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

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Executive Summary

Rockfish are assessed on a biennial stock assessment schedule to coincide with the availability of new survey data. For Gulf of Alaska rockfish in on-cycle (odd) years, we present a full stock assessment document with updated assessment and projection model results. However, due to the 2013 government shutdown, we do not present alternative model configurations in this year's assessment. Additionally, some sections may not have been fully updated from the 2011 assessment document.

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 on-cycle year, we update the 2011 assessment model estimates with new data collected since the last full assessment.

Summary of Changes in Assessment Inputs

Changes in the input data: The new data included are 2013 survey biomass estimates, 2011 survey age compositions, 2012 fishery age compositions, a final catch estimate for 2012 and a new catch estimate for 2013.

Changes in the assessment methodology: The assessment methodology is the same as the 2011 assessment with updated input data.

Summary of results

For the 2014 fishery, we recommend the maximum allowable ABC of 19,309 t from the updated model. This ABC is an 18% increase from the 2013 ABC of 16,412 t. This increase is attributed to a 67% increase in the survey biomass estimate from the previous survey and resulted in a 20% higher ABC than the 2014 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: 2013	2014	As estimated or recommended *this* year for: 2014	2015[1]
M (natural mortality)	0.062	0.062	0.061	0.061
Tier	3a	3a	3a	3a
Projected total (age 2+) biomass (t)	345,260	343,561	410,712	408,839
Female spawning biomass (t)				
Projected[2]				
Upper 95% confidence interval	n/a	n/a	227,402	225,707
Point Estimate	107,511	107,325	120,356	121,939
Lower 95% confidence interval	n/a	n/a	75,144	77,498
$B_{100\%}$	234,689	234,689	257,697	257,697
$B_{40\%}$	93,876	93,876	103,079	103,079
$B_{35\%}$	82,141	82,141	90,194	90,194
F_{OFL}	0.138	0.138	0.132	0.132
$maxF_{ABC}$	0.119	0.119	0.113	0.113
F_{ABC}	0.119	0.119	0.113	0.113
OFL (t)	**18,919**	18,601	**22,319**	22,849
maxABC (t)	16,412	16,133	**19,309**	19,764
ABC (t)	**16,412**	16,133	**19,309**	19,764
Status	As determined *last* year for: 2011	2012	As determined *this* year for: 2012	2013
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 2014 and 2015 are derived using estimated catch of 12,215 for 2013, and projected catches of 16,771 t and 17,166 t for 2014 and 2015 based on realized catches from 2010-2012. This calculation is in response to management requests to obtain more accurate projections

[2]Projected upper and lower 95% confidence intervals for female spawning biomass are derived from the MCMC estimated posterior distribution as presented in Table 9-15.

Area Apportionment

The apportionment percentages have changed with the addition of the 2013 survey biomass. The following table shows the recommended apportionment for 2014.

	Western	Central	Eastern	Total
Area Apportionment	10.8%	69.0%	20.2%	100%
Area ABC (t)	**2,086**	**13,323**	**3,900**	**19,309**
Area OFL (t)	2,412	15,399	4,508	**22,319**

Amendment 41 prohibited trawling in the Eastern area east of 140° W longitude. The ratio of biomass still obtainable in the W. Yakutat area (between 147° W and 140° W) is higher than last year at 0.71, a large increase from 0.48. This results in the following apportionment of the Eastern Gulf area:

	W. Yakutat	E. Yakutat/Southeast
Area ABC (t)	2,772	1,128
Area OFL (t)	3,205	1,303

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
Area OFL (t)	21,016

Summaries for Plan Team

Species	Year	Biomass[1]	OFL	ABC	TAC	Catch
Pacific ocean perch	2012	348,168	19,498	16,918	16,918	14,912
	2013	345,260	18,919	16,412	16,412	11,674
	2014	410,712	22,319	19,309		
	2015	408,839	22,849	19,764		

[1]Total biomass from the age-structured model

Stock/ Assemblage	Area	2013 OFL	ABC	TAC	Catch[2]	2014 OFL	ABC	2015 OFL	ABC
Pacific ocean perch	W		2,040	2,040	436		2,086		2,135
	C		10,926	10,926	9,701		13,323		13,637
	WYAK		1,641	1,641	1,537		2,772		2,838
	SEO	2,081	1,805	1,805	0	1,303	1,128	1,334	1,154
	W/C/WYK	16,838				21,016		21,515	
	Total	18,919	16,412	16,412	11,674	22,319	19,309	22,849	19,764

[2]Current as of October 4, 2013, Source: NMFS Alaska Regional Office via the Alaska Fisheries Information Network (AKFIN).

SSC and Plan Team Comments on assessments in General

Because of the government shutdown, there was only sufficient time to compile SSC and Plan Team comments. For the next full assessment, we will respond to all previous comments.

"Applying the stock structure template to rockfish species was discussed and the Team encouraged rockfish authors to use the template for at least one GOA rockfish species (and also one flatfish species). The Team noted that Dusky rockfish would be a good candidate for GOA rockfish and either flathead sole or rocksole as a candidate for GOA Flatfish." (November 2010)

We presented a stock structure analysis at the September, 2012 Joint Plan Team meeting and provided a document of the stock structure template as an appendix of the 2012 POP executive summary. Please refer to this document for further details regarding POP stock structure (http://www.afsc.noaa.gov/REFM/Docs/2012/GOApop.pdf).

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

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

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

"For the November 2012 SAFE report, the Teams recommend that authors conduct a retrospective analysis back 10 years (thus, back to 2002 for the 2012 assessments), and show the patterns for spawning biomass (both the time series of estimates and the time series of proportional changes relative to the 2012 run). This is consistent with a December 2011 NPFMC SSC request for stock assessment authors to conduct a retrospective analysis. The base model used for the retrospective analysis should be the author's recommended model, even if it differs from the accepted model from previous years." (Plan Team, September 2012)

SSC and Plan Team Comments specific to this assessment (not updated from 2012)

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

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

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

Introduction

Biology and distribution

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

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

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

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

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

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

Evidence of stock structure

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

In a study on localized depletion of Alaskan rockfish, Hanselman et al. (2007) showed that Pacific ocean perch are sometimes highly depleted in areas 5,000-10,000 km^2 in size, but a similar amount of fish return

in the following year. This result suggests that there is enough movement on an annual basis to prevent serial depletion and deleterious effects on stock structure.

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

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 Pilot Program (RPP). The intention of this program is to enhance resource conservation and improve economic efficiency for harvesters and processors in the rockfish fishery. This should spread out the fishery in time and space, allowing for better prices for product and reducing the pressure of what was an approximately two week fishery in July. In a comparison of catches in the four years before the RPP to the four years after, it appears some effort has shifted to area 620 (Chirikof) from area 630 (Kodiak) (Figure 9-21). The authors will pay close attention to the benefits and consequences of this action.

Since the original establishment of separate OFLs by management areas for POP in the rebuilding plan (Amendment 32) in 1994, the spawning stock biomass has tripled. The rebuilding plan required that female spawning biomass be greater than B_{msy} and the stock is now 35% higher than B_{msy}. Management has prosecuted harvest accurately within major management areas using ABC apportionments. While evidence of stock structure exists in the Gulf of Alaska, it does appear to be along an isolation by distance cline, not sympatric groups (Palof et al. 2011; Kamin et al. 2013)). Palof et al. (2011) also suggest that the Eastern GOA might be distinct genetically, but this area is already its own management unit, and has

additional protection with the no trawl zone. Hanselman et al. (2007) showed that POP are reasonably resilient to serial localized depletions (areas replenish on an annual basis). The NPFMC stock structure template was completed for Gulf of Alaska POP in 2012 (Hanselman et al. (2012a). Recommendations from this exercise were to continue to allocate ABCs by management area or smaller. However, the original rationale for area-specific OFLs from the rebuilding plan no longer exists because the overall population is above target levels and is less vulnerable to occasional overages. Therefore, in terms of rebuilding the stock, management area OFLs are no longer a necessity for the Gulf of Alaska POP stock.

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

Fishery

Historical Background

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

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

Detailed catch information for Pacific ocean perch in the years since 1977 is listed in Table 9-2. The reader is cautioned that actual catches of Pacific ocean perch in the commercial fishery are only shown for 1988-2012; for previous years, the catches listed are for the Pacific ocean perch complex (a former management grouping consisting of Pacific ocean perch and four other rockfish species), Pacific ocean perch alone, or all *Sebastes* rockfish, depending upon the year (see Footnote in Table 9-2). Pacific ocean perch make up the majority of catches from this complex. The acceptable biological catches and quotas in Table 9-2 are Gulfwide 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 Gulfwide 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 Pilot 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 is a five-year rationalization program that establishes cooperatives among trawl vessels and processors that receive exclusive harvest privileges for rockfish management groups. The primary rockfish management groups are northern rockfish, Pacific ocean perch, and pelagic shelf rockfish. Potential effects of this program on Pacific ocean perch include: 1) extended fishing season lasting from May 1 – November 15, 2) changes in spatial distribution of fishing effort within the Central GOA (e.g. Figure 9-21), 3) improved at-sea and plant observer coverage for vessels participating in the rockfish fishery, 4) and a higher potential to harvest 100% of the TAC in the Central GOA region. Recent data show that the Pilot project has resulted in much higher observer coverage of catch in the Central Gulf.

Hanselman et al. (2009) showed evidence that the fishery has changed over time and is more focused on younger fish and smaller boats. In response to this evidence it was suggested that we examine fishery age compositions by year, depth, and vessel size. We examine both the mean and the median because the presence of very old fish has consequences to modeling the plus group selectivity. Mean age has declined substantially from the first few years of fishery ages collected, while the median has remained steady because fewer very old fish are showing up in the catch (Figure 9-2a). Separated into three time blocks of an equal number of samples, the mean age has declined about two years from 14.8 to 12.2 in the most recent block (Figure 9-2b).There is a clear cline toward older fish starting with NMFS area 620 (Chirikof) toward NMFS area 650 (Southeast Alaska) which has been closed to trawling since 1998 (Figure 9-2c) . We examined ages by depth by parsing catch by bottom depth into intervals that contained equal sample sizes of catches. This showed a small increase in mean age with depth until the last depth interval (>161 m) which clearly contained older fish (Figure 9-2d). We examined age by vessel length by forming three groups of equal sample size. There was no obvious trend in mean or median age, except that the smallest vessels had the least variability in the ages they caught (Figure 9-2e).

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

Nominal catch rates (kg/minutes) have increased substantially since 1991 in the Gulf of Alaska. However, when compared to a measure of exploitable biomass (Age 6+), the increases in catch rate are coincident with a tripling of biomass during the same period. Increases in catch rates appear to be leveling off along with biomass estimates in recent years (Figure 9-3a). We also compared exploitation rate with CPUE and

it shows that exploitation rate has slowly risen since the 1994 and is now leveling off near around 4 or 5% (Figure 9-3b).

Bycatch and discards

Gulfwide discard rates[2] (% discarded) for Pacific ocean perch in the commercial fishery for 2000-2012 are listed as follows:

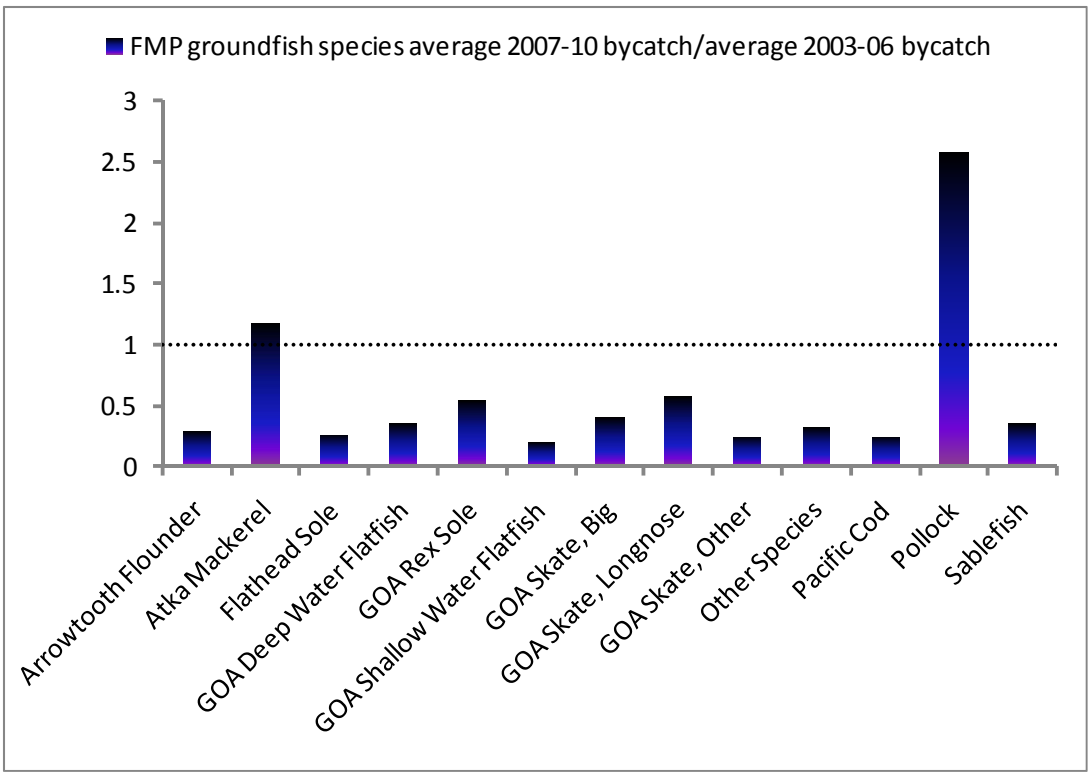
Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
% Discard	11.3	8.6	7.3	15.1	8.2	5.7	7.8	3.7	4.1	6.8	4.1

Year	2011	2012
% Discard	6.5	4.8

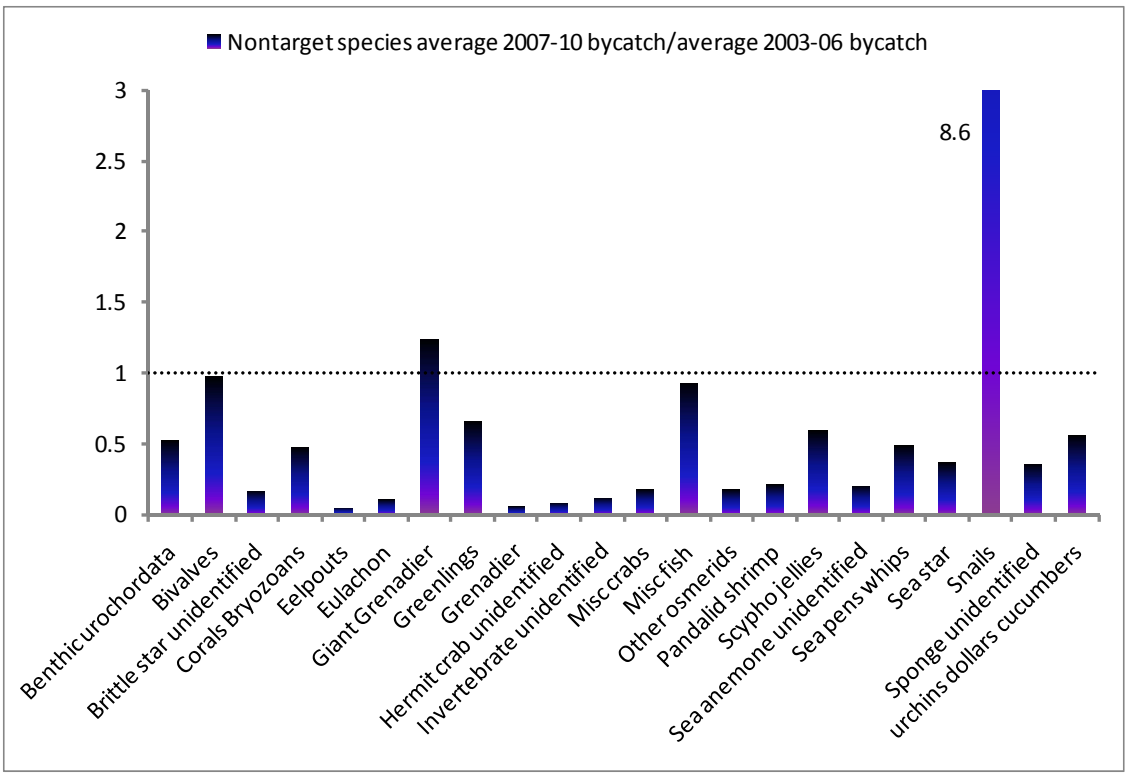
Since 1996, discard rates for Pacific ocean perch have generally decreased.

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

We compared bycatch from pre-2006 and post-2007 in the central GOA for the combined rockfish fisheries to determine impact of the Central GOA Rockfish Pilot Program implementation. We divided the average post-2006 bycatch (2007-2010) by the average pre-2007 bycatch (2003-2006) for non-rockfish species that had available information in both time periods. For the majority of FMP groundfish species, bycatch in the central GOA has been reduced since 2007, with the exception of Atka mackerel (214 t/year pre-2007 compared to 251 t/year post-2006) and walleye pollock (136 t/year pre-2007 compared to 352 t/year post-2006, see figure below):

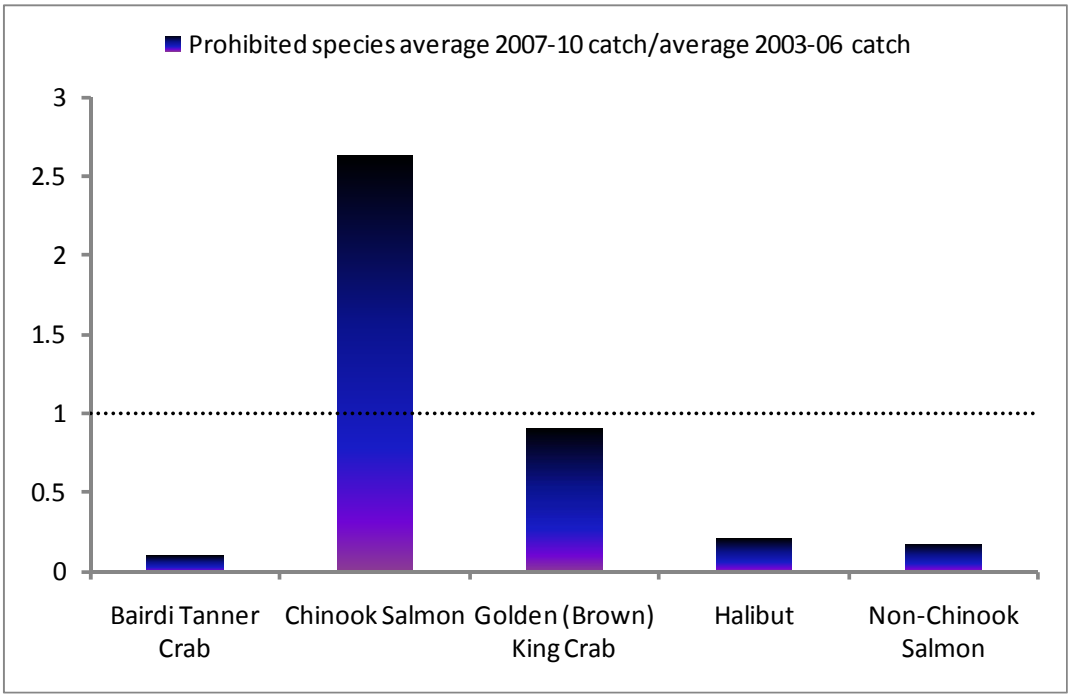


Non-FMP species catch in the rockfish target fisheries is dominated by giant grenadier (161 – 836 t), miscellaneous fish (135 – 196 t), and ocassionally dark rockfish (recently removed from FMP to state management, 13 – 112 t) (Table 9-5). Only 2 of 23 nontarget species for which bycatch data is available for the two time periods resulted in an increase in bycatch post-2006 compared to pre-2007, giant grenadier and snails (see figure below):



Prohibited species catch in the GOA rockfish fishery has been lower than average in 2011 and 2012 for all major species. The catch of golden king crab drecreased dramatically from over 3,000 animals in 2009 and 2010, to just over 100 in 2011 and 2012. (Table 9-6).

Catch of prohibited species for which data is available in the two time periods in the combined rockfish trawl fisheries has decreased since 2006 for 4 of 5 groups, with the exception of chinook salmon (see figure below):



Data

The following table summarizes the data used for this assessment:

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

Fishery

Catch

Catches range from 2,500 t to 350,000 t from 1961 to 2013. Detailed catch information for Pacific ocean perch is listed in Table 9-2 and shown graphically in Figure 9-1. This is the commercial catch history used in the assessment model. In response to Annual Catch Limits (ACLs) requirements, assessments now document all removals including catch that is not associated with a directed fishery. Research catches of Pacific ocean perch have been reported in previous stock assessments (Hanselman et al. 2009). Estimates of all removals not associated with a directed fishery including research catches are available and are presented in Appendix 9-A. In summary, research removals have typically been less than 100 t and very little is taken in recreational or halibut fisheries. These levels likely do not pose a significant risk to the Pacific ocean perch stock in the GOA.

Age and Size composition

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

Survey

Biomass Estimates from Trawl Surveys

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

Comparison of Trawl Surveys in 1984-2013

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

The biomass estimates for Pacific ocean perch were generally more imprecise between 1996-2001 than during 2003 through 2013 (Figure 9-6). Although more precise, a fluctuation in biomass of 60% in two surveys (e.g. 2003 to 2005) does not seem reasonable given the slow growth and low natural mortality rates of Pacific ocean perch. Large catches of an aggregated species like Pacific ocean perch in just a few individual hauls can greatly influence biomass estimates and may be a source of much variability. Anomalously large catches have especially affected the biomass estimates for Pacific ocean perch in the 1999 and 2001 surveys. While there are still several large catches, the distribution of Pacific ocean perch is becoming more uniform with more medium-sized catches in more places compared to previous surveys (for example compare 2009 and 2011 with 1999 Figures 9-7a, b). In past SAFE reports, we have speculated that a change in availability of rockfish to the survey, caused by unknown behavioral or environmental factors, may explain some of the observed variation in biomass. We repeat this speculation here and acknowledge that until more is known about rockfish behavior, the actual cause of changes in biomass estimates will remain the subject of conjecture. Previous research has focused on improving rockfish survey biomass estimates using alternate sampling designs (Quinn et al. 1999, Hanselman et al. 2001, Hanselman et al. 2003). Research on the utility of hydroacoustics in gaining survey precision was completed in 2011 (Hanselman et al. 2012b, Spencer et al. 2012) which confirmed again that there are ways to improve the precision, but all of them require more sampling effort in high POP density strata. In addition, there is a study underway exploring the density of fish in untrawlable grounds that are currently assumed to have an equal density of fish compared to trawlable grounds.

Biomass estimates of Pacific ocean perch were relatively low in 1984 to 1990, increased markedly in both 1993 and 1996, and became substantially higher in 1999 and 2001 with much uncertainty. Biomass estimates in 2003 have less sampling error with a total similar to the 1993 estimate indicating that the large estimates from 1996-2001 may have been a result of a few anomalous catches. However, in 2005 the estimate was similar to 1996-2001, but was more precise. To examine these changes in more detail, the biomass estimates for Pacific ocean perch in each statistical area, along with Gulfwide 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.

Age Compositions

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

Survey Size Compositions

Gulfwide 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.

Analytic Approach

Model Structure

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

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

Parameters Estimated Outside the Assessment Model

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). These data are summarized below (size is in cm fork length and age is in years) and the full maturity schedule is in Table 9-11:

Sample size	Size at 50% maturity	Age at 50% maturity
802	35.7	10

A recent study of Pacific ocean perch maturity was undertaken by Conrath and Knoth (2013). This study indicated an age of 50% of 8.4 years. The implications of this study will be examined in future assessments.

A von Bertalanffy growth curve was fitted to survey size at age data from 1984-1999 (Malecha et al. 2007). Sexes were combined. A size to age transition matrix 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. A second size to age matrix was adopted in 2003 to represent a lower density-dependent growth rate in the 1960s (Hanselman et al. 2003). The estimated parameters for the growth curve are shown below:

L_∞=41.4 cm κ=0.19 t_0=-0.47 n=9336

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_∞=984 g a=0.0004 b=2.45 n=3592

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

Parameters Estimated Inside the Assessment Model

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

Selectivity

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

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

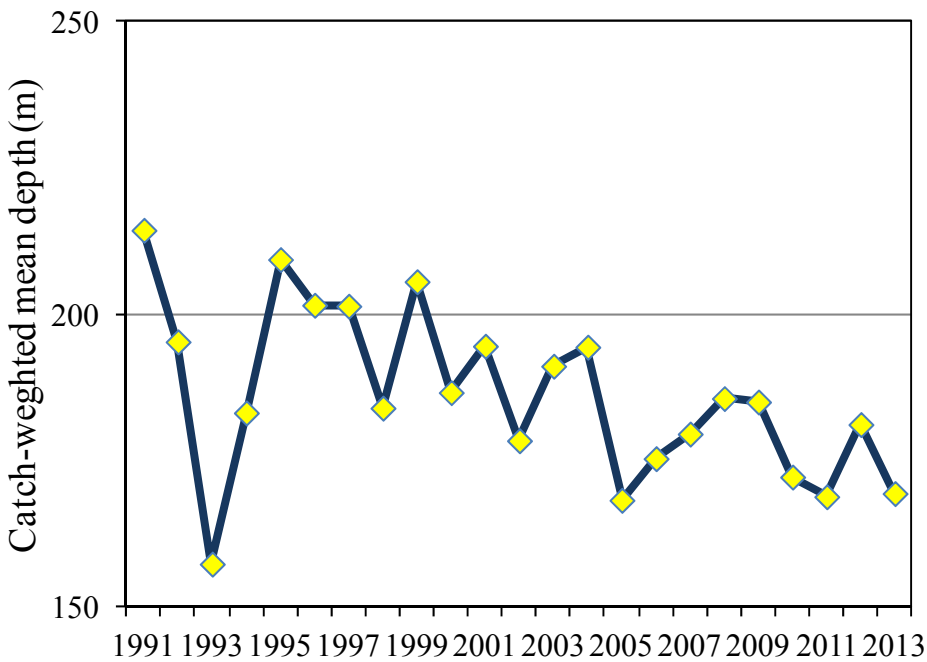


Figure. Change in catch-weighted mean depth of the Gulf of Alaska POP fishery over time.

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.

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	75
Average fishing mortality	μ_f	1
Fishing mortality deviations	ϕ_y	53
Fishery selectivity coefficients	fs_a	4
Survey selectivity coefficients	ss_a	2
Total		142

Uncertainty approach

Evaluation of model uncertainty has recently become an integral part of the "precautionary approach" in fisheries management (Hilborn et al. 2001). In complex stock assessment models, evaluating the level of uncertainty is difficult. One way is to examine the standard errors of parameter estimates from the Maximum Likelihood (ML) approach derived from the Hessian matrix. While these standard errors give some measure of variability of individual parameters, they often underestimate their variance and assume that the joint distribution is multivariate normal. An alternative approach is to examine parameter distributions through Markov Chain Monte Carlo (MCMC) methods (Gelman et al. 1995). When treated this way, our stock assessment is a large Bayesian model, which includes informative (e.g., lognormal natural mortality with a small CV) and noninformative (or nearly so, such as a parameter bounded between 0 and 10) prior distributions. In the model presented in this SAFE report, the number of parameters estimated is 142. In a low-dimensional model, an analytical solution might be possible, but in one with this many parameters, an analytical solution is intractable. Therefore, we use MCMC methods to estimate the Bayesian posterior distribution for these parameters. The basic premise is to use a Markov chain to simulate a random walk through the parameter space which will eventually converge to a stationary distribution which approximates the posterior distribution. Determining whether a particular chain has converged to this stationary distribution can be complicated, but generally if allowed to run long enough, it will converge. The "burn-in" is a set of iterations removed at the beginning of the chain. In our simulations we removed the first 1,000,000 iterations out of 10,000,000 and "thinned" the chain to one value out of every two thousand, leaving a sample distribution of 4,500. Further assurance that the chain had converged was to compare the mean of the first half of the chain with the second half after removing the "burn-in" and "thinning". Because these two values were similar we concluded that convergence had been attained. We use these MCMC methods to provide further evaluation of uncertainty in the results below including 95% credible intervals for some parameters.

BOX 1. AD Model Builder POP Model Description

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

BOX 1 (Continued)

Equations describing the observed data

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

Catch equation

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

Survey biomass index (t)

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

Survey age distribution
Proportion at age

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

Survey length distribution
Proportion at length

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

Fishery age composition
Proportion at age

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

Fishery length composition
Proportion at length

Equations describing population dynamics

Start year

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

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

This model is identical in all aspects to the model accepted in 2011 except for inclusion of new data. When we present alternative model configurations, our usual criteria for choosing a superior model are: (1) the best overall fit to the data (in terms of negative log-likelihood), (2) biologically reasonable patterns of estimated recruitment, catchabilities, and selectivities, (3) a good visual fit to length and age compositions, and (4) parsimony. Because the 2011 and 2013 models are identical and we are not providing alternative model configurations for comparison with the current model, we will only evaluate the 2013 model based on changes in results from 2011.

The model generally produces good visual fits to the data, and biologically reasonable patterns of recruitment, abundance, and selectivities. The model does not fit the 2013 survey estimate well, likely due to the large increase in this estimate compared to previous years that is difficult to explain in a long-lived species with our current model configuration. The 2013 update shows recent recruitment stabilizing and an increase in spawning and total biomass from previous projections. Therefore the, 2013 model is utilizing the new information effectively, and we use it to recommend 2014 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 approximately 400,000 t for 2013 (Figure 9-12). MCMC credible intervals indicate that the historic low is reasonably certain while recent increases are not quite as certain. These intervals also suggest that current biomass is likely between 250,000 and 750,000 t. Spawning biomass shows a similar trend, but is not as smooth as the estimates of total biomass (Figure 9-13). This is likely due to large year classes crossing a steep maturity curve. Spawning biomass estimates show a rapid increase between 1992 and 2000, and a slower increase (with considerable uncertainty) thereafter. Age of 50% selection is 5 and between 7 and 9 years for the survey and fishery, respectively (Figure 9-14). Fish are fully selected by both fishery and survey between 10 and 12. Current fishery selectivity is dome-shaped and matches well with the ages caught by the fishery. Catchability is slightly larger than 2 (2.09) and similar to that estimated in 2011 (2.03). The high catchability for POP is supported by several empirical studies using line transect densities counted from a submersible compared to trawl survey densities (Krieger 1993 [q=2.1], Krieger and Sigler 1996 [q=1.3], Hanselman et al. 2006[1] [q=2.1]).

Fully-selected fishing mortality shows that fishing mortality has decreased dramatically from historic rates and has leveled out in the last decade (Figure 9-15). Goodman et al. (2002) suggested that stock

[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.

assessment authors use a "management path" graph as a way to evaluate management and assessment performance over time. We chose to plot a phase plane plot of fishing mortality to F_{OFL} ($F_{35\%}$) and the estimated spawning biomass relative to unfished spawning biomass ($B_{100\%}$). Harvest control rules based on $F_{35\%}$ and $F_{40\%}$ and the tier 3b adjustment are provided for reference. The management path for Pacific ocean perch has been above the $F_{35\%}$ adjusted limit for most of the historical time series (Figure 9-16). In addition, since 1999, Pacific ocean perch SSB has been above $B_{40\%}$ and fishing mortality has been below $F_{40\%}$.

Recruitment

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

Uncertainty results

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

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 medians for spawning biomass and ABC, indicating possibilities of higher biomass estimates (also see Figure 9-19).

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 2011. 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 2013 estimates of these reference points are:

$B_{100\%}$	$B_{40\%}$	$B_{35\%}$	$F_{40\%}$	$F_{35\%}$
257,697	103,079	90,194	0.113	0.132

Specification of OFL and Maximum Permissible ABC

Female spawning biomass for 2014 is estimated at 120,356 t. This is above the $B_{40\%}$ value of 103,079 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 2014, yields the following ABC and OFL:

$F_{40\%}$	0.113
ABC	**19,309**
$F_{35\%}$	0.132
OFL	**22,319**

Our estimate of $F_{40\%}$ has been higher than past assessments since 2009 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 2013 numbers at age as estimated in the assessment. This vector is then projected forward to the beginning of 2014 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2013. 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 2013 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 2014, 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 2014 and 2015, 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 2010-2012 to the ABC recommended in the assessment for each of those years. For the remainder of the future years, maximum permissible ABC is used. (Rationale: In many fisheries the ABC is routinely not fully utilized, so assuming an average ratio catch to ABC will yield more realistic projections.)

Scenario 3: In all future years, F is set equal to 50% of max F_{ABC}. (Rationale: This scenario provides a likely lower bound on F_{ABC} that still allows future harvest rates to be adjusted downward when stocks fall below reference levels.)

Scenario 4: In all future years, F is set equal to the 2009-2013 average F. (Rationale: For some stocks, TAC can be well below ABC, and recent average F may provide a better indicator of F_{TAC} than F_{ABC}.)

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

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

Scenario 6: In all future years, F is set equal to F_{OFL}. (Rationale: This scenario determines whether a stock is overfished. If the stock is expected to be above 1) above its MSY level in 2013 or 2) above ½ of its MSY level in 2013 and above its MSY level in 2023 under this scenario, then the stock is not overfished.)

Scenario 7: In 2014 and 2015, 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 expected to be above its MSY level in 2026 under this scenario, then the stock is not approaching an overfished condition.)

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

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 2014, it does not provide the best estimate of OFL for 2015, because the mean 2014 catch under Scenario 6 is predicated on the 2014 catch being equal to the 2014 OFL, whereas the actual 2014 catch will likely be less than the 2014 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 (2012) is 14,912 t. This is less than the 2012 OFL of 19,498 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 2013:
a. If spawning biomass for 2013 is estimated to be below ½ $B_{35\%}$, the stock is below its MSST.
b. If spawning biomass for 2013 is estimated to be above $B_{35\%}$ the stock is above its MSST.
c. If spawning biomass for 2013 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 2023 is below $B_{35\%}$, the stock is below its MSST. Otherwise, the stock is above its MSST.

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

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

Specified catch estimation

In response to Gulf of Alaska Plan Team minutes in 2010, we have established a consistent methodology for estimating current-year and future year catches in order to provide more accurate two-year projections of ABC and OFL to management. In the past, two standard approaches in rockfish models have been employed; assume the full TAC will be taken, or use a certain date prior to publication of assessments as a final estimate of catch for that year. Both methods have disadvantages. If the author assumes the full TAC is taken every year, but it rarely is, the ABC will consistently be underestimated. Conversely, if the author assumes that the catch taken by around October is the final catch, and substantial catch is taken thereafter, ABC will consistently be overestimated. Therefore, going forward in the Gulf of Alaska rockfish assessments, for current year catch, we are applying an expansion factor to the official catch on or near October 1 by the 3-year average of catch taken between October 1 and December 31 in the last three complete catch years (e.g. 2010-2012 for this year, see example figures below). For Pacific ocean perch, the expansion factor for 2013 catch is 1.05.

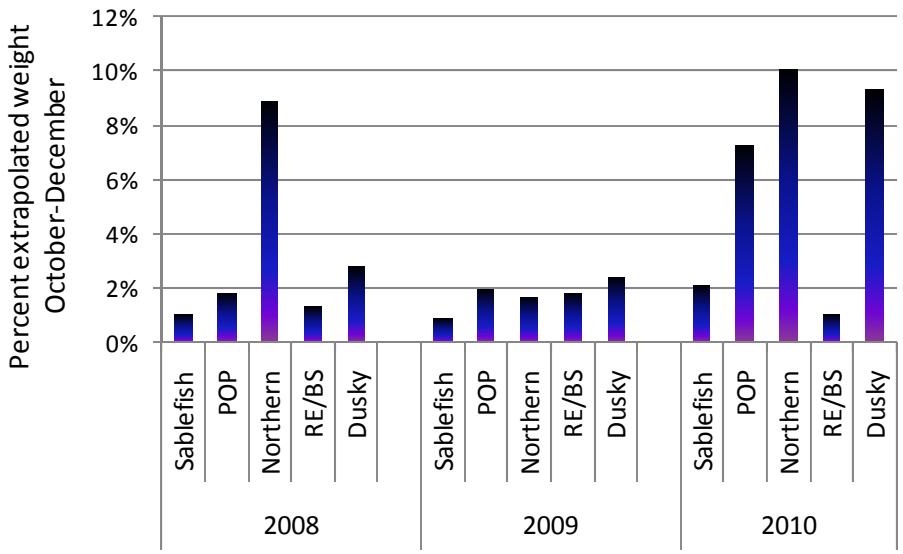


Figure. Extrapolated catch that occurs between October and December, 2008-2010.

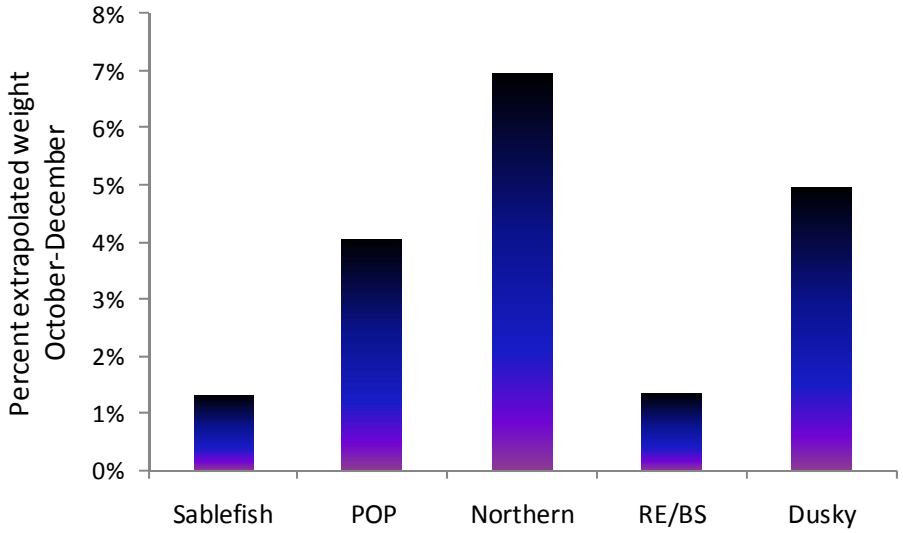


Figure. Examples of mean proportion of catch between October-December, 2008-2010.

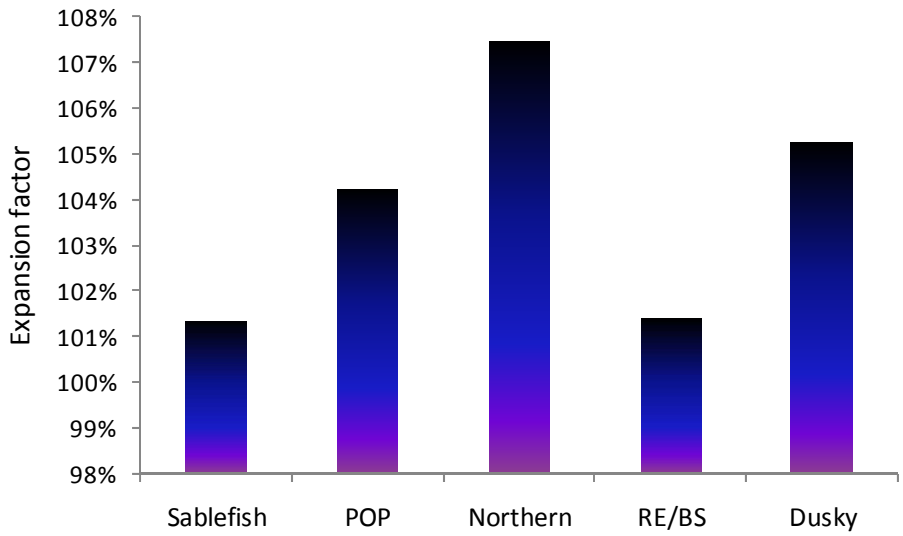


Figure. Expansion factor: $x = \sum_1^{12} C_y \,/\, \sum_1^{9} C_y$, where C_y is catch in month y.

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.

Alternate Projection

During the 2006 CIE review, it was suggested that projections should account for uncertainty in the entire assessment, not just recruitment from the endpoint of the assessment. We continue to present an alternative projection scenario using the uncertainty of the full assessment model, harvesting at maxABC (Alternative 1). This projection propagates uncertainty throughout the entire assessment procedure and is based on an MCMC chain of 10,000,000. The projection shows wide credibility intervals on future spawning biomass (Figure 9-20). The $B_{35\%}$ and $B_{40\%}$ reference points and future recruitments are based on the 1979-2011 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

For the 1996 fishery, an alternative method of apportionment was recommended by the Plan Team and accepted by the Council. Recognizing the uncertainty in estimation of biomass yet wanting to adapt to current information, the Plan Team chose to employ a method of weighting prior surveys based on the relative proportion of variability attributed to survey error. Assuming that survey error contributes 2/3 of the total variability in predicting the distribution of biomass (a reasonable assumption), the weight of a prior survey should be 2/3 the weight of the preceding survey. This results in weights of 4:6:9 for the 2009, 2011, and 2013 surveys, respectively and apportionments of 11% for the Western area, 69% for the Central area, and 20% for the Eastern area (Table 9-17). This results in recommended ABC's of **2,086** t for the Western area, **13,323** t for the Central area, and **3,900** t for the Eastern area.

Amendment 41 prohibited trawling in the Eastern area east of 140° W longitude. In the past, the Plan Team has calculated an apportionment for the West Yakutat area that is still open to trawling (between 147°W and 140°W). We calculated this apportionment using the ratio of estimated biomass in the closed area and open area. This calculation was based on the team's previous recommendation that we use the weighted average of the upper 95% confidence interval for the W. Yakutat. We computed this interval this year using the weighted average of the ratio for 2009, 2011, and 2013. We calculated the approximate upper 95% confidence interval using the weighted variance of the 2009-2013 ratios for our weighted ratio estimate. This resulted in higher ratio of 0.71, up from 0.48 in 2011. This results in an ABC apportionment of 2,772 t to the W. Yakutat area which would leave 1,128 t unharvested in the Southeast/Outside area.

Overfishing Definition

Based on the definitions for overfishing in Amendment 44 in tier 3a (i.e., $F_{OFL} = F_{35\%}$=0.132), overfishing is set equal to 22,319 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 21,016 t and 1,303 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 9-18.

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 Gulfwide 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) Update growth data for all rockfish, including age-age and age-length conversion matrices
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
4) Incorporate changes recommended by the 2013 CIE review

We plan to follow the recommendations listed in the various working group reports (e.g. the methods for averaging surveys report) submitted to the Plan Team in September 2012. In addition, we anticipate that many of the comments specific to the Pacific ocean perch assessment during the 2013 Center for Independent Experts (CIE) Alaska rockfish scientific peer review will be incorporated. 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.

Summary

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

	As estimated or specified *last* year for:		As estimated or recommended *this* year for:	
Quantity	2013	2014	2014	2015[1]
M (natural mortality)	0.062	0.062	0.061	0.061
Tier	3a	3a	3a	3a
Projected total (age 2+) biomass (t)	345,260	343,561	410,712	408,839
Female spawning biomass (t) Projected[2]				

Upper 95% confidence interval	n/a	n/a	227,402	225,707
Point Estimate	107,511	107,325	120,356	121,939
Lower 95% confidence interval	n/a	n/a	75,144	77,498
$B_{100\%}$	234,689	234,689	257,697	257,697
$B_{40\%}$	93,876	93,876	103,079	103,079
$B_{35\%}$	82,141	82,141	90,194	90,194
F_{OFL}	0.138	0.138	0.132	0.132
$maxF_{ABC}$	0.119	0.119	0.113	0.113
F_{ABC}	0.119	0.119	0.113	0.113
OFL (t)	**18,919**	18,601	**22,319**	22,849
maxABC (t)	16,412	16,133	**19,309**	19,764
ABC (t)	**16,412**	16,133	**19,309**	19,764
Status	As determined *last* year for:		As determined *this* year for:	
	2011	2012	2012	2013
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 2014 and 2015 are derived using estimated catch of 12,215 for 2013, and projected catches of 16,771 t and 17,166 t for 2014 and 2015 based on realized catches from 2010-2012. This calculation is in response to management requests to obtain more accurate projections

[2]Projected upper and lower 95% confidence intervals for female spawning biomass are derived from the MCMC estimated posterior distribution as presented in Table 9-15.

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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		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		Amendment 32 establishes rebuilding plan Assessment done with an age structured model using stock synthesis
1995	5,741	6,530	5,630		
1996	8,378	8,060	6,959		
1997	9,519	12,990	9,190		
1998	8,908	12,820	10,776		
1999	10,473	13,120	12,590		Eastern Gulf divided into West Yakutat and East Yakutat/Southeast Outside and separate ABCs and TACs assigned
2000	10,146	13,020	13,020		Amendment 41 became effective which prohibited trawling in the Eastern Gulf east of 140 degrees W.
2001	10,817	13,510	13,510		Assessment is now done using an age structured model constructed with AD Model Builder software
2002	11,734	13,190	13,190		
2003	10,847	13,663	13,660		
2004	11,640	13,336	13,340		
2005	11,248	13,575	13,580		
2006	13,595	14,261	14,261		
2007	12,954	14,636	14,636		Amendment 68 created the Central Gulf Rockfish Pilot Project
2008	12,461	14,999	14,999		
2009	12,736	15,111	15,111		
2010	15,616	17,584	17,584		
2011	14,213	16,997	16,997		
2012	14,912	16,918	16,918		
2013	11,674	16,412	16,412		Area OFL for W/C/WYK combined, SEO separate

Table 9-2. Commercial catch[a] (t) of fish of Pacific ocean perch in the Gulf of Alaska, with Gulfwide values of acceptable biological catch (ABC) and fishing quotas[b] (t), 1977-2010.

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

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 1991-2012 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; 1988-2012, Pacific ocean perch.

[b]Quota defined as follows: 1977-86, optimum yield; 1987, target quota; 1988-2012 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); 1991-2012, NMFS AKRO BLEND/Catch Accounting System via AKFIN database.

Table 9-3. FMP groundfish species caught in rockfish targeted fisheries in the Gulf of Alaska from 2008-2013. Conf. = Confidential because of less than three vessels or processors. . Source: NMFS AKRO Blend/Catch Accounting System via AKFIN 11/7/2013.

	Estimated Catch (t)					
Group Name	2008	2009	2010	2011	2012	2013
Pacific Ocean Perch	12,135	12,397	14,974	13,120	13,953	10,969
Northern Rockfish	3,805	3,855	3,833	3,163	4,883	4,365
Pelagic Shelf Rockfish	3,521	2,956	2,965	2,324	-	-
Dusky Rockfish	-	-	-	-	3,642	2,711
Atka Mackerel	1,744	1,913	2,148	1,404	1,173	1,161
Pollock	390	1,280	1,046	811	574	806
Arrowtooth Flounder	517	502	706	340	763	659
Pacific Cod	445	631	734	560	404	573
Other Rockfish	632	736	737	657	889	473
Sablefish	503	404	388	440	469	448
Rougheye Rockfish	104	97	179	286	219	269
Shortraker Rockfish	231	247	134	239	303	263
Demersal Shelf Rockfish	43	72	30	26	110	135
Thornyhead Rockfish	248	185	106	161	130	94
Shark	0	0	0	5	5	88
Rex Sole	67	83	93	51	72	83
Sculpin	0	0	0	39	55	69
Shallow Water Flatfish	71	53	47	48	65	26
Deep Water Flatfish	29	30	48	57	54	24
Flathead Sole	19	32	24	13	16	24
Skate, Longnose	12	17	12	25	23	20
Skate, Other	10	14	28	14	20	19
Squid	0	0	0	12	15	9
Skate, Big	4	4	14	8	13	2
Octopus	0	0	0	1	1	1

Table 9-4 . Catch (t) of GOA Pacific ocean perch as bycatch in other fisheries from 2008-2013. Source: NMFS AKRO Blend/Catch Accounting System via AKFIN 11/7/2013.

Target	2008	2009	2010	2011	2012	2013	Average
Rex Sole - GOA	79	420	359	291	92	713	326
Arrowtooth Flounder	163	76	83	562	496	253	272
Pollock - bottom	13	16	72	124	70	250	91
Pollock - midwater	37	4	24	48	224	132	78
Pacific Cod	17	43	9	20	53	12	26
Flathead Sole	2	2	74	2	2	19	17
Sablefish	13	25	19	17	17	4	16
Shallow Water Flatfish	2	3	0	2	3	20	5

Table 9-5. Non-FMP species bycatch estimates in tons for Gulf of Alaska rockfish targeted fisheries 2008 - 2013. Conf. = Confidential because of less than three vessels. Source: NMFS AKRO Blend/Catch Accounting System via AKFIN 11/7/2013.

	Estimated Catch (t)					
Group Name	2008	2009	2010	2011	2012	2013
Benthic urochordata	0.27	Conf.	0.08	Conf.	Conf.	Conf.
Birds	Conf.	0.03	-	Conf.	Conf.	6.48
Bivalves	0.00	Conf.	0.01	0.01	0.01	Conf.
Brittle star unidentified	0.04	0.03	0.02	0.01	0.03	0.03
Capelin	-	0.00	-	-	-	0.02
Corals Bryozoans	0.47	0.59	0.42	0.38	0.59	0.2
Dark Rockfish	17.86	46.98	112.03	12.82	59.03	42.28
Eelpouts	0.35	0.00	0.05	Conf.	0.3	Conf.
Eulachon	0.01	0.03	0.00	0.00	0.01	0.13
Giant Grenadier	161.3	684.57	539.49	418.91	347.87	836.31
Greenlings	14.73	8.1	9.52	7.91	9.05	7.35
Grenadier	3.43	3.11	34.94	110.49	89.67	9.00
Hermit crab unidentified	0.01	0.01	0.01	0.02	Conf.	0.03
Invertebrate unidentified	0.24	0.30	5.05	0.36	3.86	0.18
Lanternfishes	-	0.00	Conf.	-	-	Conf.
Misc crabs	0.07	0.10	0.07	0.04	0.05	0.01
Misc crustaceans	-	1.74	0.02	Conf.	-	Conf.
Misc deep fish	0.00	-	-	-	-	Conf.
Misc fish	195.64	134.74	167.1	133.25	156.73	160.98
Misc inverts (worms etc)	0.01	Conf.	-	Conf.	-	-
Other osmerids	Conf.	0.16	0.00	-	Conf.	0.00
Pacific Sand lance	-	-	-	Conf.	-	-
Pandalid shrimp	0.11	0.09	0.22	0.06	0.06	0.04
Polychaete unidentified	-	-	-	-	-	Conf.
Scypho jellies	0.11	0.70	1.87	0.00	0.16	0.47
Sea anemone unidentified	0.69	3.24	1.56	4.10	6.33	4.01
Sea pens whips	Conf.	0.01	0.01	0.04	-	0.02
Sea star	1.16	1.86	1.38	1.53	0.98	0.89
Snails	0.18	10.63	0.20	0.23	1.26	0.15
Sponge unidentified	2.97	6.65	3.66	4.41	1.39	1.32
Stichaeidae	-	0.01	-	-	-	Conf.
Urchins, dollars cucumbers	0.26	1.53	0.22	0.44	0.31	0.25

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 11/7/2013.

Group Name	2007	2008	2009	2010	2011	2012	Average
Bairdi Crab	0.16	0.06	0.62	0.10	0.03	0.09	0.18
Blue King Crab	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chinook Salmon	2.03	2.28	1.39	1.57	1.02	1.60	1.65
Golden K. Crab	0.13	0.34	3.28	3.00	0.13	0.11	1.17
Halibut	137	160	112	141	108	109	128
Herring	0.02	0.04	0.00	0.15	0.00	0.00	0.04
Other Salmon	0.72	0.50	0.47	0.37	0.21	0.31	0.43
Opilio Crab	0.00	0.00	0.14	0.00	0.00	0.00	0.02
Red King Crab	0.00	0.00	0.00	0.00	0.00	0.00	0.00

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

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

Length (cm)	Year 2008	2009	2010	2011	2012	2013
12	0	0	0	0	0	0
13-15	0	0	0	0	0	0
16	0	0	0	0	0	0
17	0	0	0	0	0	0
18	0	0	0	0.001	0	0
19	0	0.001	0	0.001	0	0
20	0	0	0.002	0.001	0.001	0.001
21	0	0	0.001	0.001	0.003	0
22	0.001	0.001	0.003	0.001	0.005	0.001
23	0.002	0	0.005	0.002	0.008	0.004
24	0.002	0.001	0.004	0.002	0.008	0.004
25	0.003	0.002	0.003	0.003	0.010	0.009
26	0.003	0.003	0.003	0.003	0.015	0.013
27	0.003	0.005	0.004	0.003	0.014	0.016
28	0.008	0.006	0.005	0.005	0.010	0.016
29	0.012	0.008	0.006	0.007	0.009	0.021
30	0.016	0.013	0.008	0.010	0.009	0.022
31	0.025	0.023	0.014	0.012	0.012	0.021
32	0.04	0.042	0.025	0.020	0.021	0.012
33	0.063	0.071	0.042	0.033	0.031	0.015
34	0.093	0.099	0.074	0.060	0.051	0.030
35-38	0.473	0.498	0.551	0.551	0.521	0.487
>38	0.255	0.227	0.248	0.284	0.271	0.326
Total	8,154	8,898	11,174	9,800	12,882	8,167

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

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

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

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

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

Table 9-11. Estimated numbers (thousands) in 2013, 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 2013 (1000's)	Maturity (%)	Weight (g)	Fishery selectivity (%)	Survey selectivity (%)
2	46,457	0	46	0	4
3	44,064	0	106	0	11
4	39,819	0	180	0	24
5	42,166	0	261	2	45
6	44,423	0	342	6	68
7	182,715	12	420	16	85
8	33,374	20	493	31	94
9	25,242	30	559	49	97
10	21,082	42	619	68	99
11	22,812	56	672	84	100
12	23,209	69	718	95	100
13	25,688	79	758	100	100
14	49,372	87	792	98	100
15	21,597	92	822	92	100
16	13,018	95	847	82	100
17	13,656	97	868	70	100
18	19,548	98	886	58	100
19	9,627	99	902	46	100
20	6,306	99	915	36	100
21	5,333	100	926	27	100
22	4,802	100	935	20	100
23	4,719	100	943	15	100
24	4,998	100	950	11	100
25+	66,426	100	970	7	100

Table 9-12. Summary of results from 2013 compared with 2011 results

	2011	**2013**
Likelihoods		
Catch	0.11	0.12
Survey Biomass	7.29	10.06
Fishery Ages	24.69	26.99
Survey Ages	45.85	47.59
Fishery Sizes	55.48	55.71
Data-Likelihood	133.4	140.5
Penalties/Priors		
Recruitment Devs	21.05	23.28
F Regularity	4.11	4.15
σ_r prior	5.02	4.76
q prior	1.26	1.36
M prior	2.15	2.00
Objective Fun Total	167.0	176.0
Parameter Ests.		
Active parameters	138	142
q	2.03	2.09
M	0.062	0.061
σ_r	0.90	0.92
Mean Recruitment (millions)	46.29	46.36
$F_{40\%}$	0.119	0.113
Total Biomass	348,168	410,712
$B_{CURRENT}$	107,769	120,356
$B_{100\%}$	234,689	257,697
$\mathbf{B_{40\%}}$	93,876	103,079
maxABC	16,918	**19,309**
$F_{35\%}$	0.138	0.132
$OFL_{F35\%}$	19,498	**22,319**

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

Parameter	μ	μ (MCMC)	Median (MCMC)	σ	σ(MCMC)	BCI-Lower	BCI-Upper
q	2.089	1.979	1.928	0.510	0.492	1.181	3.054
M	0.061	0.062	0.062	0.006	0.006	0.051	0.074
$F_{40\%}$	0.113	0.124	0.120	0.026	0.031	0.075	0.193
2014 SSB	120,356	136,772	131,526	33,575	39,066	75,144	227,402
2014 ABC	19,309	23,179	21,807	6,794	8,968	8,859	44,561

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

	Spawning biomass (t)		6+ Biomass (t)		Catch/6+ biomass		Age 2 recruits (1000's)	
Year	Previous	Current	Previous	Current	Previous	Current	Previous	Current
1977	27,838	27,585	94,773	93,797	0.228	0.229	17,916	17,282
1978	23,291	22,980	78,031	76,923	0.103	0.104	31,701	30,977
1979	23,011	22,669	74,560	73,310	0.111	0.114	56,858	54,603
1980	22,289	21,908	70,601	69,205	0.153	0.157	22,792	22,095
1981	20,262	19,829	64,736	63,185	0.162	0.168	18,740	18,347
1982	18,092	17,598	62,939	61,212	0.086	0.089	23,833	23,382
1983	18,040	17,493	73,871	71,566	0.038	0.040	27,478	26,625
1984	19,663	19,036	79,889	77,350	0.034	0.036	29,671	28,600
1985	21,526	20,815	84,623	81,946	0.009	0.010	46,593	45,072
1986	24,430	23,636	92,275	89,474	0.024	0.025	58,483	58,464
1987	27,339	26,450	99,159	96,154	0.045	0.047	45,291	44,613
1988	29,733	28,738	104,112	100,851	0.082	0.085	228,851	217,676
1989	30,563	29,459	109,349	105,712	0.108	0.113	64,758	66,294
1990	30,148	28,935	114,988	111,364	0.114	0.118	46,447	45,787
1991	29,601	28,305	116,904	113,157	0.056	0.058	40,612	40,462
1992	31,621	30,252	174,727	168,157	0.037	0.039	36,141	36,239
1993	37,676	36,055	196,415	189,965	0.01	0.011	34,391	34,717
1994	45,606	43,817	216,866	210,155	0.008	0.009	35,183	35,966
1995	55,074	53,077	234,015	227,268	0.025	0.025	37,994	39,240
1996	64,455	62,238	243,737	237,113	0.034	0.035	52,093	54,634
1997	73,332	70,871	248,147	241,798	0.038	0.039	90,679	99,952
1998	80,692	78,071	249,809	243,937	0.036	0.037	60,402	62,162
1999	86,202	83,542	251,477	246,287	0.042	0.043	50,938	52,189
2000	89,394	86,781	254,376	250,293	0.04	0.041	76,085	75,574
2001	91,232	88,792	267,860	266,813	0.04	0.041	119,228	149,929
2002	92,559	90,508	274,147	274,475	0.043	0.043	59,101	67,591
2003	93,189	91,575	276,856	278,379	0.039	0.039	46,331	53,094
2004	94,322	93,242	286,713	288,908	0.041	0.040	44,708	45,761
2005	96,133	95,623	307,821	318,916	0.037	0.035	43,474	37,571
2006	99,506	100,183	315,371	330,581	0.043	0.041	57,505	40,587
2007	102,246	104,120	316,137	334,968	0.041	0.039	75,432	49,172
2008	105,101	108,366	315,686	336,454	0.039	0.037	78,864	249,793
2009	108,065	112,814	314,149	334,567	0.041	0.039	47,114	56,816
2010	110,391	116,586	314,732	331,212	0.05	0.047	46,561	50,656
2011	107,304	118,372	317,547	326,607	0.042	0.043	46,335	44,992
2012		119,111		376,194		0.040		46,839
2013		118,145		381,472		0.032		46,457

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	17,282	4,004	52,173	101,448	84,921	139,401	27,585	21,396	39,961
1978	30,977	6,630	89,884	85,309	69,110	123,867	22,980	17,029	35,604
1979	54,603	10,074	122,663	84,720	68,051	125,355	22,669	16,601	35,786
1980	22,095	4,898	68,035	84,347	66,886	128,023	21,908	15,741	35,419
1981	18,347	4,249	51,352	81,639	62,771	128,843	19,829	13,804	33,489
1982	23,382	5,333	61,542	79,462	59,484	130,264	17,598	11,662	31,532
1983	26,625	5,531	71,833	82,834	61,792	138,272	17,493	11,457	32,049
1984	28,600	5,522	82,746	89,025	66,698	147,867	19,036	12,595	34,526
1985	45,072	8,444	123,448	96,186	72,271	158,558	20,815	14,017	37,242
1986	58,464	9,753	149,086	106,993	81,263	175,379	23,636	16,514	41,090
1987	44,613	7,222	177,702	117,422	89,976	191,986	26,450	18,814	45,148
1988	217,676	36,528	405,796	134,419	101,871	220,063	28,738	20,597	49,422
1989	66,294	9,102	265,066	150,251	112,116	248,858	29,459	20,783	51,625
1990	45,787	6,997	137,782	164,421	120,336	278,844	28,935	19,470	52,938
1991	40,462	6,829	119,818	177,299	127,522	305,143	28,305	18,032	54,388
1992	36,239	5,952	106,214	195,523	139,972	335,849	30,252	19,527	58,645
1993	34,717	6,378	102,749	211,550	150,947	363,616	36,055	23,334	68,028
1994	35,966	6,727	111,410	229,822	164,962	392,141	43,817	29,421	80,898
1995	39,240	6,151	122,339	246,053	178,378	416,825	53,077	36,346	95,904
1996	54,634	8,336	183,889	256,802	186,604	432,649	62,238	42,962	111,019
1997	99,952	11,317	247,445	265,904	193,537	447,834	70,871	48,846	125,590
1998	62,162	8,643	230,336	273,983	197,697	465,119	78,071	53,688	137,643
1999	52,189	7,917	195,252	282,662	204,605	483,148	83,542	57,373	147,345
2000	75,574	9,260	283,767	290,559	210,408	498,355	86,781	59,042	154,347
2001	149,929	11,449	340,366	303,055	218,901	523,268	88,792	60,152	159,098
2002	67,591	9,533	264,806	315,899	228,123	547,619	90,508	60,941	162,188
2003	53,094	7,741	175,364	327,839	235,617	570,421	91,575	61,312	165,947
2004	45,761	7,281	147,564	339,591	243,131	591,412	93,242	62,109	169,796
2005	37,571	5,923	127,332	348,326	247,987	610,774	95,623	63,901	175,004
2006	40,587	6,618	154,566	355,002	250,997	622,199	100,183	66,634	183,360
2007	49,172	7,304	265,086	357,190	252,222	631,587	104,120	69,698	191,635
2008	249,793	17,190	573,681	367,486	258,249	645,294	108,366	72,442	200,265
2009	56,816	8,000	389,781	378,730	262,908	666,708	112,814	74,843	208,565
2010	50,656	7,191	293,070	389,669	266,132	689,151	116,586	76,787	216,017
2011	44,992	6,848	218,088	396,949	265,199	706,610	118,372	76,884	220,754
2012	46,839	6,429	252,689	403,230	266,417	726,414	119,111	76,714	224,908
2013	46,457	6,914	244,394	406,436	266,783	735,054	118,145	74,376	223,804
2014	61,474	5,984	294,223	410,712	268,244	754,302	120,356	75,144	227,402
2015	61,474	5,766	274,606	408,839			121,939	77,498	225,707

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. $B_{40\%}$ = 103,079 t, $B_{35\%}$ = 90,194 t, $F_{40\%}$ = 0.113, and $F_{35\%}$ = 0.132.

Year	Maximum permissible F	Author's F* (prespecified catch)	Half maximum F	5-year average F	No fishing	Overfished	Approaching overfished
			Spawning biomass (t)				
2013	118,146	118,146	118,146	118,146	118,146	118,146	118,146
2014	120,056	120,356	121,223	120,705	122,406	119,679	120,056
2015	120,741	121,939	125,412	123,315	130,353	119,271	120,741
2016	121,875	123,720	130,092	126,366	139,123	119,355	121,506
2017	123,100	124,901	135,029	129,566	148,622	119,528	121,602
2018	123,261	124,990	139,000	131,723	157,591	118,659	120,628
2019	122,183	123,814	141,560	132,515	165,303	116,652	118,489
2020	120,527	122,050	143,229	132,531	172,073	114,201	115,899
2021	118,327	119,735	143,821	131,702	177,350	111,380	112,936
2022	116,288	117,585	144,096	130,774	181,815	108,860	110,283
2023	114,671	115,868	144,454	130,092	185,935	106,855	108,155
2024	113,468	114,575	144,980	129,704	189,838	105,345	106,525
2025	112,594	113,619	145,689	129,576	193,653	104,232	105,297
2026	111,876	112,824	146,397	129,528	197,166	103,335	104,293
			Fishing mortality				
2013	0.072	0.072	0.072	0.072	0.072	0.072	0.072
2014	0.113	0.098	0.057	0.082	-	0.132	0.132
2015	0.113	0.098	0.057	0.082	-	0.132	0.132
2016	0.113	0.113	0.057	0.082	-	0.132	0.132
2017	0.113	0.113	0.057	0.082	-	0.132	0.132
2018	0.113	0.113	0.057	0.082	-	0.132	0.132
2019	0.113	0.113	0.057	0.082	-	0.132	0.132
2020	0.113	0.113	0.057	0.082	-	0.132	0.132
2021	0.113	0.113	0.057	0.082	-	0.132	0.132
2022	0.113	0.113	0.057	0.082	-	0.132	0.132
2023	0.113	0.113	0.057	0.082	-	0.131	0.131
2024	0.113	0.113	0.057	0.082	-	0.130	0.130
2025	0.113	0.113	0.057	0.082	-	0.129	0.129
2026	0.113	0.113	0.057	0.082	-	0.128	0.128
			Yield (t)				
2013	12,215	12,215	12,215	12,215	12,215	12,215	12,215
2014	19,309	19,309	9,844	14,073	-	22,319	19,309
2015	19,579	19,764	10,342	14,554	-	22,373	19,579
2016	19,927	20,297	10,874	15,082	-	22,534	23,035
2017	19,991	20,324	11,267	15,404	-	22,375	22,819
2018	19,602	19,891	11,412	15,378	-	21,714	22,095
2019	18,832	19,074	11,306	15,025	-	20,664	20,978
2020	17,902	18,096	11,026	14,482	-	19,494	19,743
2021	17,033	17,185	10,681	13,911	-	18,456	18,648
2022	16,339	16,455	10,350	13,413	-	17,662	17,807
2023	15,853	15,939	10,080	13,035	-	17,080	17,219
2024	15,553	15,617	9,889	12,785	-	16,644	16,781
2025	15,397	15,449	9,781	12,653	-	16,398	16,516
2026	15,316	15,363	9,728	12,592	-	16,266	16,367

*Projected ABCs and OFLs for 2014 and 2015 are derived using estimated catch of 12,215 for 2013, and projected catches of 16,771 t and 17,166 t for 2014 and 2015 based on realized catches from 2010-2012. This calculation is in response to management requests to obtain more accurate projections.

Table 9-17. Apportionment of ABC and OFL for 2014 Pacific ocean perch in the Gulf of Alaska.

		Western	Central		Eastern		
Year	Weights	Shumagin	Chirikof	Kodiak	Yakutat	Southeast	Total
2009	4	5%	32%	38%	15%	10%	100%
2011	6	13%	25%	44%	9%	9%	100%
2013	9	12%	22%	46%	14%	6%	100%
Weighted mean	19	11%	25%	44%	12%	8%	100%
Area Apportionment		**10.8%**	**69.0%**		**20.2%**		
Area ABC		**2,086**	**13,323**		**3,900**		**19,309**
Subarea OFLs		2,412	15,399		4,508		22,319
2014 OFL		Western/Central/W.Yakatut				SEO	
		21,016				**1,303**	

Table 9-18. Summary of ecosystem considerations for Gulf of Alaska Pacific ocean perch. (not updated from 2011)

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

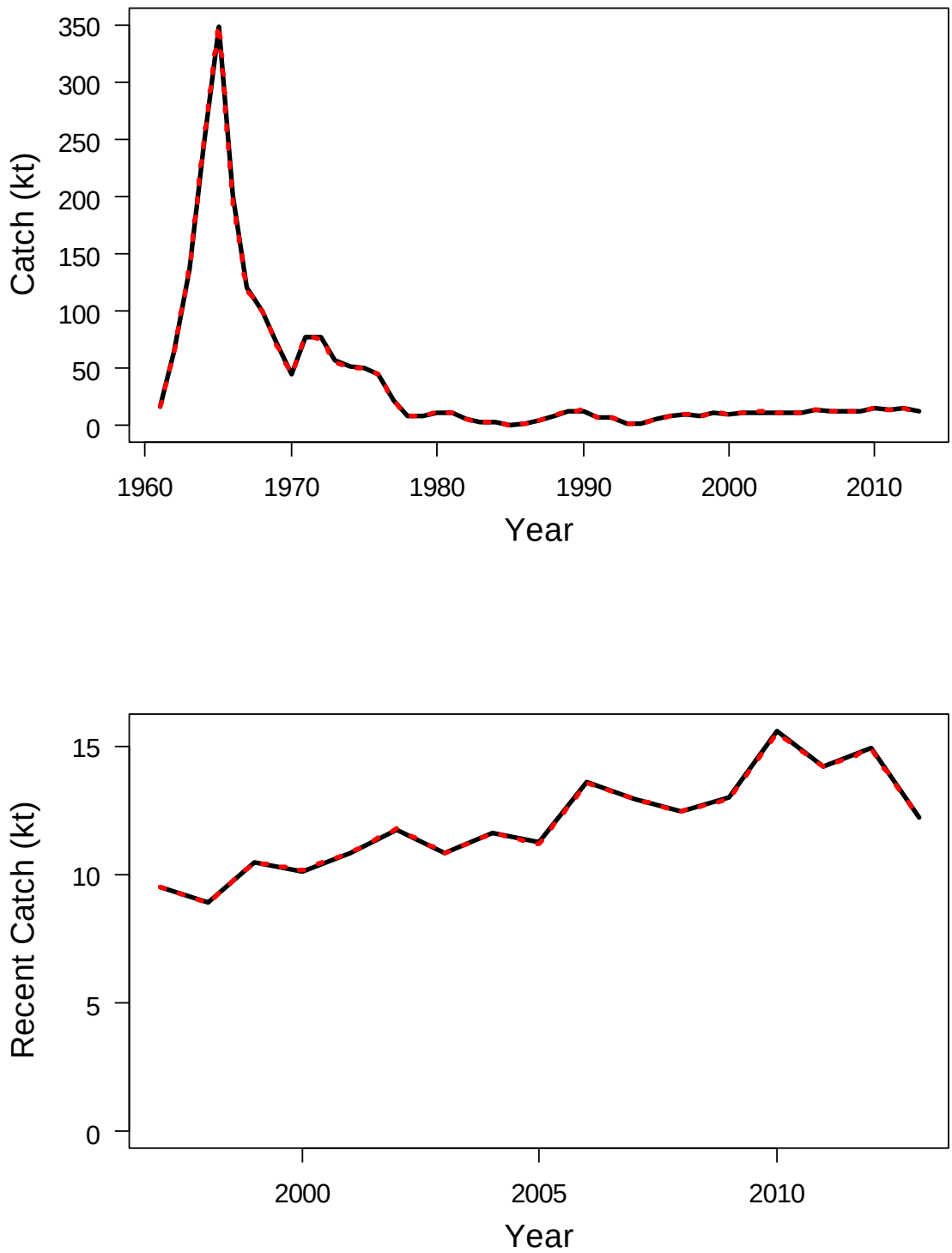


Figure 9-1. Estimated and observed long-term (a) and short-term (b) catch history for Gulf of Alaska Pacific ocean perch.

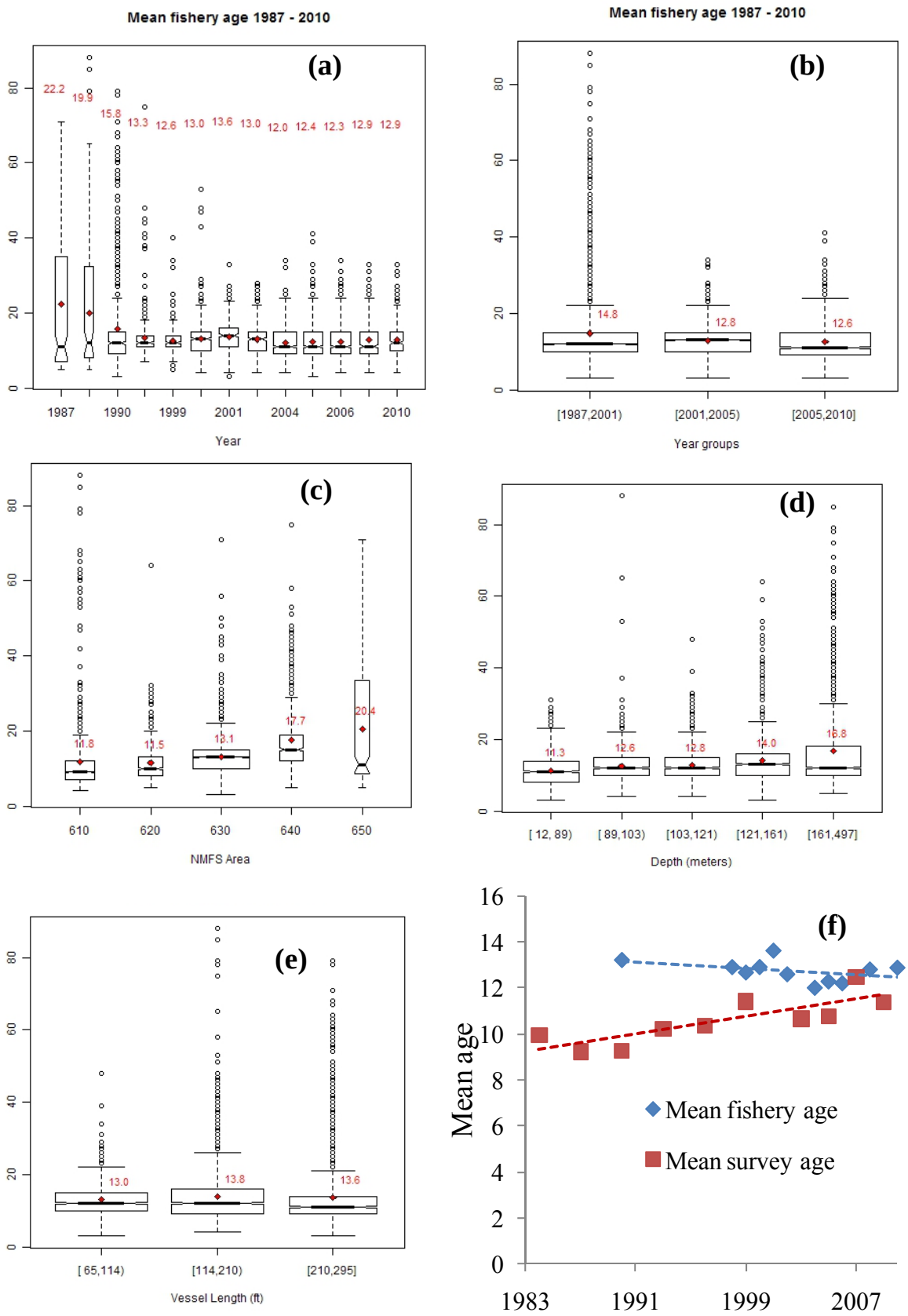


Figure 9-2. Comparisons of age compositions across time, depth, NMFS area, and vessel length.

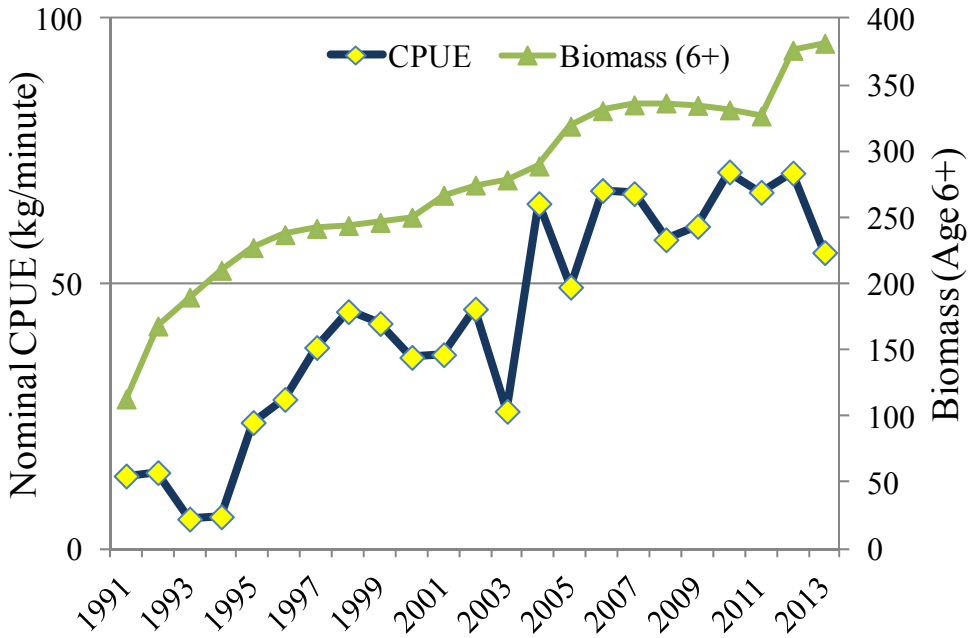


Figure 9-3a. Comparison of nominal catch-per-unit-effort (CPUE, kg/minute) and biomass (age 6+) in the Gulf of Alaska Pacific ocean perch fishery.

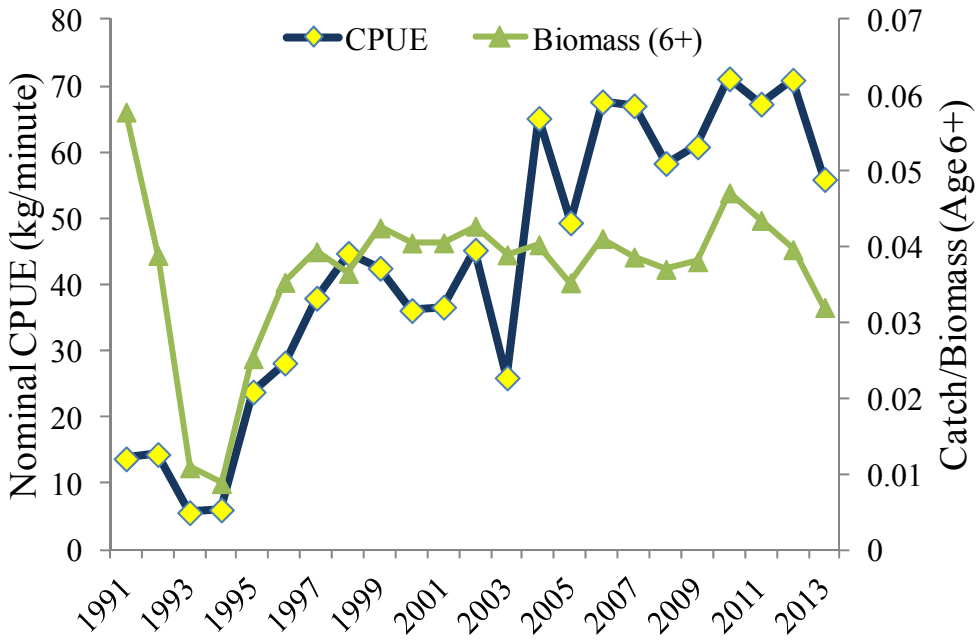


Figure 9-3b. Comparison of nominal catch-per-unit-effort (CPUE, kg/minute) and a proxy for exploitation rate (Catch/Age 6+ Biomass) for the Gulf of Alaska Pacific ocean perch fishery.

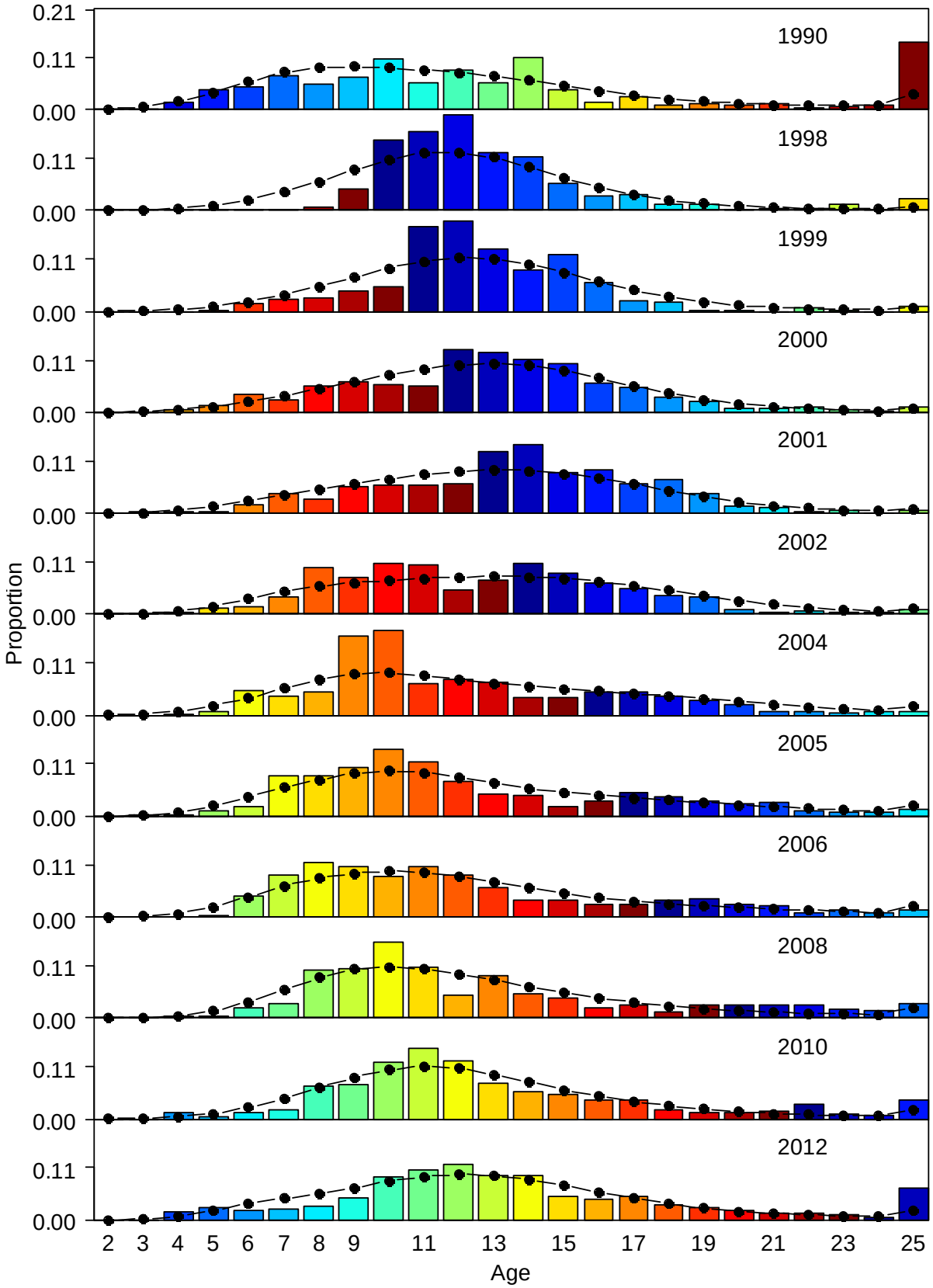


Figure 9-4. Fishery age compositions for GOA Pacific ocean perch. Observed = bars, predicted from author recommended model = line with circles. Colors follow cohorts.

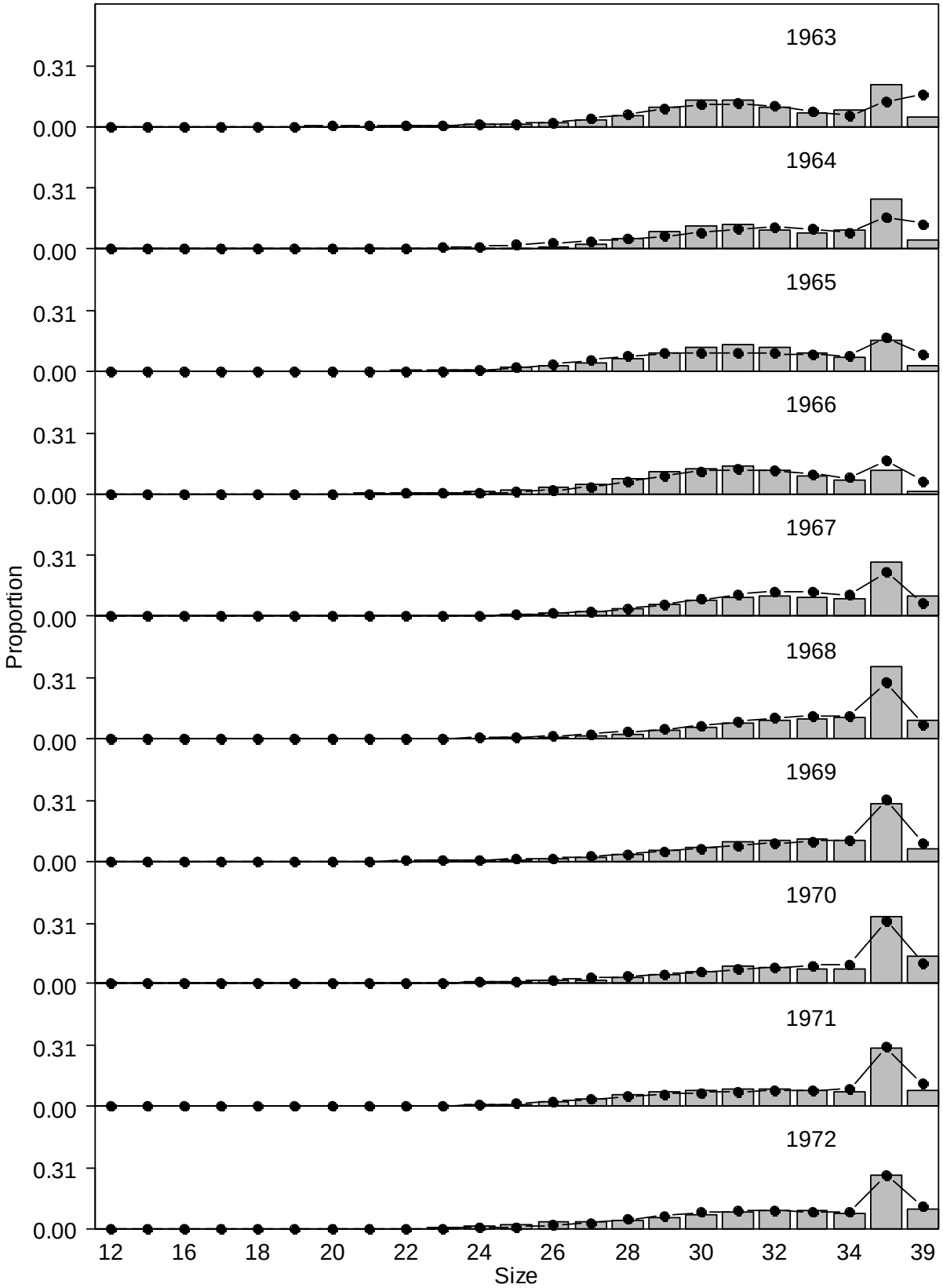


Figure 9-5. Fishery length (cm) compositions for GOA Pacific ocean perch. Observed = bars, predicted from author recommended model = line with circles.

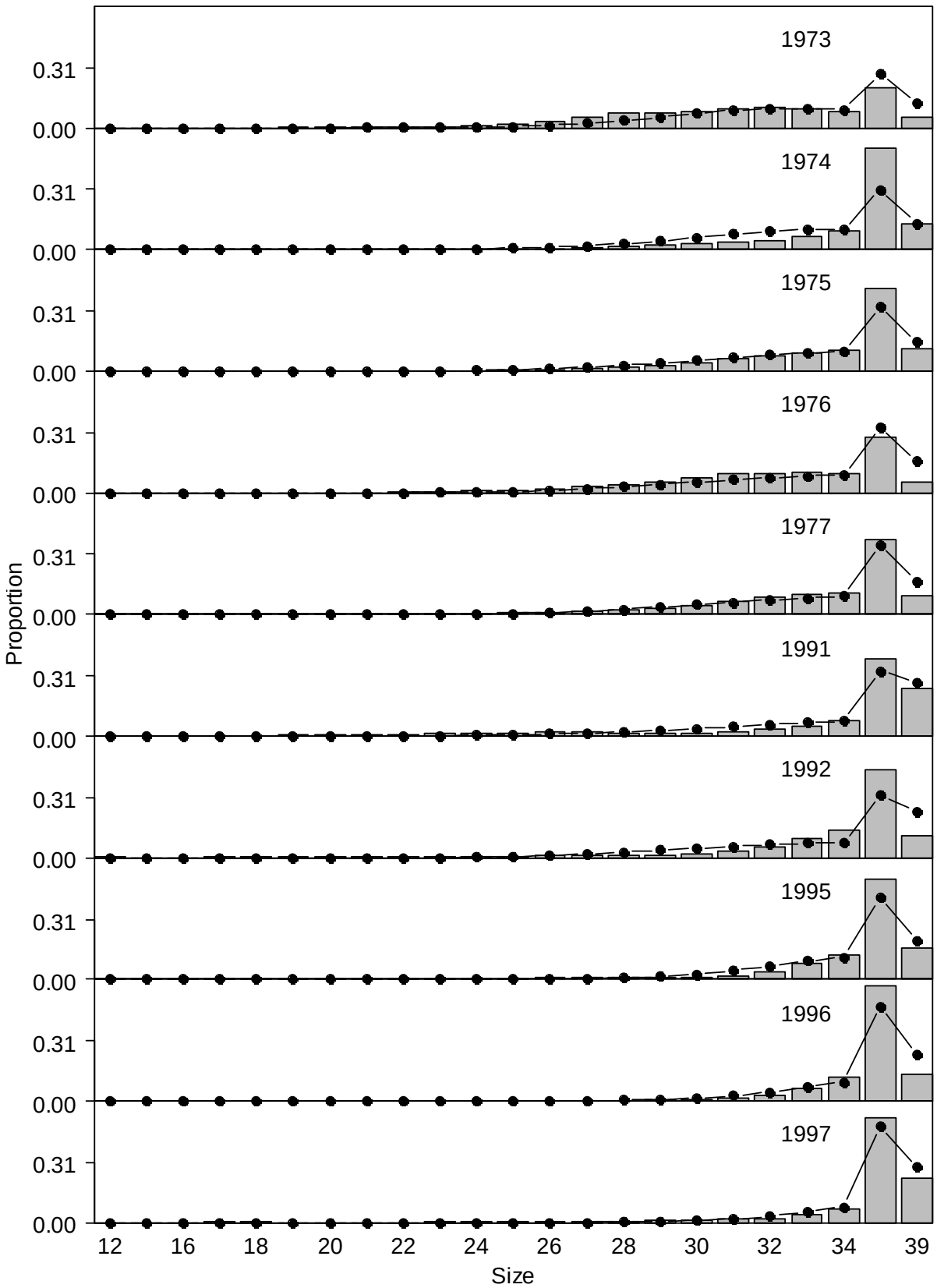


Figure 9-5. (continued) Fishery length (cm) compositions for GOA Pacific ocean perch. Observed = bars, predicted from author recommended model = line with circles.

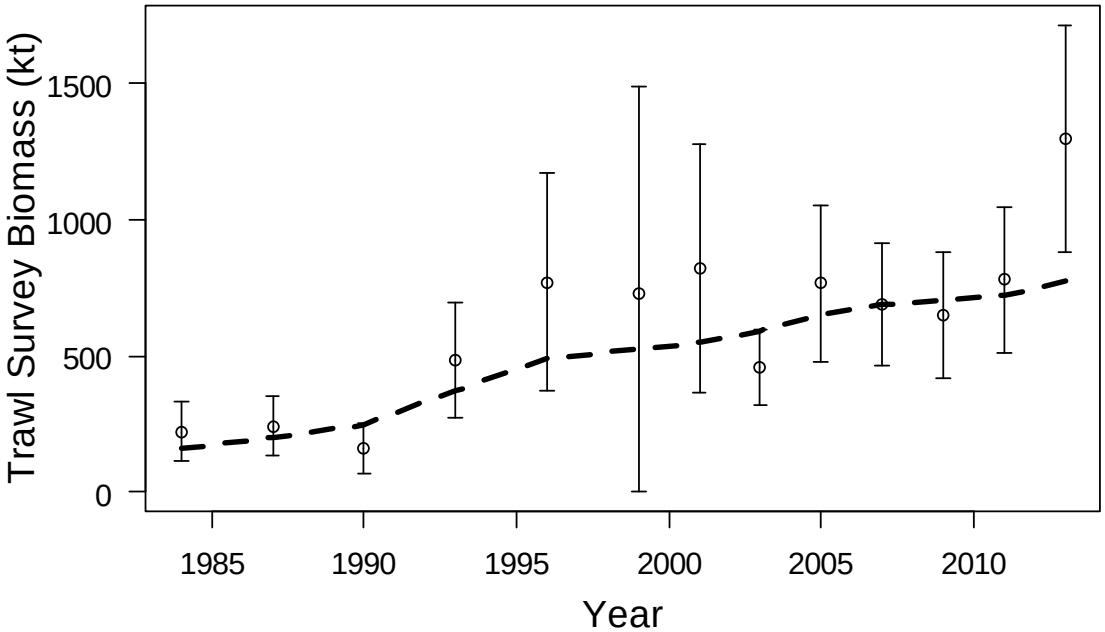


Figure 9-6. NMFS Groundfish Survey biomass estimates (solid line), with 95% sampling error confidence intervals (dashed line) and model fit (dotted line) for Gulf of Alaska Pacific ocean perch.

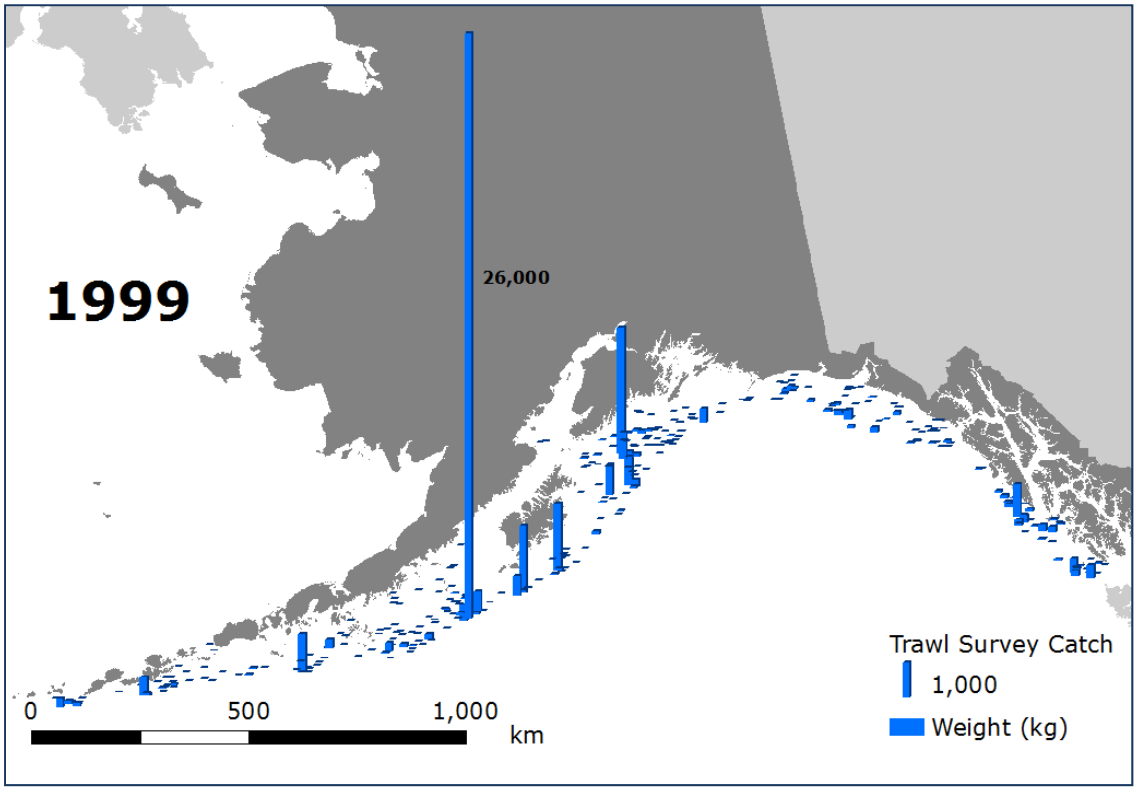
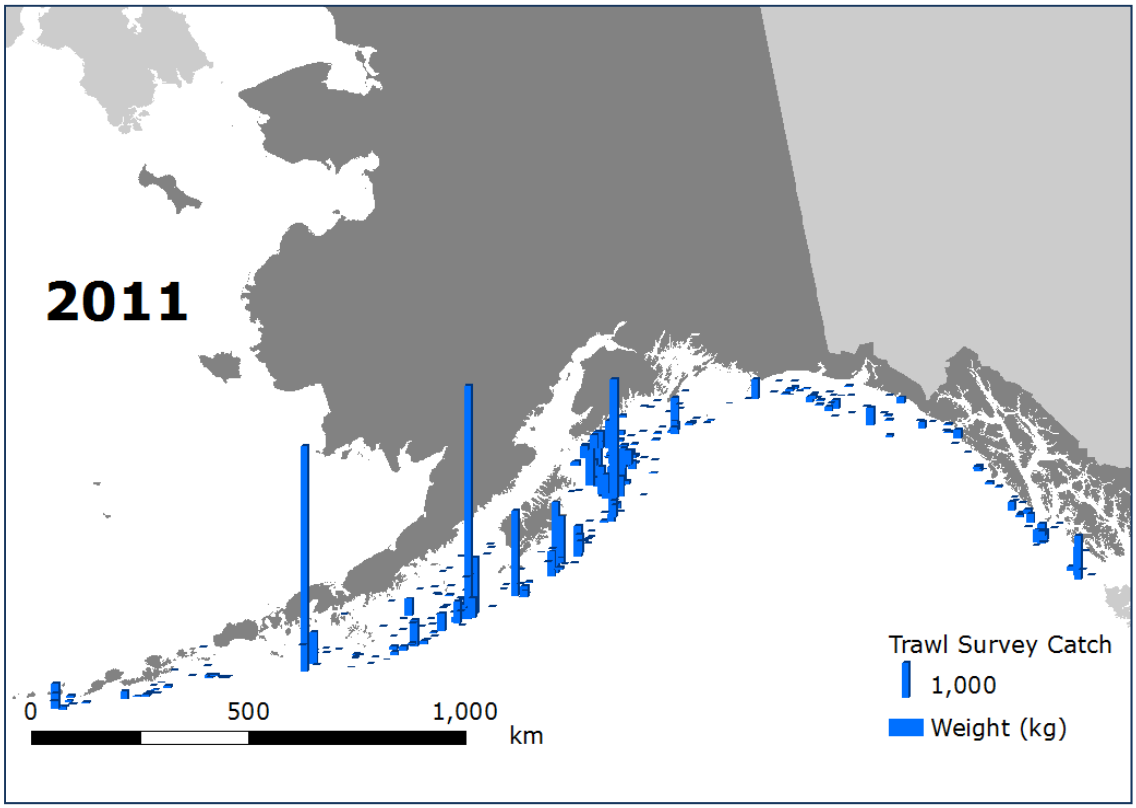


Figure 9-7a. Distribution of Gulf of Alaska Pacific ocean perch catches in the 1999 Gulf of Alaska groundfish survey.



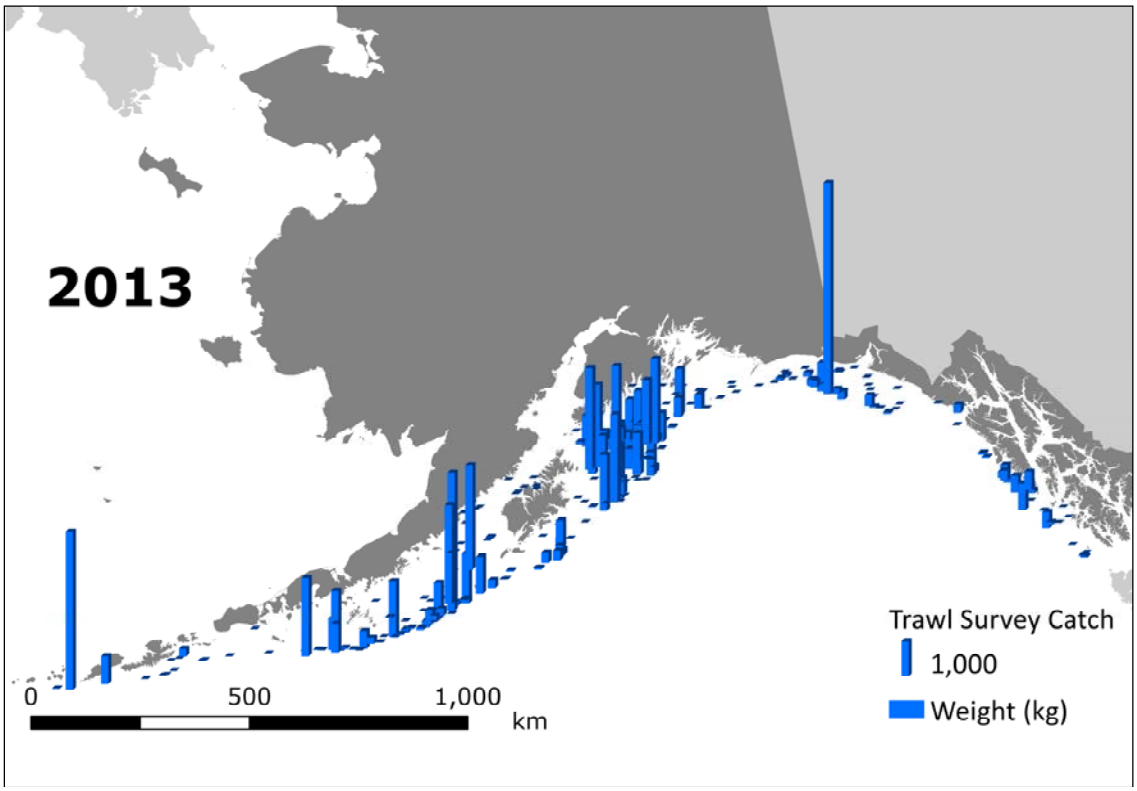


Figure 9-7b. Distribution of Gulf of Alaska Pacific ocean perch catches in the 2011 and 2013 Gulf of Alaska groundfish surveys.

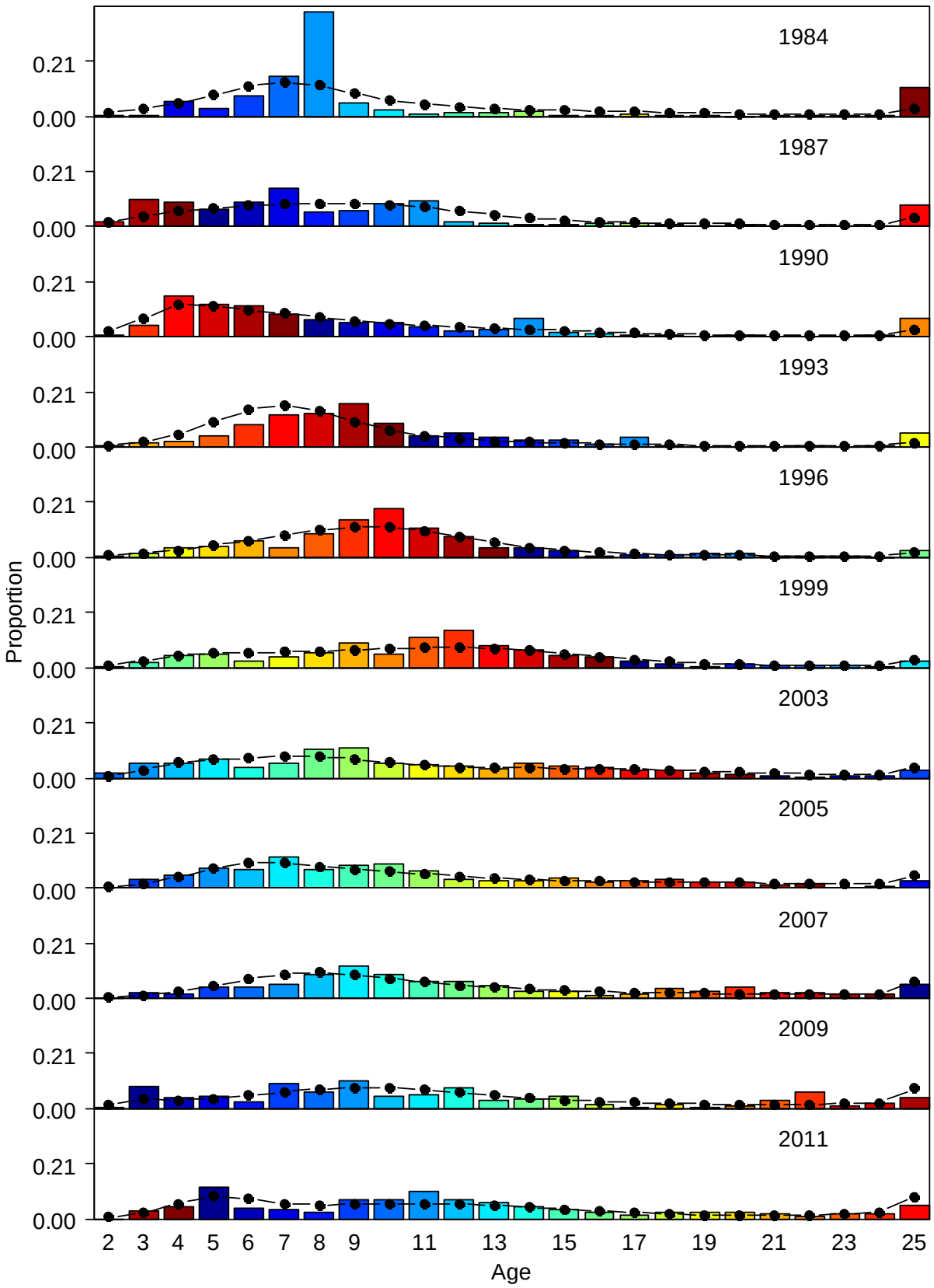


Figure 9-8. Groundfish survey age compositions for GOA Pacific ocean perch. Observed = bars, predicted from author recommended model = line with circles.

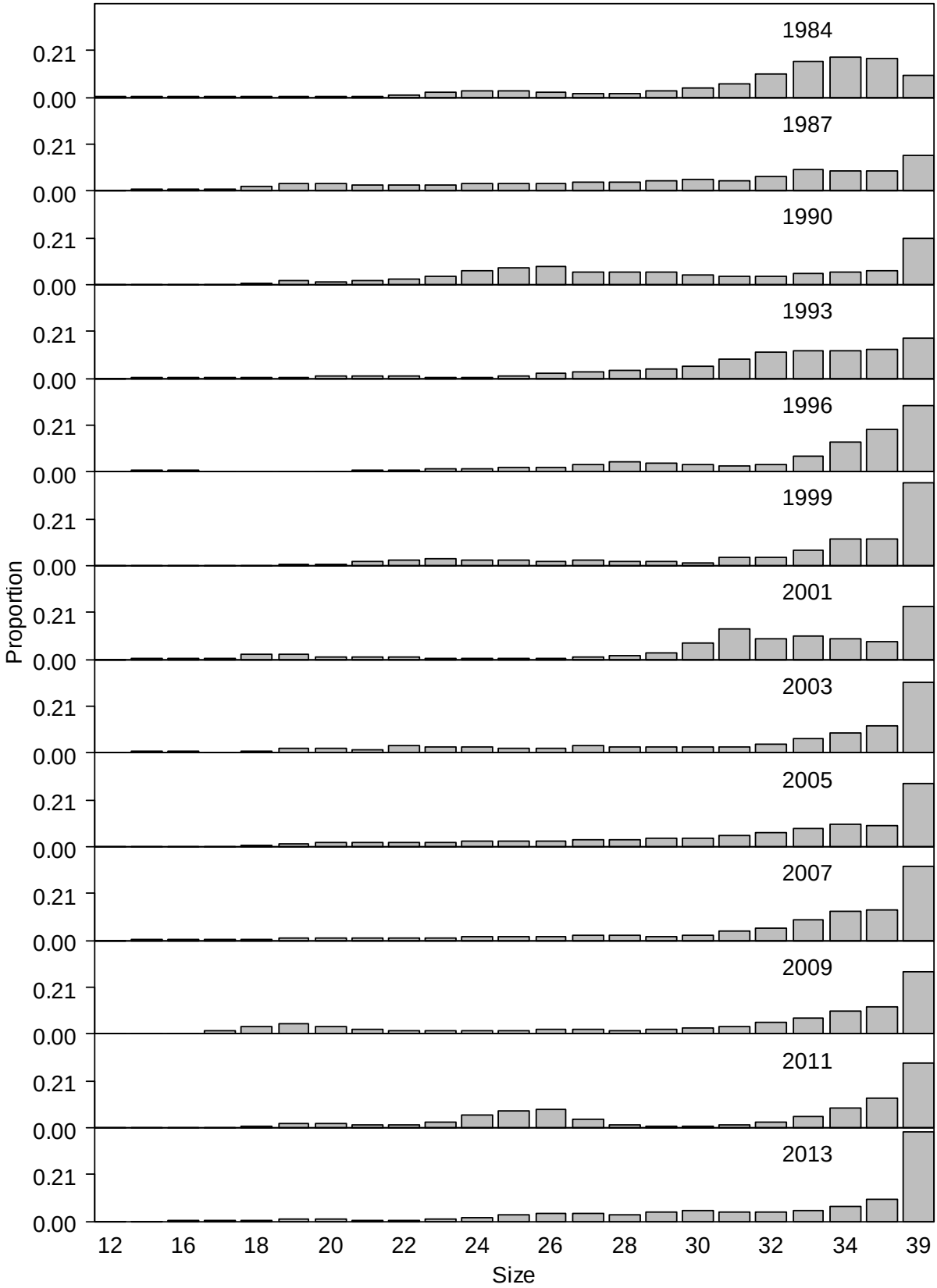


Figure 9-9. Groundfish survey length compositions for GOA Pacific ocean perch. Observed = bars. Survey size not used in Pacific ocean perch model because survey ages are available for these years.

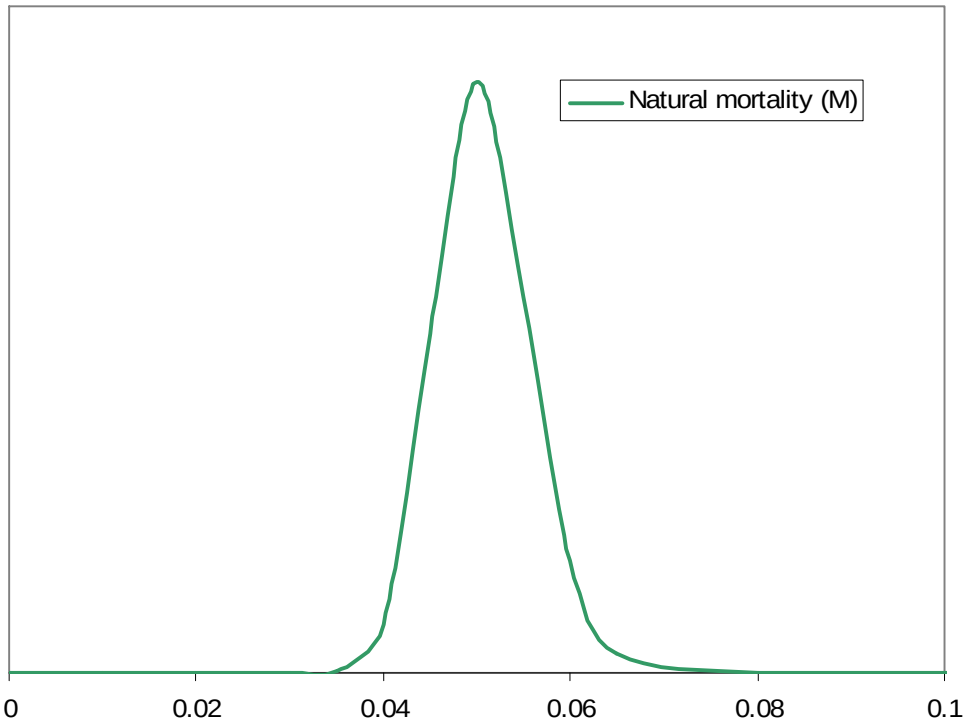


Figure 9-10. Prior distribution for natural mortality (*M*) of Pacific ocean perch, μ=0.05, CV=10%.

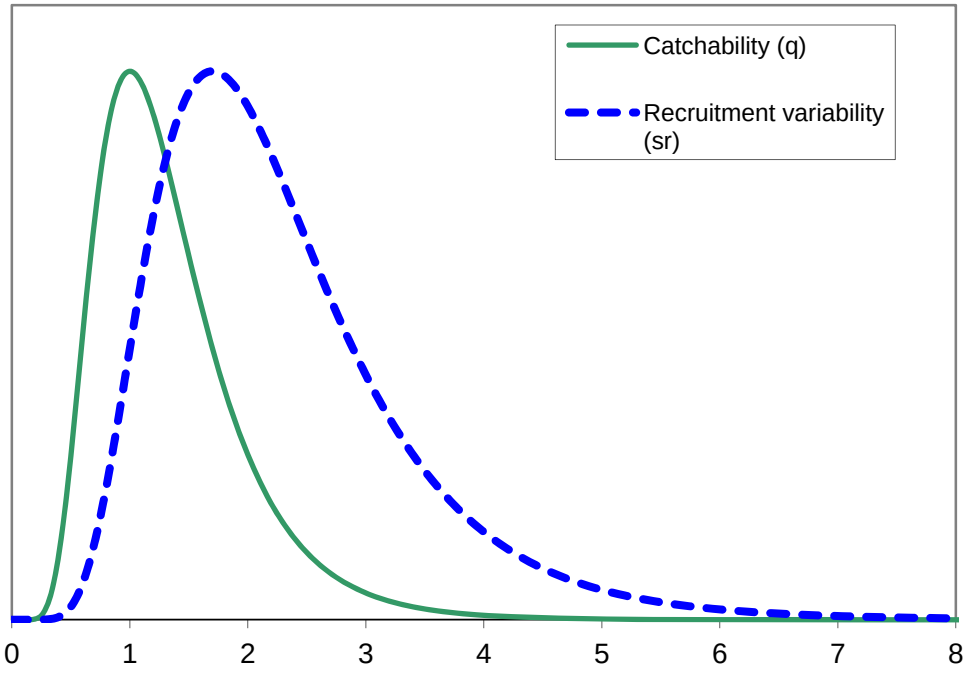


Figure 9-11. Lognormal prior distributions for catchability (*q,* μ=1, CV=45%) and recruitment variability (σ_r, μ=1.7, CV=20%) of Pacific ocean perch.

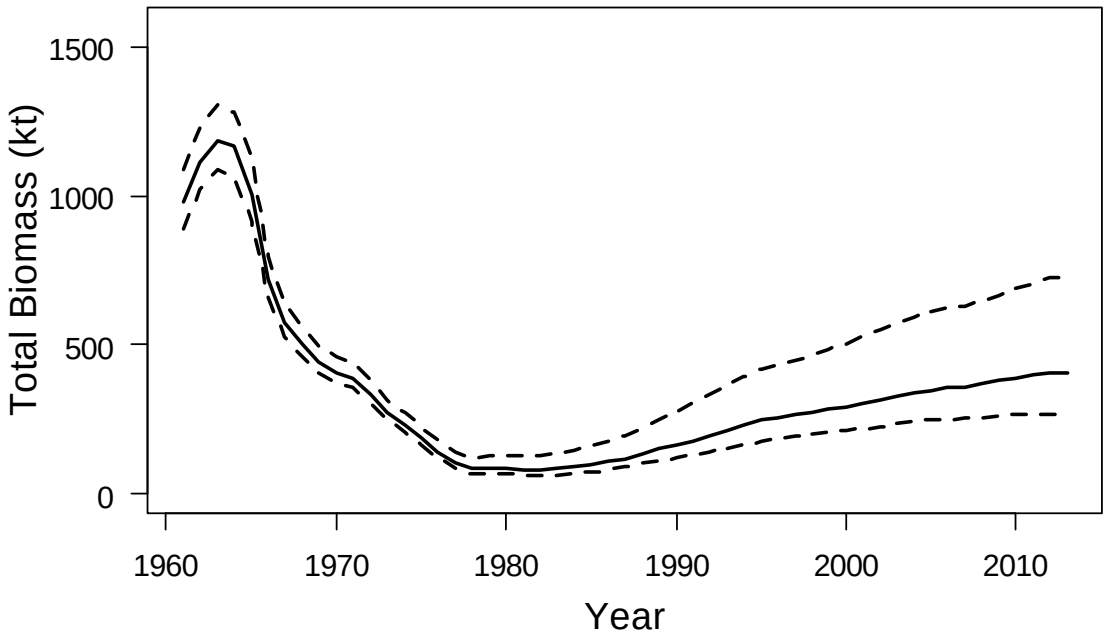


Figure 9-12. Model estimated total biomass (solid line) with 95% credible intervals determined by MCMC (dashed line) for Gulf of Alaska Pacific ocean perch.

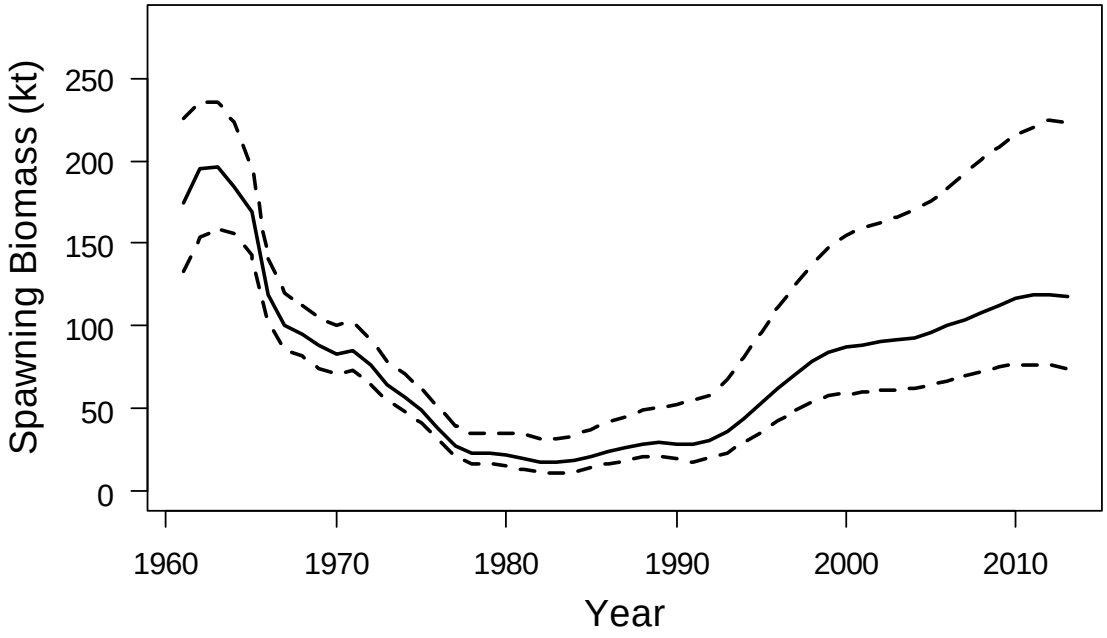


Figure 9-13. Model estimated spawning biomass (solid line) with 95% credible intervals determined by MCMC (dashed line) for Gulf of Alaska Pacific ocean perch.

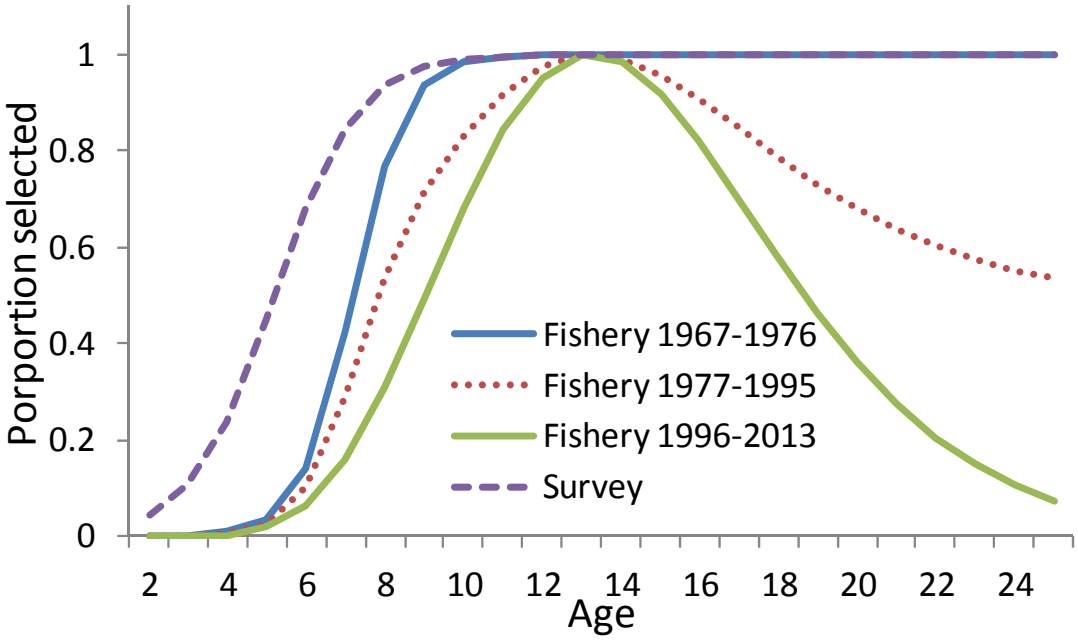


Figure 9-14. Estimated selectivities for the fishery for three periods and groundfish survey for Gulf of Alaska Pacific ocean perch.

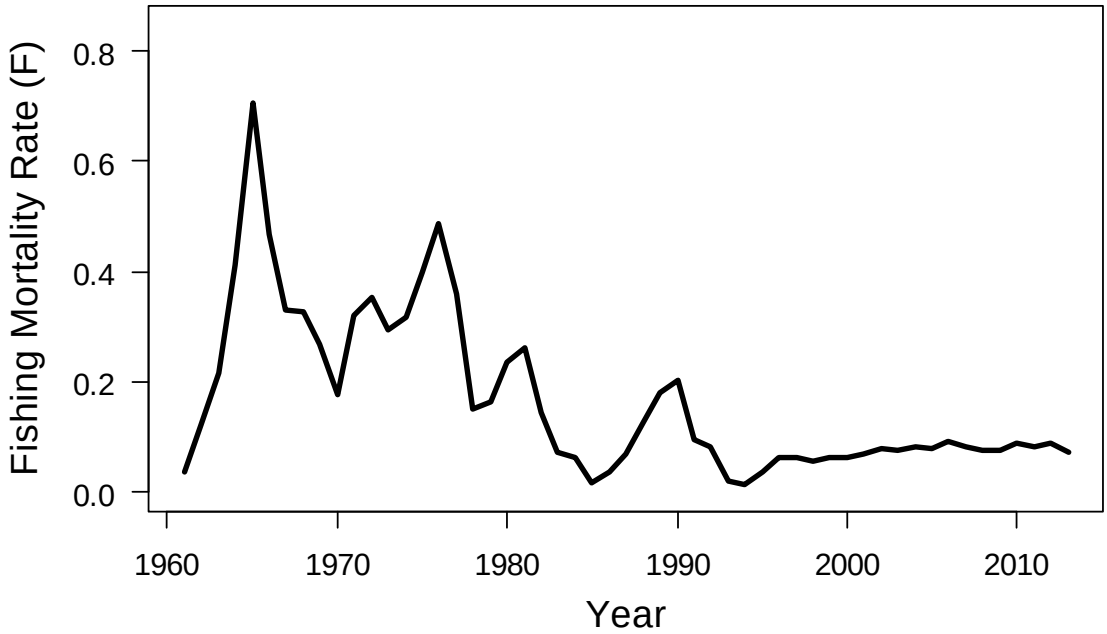


Figure 9-15. Estimated fully selected fishing mortality over time for GOA Pacific ocean perch.

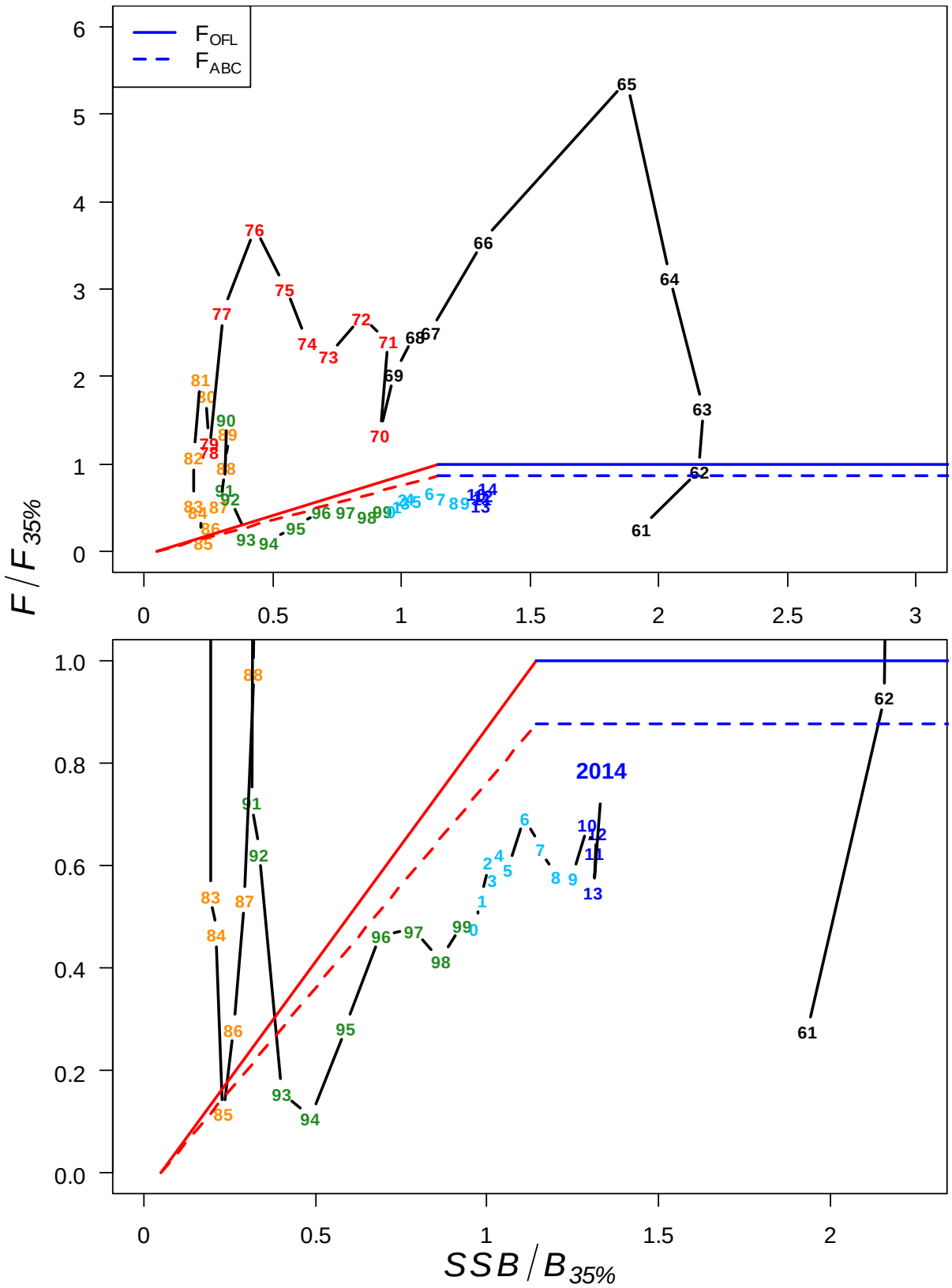
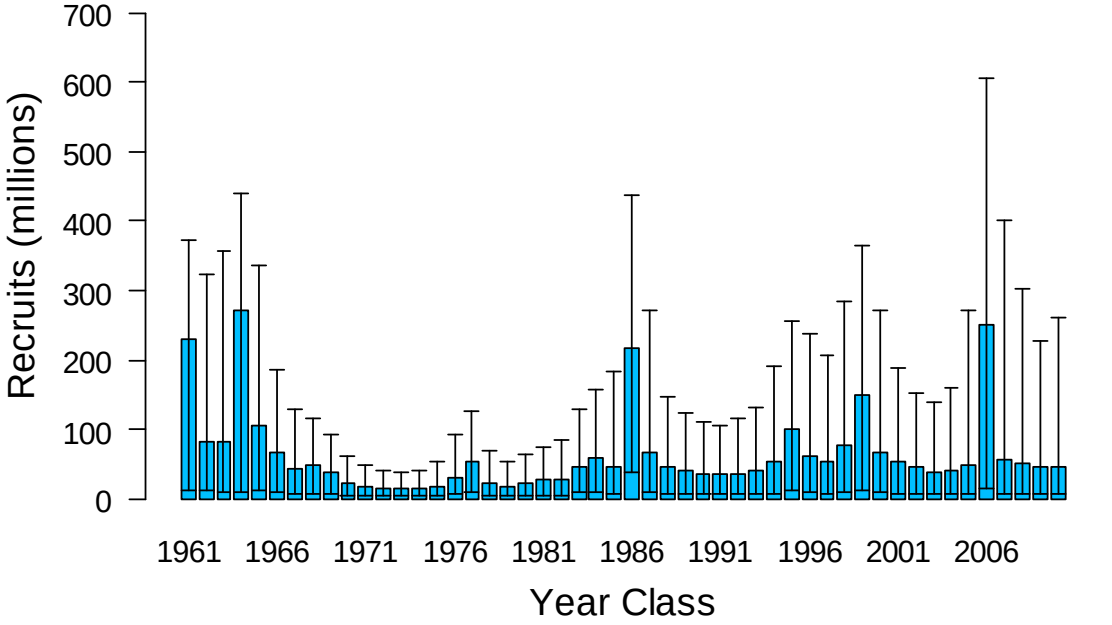


Figure 9-16. Time series of Pacific ocean perch estimated spawning biomass relative to the target level $B_{35\%}$ level and fishing mortality relative to $F_{35\%}$ for author recommended model. Top shows whole time series. Bottom shows close up on more recent management path.



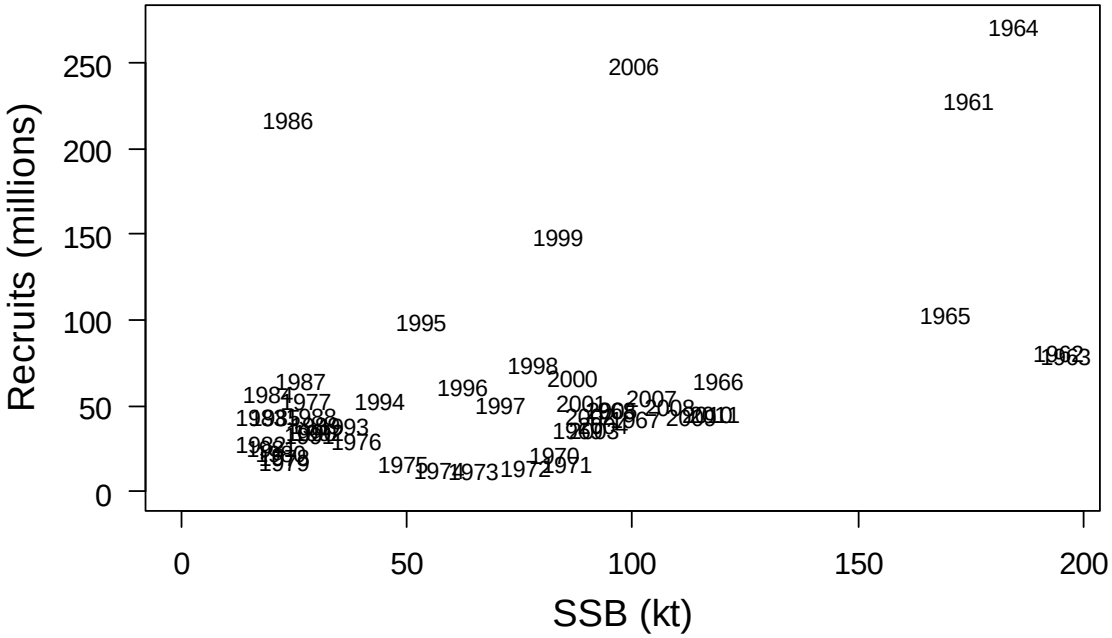


Figure 9-17. Estimated recruitment of Gulf of Alaska Pacific ocean perch (age 2) by year class with 95% credible intervals derived from MCMC (top). Estimate recruits per spawning stock biomass (bottom).

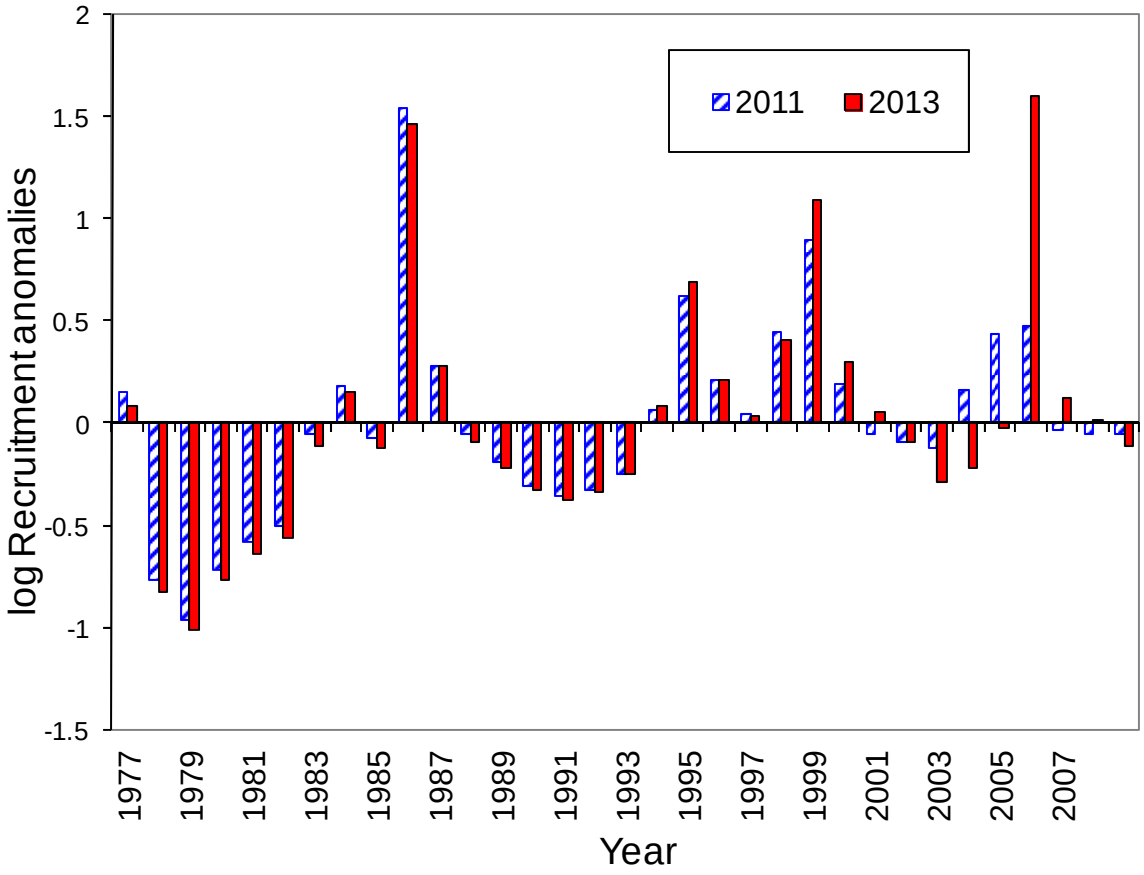


Figure 9-18. Recruitment deviations from average on the log-scale comparing last cycle's model tocurrent for Gulf of Alaska Pacific ocean perch.

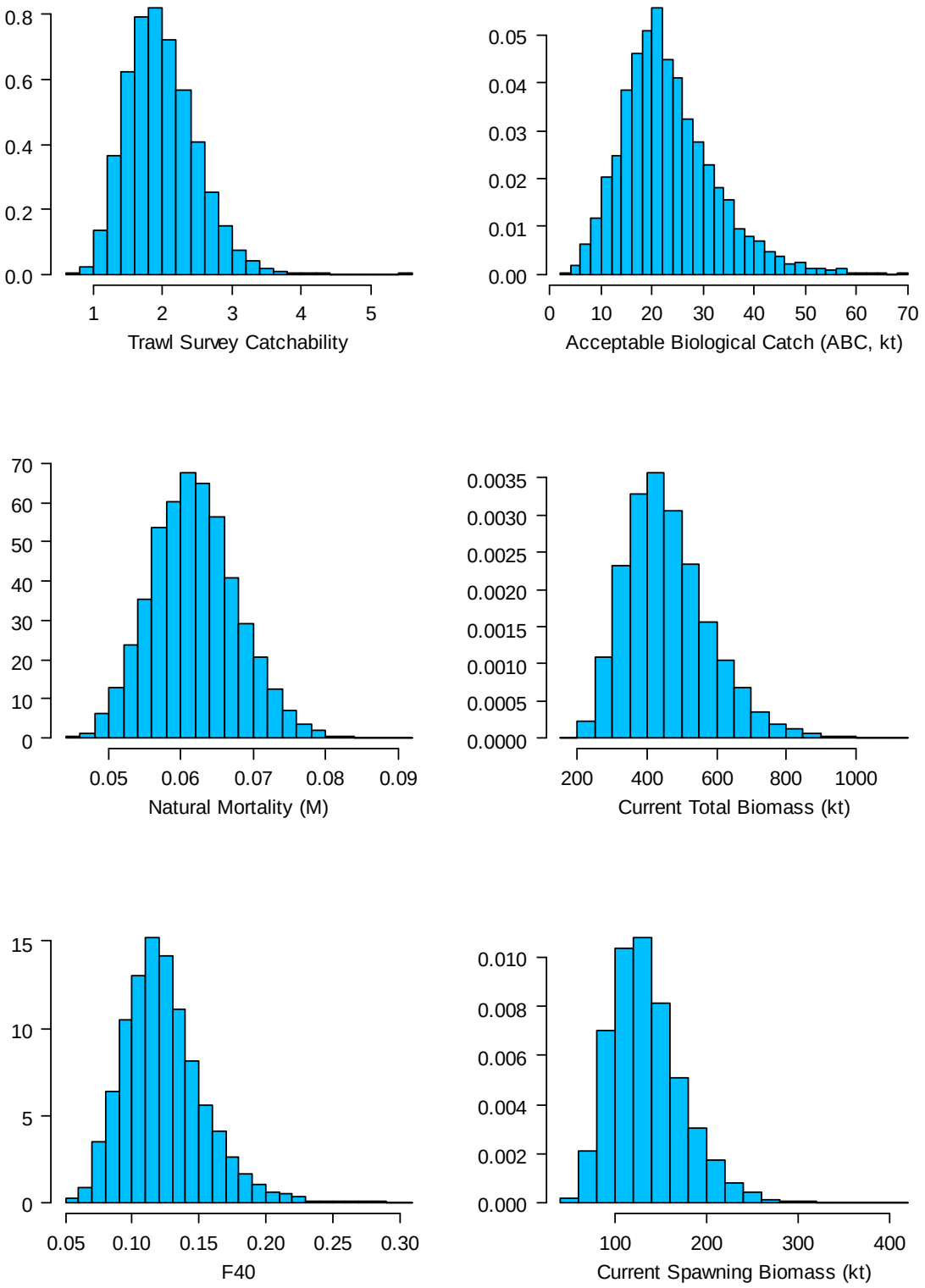


Figure 9-19. Histograms of estimated posterior distributions of key parameters derived from MCMC for Gulf of Alaska Pacific ocean perch.

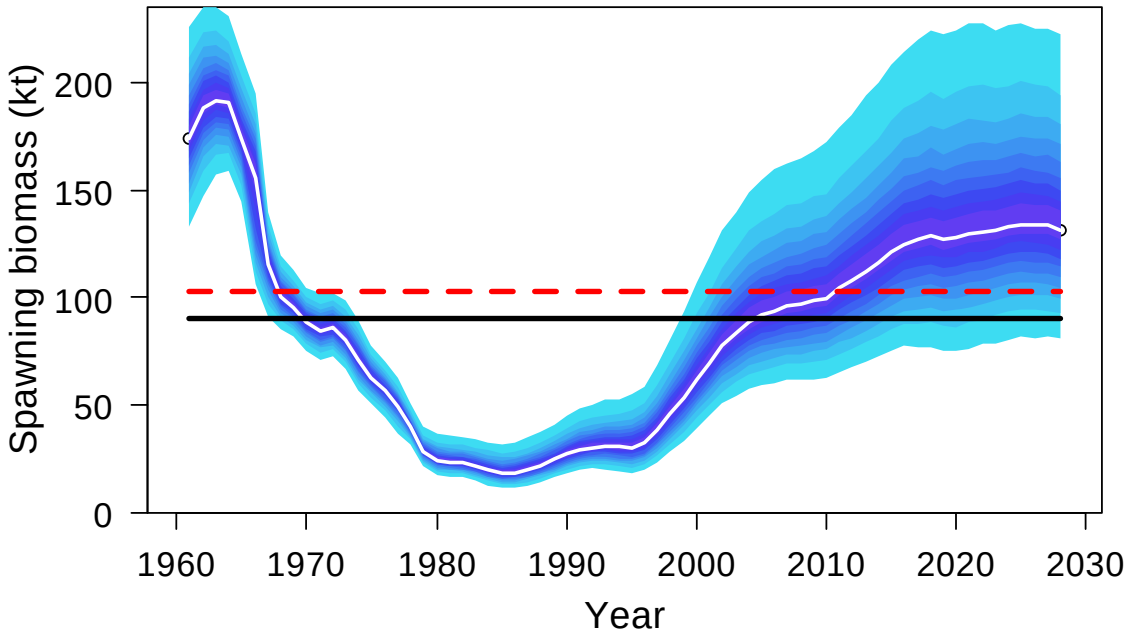


Figure 9-20. Bayesian credible intervals for entire spawning stock biomass series including projections through 2024. Red dashed line is $B_{40\%}$ and black solid line is $B_{35\%}$ based on recruitments from 1979-2009. The white line is the median of MCMC simulations. Each shade is 5% of the posterior distribution.

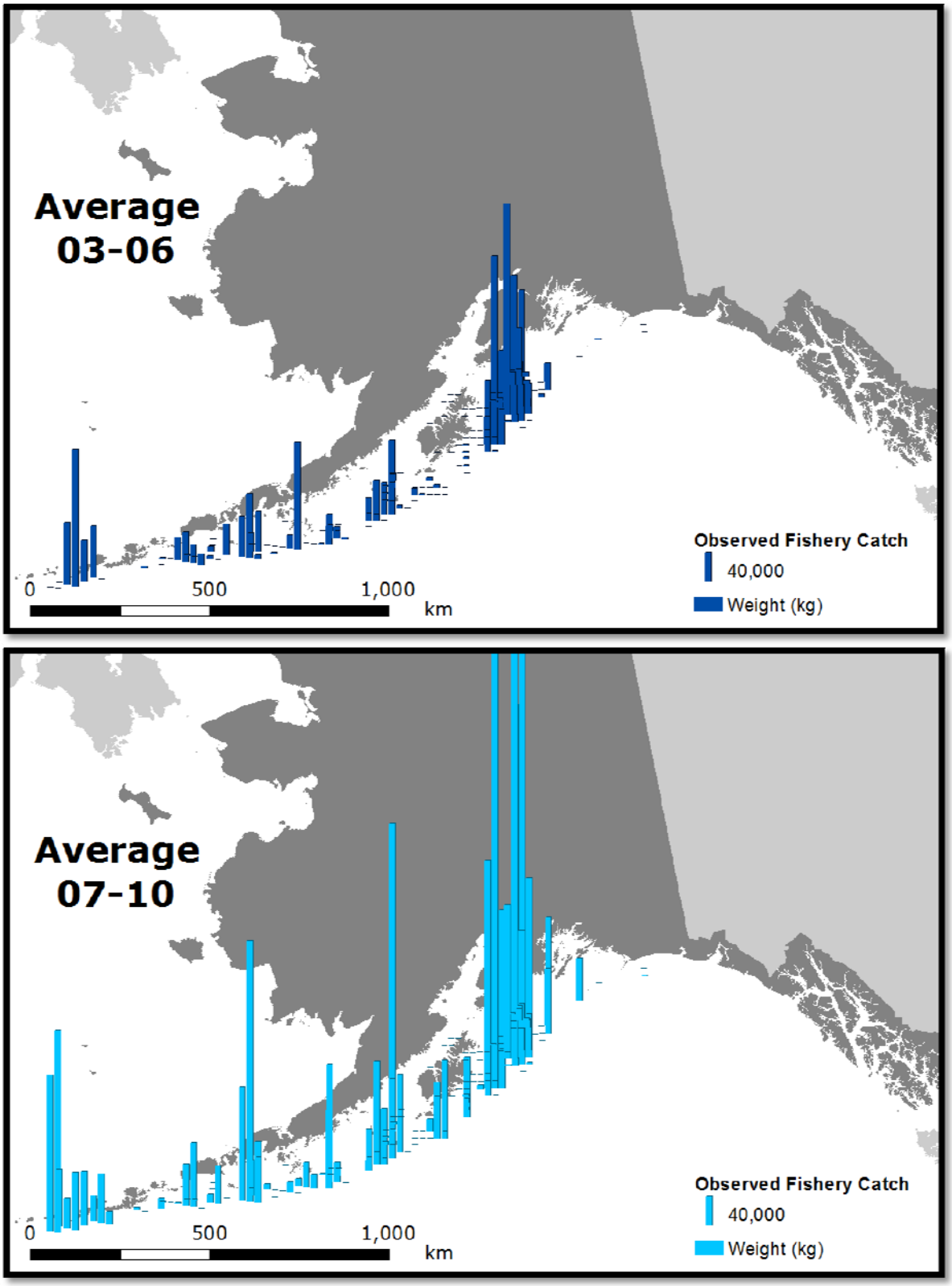


Figure 9-21. Maps of fishery catch based on observer data by 100 km^2 blocks for Pacific ocean perch from four years before and after the Rockfish Pilot Program.

Appendix 9A.—Supplemental catch data (not updated from 2011)

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 16,412 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		63	<1	64
2012		<1	<1	1

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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