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.

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 2014 assessment model estimates with new data collected since the last full assessment.

Summary of Changes in Assessment Inputs

Changes in the input data: The input data were updated to include survey biomass estimates for 2015, survey age compositions for 2013, and final catch for 2014 and preliminary catch for 2015-2017 (see *Specified catch estimation* section).

Changes in the assessment methodology: The assessment methodology has changed since the 2014 assessment and incorporates the following changes:

1. In the past trawl survey age samples were treated as if they were randomly collected when estimating growth. Growth is now estimated taking into account that ages are collected under a length-stratified sampling design.
2. The ageing error matrix was updated and extended to more appropriately model the ages at or near the plus age group. An ageing error matrix was constructed that extends the modeled ages compared to the ages fit in the data until >99.9% were in the plus age group of the data.

Summary of Results

For the 2016 fishery, we recommend the maximum allowable ABC of **24,437** t from the recommended model. This ABC is a 16% increase from the 2015 ABC of 21,012 t. The increase is attributed to the 2015 survey biomass estimate which is the second largest on record, second only to the 2013 survey biomass estimate. This also resulted in a 14% higher ABC than the 2016 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: 2015	2016	As estimated or recommended *this* year for: 2016	2017[1]
M (natural mortality)	0.061	0.061	0.061	0.061
Tier	3a	3a	3a	3a
Projected total (age 2+) biomass (t)	416,140	412,351	457,768	449,416
Projected Female spawning biomass	142,029	144,974	157,080	158,124
$B_{100\%}$	283,315	283,315	285,327	285,327
$B_{40\%}$	113,326	113,326	114,131	114,131
$B_{35\%}$	99,160	99,160	99,865	99,865
F_{OFL}	0.139	0.139	0.119	0.119
$maxF_{ABC}$	0.119	0.119	0.102	0.102
F_{ABC}	0.119	0.119	0.102	0.102
OFL (t)	**24,360**	24,849	**28,431**	28,141
maxABC (t)	21,012	21,436	**24,437**	24,189
ABC (t)	**21,012**	21,436	**24,437**	24,189
Status	As determined *last* year for: 2013	2014	As determined *this* year for: 2014	2015
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 2016 and 2017 are derived using estimated catch of 18,326 for 2015, and projected catches of 21,176 t and 20,752 t for 2016 and 2017 based on realized catches from 2012-2014. This calculation is in response to management requests to obtain more accurate projections.

Area Apportionment

The following table shows the recommended apportionment for 2016 and 2017 from the random effects model.

Area Apportionment	Western	Central	Eastern	Total
	11.2%	69.7%	19.1%	100%
2016 Area ABC (t)	**2,737**	**17,033**	**4,667**	**24,437**
2017 Area ABC (t)	**2,709**	**16,860**	**4,620**	**24,189**

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 smaller than the 2014 assessment at 0.61, a decrease from 0.71. 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
2016 Area ABC (t)	**2,847**	**1,820**	**4,667**
2017 Area ABC (t)	**2,818**	**1,802**	**4,620**

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
2016 Area OFL (t)	**26,313**	**2,118**	**28,431**
2017 Area OFL (t)	**26,045**	**2,096**	**28,141**

Summaries for Plan Team

Species	Year	Biomass[1]	OFL	ABC	TAC	Catch[2]
Pacific ocean perch	2014	410,712	22,319	19,309	19,309	17,666
	2015	416,140	24,360	21,012	21,012	16,442
	2016	457,768	28,431	24,437		
	2017	449,416	28,141	24,189		

[1]Total biomass from the age-structured model

Stock	Area	2015 OFL	ABC	TAC	Catch[2]	2016 OFL	ABC	2017 OFL	ABC
Pacific ocean perch	W		2,302	2,302	2,039		2,737		2,709
	C		15,873	15,873	12,423		17,033		16,860
	WYAK		2,014	2,014	1,980		2,847		2,818
	SEO	954	823	823	0	2,118	1,820	2,096	1,802
	W/C/WYK	23,406				26,313		26,045	
	Total	24,360	21,012	21,012	16,442	28,431	24,437	28,141	24,189

[2]Current as of October 1, 2015, Source: NMFS Alaska Regional Office via the Alaska Fisheries Information Network (AKFIN).

SSC and Plan Team Comments on Assessments in General

"The SSC requests that stock assessment authors utilize the following model naming conventions in SAFE chapters:

- *Model 0: last years' model with no new data,*
- *Model 1: last years' model with updated data, and*
- *Model numbers higher than 1 are for proposed new models."* (SSC, December 2014)

"For this year's final assessments, the Teams recommend that each author of an age-structured assessment use one of the following model naming conventions ("TPA" represents the alternative described in the Team procedures document)…" (Joint Plan Team, September, 2015)

"Of the options presented in the Joint Plan Teams minutes, the SSC agrees that that Option 4 has several advantages and recommends that this Option be advanced next year." (SSC, October 2015)

For this assessment, we will use the simplified convention suggested in the December SSC minutes and will investigate further detailed naming for the next full assessment cycle.

The SSC also requests that stock assessment authors utilize the random effects model for area apportionment of ABCs" (SSC, December 2014)

"The Teams recommend that the random effects survey smoothing model be used as a default for determining current survey biomass and apportionment among areas." (Joint Plan Teams, September 2015)

Since 2014 we have been 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.

SSC and Plan Team Comments Specific to this Assessment

"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)

An AFSC response to the rockfish CIE review was prepared that addresses some of their concerns. Please refer to the "Summary and response to the 2013 CIE review of the AFSC rockfish" document presented to the September 2013 Plan Team for further details (http://www.afsc.noaa.gov/REFM/stocks/Plan_Team/2013/Sept/2013_Rockfish_CIE_Response.pdf). Specifically, in response to SSC comments above:

1. In this year's dusky rockfish assessment, an alternative survey estimator methodology for computing survey biomass estimates is presented. This estimator is based on a geostatistical generalized linear mixed model. This approach provides an alternative methodology for estimating biomass from catch data than the traditional design-based estimates commonly used. For POP, this estimator may not significantly out-perform design-based estimators as it does for dusky or northern rockfish, because the design-based estimates are more precise. We will continue to evaluate this approach as a potential alternative for estimating survey biomass for

POP.

2. In the past trawl survey age samples were treated as if they were randomly collected when estimating growth. In September, 2015, three GOA rockfish modeling updates were presented: where growth was estimated taking into account that ages are collected under a length-stratified sampling design, extending the ageing error matrix to more appropriately model the plus age group, and briefly examining the best age for the plus group age bin. In this assessment we present alternative model runs incorporating all of these changes.
3. For POP, natural mortality is estimated within the model.

"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 future 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. We will also consider the recommendations developed by the CAPAM workshop held in October 2015 with regards to data weighting.

The Team recommends moving forward with these three improvements and encourages the authors to further examine choosing the appropriate plus age groups. To facilitate model evaluation, the Team recommends the authors present the two alternative models suggested. (Plan Team, September 2015)

The improvements identified by the Plan Team (length-stratified growth, ageing error matrix extension, and plus age group analysis) have been incorporated in the recommended model for this year's Pacific ocean perch assessment.

The SSC suggests that Dr. Hulson should also explore the utility of delay-difference models as an alternative way to model the plus age group. Dr. Quinn and others have published on this approach. (SSC, October 2015)

We assume this comment pertains to how to model the weight and length of the plus group. The methodology suggested by Deriso, Quinn and others to account for differing growth in the plus age group is analogous to the correction employed in the POP model to set the weight at age of the plus group to 1/2 the difference between the age before the plus group and W_∞. We will explore other methods for making these approximations in the future.

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). Rooper et al. (2012) found that potential growth of POP in the nursery area was correlated to recruitment indicating this is a very important life stage for this species. As they grow, they continue to migrate deeper, eventually reaching the continental slope where they attain adulthood. Adult and juvenile populations are believed to be spatially separated (Carlson and Straty, 1981; Rooper et al., 2007).

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 (8.4 - 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 presented the completed 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 effort (15 catcher/processors) for a one day fishery (shortest allowed) exceeded the available TAC. The 2014 fishery in this area didn’t occur until October but nearly all of the TAC was harvested. Because of agreement among the fleet and the ability to collectively remain below TAC, we expect TAC to be fully taken in the future.

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 1988-2015; 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.

Hanselman et al. (2009) showed evidence that the fishery has changed over time and is more focused on younger fish and fishing with smaller vessels. 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. 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.

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 sought-after 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. 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 2000-2015 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	2014	2015
% Discard	6.5	4.8	7.6	9.5	3.9

Total FMP groundfish catch estimates in the GOA rockfish targeted fisheries from 2011-2015 are shown in Table 9-3. For the GOA rockfish fishery during 2011-2015, the largest non-rockfish bycatch groups are Atka mackerel (1,032 t/year), walleye pollock (915 t/year), arrowtooth flounder (933 t/year), and Pacific cod (587 t/year).Catch of Pacific ocean perch in other Gulf of Alaska fisheries is mainly in rex sole (350 t/year average) and arrowtooth (692 t/year) targeted fishing (Table 9-4). Non-FMP species catch in the rockfish target fisheries is dominated by giant grenadier and miscellaneous fish (Table 9-5). The increase in POP discards in 2014 can likely be attributed to an extremely high bycatch of POP in the arrowtooth flounder directed fishery in that year (Table 9-4). Hulson et al. (2014) compared bycatch for the combined rockfish fisheries in the Central GOA from before and during the Rockfish Program to determine the impacts of the Rockfish Program and found the bycatch of the majority of FMP groundfish species in the Central GOA was reduced following implementation of the Rockfish Program.

Prohibited species catch in the GOA rockfish fishery is generally low for most species. Catch of prohibited and non-target species generally decreased with implementation of the Central GOA Rockfish

Program (Hulson et al. 2014). The only increase of prohibited species catch observed in 2015 in the combined rockfish fisheries was in halibut catch, which was nearly 20 tons greater than the 2014 catch (Table 9-6). Chinook salmon catch was lower than the five year average in both 2014 and 2015.

Data

The following table summarizes the data used for this assessment (bold font denotes new data to this year's assessment):

Source	Data	Years
NMFS Groundfish survey	Survey biomass	1984-1999 (triennial), 2001-**2015** (biennial)
	Age Composition	1984, 1987, 1990, 1993, 1996, 1999, 2003, 2005, 2007, 2009, 2011, **2013**
U.S. trawl fisheries	Catch	1961-**2015**
	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 2015. 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 1998-2015. Table 9-8 summarizes age compositions from 1999-2002, 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 2015 surveys are provided in Table 9-9.

Comparison of Trawl Surveys in 1984-2015

Gulf-wide biomass estimates for Pacific ocean perch are shown in Table 9-9. Gulf-wide biomass estimates for 1984-2015 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 2013 and 2015 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 was less precise than the Western and Central Gulf. Biomass decreased slightly in 2015 but is the second highest on record behind 2013. Specifically, the Western and Central areas decreased slightly but the Yakutat region biomass estimate was less than half of the 2013 estimate in 2015. Conversely, the Southeastern biomass estimate was more than double in 2015 than that of the 2013 estimate.

Age Compositions

Ages were determined from the break-and-burn method (Chilton and Beamish 1982). The survey age compositions from 1984-2013 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 but this year class is not prominent in the 2013 age compositions.

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 a request by 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 (Hulson et al. 2014). 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 management related quantities.

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.

Model Selection

In total, two changes were made to input data and model configuration in this year's assessment compared to the 2014 assessment. We present these changes in a step-wise manner, building upon each previous model change to arrive at the preferred model for this year's assessment. The following table provides the model case name and description of the changes made to the model.

Model case	Description
M0	2014 model
M1	Same model as 2014, but with updated data
M2	Same model as M1, but uses length-stratified estimates of growth parameters for weight-at-age and size-age conversion matrix
M3	Same model as M2, but with an updated ageing error matrix and extended number of ages in the model compared to the number of ages in data within the ageing error matrix

Note, each additional model case includes the changes made to the model in the previous model case. For example, model case M3 would also include length-stratified estimates of growth from model case M2 in addition to the extension of the ageing error matrix. A brief description of each model changed is provided below.

M2 – Length-stratified growth

Otolith collections for rockfish in the AFSC bottom trawl survey are done following a length-stratified design (i.e., a specified number of otoliths are collected for each length category). Corresponding growth estimates are then derived with these samples. In previous rockfish assessments growth observations have been treated as if they were collected randomly. However, this assumption incurs bias in the growth parameters because these samples should be weighted by the total number of lengths sampled to account for the length-stratified sampling design used to collect age speciments. In this year's assessment we use new estimates of growth, for weight-at-age and the size-age conversion matrix used in the assessment model, based on length-stratified methods rather than random methods (Quinn and Deriso 1999, Bettoli and Miranda 2001). Following the method presented in Bettoli and Miranda (2001), mean length was calculated as:

$$\bar{L}_a = \frac{\sum N_{a,l}\bar{l}_{a,l}}{N_a}$$

where $N_{a,l}$ is the estimated age-length key (estimated total numbers at age-*a* and length-*l*) and $\bar{l}_{a,l}$ is the measured length at age-*a* and length-*l*, which is simply the length bin label. The age-length key is calculated as:

$$N_{a,l} = N_l \frac{n_{a,l}}{n_l}$$

where N_l is the total number of fish measured at length-*l*, $n_{a,l}$ is the number of fish sampled at age-*a* and length-*l*, and n_l is the number of fish sampled for ages at length-*l* (the sum of $n_{a,l}$ across ages). The standard deviation for in length for age-*a* is calculated as:

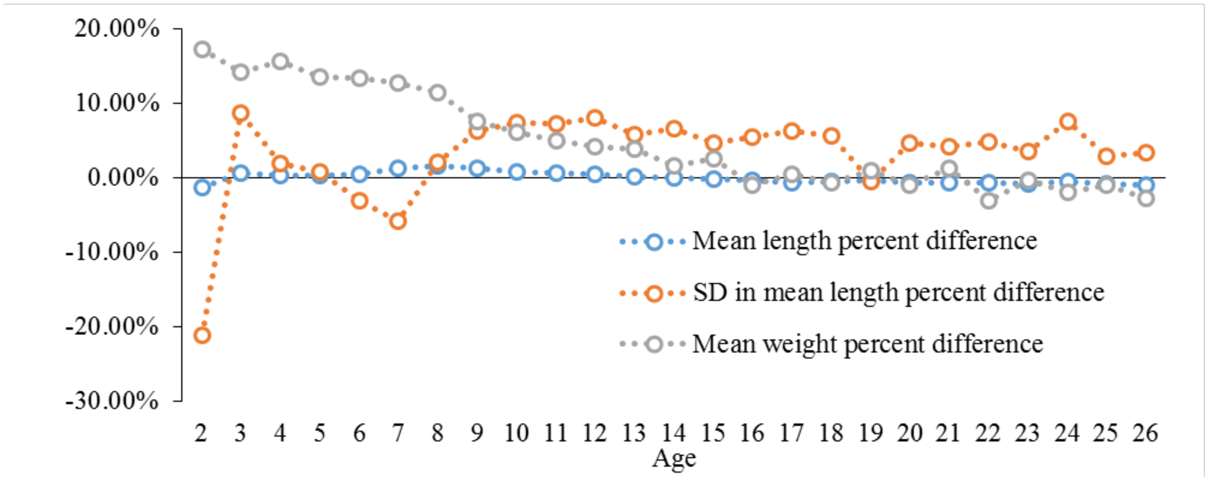
$$SD_a = \sqrt{\frac{\sum N_{a,l}\left(\bar{l}_{a,l} - \bar{L}_a\right)^2}{N_a - 1}}$$

Mean weight is calculated in a similar manner (Quinn and Deriso 1999). The same age-length key used to calculate mean length is used to calculate mean weight ($N_{a,l}$), the only difference between the two is that $\bar{l}_{a,l}$, which is the length bin label, is replaced above with the mean weight observed at age-*a* and length-*l* (for which there can be multiple weight observations). Thus, mean weight is given by:

$$\bar{W}_a = \frac{\sum N_{a,l}\bar{W}_{a,l}}{N_a}$$

where $\overline{W}_{a,l}$ is the mean weight observed at age-*a* and length-*l*.

The following figure compares the percent difference between random and length-stratified mean length, standard deviation (SD) in mean length, and mean weight (positive values indicate that the mean value from random methods is larger than the mean value from length-stratified methods).



Overall, the differences in mean length were small between length-stratified and random methods. However, the SD in mean length was, on average, up to 10% larger for ages greater than 10 from length-stratified methods compared to random methods. Mean weight was, on average, larger for younger ages than older ages from the length-stratified methods compared to random and for some ages could be upwards of 10% larger. In the following section, 'Parameters Estimated Outside the Assessment Model', the parameter estimates from the von Bertalanffy growth curve that are shown were obtained from length-stratified methods to determine mean length and weight. This data change is reflected in model case M2 and is used in the following model case M3.

M3 – Update and extension of the ageing error matrix

In model case M3 we first update the ageing error matrix with additional data for percent agreement tests. Previous Pacific ocean perch assessments have used an ageing error matrix that was constructed in 2001, in this year's assessment we update this matrix with agreement data through 2009. The estimated standard deviations in age readings was, on average, nearly 70% smaller with the updated agreement data compared to the standard deviations used in previous assessments.

Previous rockfish assessments have noted that the model consistently over-estimated the proportions-at-age in the age classes adjacent to the plus age group in the bottom trawl survey and fishery age composition datasets. Further investigations revealed that this was due to the construction of the ageing error matrix. In its current form, the ageing error matrix distributes the fish in the plus age group based on the ageing error of the first age in the plus age group. For example, in the 2014 Pacific ocean perch assessment the plus age group was started at age-25. Thus, the distribution of fish in the plus age group into age classes younger than the plus age group were based on the ageing error of age-25, rather than based on the ageing error of all the fish greater than age-25. This translates into a greater probability of fish in the plus age group being in the adjacent age classes that are younger than the plus age group than would be present for all fish older than the plus age group. This explains the consistent over estimation of the age class proportions that are adjacent to the plus age group. In model case M3 we provide an alternative ageing error matrix that extends the plus age group in the model compared to the plus age group in the data until 99.9% of the fish in the model's plus age group are within the plus age group of the data.

We also investigated the plus age group placement, similar to the analyses in the northern and dusky rockfish assessments. We considered the following guidelines from the most recent Plan Team and SSC for setting the plus group: (1) reduce the plus age group proportion to no more than 10-15% of the total samples, (2) ensure plus age group is less than the maximum proportion in the remainder of the age composition data, (3) minimize age bins with zero samples, (4) examine model fits and residuals, and (5) consider sensitivity to selectivity changes while adding age bins. However, for Pacific ocean perch, with a plus age group starting at age-25 the plus age group proportions already satisfied these basic guidelines: therefore, we did not adjust the plus age group.

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 conversion 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 conversion matrices used in the model (pre- and post-1980). In this year's assessment the size at age data was updated through the 2013 survey, and growth was estimated with length-stratified methods. Sexes were combined. The size to age conversion 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_∞=41.2 cm κ=0.18 t_0=-0.45

The previous assessments growth curve parameters were:

L_∞=41.3 cm κ=0.19 t_0=-0.40

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 $(W_\infty - W_{25})/2$ was used for the weight of the pooled ages (Schnute et al. 2001).

W_∞=917 g κ=0.20 t_0=-0.35 β=3.04

The previous assessments weight-at-age parameters were:

W_∞=1023 g κ=0.17 t_0=-0.52 β =3.05

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%. 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%. 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%.

Selectivity

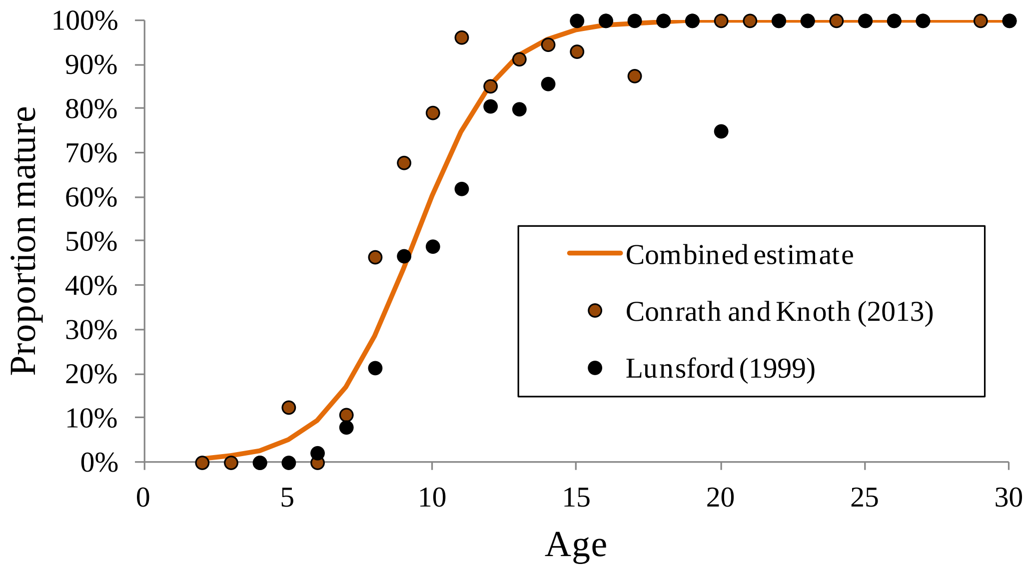
In 2009, we presented empirical evidence that the fishery has changed its fishing practices over the time period (Hanselman et al. 2009). We noted that the fishery selectivity, which at that time was a nonparametric selectivity by age was drifting toward a dome shape. The fishery was catching a much 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. 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.

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	81
Average fishing mortality	μ_f	1
Fishing mortality deviations	ϕ_y	55
Fishery selectivity coefficients	fs_a	4
Survey selectivity coefficients	ss_a	2
Maturity-at-age coefficients	m_a	2
Total		152

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 152. 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

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

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

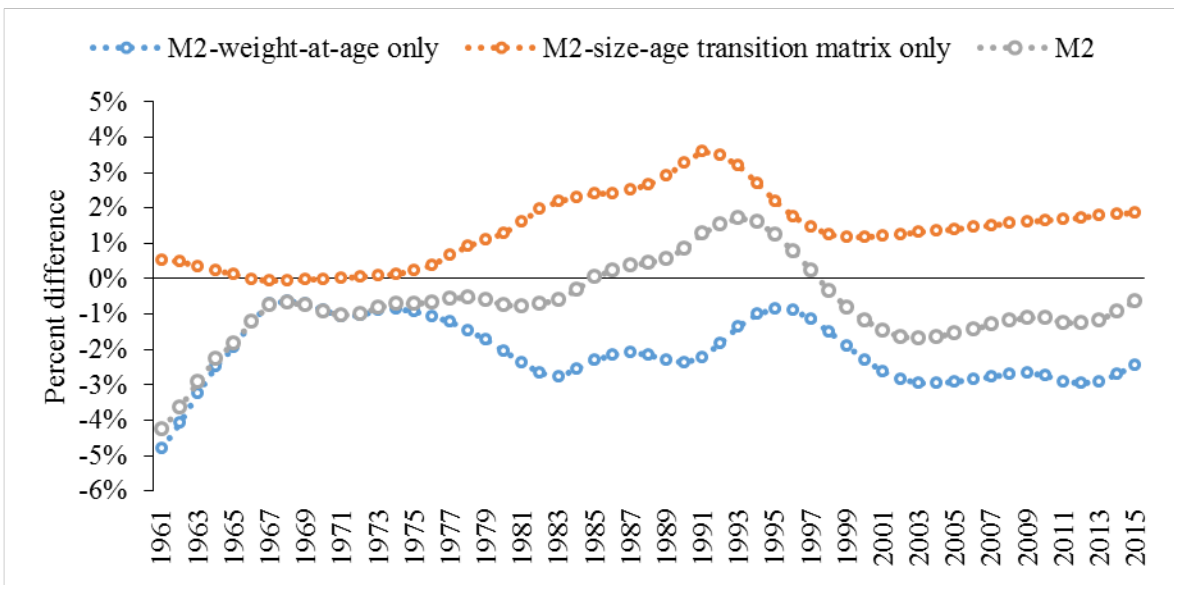
$s_{a,s}^g=\left(1+e^{(-\delta_{g,s}(a-a_{50\%,g,s}))}\right)^{-1}$	Logistic selectivity
$s_{a,s}^g=\left(\frac{a}{a_{\max}}\right)^{a_{\max,g,s}/p}e^{(a_{\max,g,s}-a)/p}$ $p=0.5\left[\sqrt{a_{\max,g,s}{}^2+4\delta_{g,s}{}^2}-a_{\max,g,s}\right]$	Reparameterized gamma distribution

Results

Model Evaluation

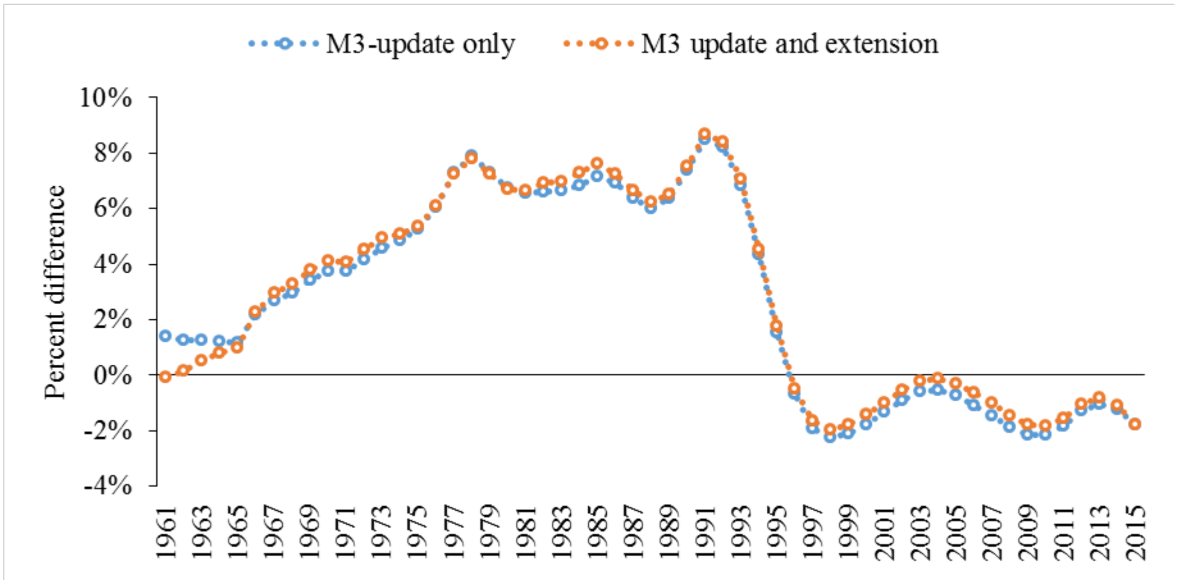
The recommended changes to this year's assessment compared to the model used in 2014 were described above in the 'Model Selection' section. In summary, two changes are recommended for this year's assessment: (1) updating growth information to use length-stratified rather than random methods (model case M2), and (2) updating and extending the ageing error matrix (model case M3). 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.

When updating the growth information with length-stratified methods the overall data negative log-likelihood decreases slightly (Table 9-12). Decreases in individual negative log-likelihoods occurred for the trawl survey biomass and fishery sizes. Slight increases in the negative log-likelihood values resulted for the fishery and survey ages. The following figure compares the percent differences in spawning biomass from model case M2 compared to model case M1 (the base 2014 model but with updated data, negative values indicate estimates that are smaller in model case M2 compared to M1).



Overall, updating the growth information in model case M2 had little influence on the estimated spawning biomass compared to model case M1; the estimated spawning biomass from model case M2 decreased by around 1% towards the end of the time series.

Upon updating and extending the ageing error matrix to more properly model the plus age group in model case M3, the total data negative log-likelihood decreased by 10% (Table 9-12). This decrease was due to the large decreases in the negative log-likelihoods for the age data; the fishery age composition negative log-likelihood decreased by over 33% and the survey age composition negative log-likelihood decreased by over 35%. Alternatively, the catch negative log-likelihood increased by over 7%, the trawl survey biomass negative log-likelihood increased by over 8%, and the fishery size composition negative log-likelihood increased by over 2%. The following figure compares the percent differences in spawning biomass from model case M3 after updating the ageing error only, then updating both the ageing error and extending the ageing error matrix compared to model case M2 (negative values indicate estimates that are smaller in model case M3 compared to M2).



Overall, updating the ageing error matrix in model case M3 had the majority of the influence on model changes in spawning biomass compared to model case M2. Extending the aging error matrix had little influence on the model results in this case. The differences in spawning biomass are related to differences in recruitment estimates (Figures 9-14 and 9-15) which are due to the decrease in ageing error variability in the updated ageing error matrix.

We recommend model case M3 as the preferred model for the 2015 Pacific ocean perch rockfish assessment for the following reasons: (1) growth should be modeled based on the manner in which the observations were collected, and (2) updating and extending the ageing error matrix results in improvements to the fit of the age composition datasets. The 2015 recommended model (model case M3) generally produces good visual fits to the data, and biologically reasonable patterns of recruitment, abundance, and selectivities. This model does not fit the 2013 and 2015 survey estimates well (Figure 9-6), likely due to the large increase in these estimates compared to previous years that is difficult to explain in a long-lived species with our current model configuration. In general, the 2015 recommended model is utilizing the new information effectively, and we use it to recommend 2016 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 450,000 t for 2015 (Figure 9-10). 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 300,000 and 760,000 t. Spawning biomass shows a similar trend, but is not as smooth as the estimates of total biomass (Figure 9-10). 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 9-11). 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 (1.95) than that estimated in 2014 (2.00). 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]). Compared to the last full assessment (2014), spawning biomass and age-6+ total biomass has increased in response to fitting the large 2015 trawl survey biomass (Table 9-14). Some large differences results in estimated recruitment (Table 9-14 and Figures 9-14 and 9-15), which should not be unexpected given the large differences in ageing error that have been applied in this year's recommended model compared to the previous assessment.

Fully-selected fishing mortality shows that fishing mortality has decreased dramatically from historic rates and has leveled out in the last decade (Figure 9-12). 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 9-13). 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 9-14). 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 2015 survey biomass suggests that the 2006 year class may be above average (Figure 9-15). However, these recent recruitments are still highly uncertain as indicated by the MCMC credible intervals in Figure 9-14. 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 9-14).

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 9-16) 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 9-10, 9-14, and 9-17).

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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 9-17).

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 0.02, indicating that the model decreases the estimate of female spawning biomass in recent years as data is added to the assessment. This indicates a low retrospective pattern relative to other AFSC assessments. The retrospective female spawning biomass and the relative difference in female spawning biomass from the model in the terminal year are shown in Figure 9-18 (with 95% credible intervals from MCMC). In general the relative difference in female spawning biomass in recent years was quite low, but there are some large changes (-30% to 50%), 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 2013 (i.e., the 1977 – 2011 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 2015 estimates of these reference points are:

$B_{100\%}$	$B_{40\%}$	$B_{35\%}$	$F_{40\%}$	$F_{35\%}$
285,327	114,131	99,865	0.102	0.119

Specification of OFL and Maximum Permissible ABC

Female spawning biomass for 2016 is estimated at 157,080 t. This is above the $B_{40\%}$ value of 114,131 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 2016, yields the following ABC and OFL:

$F_{40\%}$	0.102
ABC	24,437
$F_{35\%}$	0.119
OFL	**28,431**

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 2015 numbers at age as estimated in the assessment. This vector is then projected forward to the beginning of 2016 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2015. 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 2015 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 2016, 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 2016 and 2017, *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 2012-2014 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 2010-2014 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 2015 or 2) above ½ of its MSY level in 2015 and above its MSY level in 2025 under this scenario, then the stock is not overfished.)

Scenario 7: In 2016 and 2017, *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 2017 or 2) above 1/2 of its MSY level in 2017 and expected to be above its MSY level in 2027 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 2016, it does not provide the best estimate of OFL for 2017, because the mean 2016 catch under Scenario 6 is predicated on the 2016 catch being equal to the 2016 OFL, whereas the actual 2016 catch will likely be less than the 2016 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 (2014) is 17,666 t. This is less than the 2014 OFL of 22,319 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 2015:
a. If spawning biomass for 2015 is estimated to be below ½ $B_{35\%}$, the stock is below its MSST.
b. If spawning biomass for 2015 is estimated to be above $B_{35\%}$ the stock is above its MSST.

c. If spawning biomass for 2015 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 2025 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 2017 is below 1/2 $B_{35\%}$, the stock is approaching an overfished condition.
b. If the mean spawning biomass for 2017 is above $B_{35\%}$, the stock is not approaching an overfished condition.
c. If the mean spawning biomass for 2017 is above 1/2 $B_{35\%}$ but below $B_{35\%}$, the determination depends on the mean spawning biomass for 2027. If the mean spawning biomass for 2027 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. 2012-2014 for this year). For Pacific ocean perch, the expansion factor for 2015 catch is 1.11.

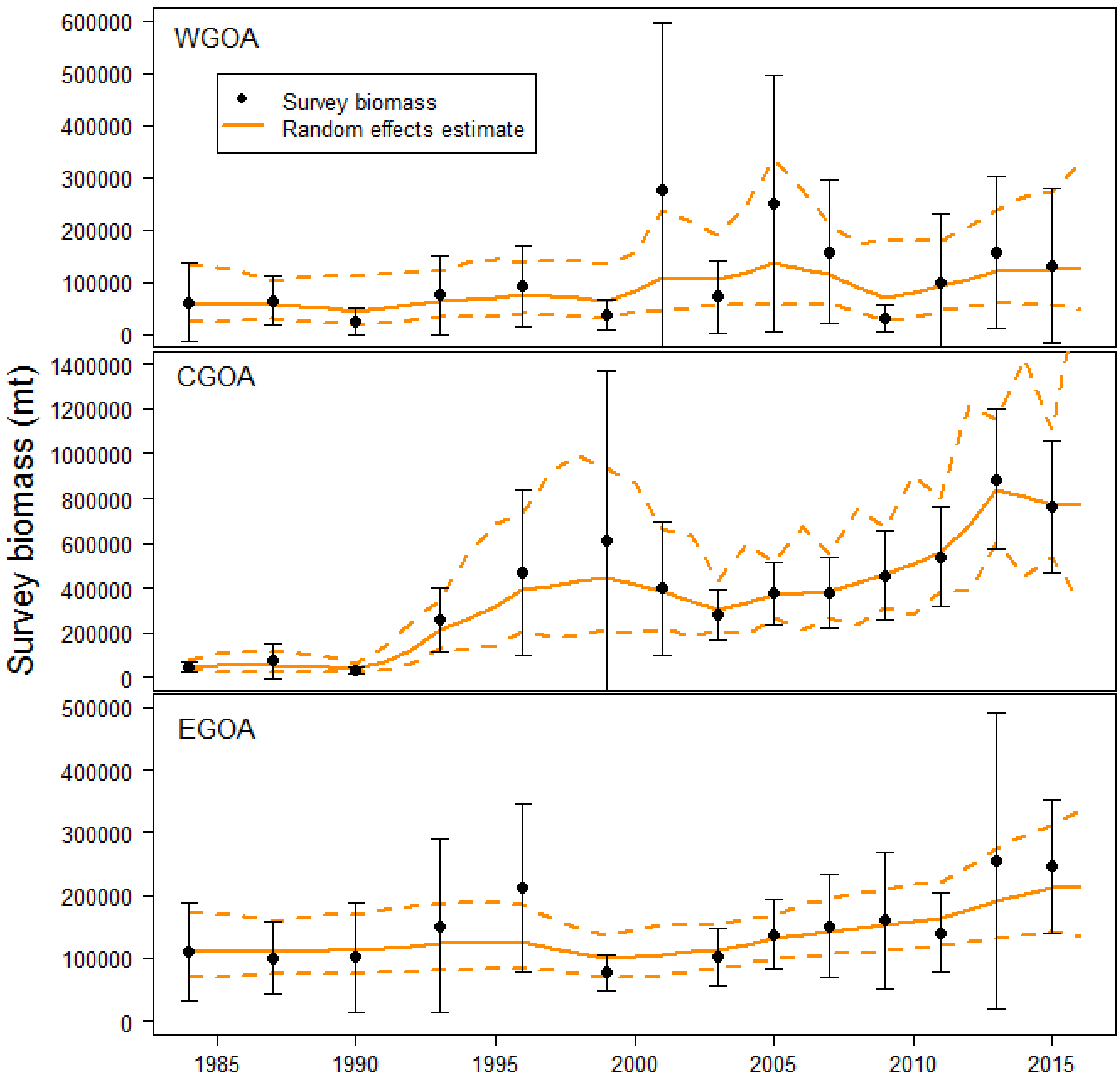
For catch projections into the next two years, we are using the ratio of the last three official catches to the last three TACs multiplied against the future two years' ABCs (if TAC is normally the same as ABC). This method results in slightly higher ABCs in each of the future two years of the projection, 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 (0.87), which was the average of the ratio of catch to ABC for the last three complete catch years (2012-2014). This yield ratio was multiplied by the projected ABCs for 2016 and 2017 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 the same estimated yield ratio as Scenario 2, except for all years instead of the next two. 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 9-17). The $B_{35\%}$ and $B_{40\%}$ reference points and future recruitments are based on the 1979-2013 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. The random effects model estimates stay nearly the same as in 2013 for the Western area, decrease slightly in the

Central area, and increase in the Eastern area upon fitting the more precise biomass estimate in 2015 compared to 2013. Using the random effects model estimates of survey biomass the apportionment results in 11.2% for the Western area (up slightly from 11.0% in 2014), 69.7% for the Central area (down from 75.5% in 2014), and 19.1% for the Eastern area (up from 13.5% in 2014). In comparison to the 4:6:9 weighting method that was used in previous assessments, the Western area random effects estimate is slightly smaller than the 4:6:9 weighted estimate of 11.9%, the Central area random effects estimate is larger than the weighted estimate of 67.8%, and the Eastern area random effects estimate is smaller than the weighted estimate of 20.3%. Using the results of the random effects model this results in recommended ABC's of **2,737** t for the Western area, **17,033** t for the Central area, and **4,667** 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 2011, 2013, and 2015. We calculated the approximate upper 95% confidence interval using the variance of a weighted mean for the 2011-2015 weighed mean ratio. This resulted in lower ratio of 0.61, down from 0.71 in 2013. This results in an ABC apportionment of **2,847** t to the W. Yakutat area which would leave **1,820** t unharvested in the Southeast/Outside area.

Overfishing Definition

Based on the definitions for overfishing in Amendment 44 in tier 3a (i.e., $F_{OFL} = F_{35\%}$=0.119), overfishing is set equal to 28,431 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 **26,313** t and **2,118** 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) 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)
2) Synthesize previous studies on rockfish catchability with submersibles into informative prior distributions on catchability in the model
3) 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: 2015	2016	As estimated or recommended *this* year for: 2016	2017[1]
M (natural mortality)	0.061	0.061	0.061	0.061
Tier	3a	3a	3a	3a
Projected total (age 2+) biomass (t)	416,140	412,351	457,768	449,416
Projected Female spawning biomass	142,029	144,974	157,080	158,124
$B_{100\%}$	283,315	283,315	285,327	285,327
$B_{40\%}$	113,326	113,326	114,131	114,131
$B_{35\%}$	99,160	99,160	99,865	99,865
F_{OFL}	0.139	0.139	0.119	0.119
$maxF_{ABC}$	0.119	0.119	0.102	0.102
F_{ABC}	0.119	0.119	0.102	0.102
OFL (t)	**24,360**	24,849	**28,431**	28,141
maxABC (t)	21,012	21,436	**24,437**	24,189
ABC (t)	**21,012**	21,436	**24,437**	24,189
Status	As determined *last* year for: 2013	2014	As determined *this* year for: 2014	2015
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 2016 and 2017 are derived using estimated catch of 18,326 for 2015, and projected catches of 21,176 t and 20,752 t for 2016 and 2017 based on realized catches from 2012-2014. 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	17,666	19,309	19,309	22,319	
2015*	16,443	21,012	21,012	24,360	

* Catch as of 10/1/2015

Table 9-2. Commercial catch[a] (t) 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.	3,682	7,677	1,040	12,399	15,111	15,111
2010	U.S.	3,141	10,550	1,926	15,616	17,584	17,584
2011	U.S.	1,819	10,527	1,870	14,213	16,997	16,997
2012	U.S.	2,452	10,779	1,682	14,912	16,918	16,918
2013	U.S.	447	11,200	1,537	13,183	16,412	16,412
2014	U.S.	2,096	13,700	1,870	17,666	19,309	19,309
2015*	U.S.	2,039	12,423	1,981	16,443	21,012	21,012

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.

* Catch as of 10/1/2015

Table 9-3. FMP groundfish species caught in rockfish targeted fisheries in the Gulf of Alaska from 2011-2015. Conf. = Confidential because of less than three vessels or processors. Source: NMFS AKRO Blend/Catch Accounting System via AKFIN 10/15/2015.

Group Name	2011	2012	2013	2014	2015	Average
Pacific Ocean Perch	13,120	13,953	11,555	15,283	15,895	13,961
Northern Rockfish	3,164	4,883	4,527	3,650	3,600	3,965
Dusky Rockfish	2,315	3,642	2,870	2,752	2,480	2,812
Arrowtooth Flounder	340	764	766	1,425	1,370	933
Walleye Pollock	813	574	829	1,339	1,022	915
Atka Mackerel	1,404	1,173	1,162	446	973	1,032
Pacific cod	560	404	584	624	763	587
Harlequin Rockfish	350	603	305	437	565	452
Sablefish	440	470	495	527	410	468
Shortraker Rockfish	239	303	290	243	237	262
Rougheye Rockfish	286	219	274	359	223	272
Thornyhead Rockfish	161	130	104	243	216	171
Rex Sole	51	72	89	84	115	82
Yelloweye Rockfish	69	188	179	86	113	127
Sharpchin Rockfish	112	82	45	93	96	86
Flathead Sole	13	16	25	30	44	26
Sculpin	39	55	70	33	43	48
Redstripe Rockfish	67	54	22	70	42	51
Dover Sole	15	37	24	30	33	28
Longnose Skate	25	23	23	26	31	26
Silvergray Rockfish	57	28	14	25	30	31
Rock Sole	44	61	26	28	26	37
Redbanded Rockfish	25	14	14	31	24	22
Majestic Squid	12	15	10	19	23	16
Skate, Other	14	14	18	36	22	21

Table 9-4 . Catch (t) of GOA Pacific ocean perch as bycatch in other fisheries from 2011-2015. Source: NMFS AKRO Blend/Catch Accounting System via AKFIN 10/15/2015.

Target	2011	2012	2013	2014	2015	Average
Arrowtooth Flounder	566	496	424	1395	577	692
Deep Water Flatfish - GOA	-	-	1	1	1	1
Flathead Sole	2	2	19	6	0	6
Pacific Cod	20	53	12	15	135	47
Pollock - bottom	124	70	294	179	60	145
Pollock - midwater	48	224	133	351	53	162
Rex Sole - GOA	291	94	714	423	226	350
Sablefish	17	17	8	2	2	9
Shallow Water Flatfish - GOA	2	3	20	11	0	7

Table 9-5. Non-FMP species bycatch estimates in tons for Gulf of Alaska rockfish targeted fisheries 2011 - 2015. Conf. = Confidential because of less than three vessels. Source: NMFS AKRO Blend/Catch Accounting System via AKFIN 10/15/2015.

Group Name	2011	2012	2013	2014	2015
Benthic urochordata	Conf.	Conf.	Conf.	Conf.	Conf.
Birds	Conf.	Conf.	Conf.	Conf.	Conf.
Bivalves	0.01	0.01	Conf.	0.01	Conf.
Brittle star unidentified	0.01	0.04	0.02	0.05	0.06
Capelin	-	-	0.02	-	-
Corals Bryozoans	0.11	Conf.	Conf.	Conf.	Conf.
Dark Rockfish	12.82	55.38	42.16	47.91	45.12
Eelpouts	Conf.	.30	.04	.13	Conf.
Eulachon	Conf.	Conf.	0.07	0.02	0.03
Giant Grenadier	449.33	310.82	889.11	512.50	727.33
Greenlings	7.67	8.76	6.99	4.16	8.14
Pacific Grenadier	-	-	-	-	-
Hermit crab unidentified	0.02	Conf.	0.03	.04	0.03
Invertebrate unidentified	0.35	3.85	0.18	Conf.	0.19
Lanternfishes	-	-	Conf.	-	0.04
Misc crabs	0.04	0.04	0.01	0.04	Conf.
Misc crustaceans	Conf.	-	Conf.	Conf.	Conf.
Misc deep fish	-	-	Conf.	-	-
Misc fish	129.52	151.71	159.64	124.55	142.73
Misc inverts (worms etc)	Conf.	-	-	-	-
Other osmerids	-	Conf.	0.02	Conf.	-
Pacific Sand lance	Conf.	-	-	-	-
Pandalid shrimp	0.06	0.06	0.06	0.10	0.05
Polychaete unidentified	-	-	Conf.	-	-
Scypho jellies	0.02	0.16	0.39	5.13	1.23
Sea anemone unidentified	4.07	6.27	4.02	2.15	1.12
Sea pens whips	0.04	-	0.04	0.06	-
Sea star	1.46	0.92	0.89	1.60	3.46
Snails	0.23	1.26	0.15	0.12	0.26
Sponge unidentified	3.95	1.37	1.28	1.81	5.45
Stichaeidae	-	-	Conf.	Conf.	Conf.
Urchins, dollars cucumbers	0.44	0.30	0.28	0.21	0.98

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 10/15/2015.

Group Name	2011	2012	2013	2014	2015	Average
Bairdi Crab	0.03	0.09	0.07	0.17	0.05	0.08
Blue King Crab	0.00	0.00	0.00	0.00	0.00	0.00
Chinook Salmon	1.01	1.58	2.32	1.25	0.88	1.41
Golden K. Crab	0.13	0.11	0.10	0.03	0.02	0.08
Halibut	121.70	109.22	112.95	126.99	144.46	123.06
Herring	0.00	0.00	0.00	0.00	0.00	0.00
Other Salmon	0.21	0.31	2.02	0.56	0.34	0.69
Opilio Crab	0.00	0.00	0.00	0.00	0.03	0.01
Red King Crab	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	2015
12	0	0	0	0	0	0	0	0
13-15	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0
18	0	0	0	0.001	0	0	0	0
19	0	0.001	0	0.001	0	0	0.001	0
20	0	0	0.002	0.001	0.001	0.001	0.001	0.001
21	0	0	0.001	0.001	0.003	0.000	0.002	0.002
22	0.001	0.001	0.003	0.001	0.005	0.001	0.003	0.002
23	0.002	0	0.005	0.002	0.008	0.003	0.003	0.003
24	0.002	0.001	0.004	0.002	0.008	0.004	0.003	0.004
25	0.003	0.002	0.003	0.003	0.010	0.008	0.003	0.007
26	0.003	0.003	0.003	0.003	0.015	0.013	0.003	0.008
27	0.003	0.005	0.004	0.003	0.014	0.014	0.005	0.010
28	0.008	0.006	0.005	0.005	0.010	0.015	0.007	0.007
29	0.012	0.008	0.006	0.007	0.009	0.019	0.012	0.006
30	0.016	0.013	0.008	0.010	0.009	0.020	0.020	0.008
31	0.025	0.023	0.014	0.012	0.012	0.022	0.024	0.010
32	0.04	0.042	0.025	0.020	0.021	0.014	0.028	0.014
33	0.063	0.071	0.042	0.033	0.031	0.017	0.034	0.021
34	0.093	0.099	0.074	0.060	0.051	0.032	0.045	0.039
35-38	0.473	0.498	0.551	0.551	0.521	0.489	0.470	0.450
>38	0.255	0.227	0.248	0.284	0.272	0.326	0.337	0.408
Total	8,154	8,898	11,174	9,800	12,861	10,765	14,462	4,957

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 1984-2015 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%
2015	130,364	280,345	482,849	93,661	153,188	1,140,407	793,855	1,486,959	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	2013
2	0.003	0.019	0.005	0.006	0.006	0.006	0.016	0.001	0.003	0.005	0.001	0.000
3	0.002	0.101	0.043	0.018	0.016	0.020	0.057	0.034	0.020	0.087	0.030	0.022
4	0.058	0.092	0.155	0.021	0.036	0.045	0.053	0.050	0.018	0.044	0.046	0.012
5	0.029	0.066	0.124	0.044	0.043	0.052	0.071	0.077	0.044	0.049	0.124	0.067
6	0.079	0.091	0.117	0.088	0.063	0.026	0.040	0.073	0.041	0.025	0.042	0.058
7	0.151	0.146	0.089	0.125	0.038	0.041	0.054	0.119	0.056	0.096	0.036	0.064
8	0.399	0.056	0.065	0.129	0.088	0.059	0.107	0.069	0.089	0.065	0.024	0.055
9	0.050	0.061	0.054	0.166	0.145	0.095	0.115	0.087	0.125	0.106	0.071	0.057
10	0.026	0.087	0.055	0.092	0.185	0.054	0.057	0.092	0.094	0.047	0.073	0.042
11	0.010	0.096	0.036	0.045	0.110	0.114	0.053	0.063	0.063	0.053	0.105	0.066
12	0.016	0.018	0.024	0.052	0.080	0.144	0.044	0.035	0.064	0.079	0.073	0.064
13	0.015	0.011	0.028	0.038	0.034	0.086	0.036	0.027	0.050	0.035	0.065	0.067
14	0.019	0.011	0.072	0.025	0.036	0.067	0.057	0.031	0.030	0.039	0.047	0.059
15	0.005	0.009	0.017	0.026	0.028	0.046	0.048	0.039	0.026	0.047	0.037	0.053
16	0.003	0.011	0.011	0.011	0.006	0.040	0.042	0.022	0.013	0.013	0.024	0.029
17	0.008	0.013	0.005	0.036	0.013	0.023	0.032	0.027	0.018	0.006	0.015	0.030
18	0.004	0.007	0.008	0.007	0.009	0.013	0.029	0.036	0.039	0.015	0.024	0.037
19	0.002	0.005	0.004	0.003	0.014	0.003	0.016	0.024	0.028	0.005	0.024	0.029
20	0.000	0.005	0.006	0.002	0.013	0.012	0.015	0.021	0.043	0.012	0.023	0.024
21	0.003	0.004	0.004	0.002	0.003	0.007	0.010	0.013	0.024	0.032	0.018	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	0.011
23	0.002	0.002	0.002	0.002	0.003	0.012	0.006	0.004	0.016	0.013	0.018	0.016
24	0.003	0.002	0.006	0.004	0.000	0.004	0.007	0.008	0.018	0.022	0.019	0.016
25+	0.110	0.083	0.070	0.054	0.027	0.025	0.031	0.030	0.055	0.043	0.053	0.104
Total	1428	1824	1754	1378	641	898	985	1009	1177	418	794	880

Table 9-11. Estimated numbers (thousands) in 2015, 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 2015 (1000's)	Maturity (%)	Weight (g)	Fishery selectivity (%)	Survey selectivity (%)
2	52,880	0.7	43	0.0	8.0
3	50,180	1.3	98	0.2	15.7
4	42,613	2.5	167	1.6	28.5
5	56,095	4.7	244	5.6	46.0
6	36,847	8.8	323	13.5	64.5
7	88,318	15.8	400	25.4	79.5
8	58,599	26.9	471	40.2	89.3
9	105,211	41.8	536	56.2	94.7
10	32,693	58.4	594	71.5	97.4
11	31,973	73.3	644	84.3	98.8
12	16,713	84.3	688	93.6	99.4
13	38,583	91.3	725	98.8	99.7
14	24,305	95.3	757	100.0	99.9
15	38,190	97.6	784	97.6	99.9
16	22,956	98.7	807	92.4	100.0
17	33,734	99.3	825	85.2	100.0
18	14,847	99.7	841	76.7	100.0
19	10,841	99.8	854	67.6	100.0
20	16,571	99.9	865	58.5	100.0
21	14,255	100.0	874	49.8	100.0
22	5,563	100.0	882	41.7	100.0
23	6,558	100.0	888	34.5	100.0
24	5,441	100.0	893	28.1	100.0
25	5,023	100.0	897	22.7	100.0
26	3,677	100.0	901	18.1	100.0
27	7,819	100.0	903	14.3	100.0
28	9,002	100.0	906	11.2	100.0
29+	45,451	100.0	912	8.7	100.0

Table 9-12. Summary of results from 2015 compared with 2014 results

	M0-2014	**M1**	**M2**	**M3**
Likelihoods				
Catch	0.12	0.13	0.13	0.14
Survey Biomass	10.26	11.37	11.22	12.21
Fishery Ages	27.06	27.29	27.39	18.24
Survey Ages	47.67	49.68	49.78	32.03
Fishery Sizes	54.28	54.65	54.18	55.34
Maturity	103.52	103.52	103.52	103.52
Data-Likelihood	242.91	246.64	246.22	221.48
Penalties/Priors				
Recruitment Devs	22.18	22.04	21.74	21.56
F Regularity	4.25	4.39	4.42	4.63
σ_r prior	5.03	5.13	5.18	5.48
q prior	1.21	1.17	1.13	1.12
M prior	2.15	2.05	2.06	2.02
Objective Fun Total	277.7	281.42	280.75	256.29
Parameter Ests.				
Active parameters	146	148	148	152
q	2.00	1.98	1.96	1.95
M	0.062	0.061	0.061	0.061
σ_r	0.90	0.90	0.89	0.88
Mean Recruitment (millions)	49.32	50.44	51.69	52.74
$F_{40\%}$	0.119	0.118	0.121	0.102
Total Biomass	416,140	452,500	461,490	457,768
$B_{CURRENT}$	142,029	161,531	160,845	157,080
$B_{100\%}$	283,315	298,728	288,334	285,327
$\mathbf{B_{40\%}}$	113,326	119,491	115,334	114,131
maxABC	21,012	24,116	25,407	**24,437**
$F_{35\%}$	0.139	0.138	0.142	0.119
$OFL_{F35\%}$	24,360	27,966	29,510	**28,431**

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	1.954	1.974	1.942	0.431	0.430	1.231	2.906
M	0.061	0.062	0.062	0.006	0.006	0.052	0.075
$F_{40\%}$	0.102	0.114	0.109	0.023	0.030	0.069	0.186
2016 SSB	157,060	163,616	158,002	38,426	41,694	98,272	257,558
2016 ABC	24,437	28,495	26,693	8,221	10,804	12,606	54,792

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	32,872	34,839	94,879	99,660	0.227	0.217	18,820	14,244
1978	27,427	29,188	78,461	82,686	0.102	0.097	33,426	77,505
1979	27,039	28,591	75,301	78,817	0.111	0.106	59,379	29,198
1980	26,220	27,562	71,618	74,112	0.152	0.147	24,265	23,413
1981	23,990	25,194	65,909	66,846	0.161	0.159	20,104	19,082
1982	21,720	22,888	64,013	75,765	0.085	0.072	25,623	45,155
1983	21,849	23,100	74,359	80,390	0.038	0.035	29,303	29,234
1984	23,542	25,079	80,652	86,245	0.034	0.032	31,205	31,333
1985	25,991	27,910	85,860	90,703	0.009	0.009	47,698	53,579
1986	29,892	32,106	94,025	103,221	0.024	0.021	62,204	86,788
1987	33,679	36,066	101,375	110,812	0.045	0.041	49,982	66,669
1988	36,581	39,094	106,678	116,222	0.081	0.074	235,995	121,897
1989	37,647	40,469	111,647	122,813	0.107	0.097	58,052	92,906
1990	37,360	40,749	117,233	135,100	0.112	0.097	44,411	76,304
1991	37,196	41,286	119,805	143,023	0.055	0.046	43,268	33,762
1992	40,989	45,609	173,688	172,212	0.038	0.038	39,043	43,218
1993	46,788	51,609	193,393	196,693	0.011	0.011	37,125	43,587
1994	56,578	60,934	213,498	222,274	0.009	0.008	38,478	48,607
1995	68,622	71,757	231,740	236,858	0.025	0.024	42,353	37,917
1996	80,151	81,651	242,963	247,307	0.035	0.034	57,344	88,776
1997	89,560	89,728	248,970	253,329	0.038	0.038	105,296	93,711
1998	96,239	95,719	252,321	257,976	0.035	0.035	67,019	55,331
1999	100,883	100,181	255,829	259,599	0.041	0.040	56,122	67,979
2000	103,137	102,609	260,333	271,283	0.039	0.038	80,845	137,833
2001	104,702	104,573	276,525	285,742	0.039	0.038	156,280	83,326
2002	105,956	106,407	284,964	290,951	0.041	0.040	71,913	122,753
2003	107,436	108,607	289,777	297,668	0.037	0.036	56,160	69,073
2004	110,457	112,270	300,885	322,808	0.039	0.036	48,503	97,002
2005	114,271	116,649	329,585	336,016	0.034	0.033	40,164	37,284
2006	119,152	122,123	342,081	359,219	0.040	0.038	43,583	63,633
2007	123,774	127,528	347,558	367,615	0.037	0.035	53,275	58,495
2008	129,172	133,826	350,298	382,212	0.036	0.033	247,509	170,831
2009	134,664	140,419	349,807	382,031	0.037	0.034	60,006	87,209
2010	138,931	146,233	347,682	385,250	0.045	0.040	53,389	121,603
2011	140,821	149,871	344,277	383,380	0.041	0.037	47,712	47,296
2012	141,890	153,001	387,212	410,234	0.038	0.036	49,756	67,471
2013	142,586	155,268	392,662	419,078	0.034	0.031	49,404	48,162
2014	139,765	158,513	396,767	437,813	0.045	0.040	49,318	53,343
2015		154,984		434,080		0.042		52,880

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	14,244	3,913	35,867	106,881	88,130	144,369	34,839	27,334	48,315
1978	77,505	43,901	135,678	92,199	73,152	129,765	29,188	21,819	42,871
1979	29,198	8,191	64,506	92,015	72,168	131,571	28,591	21,087	42,637
1980	23,413	7,697	51,537	92,160	70,975	133,775	27,562	19,990	41,804
1981	19,082	5,804	44,298	89,860	67,276	134,202	25,194	17,479	39,757
1982	45,154	21,127	86,664	88,859	64,888	136,341	22,888	15,241	37,563
1983	29,234	9,007	65,001	93,381	67,547	144,717	23,100	15,171	38,178
1984	31,333	10,637	67,449	100,844	72,932	155,666	25,079	16,719	40,835
1985	53,579	22,539	107,685	109,404	79,632	168,243	27,910	19,033	44,704
1986	86,788	43,348	161,481	122,486	90,248	186,951	32,106	22,540	50,694
1987	66,669	22,391	135,836	135,971	100,162	205,982	36,066	25,619	56,039
1988	121,897	61,620	232,384	151,356	111,570	229,452	39,094	27,697	60,936
1989	92,906	33,676	188,010	165,526	120,766	252,963	40,469	28,146	63,616
1990	76,304	25,373	153,113	178,501	128,302	277,336	40,749	27,468	65,929
1991	33,762	8,675	83,994	189,969	134,710	298,852	41,286	26,936	68,747
1992	43,218	13,450	91,414	207,340	146,833	326,083	45,609	29,940	75,694
1993	43,587	13,562	97,336	223,048	157,940	350,037	51,609	34,044	85,215
1994	48,607	16,135	104,046	241,641	172,202	376,715	60,934	41,323	98,615
1995	37,917	9,834	90,760	258,200	185,145	399,105	71,757	49,599	114,013
1996	88,776	38,417	175,445	270,689	194,812	417,336	81,651	56,765	129,026
1997	93,711	37,382	183,456	281,034	202,343	431,524	89,728	62,342	141,251
1998	55,331	15,086	127,729	289,816	207,755	445,541	95,719	66,318	150,420
1999	67,979	19,073	147,158	299,521	214,222	458,879	100,181	69,423	156,953
2000	137,833	69,640	269,853	310,724	221,344	475,935	102,609	70,500	161,654
2001	83,326	23,526	177,229	323,313	229,857	495,899	104,573	71,484	165,110
2002	122,753	54,478	243,240	338,120	240,206	519,526	106,407	72,038	168,102
2003	69,072	18,998	163,566	352,254	248,727	543,000	108,607	73,289	172,047
2004	97,002	37,379	204,512	368,436	259,883	571,381	112,270	75,562	177,568
2005	37,284	8,236	105,867	381,687	267,960	593,680	116,649	78,438	184,597
2006	63,633	17,742	149,987	393,775	276,561	612,404	122,123	82,315	193,511
2007	58,495	12,458	161,504	401,210	280,315	625,544	127,528	85,499	203,032
2008	170,831	61,203	395,389	411,981	287,005	644,637	133,826	89,341	213,041
2009	87,209	14,765	270,310	423,087	293,691	663,529	140,419	93,491	224,430
2010	121,603	23,411	358,465	435,679	300,940	687,456	146,233	97,276	233,914
2011	47,296	8,610	181,082	444,189	303,623	704,616	149,871	98,765	240,402
2012	67,471	10,957	268,931	453,197	306,990	723,775	153,001	100,197	246,484
2013	48,162	8,062	226,277	459,054	308,113	737,952	155,268	100,712	251,377
2014	53,343	8,574	294,969	464,135	308,855	753,309	158,513	102,194	257,685
2015	52,880	8,207	279,884	462,096	305,490	763,570	154,984	98,048	253,027
2016	68,583	12,023	249,536	457,680	300,317	766,472	157,060	98,272	257,558
2017	68,583	11,903	242,590	449,090	296,470	749,778	158,030	99,431	256,246

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. $B_{40\%}$ = 114,131 t, $B_{35\%}$ = 99,865 t, $F_{40\%}$ =0.102, and $F_{35\%}$ =0.119.

Year	Maximum permissible F	Author's F* (prespecified catch)	Half maximum F	5-year average F	No fishing	Overfished	Approaching overfished
			Spawning biomass (t)				
2015	154,985	154,985	154,985	154,985	154,985	154,985	154,985
2016	156,625	157,080	158,282	157,798	159,965	156,063	156,625
2017	156,295	158,124	162,941	160,971	169,956	154,101	156,295
2018	154,839	157,561	166,417	162,944	179,130	151,114	154,286
2019	151,986	154,568	168,247	163,317	186,829	146,880	149,850
2020	148,058	150,461	168,551	162,282	192,934	141,770	144,499
2021	143,679	145,885	167,819	160,390	197,743	136,427	138,903
2022	139,479	141,487	166,629	158,266	201,747	131,469	133,696
2023	135,911	137,729	165,481	156,415	205,429	127,306	129,304
2024	133,128	134,774	164,532	155,074	209,087	124,048	125,840
2025	131,043	132,536	164,504	154,237	212,808	121,566	123,177
2026	129,486	130,844	164,794	153,795	216,573	119,673	121,120
2027	128,292	129,532	164,846	153,621	220,321	118,207	119,502
2028	127,324	128,460	164,614	153,596	223,968	117,026	118,183
			Fishing mortality				
2015	0.076	0.076	0.076	0.076	0.076	0.076	0.076
2016	0.102	0.088	0.051	0.066	-	0.119	0.119
2017	0.102	0.087	0.051	0.066	-	0.119	0.119
2018	0.102	0.102	0.051	0.066	-	0.119	0.119
2019	0.102	0.102	0.051	0.066	-	0.119	0.119
2020	0.102	0.102	0.051	0.066	-	0.119	0.119
2021	0.102	0.102	0.051	0.066	-	0.119	0.119
2022	0.102	0.102	0.051	0.066	-	0.119	0.119
2023	0.102	0.102	0.051	0.066	-	0.119	0.119
2024	0.102	0.102	0.051	0.066	-	0.119	0.119
2025	0.102	0.102	0.051	0.066	-	0.119	0.119
2026	0.102	0.102	0.051	0.066	-	0.119	0.119
2027	0.102	0.102	0.051	0.066	-	0.118	0.118
2028	0.102	0.102	0.051	0.066	-	0.117	0.117
			Yield (t)				
2015	18,326	18,326	18,326	18,326	18,326	18,326	18,326
2016	24,437	24,437	12,449	15,988	-	28,431	24,437
2017	23,948	24,189	12,655	16,080	-	27,517	23,948
2018	23,249	23,726	12,728	16,006	-	26,396	27,045
2019	22,330	22,759	12,646	15,746	-	25,068	25,643
2020	21,275	21,650	12,433	15,337	-	23,637	24,132
2021	20,201	20,520	12,136	14,847	-	22,244	22,660
2022	19,222	19,488	11,813	14,352	-	21,018	21,359
2023	18,410	18,626	11,509	13,907	-	20,030	20,305
2024	17,798	17,971	11,257	13,551	-	19,303	19,521
2025	17,371	17,508	11,068	13,291	-	18,796	18,975
2026	17,093	17,200	10,938	13,115	-	18,406	18,576
2027	16,926	17,011	10,861	13,010	-	18,127	18,281
2028	16,843	16,912	10,830	12,965	-	17,967	18,098

*Projected ABCs and OFLs for 2016 and 2017 are derived using estimated catch of 18,326 for 2015, and projected catches of 21,176 t and 20,752 t for 2016 and 2017 based on realized catches from 2012-2014. 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

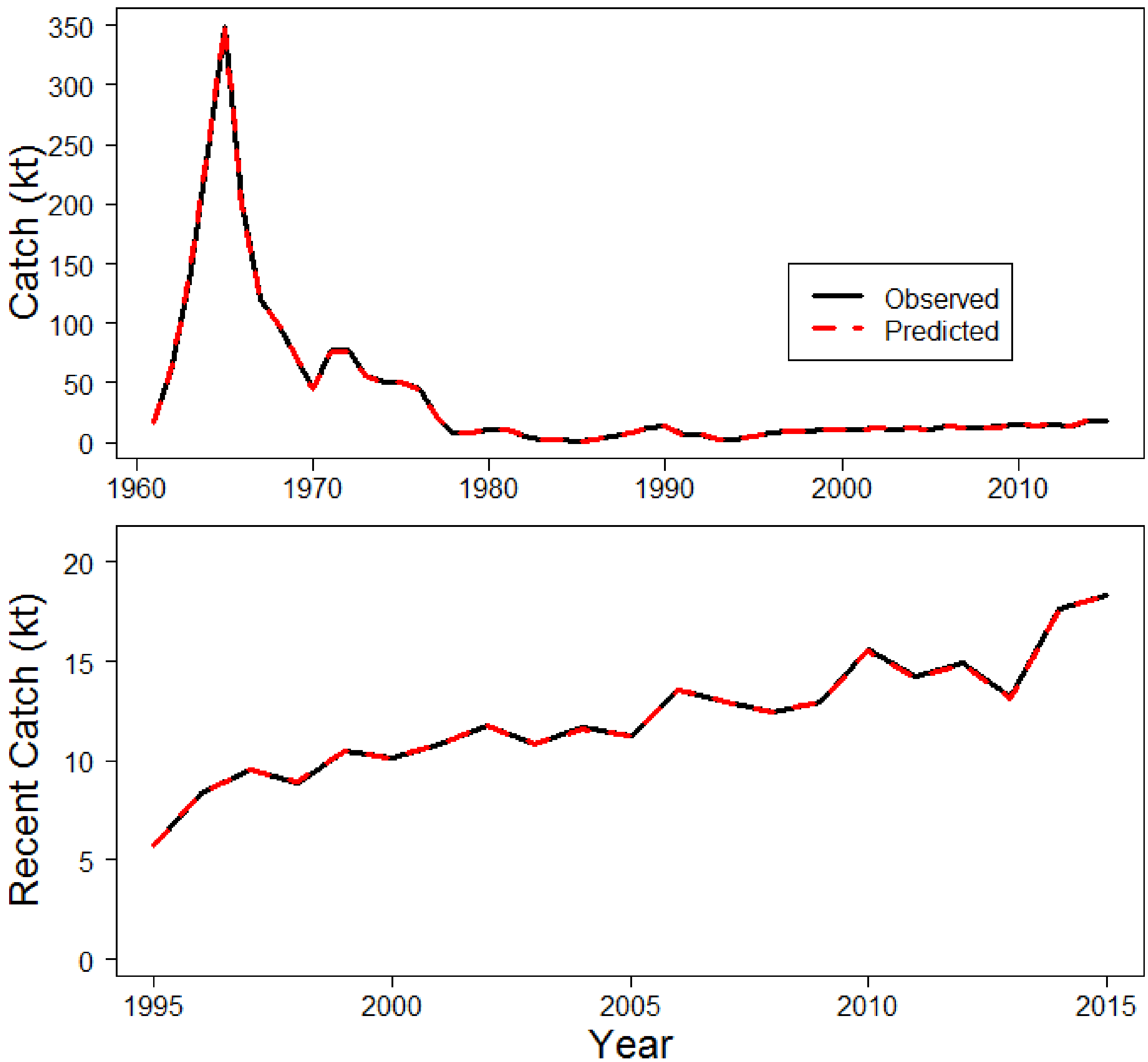

Figure 9-1. Estimated and observed long-term (top figure) and short-term (bottom figure) catch history for Gulf of Alaska Pacific ocean perch.

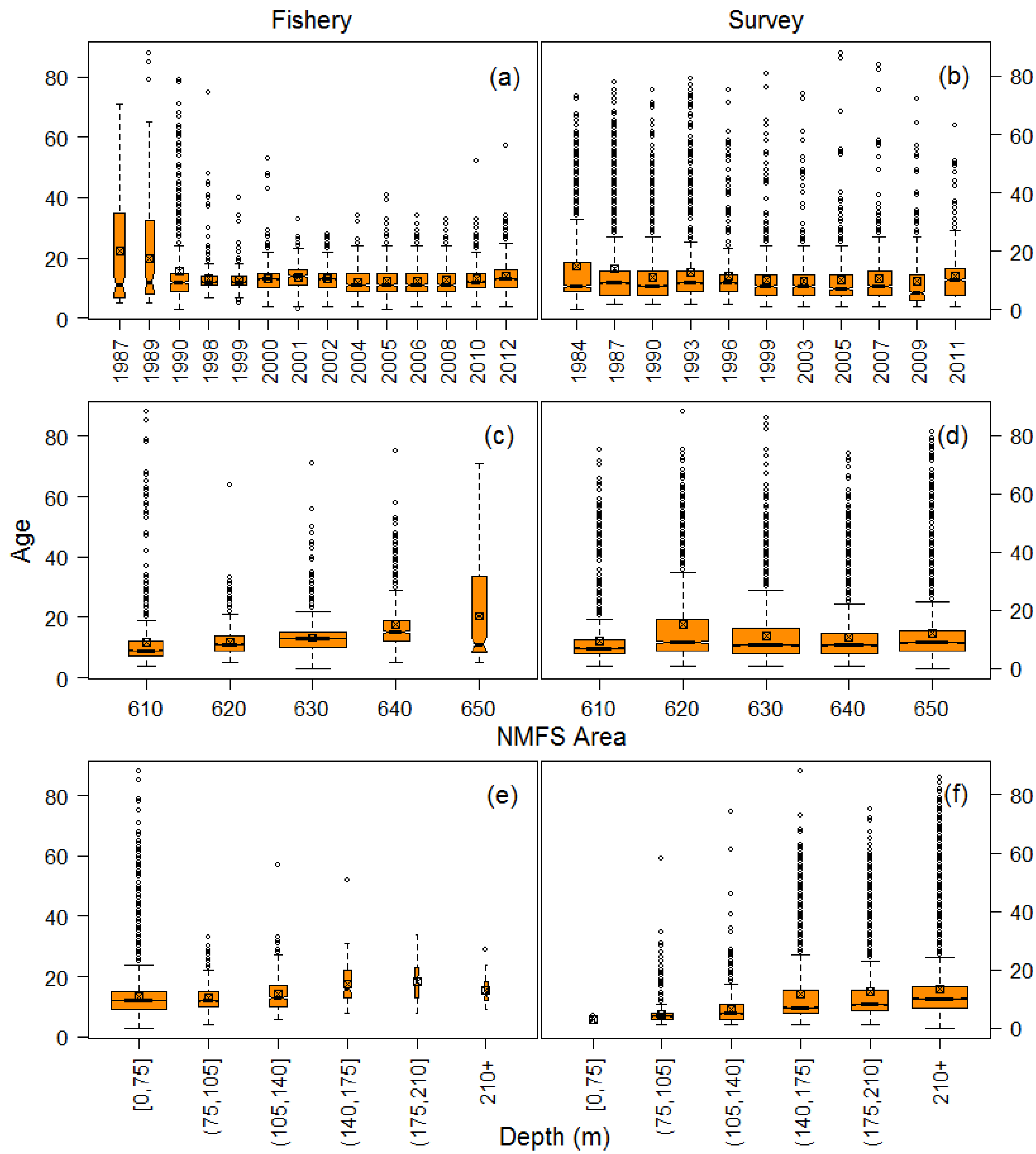

Figure 9-2. Comparisons of fishery and survey age compositions across time, depth, and NMFS area.

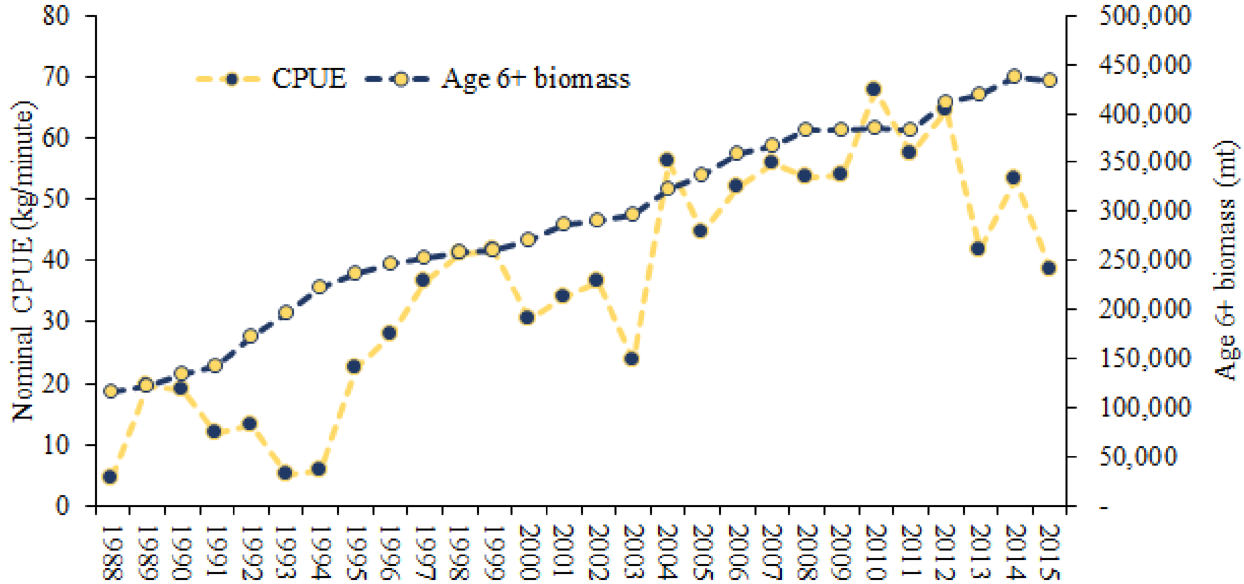

Figure 9-3a. Comparison of nominal catch-per-unit-effort (CPUE, kg/minute) and biomass (age 6+) in the Gulf of Alaska Pacific ocean perch fishery.

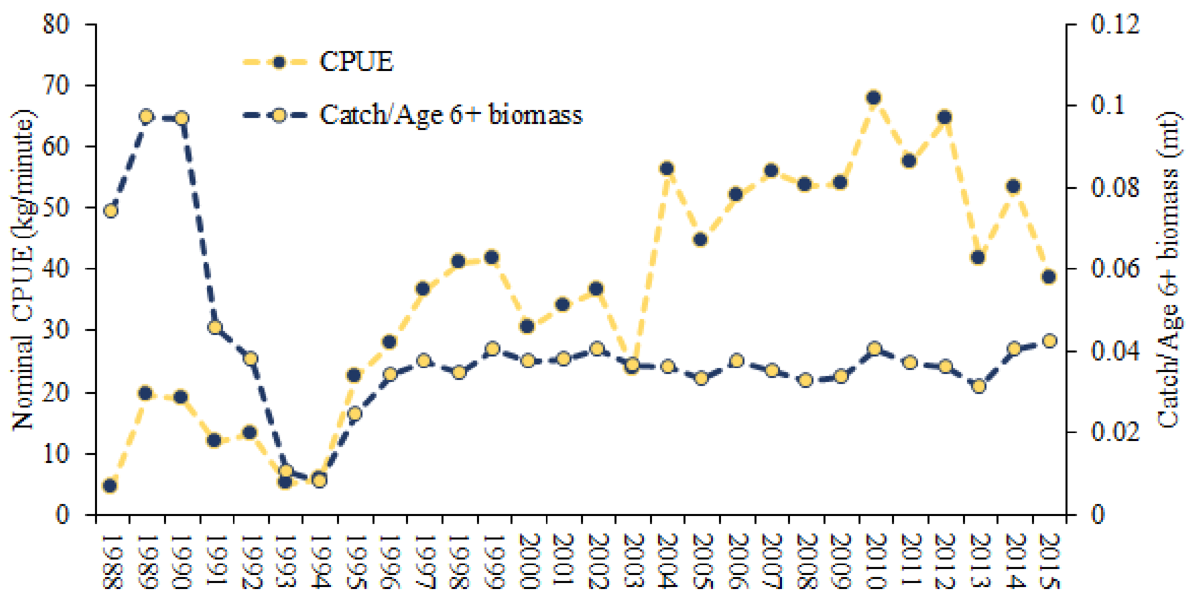

Figure 9-3b. Comparison of nominal catch-per-unit-effort (CPUE, kg/minute) and a proxy for exploitation rate (Catch/Age 6+ Biomass) for the Gulf of Alaska Pacific ocean perch fishery.

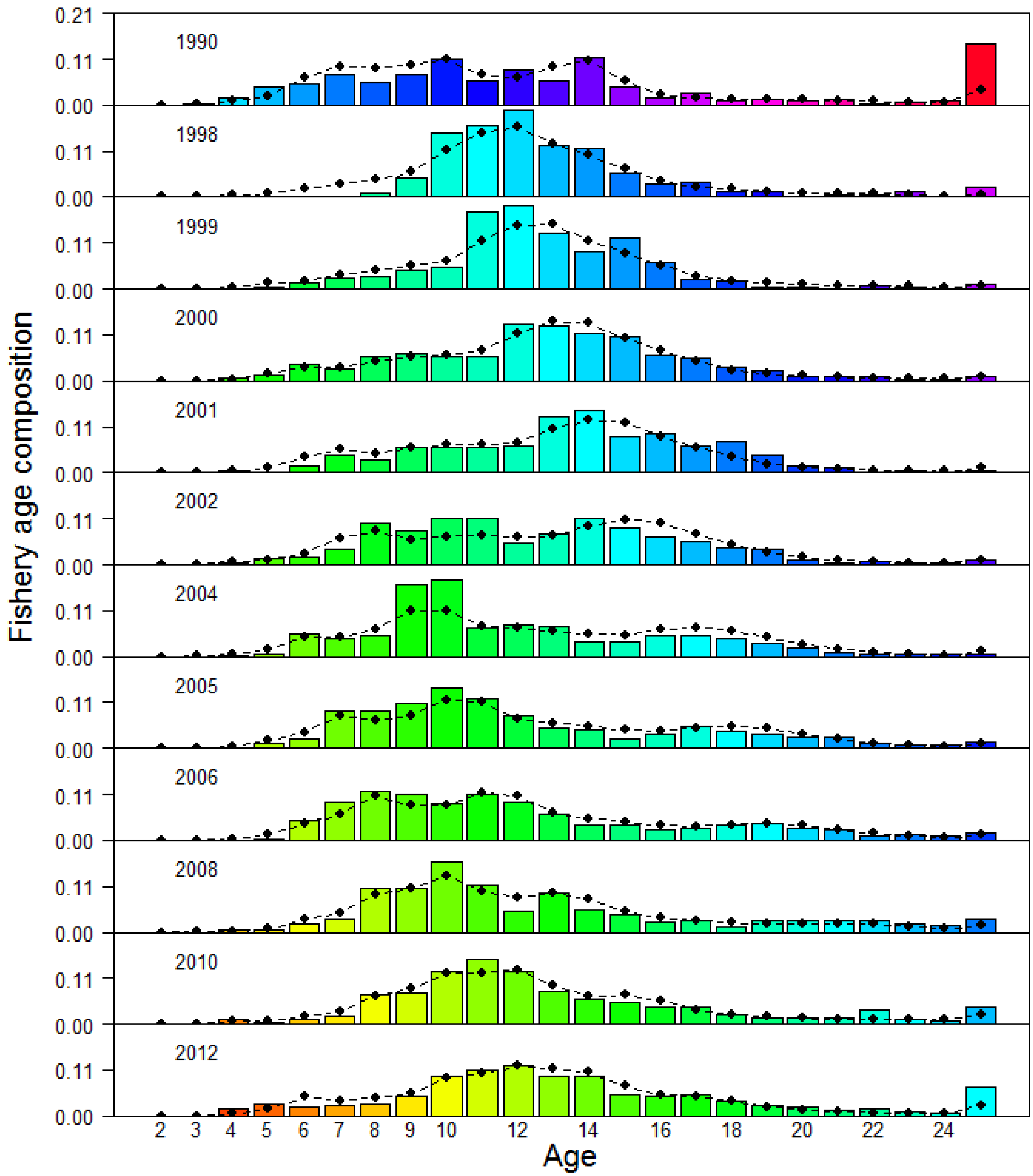

Figure 9-4. Fishery age compositions for GOA Pacific ocean perch. Observed = bars, actual age composition predicted from author recommended model = line with circles. Colors follow cohorts.

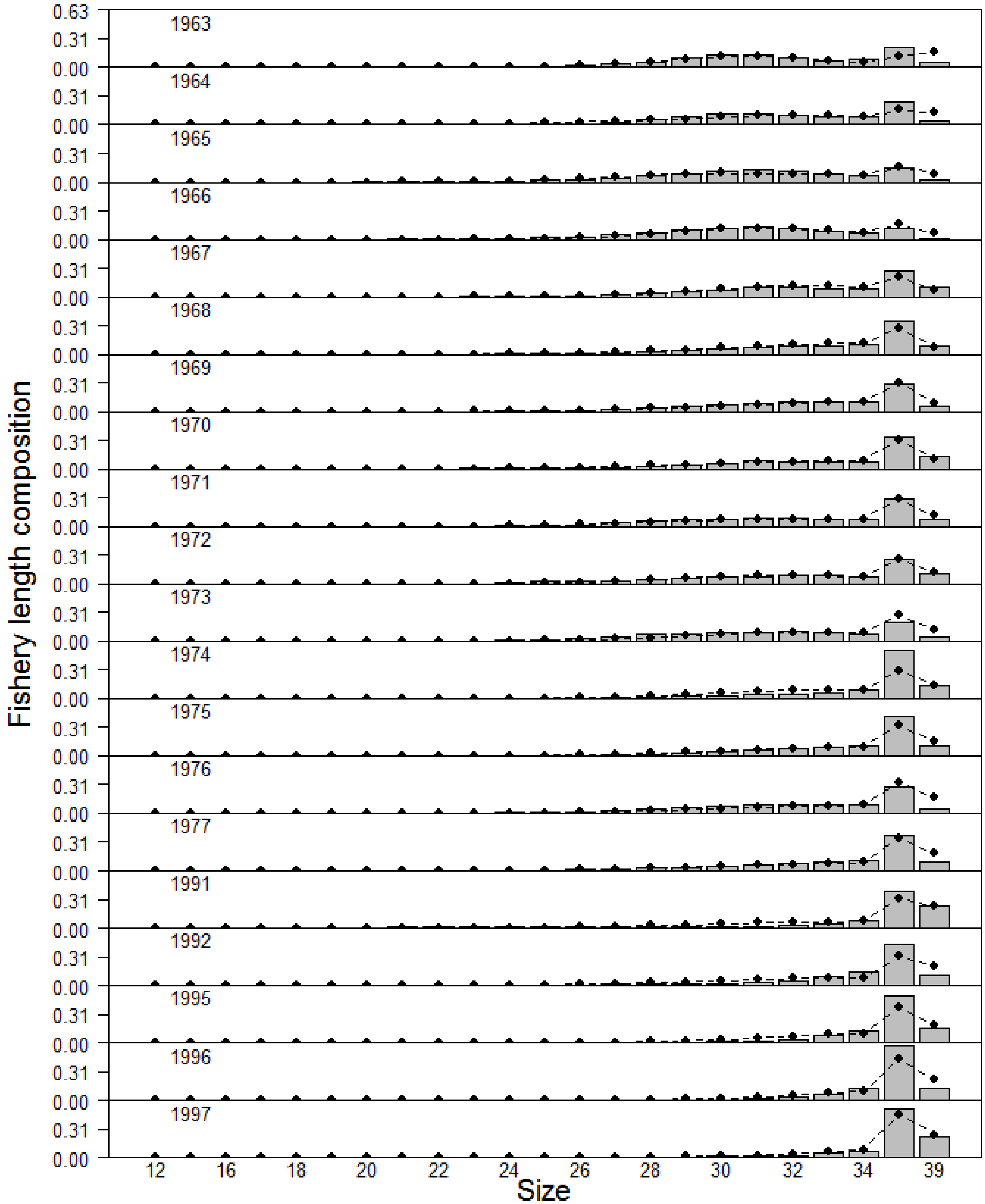

Figure 9-5. Fishery length (cm) compositions for GOA Pacific ocean perch. Observed = bars, predicted from author recommended model = line with circles.

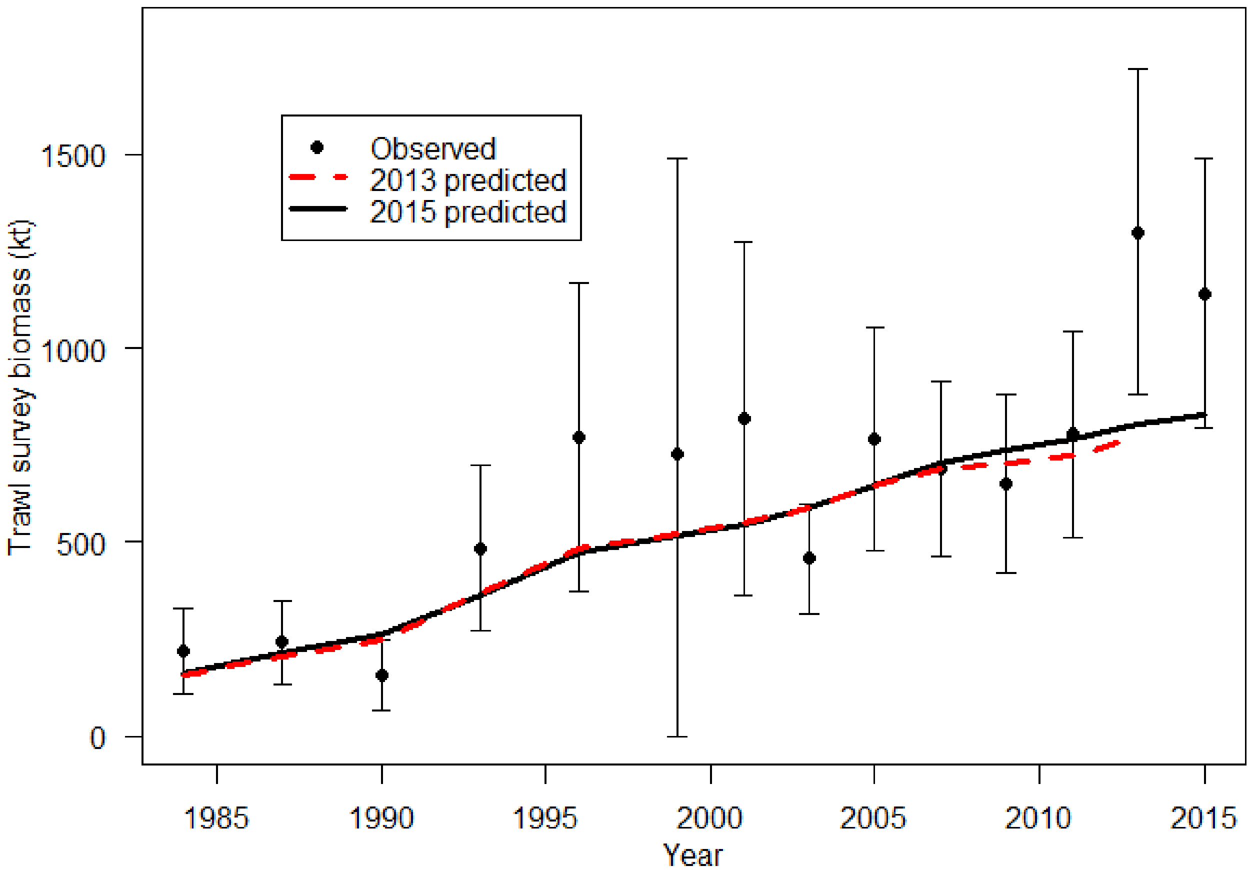

Figure 9-6. NMFS Groundfish Survey observed biomass estimates (open circles) with 95% sampling error confidence intervals for Gulf of Alaska Pacific ocean perch. Predicted estimates from the recommended model (black dashed line) compared with last year's model fit (blue dotted line).

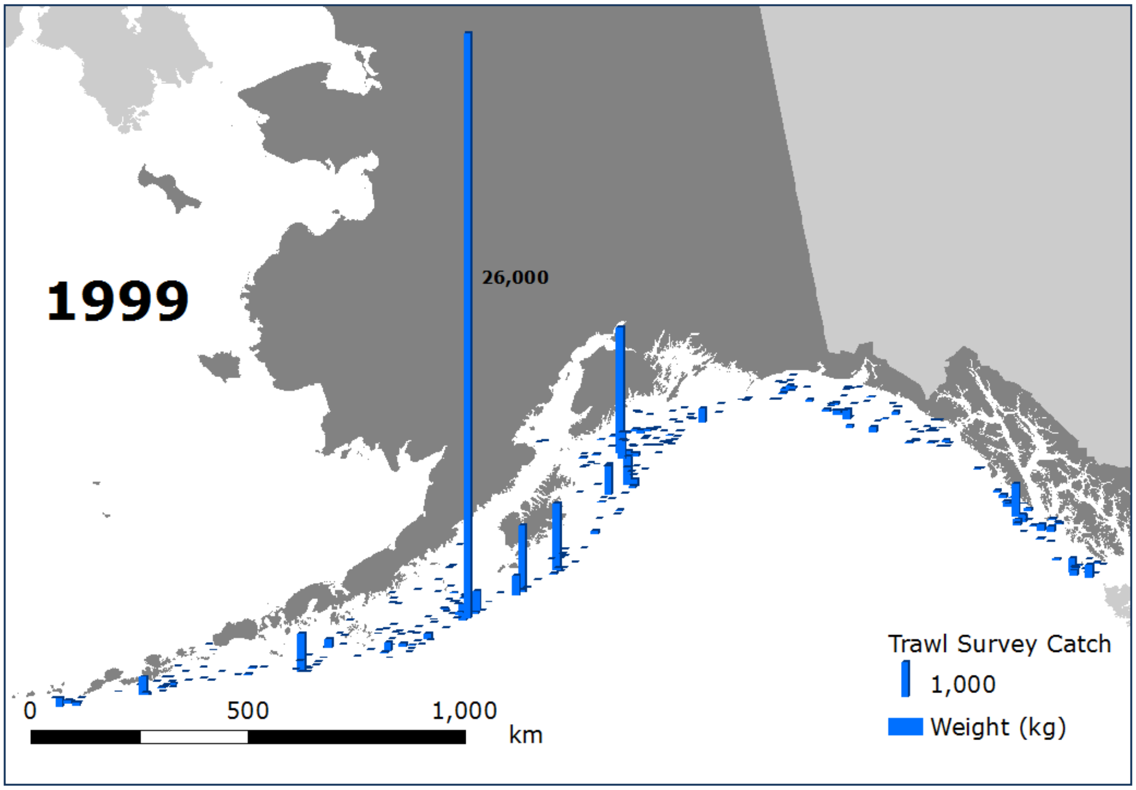

Figure 9-7a. Distribution of Gulf of Alaska Pacific ocean perch catches in the 1999 Gulf of Alaska groundfish survey.

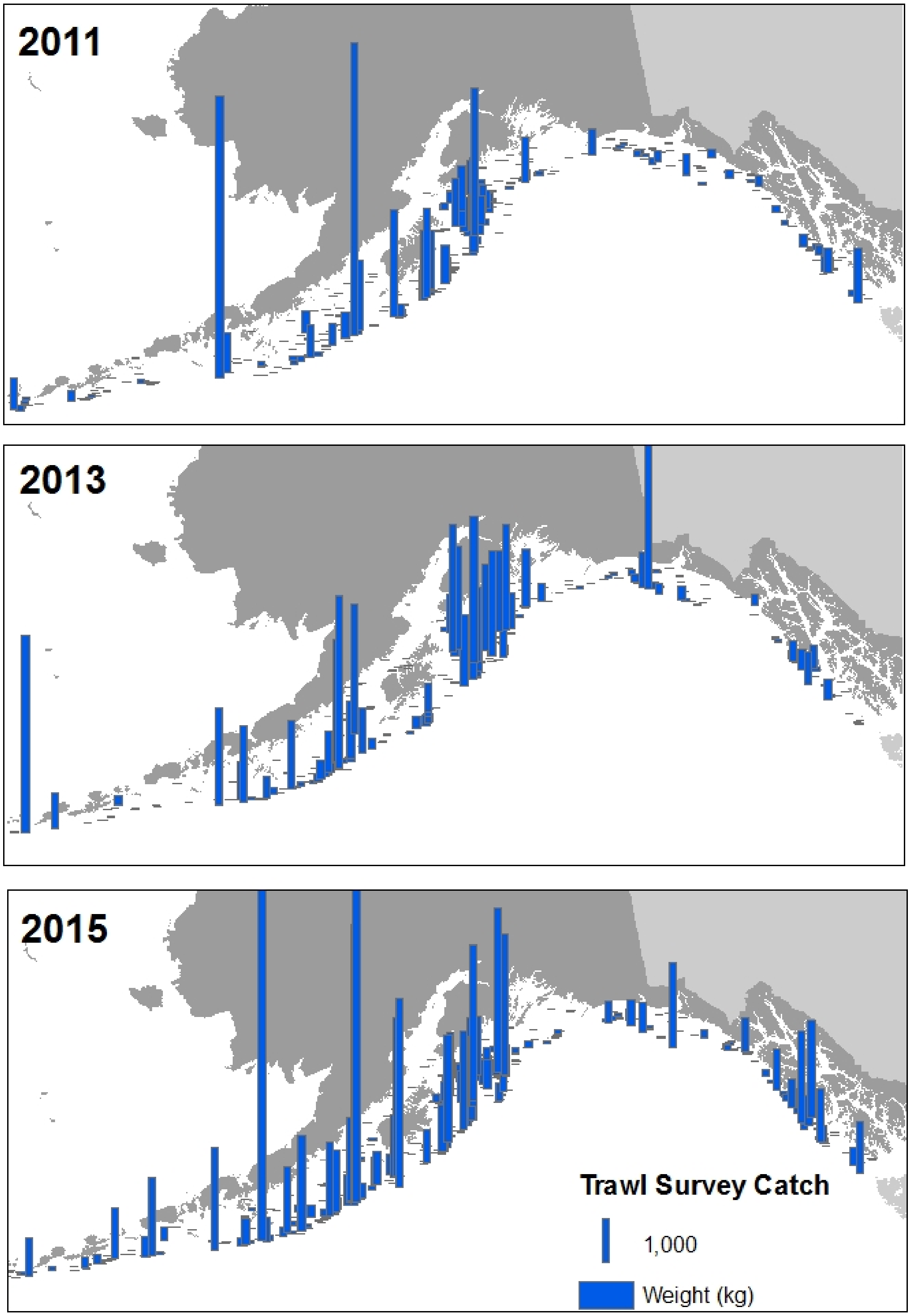

Figure 9-7b. Distribution of Gulf of Alaska Pacific ocean perch catches in the 2011-2015 Gulf of Alaska groundfish surveys.

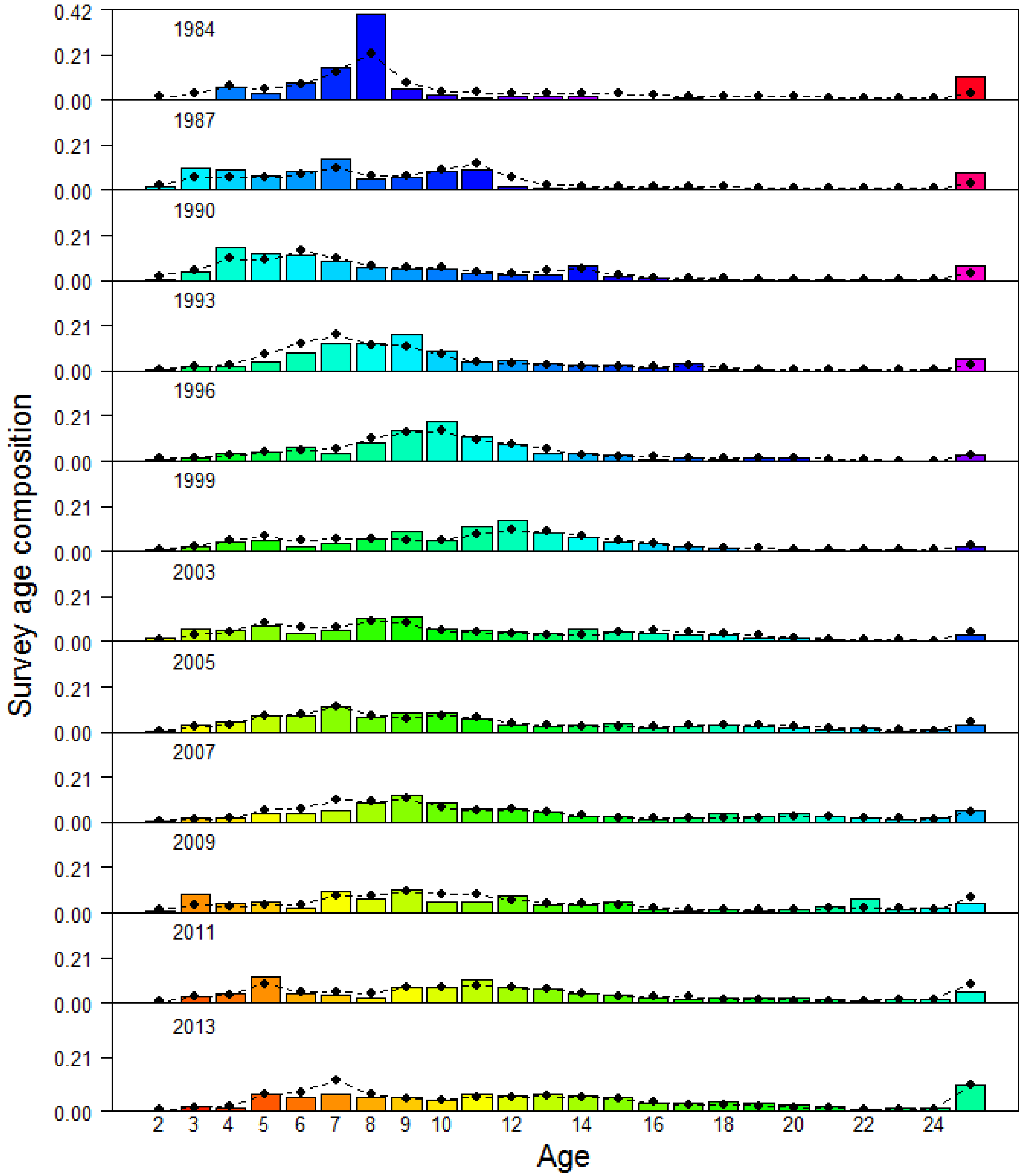

Figure 9-8. Groundfish survey age compositions for GOA Pacific ocean perch. Observed = bars, actual age composition predicted from author recommended model = line with circles.

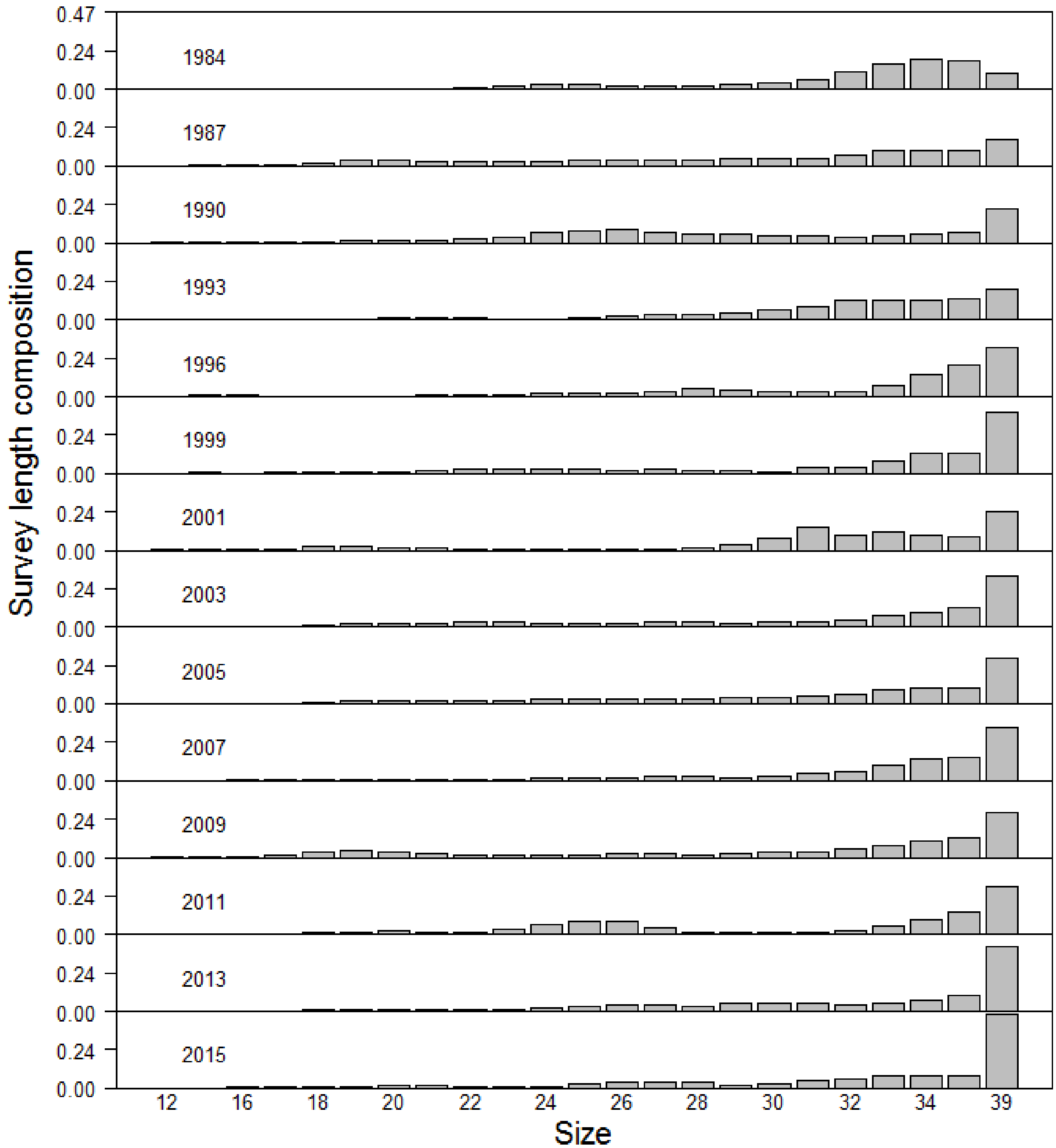

Figure 9-9. Groundfish survey length compositions for GOA Pacific ocean perch. Observed = bars. Survey size not used in Pacific ocean perch model because survey ages are available for these years.

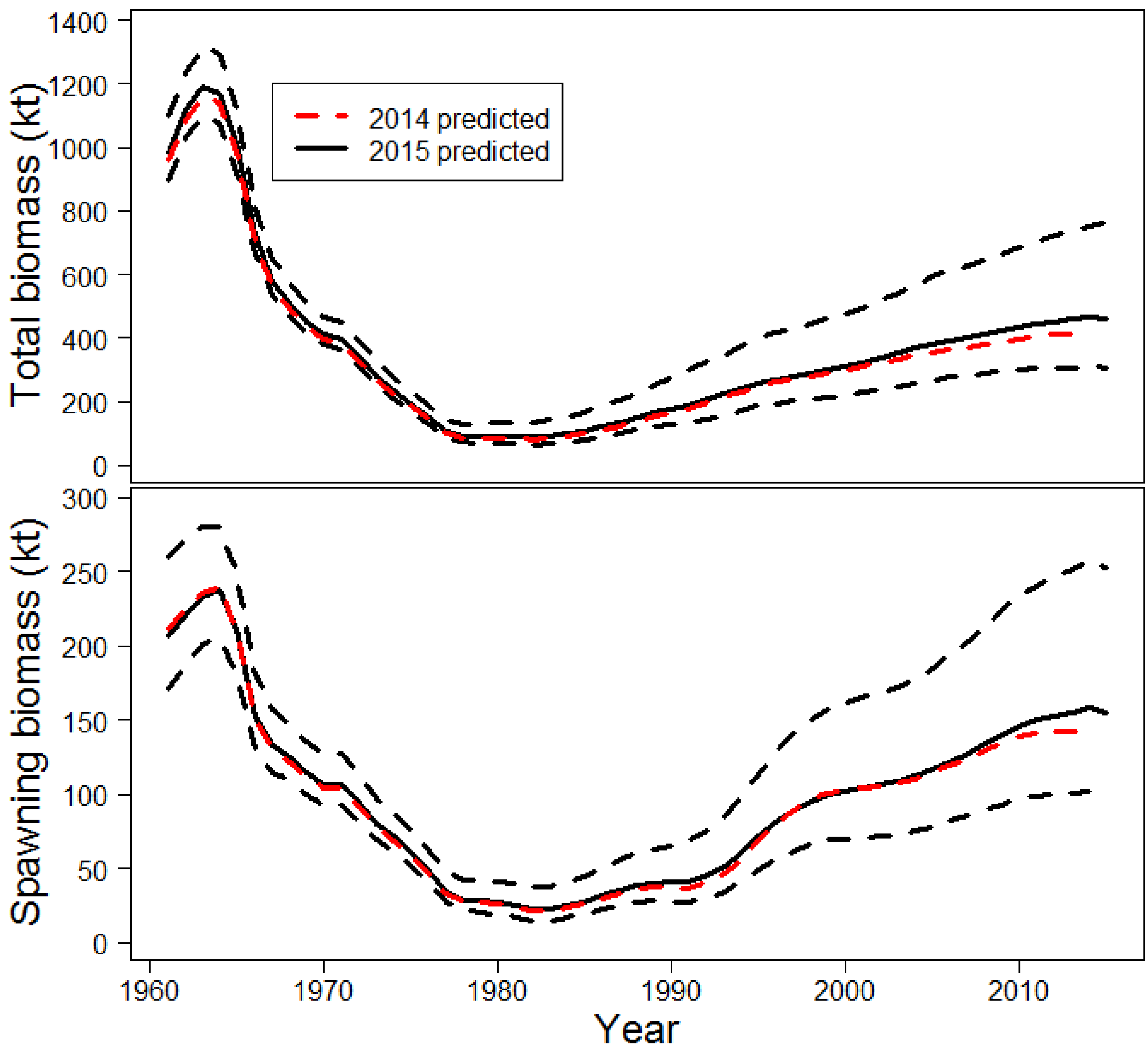

Figure 9-10. Model estimated total biomass (top panel, solid black line) and spawning biomass (bottom panel) with 95% credible intervals determined by MCMC (dashed black lines) for Gulf of Alaska Pacific ocean perch. Last year's model estimates included for comparison (dashed red line).

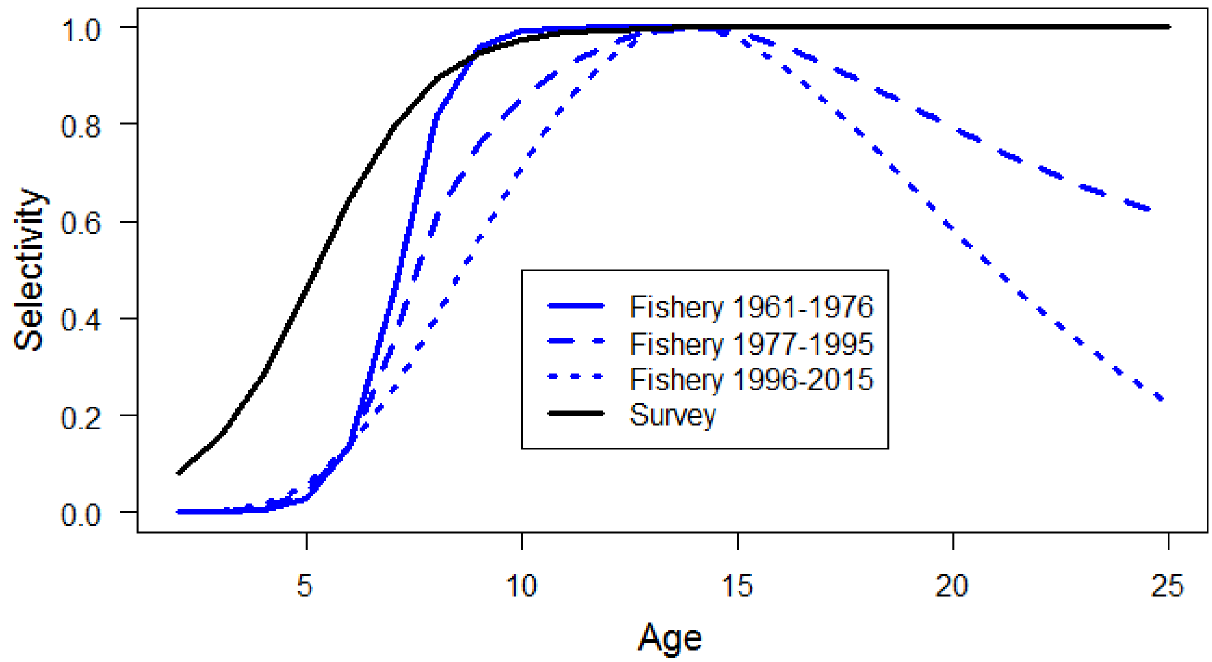

Figure 9-11. Estimated selectivities for the fishery for three periods and groundfish survey for Gulf of Alaska Pacific ocean perch.

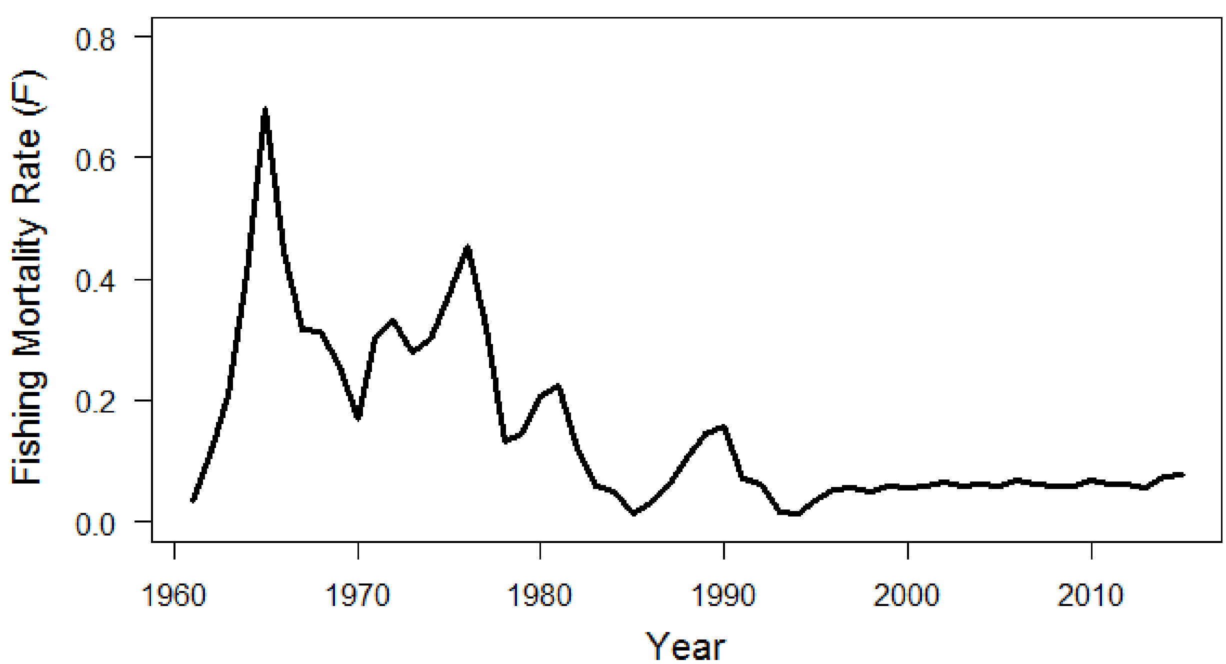

Figure 9-12. Estimated fully selected fishing mortality over time for GOA Pacific ocean perch.

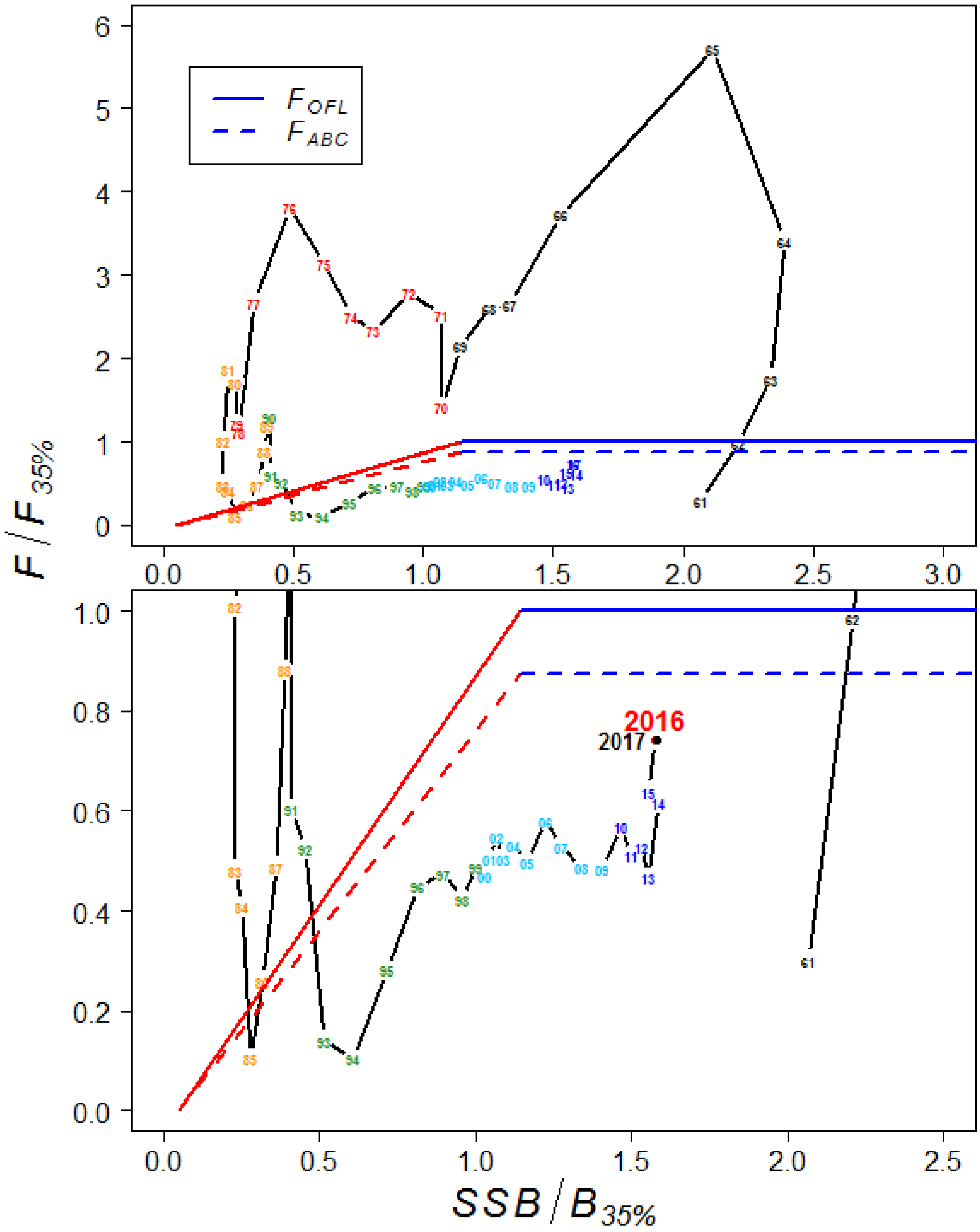

Figure 9-13. Time series of Pacific ocean perch estimated spawning biomass relative to the target level $B_{35\%}$ level and fishing mortality relative to $F_{35\%}$ for author recommended model. Top shows whole time series. Bottom shows close up on more recent management path.

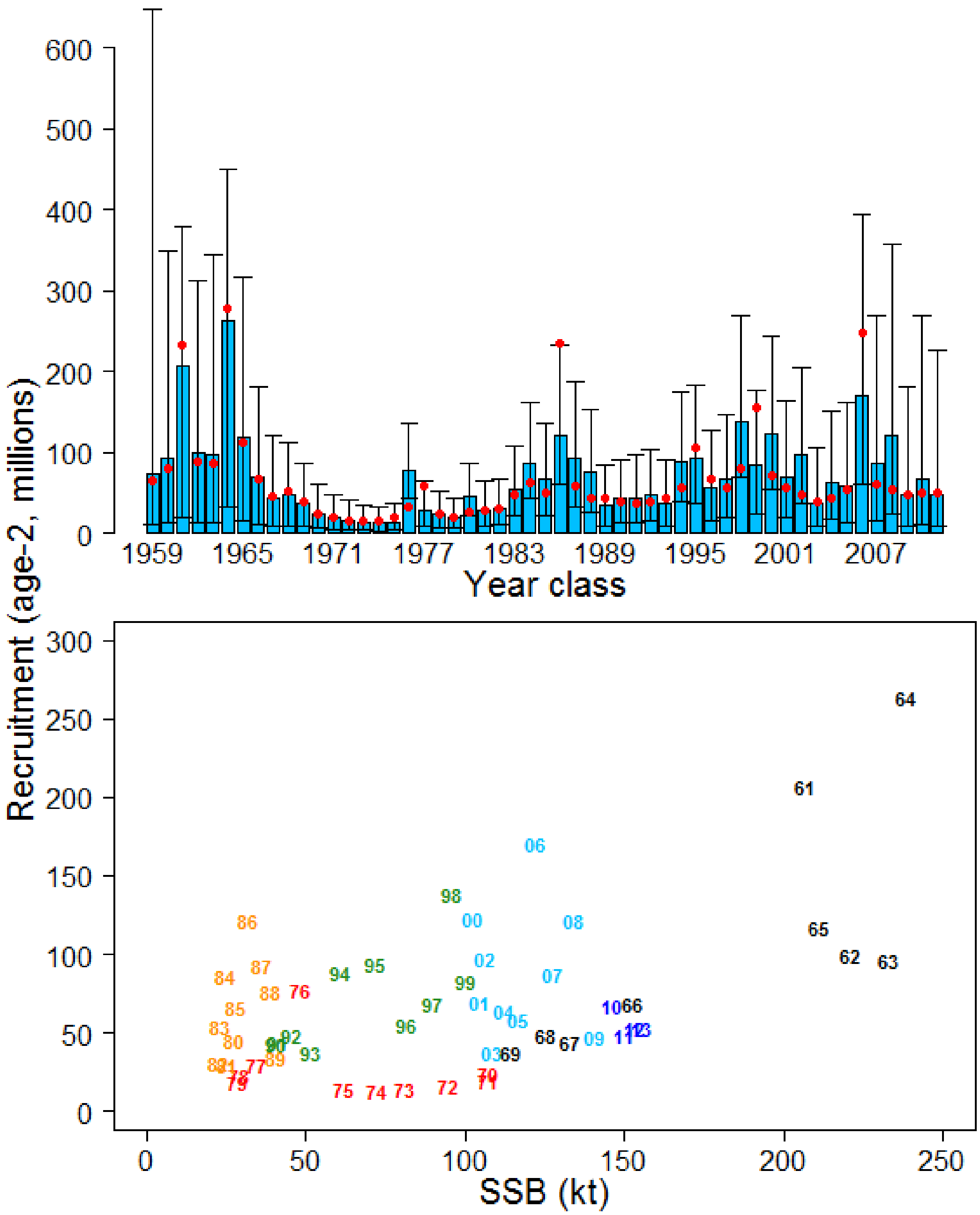

Figure 9-14. Estimated recruitment of Gulf of Alaska Pacific ocean perch (age 2) by year class with 95% credible intervals derived from MCMC (top). Estimated recruits per spawning stock biomass (bottom). Red circles in top graph are last year's estimates for comparison.

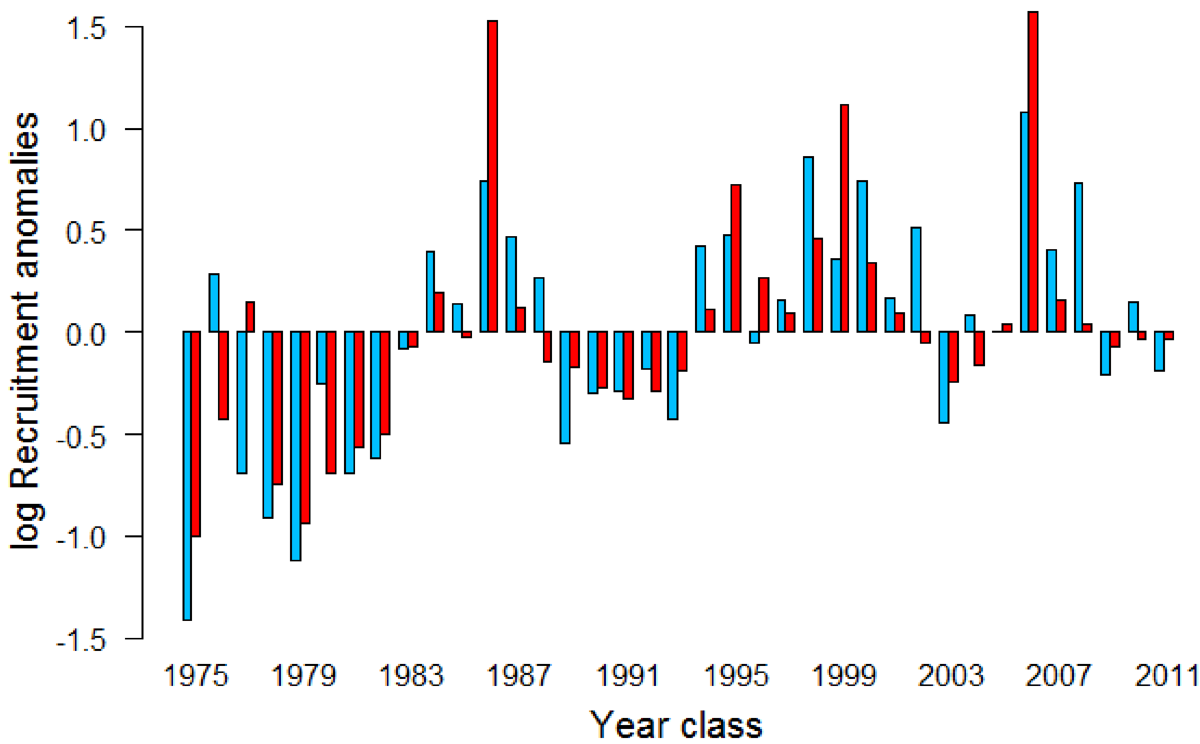

Figure 9-15. Recruitment deviations from average on the log-scale comparing last cycle's model (red) to current year recommended model (blue) for Gulf of Alaska Pacific ocean perch.

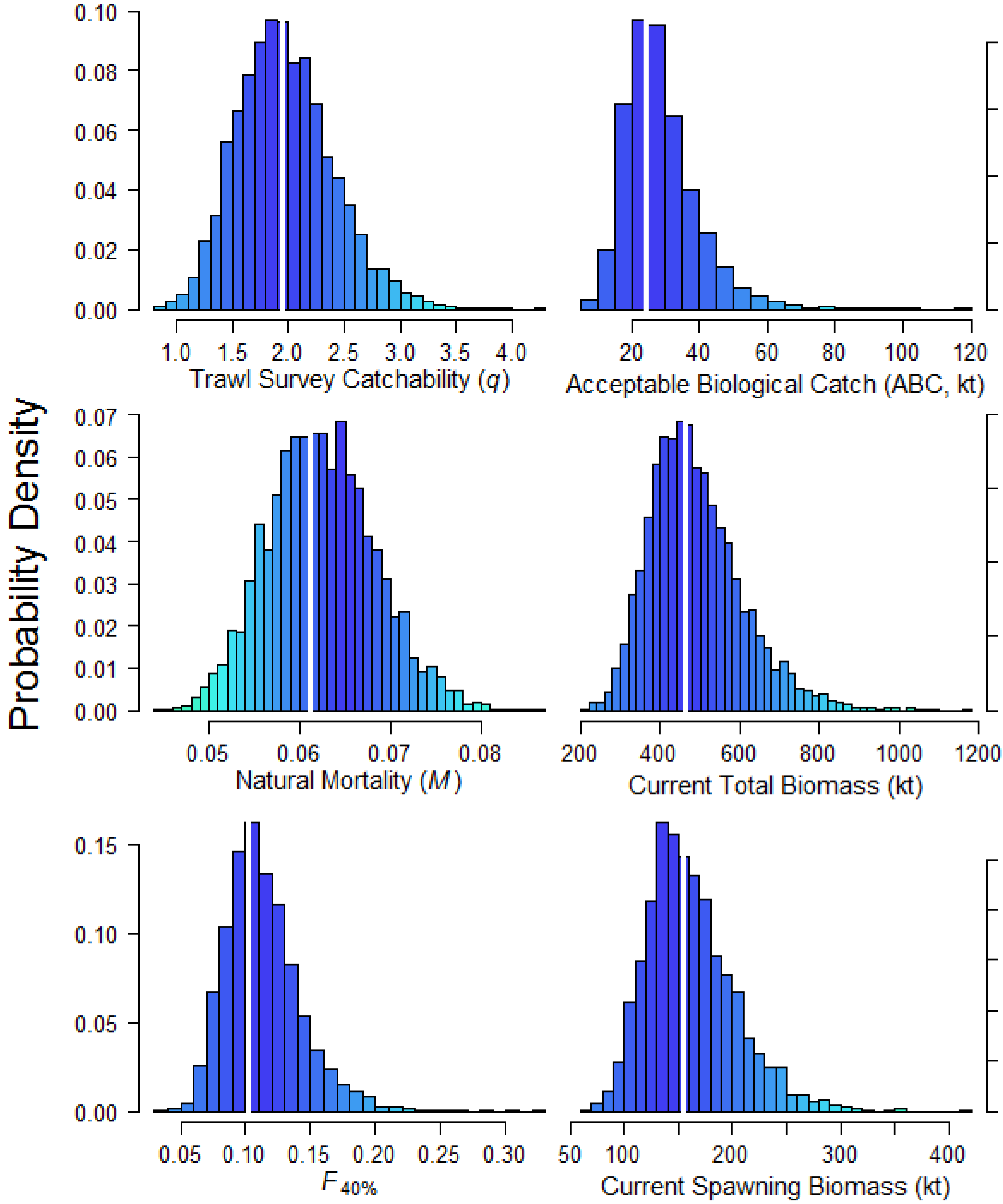

Figure 9-16. Histograms of estimated posterior distributions of key parameters derived from MCMC for Gulf of Alaska Pacific ocean perch. The vertical white lines are the recommended model estimates.

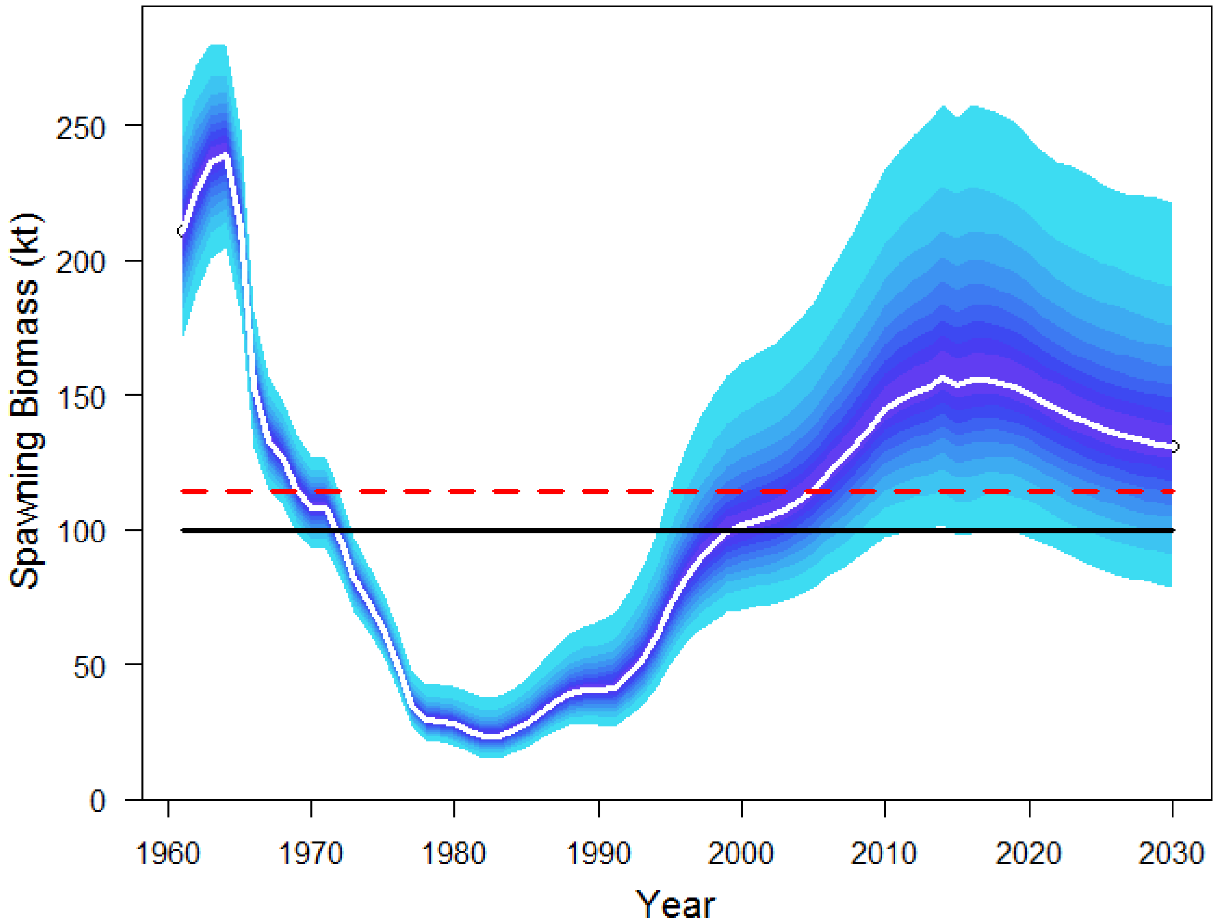

Figure 9-17. Bayesian credible intervals for entire spawning stock biomass series including projections through 2030. Red dashed line is $B_{40\%}$ and black solid line is $B_{35\%}$ based on recruitments from 1979-2013. The white line is the median of MCMC simulations. Each shade is 5% of the posterior distribution.

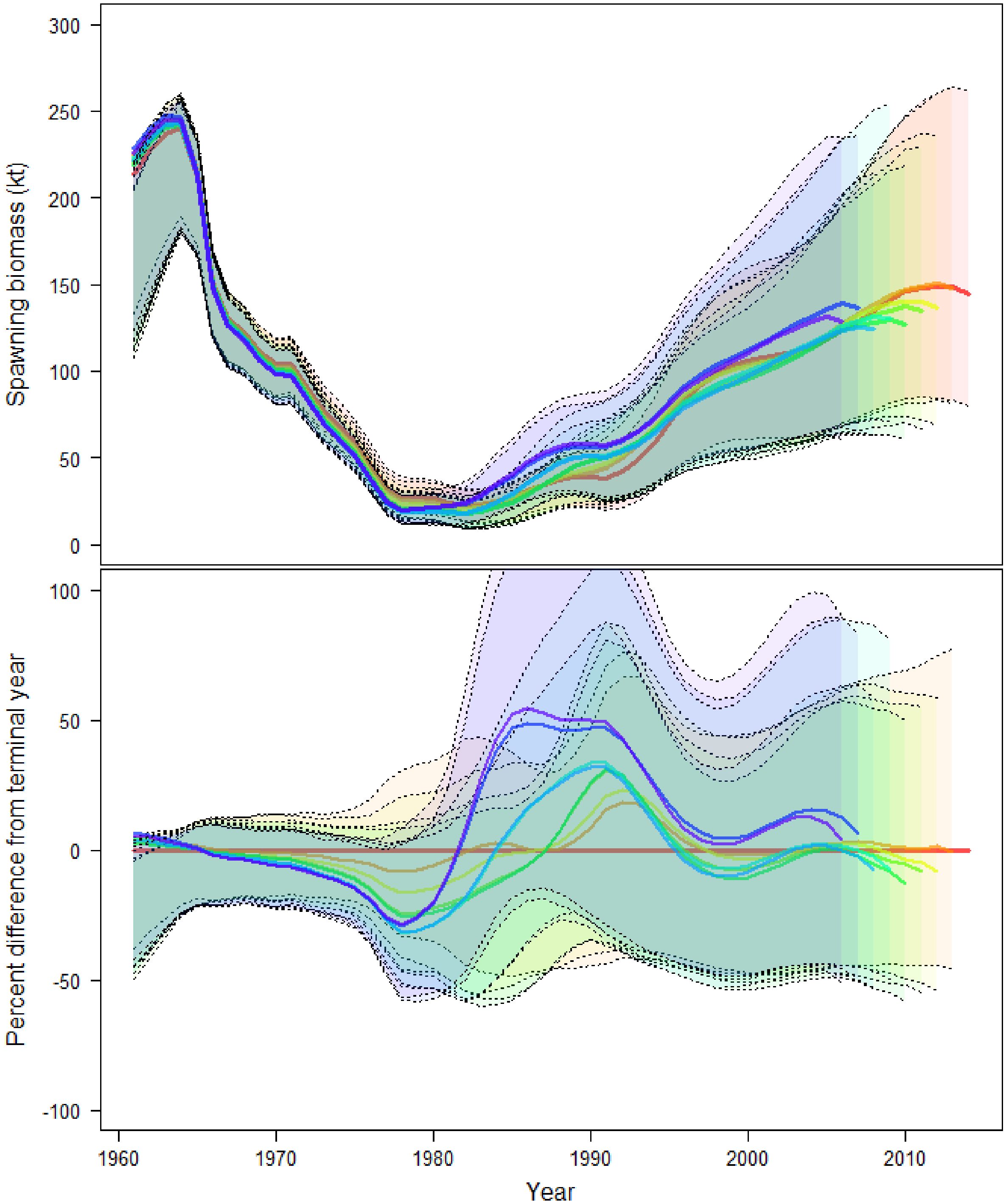

Figure 9-18. Retrospective peels of estimated female spawning biomass for the past 10 years from the recommended model with 95% credible intervals derived from MCMC (top), and the percent difference in female spawning biomass from the recommended model in the terminal year with 95% credible intervals 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
2014		4	<1	5

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.

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