessment year, assessment year survey length composition *included*

Cases were evaluated across multiple years and the model was fit to data with ending years that coincided with bottom trawl surveys in the GOA between 2003 and 2011 (e.g., model comparison was made every 2 years from 2003 to 2011). The analysis was conducted for GOA POP, northern rockfish, and dusky rockfish providing results for three separate stock assessment models.

For case C2, several sub-cases were investigated that evaluated the input sample size used for the bottom trawl survey length composition fitted. These sub-cases included:

Model C2 sub-case	Description
C2a	Mean input sample size for bottom trawl survey age composition (square root of age sample size)
C2b	Square root of survey length sample size, scaled to 100
C2c	Square root of survey length sample size, scaled to 200
C2d	Square root of number of hauls from which survey lengths were sampled
C2e	Square root of survey length sample size * hauls, scaled to 100

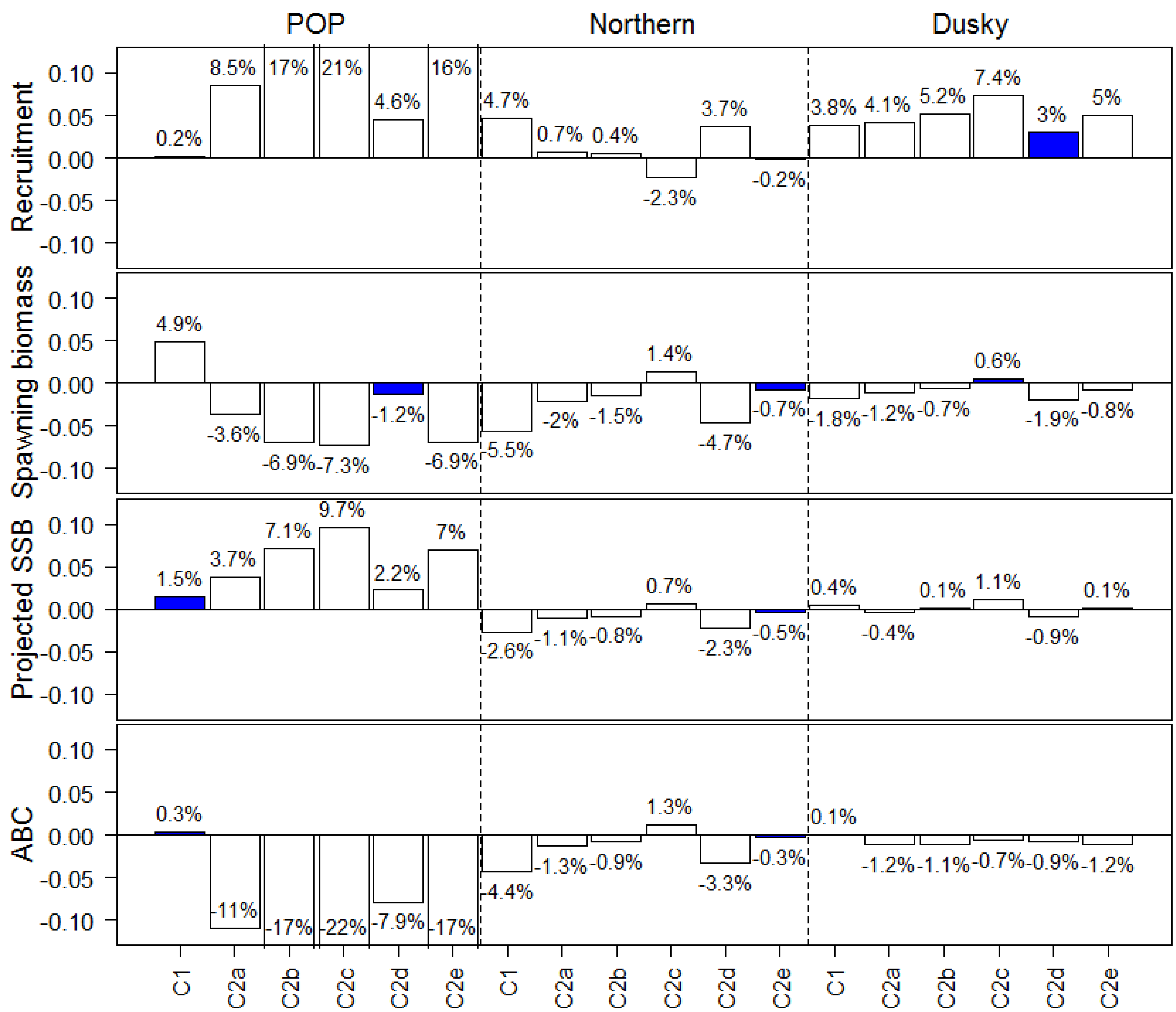
Each of these sub-cases reflect input sample sizes that were related to either the number of samples and/or number of hauls from which samples were taken, which have been shown to be related to the effective sample size of age/length composition data (Pennington et al. 2002, Hulson et al. 2011). These cases were also representative of several of the methods used for defining input sample sizes in AFSC groundfish assessments.

Several performance statistics were developed. These included:

1. The mean percent change in the model estimates relative to case C0. Specifically, the model estimates evaluated included:
    a. the most recent 15 years of estimated recruitment,
    b. the most recent 15 years of estimated spawning biomass,
    c. the 15-year projected spawning biomass, and
    d. the estimated ABC.
2. Likelihoods of fitted data (bottom trawl survey biomass and age composition, fishery age and length composition) and the recruitment deviations penalty from the model cases were investigated. The likelihood performance measures can highlight similarities among model cases. The survey age composition likelihood was calculated for years that cases C1 – C2e were overlapped with C0 as well as the final year likelihood (i.e., as cases C1 – C2e had one less year than case C0 the final year's survey age composition was estimated for models C1 – C2e and the likelihood was computed with the final year's observed age composition and added to the model's likelihood).
3. Retrospective statistics for spawning biomass were calculated (to see if any of the retrospective patterns in model scenarios C1 – C2e were an improvement over C0):
    a. the revised Mohn's ρ (Retrospective Working Group),
    b. Wood's Hole ρ (Legault 2009), and
    c. the root-mean-squared error (RMSE, Parma 1993).

Results and Discussion

In the following figure the percent difference in the most recent 15 years of estimated recruitment, the most recent 15 years of estimated spawning biomass, the 15-year projected spawning biomass, and the estimated ABC between model cases C1 – C2e and C0 are shown, with the closest estimate to case C0 highlighted in blue. The percent difference between model cases C1 – C2e and C0 are shown in text above each bar.

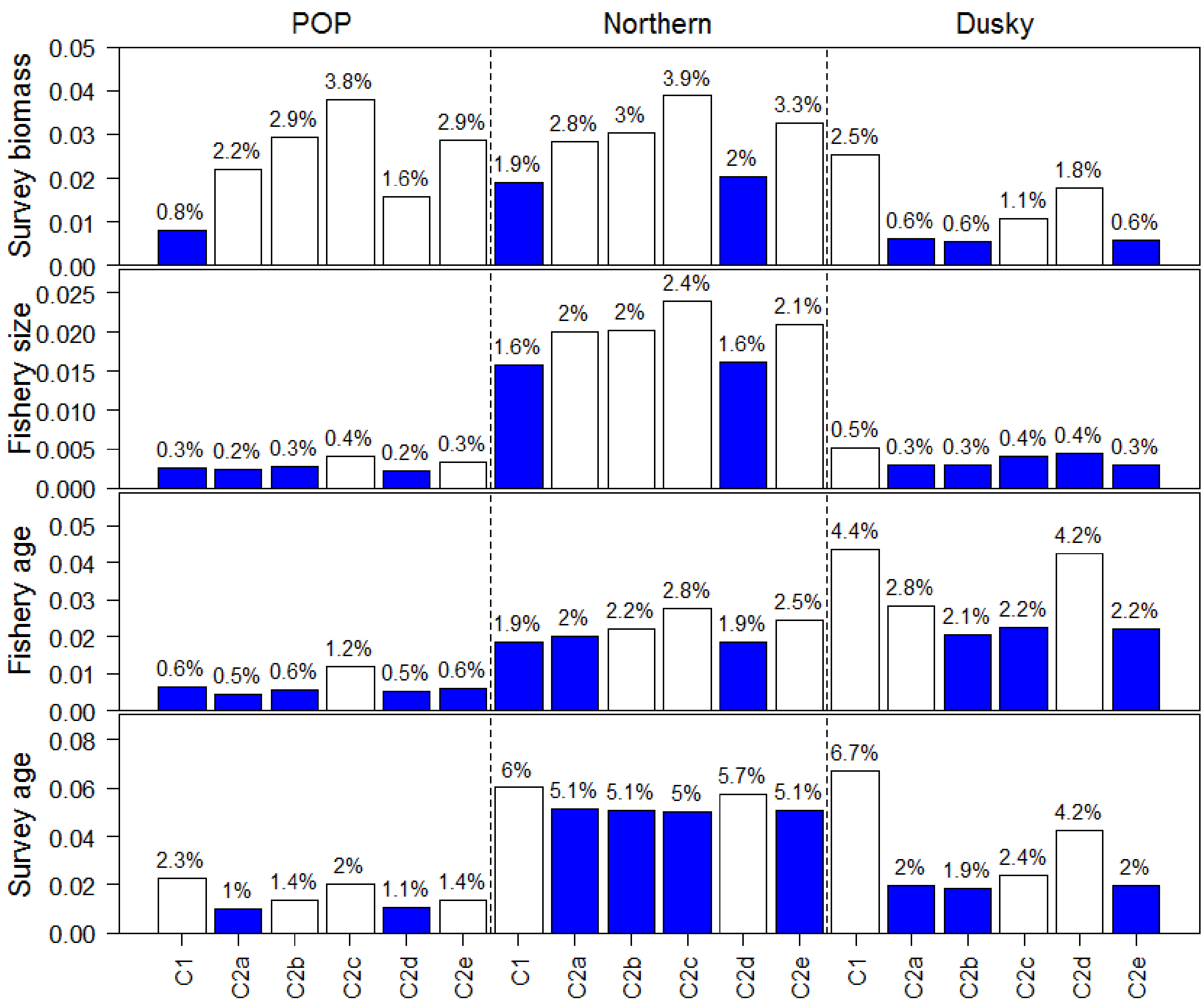


For POP, model case C1 resulted in the most similar estimates to C0 for 3 of the 4 model estimates evaluated (recruitment, projected spawning biomass, and ABC). Only for the estimates of spawning biomass over the final 15 years of the model was C1 not the closest model to case C0. The general results for POP when the survey length composition in the most recent survey was included in cases C2a – C2e was that recruitment in the final 15 years and projected spawning biomass were overestimated, and spawning biomass in the final15 years and ABC were underestimated. In these cases the most recent recruitments were greatly overestimated when the survey length data was used, which resulted in an overestimate of the projected spawning biomass once these year-classes reached full maturity compared to case C0. Alternatively, for northern and dusky rockfish the model cases that were the most similar to case C0 were one of the sub-cases of case C2, with the exception of ABC for dusky rockfish, in which C1 was the most similar. For northern rockfish the most similar case to C0 was C2e, whereas for dusky the most similar cases varied by the model estimate evaluated. For each of these model estimates for northern and dusky rockfish, however, the changes compared to model case C0 were relatively small, with a maximum difference of 7.4%. The following table includes the absolute percent differences in these four model estimates compared to case C0, with the smallest difference highlighted in bold.

Species	Model case	Recruitment	Spawning biomass	Projected SSB	ABC
POP	C1	**1.7%**	5.5%	**1.7%**	**3.1%**
	C2a	8.5%	3.6%	3.9%	11.0%
	C2b	16.7%	6.9%	7.1%	17.4%
	C2c	21.2%	7.3%	9.7%	21.8%
	C2d	4.6%	**2.9%**	2.4%	7.9%
	C2e	16.4%	6.9%	7.0%	17.3%
Northern	C1	5.0%	6.3%	2.7%	5.8%
	C2a	**1.0%**	2.6%	1.1%	2.0%
	C2b	1.2%	2.2%	0.8%	1.4%
	C2c	2.3%	**1.6%**	0.7%	1.4%
	C2d	4.0%	5.4%	2.3%	4.6%
	C2e	1.6%	1.9%	**0.5%**	**0.9%**
Dusky	C1	6.4%	2.6%	7.1%	3.3%
	C2a	**4.2%**	2.0%	2.1%	2.2%
	C2b	5.5%	1.6%	1.3%	2.1%
	C2c	8.5%	**1.5%**	2.9%	**1.4%**
	C2d	4.4%	2.6%	5.5%	2.5%
	C2e	5.3%	1.7%	**1.2%**	2.1%

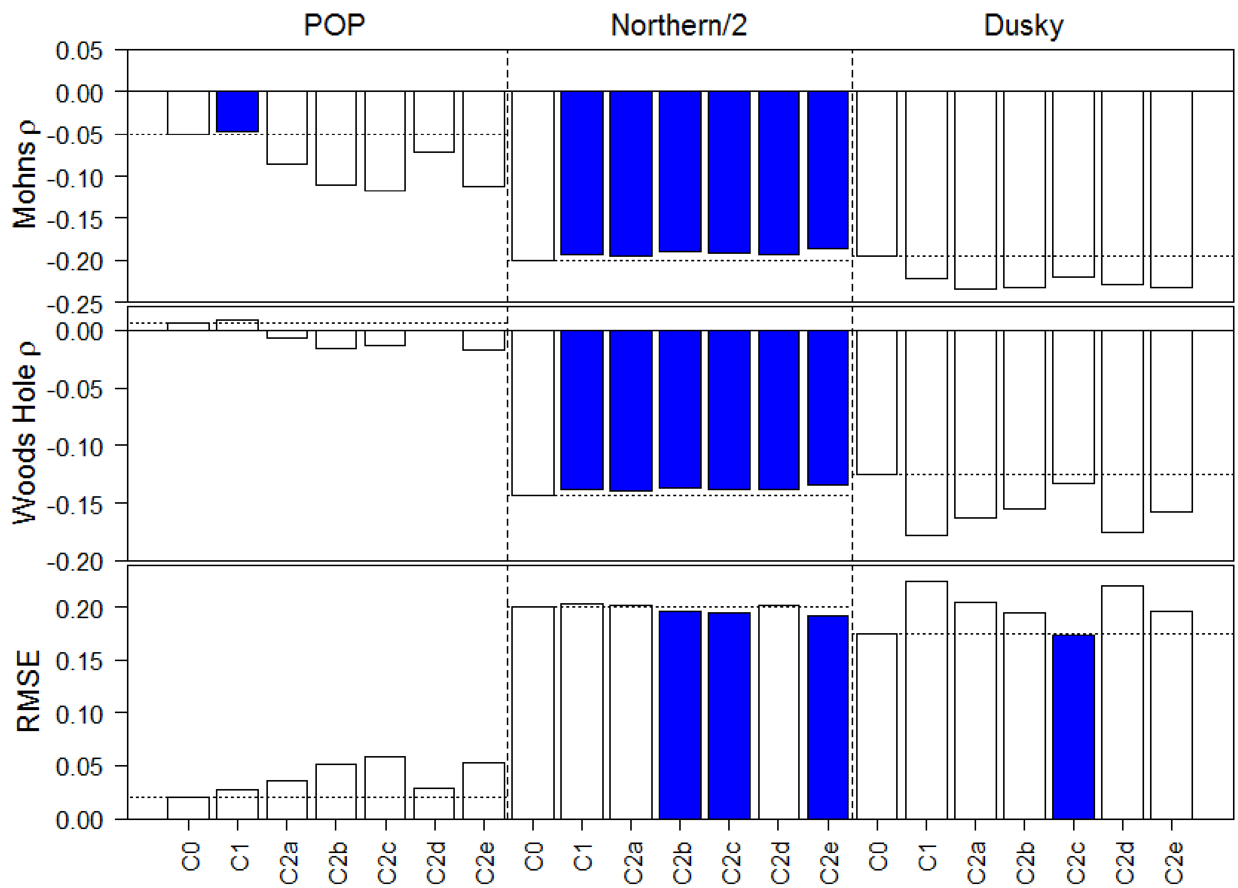
For POP, the absolute percent difference resulted in the same general trend as the standard percent difference, with case C1 resulting in the smallest value for 3 of 4 model estimates. However, for northern rockfish, rather than case C2e being consistently smaller in only 2 of 4 model estimates was this case the smallest. For dusky rockfish, case C2c was smaller than case C1 for ABC, which was the only estimate for which case C1 was the smallest in terms of standard percent difference.

The percent difference of the likelihoods for cases C1 – C2e compared to C0 are shown in the following figure. The smallest model case (i.e., the case with likelihoods most similar to C0) and model cases that were within 0.1% of the smallest case (i.e., cases that were essentially the same as the smallest case) are highlighted in blue. The percent difference between model cases C1 – C2e and C0 are shown in text above each bar.



For each of the species investigated there did not seem to be any single case among model cases C1 – C2e where the likelihood components were consistently closest to the base case C0. Indeed, across the species and likelihood components, with only a single exception, there were at least two model cases that were the closest to the base case (or within 0.1% of the closest case). The only exception to this was in the survey biomass likelihood for POP, in which case C1 was the closest to C0 and none of the C2 sub-cases were within 0.1% of C1. For both POP and northern rockfish, case C1 was one of the closest cases to C0 for 3 of 4 likelihood components, including the fit to the survey biomass. Thus, there did not seem to be a case that included the survey length composition in the final year of the model (C2a – C2e) that provided a marked improvement to the model over not including the final year’s length data (C1). However, for dusky rockfish there did seem to be an improvement to the likelihood components when the survey length composition was included in the most recent year, as C1 was not within 0.1% of the smallest case for any of the likelihood components. Although, for dusky there was not a single C2 sub-case that was consistently closer than any other sub-case to the likelihoods of C0.

In the figure below the retrospective statistics investigated for POP, northern rockfish, and dusky rockfish are shown. The horizontal dashed line is the value for model case C0 and model cases that are an improvement over C0 are highlighted in blue (note for northern rockfish the values are divided by 2 so the statistics can be seen more easily).



For POP the best model scenario in terms of retrospective patterns for Mohn's ρ was case C1 and for Woods Hole ρ was C2d. In terms of RMSE model scenario C0 had the smallest RMSE, followed by model cases C1 and C2d. For northern rockfish, which has a strong retrospective pattern, any of the cases C1 – C2e was an improvement over case C0 for both Mohn's ρ and Woods Hole ρ. In terms of RMSE, only cases C2b, C2c, and C2e were smaller than C0 for northern rockfish. For dusky rockfish none of the scenarios C1 – C2e was better than case C0 for either Mohn's ρ or Woods Hole ρ. The RMSE for model case C2c was slightly smaller than C0 for dusky rockfish. In general, the retrospective statistics investigated were consistent across different models and no single approach appeared to be favored.

Conclusion

Overall, the results of this analysis suggest that the usefulness of including the most recent year's bottom trawl survey length composition is case specific. For example, in the evaluation of likelihoods compared to the base case it seemed that including the most recent year's length composition consistently performed better than excluding those data for dusky rockfish. However, the results for POP and northern rockfish suggest that it was better to exclude the most recent length information. Indeed, there were several likelihoods for which the case that excluded the most recent survey's length composition performed better than the cases that included the data for POP and northern rockfish. Statistics comparing the estimation differences for northern and dusky rockfish performed well when the most recent survey's length composition was used. In contrast, for POP case C1 (excludes the most recent survey's length composition) results were most similar to the base case for the majority of model estimates, including ABC. Specifically for POP, the results of using the most recent year's survey length composition failed to provide a consistent improvement over the status quo model for any of the statistics evaluated, and in some cases induced greater variability in model estimates. Additionally, in many cases recent recruitments were overestimated resulting in incorrect perceptions regarding population size.

In the interest of model stability and consistency we recommend that the status quo assessment model that does not include the most recent year's survey length composition continue to be used for POP. However, we recommend that the northern and dusky rockfish assessment authors consider using the most recent year's survey length composition, as it provided improvements relative to case C1. Further analyses of additional assessment models with species that exhibit a range of life histories may be warranted to help guide appropriate used of length composition data prior to having age composition data available. For the species evaluated here, POP ages are sampled at higher levels than northern and dusky rockfish, which could influence the usefulness of survey length data.

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