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

Dana Hanselman, S. Kalei Shotwell, P.J.F. Hulson, Jonathan Heifetz, and James N. Ianelli

November 2011

Executive Summary

We use a separable age-structured model as the primary assessment tool for Gulf of Alaska Pacific ocean perch. 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 Gulf of Alaska rockfish in alternate (even) years, we present an executive summary to recommend harvest levels for the next (odd) year. For this on-cycle year, we update the 2009 assessment model estimates with new data collected since the last full assessment.

Changes in the input data: The new data included are 2011 survey biomass estimates, 2009 survey age compositions, 2010 fishery age compositions, a revised catch estimate for 2010 and a new catch estimate for 2011.

Changes in the assessment methodology: No changes in assessment methodology.

Summary of results: For the 2012 fishery, we recommend the maximum allowable ABC of 16,918 t from the updated model. This ABC is nearly identical to the 2011 ABC of 16,997 t. This stability is attributed to a relatively precise survey biomass estimate that was slightly above the average of the last five surveys. This resulted in a 5% higher ABC than the 2012 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. The stock is not overfished, nor is it approaching overfishing status.

Quantity	As estimated or specified *last* year for: 2011	2012	As estimated or recommended *this* year for: 2012	2013[1]
M	0.061	0.061	0.062	0.062
Tier	3a	3a	3a	3a
Projected total (age 2+) biomass (t)	330,480	326,324	348,168	346,171
Female spawning biomass (t)				
Projected	108,212	107,185	107,769	107,914
$B_{100\%}$	227,610	227,610	234,689	234,689
$B_{40\%}$	91,044	91,044	93,876	93,876
$B_{35\%}$	79,664	79,664	82,141	82,141
F_{OFL}	0.142	0.142	0.138	0.138
$maxF_{ABC}$	0.123	0.123	0.119	0.119
F_{ABC}	0.123	0.123	0.119	0.119
OFL (t)	**19,566**	18,635	**19,498**	19,021
maxABC (t)	**16,997**	16,187	**16,918**	16,500
ABC (t)	**16,997**	16,187	**16,918**	16,500
Status	As determined *last* year for: 2009	2010	As determined *this* year for: 2010	2011
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 2012 and 2013 are derived using estimated catch of 13,918 for 2011, and projected catches of 14,549 t and 14,190 t for 2012 and 2013 based on realized catches from 2008-2010. This calculation is in response to management requests to obtain more accurate projections.

Area Apportionment

The apportionment percentages have changed with the addition of the 2011 survey biomass. The following table shows the recommended apportionment for 2012.

	Western	Central	Eastern	Total
Area Apportionment	12.4%	66.6%	21.0%	100%
Area ABC (t)	**2,102**	**11,263**	**3,553**	**16,918**
Area OFL (t)	2,423	12,980	4,095	**19,498**

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 lower than last year at 0.48, down from 0.50. This results in the following apportionment of the Eastern Gulf area:

	W. Yakutat	E. Yakutat/Southeast
Area ABC (t)	1,692	1,861

Summaries for Plan Team

Species	Year	Biomass[1]	OFL	ABC	TAC	Catch
Pacific ocean perch	2010	334,797	20,243	17,584	17,584	15,616
	2011	330,480	19,566	16,997	16,997	13,354
	2012	348,168	19,498	16,918		
	2013	346,171	19,021	16,500		

[1]Total biomass from the age-structured model

Stock/ Assemblage	Area	2011 OFL	ABC	TAC	Catch[2]	2012 OFL	ABC	2013 OFL	ABC
								2,364	
Pacific ocean perch	W	3,221	2,798	2,798	1,811	2,423	2,102	12,980**11,263**	2,050
	C	11,948	10,379	10,379	9,673	12,980	11,263	12,662 1,692	10,985
	WYAK		1,937	1,937	1,870		1,692	1,861	1,650
	SEO		1,883	1,883	0		1,861	4,095	1,815
	E	4,397		--	--	4,095		3,995	
	Total	19,566	16,997	16,997	13,354	19,498	16,918	19,021	16,500

[2]Current as of October 4, 2011, Source: NMFS Alaska Regional Office via the Alaska Fisheries Information Network (AKFIN).

Responses to SSC comments since the last full assessment

"The methods for area apportionment of the ABC that are used in the specific chapters are different from those given in the general introductory material to the SAFE on page 4. The SSC suggests that the table be updated. Also, a different number of years are used for various species (e.g., 5 years for sablefish, 4 years for pollock, 3 surveys, most recent survey). SSC members recall extensive discussions about these issues but the rationale for the decision is not given in the SAFE chapters. The SSC suggests that description of the apportionment rationale in each SAFE chapter of area-apportioned species would be helpful to the reader." (December 2009)

The annual allocation of the Gulf-wide ABC for Pacific ocean perch amongst the three regulatory areas in the Gulf has been based on the geographic distribution of biomass in the trawl surveys. Since the 1996 SAFE report, this distribution has been computed as a weighted average of the percent biomass distribution for each area in the three most recent trawl surveys. Details can be found in Section ***Area Allocation of Harvests***.

"The SSC notes that the MCMC estimate of trawl survey q for the rougheye complex (0.381) is considerably different from the q for dusky rockfish (0.911). It would be useful to compare the model estimates of q for different species of rockfish and consider whether the estimates are reasonable." (December 2009)

In this comment, the SSC was referring to the contribution of the prior distribution on trawl survey q to the objective function for GOA rougheye and blackspotted rockfish, not the point estimate. The catchability estimate for the RE/BS is 1.42, which is higher than northerns and dusky (0.67 and 0.90), but lower than Pacific ocean perch (2.03). These estimates at least relative to each other correspond with our perception from submersible studies on how the species range from untrawlable to trawlable habitat. Pacific ocean perch has been the subject of three studies which all yielded catchabilities above 1 (2.1, 1.3, and 2.1). Rougheye catches were compared with submersible observations in a 2006 analysis and yielded a catchability of 0.85. In the future we hope to synthesize the results of these studies to derive informative prior distributions for our catchability estimates.

"The SSC recommends that stock assessment authors and plan teams address this issue in the upcoming stock assessment cycle. Stock assessment authors should clearly lay out which sources of removals are currently included in the assessment, how removals from each source are estimated, and how they are being included in (A) and (B) above. To the extent possible, authors should discuss all known sources of mortality (including handling mortality, indirect mortality, subsistence, etc.) and which of these sources are considered in the assessment." (June 2011)

Estimates of non-commercial catch of Pacific ocean perch are documented in Appendix 9-A.

Responses to Plan Team comments since the last full assessment

"Show comparisons of ages by depth and vessel types" (November 2009)

"Include fishery age composition by depth." (November 2009)

A series of figures are presented and discussed in the ***Fishery*** section.

"Modify figure 9-23 so it is clear that control changes rates at 40% (not 35% as appears)" (November 2010)

This is corrected in Figure 9-16.

"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 plan to apply the stock structure template to Pacific ocean perch for the September 2012 Plan Team meeting.

"The Team discussed the different catch assumptions made across assessments … The Team noted that authors should be clear in how catch is projected and what assumptions are made to make the catch estimate for the projection." (November 2010)

We discuss a modified methodology for estimating full-year catch for the current year and for projecting future catches for the two year projection of ABC and OFL in subsection *Specified catch estimation* in the ***Projections and Harvest Alternatives*** section.

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 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 20% 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. 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.

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). 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). In terms of rebuilding the stock, management area OFLs are no longer a necessity for the Gulf of Alaska POP stock. However, we intend to complete the NPFMC stock structure template for the September 2012 Plan Team meeting to aid in reviewing some of our stock structure assumptions.

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 the last several years, the TAC's for Pacific ocean perch have 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.)

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 1988-2011; 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

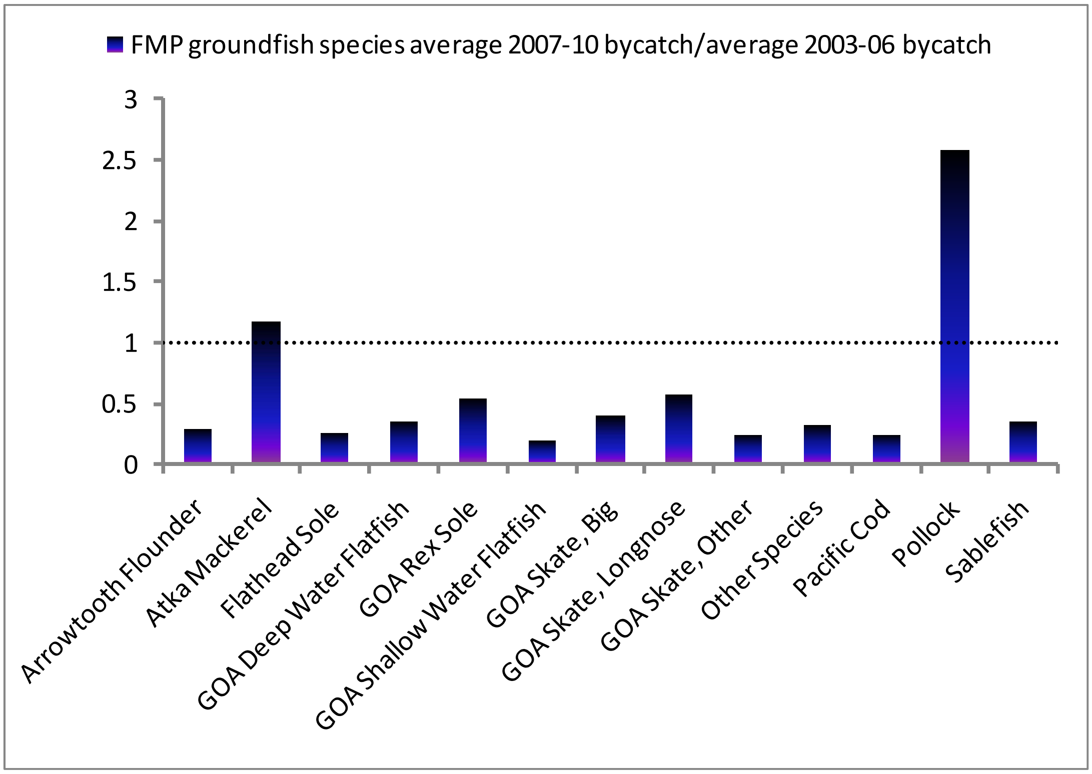
Gulfwide discard rates[2] (% discarded) for Pacific ocean perch in the commercial fishery for 2000-2011 are listed as follows:

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
% Discard	11.3	8.6	7.3	15.1	8.2	5.7	7.8	3.7	4.1	6.8	4.1	5.7

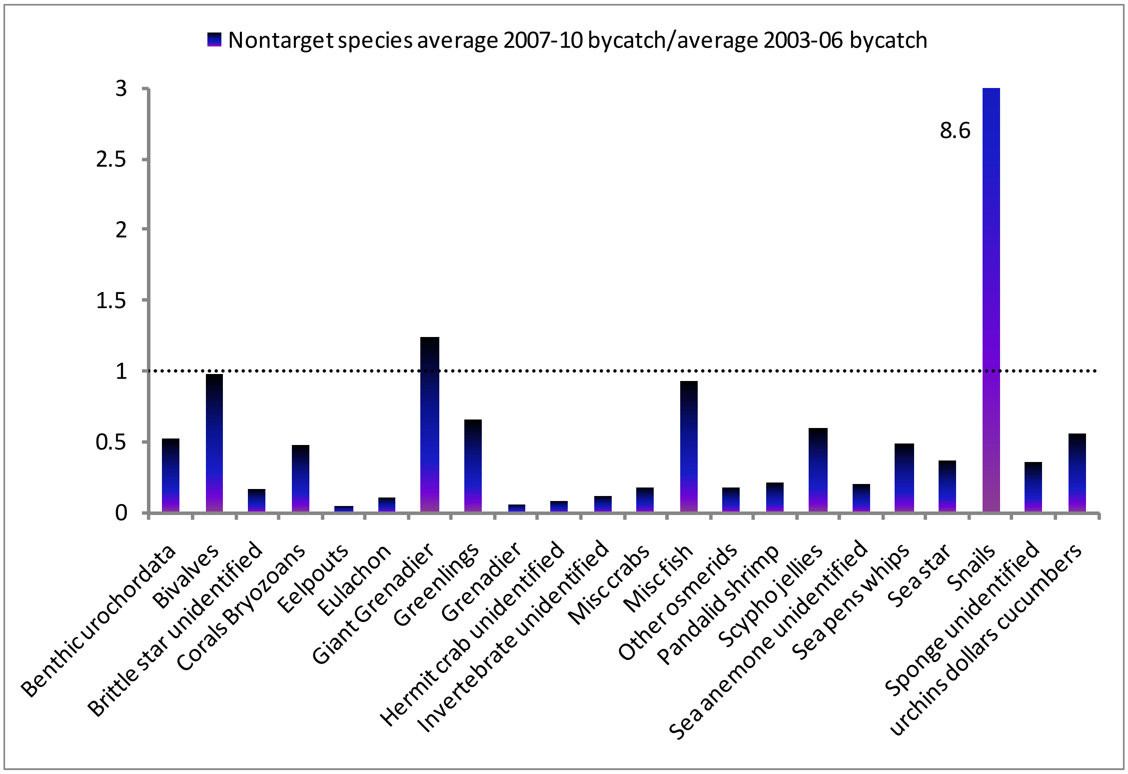
Since 1996, discard rates for Pacific ocean perch have generally decreased.

For the combined rockfish trawl fisheries during 1991-2010 for the GOA the largest non-rockfish bycatch groups are arrowtooth flounder (1,540 t/year), sablefish (948 t/year), Pacific cod (814 t/year), Atka mackerel (585 t/year) and walleye pollock (352 t/year). Total FMP groundfish catch estimates targeted in the rockfish fishery from 2006-2010 are shown in Table 9-3. Catch of Pacific ocean perch in other Gulf of Alaska fisheries is mainly in the rex sole (219 t/year average) and arrowtooth (156 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):

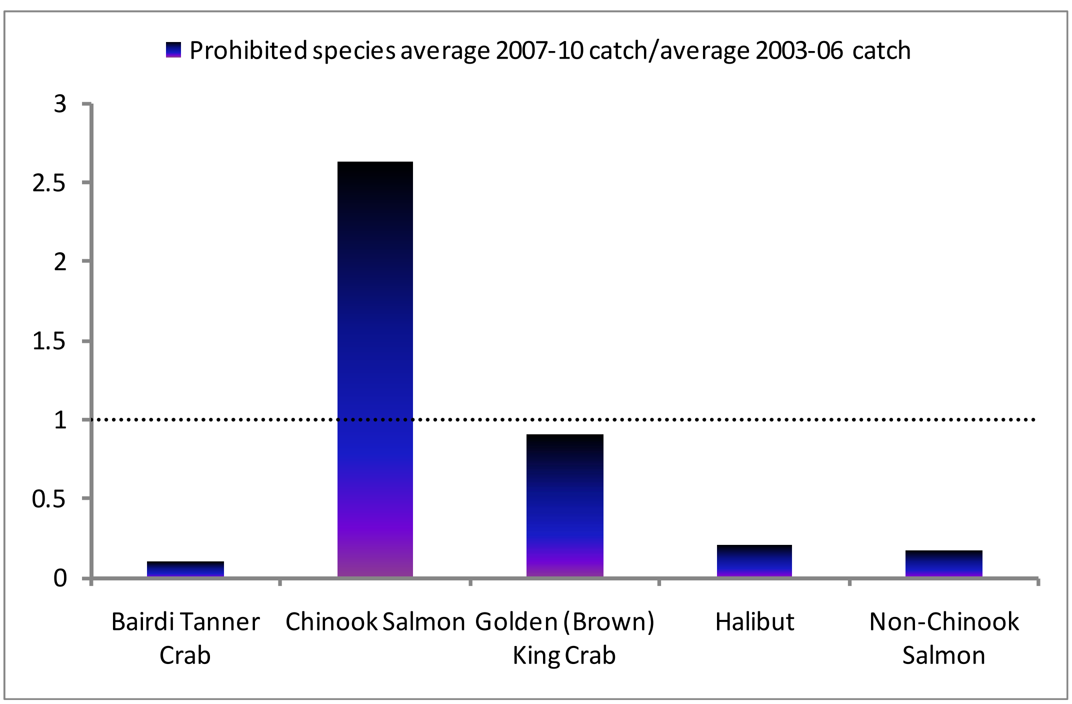


Non-FMP species catch in the rockfish target fisheries is dominated by giant grenadier (127 – 423 t), miscellaneous fish (132 – 181 t), and ocassionally dark rockfish (recently removed from FMP to state management, 0 – 111 t) (Table 9-5). Only 2 of 23 nontarget species for which bycatch data is available 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 decreasing for all the major species with the exception of golden king crab which increased to over 3,000 animals in 2009 and 2010. Halibut catch during rockfish targeted hauls has declined since 2005 from 368 t to 142 t in 2010 (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), 2001-2011 (biennial)
	Age Composition	1984, 1987, 1990, 1993, 1996, 1999, 2003, 2005, 2007, 2009
U.S. trawl fisheries	Catch	1961-2011
	Age Composition	1990,1998-2002, 2004, 2005, 2006, 2008, 2010
	Length Composition	1963-1977, 1991-1997

Fishery Data

Catch

Catches range from 2,500 t to 350,000 t from 1961 to 2011. 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). For this year, 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 1995-2010. Table 9-8 summarizes age compositions from 1990, 1998-2002, 2004-2006, 2008, and 2010 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 2010 fishery age composition shows a relatively high number of the 2006 year class which also shows up as a high proportion in the survey age composition. The fishery age data show high correlation when lagged, indicating ages and collections are consistent.

Survey Data

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 2011 surveys are provided in Table 9-9.

Comparison of Trawl Surveys in 1984-2011

Gulfwide biomass estimates for Pacific ocean perch are shown in Table 9-9. Gulfwide biomass estimates for 1984-2011 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 extremely imprecise between 1996-2001, but were more precise in the surveys from 2003 through 2011 (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 (Spencer et al. 2011) 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 be equal 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. Precision remains reasonably high relative to the 1990s.

Age Compositions

Ages were determined from the break-and-burn method (Chilton and Beamish 1982). The survey age compositions from 1984-2009 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 very large year class. Preliminary indications from the 2009 survey and the 2010 fishery age compositions suggest that the 2006 year class could rival the 1986 year class

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.

Analytic Approach

Model Structure

We present results for Pacific ocean perch based on an age-structured model using AD Model Builder software (ADMB Project 2009). 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 Independently

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 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 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_∞-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 conditionally

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. We had 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.

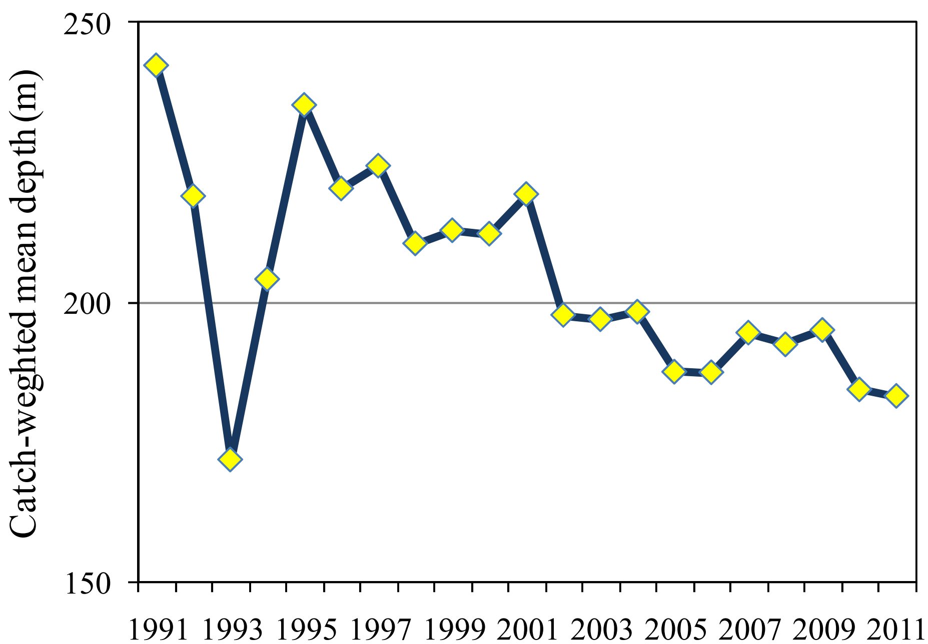


Figure. Change in catch-weighted mean depth of the Gulf of Alaska POP fishery over time.

Based on the data examined in Hanselman et al. (2009), we recommended 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 2^{nd} block, and a gamma function for the 3^{rd} block. 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	73
Average fishing mortality	μ_f	1
Fishing mortality deviations	ϕ_y	51
Fishery selectivity coefficients	fs_a	4
Survey selectivity coefficients	ss_a	2
Total		138

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 138. 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 2,000,000 iterations out of 20,000,000 and "thinned" the chain to one value out of every four 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

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

Number at age of recruitment

Number at ages between recruitment and pooled age class

Number in pooled age class

Subsequent years

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

Number at age of recruitment

Number at ages between recruitment and pooled age class

Number in pooled age class

Formulae for likelihood components **BOX 1 (Continued)**

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

Selectivity equations

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

Model Evaluation

This model is the same model accepted in 2009 with additional data.

Model Results

Key results have been summarized in Tables 9-12 to 9-15. Model predictions 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, with the exception of catchability and fishing mortality.

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 had gradually increased from a low near 85,000 t in 1980 to about 350,000 t for 2011 (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 200,000 and 600,000 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 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 near two and slightly increased from 2009. The high catchability for POP is supported by several empirical studies using line transect densities counted from a submersible compared to trawl survey densities (Krieger 1993 [q=2.1], Krieger and Sigler 1996 [q=1.3], Hanselman et al. 2006[1] [q=2.1]).

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

Recruitment

Recruitment (as measured by age 2 fish) for Pacific ocean perch is highly variable and large recruitments comprise much of the biomass for future years (Figure 9-17). Recruitment appears to have increased since the early 1970s, with the 1986 year class remaining the highest in recent history. The 1990s are starting to show some steady higher than average recruitments (average from 1979-2009). The addition of new age data in this year’s model has increased the recruitment estimates for the 2005 and 2006 year classes (Figure 9-18). However, these recent recruitments are still highly uncertain as indicated by the MCMC

---

[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.

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 9-8 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, $F_{40\%}$, and female spawning biomass but the MCMC standard deviations are larger for the estimates of natural mortality, and ABC. These larger standard deviations indicate that these parameters are more uncertain than indicated by the Hessian approximation. The distribution of ABC and spawning biomass are skewed and also higher medians, indicating possibilities of higher biomass estimates (also see Figure 9-19).

Projections and Harvest Alternatives

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 2009. 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 2011 estimates of these reference points are:

$B_{100\%}$	$B_{40\%}$	$B_{35\%}$	$F_{40\%}$	$F_{35\%}$
234,689	93,876	82,141	0.119	0.138

Specification of OFL and Maximum Permissible ABC

Female spawning biomass for 2012 is estimated at 107,769 t. This is above the $B_{40\%}$ value of 93,876 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 2012, yields the following ABC and OFL:

$F_{40\%}$	0.119
ABC	**16,918**
$F_{35\%}$	0.138
OFL	**19,498**

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 years 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 2011 numbers at age as estimated in the assessment. This vector is then projected forward to the beginning of 2012 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2011. 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 2011 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 2012, 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 2012 and 2013, 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 2008-2010 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 2007-2011 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 2011 or 2) above ½ of its MSY level in 2011 and above its MSY level in 2021 under this scenario, then the stock is not overfished.)

Scenario 7: In 2012 and 2013, 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 2024 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 2012, it does not provide the best estimate of OFL for 2013, because the mean 2012 catch under Scenario 6 is predicated on the 2012 catch being equal to the 2012 OFL, whereas the actual 2012 catch will likely be less than the 2012 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 (2010) is 15,616 t. This is less than the 2010 OFL of 20,243 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 2011:
a. If spawning biomass for 2011 is estimated to be below ½ $B_{35\%}$, the stock is below its MSST.
b. If spawning biomass for 2011 is estimated to be above $B_{35\%}$ the stock is above its MSST.
c. If spawning biomass for 2011 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 2021 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 2014 is below 1/2 $B_{35\%}$, the stock is approaching an overfished condition.
b. If the mean spawning biomass for 2014 is above $B_{35\%}$, the stock is not approaching an overfished condition.

c. If the mean spawning biomass for 2014 is above 1/2 $B_{35\%}$ but below $B_{35\%}$, the determination depends on the mean spawning biomass for 2024. If the mean spawning biomass for 2024 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 2011 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. 2008-2010 for this year, see example figures below). For Pacific ocean perch, the expansion factor for 2011 catch is 1.04.

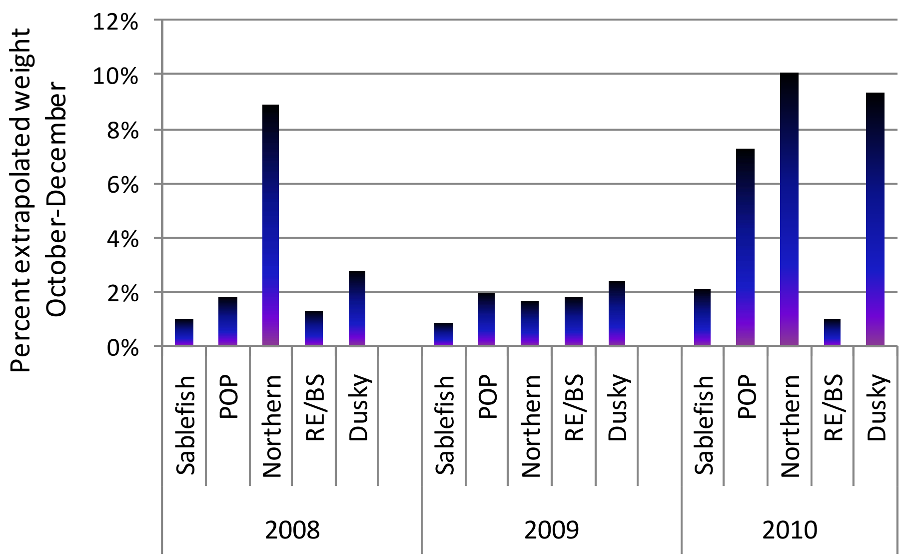


Figure. Extrapolated catch that occurs between October and December, 2008-2010.

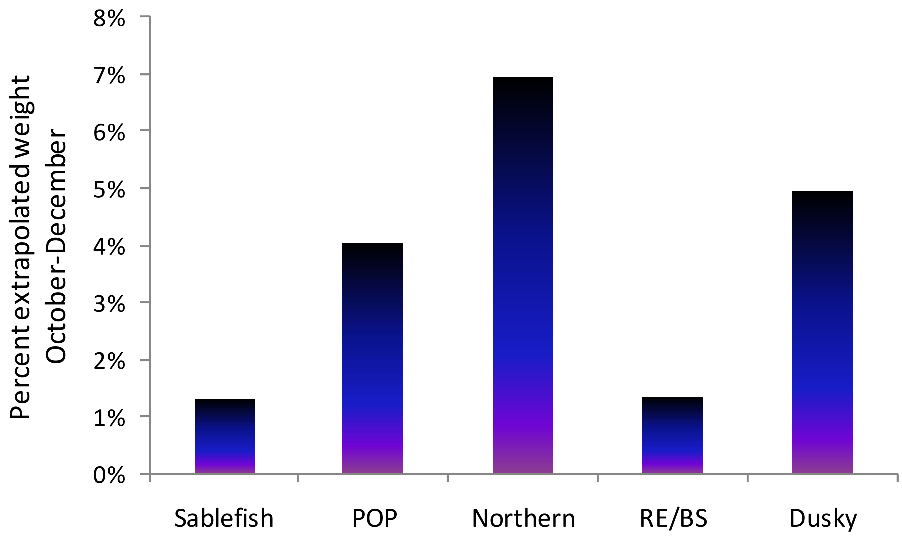


Figure. Examples of mean proportion of catch between October-December, 2008-2010.

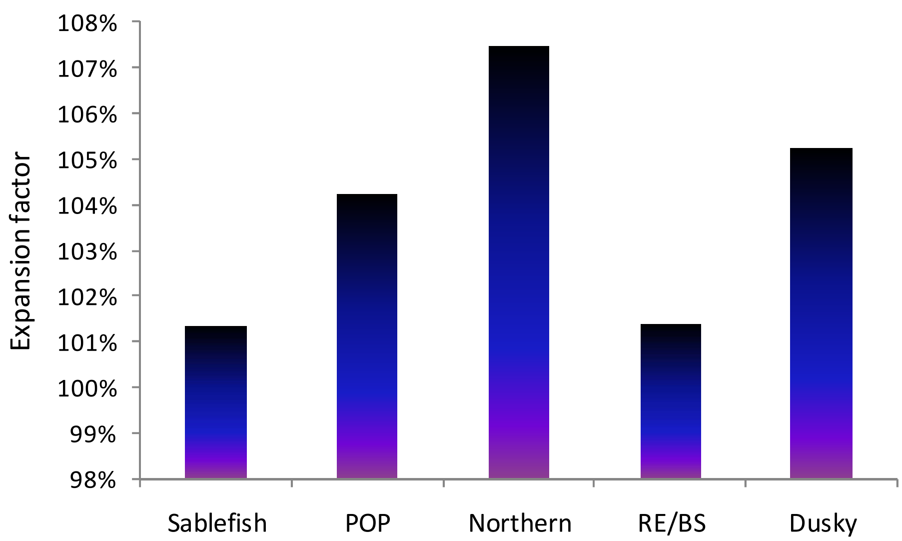


Figure. Expansion factor: $x = \sum_1^{12} C_y \,/\, \sum_1^{9} C_y$, where C_y is catch in month *y*.

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 20,000,000. 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 1979-2009 age-2 recruitments, and this projection predicts that the median spawning biomass will eventually tend toward these reference points 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 2007, 2009, and 2011 surveys, respectively and apportionments of 12% for the Western area, 67% for the Central area, and 21% for the Eastern area (Table 9-17). This results in recommended ABC's of **2,102** t for the Western area, **11,263** t for the Central area, and **3,553** 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^{o}W and 140^{o}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 2007, 2009, and 2011. We calculated the approximate upper 95% confidence interval using the weighted variance of the 2007-2011 ratios for our weighted ratio estimate. This resulted in slightly lower ratio of 0.48, down from 0.50 in 2009. This results in an ABC apportionment of 1,692 t to the W. Yakutat area which would leave 1,861 t unharvested in the Southeast/Outside area.

Overfishing Definition

Based on the definitions for overfishing in Amendment 44 in tier 3a (i.e., $F_{OFL} = F_{35\%}$=0.138), overfishing is set equal to 19,498 t for Pacific ocean perch. The overfishing level is apportioned by area for Pacific ocean perch. Using the apportionment described above, results in overfishing levels by area of 2,423 t in the Western Gulf, 12,980 t in the Central Gulf, and 4,095 t in the Eastern Gulf.

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 transition 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

Summary

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

Quantity	As estimated or specified *last* year for: 2011	2012	As estimated or recommended *this* year for: 2012	2013[1]
M	0.061	0.061	0.062	0.062
Tier	3a	3a	3a	3a
Projected total (age 2+) biomass (t)	330,480	326,324	348,168	346,171
Female spawning biomass (t)				
Projected	108,212	107,185	107,769	107,914
$B_{100\%}$	227,610	227,610	234,689	234,689
$B_{40\%}$	91,044	91,044	93,876	93,876
$B_{35\%}$	79,664	79,664	82,141	82,141
F_{OFL}	0.142	0.142	0.138	0.138
$maxF_{ABC}$	0.123	0.123	0.119	0.119
F_{ABC}	0.123	0.123	0.119	0.119
OFL (t)	**19,566**	18,635	**19,498**	19,021
maxABC (t)	**16,997**	16,187	**16,918**	16,500
ABC (t)	**16,997**	16,187	**16,918**	16,500
Status	As determined *last* year for: 2009	2010	As determined *this* year for: 2010	2011
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 2012 and 2013 are derived using estimated catch of 13,918 for 2011, and projected catches of 14,549 t and 14,190 t for 2012 and 2013 based on realized catches from 2008-2010. This calculation is in response to management requests to obtain more accurate projections.

Literature Cited

ADMB Project. 2009. AD Model Builder: automatic differentiation model builder. Developed by David Fournier and freely available from admb-project.org.

Ainley, D.G., Sydeman, W.J., Parrish, R.H., and Lenarz, W.H. 1993. Oceanic factors influencing distribution of young rockfish (Sebastes) in central California: A predator's perspective. CalCOFI Report 34: 133-139.

Allen, M .J., and G. B. Smith. 1988. Atlas and zoogeography of common fishes in the Bering Sea and northeastern Pacific. U.S. Dep. Commer., NOAA Tech. Rept. NMFS 66, 151 p.

Archibald, C. P., W. Shaw, and B. M. Leaman. 1981. Growth and mortality estimates of rockfishes (Scorpaenidae) from B.C. coastal waters, 1977-1979. Can. Tech. Rep. Fish. Aquat. Sci. 1048: iv +57 p.

Berkeley, S. A., C. Chapman, and S. M. Sogard. 2004. Maternal age as a determinant of larval growth and survival in a marine fish, Sebastes melanops. Ecology 85(5):1258-1264.

Bobko, S.J. and S.A. Berkeley. 2004. Maturity, ovarian cycle, fecundity, and age-specific parturition of black rockfish (Sebastes melanops). Fisheries Bulletin 102:418-429.

Brodeur, R. D. 2001. Habitat-specific distribution of Pacific ocean perch (Sebastes alutus) in Pribilof Canyon, Bering Sea. Continent. Shelf Res., 21:207-224.

Byerly, Michael M. 2001. The ecology of age-1 Copper Rockfish (Sebastes caurinus) in vegetated habitats of Sitka sound, Alaska. M.S. thesis. University of Alaska, Fairbanks. Fisheries Division, 11120 Glacier Hwy, Juneau, AK 99801.

Carlson, H. R., and R. E. Haight. 1976. Juvenile life of Pacific ocean perch, *Sebastes alutus*, in coastal fiords of southeastern Alaska: their environment, growth, food habits, and schooling behavior. Trans. Am. Fish. Soc. 105:191-201.

Carlson, H. R., and R. R. Straty. 1981. Habitat and nursery grounds of Pacific rockfish, *Sebastes* spp., in rocky coastal areas of Southeastern Alaska. Mar. Fish. Rev. 43: 13-19.

Carlson, H.R., D.H. Ito, R.E. Haight, T.L. Rutecki, and J.F. Karinen. 1986. Pacific ocean perch. In R.L. Major (editor), Condition of groundfish resources of the Gulf of Alaska region as assessed in 1985, p. 155-209. U.S. Dept. Commer., NOAA Tech. Memo. NMFS F/NWC-106.

Chilton, D.E. and R.J. Beamish. 1982. Age determination methods for fishes studied by the groundfish program at the Pacific Biological Station. Can. Spec. Pub. Fish. Aquat. Sci. 60.

Courtney, D.L., J. Heifetz, M. F. Sigler, and D. M. Clausen. 1999. An age structured model of northern rockfish, *Sebastes polyspinis*, recruitment and biomass in the Gulf of Alaska. In Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska as projected for 2000. Pp. 361-404. North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306 Anchorage, AK 99501.

Courtney, D.L., J. N. Ianelli, D. Hanselman, and J. Heifetz. 2007. Extending statistical age-structured assessment approaches to Gulf of Alaska rockfish (Sebastes spp.). In: Heifetz, J., DiCosimo J., Gharrett, A.J., Love, M.S, O'Connell, V.M, and Stanley, R.D. (eds.). Biology, Assessment, and Management of North Pacific Rockfishes. Alaska Sea Grant, University of Alaska Fairbanks. pp 429–449.

de Bruin, J., R. Gosden, C. Finch, and B. Leaman. 2004. Ovarian aging in two species of long-lived rockfish, sebastes aleutianus and S. alutus. Biol. Reprod. 71: 1036-1042.

Gelman, A., J.B. Carlin, H.S. Stern, and D.B. Rubin. 1995. Bayesian data analysis. Chapman and Hall, London. 526 pp.

Gharrett, A. J., A.K. Gray, and J. Heifetz. 2001. Identification of rockfish (*Sebastes* spp.) from restriction site analysis of the mitochondrial NM-3/ND-4 and 12S/16S rRNA gene regions. Fish. Bull. 99:49-62.

Gharrett, A. J., Z. Li, C. M. Kondzela, and A. W. Kendall. 2002. Final report: species of rockfish (*Sebastes* spp.) collected during ABL-OCC cruises in the Gulf of Alaska in 1998-2002. (Unpubl. manuscr. available from the NMFS Auke Bay Laboratory, 11305 Glacier Hwy., Juneau AK 99801.)

Goodman, D., M. Mangel, G. Parkes, T.J. Quinn II, V. Restrepo, T. Smith, and K. Stokes. 2002. Scientific Review of the Harvest Strategy Currently Used in the BSAI and GOA Groundfish Fishery Management Plans. Draft report. North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306 Anchorage, AK 99501.

Haldorson, L, and M. Love. 1991. Maturity and fecundity in the rockfishes, Sebastes spp., a review. Mar. Fish. Rev. 53(2):25–31.

Hanselman, D. H., J. Heifetz, J. Fujioka, and J. N. Ianelli. 2003. Gulf of Alaska Pacific ocean perch. In Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska as projected for 2004. North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306 Anchorage, AK 99501.

Hanselman, D.H., T.J. Quinn II, C. Lunsford, J. Heifetz and D.M. Clausen. 2001. Spatial implications of adaptive cluster sampling on Gulf of Alaska rockfish. In Proceedings of the 17th Lowell-Wakefield Symposium: Spatial Processes and Management of Marine Populations, pp. 303-325. Univ. Alaska Sea Grant Program, Fairbanks, AK.

Hanselman, D.H., T.J. Quinn II, C. Lunsford, J. Heifetz and D.M. Clausen. 2003. Applications in adaptive cluster sampling of Gulf of Alaska rockfish. Fish. Bull. 101(3): 501-512.

Hanselman, D., P. Spencer, K. Shotwell,and R. Reuter. 2007. Localized depletion of three Alaska rockfish species. In: Heifetz, J., DiCosimo J., Gharrett, A.J., Love, M.S, O'Connell, V.M, and Stanley, R.D. (eds.). Biology, Assessment, and Management of North Pacific Rockfishes. Alaska Sea Grant, University of Alaska Fairbanks. pp 493 – 511.

Heppell, S.S., S.A. Heppell, P. Spencer, W.D. Smith, and L. Arnold. 2009. Assessment of female reproductive effort and maternal effects in Pacific Ocean Perch *Sebastes alutus*: do big old females matter? Project 629 Final Report to the North Pacific Research Board.

Heifetz, J., D. M. Clausen, and J. N. Ianelli. 1994. Slope rockfish. In Stock assessment and fishery evaluation report for the 1995 Gulf of Alaska groundfish fishery, p. 5-1 - 5-24. North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306 Anchorage, AK 99501.

Heifetz, J., J. N. Ianelli, D. M. Clausen, D. L. Courtney, and J. T. Fujioka. 2000. Slope rockfish. In Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska as projected for 2001. North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306 Anchorage, AK 99501.

Hilborn, R., J. Maguire, A. Parma, and A. Rosenberg, A. 2001. The Precautionary Approach and risk management: can they increase the probability of successes in fishery management? Can. J. Fish. Aquat. Sci. 58: 99-107.

Hobson, E.S., J.R. Chess, D.F. Howard. 2001. Interannual variation in predation on first-year Sebastes spp. by three northern California predators. Fish. Bull. 99: 292-302.

Karinen, J. F., and B. L. Wing. 1987. Pacific ocean perch. In R. L. Major (editor), Condition of groundfish resources of the Gulf of Alaska region as assessed in 1986, p. 149-157. U.S. Dep. Commer., NOAA Tech. Memo. NMFS F/NWC-119.

Kendall, A. W., and W. H. Lenarz. 1986. Status of early life history studies of northeast Pacific rockfishes. Proc. Int. Rockfish Symp. Oct. 1986, Anchorage Alaska; p. 99-117.

Kendall, A.W., Jr. 2000. An historical review of Sebastes taxonomy and systematics. Mar. Fish. Rev. 62: 1-16.

Krieger, K.J., 1993. Distribution and abundance of rockfish determined from a submersible and by bottom trawling. Fish. Bull. 91, 87-96.

Krieger, K.J., and M.F. Sigler. 1996. Catchability coefficient for rockfish estimated from trawl and submersible surveys. Fish. Bull. 94, 282-288.

Leaman, B. M. 1991. Reproductive styles and life history variables relative to exploitation and management of Sebastes stocks. Environmental Biology of Fishes 30: 253-271.

Leaman, B.M. and R.J. Beamish. 1984. Ecological and management implications of longevity in some Northeast Pacific groundfishes. Int. North Pac. Fish. Comm. Bull. 42:85-97.

Li, Z. 2004. Phylogenetic relationships and identification of juveniles of the genus Sebastes. University of Alaska-Fairbanks, School of Fisheries and Ocean Sciences. M.S. thesis.

Longhurst, A., 2002. Murphy's law revisited: longevity as a factor in recruitment to fish populations.. Fish. Res. 56:125-131.

Love, M.S., M.H. Carr, and L.J. Haldorson. 1991. The ecology of substrate-associated juveniles of the genus Sebastes. Environmental Biology of Fishes 30:225-243.

Love M.S, M.M. Yoklavich, and L. Thorsteinson 2002. The Rockfishes of the Northeast Pacific. University of California Press, Los Angeles.

Lunsford, C. 1999. Distribution patterns and reproductive aspects of Pacific ocean perch (*Sebastes alutus*) in the Gulf of Alaska. M.S. thesis. University of Alaska Fairbanks, Juneau Center, School of Fisheries and Ocean Sciences.

Malecha, P. W., D. H. Hanselman, and J. Heifetz. 2007. Growth and mortality of rockfish (Scorpaenidae) from Alaskan waters. NOAA Tech. Memo. NMFS-AFSC-172. 61 p.

Major, R. L., and H. H. Shippen. 1970. Synopsis of biological data on Pacific ocean perch, *Sebastodes alutus*. FAO Fisheries Synopsis No. 79, NOAA Circular 347, 38 p.

Methot, R.D. 1990. Synthesis model: An adaptable framework for analysis of diverse stock assessment data. INPFC Bull. 50: 259-289.

National Marine Fisheries Service. 2005. Final Environmental Impact Statement for Essential Fish Habitat Identification and Conservation in Alaska. http://www.fakr.noaa.gov/habitat/seis/efheis.htm.

Palof, K.J. 2008. Population genetic structure of Alaskan Pacific ocean perch (*Sebastes alutus*). M.S. thesis, University of Alaska Fairbanks, Fairbanks, Alaska. 65 pp.

Palof, K. J., J. Heifetz, and A. J. Gharrett. 2011. Geographic structure in Alaskan Pacific Ocean perch (*Sebastes alutus*) indicates limited life-time dispersal.Marine Biology 158:779–792.

Pearcy, W. G., D. L. Stein, M. A. Hixon, E. K. Pikitch, W. H. Barss, and R. M. Starr. 1989. Submersible observations of deep-reef fishes of Heceta Bank, Oregon. Fishery Bulletin 87:955-965.

Quinn II, T.J., D. Hanselman, D.M. Clausen, J. Heifetz, and C. Lunsford. 1999. Adaptive cluster sampling of rockfish populations. Proceedings of the American Statistical Association 1999 Joint Statistical Meetings, Biometrics Section, 11-20.

Rooper, C.N. and J.L. Boldt. 2005. Distribution of juvenile Pacific ocean perch *Sebastes alutus* in the Aleutian Islands in Relation to Benthic Habitat. Alaska Fishery Research Bulletin 11(2):102-112.

Schnute, J.T., R. Haigh, B.A. Krishka, and P. Starr. 2001. Pacific ocean perch assessment for the west coast of Canada in 2001. Canadian research document 2001/138. 90 pp.

Seeb, L. W. and D.R. Gunderson. 1988. Genetic variation and population structure of Pacific ocean perch (*Sebastes alutus*). Can. J. Fish. Aquat. Sci. 45:78-88.

Seeb, L. W., and A. W. Kendall, Jr. 1991. Allozyme polymorphisms permit the identification of larval and juvenile rockfishes of the genus Sebastes. Environmental Biology of Fishes 30:191-201.

Spencer, P., Hanselman, D. and Dorn, M. 2007. The effect of maternal age of spawning on estimation of Fmsy for Alaska Pacific ocean perch. In: Heifetz, J., DiCosimo J., Gharrett, A.J., Love, M.S, O'Connell, V.M, and Stanley, R.D. (eds.). Biology, Assessment, and Management of North Pacific Rockfishes. Alaska Sea Grant, University of Alaska Fairbanks. pp 513 – 533.

Spencer, P.D., Hanselman, D.H., and McKelvey, D.R. 2011. Evaluation of echosign data in improving trawl survey biomass estimates for patchily-distributed rockfish. North Pacific Research Board Final Report 809, 110 p.

Withler, R.E., T.D. Beacham, A.D. Schulze, L.J. Richards, and K.M. Miller. 2001. Co-existing populations of Pacific ocean perch, *Sebastes alutus*, in Queen Charlotte Sound, British Columbia. Mar. Bio. 139: 1-12.

Yang, M-S. 1993. Food habits of the commercially important groundfishes in the Gulf of Alaska in 1990. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-22, 150 p.

Yang, M-S. 1996. Diets of the important groundfishes in the Aleutian Islands in summer 1991. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-60, 105 p.

Yang, M.S. 2003. Food habits of the important groundfishes of the Aleutian Islands in 1994 and 1997. National Marine Fisheries Service. AFSC Processed report 2003-07: 233 pp.

Yang, M.-S., and M.W. Nelson. 2000. Food habits of the commercially important groundfishes in the Gulf of Alaska in 1990, 1993, and 1996. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-112, 174 p.

Yang, M-S., K. Dodd, R. Hibpshman, and A. Whitehouse. 2006. Food habits of groundfishes in the Gulf of Alaska in 1999 and 2001. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-164, 199 p.

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	13,354	16,997	16,997		

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

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 1991-2010 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; 1988-2010, Pacific ocean perch.

[b]Quota defined as follows: 1977-86, optimum yield; 1987, target quota; 1988-2010 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); 1991-2010, 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 2006-2011. Conf. = Confidential because of less than three vessels or processors. . Source: NMFS AKRO Blend/Catch Accounting System via AKFIN 10/10/2011.

	Estimated Catch (t)					
Group Name	2006	2007	2008	2009	2010	2011
Pacific Ocean Perch	13,104	12,641	12,136	12,397	14,974	12,669
Northern Rockfish	4,653	3,957	3,812	3,855	3,833	3,143
Pelagic Shelf Rockfish	2,243	3,113	3,515	2,950	2,958	2,308
Atka Mackerel	779	1,094	1,745	1,913	2,148	1,404
Pollock	351	124	390	1,280	1,046	787
Other Rockfish	742	492	629	733	734	656
Pacific Cod	521	250	445	630	731	545
Sablefish	856	641	503	404	388	435
Arrowtooth Flounder	1,085	688	517	502	706	319
Rougheye Rockfish	83	114	104	97	179	285
Shortraker Rockfish	273	291	231	247	134	237
Thornyhead Rockfish	312	300	248	185	106	160
Deep Water Flatfish	92	45	29	30	48	56
Rex Sole	98	52	67	83	93	50
Shallow Water Flatfish	45	22	71	53	47	47
Sculpin	0	0	0	0	0	37
Skate, Longnose	21	17	12	17	12	24
Skate, Other	49	20	10	13	28	14
Flathead Sole	25	18	19	32	24	13
Squid	0	0	0	0	0	12
Skate, Big	4	0	4	4	13	5
Shark	0	0	0	0	0	3
Demersal Shelf Rockfish	13	1	Conf.	Conf.	Conf.	Conf.
Octopus	0	0	0	0	0	1

Table 9-4 . Catch (t) of Pacific ocean perch as bycatch in other fisheries from 2006-2011. Source: NMFS AKRO Blend/Catch Accounting System via AKFIN 10/10/2011.

Target	2006	2007	2008	2009	2010	2011	Average
Rex Sole	100	68	79	420	359	291	219
Arrowtooth	218	69	162	76	42	369	156
Pollock	64	28	43	12	48	72	45
Sablefish	0	16	7	13	10	8	9
Pacific Cod	27	3	6	11	2	6	9

Table 9-5. Non-FMP species bycatch estimates in tons for Gulf of Alaska rockfish targeted fisheries 2006 - 2011. Conf. = Confidential because of less than three vessels. Source: NMFS AKRO Blend/Catch Accounting System via AKFIN 10/10/2011.

	Estimated Catch (t)					
Group Name	2006	2007	2008	2009	2010	2011
Benthic urochordata	0.04	0.03	0.27	Conf.	0.08	Conf.
Birds	-	Conf.	Conf.	0.01	-	Conf.
Bivalves	0.01	-	0.00	Conf.	0.01	0.01
Brittle star unidentified	0.09	0.01	0.04	0.03	0.02	0.01
Capelin	-	-	-	0.00	-	-
Corals Bryozoans	0.39	2.27	0.47	0.36	0.42	0.38
Dark Rockfish	-	-	17.86	46.98	110.85	12.82
Eelpouts	0.03	0.12	0.35	0.00	0.05	Conf.
Eulachon	0.30	0.05	0.01	0.03	0.00	0.00
Giant Grenadier	272.06	127.14	161.30	298.50	374.15	423.43
Greenlings	5.94	7.74	14.77	8.10	9.52	7.34
Grenadier	65.54	70.61	3.43	3.11	34.94	110.64
Hermit crab unidentified	0.06	Conf.	0.01	0.01	0.01	0.02
Invertebrate unidentified	0.04	0.01	0.24	0.30	5.05	0.38
Lanternfishes	-	Conf.	-	0.00	Conf.	-
Misc crabs	0.41	0.13	0.07	0.10	0.07	0.04
Misc crustaceans	-	-	-	0.36	0.02	Conf.
Misc deep fish	-	-	0.00	-	-	-
Misc fish	180.74	186.07	195.90	134.74	167.24	132.49
Misc inverts (worms etc)	0.01	-	0.01	Conf.	-	Conf.
Other osmerids	0.26	0.09	Conf.	0.16	0.01	-
Pacific Sand lance	-	-	-	-	-	Conf.
Pandalid shrimp	0.17	0.11	0.11	0.09	0.22	0.06
Scypho jellies	0.43	0.21	0.11	0.70	1.89	0.00
Sea anemone unidentified	0.62	0.20	0.69	3.24	1.56	4.10
Sea pens whips	-	-	Conf.	0.01	0.01	0.04
Sea star	2.22	0.66	1.16	1.79	1.38	1.52
Snails	0.80	0.07	0.18	10.63	0.20	0.23
Sponge unidentified	0.96	0.65	2.97	6.65	3.66	4.41
Stichaeidae	0.01	-	-	0.01	-	-
Urchins, dollars cucumbers	0.30	0.17	0.26	0.66	0.22	0.44

Table 9-6. Prohibited Species Catch (PSC) estimates reported in tons for halibut and herring, and thousands of animals for crab and salmon, by year, for the GOA rockfish fishery. Source: NMFS AKRO Blend/Catch Accounting System PSCNQ via AKFIN 10/10/2011.

Group Name	2005	2006	2007	2008	2009	2010	Average
Bairdi Crab	1.75	0.96	0.16	0.06	0.30	0.10	0.56
Blue King Crab	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chinook Salmon	0.45	0.26	2.04	2.28	1.39	1.60	1.34
Golden K. Crab	0.00	0.07	0.13	0.34	3.28	3.00	1.14
Halibut	368	254	137	160	110	142	195
Herring	0.00	0.00	0.02	0.04	0.00	0.15	0.04
Other Salmon	3.38	1.83	0.72	0.53	0.47	0.37	1.22
Opilio Crab	0.00	0.00	0.00	0.00	0.02	0.00	0.00
Red King Crab	0.00	0.00	0.00	0.00	0.00	0.00	0.00

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

Length (cm)	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
12	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
13-15	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
16	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
17	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
18	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
19	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000
20	0.000	0.001	0.000	0.001	0.000	0.000	0.000	0.001	0.001	0.001	0.000	0.000	0.002
21	0.000	0.000	0.001	0.001	0.001	0.001	0.000	0.001	0.001	0.001	0.000	0.000	0.001
22	0.000	0.000	0.000	0.002	0.001	0.001	0.001	0.002	0.001	0.002	0.001	0.001	0.003
23	0.000	0.001	0.001	0.001	0.002	0.001	0.001	0.003	0.001	0.003	0.002	0.000	0.005
24	0.001	0.003	0.001	0.001	0.002	0.001	0.002	0.002	0.003	0.004	0.002	0.001	0.004
25	0.002	0.003	0.002	0.002	0.006	0.002	0.003	0.004	0.003	0.004	0.003	0.002	0.003
26	0.003	0.004	0.004	0.002	0.006	0.002	0.004	0.006	0.005	0.006	0.003	0.003	0.003
27	0.002	0.004	0.007	0.003	0.006	0.004	0.003	0.005	0.007	0.009	0.003	0.005	0.004
28	0.003	0.004	0.007	0.005	0.007	0.007	0.006	0.010	0.010	0.009	0.008	0.006	0.005
29	0.005	0.008	0.010	0.007	0.008	0.008	0.014	0.011	0.015	0.014	0.012	0.008	0.006
30	0.005	0.006	0.009	0.010	0.009	0.008	0.018	0.018	0.022	0.015	0.016	0.013	0.008
31	0.008	0.009	0.014	0.012	0.011	0.012	0.013	0.026	0.030	0.026	0.025	0.023	0.014
32	0.012	0.015	0.014	0.018	0.019	0.015	0.018	0.035	0.057	0.041	0.040	0.042	0.025
33	0.021	0.032	0.023	0.033	0.038	0.024	0.026	0.045	0.075	0.068	0.063	0.071	0.042
34	0.053	0.068	0.057	0.052	0.067	0.057	0.042	0.063	0.091	0.099	0.093	0.099	0.074
35-38	0.640	0.583	0.581	0.556	0.503	0.519	0.514	0.495	0.425	0.475	0.473	0.498	0.551
>38	0.240	0.257	0.268	0.292	0.315	0.337	0.333	0.273	0.255	0.226	0.255	0.227	0.248
Total	18,724	5,126	7,027	5,750	6,156	7,112	6,140	5,563	6,094	9,784	8,154	8,898	11,174

Table 9-8. Fishery age compositions for GOA Pacific ocean perch 1998-2010.

Age Class	1998	1999	2000	2001	2002	2004	2005	2006	2008	2010
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	0.000	0.002	0.000	0.000	0.001	0.000	0.000	0.000
4	0.000	0.000	0.005	0.004	0.003	0.002	0.001	0.001	0.005	0.024
5	0.000	0.003	0.015	0.002	0.014	0.007	0.012	0.003	0.005	0.006
6	0.000	0.016	0.037	0.017	0.016	0.051	0.021	0.045	0.021	0.021
7	0.002	0.024	0.026	0.040	0.035	0.040	0.085	0.089	0.031	0.024
8	0.008	0.029	0.056	0.029	0.097	0.049	0.085	0.114	0.102	0.082
9	0.045	0.043	0.064	0.058	0.078	0.166	0.103	0.108	0.103	0.061
10	0.148	0.051	0.057	0.060	0.108	0.177	0.142	0.084	0.161	0.134
11	0.166	0.178	0.054	0.060	0.105	0.067	0.114	0.106	0.108	0.128
12	0.203	0.191	0.132	0.063	0.051	0.075	0.074	0.087	0.048	0.122
13	0.121	0.130	0.127	0.131	0.070	0.069	0.047	0.061	0.090	0.067
14	0.113	0.088	0.110	0.146	0.108	0.036	0.044	0.037	0.051	0.043
15	0.057	0.120	0.104	0.084	0.086	0.036	0.021	0.035	0.043	0.049
16	0.031	0.061	0.060	0.092	0.065	0.049	0.032	0.026	0.023	0.043
17	0.033	0.021	0.052	0.061	0.054	0.050	0.050	0.027	0.026	0.040
18	0.014	0.019	0.031	0.071	0.038	0.041	0.041	0.035	0.011	0.012
19	0.014	0.003	0.025	0.040	0.035	0.030	0.032	0.038	0.026	0.018
20	0.002	0.003	0.008	0.015	0.011	0.021	0.026	0.027	0.028	0.012
21	0.004	0.000	0.010	0.012	0.003	0.009	0.028	0.025	0.026	0.012
22	0.004	0.008	0.011	0.002	0.005	0.007	0.011	0.010	0.026	0.040
23	0.012	0.003	0.004	0.006	0.003	0.005	0.008	0.015	0.020	0.015
24	0.002	0.000	0.001	0.000	0.003	0.006	0.007	0.010	0.015	0.009
25+	0.023	0.011	0.011	0.006	0.011	0.006	0.015	0.016	0.030	0.040
Sample size	513	376	734	521	370	802	727	734	609	329

Table 9-9. Biomass estimates (t) and Gulfwide confidence intervals for Pacific ocean perch in the Gulf of Alaska based on the 1984-2011 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%

*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
2	0.003	0.019	0.005	0.006	0.006	0.006	0.016	0.001	0.003	0.005
3	0.002	0.101	0.043	0.018	0.016	0.020	0.057	0.034	0.020	0.089
4	0.058	0.092	0.155	0.021	0.036	0.045	0.053	0.050	0.018	0.043
5	0.029	0.066	0.124	0.044	0.043	0.052	0.071	0.077	0.044	0.050
6	0.079	0.091	0.117	0.088	0.063	0.026	0.040	0.073	0.041	0.025
7	0.151	0.146	0.089	0.125	0.038	0.041	0.054	0.119	0.056	0.099
8	0.399	0.056	0.065	0.129	0.088	0.059	0.107	0.069	0.089	0.068
9	0.050	0.061	0.054	0.166	0.145	0.095	0.115	0.087	0.125	0.107
10	0.026	0.087	0.055	0.092	0.185	0.054	0.057	0.092	0.094	0.049
11	0.010	0.096	0.036	0.045	0.110	0.114	0.053	0.063	0.063	0.055
12	0.016	0.018	0.024	0.052	0.080	0.144	0.044	0.035	0.064	0.080
13	0.015	0.011	0.028	0.038	0.034	0.086	0.036	0.027	0.050	0.035
14	0.019	0.011	0.072	0.025	0.036	0.067	0.057	0.031	0.030	0.032
15	0.005	0.009	0.017	0.026	0.028	0.046	0.048	0.039	0.026	0.047
16	0.003	0.011	0.011	0.011	0.006	0.040	0.042	0.022	0.013	0.013
17	0.008	0.013	0.005	0.036	0.013	0.023	0.032	0.027	0.018	0.006
18	0.004	0.007	0.008	0.007	0.009	0.013	0.029	0.036	0.039	0.015
19	0.002	0.005	0.004	0.003	0.014	0.003	0.016	0.024	0.028	0.005
20	0.000	0.005	0.006	0.002	0.013	0.012	0.015	0.021	0.043	0.013
21	0.003	0.004	0.004	0.002	0.003	0.007	0.010	0.013	0.024	0.033
22	0.003	0.003	0.002	0.004	0.004	0.008	0.005	0.018	0.022	0.053
23	0.002	0.002	0.002	0.002	0.003	0.012	0.006	0.004	0.016	0.014
24	0.003	0.002	0.006	0.004	0.000	0.004	0.007	0.008	0.018	0.023
25+	0.110	0.083	0.070	0.054	0.027	0.025	0.031	0.030	0.055	0.040
Total	1,427	1,824	1,754	1,378	641	898	985	1,009	1,177	408

Table 9-11. Estimated numbers (thousands) in 2011, 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 2011 (1000's)	Maturity (%)	Weight (g)	Fishery selectivity (%)	Survey selectivity (%)
2	46,335	0	46	0	4
3	43,783	0	106	0	11
4	41,659	0	180	0	25
5	65,557	0	261	2	48
6	58,861	0	342	6	72
7	41,924	12	420	17	87
8	29,328	20	493	32	95
9	27,497	30	559	52	98
10	25,517	42	619	72	99
11	28,633	56	672	88	100
12	50,093	69	718	97	100
13	27,495	79	758	100	100
14	15,814	87	792	96	100
15	16,198	92	822	87	100
16	21,234	95	847	75	100
17	10,806	97	868	62	100
18	7,095	98	886	50	100
19	6,013	99	902	38	100
20	5,462	99	915	29	100
21	5,403	100	926	21	100
22	5,773	100	935	15	100
23	6,321	100	943	10	100
24	8,485	100	950	7	100
25+	65,890	100	970	5	100

Table 9-12. Summary of results from 2011 compared with 2009 results

	2009	2011
Likelihoods		
Catch	0.10	0.11
Survey Biomass	6.91	7.29
Fishery Ages	22.48	24.69
Survey Ages	42.28	45.85
Fishery Sizes	55.37	55.48
Data-Likelihood	127.1	133.4
Penalties/Priors		
Recruitment Devs	21.60	21.05
F Regularity	4.12	4.11
σ_r prior	4.77	5.02
q prior	1.14	1.26
M prior	2.08	2.15
Objective Fun Total	160.8	167.0
Parameter Ests.		
Active parameters	134	138
q	1.97	2.03
M	0.061	0.062
σ_r	0.92	0.90
Mean Recruitment (millions)	44.93	46.29
$F_{40\%}$	0.123	0.119
Total Biomass	334,797	348,168
$B_{CURRENT}$	107,763	107,769
$B_{100\%}$	227,610	234,689
$\mathbf{B_{40\%}}$	91,044	93,876
maxABC	17,584	**16,918**
$F_{35\%}$	0.142	0.138
$OFL_{F35\%}$	20,243	**19,498**

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	2.034	1.920	1.870	0.526	0.500	1.074	3.021
M	0.062	0.063	0.062	0.006	0.006	0.052	0.076
$F_{40\%}$	0.119	0.130	0.126	0.027	0.033	0.079	0.207
2012 SSB	107,769	124,929	118,632	32,527	39,030	65,358	220,250
2012 ABC	16,918	21,040	19,818	6,205	8,899	7,063	41,995

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	28,105	27,838	95,464	94,773	0.226	0.228	17,697	17,916
1978	23,580	23,291	78,682	78,031	0.102	0.103	31,616	31,701
1979	23,311	23,011	75,153	74,560	0.11	0.111	59,149	56,858
1980	22,590	22,289	71,129	70,601	0.152	0.153	22,559	22,792
1981	20,552	20,262	65,189	64,736	0.161	0.162	18,610	18,740
1982	18,361	18,092	63,355	62,939	0.085	0.086	24,001	23,833
1983	18,289	18,040	74,891	73,871	0.038	0.038	27,958	27,478
1984	19,935	19,663	80,933	79,889	0.034	0.034	30,140	29,671
1985	21,814	21,526	85,691	84,623	0.009	0.009	47,647	46,593
1986	24,746	24,430	93,429	92,275	0.024	0.024	59,358	58,483
1987	27,700	27,339	100,477	99,159	0.045	0.045	45,187	45,291
1988	30,160	29,733	105,600	104,112	0.081	0.082	236,576	228,851
1989	31,059	30,563	111,178	109,349	0.106	0.108	62,835	64,758
1990	30,718	30,148	117,142	114,988	0.112	0.114	46,601	46,447
1991	30,251	29,601	119,126	116,904	0.056	0.056	40,712	40,612
1992	32,313	31,621	179,026	174,727	0.034	0.037	36,298	36,141
1993	38,711	37,676	200,982	196,415	0.01	0.010	34,424	34,391
1994	46,817	45,606	221,688	216,866	0.008	0.008	34,803	35,183
1995	56,498	55,074	238,999	234,015	0.024	0.025	37,178	37,994
1996	66,105	64,455	248,849	243,737	0.034	0.034	50,834	52,093
1997	75,218	73,332	253,307	248,147	0.038	0.038	93,334	90,679
1998	82,759	80,692	254,848	249,809	0.035	0.036	60,606	60,402
1999	88,355	86,202	256,182	251,477	0.041	0.042	51,114	50,938
2000	91,595	89,394	258,630	254,376	0.039	0.040	79,524	76,085
2001	93,401	91,232	272,647	267,860	0.04	0.040	115,611	119,228
2002	94,720	92,559	278,944	274,147	0.042	0.043	54,299	59,101
2003	95,310	93,189	281,640	276,856	0.039	0.039	42,681	46,331
2004	96,394	94,322	292,330	286,713	0.039	0.041	41,492	44,708
2005	98,291	96,133	312,650	307,821	0.036	0.037	41,054	43,474
2006	101,631	99,506	318,748	315,371	0.043	0.043	46,378	57,505
2007	104,300	102,246	318,187	316,137	0.041	0.041	43,534	75,432
2008	106,994	105,101	316,413	315,686	0.039	0.039	45,002	78,864
2009	109,724	108,065	313,777	314,149	0.04	0.041	44,940	47,114
2010		110,391		314,732		0.050		46,561
2011		107,304		317,547		0.042		46,335

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	17,915	4,250	54,018	102,732	85,316	147,802	27,838	21,173	41,746
1978	31,700	6,814	92,682	86,728	69,809	133,312	23,291	16,776	37,625
1979	56,859	11,320	128,026	86,366	68,271	135,645	23,011	16,474	37,998
1980	22,791	5,046	73,285	86,239	67,134	139,082	22,289	15,920	37,619
1981	18,740	4,306	53,244	83,775	63,238	140,377	20,262	13,946	36,196
1982	23,832	5,148	63,512	81,826	60,002	143,755	18,092	11,775	34,215
1983	27,478	6,029	73,941	85,425	62,356	151,000	18,040	11,579	34,809
1984	29,671	5,973	85,312	91,844	67,242	162,178	19,663	12,833	37,585
1985	46,593	9,089	125,497	99,261	73,078	175,613	21,525	14,224	40,688
1986	58,483	10,469	154,596	110,287	81,826	191,194	24,430	16,567	45,227
1987	45,289	7,624	167,839	120,916	90,120	210,672	27,338	18,990	50,100
1988	228,849	64,895	442,417	138,570	101,692	242,339	29,732	20,702	53,923
1989	64,757	9,780	238,838	155,008	112,346	276,459	30,562	20,871	56,621
1990	46,446	7,414	139,225	169,799	120,811	310,141	30,147	19,813	58,623
1991	40,611	7,213	123,459	183,217	127,477	340,725	29,601	18,360	60,252
1992	36,141	6,421	104,534	201,847	140,985	374,475	31,620	19,627	64,781
1993	34,391	6,518	98,754	218,118	152,584	403,374	37,675	23,548	76,200
1994	35,182	6,486	107,659	236,460	167,044	433,182	45,605	29,381	90,197
1995	37,993	6,919	119,509	252,571	179,628	457,542	55,073	36,496	105,772
1996	52,092	7,905	171,342	262,969	187,301	474,699	64,454	43,040	122,545
1997	90,680	11,006	229,918	271,183	192,433	490,565	73,332	48,984	139,216
1998	60,401	8,626	211,910	278,148	195,970	504,993	80,691	53,927	153,038
1999	50,937	8,514	192,364	285,557	200,318	519,599	86,201	57,526	163,407
2000	76,084	9,878	266,927	292,209	204,951	535,682	89,392	59,184	170,018
2001	119,229	12,737	307,982	302,125	211,302	553,557	91,231	60,204	174,402
2002	59,100	8,738	219,997	311,894	216,492	572,653	92,558	60,355	177,012
2003	46,330	7,450	160,038	320,332	220,317	592,462	93,188	60,278	180,933
2004	44,707	7,250	159,745	328,615	226,017	608,899	94,320	60,638	182,934
2005	43,473	6,998	155,943	334,450	229,990	623,550	96,132	61,320	187,802
2006	57,504	7,896	218,152	339,500	232,568	635,240	99,504	63,359	195,346
2007	75,432	8,798	325,022	341,943	232,316	646,040	102,245	64,607	201,773
2008	78,865	9,335	424,004	345,403	233,508	661,109	105,100	66,291	208,139
2009	47,113	7,478	237,612	348,637	235,710	671,403	108,064	67,723	215,130
2010	46,560	6,840	245,083	350,458	236,297	683,077	110,390	68,864	220,447
2011	46,334	7,091	234,272	348,896	232,923	690,284	107,303	65,229	219,809
2012	56,647	6,525	256,356	348,639	228,956	694,388	107,653	65,358	220,250

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. $B_{40\%}$ = 93,876 t, $B_{35\%}$ = 82,141 t, $F_{40\%}$ = 0.119, and $F_{35\%}$ = 0.138.

Year	Maximum permissible F	Author's F* (prespecified catch)	Half maximum F	5-year average F	No fishing	Overfished	Approaching overfished
			Spawning biomass (t)				
2011	107,270	107,270	107,270	107,270	107,270	107,270	107,270
2012	107,481	107,769	108,522	107,932	109,580	107,150	107,481
2013	106,774	107,914	110,946	108,559	115,388	105,487	106,774
2014	105,787	107,518	112,969	108,820	120,958	103,635	105,484
2015	104,914	106,571	114,959	109,108	126,595	101,983	103,730
2016	104,157	105,722	116,950	109,442	132,322	100,513	102,143
2017	103,468	104,932	118,734	109,776	138,053	99,170	100,680
2018	102,647	104,008	120,351	109,898	143,473	97,762	99,153
2019	101,715	102,976	121,503	109,810	148,446	96,320	97,598
2020	100,932	102,100	122,549	109,779	153,188	95,100	96,271
2021	100,211	101,294	123,639	109,721	157,541	94,035	95,093
2022	99,651	100,657	124,686	109,765	161,706	93,206	94,158
2023	99,271	100,205	125,881	109,945	165,788	92,606	93,462
2024	99,022	99,890	126,696	110,222	169,794	92,166	92,937
			Fishing mortality				
2011	0.095	0.095	0.095	0.095	0.095	0.095	0.095
2012	0.119	0.102	0.059	0.093	-	0.138	0.138
2013	0.119	0.102	0.059	0.093	-	0.138	0.138
2014	0.119	0.119	0.059	0.093	-	0.138	0.138
2015	0.119	0.119	0.059	0.093	-	0.138	0.138
2016	0.119	0.119	0.059	0.093	-	0.138	0.138
2017	0.119	0.119	0.059	0.093	-	0.138	0.138
2018	0.119	0.119	0.059	0.093	-	0.138	0.138
2019	0.119	0.119	0.059	0.093	-	0.138	0.138
2020	0.119	0.119	0.059	0.093	-	0.137	0.137
2021	0.119	0.119	0.059	0.093	-	0.136	0.136
2022	0.119	0.119	0.059	0.093	-	0.135	0.135
2023	0.119	0.119	0.059	0.093	-	0.134	0.134
2024	0.118	0.118	0.059	0.093	-	0.133	0.133
			Yield (t)				
2011	13,918	13,918	13,918	13,918	13,918	13,918	13,918
2012	16,918	16,918	8,649	13,364	-	19,498	16,918
2013	16,307	16,500	8,691	13,116	-	18,546	16,307
2014	15,860	16,225	8,760	12,954	-	17,837	18,287
2015	15,534	15,845	8,842	12,852	-	17,309	17,687
2016	15,229	15,485	8,899	12,742	-	16,834	17,141
2017	14,887	15,091	8,902	12,577	-	16,341	16,583
2018	14,525	14,683	8,856	12,372	-	15,855	16,040
2019	14,204	14,323	8,786	12,170	-	15,441	15,580
2020	13,971	14,058	8,723	12,014	-	15,081	15,230
2021	13,839	13,902	8,686	11,924	-	14,809	14,947
2022	13,775	13,825	8,674	11,888	-	14,651	14,766
2023	13,750	13,795	8,684	11,891	-	14,583	14,676
2024	13,759	13,797	8,712	11,922	-	14,578	14,650

*Projected ABCs and OFLs for 2012 and 2013 are derived using estimated catch of 13,918 for 2011, and projected catches of 14,549 t and 14,190 t for 2012 and 2013 based on realized catches from 2008-2010. This calculation is in response to management requests to obtain more accurate projections.

Table 9-17. Apportionment of ABC and OFL for 2012 Pacific ocean perch in the Gulf of Alaska.

		Western	Central		Eastern		
Year	Weights	Shumagin	Chirikof	Kodiak	Yakutat	Southeast	Total
2007	4	23%	11%	44%	8%	14%	100%
2009	6	5%	32%	38%	15%	10%	100%
2011	9	13%	25%	44%	9%	9%	100%
Weighted mean	19	12%	25%	42%	10%	11%	100%
Area Apportionment		**12.4%**	**66.6%**		**21.0%**		
Area ABC		**2,102**	**11,263**		**3,553**		**16,918**
Area OFL		**2,423**	**12,980**		**4,095**		**19,498**

Table 9-18. Summary of ecosystem considerations for Gulf of Alaska Pacific ocean perch.

Indicator	Observation	Interpretation	Evaluation
Ecosystem effects on *GOA Pacific ocean perch*			
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

Indicator	Observation	Interpretation	Evaluation
***GOA POP* fishery effects on ecosystem**			
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

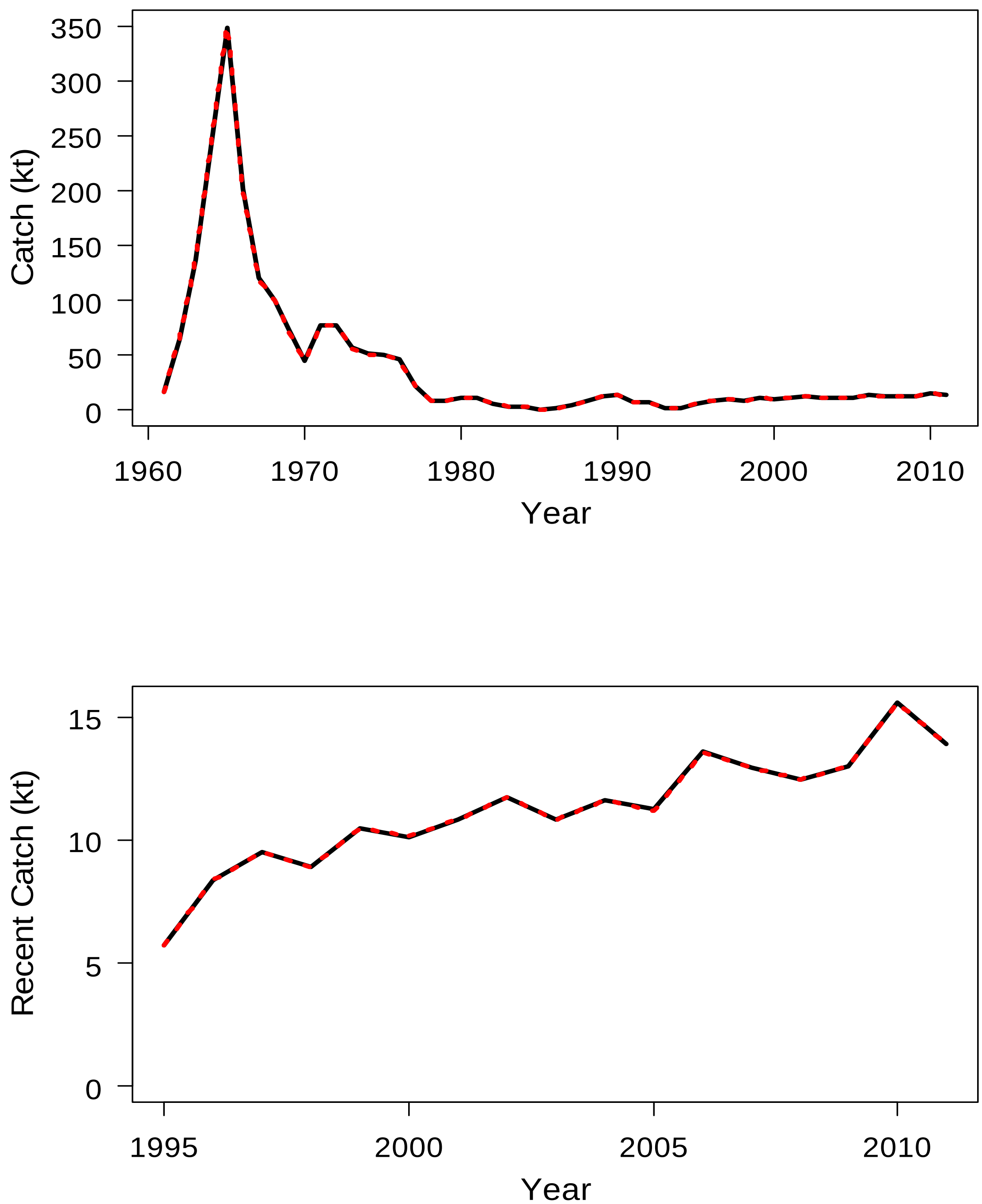


Figure 9-1. Estimated and observed long-term (a) and short-term (b) catch history for Gulf of Alaska Pacific ocean perch.

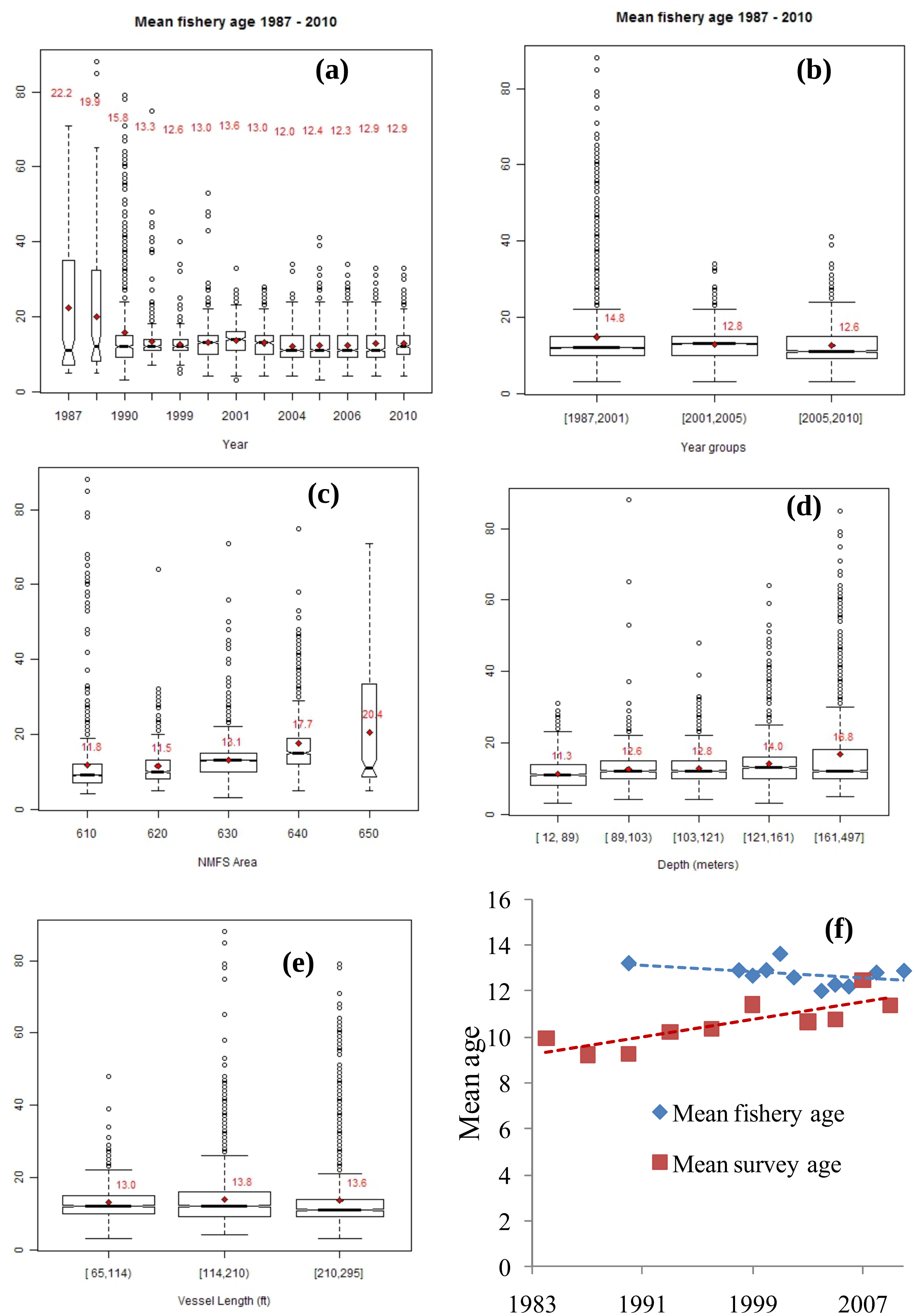


Figure 9-2. Comparisons of age compositions across time, depth, NMFS area, and vessel length.

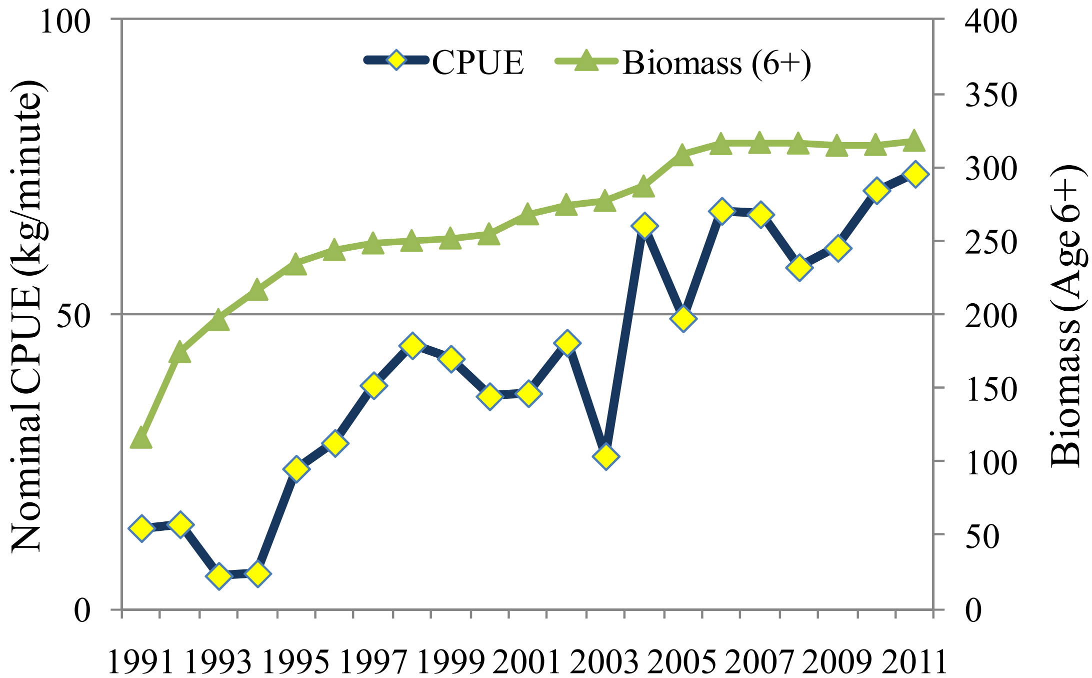


Figure 9-3a. Comparison of nominal catch-per-unit-effort (CPUE, kg/minute) and biomass (age 6+) in the Gulf of Alaska Pacific ocean perch fishery.

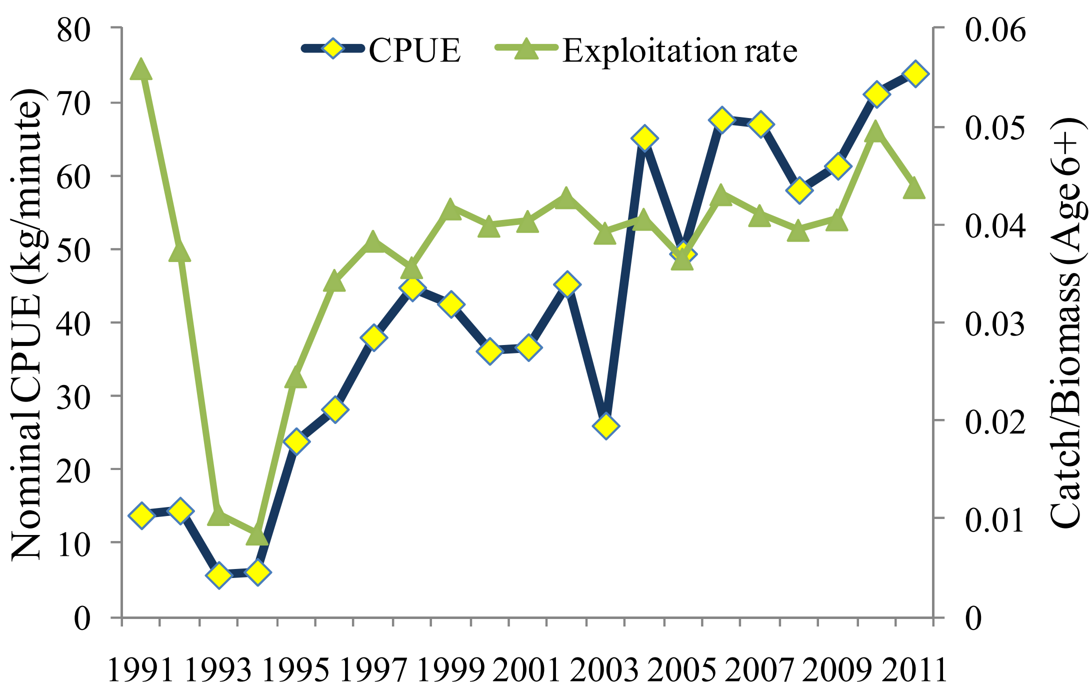


Figure 9-3b. Comparison of nominal catch-per-unit-effort (CPUE, kg/minute) and a proxy for exploitation rate (Catch/Age 6+ Biomass) for the Gulf of Alaska Pacific ocean perch fishery.

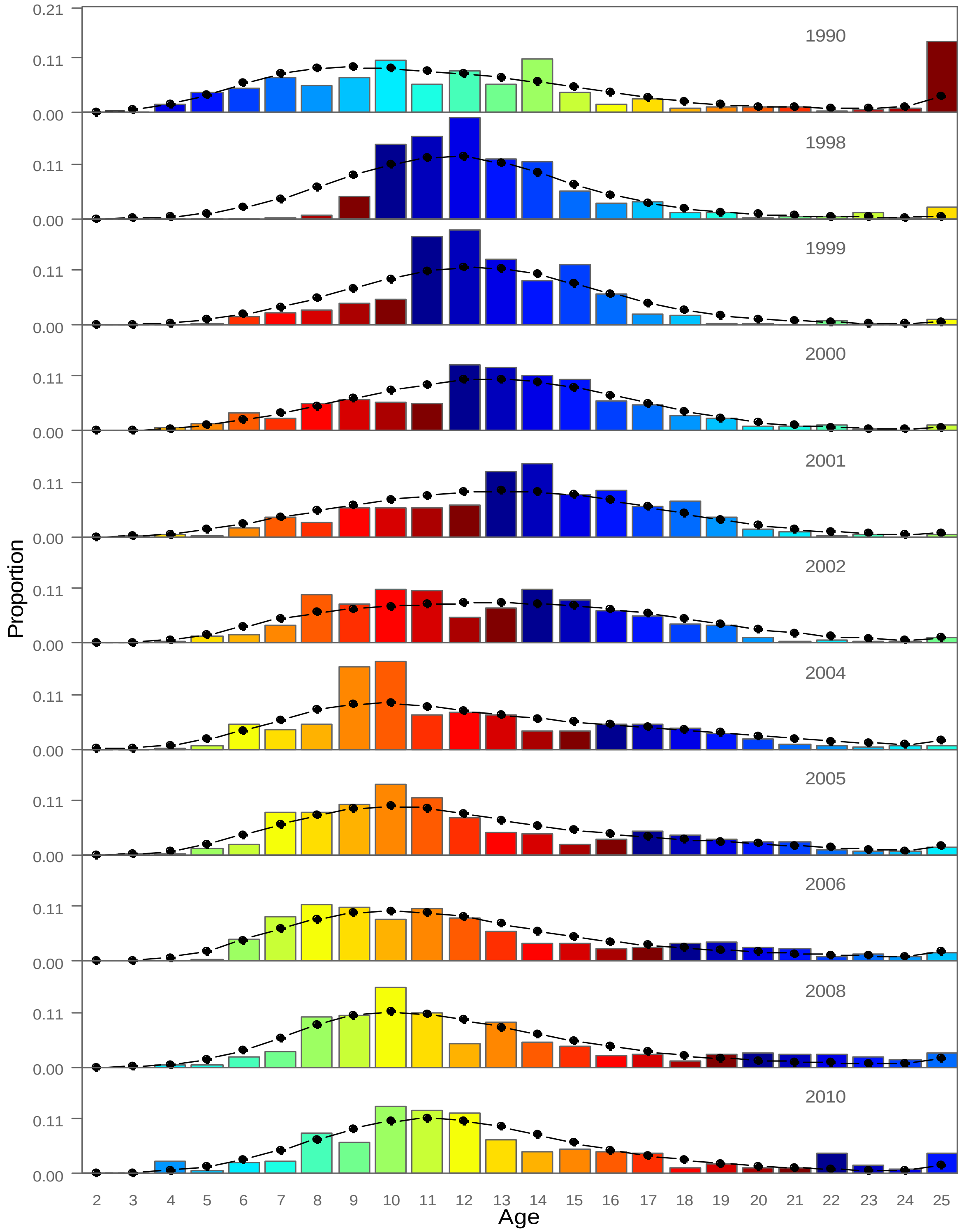


Figure 9-4. Fishery age compositions for GOA Pacific ocean perch. Observed = bars, predicted from author recommended model = line with circles. Colors follow cohorts.

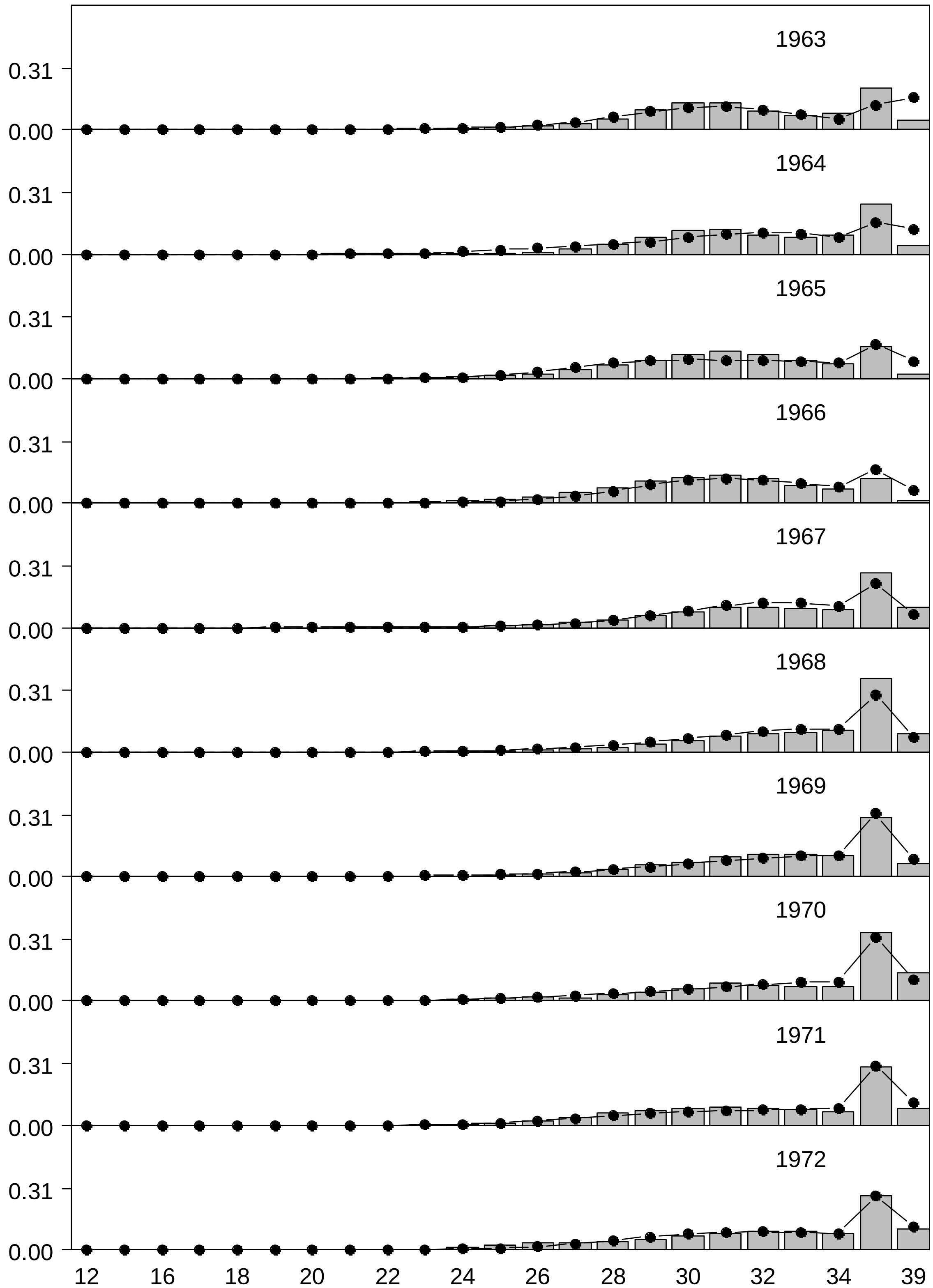


Figure 9-5. Fishery length (cm) compositions for GOA Pacific ocean perch. Observed = bars, predicted from author recommended model = line with circles.

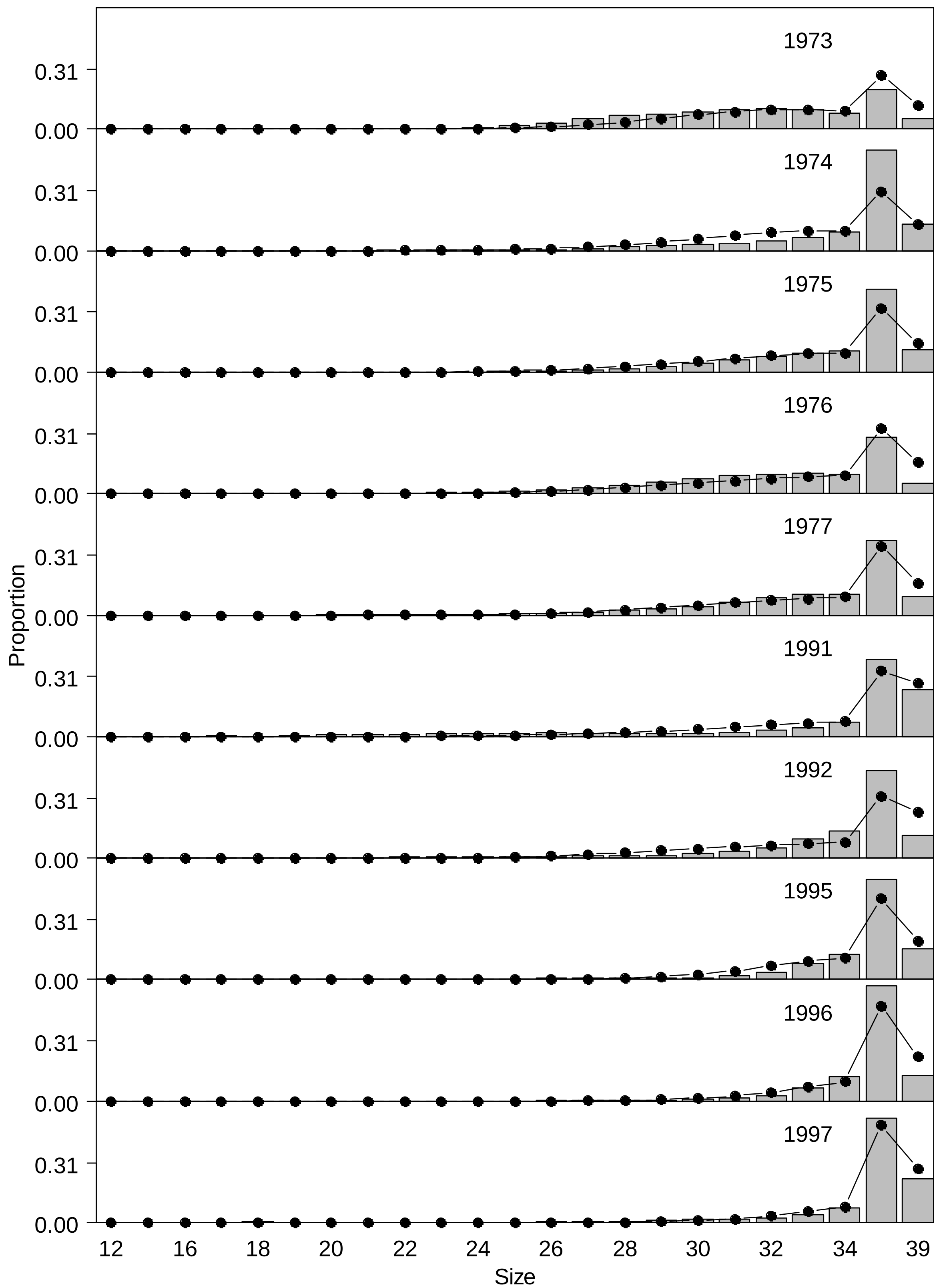


Figure 9-5. (continued) Fishery length (cm) compositions for GOA Pacific ocean perch. Observed = bars, predicted from author recommended model = line with circles.

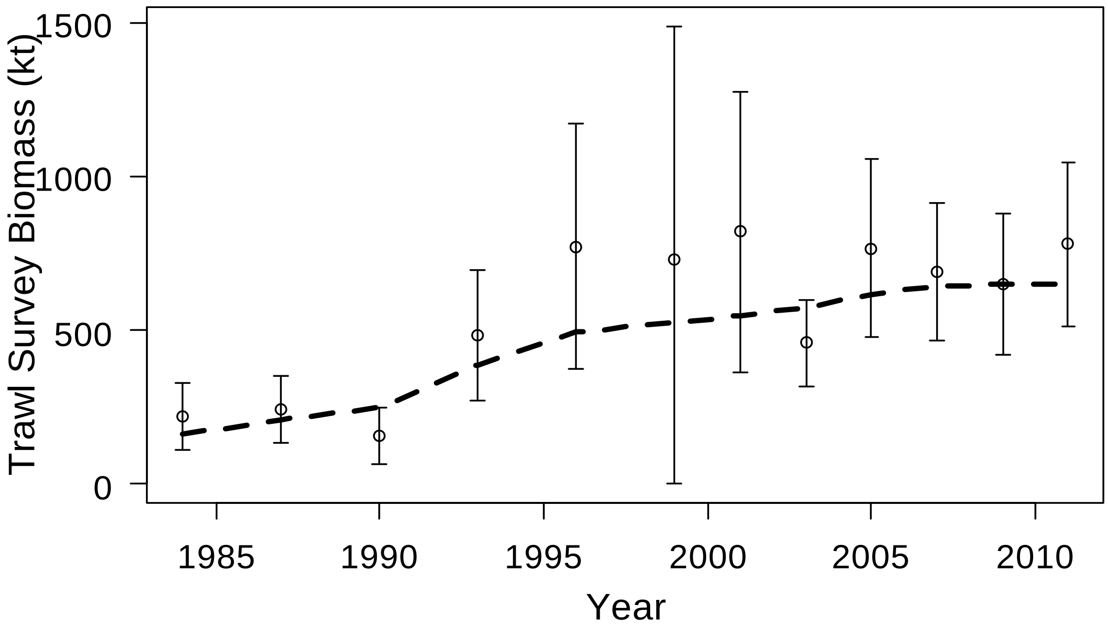


Figure 9-6. NMFS Groundfish Survey biomass estimates (solid line), with 95% sampling error confidence intervals (dashed line) and model fit (dotted line) for Gulf of Alaska Pacific ocean perch.

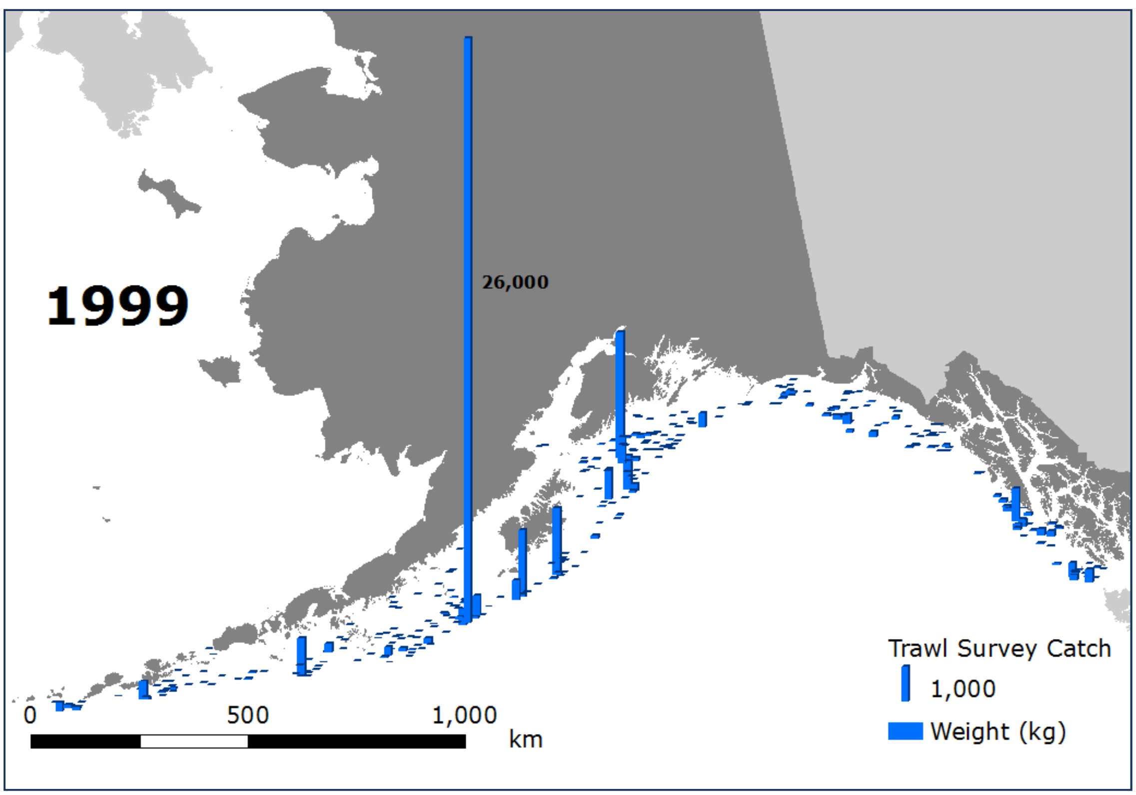


Figure 9-7a. Distribution of Gulf of Alaska Pacific ocean perch catches in the 1999 Gulf of Alaska groundfish survey.

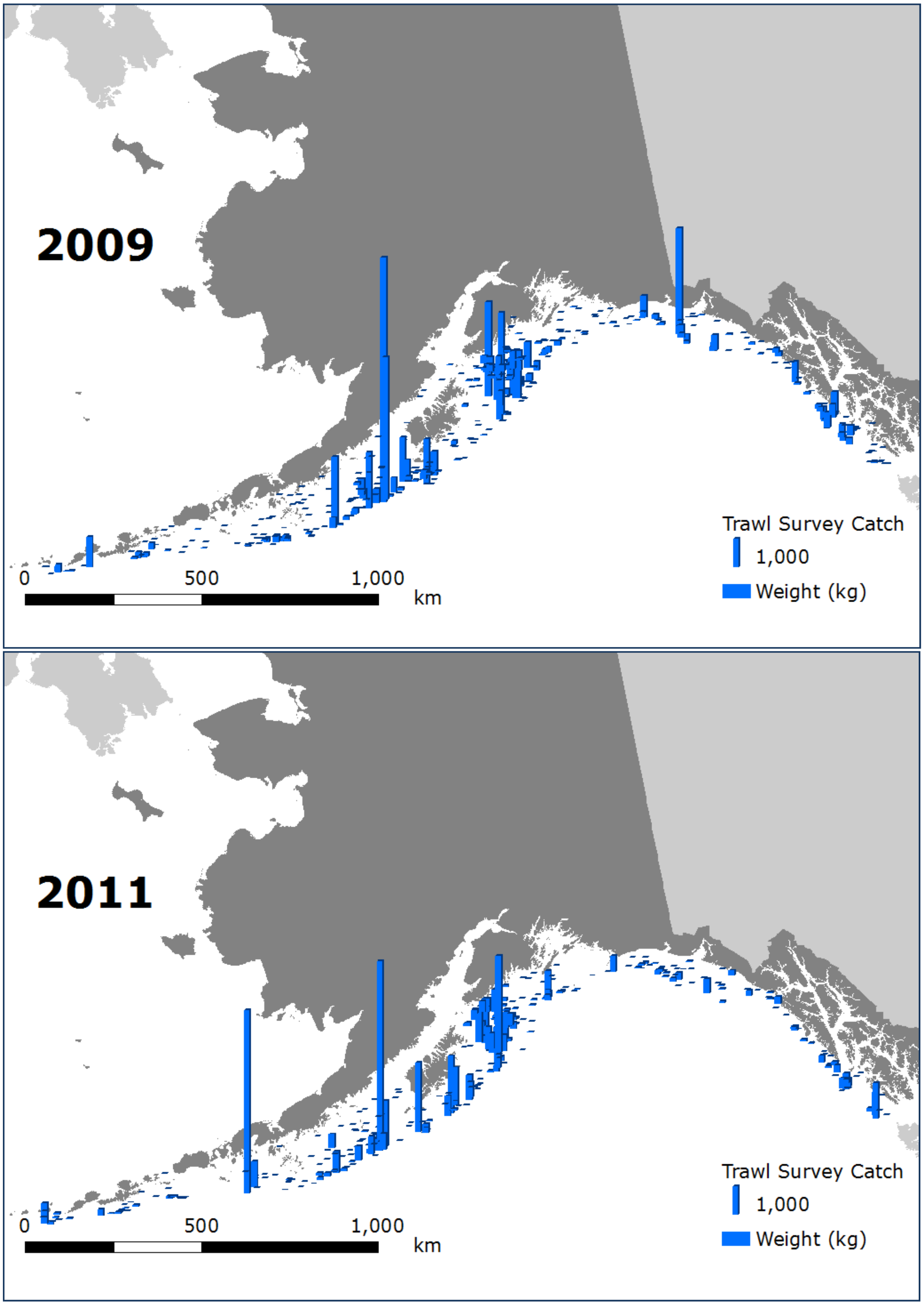


Figure 9-7b. Distribution of Gulf of Alaska Pacific ocean perch catches in the 2009 and 2011 Gulf of Alaska groundfish surveys.

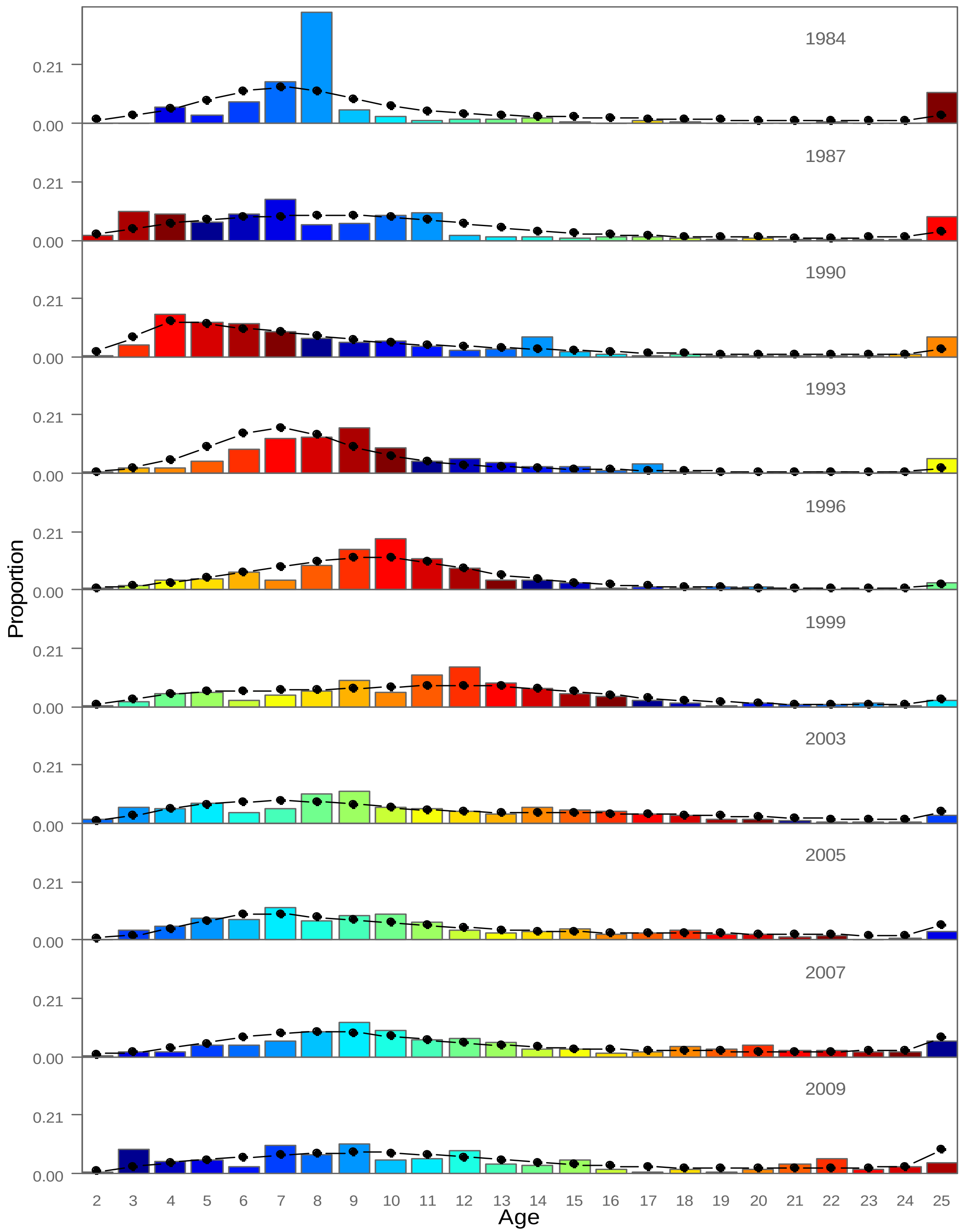


Figure 9-8. Groundfish survey age compositions for GOA Pacific ocean perch. Observed = bars, predicted from author recommended model = line with circles.

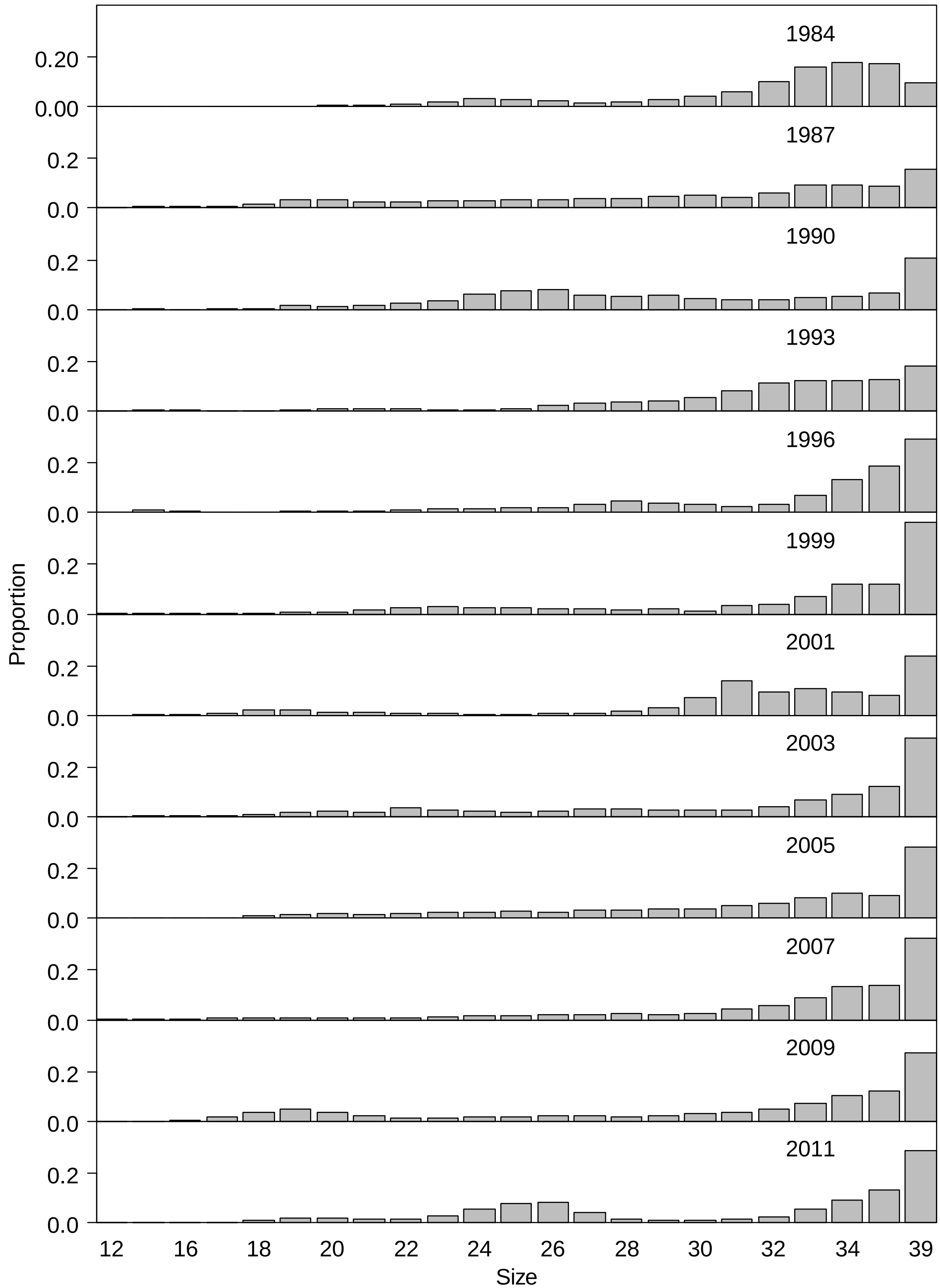


Figure 9-9. Groundfish survey length compositions for GOA Pacific ocean perch. Observed = bars. Survey size distributions not used in Pacific ocean perch model because survey ages are available for these years.

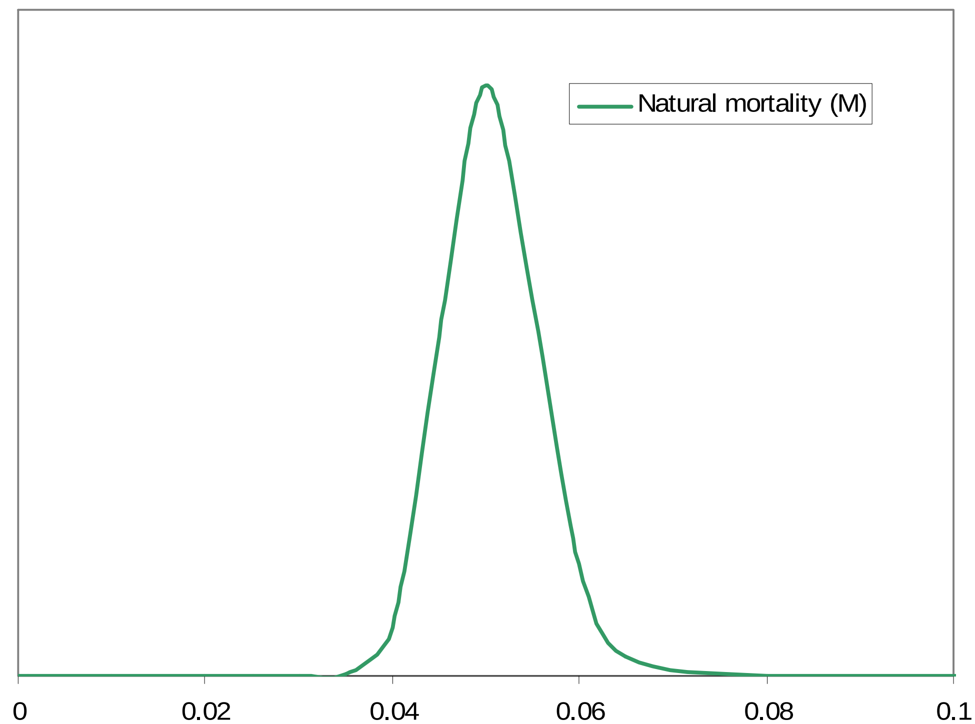


Figure 9-10. Prior distribution for natural mortality (*M*) of Pacific ocean perch, μ=0.05, CV=10%.

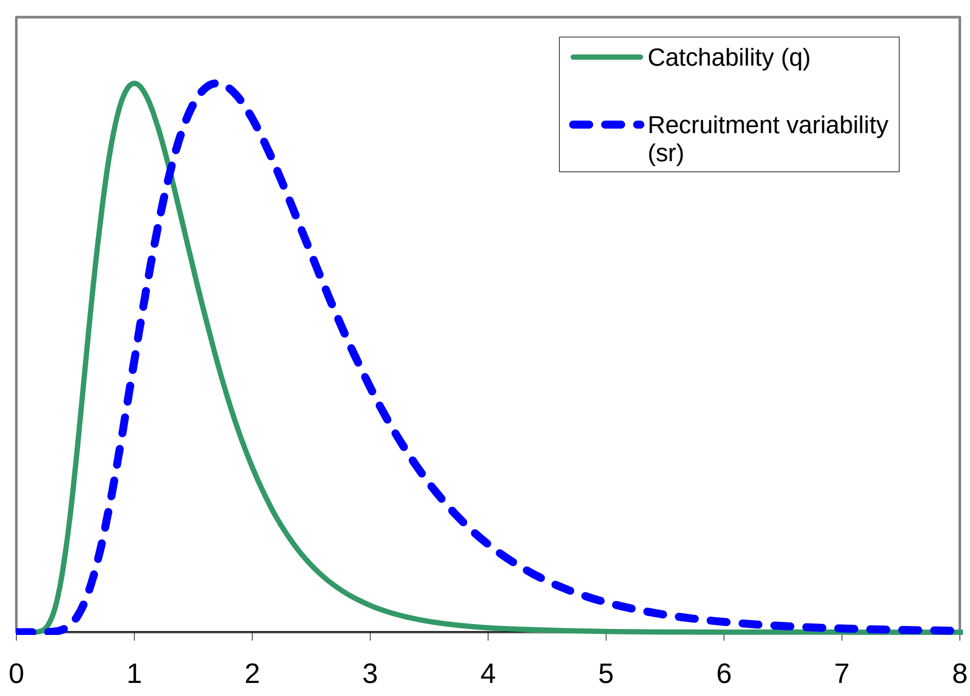


Figure 9-11. Lognormal prior distributions for catchability (*q*, μ=1, CV=45%) and recruitment variability (σ_r, μ=1.7, CV=20%) of Pacific ocean perch.

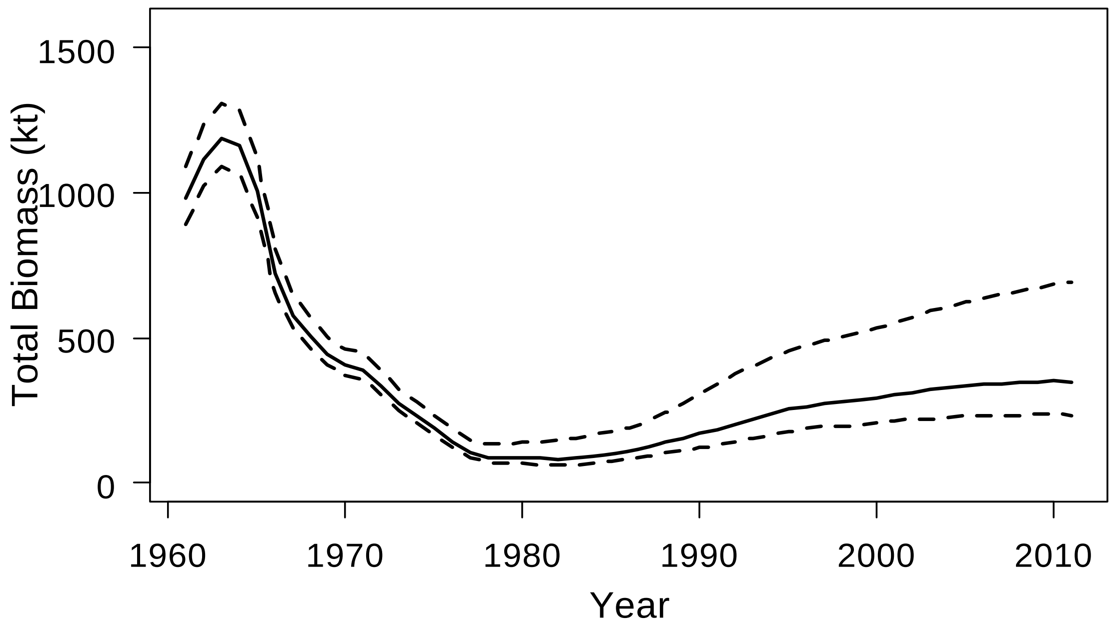


Figure 9-12. Model estimated total biomass (solid line) with 95% credible intervals determined by MCMC (dashed line) for Gulf of Alaska Pacific ocean perch.

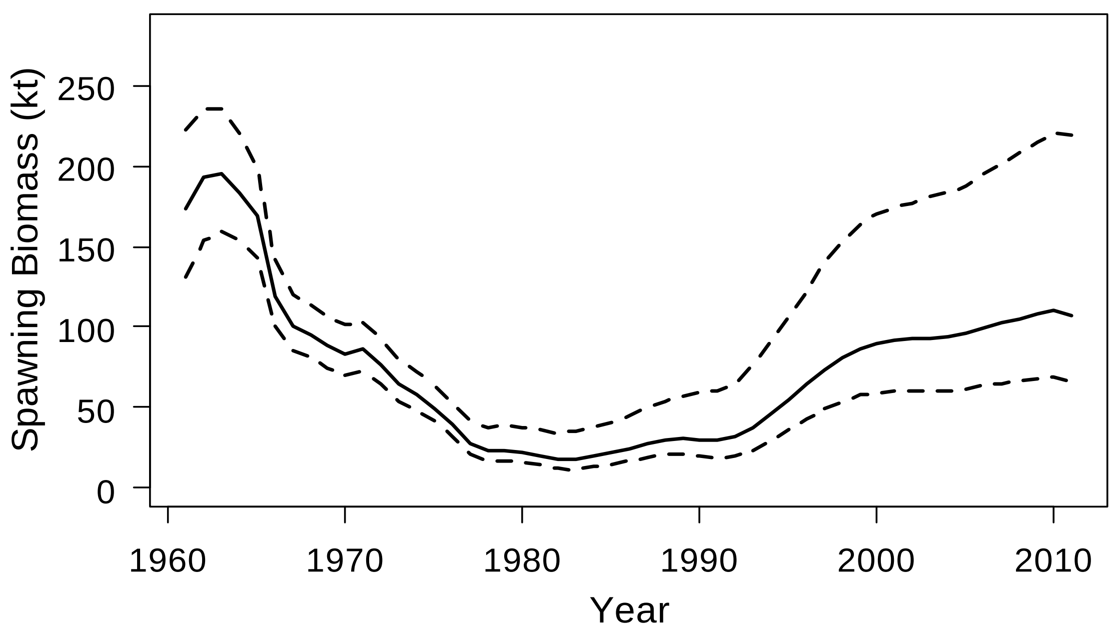


Figure 9-13. Model estimated spawning biomass (solid line) with 95% credible intervals determined by MCMC (dashed line) for Gulf of Alaska Pacific ocean perch.

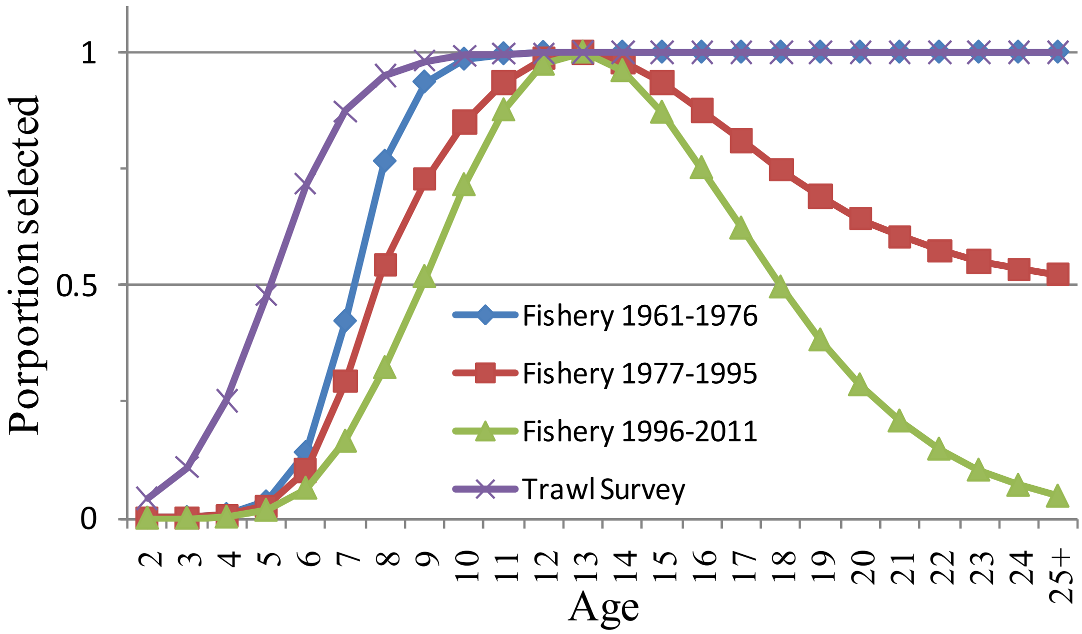


Figure 9-14. Estimated selectivities for the fishery for three periods and groundfish survey for Gulf of Alaska Pacific ocean perch.

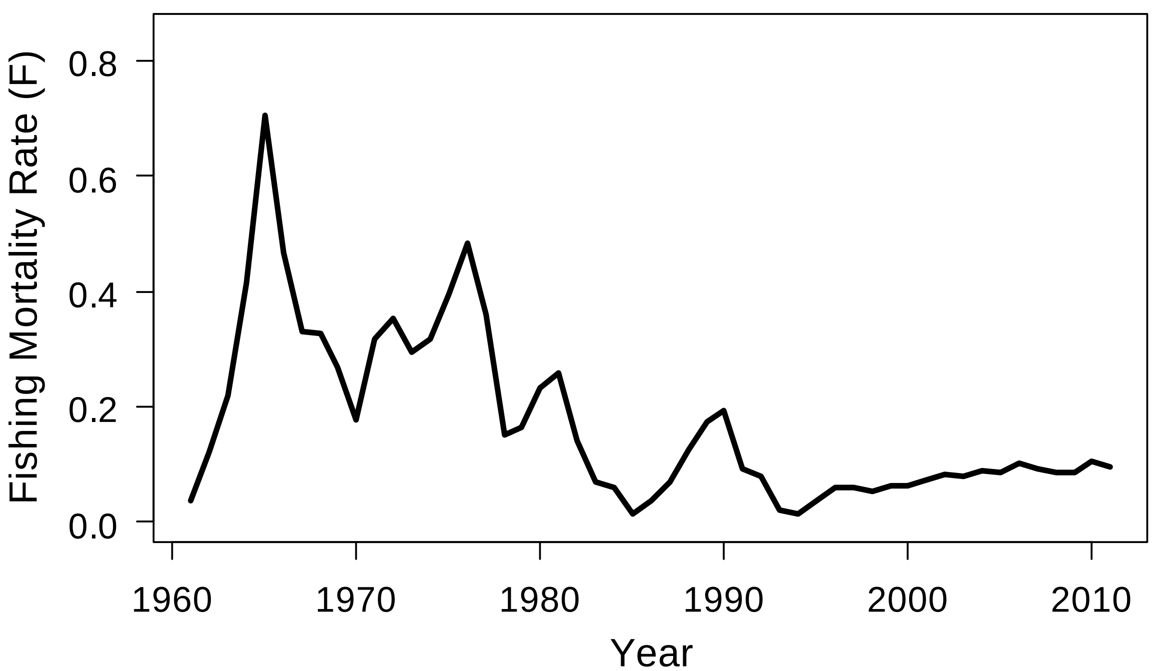


Figure 9-15. Estimated fully selected fishing mortality over time for GOA Pacific ocean perch.

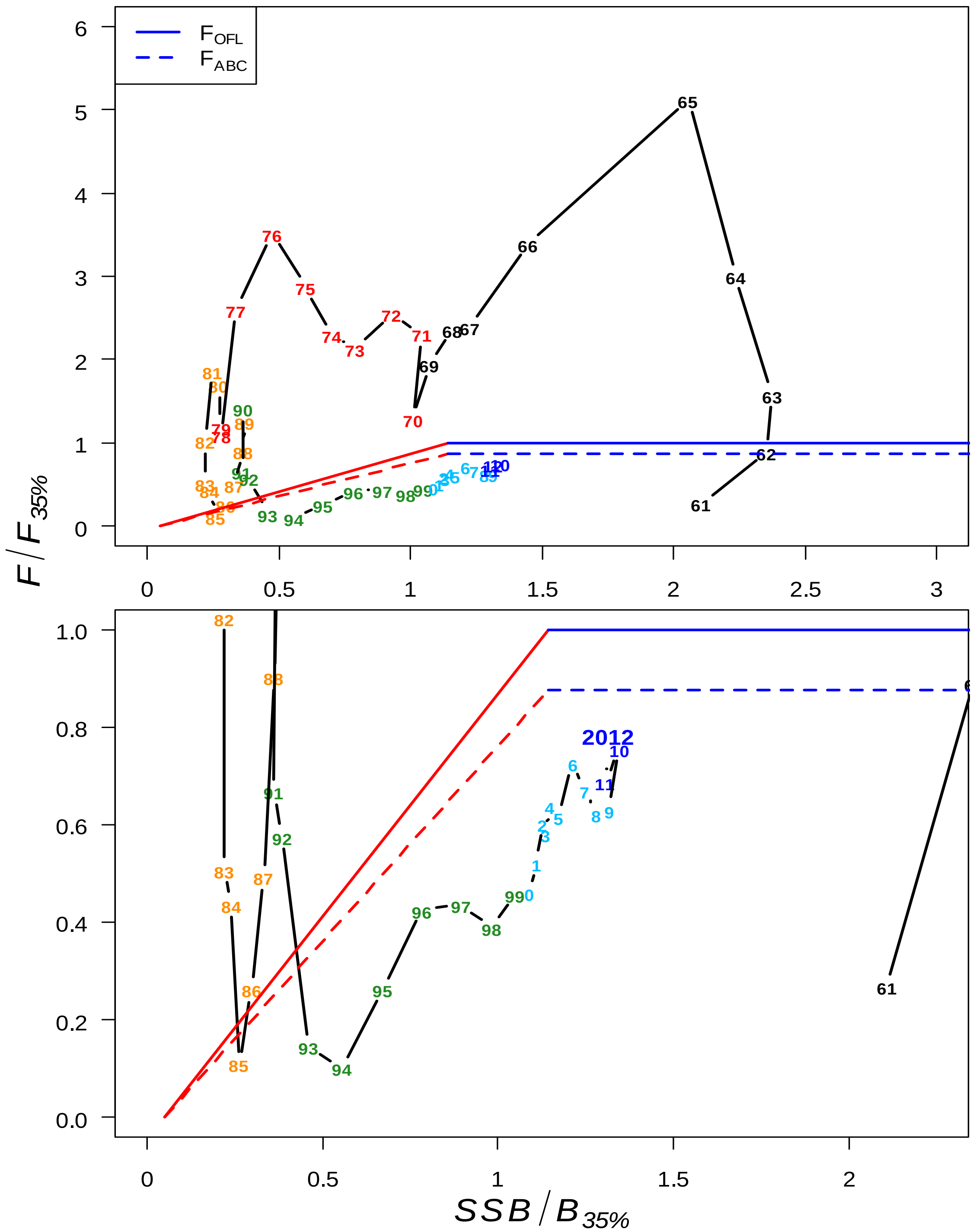
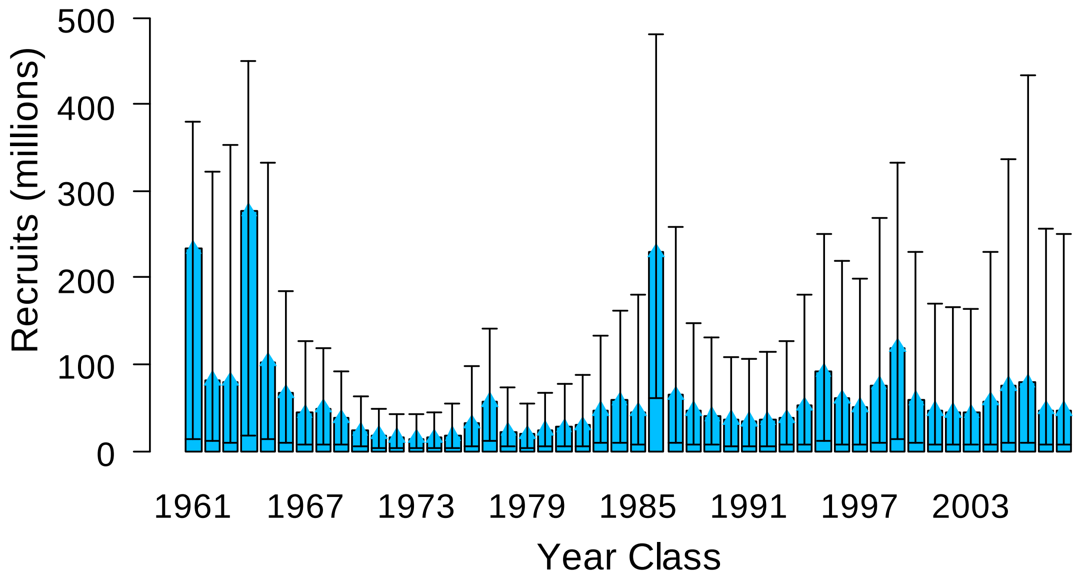


Figure 9-16. Time series of Pacific ocean perch estimated spawning biomass relative to the target level $B_{35\%}$ level and fishing mortality relative to $F_{35\%}$ for author recommended model. Top shows whole time series. Bottom shows close up on more recent management path.



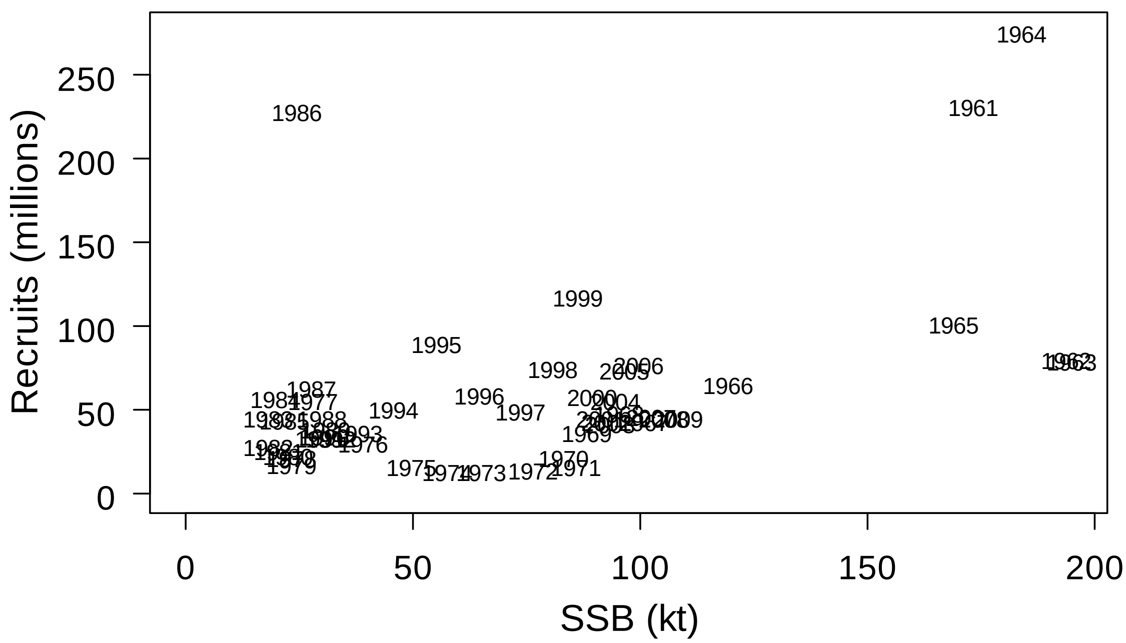


Figure 9-17. Estimated recruitment of Gulf of Alaska Pacific ocean perch (age 2) by year class with 95% credible intervals derived from MCMC (top). Estimate recruits per spawning stock biomass (bottom).

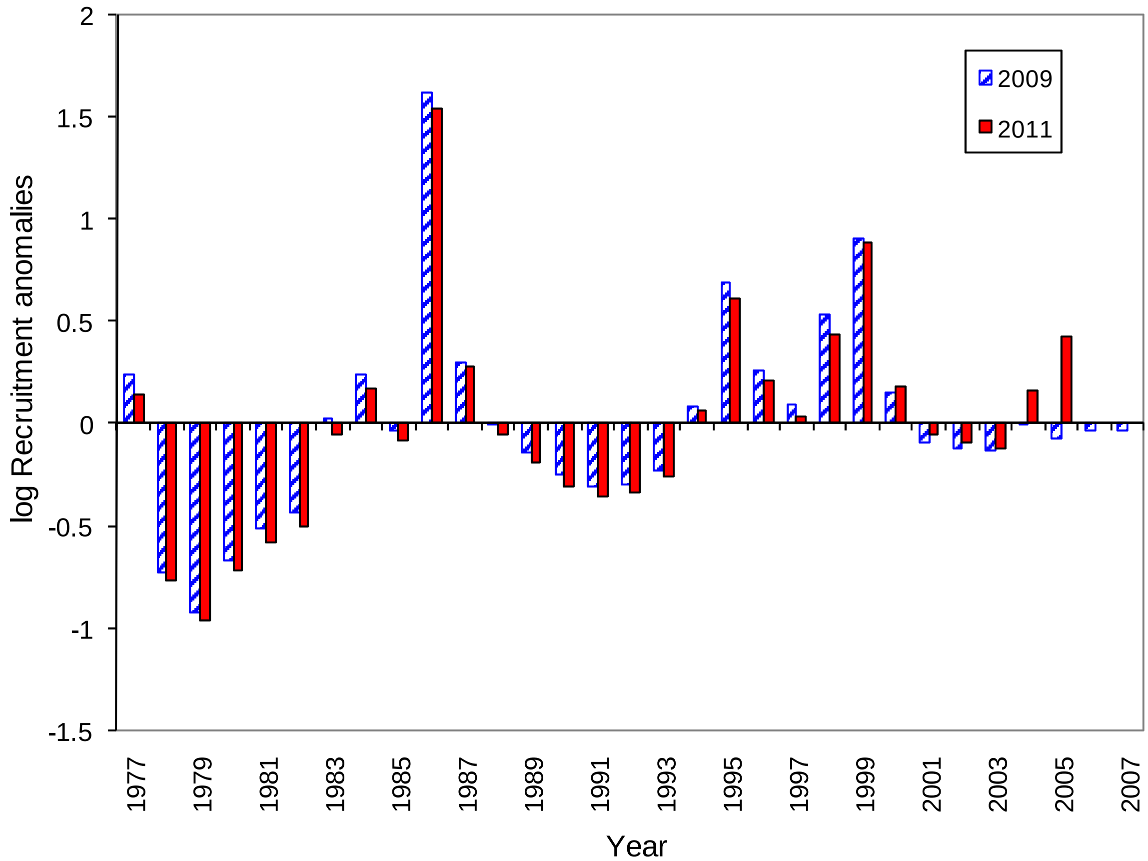


Figure 9-18. Recruitment deviations from average on the log-scale comparing last cycle's model to current for Gulf of Alaska Pacific ocean perch.

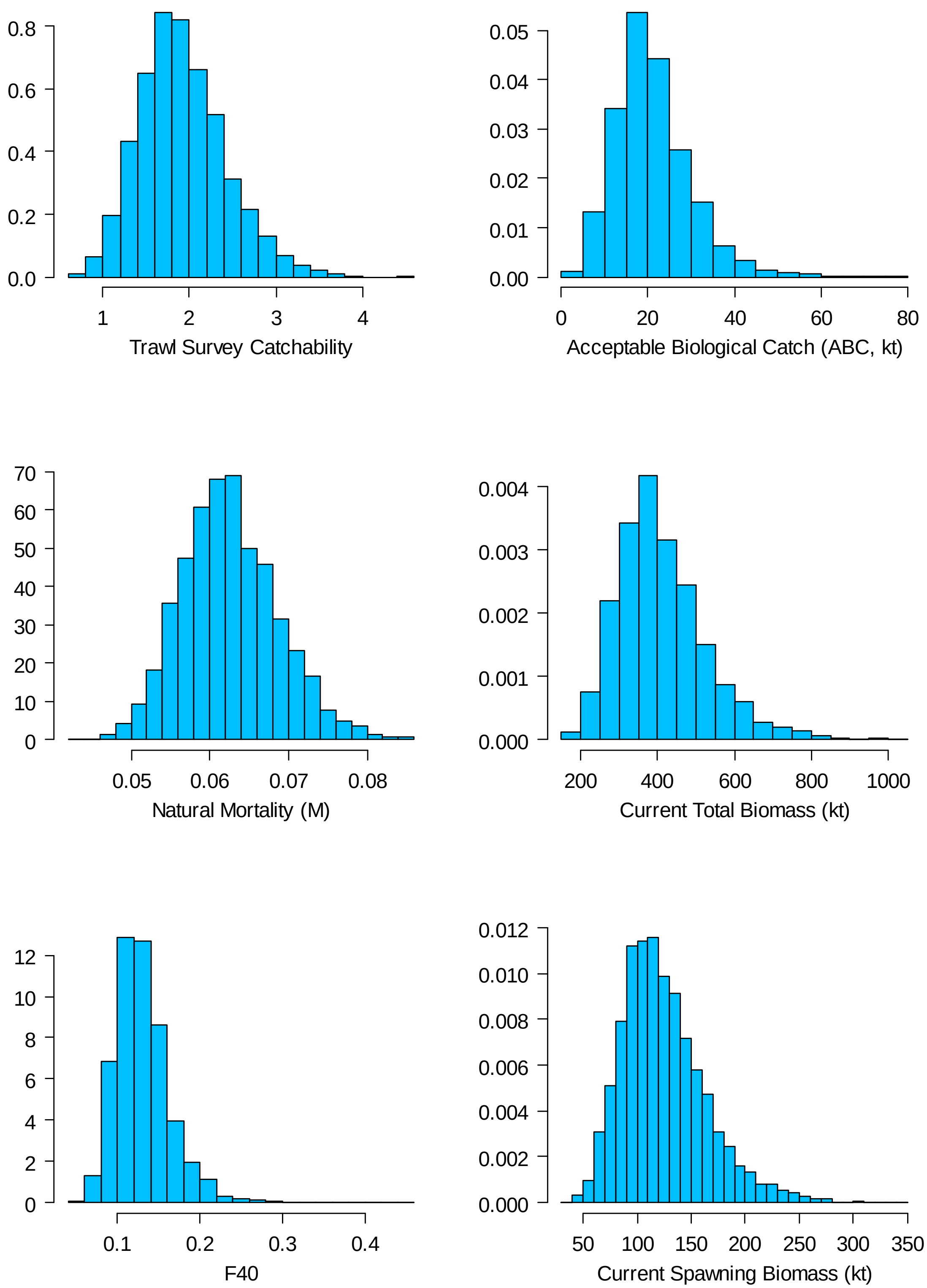


Figure 9-19. Histograms of estimated posterior distributions of key parameters derived from MCMC for Gulf of Alaska Pacific ocean perch.

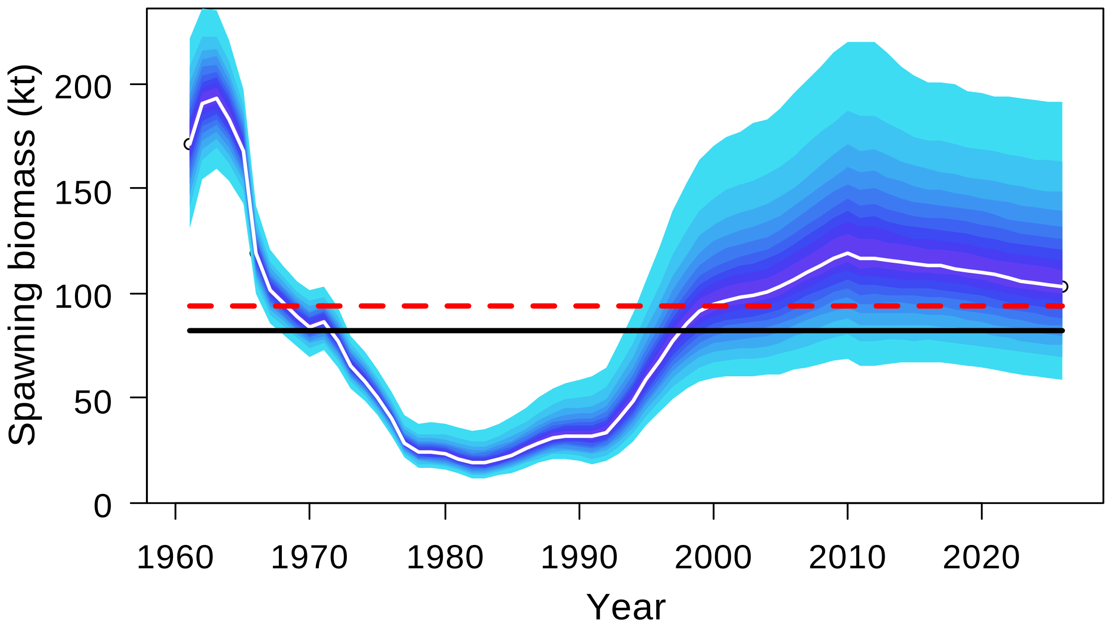


Figure 9-20. Bayesian credible intervals for entire spawning stock biomass series including projections through 2024. Red dashed line is $B_{40\%}$ and black solid line is $B_{35\%}$ based on recruitments from 1979-2009. The white line is the median of MCMC simulations. Each shade is 5% of the posterior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

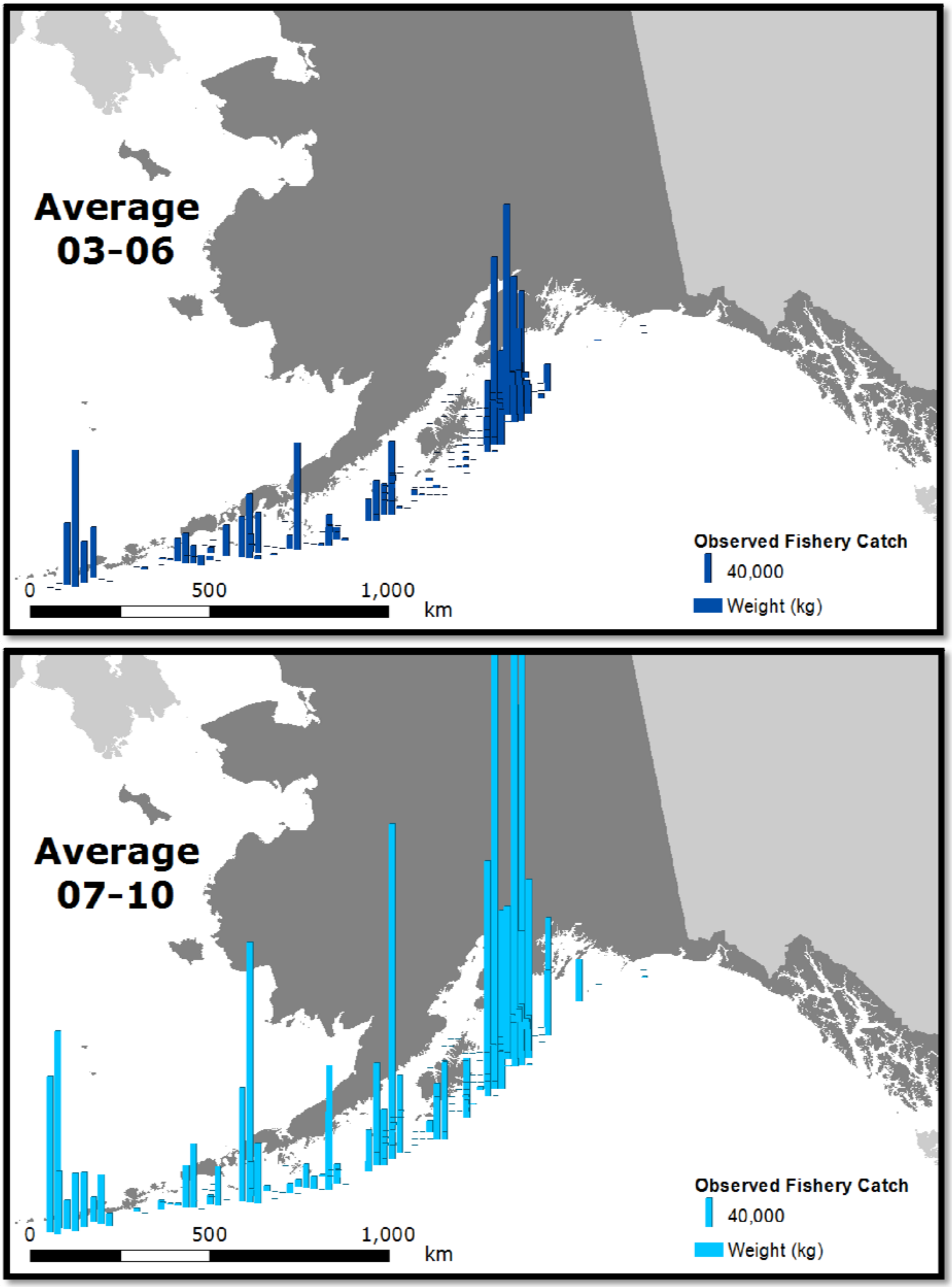


Figure 9-21. Maps of fishery catch based on observer data by 100 km^2 blocks for Pacific ocean perch from four years before and after the Rockfish Pilot Program.

Appendix 9A.—Supplemental catch data

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 **16,997** 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	0	3

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.

(This page intentionally left blank)