Chapter 9: Assessment of Pacific ocean perch in the Gulf of Alaska

Dana Hanselman, S. Kalei Shotwell, Jonathan Heifetz, Jeffrey T. Fujioka, and James N. Ianelli

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Executive Summary

Rockfish are assessed on a biennial stock assessment schedule to coincide with new survey data. We use a separable age-structured model as the primary assessment tool for Gulf of Alaska Pacific ocean perch. This consists of an assessment 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 assessment 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 2007 assessment model estimates with new data acquired since and present two alternative model configurations.

Changes in the input data: The new data included are 2009 survey biomass estimates, 2007 survey age compositions, 2006 and 2008 fishery age compositions, a revised catch estimate for 2008 and a new catch estimate for 2009. In addition, historic data has been updated to reflect database changes.

Changes in the assessment methodology: We present evidence for a change in selectivity in the fishery and implement new selectivity functions to describe the current activity of the fishing fleet. We recommend this revised model for setting management quantities for 2010.

For the 2010 fishery, we recommend the maximum allowable ABC of 17,584 t from the revised model. This ABC is a 16% increase from last year's ABC of 15,111 t. This increase is attributed to a lower catchability parameter, not the change in recommended fishing mortality from 0.06 to 0.12. The change in F is due to different fishery selectivity. While 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. 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.

Summary	2008 Projection:		**2009 projection:**	
Projection Year	2009	2010	2010	2011[1]
Tier 3a				
Total Biomass (Age 2+)	318,336	318,965	334,797	330,277
Female Spawning Biomass (t)	94,538	97,091	107,763	108,192
$B_{100\%}$ (t, female spawning biomass)	222,987	--	227,610	227,610
$B_{40\%}$ (t, female spawning biomass)	89,195	--	91,044	91,044
$B_{35\%}$ (t, female spawning biomass)	78,045	--	79,664	79,664
M	0.06	0.06	0.061	0.061
F_{ABC} (maximum allowable = $F_{40\%}$)	0.061	0.061	0.123	0.123
F_{OFL}	0.073	0.073	0.142	0.142
ABC (t, maximum allowable)	15,111	15,098	**17,584**	16,993
OFL (t)	17,940	17,925	**20,243**	19,560

[1]**Projected ABCs and OFLs for 2011 are derived using an expected catch value of 14,770 t for 2010 based on recent ratios of catch to ABC.** This calculation is in response to management requests to obtain a more accurate one-year projection.

Area Apportionment

The apportionment percentages have changed with the addition of the 2009 survey biomass. The following table shows the recommended apportionment for 2010.

	Western	Central	Eastern	Total
Area Apportionment	16%	61%	23%	100%
Area ABC (t)	**2,895**	**10,737**	**3,952**	**17,584**
Area OFL (t)	3,332	12,361	4,550	**20,243**

Amendment 41 prohibited trawling in the Eastern area east of 140° W longitude. The ratio of biomass still obtainable in the W. Yakutat area (between 147° W and 140° W) is higher than last year at 0.50. This results in the following apportionment of the Eastern Gulf area:

	W. Yakutat	E. Yakutat/Southeast
Area ABC (t)	2,004	1,948

Responses to Council, SSC, and Plan Team Comments

No comments in 2008 SSC or Plan Team minutes were pertinent to the Gulf Alaska Pacific ocean perch assessment. In 2007, the SSC encouraged plotting catch distributions, which is included in Figures 28-32. Data were not yet available for 2008 and 2009.

Research Priorities

There is little information on larval, post-larval, or early juvenile stages slope rockfish. Habitat requirements for these stages are mostly unknown. Habitat requirements for later stage juvenile and adult fish are anecdotal or conjectural. Research needs to be done on the bottom habitat of the major fishing grounds, on what HAPC biota are found on these grounds, and on what impact bottom trawling has on these biota. Additionally, Pacific ocean perch are undersampled by the current survey design. The stock assessment would benefit from additional survey effort on the continental slope. Further research on trawl catchability and trawlable/untrawlable grounds would be very useful. For Pacific ocean perch and the other Gulf of Alaska rockfish assessed with age-structured models, we plan to focus on optimizing and making consistent the methods we use for multinomial sample sizes, the way we choose our bins for age and length compositions, and examine growth for changes over time.

Summaries for Plan Team

Species	Year	Biomass[1]	OFL	ABC	TAC	Catch
Pacific ocean perch	2008	317,511	17,807	14,999	14,999	12,400
	2009	318,336	17,940	15,111	15,111	12,736
	2010	334,797	20,243	17,584		
	2011	330,277	19,560	16,993		

[1]Total biomass from the age-structured model

Stock/ Assemblage	Area	2009 OFL	ABC	TAC	Catch[2]	2010 OFL	ABC	2011 OFL	ABC
Pacific ocean perch	W	4,409	3,713	3,713	3,803	3,332	2,895	3,220	2,797
	C	9,790	8,246	8,246	7,756	12,361	10,737	11,944	10,376
	WYAK		1,108	1,108	1,104		2,004		1,937
	SEO		2,044	2,044	0		1,948		1,882
	E	3,741		--	--	4,550		4,396	
	Total	17,940	15,111	15,111	12,736	20,243	17,584	19,560	16,993

[2]Current as of October 10, 2009 (http://www.fakr.noaa.gov) and includes research catches of 73 tons.

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 at night to feed, apparently following diel euphausiid migrations. 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 of 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-truncation could be ruinous to a population with highly episodic recruitment like rockfish (Longhurst 2002). Recent work 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. The AFSC has funded a project to determine if this relationship occurs for Pacific ocean perch in the Central Gulf of 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 on biological reference points produced by the model are ambiguous. Reduced survival of larvae from younger females results in reduced reproductive potential per recruit for a given level of fishing mortality, but also increased estimated resiliency, which results from the estimated recruitments being associated with a reduced measure of reproductive potential. For Gulf of Alaska Pacific ocean perch, these two effects nearly counteract each other. Recent 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.

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). 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 stuck structure.

Management measures

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 exploitable biomass.

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.

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. The intention of this Program is to enhance resource conservation and improve economic efficiency for harvesters and processors in the rockfish fishery. This should spread out the fishery in time and space, allowing for better prices for product and reducing the pressure of what was an approximately two week fishery in July. The authors will pay close attention to the benefits and consequences of this action.

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	6,348	20,000	20,000		
1990	21,114	17,700	17,700		
1991	6,631	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	6,159	5,730	5,200		
1993	2,060	3,378	2,560		
1994	1,853	3,030	2,550		Assessment done with an age structured model using stock synthesis
1995	5,742	6,530	5,630		
1996	8,378	8,060	6,959		
1997	9,531	12,990	9,190		
1998	8,961	12,820	10,776		
1999	10,472	13,120	12,590		Eastern Gulf divided into West Yakutat and East Yakutat/Southeast Outside and separate ABCs and TACs assigned
2000	10,157	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	11,729	13,190	13,190		
2003	10,861	13,660	13,660		
2004	11,528	13,340	13,340		
2005	11,272	13,580	13,580		
2006	13,590	14,261	14,261		
2007	12,954	14,636	14,636		Amendment 68 created the Central Gulf Rockfish Pilot Project
2008	12,400	14,999	14,999		
2009	12,736	15,111	15,111		

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 Southeastern. (The prohibition of trawling in Southeastern 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, including research catches, is listed in Table 9-1. The reader is cautioned that actual catches of Pacific ocean perch in the commercial fishery are only shown for 1988-2002; 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 9-1). Pacific ocean perch make up the majority of catches from this complex. The acceptable biological catches and quotas in Table 9-1 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. (As explained in ***Management measures***, the Eastern area for Pacific ocean perch has been subdivided into two areas, so there are now a total of four regulatory areas because of the Eastern Yakutat/Southeast Outside and West Yakutat split.)

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 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, 3) Improved at-sea and plant observer coverage for vessels participating in the rockfish fishery, 4) 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 (see figure below). Future analyses regarding the effect of the Pilot Project upon Pacific ocean perch will be possible as more data become available.

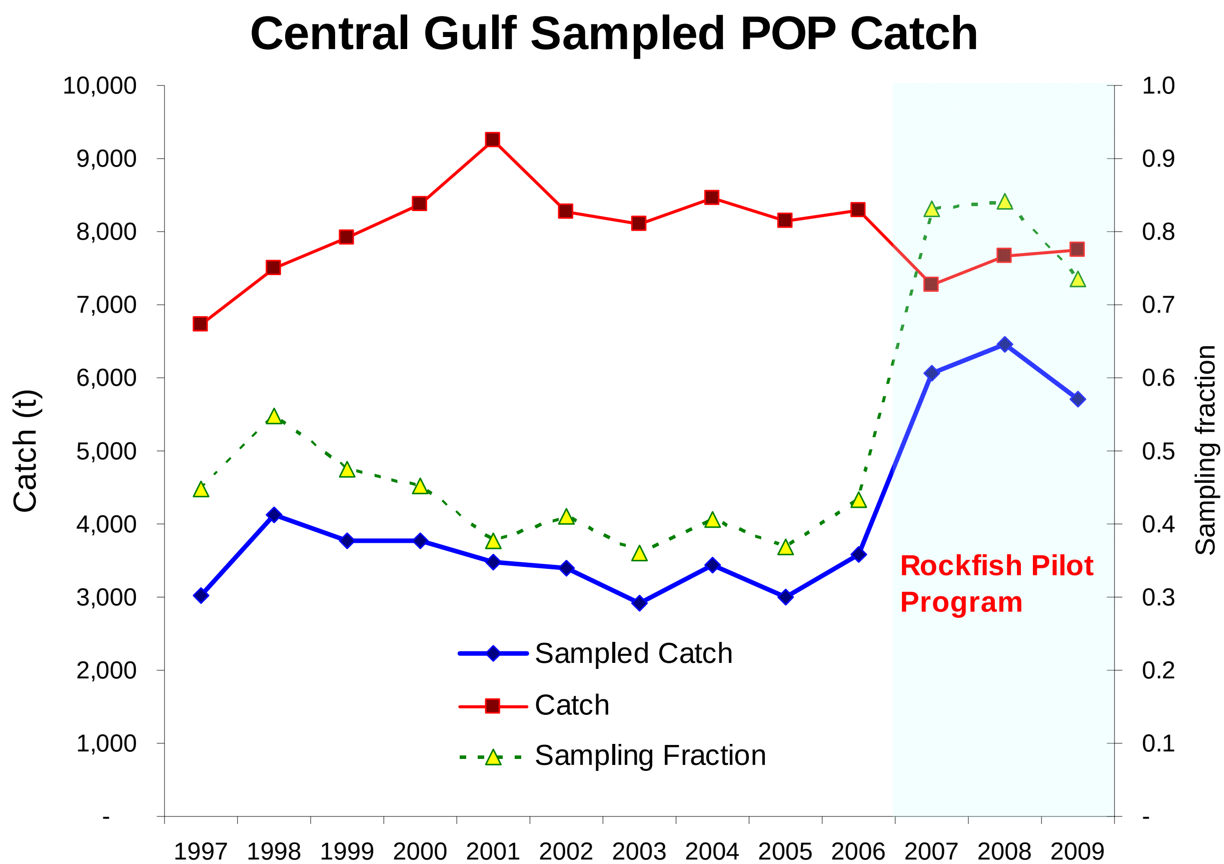

Figure. Increase in sampled catch by the observer program in the Central Gulf since the inception of the Rockfish Pilot Program. Sampling fraction is the proportion of total catch where the hauls were sampled by observers.

Bycatch

Ackley and Heifetz (2001) examined bycatch in Pacific ocean perch fisheries of the Gulf of Alaska by using data from the observer program for the years 1993-95. For hauls targeting Pacific ocean perch, the major bycatch species were arrowtooth flounder (*Atheresthes stomias*), shortraker/rougheye/blackspotted rockfish (*S. borealis/S. aleutianus/S. melanostictus*), sablefish (*Anoplopoma fimbria*), and "other slope rockfish". (This was based only on data for 1995, as there was no directed fishery for Pacific ocean perch in 1993-94). Data from 1997-2004 (Gaichas and Ackley estimates[2]) show that the largest bycatch groups in the combined rockfish trawl fishery are Pacific cod (*Gadus macrocephalus*, 1,750 t/year), arrowtooth flounder (1500 t/year), and sablefish (1100 t/year). The same data set shows that the only major non-rockfish fisheries that catch substantial Pacific ocean perch are rex sole (*Glyptocephalus zachirus*) and arrowtooth flounder, averaging 500 t per year. Small amounts of Pacific ocean perch are also taken in other flatfish, Pacific cod and sablefish fisheries[1]. More recent data for 2007-2009 indicates an increase in bycatch of greenling/Atka mackerel (1,584 t/year) and walleye pollock (590 t/year), and decreases of arrowtooth flounder (565 t/year), sablefish (515 t/year), and Pacific cod (422 t/year).

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[1] NOAA Fisheries, Alaska Region, Fishery Management Section, P.O. Box 21668, Juneau, AK 99801-1688, http://www.fakr.noaa.gov. Data are from weekly production and observer reports through Sep. 1, 2007.

Discards

Gulfwide discard rates[2] (% discarded) for Pacific ocean perch in the commercial fishery for 1998-2009 are listed as follows:

Year	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
% Discard	14.0	13.8	11.3	8.6	7.2	15.1	7.4	5.6	8.2	6.1	4.4	7.0

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

Data

The following table summarizes the data used for this assessment:

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

Fishery Data

Catch

Catches range from 2,500 t to 350,000 t from 1961 to 2009. Detailed catch information for Pacific ocean perch is listed in Table 9-1 and shown graphically in Figure 9-1.

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 9-2 summarizes the length compositions from 1995-2008. Table 9-3 summarizes age compositions from 1990, 1998-2002, 2004-2006, and 2008 for the fishery. Figures 9-2 and 9-3 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 2008 fishery age composition shows a very large 1998 year class, which also shows up in the survey age compositions. 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 2009 surveys are provided in Table 9-4.

Comparison of Trawl Surveys in 1984-2009

Gulfwide biomass estimates for Pacific ocean perch are shown in Table 9-4. Gulfwide biomass estimates for 1984-2009 and 95% confidence intervals are shown n Figure 9-4. 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 2009 (Figure 9-4). Although more precise, a fluctuation in biomass of 60% in two years 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. With the exception of one very large catch in the western Gulf of Alaska, the distribution of Pacific ocean perch seems to be more uniform with more medium-sized catches in more places compared to previous surveys (for example compare 2007 and 1999 Figures 9-5 a, 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. Recent 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 is also underway. In addition, there is a center-wide initiative 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 9-4. 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 15,221 t in 1990 to 154,013 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 9-5a). 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 9-5b). 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 9-5b).

Age Compositions

Ages were determined from the break-and-burn method (Chilton and Beamish 1982). The survey age compositions from 1984-2007 surveys showed that although the fish ranged in age up to 84 years, most of the population was relatively young; mean population age was 11.2 years in 1996 and 13.9 years in 1999 (Table 9-5). 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 9-6). 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.

Survey Size Compositions

Gulfwide population size compositions for Pacific ocean perch are shown in Figure 9-7. 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.

Analytic Approach

Model Structure

We present results for Pacific ocean perch based on an age-structured model using AD Model Builder software (Otter Research Ltd 2000). 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. The model has been in its current form since 2003. For 2009, further modifications were made to accommodate MCMC projections that use a pre-specified proportion of ABC for annual catch. We are also recommending a change in selectivity curves for this assessment, so the model now allows 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 9-6:

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

W_∞=984 g a=0.0004 b=2.45 n=3592

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

Parameters estimated 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 notoriously a difficult parameter to estimate within the model so we assign a "tight" prior CV of 10% (Figure 9-8). 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 9-9). This allows the parameter more freedom than that allowed to natural mortality. Recruitment deviation is the amount of variability that the model assigns 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 45% (Figure 9-9).

Selectivity

Since the model was reconfigured in 2003, the catchability coefficient (*q*) has been drifting upward from 1.7 to over two. While we believe there is evidence to suggest that catchability is greater than one, we are uncomfortable with its progression to such a high value. Since the survey or the availability of POP to the survey is likely not changing, we hypothesized that the fishery selectivity curves may be causing some of this drift. We also feel using an approach that has some empirical evidence is more transparent to merely increasing the precision on the prior of catchability to make it lower.

The current selectivity pattern for the fishery is penalized to not allow for the right limb to descend or go "dome-shaped." However, despite this penalty this curve has been moving slightly toward a dome-shape. Since the fishery has gone through some changes over the timeframe of the model, we examined age data for evidence of dome-shaped selectivity in the fishery. We examined three time blocks for potential changes in selectivity.

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 choose 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. We have fishery and survey age structures to examine in this period.
3) 1996-Present: During this period we have noted the emergence of smaller catcher-boats, semi-pelagic trawling and fishing cooperatives. The fishing season has also been recently greatly expanded. We have fishery and survey age structures to examine in this period.

When the age compositions during the 2nd time block (the "eighties") are compared with the 3rd time block (the "noughties") (Figure 9-10), it suggests that the fishery was previously harvesting a considerable number of age 25+ fish, while recently the fishery has focused on the middle-range of the age distribution. When the age compositions from the trawl survey are compared for the same two periods (Figure 9-11), it appears there are in fact more older fish in the early period. We compare the relative proportions of old fish in the fishery and the survey from the two periods in Figures 9-12 and 9-13. 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, and the trend since 1995 has been about a 50 meter decrease in catch-weighted average fishing depth (see figure below). This evidence led to us consider allowing the fishery selectivity to become more dome-shaped.

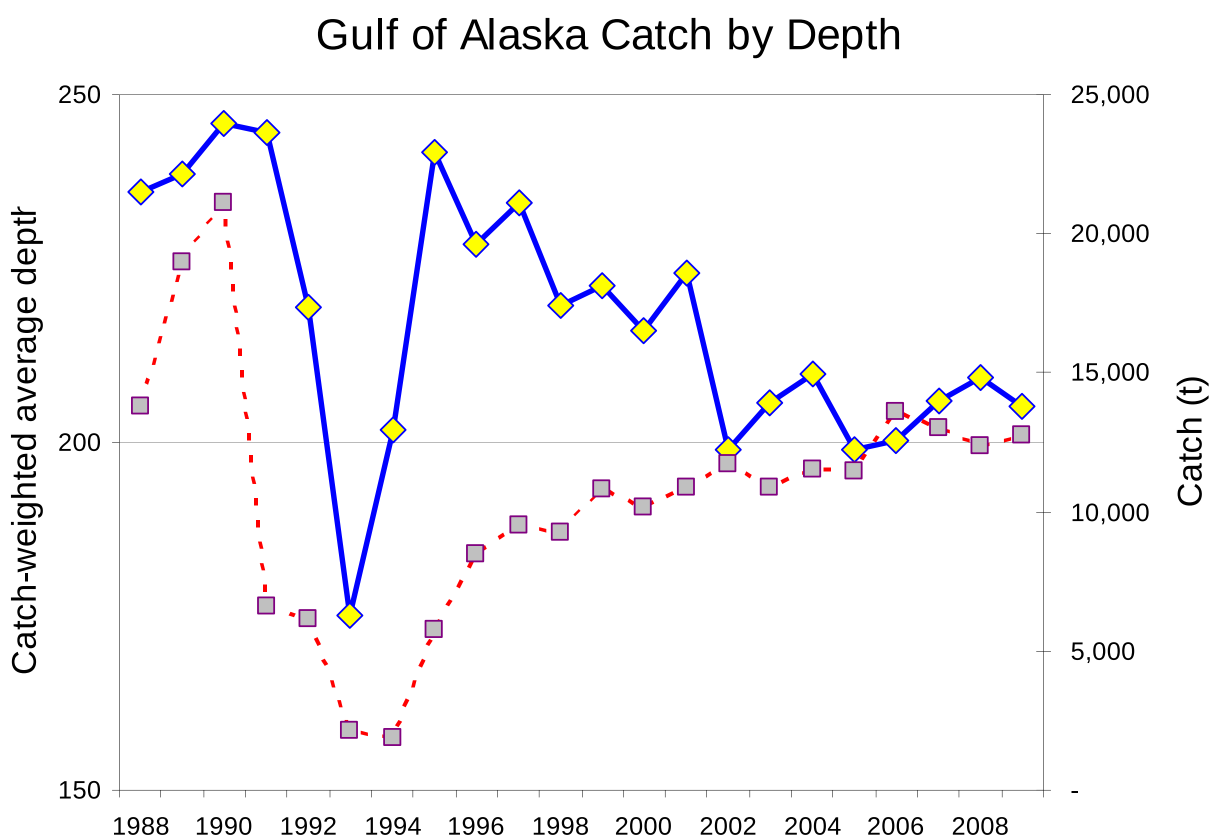

Figure. Change in catch-weighted average depth of the Gulf of Alaska POP fishery over time.

We first fitted selectivities to the average age compositions shown previously. In figures 9-14 and 9-15, we fitted logistic and gamma selectivity curves to the survey ages. The logistic fit was superior (relative SSQ of logistic was 0.63 of the SSQ for the gamma), and fitted the pooled age group better. The gamma curve when fitted showed little dome-shapedness. When we fitted these same two curves to the fishery data from the "noughties" (Figures 9-16 and 9-17), the dome-shaped gamma function fit was far superior (relative SSQ of 0.21 for the gamma compared to the logistic) and fitted the pooled age group very well. This yielded a strong dome-shape.

We took this as sufficient evidence to present a model that transitions into dome-shaped selectivity for the fishery in the three time blocks described previously. We fitted a logistic curve for the first block, an averaged logistic-gamma in the 2nd block, and a gamma function for the 3rd block. We also switched to fitting survey selectivity with the logistic curve (it was already very similar to the logistic) to be consistent. This accomplishes a reduction of nine parameters that were used in the original non-parametric selectivities.

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	71
Average fishing mortality	μ_f	1
Fishing mortality deviations	ϕ_y	49
Fishery selectivity coefficients	fs_a	4
Survey selectivity coefficients	ss_a	2
Total		134

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 such as this model, 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 134. In a low-dimensional model, an analytical solution might be possible, but in one with this many parameters, an analytical solution is intractable. Therefore, we use MCMC methods to estimate the Bayesian posterior distribution for these parameters. The basic premise is to use a Markov chain to simulate a random walk through the parameter space which will eventually converge to a stationary distribution which approximates the posterior distribution. Determining whether a particular chain has converged to this stationary distribution can be complicated, but generally if allowed to run long enough, it will converge. The “burn-in” is a set of iterations removed at the beginning of the chain. In our simulations we removed the first 1,000,000 iterations out of 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

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

Number at age of recruitment

Number at ages between recruitment and pooled age class

Number in pooled age class

Subsequent years

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

Number at age of recruitment

Number at ages between recruitment and pooled age class

Number in pooled age class

Formulae for likelihood components	**BOX 1 (Continued)**
$L_1 = \lambda_1 \sum_y \left(\ln \left[\frac{C_y + 0.01}{\hat{C}_y + 0.01} \right] \right)^2$	Catch likelihood
$L_2 = \lambda_2 \sum_y \frac{\left(I_y - \hat{I}_y \right)^2}{2 * \hat{\sigma}^2 \left(I_y \right)}$	Survey biomass index likelihood
$L_3 = \lambda_3 \sum_{styr}^{endyr} -n^*{}_y \sum_a^{a+} \left(P_{y,a} + 0.001 \right) * \ln \left(\hat{P}_{y,a} + 0.001 \right)$	Fishery age composition likelihood ($n^*{}_y$ =sample size, standardized to maximum of 100)
$L_4 = \lambda_4 \sum_{styr}^{endyr} -n^*{}_y \sum_l^{l+} \left(P_{y,l} + 0.001 \right) * \ln \left(\hat{P}_{y,l} + 0.001 \right)$	Fishery length composition likelihood
$L_5 = \lambda_5 \sum_{styr}^{endyr} -n^*{}_y \sum_a^{a+} \left(P_{y,a} + 0.001 \right) * \ln \left(\hat{P}_{y,a} + 0.001 \right)$	Survey age composition likelihood
$L_6 = \lambda_6 \sum_{styr}^{endyr} -n^*{}_y \sum_l^{l+} \left(P_{y,l} + 0.001 \right) * \ln \left(\hat{P}_{y,l} + 0.001 \right)$	Survey size composition likelihood
$L_7 = \frac{1}{2\sigma_M^2} \left(\ln \left(M / M_{prior} \right) \right)^2$	Penalty on deviation from prior distribution of natural mortality
$L_8 = \frac{1}{2\sigma_q^2} \left(\ln \left(q / q_{prior} \right) \right)^2$	Penalty on deviation from prior distribution of catchability coefficient
$L_9 = \frac{1}{2\sigma_{\sigma_r}^2} \left(\ln \left(\sigma_r / \sigma_{r(prior)} \right) \right)^2$	Penalty on deviation from prior distribution of recruitment deviations
$L_{10} = \lambda_{10} \left[\frac{1}{2 * \sigma_r^2} \sum_y \tau_y^2 + n_y * \ln \left(\sigma_r \right) \right]$	Penalty on recruitment deviations
$L_{11} = \lambda_{11} \sum_y \varepsilon_y^2$	Fishing mortality regularity penalty
$L_{12} = \lambda_{12} \bar{s}^2$	Average selectivity penalty (attempts to keep average selectivity near 1)
$L_{13} = \lambda_{13} \sum_{a_0}^{a_+} \left(s_i - s_{i+1} \right)^2$	Selectivity dome-shapedness penalty – only penalizes when the next age's selectivity is lower than the previous (penalizes a downward selectivity curve at older ages)
$L_{14} = \lambda_{14} \sum_{a_0}^{a_+} \left(FD(FD(s_i - s_{i+1}) \right)^2$	Selectivity regularity penalty (penalizes large deviations from adjacent selectivities by adding the square of second differences
$L_{total} = \sum_{i=1}^{14} L_i$	Total objective function value
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 used since 2003 with additional data. For the 2009 assessment, we present several alternative models based on routine maintenance and some new analysis on fishery selectivity presented in the **Model parameters estimated conditionally** section. The three models are identical in all aspects except the number of selectivity parameters estimated. Our criteria for choosing a superior model are: (1) the best overall fit to the data (in terms of negative log-likelihood), (2) biologically reasonable patterns of estimated recruitment, catchabilities, and selectivities, (3) a good visual fit to length and age compositions, and (4) parsimony. The basic features of the model runs presented in this document are described in the following table:

Model Number	Model Description
Model 1 (Base case)	• Model from Hanselman et al. 2007, the base model appended with new data since the 2007 assessment.
Model 2	• Update all data
Model 3	• Time block selectivity for the fishery including a transition to a dome-shaped selectivity function for the contemporary fishery • Change from non-parametric forms to parametric forms • Estimate survey with logistic selectivity • Reduction of 9 parameters.

Model 1 is the base model from 2005 and 2007. Only changes that have occurred were appending new data. When compared with 2007, the fits and results are very similar. The catchability parameter continues to drift slightly higher.

Model 2 is structurally identical to Model 1, but it was necessary to do some routine data maintenance as some of the input data has changed because of database screening, strata area recalculation, or compositional data updates. Most of the data updates were trivial, and the main data update that affected the model was the survey biomass time series, which has changed some over time. While the trend remains intact, several of the standard errors were smaller in the early part of the time series. This generally resulted in a large increase in catchability from 2.1 to 2.4 and an associated reduction in biomass. The model fit to the new data was superior to the old data, primarily due to fitting the survey biomass and survey ages better. However, we were already uncomfortable with the upward drift in catchability, and we reject this model outright due to this large increase in catchability.

Model 3 presents some modifications to fishery and survey selectivity as an alternative model. In the past, Pacific ocean perch selectivities have been modeled with a non-parametric smooth of selectivity coefficients to a specified age and then held constant. The amount of smoothing, the constraint applied to prevent a descending right limb, and the age chosen to cease estimating coefficients were somewhat arbitrarily chosen based on “eyeball” estimates of how the curve looked. For this model, we block fishery selectivity into three time periods based on differences in the fishery, and change the function used to estimate selectivity for the more recent periods to reflect what we perceive to be structural changes in the fishery. We also change the survey selectivity to a logistic curve to be consistent. These changes result in an overall better fit to the data than either of the previous two models. This is accomplished by fitting the fishery age compositions substantially better, which was in part what the change in selectivity was aiming to accomplish. This is evident visually when comparing model fits in Figure 9-18, where Model 3 fitted the pooled group in the fishery age compositions much better. In addition, the model reduced catchability below two. This model also fitted the data better with nine less parameters, which is compelling in terms of parsimony. Given these aspects of Model 3, we recommend it to estimate management quantities for 2010, and we show results for Model 3 in the following section.

Model Results

Key results have been summarized in Tables 9-7 and 9-8. Model predictions fitted the data well (Figures 9-2, 9-4, 9-5, and 9-6) 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 number of age two Pacific ocean perch. Fishing mortality is fully-selected F, meaning the mortality at the age the fishery has fully selected the fish.

Biomass and exploitation trends

Estimated total biomass (age 2 and greater fish) had gradually increased from a low near 100,000 t in 1980 to over 325,000 t for 2009 (Figure 9-19). 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 9-20). This is likely due to large year classes crossing a steep maturity curve. Spawning biomass estimates show a fairly rapid increase between 1992 and 2000, and a slower increase (with considerable uncertainty) thereafter. Age of 50% first selection is 5 and between 7 and 9 years for survey and fishery, respectively (Figure 9-21). Fish are fully selected by both fishery and survey by about age 8. Current fishery selectivity is dome-shaped and matches well with the ages caught by the fishery. Catchability is near two, which is supported by several empirical studies using line transects densities counted from a submersible compared to trawl survey densities (Krieger 1993, Krieger and Sigler 1996, Hanselman et al. 2006[2]).

Fully-selected fishing mortality (fishing mortality at full selectivity) shows that fishing mortality has decreased dramatically from historic rates and has leveled out in the last decade (Figure 9-22). 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_{OFL} adjusted limit for most of the historical time series (Figure 9-23a). In addition, since 1999, Pacific ocean perch SSB has been above $B_{40\%}$ and fishing mortality has been below $F_{40\%}$ (Figure 9-23b).

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 9-24). 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 1979-2007). The addition of new age data in this year’s model has increased the recruitment estimates for the 1998 and 1999 year classes (Figure 9-25). However, these recruitments, especially recently, are still highly uncertain as indicated by the MCMC credible intervals in Figure 9-24. Pacific ocean perch do not seem to exhibit much of a stock-

[2] 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.

recruitment relationship because large recruitments have occurred during periods of high and low biomass (Figure 9-24, bottom).

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 9-26) and credible intervals (Table 9-8). We also use these posterior distributions to show uncertainty around time series estimates such as total biomass, spawning biomass, and recruitment (Figs. 9-19, 9-20, 9-24).

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, ABC and σ_r (recruitment deviation). These larger standard deviations indicate that these parameters are more uncertain than indicated by the standard modeling, especially in the case of σ_r in which the MLE estimate is far out of the Bayesian credible intervals. This highlights a concern that σ_r requires a fairly informative prior distribution since it is confounded with available data on recruitment variability. To illustrate this problem, imagine a stock that truly has variable recruitment. If this stock lacks age data (or the data are very noisy), then the modal estimate of σ_r is near zero. As an alternative, we could run sensitivity analyses to determine an optimum value for σ_r and fix it at that value instead of estimating it within the model. The distribution of ABC and spawning biomass are skewed, indicating possibilities of higher biomass estimates (also see Figure 9-20).

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 recruitment between 1979 and 2007. 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 2009 estimates of these reference points are:

$B_{100\%}$	$B_{40\%}$	$B_{35\%}$	$F_{40\%}$	$F_{35\%}$
227,610	91,044	79,664	0.123	0.142

Specification of OFL and Maximum Permissible ABC

Female spawning biomass for 2010 is estimated at 107,763 t. This is above the $B_{40\%}$ value of 91,044 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 2010, yields the following ABC and OFL:

$F_{40\%}$	0.123
ABC	**17,584**
$F_{35\%}$	0.142
OFL	**20,243**

A notable change from the 2007 configuration is a much larger value of $F_{40\%}$ and $F_{35\%}$. This increase in recommended fishing mortality from 0.06 to 0.12 is due to the change in current fishery selectivity. 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. Therefore the increase in ABC is more due to a lower estimated catchability, then the large increase in $F_{40\%}$.

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 2009 numbers at age as estimated in the assessment. This vector is then projected forward to the beginning of 2010 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2009. 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 2009 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 2010, 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 all future years, F is set equal to a constant fraction of *max* F_{ABC}, where this fraction is equal to the ratio of the catch in 2009 to the ABC recommended in the assessment for 2009. (Rationale: When F_{ABC} is set at a value below *max* F_{ABC}, it is often set at the value recommended in the stock assessment.) In this scenario we use the ratio of most recent catch to ABC, and apply it to estimated ABCs for 2010 and 2011 to determine the catch for 2010 and 2011, then maximum permissible thereafter. Projections incorporating estimated catches help produce more accurate projections for fisheries that do not utilize all of the TAC.

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 2005-2009 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 2009 or 2) above ½ of its MSY level in 2009 and above its MSY level in 2019 under this scenario, then the stock is not overfished.)

Scenario 7: In 2010 and 2011, 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 2022 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 9-10). 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 sablefish) where the catch is usually less than the ABC. This was suggested to help management with setting preliminary ABCs and OFLs for 2010 and 2011. In this scenario we use the ratio of most recent catch to ABC, and apply it to estimated ABCs for 2010 and 2011 to determine the catch for 2010 and 2011, then set catch at maximum permissible thereafter.

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 2010, it does not provide the best estimate of OFL for 2011, because the mean 2010 catch under Scenario 6 is predicated on the 2010 catch being equal to the 2010 OFL, whereas the actual 2010 catch will likely be less than the 2009 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 (2008) is 14,335 t. This is less than the 2008 OFL of 21,310 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 2009:
a. If spawning biomass for 2009 is estimated to be below ½ $B_{35\%}$, the stock is below its MSST.
b. If spawning biomass for 2009 is estimated to be above $B_{35\%}$ the stock is above its MSST.

c. If spawning biomass for 2009 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 9-10). If the mean spawning biomass for 2019 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 2012 is below 1/2 $B_{35\%}$, the stock is approaching an overfished condition.
b. If the mean spawning biomass for 2012 is above $B_{35\%}$, the stock is not approaching an overfished condition.
c. If the mean spawning biomass for 2012 is above 1/2 $B_{35\%}$ but below $B_{35\%}$, the determination depends on the mean spawning biomass for 2022. If the mean spawning biomass for 2022 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 9-10, the stock is not overfished and is not approaching an overfished condition.

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 *author's F* (0.84 maximum permissible based on recent ratios of catch to ABC). This is conservative relative to a maxABC or alternative 1 projection scenario. 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 9-27). The $B_{35\%}$ and $B_{40\%}$ reference points are based on the 1979-2007 age-2 recruitments, and this projection predicts that the median spawning biomass will eventually move toward $B_{40\%}$, but slowly because harvest is not being taken at $maxF_{ABC}$..

Area Apportionment of Harvests

Prior to the 1996 fishery, the apportionment of ABC among areas was determined from distribution of biomass based on the average proportion of exploitable biomass by area in the most recent three triennial trawl surveys. 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 2005, 2007, and 2009 surveys, respectively and apportionments of 16% for the Western area, 61% for the Central area, and 23% for the Eastern area (Table 9-11). This results in recommended ABC's of **2,895** t for the Western area, **10,737** t for the Central area, and **3,952** t for the Eastern area.

Amendment 41 prohibited trawling in the Eastern area east of 140° W longitude. In the past, the Plan Team has calculated an apportionment for the West Yakutat area that is still open to trawling (between 147°W and 140°W). We calculated this apportionment using the ratio of estimated biomass in the closed area and open area. This calculation was based on the team's previous recommendation that we use the weighted average of the upper 95% confidence interval for the W. Yakutat. We computed this interval this year using the weighted average of the ratio for 2005, 2007, and 2009. We calculated the approximate upper 95% confidence interval using the weighted variance of the 2003-2007 ratios for our weighted ratio estimate. This resulted in slightly higher ratio than last year of 0.50. This results in an ABC apportionment of 2,004 t to the W. Yakutat area which would leave 1,948 t unharvested in the Southeast/Outside area.

Overfishing Definition

Based on the definitions for overfishing in Amendment 44 in tier 3a (i.e., $F_{OFL} = F_{35\%}$=0.142), overfishing is set equal to 20,243 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 3,332 t in the Western area, 12,361 t in the Central area, and 4,550 t in the Eastern area.

Ecosystem Considerations

In general, a determination of ecosystem considerations for Pacific ocean perch is hampered by the lack of biological and habitat information. A summary of the ecosystem considerations presented in this section is listed in Table 9-12.

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 9-13).

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 9-13, 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 9-13 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 (1652 kg), sea anemones (1554 kg), and sponges (2473 kg) by rockfish fisheries in the GOA represented 61%, 8%, and 42% respectively of those species taken by all Gulfwide fisheries.

Data Gaps and Research Priorities

There is little information on larval, post-larval, or early juvenile stages slope rockfish. Habitat requirements for these stages are mostly unknown. Habitat requirements for later stage juvenile and adult fish are anecdotal or conjectural. Research needs to be done on the bottom habitat of the major fishing grounds, on what HAPC biota are found on these grounds, and on what impact bottom trawling has on these biota. Additionally, Pacific ocean perch are undersampled by the current survey design. The stock assessment would benefit from additional survey effort on the continental slope. Further research on trawl catchability and trawlable/untrawlable grounds would be very useful. For Pacific ocean perch and the other Gulf of Alaska rockfish assessed with age-structured models, we plan to focus on optimizing and making consistent the methods we use for multinomial sample sizes, the way we choose our bins for age and length compositions, and examine growth for changes over time.

Summary

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

Summary	2008 Projection:		**2009 projection:**	
Projection Year	2009	2010	2010	2011[1]
Tier 3a				
Total Biomass (Age 2+)	318,336	318,965	334,797	330,277
Female Spawning Biomass (t)	94,538	97,091	107,763	108,192
$B_{100\%}$ (t, female spawning biomass)	222,987	--	227,610	227,610
$B_{40\%}$ (t, female spawning biomass)	89,195	--	91,044	91,044
$B_{35\%}$ (t, female spawning biomass)	78,045	--	79,664	79,664
M	0.06	0.06	0.061	0.061
F_{ABC} (maximum allowable = $F_{40\%}$)	0.061	0.061	0.123	0.123
F_{OFL}	0.073	0.073	0.142	0.142
ABC (t, maximum allowable)	15,111	15,098	**17,584**	16,993
OFL (t)	17,940	17,925	**20,243**	19,560

[1]**Projected ABCs and OFLs for 2011 are derived using an expected catch value of 14,770 t for 2010 based on recent ratios of catch to ABC.** This calculation is in response to management requests to obtain a more accurate one-year projection.

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Tables

Table 9-1. 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), 1977-2007.

		Regulatory Area				Gulfwide		Gulfwide value
Year	Fishery	Western	Central	Eastern	Research	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	13.0	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	5.7	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	12.2	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	12.6	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	57.1	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	15.2	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	2.4	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	76.5	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	35.2	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	14.4	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	68.8	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	0.3	13,779	16,800	16,800

Table 9-1 (continued)

		Regulatory Area				Gulfwide value		
Year	Fishery	Western	Central	Eastern	Research	Total	ABC	Quota
1989	U.S.	4,339	8,315	6,348	0.98	19,003	20,000	20,000
1990	U.S.	5,203	9,973	5,938	25.5	21,140	17,700	17,700
1991	U.S.	1,589	2,956	2,087	0.1	6,632	5,800	5,800
1992	U.S.	1,266	2,658	2,234	0	6,158	5,730	5,200
1993	U.S.	477	1,140	443	59.2	2,119	3,378	2,560
1994	U.S.	165	920	768	tr	1,853	3,030	2,550
1995	U.S.	1,422	2,598	1,722	tr	5,742	6,530	5,630
1996	U.S.	987	5,145	2,246	81.2	8,459	8,060	6,959
1997	U.S.	1,832	6,720	979	tr	9,531	12,990	9,190
1998	U.S.	850	7,501	610	305	9,266	12,820	10,776
1999	U.S.	1,935	7,910	627	330.2	10,802	13,120	12,590
2000	U.S.	1,160	8,379	618	0	10,157	13,020	13,020
2001	U.S.	944	9,249	624	42.5	10,860	13,510	13,510
2002	U.S.	2,720	8,261	748	tr	11,729	13,190	13,190
2003	U.S.	2,149	8,106	606	50.4	10,911	13,663	13,660
2004	U.S.	2,196	8,455	877	tr	11,528	13,336	13,340
2005	U.S.	2,339	8,145	872	84.4	11,440	13,575	13,580
2006	U.S.	4,050	8,282	1,258	tr	13,590	14,261	14,261
2007	U.S.	4,430	7,281	1,242	92.7	13,046	14,636	14,635
2008	U.S.	3,682	7,677	1,040	1.3	12,400	14,999	14,999
2009*	U.S.	3,803	7,756	1,104	73	12,736	15,111	15,111

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 1991-2003 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; 1988-2003, Pacific ocean perch.

[b]Quota defined as follows: 1977-86, optimum yield; 1987, target quota; 1988-2003 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); 1987-2000, Heifetz et al. (2000); 2001-2007, NMFS Alaska Regional Office catch reports (http://www.fakr.noaa.gov). *2009 catch as of 10/10/2009. Research catches include all RACEBASE surveys and recent MACE surveys.

Table 9-2. Fishery length frequency data for Pacific ocean perch in the Gulf of Alaska.

Length (cm)	1995	1996	1997	1998	1999	Year 2000	2001	2002	2003	2004	2005	2006	2007	2008
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	0.000
13-15	0.000	0.000	0.001	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	0.002	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	0.002	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	0.005	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	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000
20	0.000	0.000	0.002	0.000	0.001	0.000	0.001	0.000	0.000	0.000	0.001	0.001	0.001	0.000
21	0.000	0.000	0.002	0.000	0.000	0.001	0.001	0.001	0.001	0.000	0.000	0.001	0.001	0.000
22	0.000	0.000	0.002	0.000	0.000	0.000	0.002	0.001	0.001	0.001	0.002	0.001	0.002	0.001
23	0.001	0.000	0.003	0.001	0.001	0.000	0.001	0.002	0.001	0.001	0.002	0.001	0.003	0.001
24	0.003	0.001	0.002	0.002	0.003	0.001	0.001	0.003	0.001	0.002	0.001	0.002	0.004	0.002
25	0.005	0.002	0.004	0.002	0.003	0.001	0.003	0.006	0.001	0.003	0.002	0.003	0.004	0.002
26	0.010	0.002	0.005	0.003	0.004	0.004	0.002	0.006	0.002	0.004	0.005	0.003	0.006	0.003
27	0.008	0.003	0.008	0.003	0.005	0.008	0.004	0.006	0.004	0.004	0.004	0.005	0.009	0.003
28	0.007	0.004	0.009	0.004	0.005	0.006	0.005	0.008	0.007	0.007	0.010	0.010	0.009	0.007
29	0.010	0.006	0.011	0.005	0.009	0.009	0.009	0.009	0.008	0.016	0.013	0.016	0.014	0.010
30	0.010	0.009	0.016	0.006	0.006	0.010	0.010	0.009	0.009	0.020	0.020	0.024	0.015	0.020
31	0.020	0.018	0.018	0.008	0.009	0.015	0.013	0.012	0.012	0.014	0.029	0.033	0.026	0.035
32	0.039	0.029	0.024	0.012	0.015	0.014	0.019	0.020	0.018	0.020	0.040	0.063	0.041	0.048
33	0.081	0.066	0.044	0.021	0.034	0.023	0.034	0.043	0.027	0.029	0.050	0.084	0.068	0.061
34	0.128	0.125	0.074	0.057	0.071	0.056	0.055	0.072	0.063	0.046	0.065	0.098	0.099	0.083
35-38	0.515	0.599	0.539	0.641	0.580	0.574	0.564	0.509	0.524	0.510	0.486	0.412	0.473	0.409
>38	0.161	0.135	0.227	0.236	0.254	0.275	0.273	0.292	0.321	0.322	0.271	0.244	0.226	0.316
Total	6580	11,140	14,611	14,110	4,650	6,157	4,776	4,980	5,885	5,034	4,572	5,206	9,724	17,634

Table 9-3. Fishery age compositions for GOA Pacific ocean perch 1990-2006.

Age Class	1990	1998	1999	2000	2001	2002	2004	2005	2006	2008
2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	0.002	0.000	0.000	0.000	0.002	0.000	0.000	0.001	0.000	0.000
4	0.016	0.000	0.000	0.005	0.004	0.003	0.002	0.001	0.001	0.005
5	0.042	0.000	0.003	0.015	0.002	0.014	0.007	0.012	0.003	0.005
6	0.048	0.000	0.016	0.037	0.017	0.016	0.051	0.021	0.045	0.021
7	0.071	0.002	0.024	0.026	0.040	0.035	0.040	0.085	0.089	0.031
8	0.054	0.008	0.029	0.056	0.029	0.097	0.049	0.085	0.114	0.102
9	0.069	0.045	0.043	0.064	0.058	0.078	0.166	0.103	0.108	0.103
10	0.106	0.148	0.051	0.057	0.060	0.108	0.177	0.142	0.084	0.161
11	0.057	0.166	0.178	0.054	0.060	0.105	0.067	0.114	0.106	0.108
12	0.083	0.203	0.191	0.132	0.063	0.051	0.075	0.074	0.087	0.048
13	0.057	0.121	0.130	0.127	0.131	0.070	0.069	0.047	0.061	0.090
14	0.109	0.113	0.088	0.110	0.146	0.108	0.036	0.044	0.037	0.051
15	0.042	0.057	0.120	0.104	0.084	0.086	0.036	0.021	0.035	0.043
16	0.016	0.031	0.061	0.060	0.092	0.065	0.049	0.032	0.026	0.023
17	0.028	0.033	0.021	0.052	0.061	0.054	0.050	0.050	0.027	0.026
18	0.009	0.014	0.019	0.031	0.071	0.038	0.041	0.041	0.035	0.011
19	0.012	0.014	0.003	0.025	0.040	0.035	0.030	0.032	0.038	0.026
20	0.010	0.002	0.003	0.008	0.015	0.011	0.021	0.026	0.027	0.028
21	0.012	0.004	0.000	0.010	0.012	0.003	0.009	0.028	0.025	0.026
22	0.003	0.004	0.008	0.011	0.002	0.005	0.007	0.011	0.010	0.026
23	0.005	0.012	0.003	0.004	0.006	0.003	0.005	0.008	0.015	0.020
24	0.009	0.002	0.000	0.001	0.000	0.003	0.006	0.007	0.010	0.015
25+	0.142	0.023	0.011	0.011	0.006	0.011	0.006	0.015	0.016	0.030
Sample size	578	513	376	734	521	370	802	727	734	609

Table 9-4. Biomass estimates (t) and Gulfwide confidence intervals for Pacific ocean perch in the Gulf of Alaska based on the 1984-2009 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	28%
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	25%
2009	31,739	209,756	247,737	97,188	63,029	649,449	418,638	880,260	23%

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

Table 9-6. Estimated numbers (thousands) in 2009, 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 2009 (1000's)	Percent mature	Weight (g)	Fishery selectivity	Survey selectivity
2	44,940	0	46	0	0
3	42,326	0	106	0	12
4	38,511	0	180	1	22
5	38,581	0	261	3	35
6	32,080	0	342	6	57
7	30,336	12	420	16	98
8	28,934	20	493	32	100
9	33,630	30	559	52	100
10	64,198	42	619	72	100
11	38,847	56	672	88	100
12	21,641	69	718	98	100
13	22,069	79	758	100	100
14	29,250	87	792	95	100
15	13,824	92	822	85	100
16	8,898	95	847	72	100
17	7,459	97	868	58	100
18	6,728	98	886	45	100
19	6,579	99	902	34	100
20	6,939	99	915	25	100
21	7,543	100	926	18	100
22	9,741	100	935	12	100
23	35,375	100	943	8	100
24	6,493	100	950	5	100
25+	37,695	100	970	4	100

Table 9-7. Summary of results from 2009 models compared with 2007 results

	2007	**2009**		
		BASE + 2009 data	Updated data components	Dome-shape fishery selectivity
Likelihoods		**1**	**2**	**3**
Catch	0.10	0.11	0.12	0.10
Survey Biomass	8.03	8.04	6.44	6.91
Fishery Ages	27.99	29.95	30.03	22.48
Survey Ages	45.75	47.73	43.33	42.28
Fishery Sizes	49.71	49.90	49.50	55.37
Data-Likelihood	131.6	135.7	129.4	127.2
Penalties/Priors				
Recruitment Devs	24.75	23.99	26.13	21.59
Fishery Selectivity	1.97	1.94	1.82	0.00
Survey Selectivity	0.42	0.41	0.36	0.00
Fish-Sel Domeshape	0.00	0.00	0.00	0.00
Survey-Sel Domeshape	0.00	0.00	0.00	0.00
Average Selectivity	0.00	0.00	0.00	0.00
F Regularity	4.65	4.85	4.68	4.12
σ_r prior	0.89	1.12	1.02	4.77
q prior	1.43	1.41	1.86	1.14
M prior	1.80	1.86	2.44	2.08
Objective Fun Total	167.6	171.3	167.7	160.8
Parameter Ests.				
Active parameters	139	143	143	134
q	2.10	2.12	2.37	1.97
M	0.060	0.061	0.062	0.061
σ_r	0.89	0.87	0.90	0.92
log-mean-recruitment	3.73	3.76	3.78	3.81
$F_{40\%}$	0.061	0.061	0.060	0.123
Total Biomass	317,511	317,331	288,216	335,063
B_{2010}	90,898	99,966	89,141	107,546
$B_{100\%}$	222,987	220,112	202,004	227,740
$\mathbf{B_{40\%}}$	89,195	88,045	80,802	91,096
$\mathbf{ABC_{F40\%}}$	14,999	15,206	13,899	17,554
$F_{35\%}$	0.073	0.073	0.071	0.142
$OFL_{F35\%}$	17,807	18,054	16,500	20,209

Table 9-8.Estimates of key parameters with Hessian estimates of standard deviation (σ), MCMC standard deviations (σ(MCMC)) and 95% Bayesian credible intervals (BCI) derived from MCMC simulations.

Parameter	μ	μ (MCMC)	Median (MCMC)	σ	σ(MCMC)	BCI-Lower	BCI-Upper
q	1.97	2.21	2.17	0.53	0.59	1.20	3.43
M	0.061	0.055	0.055	0.006	0.006	0.045	0.067
$F_{40\%}$	0.123	0.128	0.128	0.123	0.032	0.077	0.201
2010 SSB	107,763	108,387	101,297	33,133	28,054	51,405	161,832
2010 ABC	17,584	18,038	16,918	6,515	8,429	5,320	38,351
σ_r	0.917	1.902	1.885	0.095	0.242	1.475	2.420

Table 9-9.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	Current	Previous	Current	Previous	Current	Previous	Current	Previous
1977	28,105	26,362	95,464	87,806	0.226	0.246	17,697	14,497
1978	23,580	21,542	78,682	70,446	0.275	0.114	31,616	26,072
1979	23,311	20,952	75,153	66,371	0.106	0.125	59,149	50,501
1980	22,590	19,861	71,129	61,683	0.117	0.175	22,559	17,833
1981	20,552	17,448	65,189	54,851	0.166	0.191	18,610	16,794
1982	18,361	14,932	63,355	51,488	0.166	0.105	24,001	23,590
1983	18,289	14,473	74,891	60,525	0.072	0.047	27,958	21,802
1984	19,935	15,664	80,933	64,950	0.035	0.042	30,140	22,132
1985	21,814	17,043	85,691	68,889	0.032	0.012	47,647	28,787
1986	24,746	19,464	93,429	76,342	0.009	0.029	59,358	63,291
1987	27,700	21,892	100,477	81,779	0.022	0.055	45,187	40,114
1988	30,160	23,755	105,600	84,741	0.043	0.101	236,576	213,328
1989	31,059	24,059	111,178	85,084	0.077	0.138	62,835	60,152
1990	30,718	22,941	117,142	91,408	0.101	0.143	46,601	49,453
1991	30,251	21,878	119,126	91,951	0.110	0.072	40,712	34,880
1992	32,313	23,214	179,026	145,554	0.037	0.042	36,298	26,618
1993	38,711	28,549	200,982	166,077	0.031	0.012	34,424	26,602
1994	46,817	35,583	221,688	187,205	0.009	0.01	34,803	30,114
1995	56,498	44,362	238,999	203,191	0.008	0.028	37,178	32,131
1996	66,105	53,129	248,849	210,777	0.023	0.04	50,834	54,072
1997	75,218	61,367	253,307	213,375	0.033	0.045	93,334	120,620
1998	82,759	68,136	254,848	213,914	0.037	0.042	60,606	47,642
1999	88,355	73,111	256,182	214,324	0.035	0.049	51,114	48,433
2000	91,595	75,786	258,630	218,210	0.040	0.047	79,524	81,530
2001	93,401	77,249	272,647	240,575	0.037	0.045	115,611	76,886
2002	94,720	78,862	278,944	245,787	0.039	0.048	54,299	84,269
2003	95,310	79,722	281,640	249,514	0.042	0.044	42,681	54,924
2004	96,394	81,463	292,330	262,349	0.037	0.044	41,492	47,172
2005	98,291	84,111	312,650	274,041	0.037	0.041	41,054	39,651
2006	101,631	87,536	318,748	288,305	0.035	0.047	46,378	42,219
2007	104,300	90,947	318,187	292,800	0.043	0.042	43,534	42,324
2008	106,994		316,413		0.041		45,002	
2009	109,724		313,777		0.040		44,940	

Table 9-10. 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. $B_{40\%}$ = 91,044 t, $B_{35\%}$ = 79,664 t, $F_{40\%}$ = 0.123, and $F_{35\%}$ = 0.142.

Year	Maximum permissible F	Author's F* (prespecified catch)	Half maximum F	5-year average F	No fishing	Overfished	Approaching overfished
			Spawning biomass (t)				
2009	106,060	106,060	106,060	106,060	106,060	106,060	106,060
2010	107,434	107,763	108,476	107,954	109,536	107,105	107,434
2011	106,859	108,192	111,125	108,961	115,679	105,553	106,859
2012	105,185	106,199	112,617	108,802	120,942	102,980	104,873
2013	103,077	104,040	113,445	108,065	125,601	100,093	101,877
2014	100,831	101,730	113,798	107,003	129,652	97,200	98,853
2015	98,894	99,725	113,968	106,074	133,443	94,730	96,248
2016	97,362	98,129	114,397	105,412	137,122	92,751	94,142
2017	96,186	96,895	114,823	104,999	140,701	91,202	92,468
2018	95,433	96,089	115,482	104,940	144,377	90,147	91,284
2019	94,970	95,579	116,491	105,131	148,118	89,446	90,462
2020	94,774	95,340	117,778	105,570	152,042	89,039	89,949
2021	94,654	95,178	119,137	106,051	155,896	88,727	89,544
2022	94,594	95,078	119,889	106,568	159,723	88,488	89,222
			Fishing mortality				
2009	0.087	0.087	0.087	0.087	0.087	0.087	0.087
2010	0.123	0.102	0.061	0.092	-	0.142	0.142
2011	0.123	0.123	0.061	0.092	-	0.142	0.142
2012	0.123	0.123	0.061	0.092	-	0.142	0.142
2013	0.123	0.123	0.061	0.092	-	0.142	0.142
2014	0.123	0.123	0.061	0.092	-	0.142	0.142
2015	0.123	0.123	0.061	0.092	-	0.142	0.142
2016	0.123	0.123	0.061	0.092	-	0.142	0.142
2017	0.123	0.123	0.061	0.092	-	0.141	0.141
2018	0.123	0.123	0.061	0.092	-	0.140	0.140
2019	0.122	0.122	0.061	0.092	-	0.138	0.138
2020	0.122	0.122	0.061	0.092	-	0.137	0.137
2021	0.122	0.122	0.061	0.092	-	0.137	0.137
2022	0.121	0.122	0.061	0.092	-	0.136	0.136
			Yield (t)				
2009	12,736	12,736	12,736	12,736	12,736	12,736	12,736
2010	17,584	17,584	9,001	13,336	-	20,243	17,584
2011	16,745	16,993	8,977	12,996	-	19,560	16,745
2012	15,725	15,948	8,795	12,465	-	17,604	18,105
2013	14,679	14,862	8,510	11,844	-	16,252	16,664
2014	13,756	13,901	8,202	11,252	-	15,104	15,430
2015	13,048	13,158	7,933	10,774	-	14,247	14,496
2016	12,590	12,671	7,748	10,454	-	13,703	13,887
2017	12,370	12,428	7,660	10,300	-	13,360	13,558
2018	12,341	12,382	7,664	10,288	-	13,199	13,379
2019	12,425	12,459	7,737	10,374	-	13,214	13,356
2020	12,557	12,588	7,849	10,515	-	13,334	13,441
2021	12,713	12,740	7,981	10,678	-	13,495	13,575
2022	12,870	12,892	8,111	10,837	-	13,656	13,717

*** Projected ABCs and OFLs for 2011 are derived using an expected catch value of 14,770 t for 2010 based on recent ratios of catch to ABC. This is shown in Scenario 2, Author's F.**

Table 9-11. Apportionment of ABC and OFL for 2010 Pacific ocean perch in the Gulf of Alaska.

		Western	Central		Eastern		
Year	Weights	Shumagin	Chirikof	Kodiak	Yakutat	Southeast	Total
2005	4	33%	10%	39%	10%	8%	100%
2007	6	23%	11%	44%	8%	14%	100%
2009	9	5%	32%	38%	15%	10%	100%
Weighted Mean	19	16%	21%	40%	12%	11%	100%
Area Apportionment		**16%**	**61%**		**23%**		
Area ABC		**2,895**	**10,737**		**3,952**		**17,584**
Area OFL		**3,332**	**12,361**		**4,550**		**20,243**

Table 9-12. Summary of ecosystem considerations GOA.

Ecosystem effects on *GOA Pacific ocean perch*			
Indicator	Observation	Interpretation	Evaluation
Prey availability or abundance trends			
Phytoplankton and Zooplankton	Primary contents of stomach	Important for all life stages, no time series	Unknown
Predator population trends			
Marine mammals	Not commonly eaten by marine mammals	No effect	No concern
Birds	Stable, some increasing some decreasing	Affects young-of-year mortality	Probably no concern
Fish (Halibut, ling cod, rockfish, arrowtooth)	Arrowtooth have increased, others stable	More predation on juvenile rockfish	Possible concern
Changes in habitat quality			
Temperature regime	Higher recruitment after 1977 regime shift	Contributed to rapid stock recovery	No concern
Winter-spring environmental conditions	Affects pre-recruit survival	Different phytoplankton bloom timing	Causes natural variability, rockfish have varying larval release to compensate
Production	Relaxed downwelling in summer brings in nutrients to Gulf shelf	Some years are highly variable like El Nino 1998	Probably no concern, contributes to high variability of rockfish recruitment
***GOA POP* fishery effects on ecosystem**			
Indicator	Observation	Interpretation	Evaluation
Fishery contribution to bycatch			
Prohibited species	Stable, heavily monitored	Minor contribution to mortality	No concern
Forage (including herring, Atka mackerel, cod, and pollock)	Stable, heavily monitored (P. cod most common)	Bycatch levels small relative to forage biomass	No concern
HAPC biota	Medium bycatch levels of sponge and corals	Bycatch levels small relative to total HAPC biota, but can be large in specific areas	Probably no concern
Marine mammals and birds	Very minor take of marine mammals, trawlers overall cause some bird mortality	Rockfish fishery is short compared to other fisheries	No concern
Sensitive non-target species	Likely minor impact on non-target rockfish	Data limited, likely to be harvested in proportion to their abundance	Probably no concern
Fishery concentration in space and time	Duration is short and in patchy areas	Not a major prey species for marine mammals	No concern, fishery is being extended for several month starting 2007
Fishery effects on amount of large size target fish	Depends on highly variable year-class strength	Natural fluctuation	Probably no concern
Fishery contribution to discards and offal production	Decreasing	Improving, but data limited	Possible concern with non-targets rockfish
Fishery effects on age-at-maturity and fecundity	Black rockfish show older fish have more viable larvae	Inshore rockfish results may not apply to longer-lived slope rockfish	Definite concern, studies initiated in 2005 and ongoing

Table 9-13. Nontarget species bycatch estimates in kilograms for Gulf of Alaska rockfish targeted fisheries 2004-2009. Source: Alaska Regional Office, data prepared by Olav Orsmeth.

	Estimated Catch (kg)					
Group Name	2004	2005	2006	2007	2008	2009
Benthic urochordata	133		44	31	267	1
Birds				83	40	18
Brittle star unidentified	2	47	93	8	37	26
Corals Bryozoans	65	6,128	390	2,272	469	340
Eelpouts	222	9,604	32	123	376	5
Eulachon	205	79	299	51	7	25
Giant Grenadier	445	134,573	272,059	127,139	163,570	283,684
Greenlings	6,971	3,564	5,945	7,735	15,083	8,026
Grenadier	2,830,011	77,036	65,538	70,609	3,429	3,199
Hermit crab unidentified	10	40	56	5	6	12
Invertebrate unidentified	949	98	40	12	239	306
Large Sculpins	43,292	15,478	28,314	26,878	19,788	29,761
Misc crabs	342	742	406	135	66	98
Misc crustaceans	24					369
Octopus	425	194	468	58	2,893	1,144
Other osmerids	145	15	263	89	0	137
Other Sculpins	15,039	12,175	3,896	4,488	3,502	3,810
Pandalid shrimp	297	235	172	113	108	88
Scypho jellies	2,982	151	429	206	112	696
Sea anemone unidentified	2,965	298	619	205	690	3,206
Sea pens whips	2	44			19	14
Sea star	2,128	1,457	2,218	657	1,157	1,813
Shark, Other	221	178	1,614	397	37	5
Shark, pacific sleeper	753	150	386	39	1,110	274
Shark, salmon	120	500	620	492	722	381
Shark, spiny dogfish	2,296	2,812	2,002	6,216	4,785	1,350
Skate, Big	6,635	4,622	4,210	128	3,721	3,604
Skate, Longnose	16,417	8,941	8,093	15,035	10,863	13,228
Skate, Other	10,380	45,017	35,787	16,664	8,086	10,985
Snails	304	153	799	68	184	11,902
Sponge unidentified	1,141	1,138	956	646	2,970	6,642
Squid	11,940	1,525	10,226	3,052	5,235	13,875
urchins dollars cucumbers	616	162	298	168	258	660

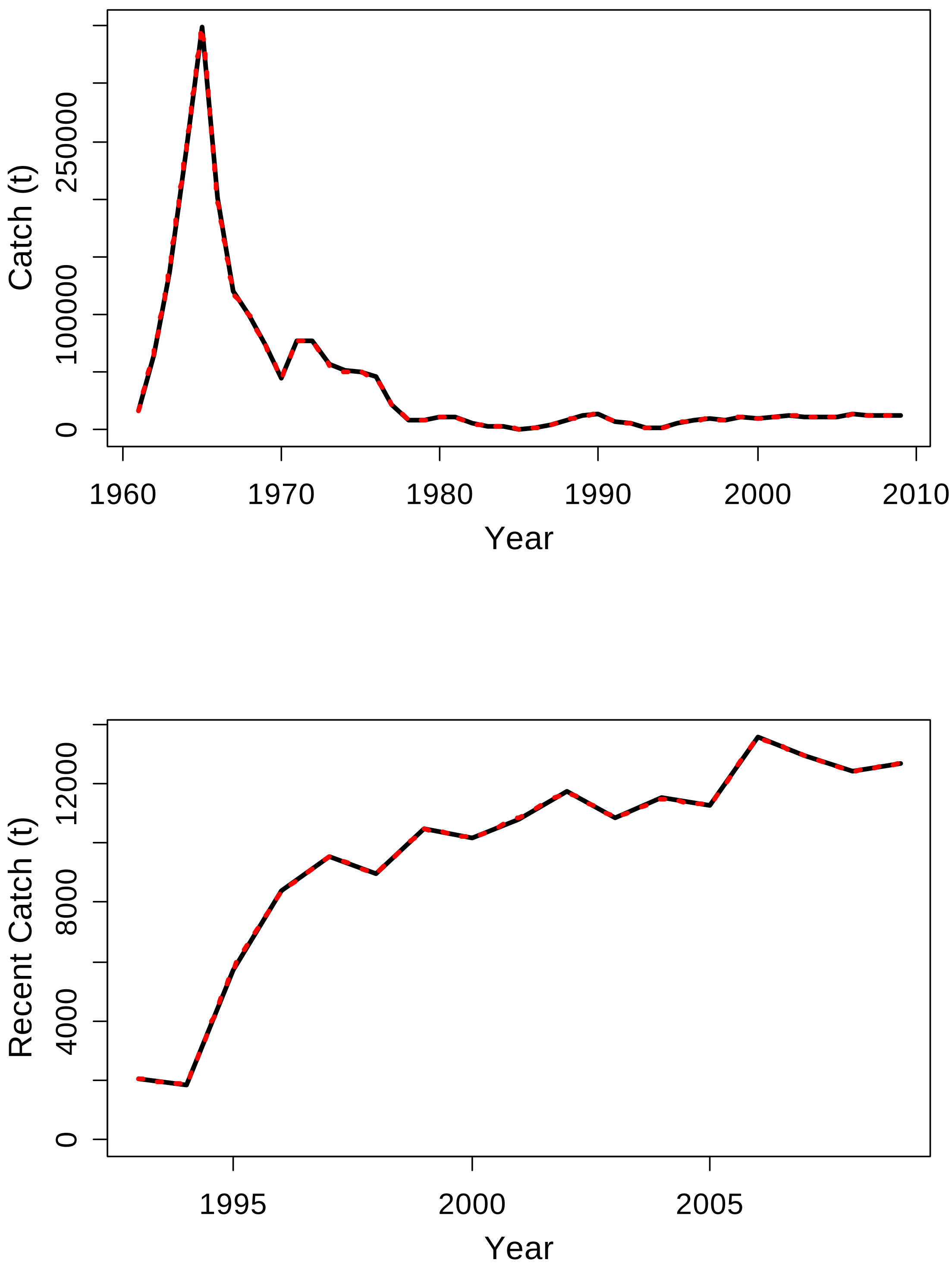


Figure 9-1. Estimated and observed long-term (a) and short-term (b) catch history for Gulf of Alaska Pacific ocean perch.

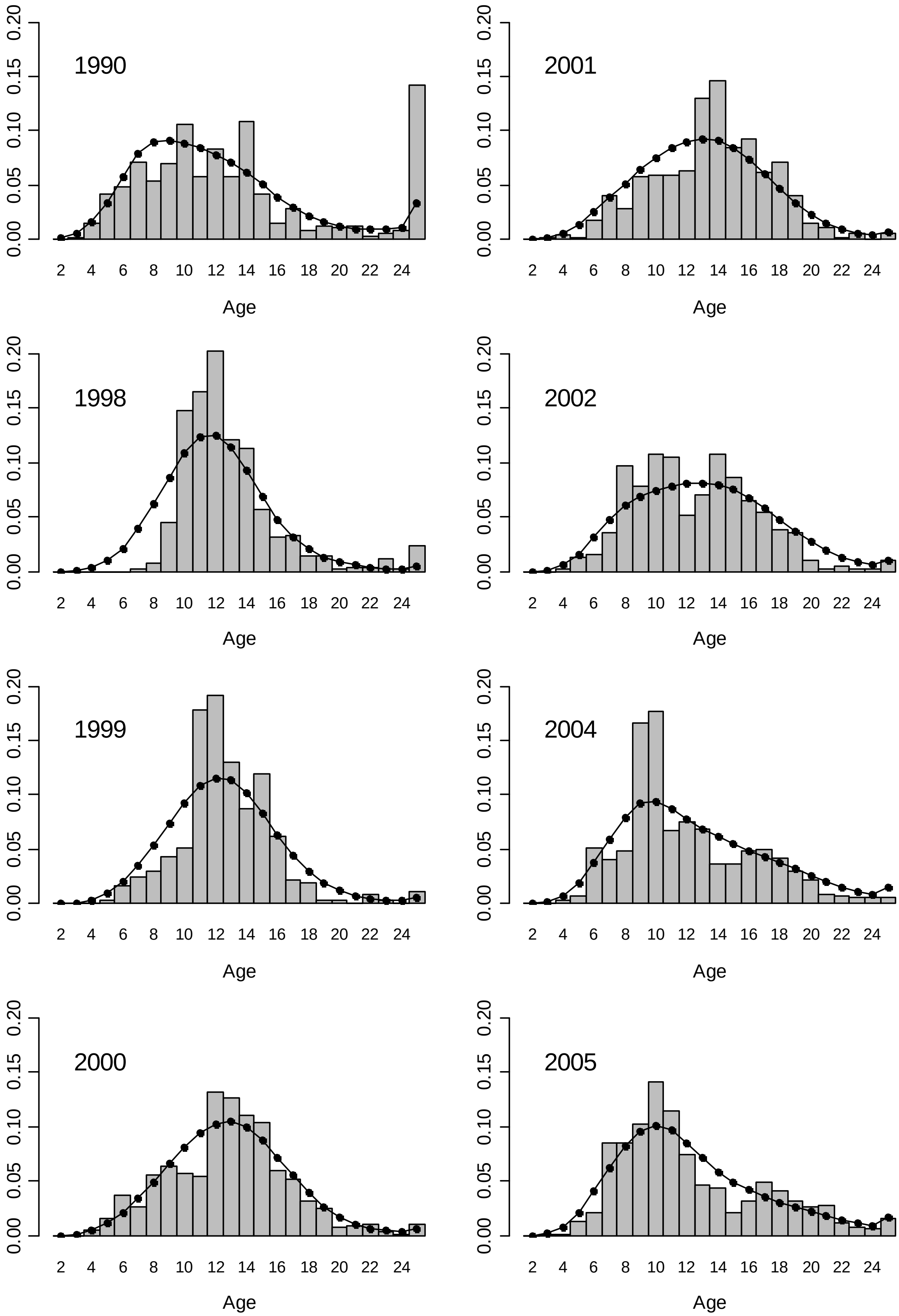


Figure 9-2. Fishery age compositions for GOA Pacific ocean perch. Observed = bars, predicted from author recommended model = line with circles.

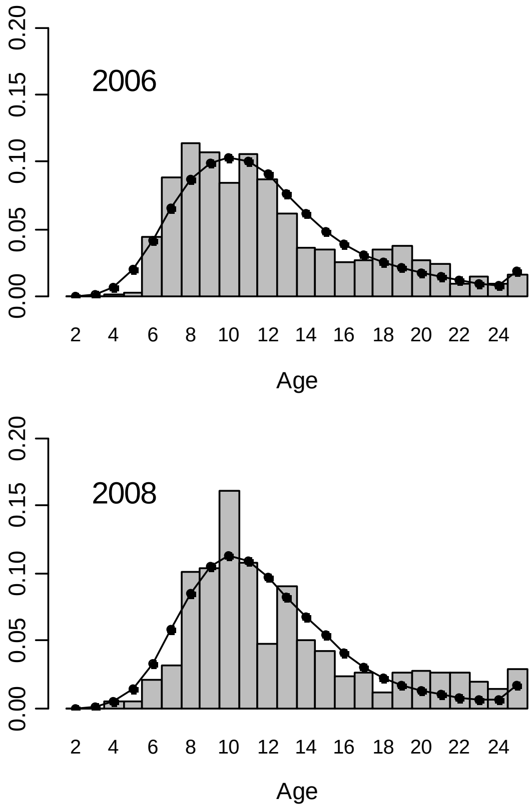


Figure 9-2 (continued). Fishery age compositions for GOA Pacific ocean perch. Observed = bars, predicted from author recommended model = line with circles.

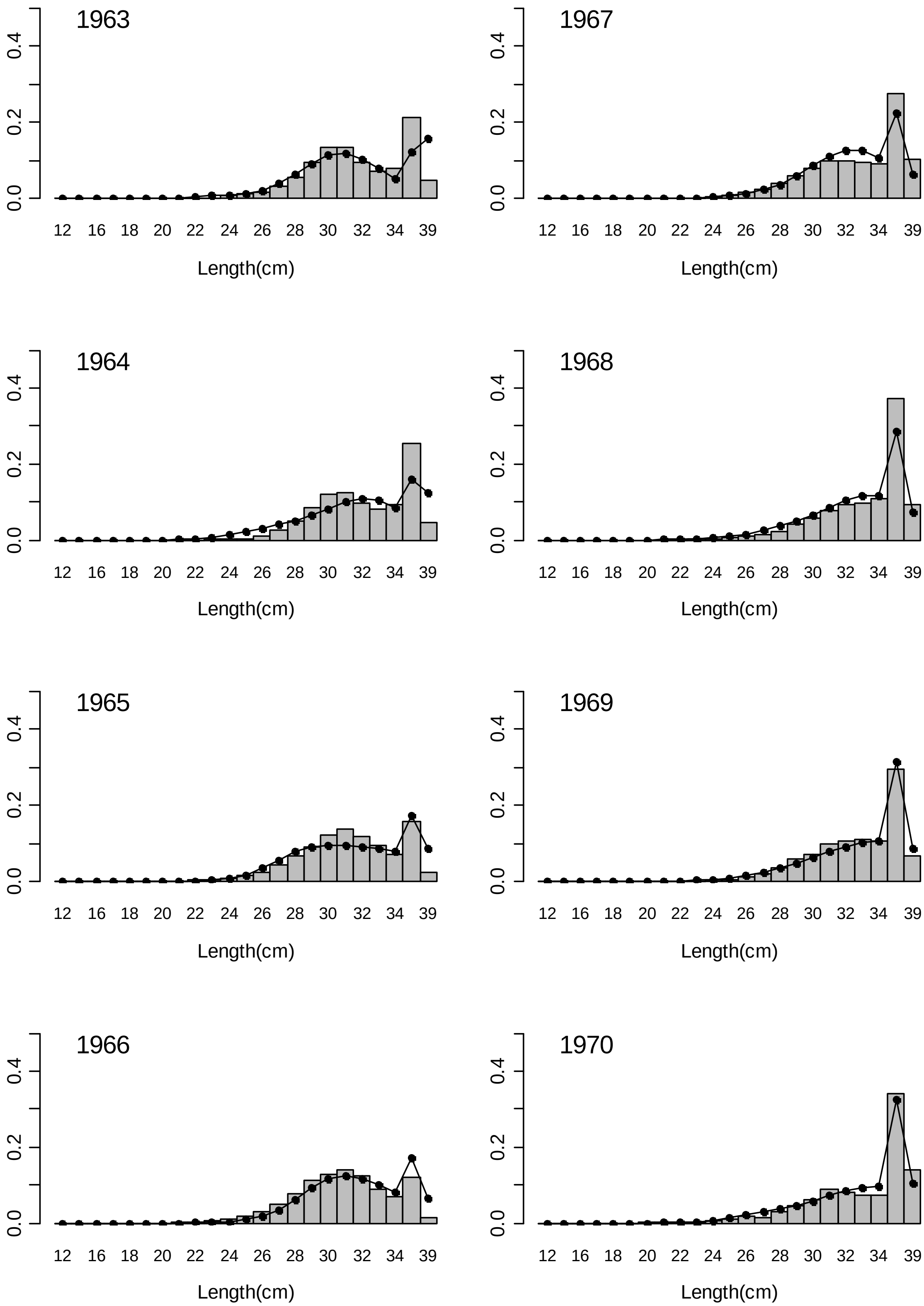


Figure 9-3. Fishery length compositions for GOA Pacific ocean perch. Observed = bars, predicted from author recommended model = line with circles.

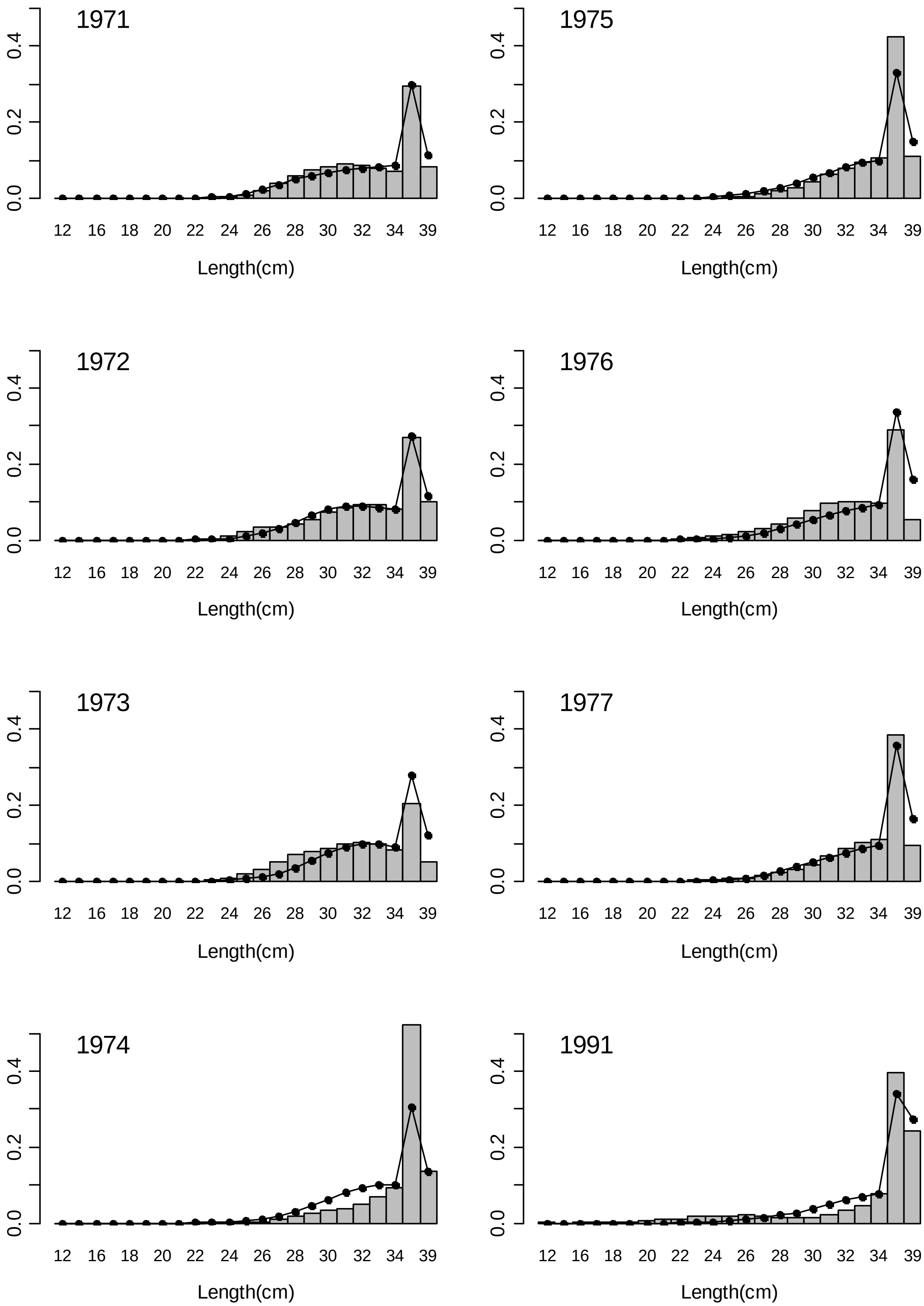


Figure 9-3 (continued). Fishery length compositions for GOA Pacific ocean perch. Observed = bars, predicted from author recommended model = line with circles.

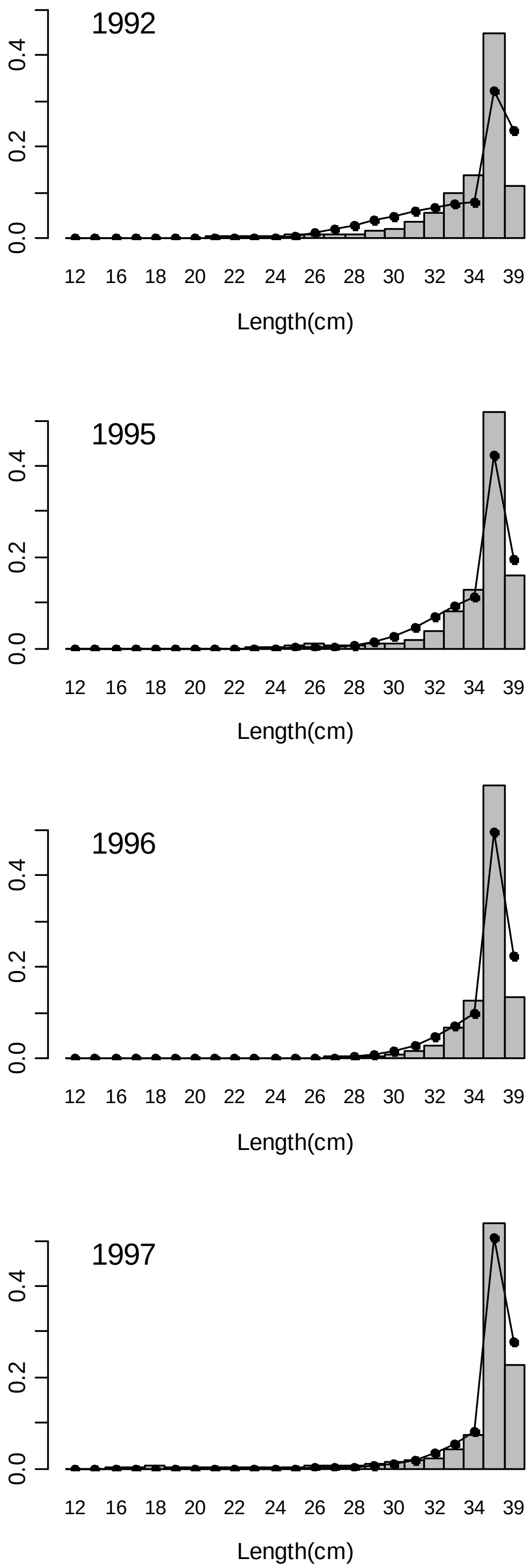


Figure 9-3 (continued). Fishery length compositions for GOA Pacific ocean perch. Observed = bars, predicted from author recommended model = line with circles.

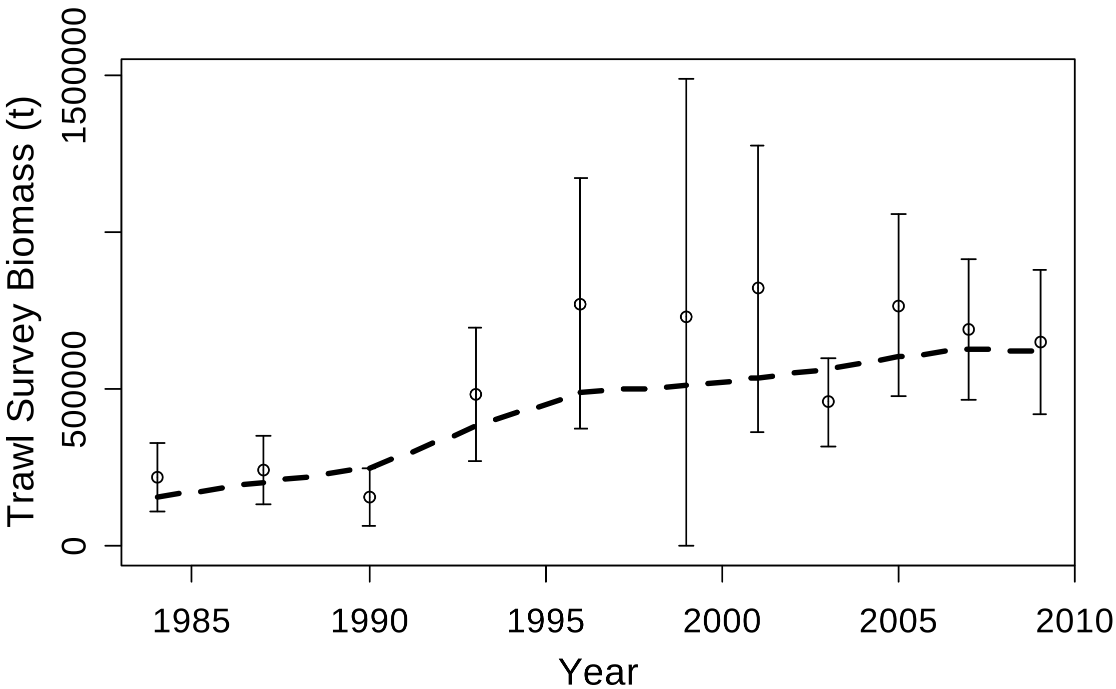


Figure 9-4. NMFS Groundfish Survey biomass estimates (solid line), with 95% sampling error confidence intervals (dashed line) and model fit (dotted line) for Gulf of Alaska Pacific ocean perch.

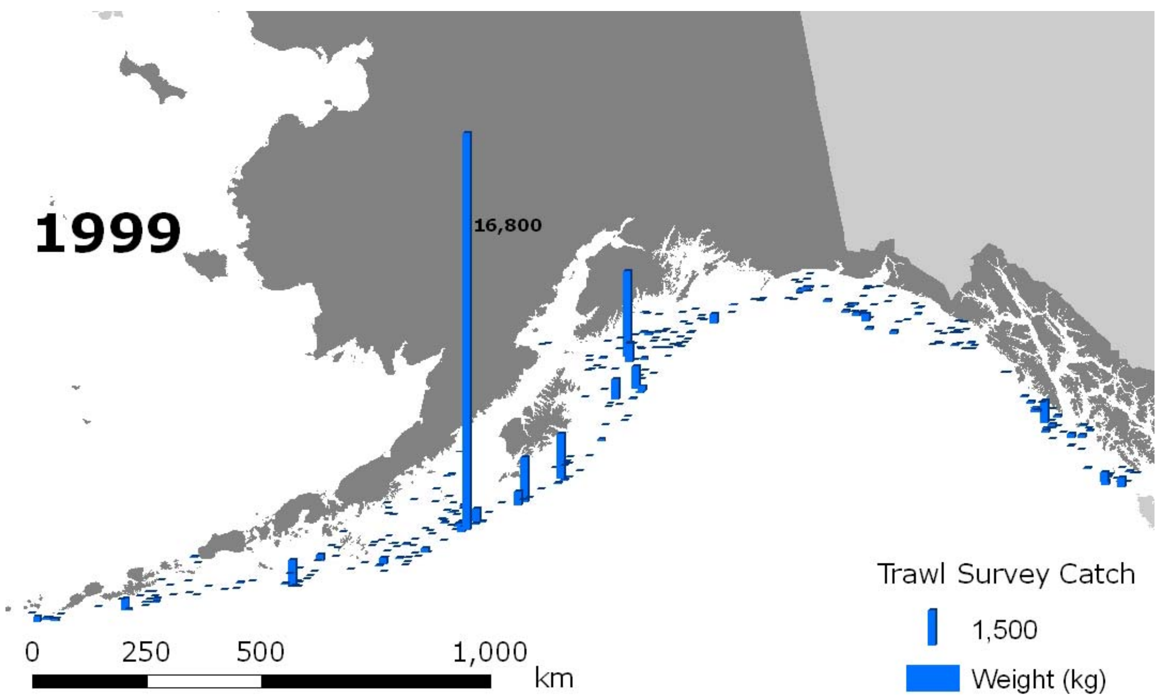
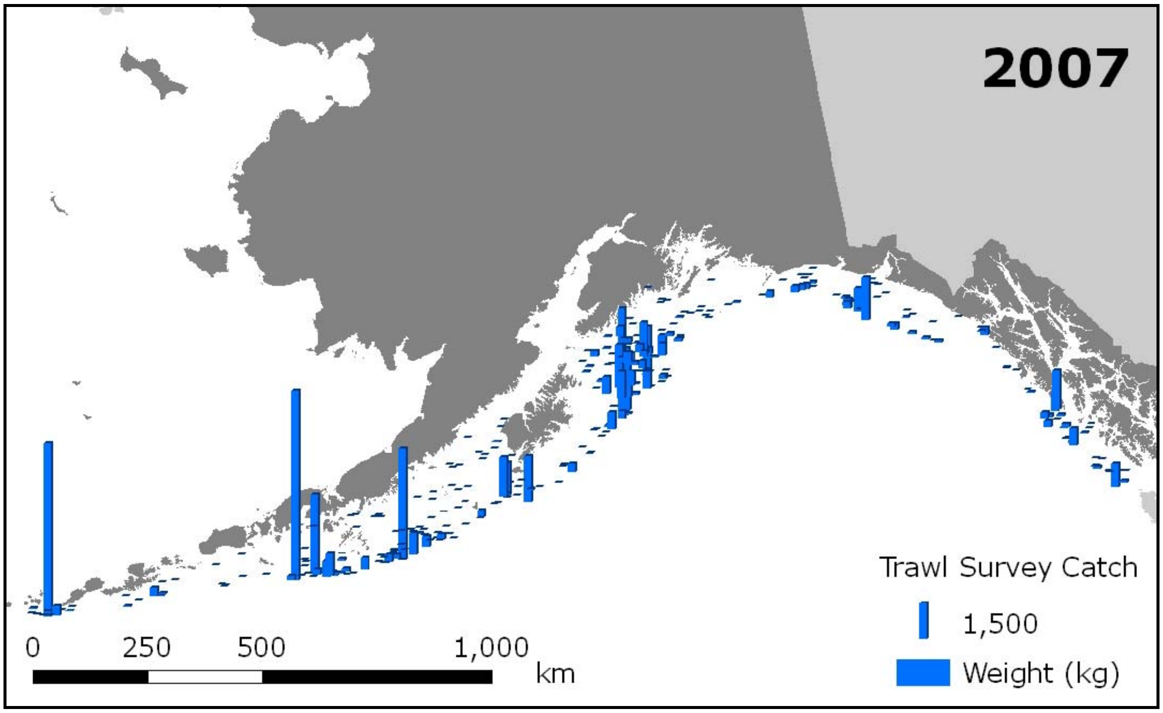


Figure 9-5a. Distribution of Gulf of Alaska Pacific ocean perch catches in the 1999 Gulf of Alaska groundfish survey.



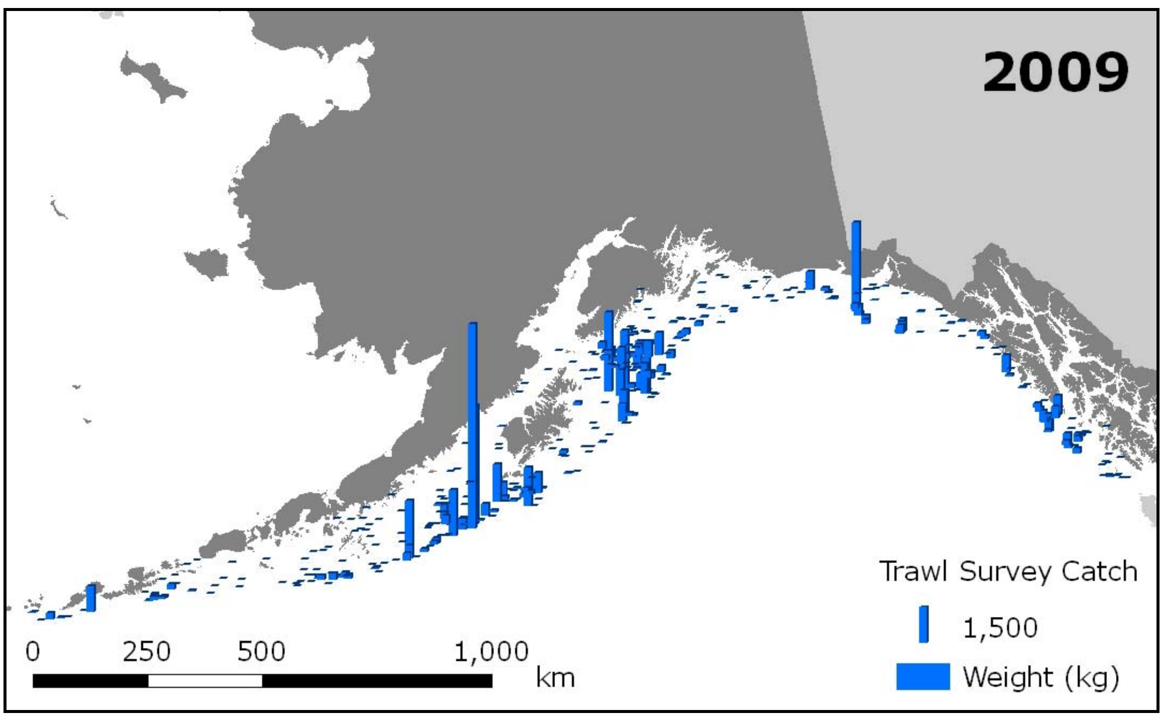


Figure 9-5b. Distribution of Gulf of Alaska Pacific ocean perch catches in the 2007 and 2009 Gulf of Alaska groundfish surveys.

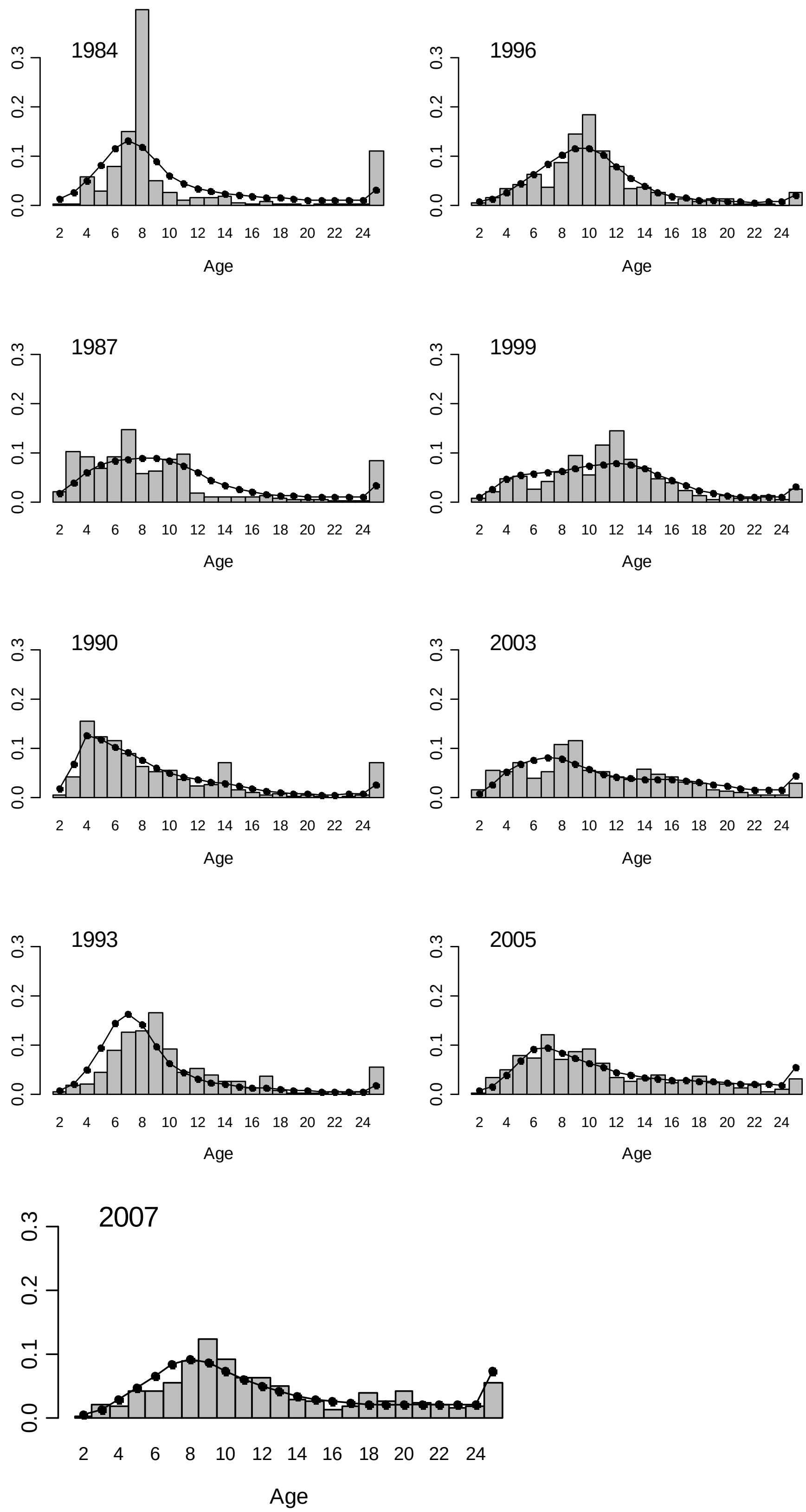


Figure 9-6. Groundfish survey age compositions for GOA Pacific ocean perch. Observed = bars, predicted from author recommended model = line with circles.

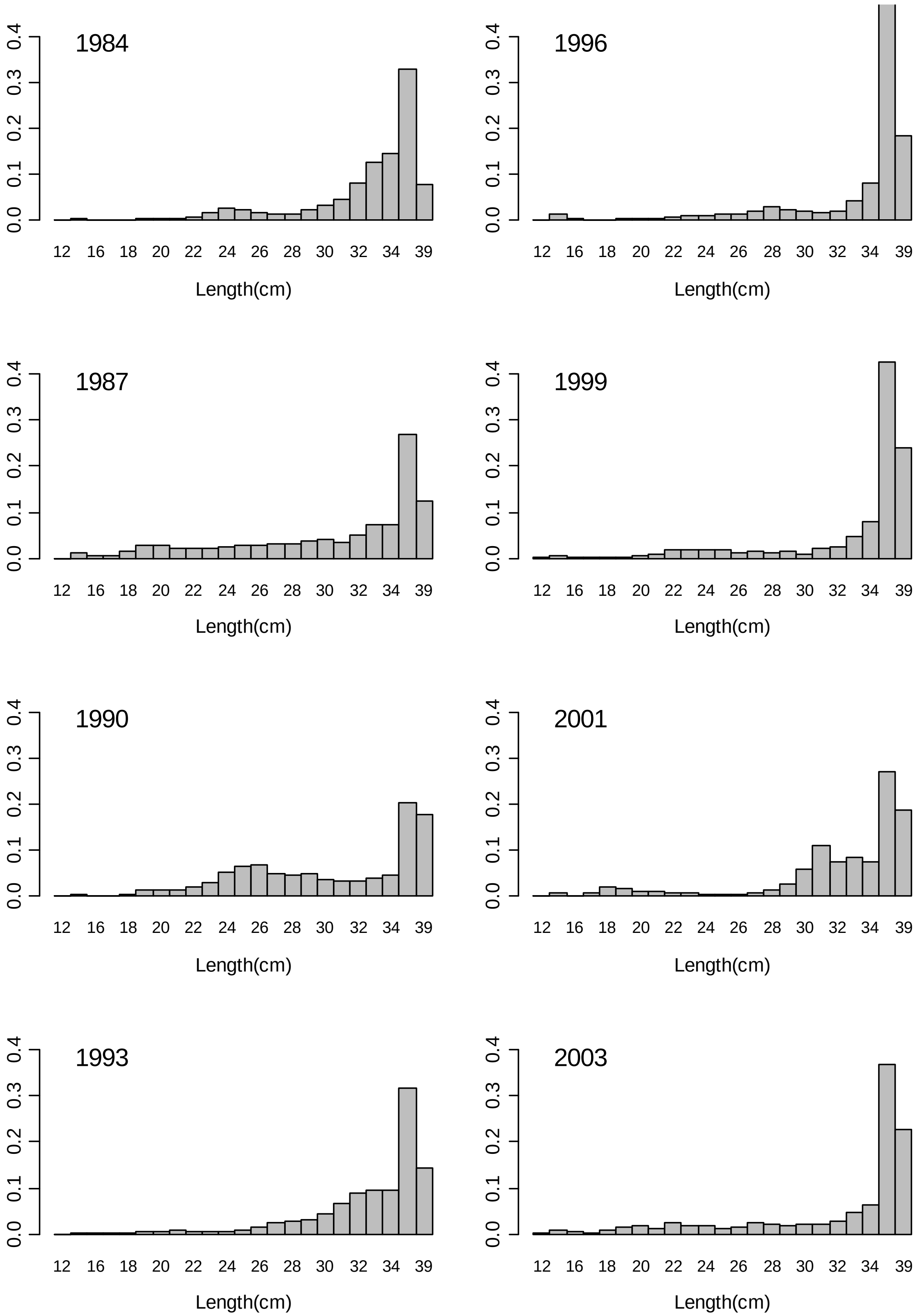


Figure 9-7. Groundfish survey length compositions for GOA Pacific ocean perch. Observed = bars, predicted from author recommended model = line with circles. Survey size distributions not used in Pacific ocean perch model because survey ages are available for these years.

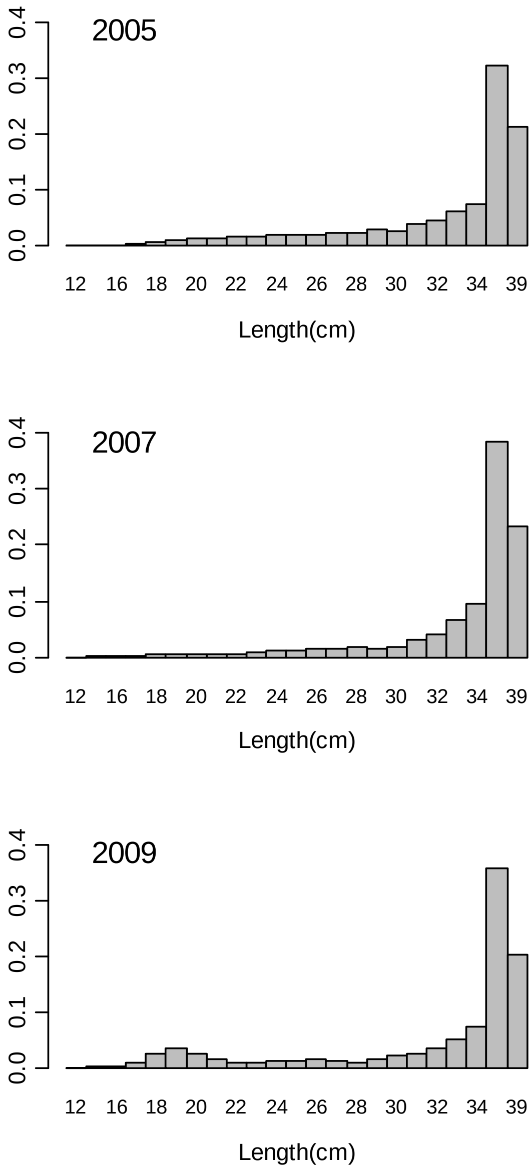


Figure 9-7 (continued). Groundfish survey length compositions for GOA Pacific ocean perch. Observed = bars, predicted from author recommended model = line with circles. Survey size distributions not used in Pacific ocean perch model because survey ages are available for these years.

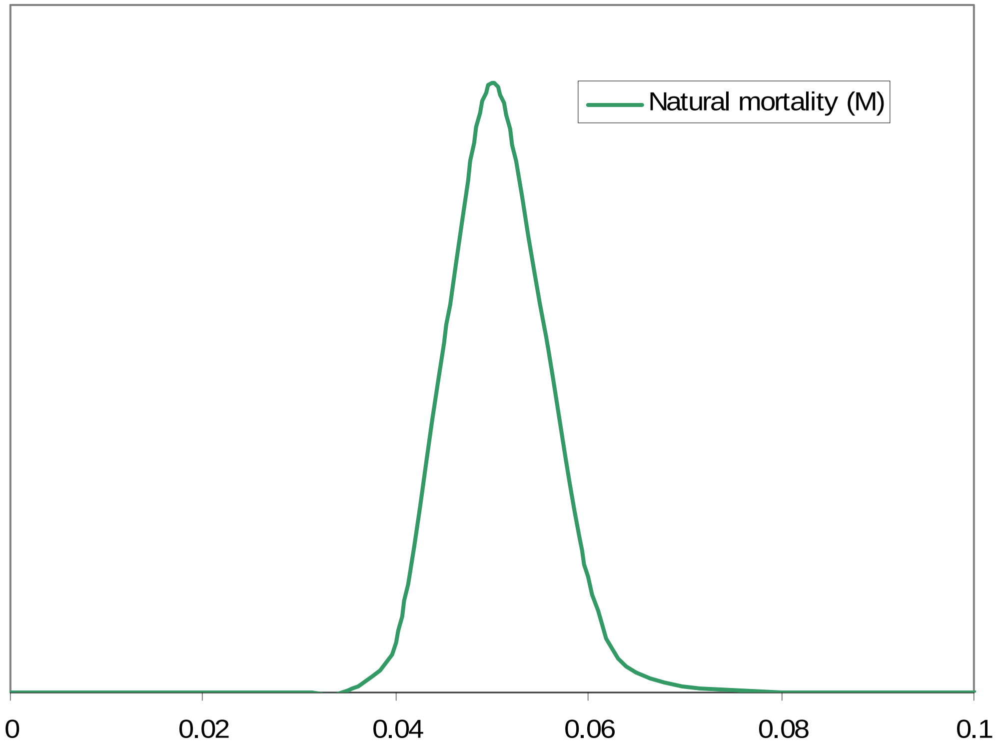


Figure 9-8. Prior distribution for natural mortality (*M*) of Pacific ocean perch, μ=0.05, CV=10%.

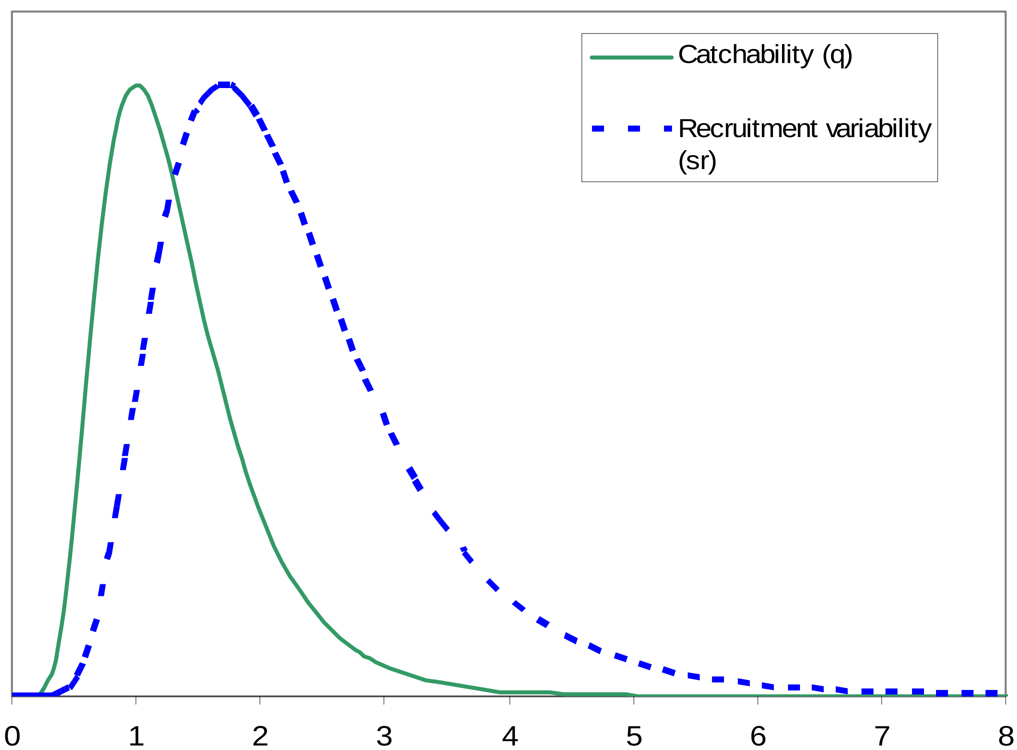


Figure 9-9. Prior distributions for catchability (*q*, μ=1, CV=45%) and recruitment variability (σ_r, μ=1.7, CV=45%) of Pacific ocean perch.

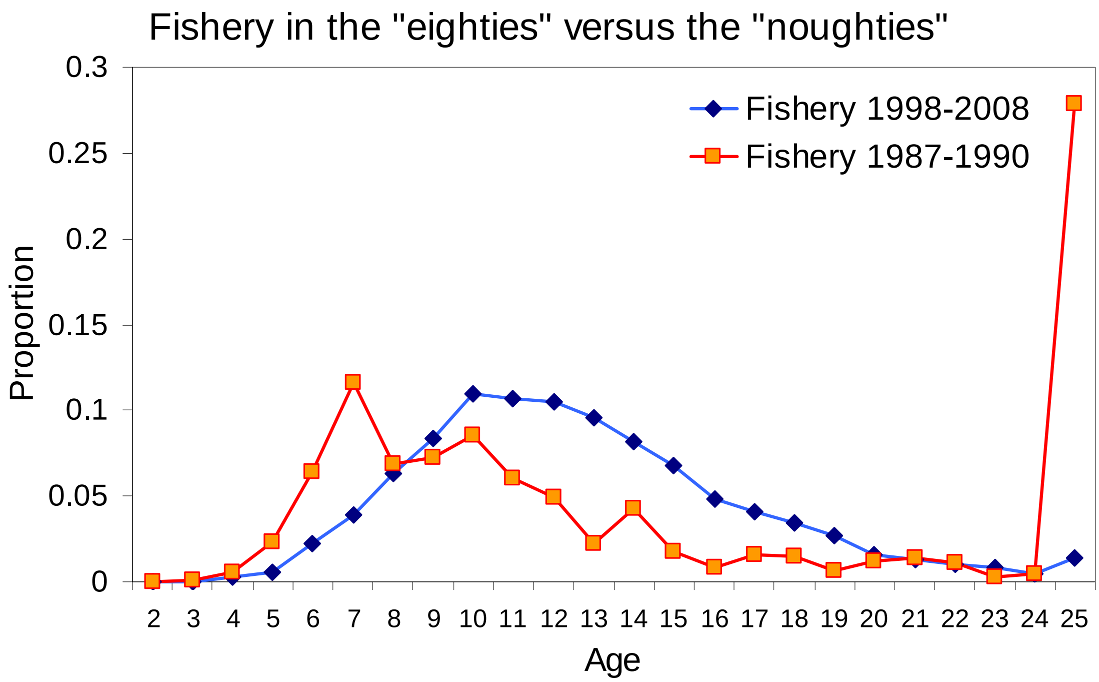


Figure 9-10. Average fishery age compositions for two time periods for Gulf of Alaska Pacific ocean perch.

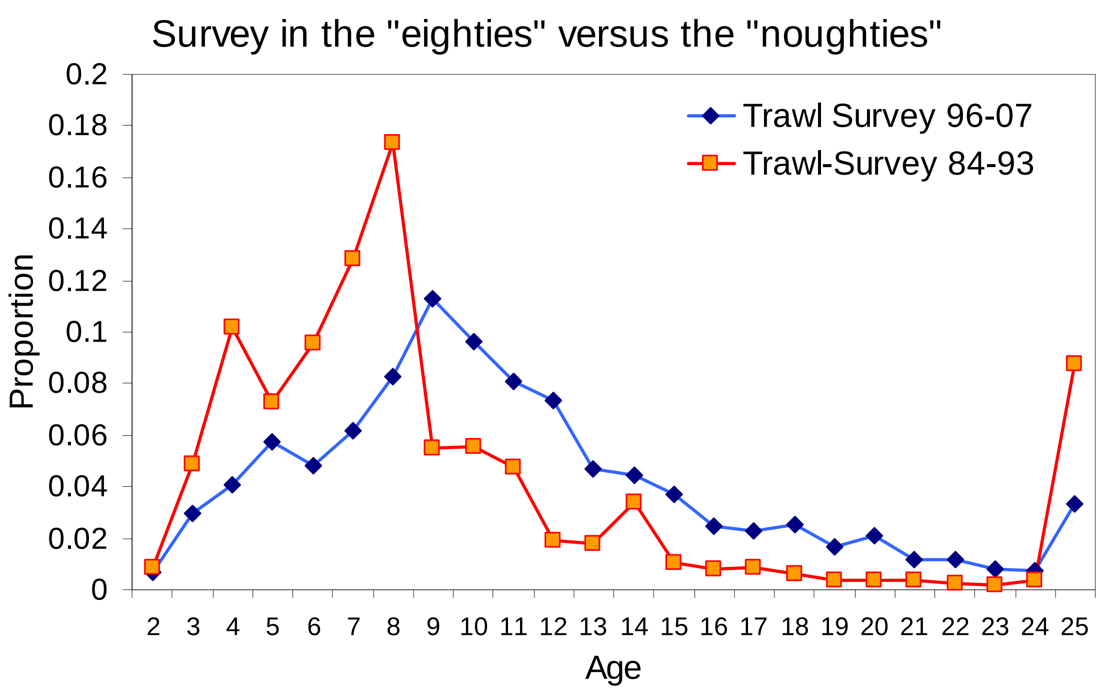


Figure 9-11. Average survey age compositions for two time periods for Gulf of Alaska Pacific ocean perch.

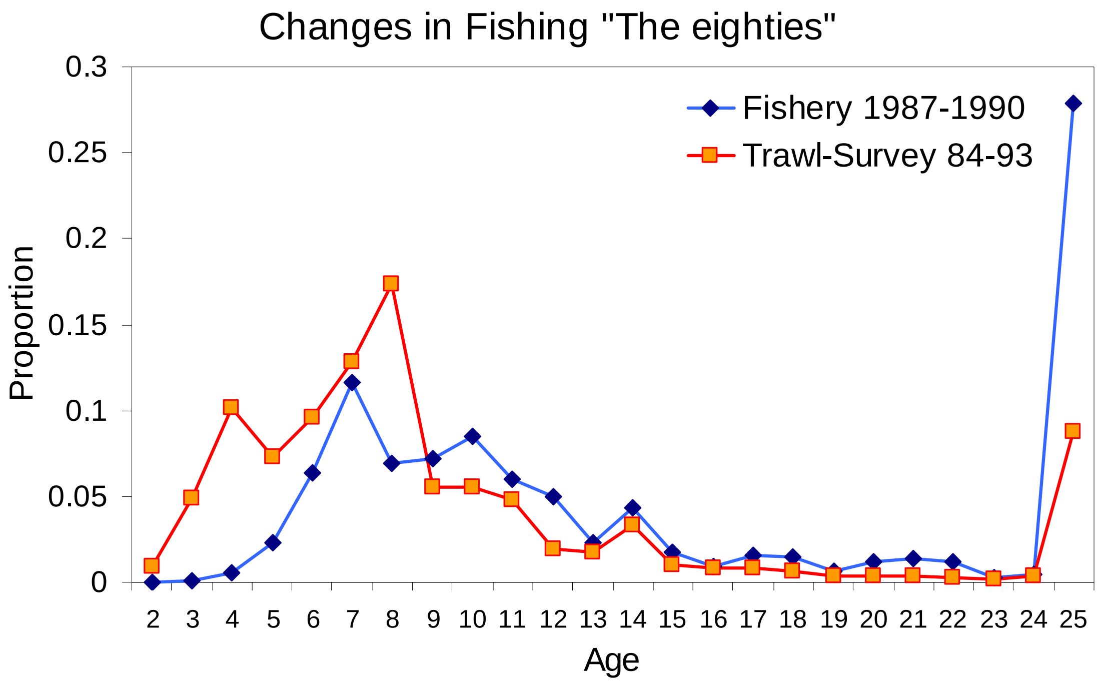


Figure 9-12. Average survey and fishery age compositions for the "eighties" time block for Gulf of Alaska Pacific ocean perch.

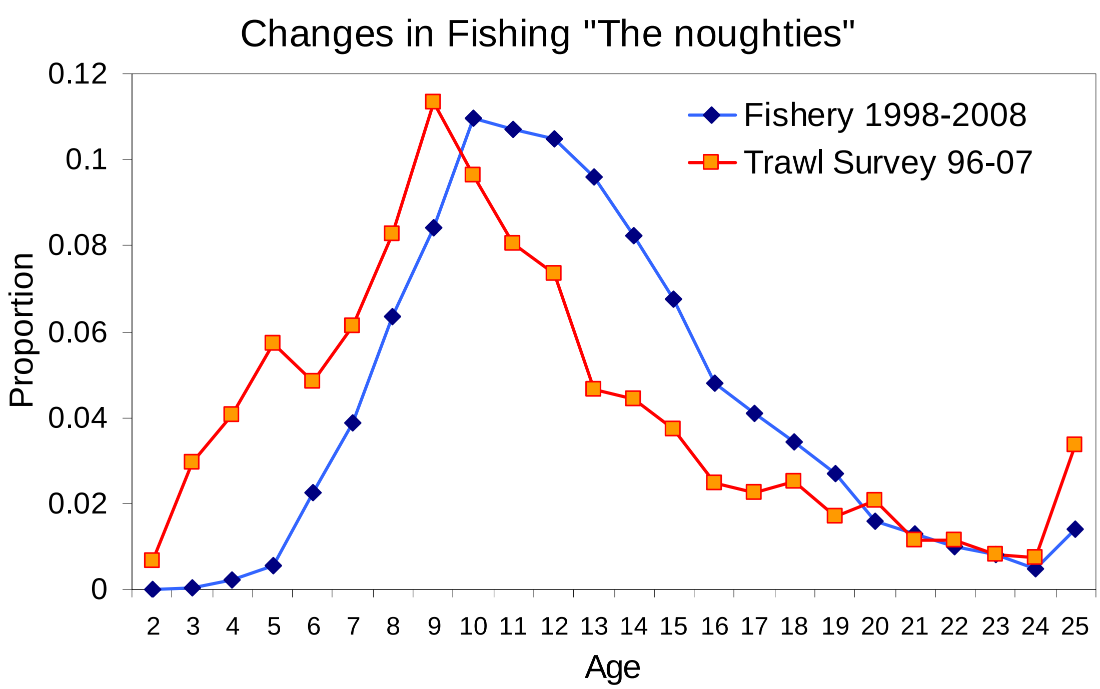


Figure 9-13. Average survey and fishery age compositions for the "noughties" time block for Gulf of Alaska Pacific ocean perch.

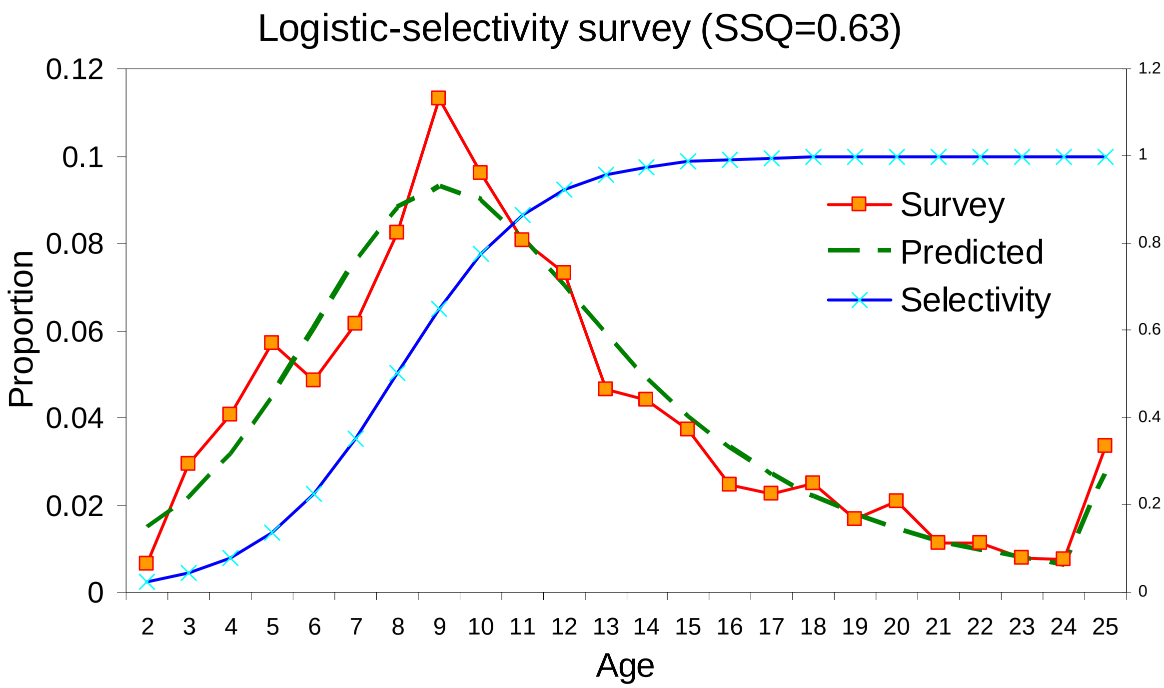


Figure 9-14. Logistic selectivity fit to average survey age composition 1996-2007. SSQ is relative fit to the gamma distribution in Figure 9-15.

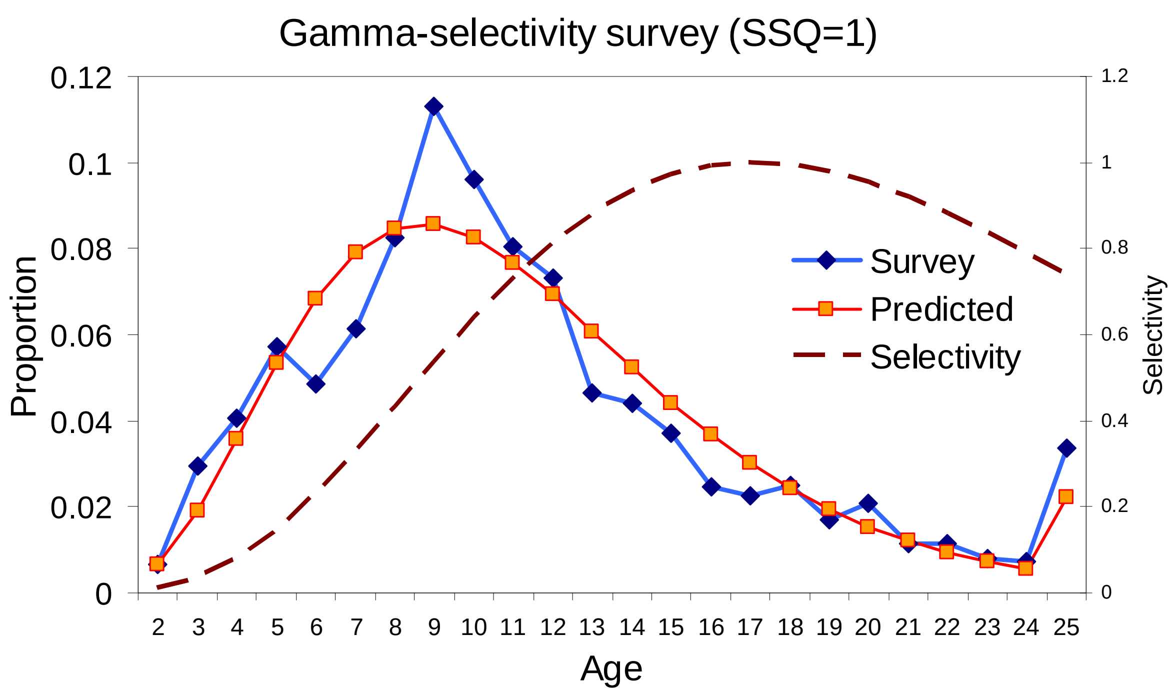


Figure 9-15. Gamma selectivity fit to average survey age composition 1996-2007. SSQ is the fit relative to the logistic curve in Figure 9-14.

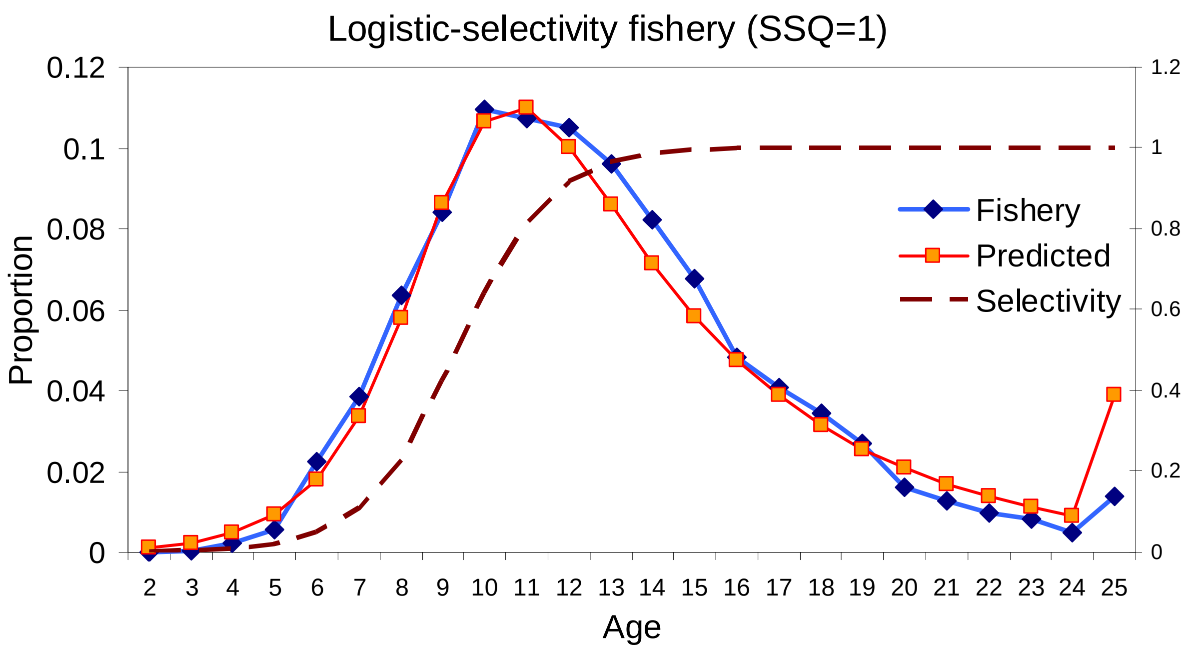


Figure 9-16. Logistic selectivity fit to average fishery age composition 1996-2008. SSQ is the fit relative to the gamma curve in Figure 9-17.

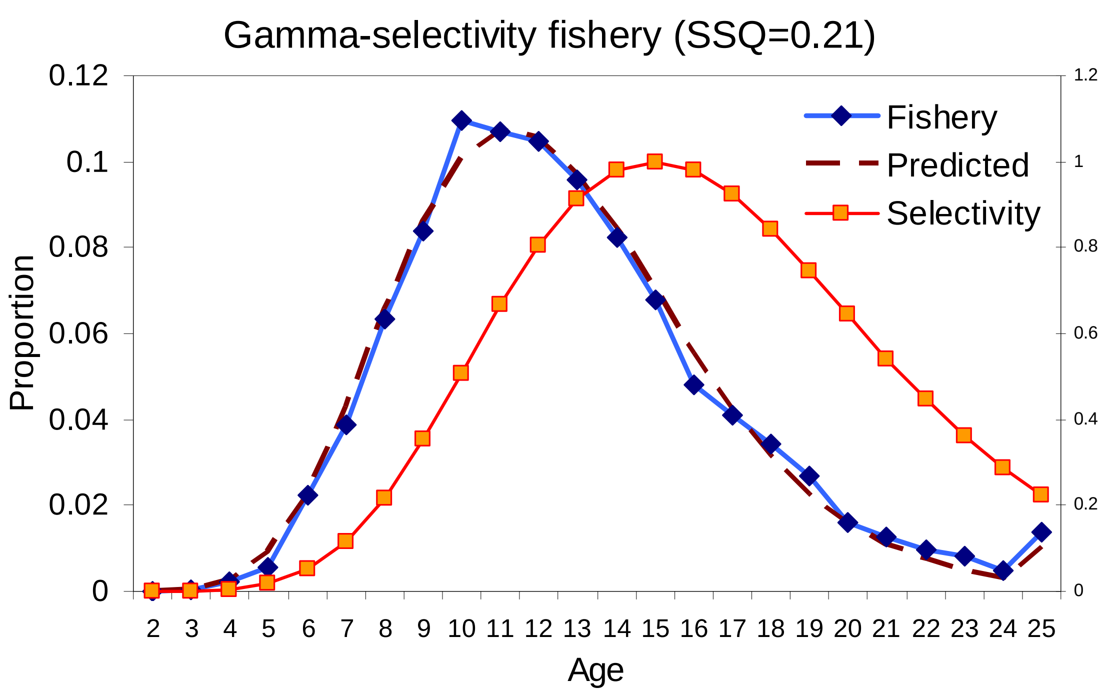


Figure 9-17. Gamma selectivity fit to average fishery age composition 1996-2008. SSQ is the fit relative to the logistic curve in Figure 9-16.

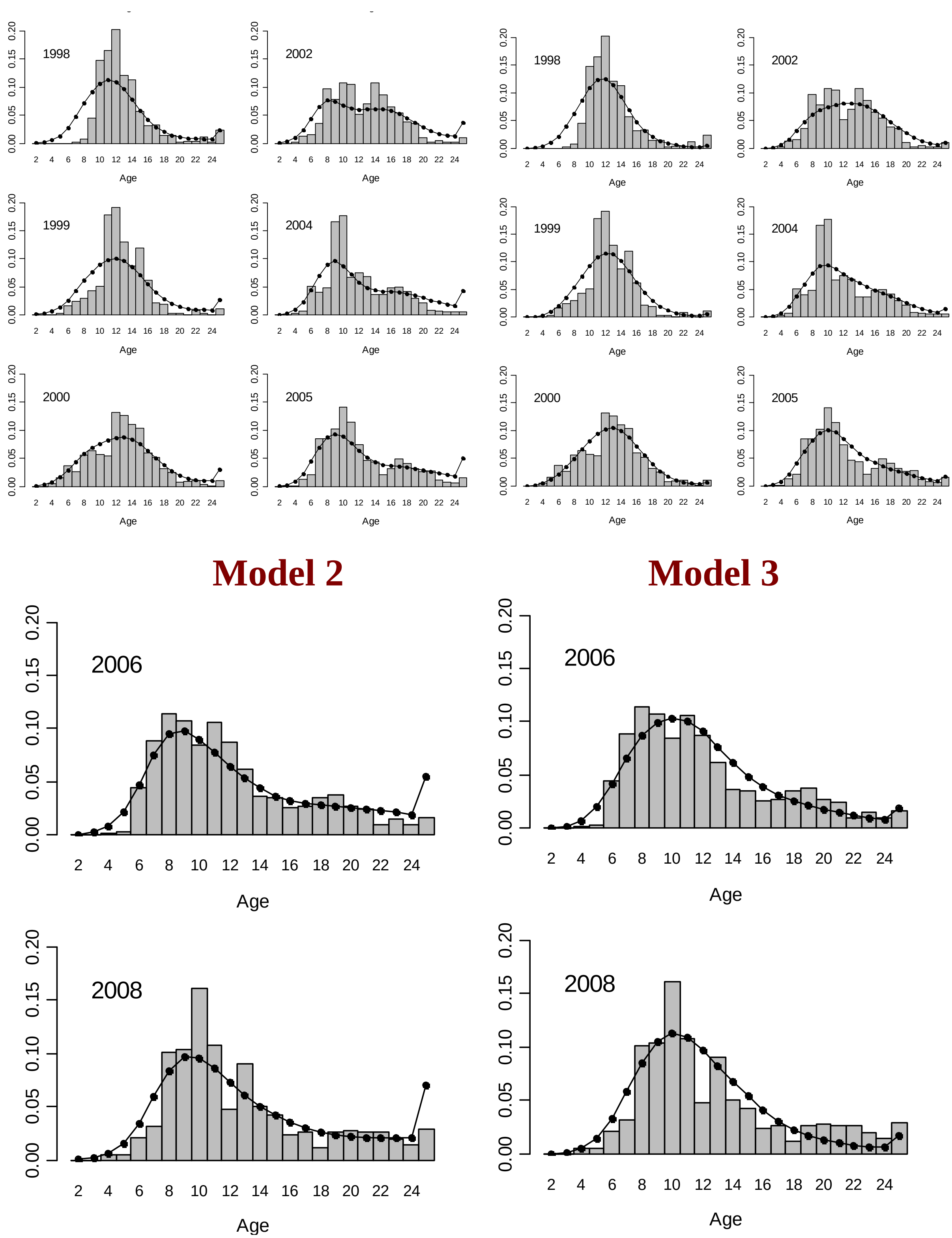


Figure 9-18. Comparison of the fits to fishery ages for Models 2 and 3. Note the far superior fit to the pooled age in Model 3.

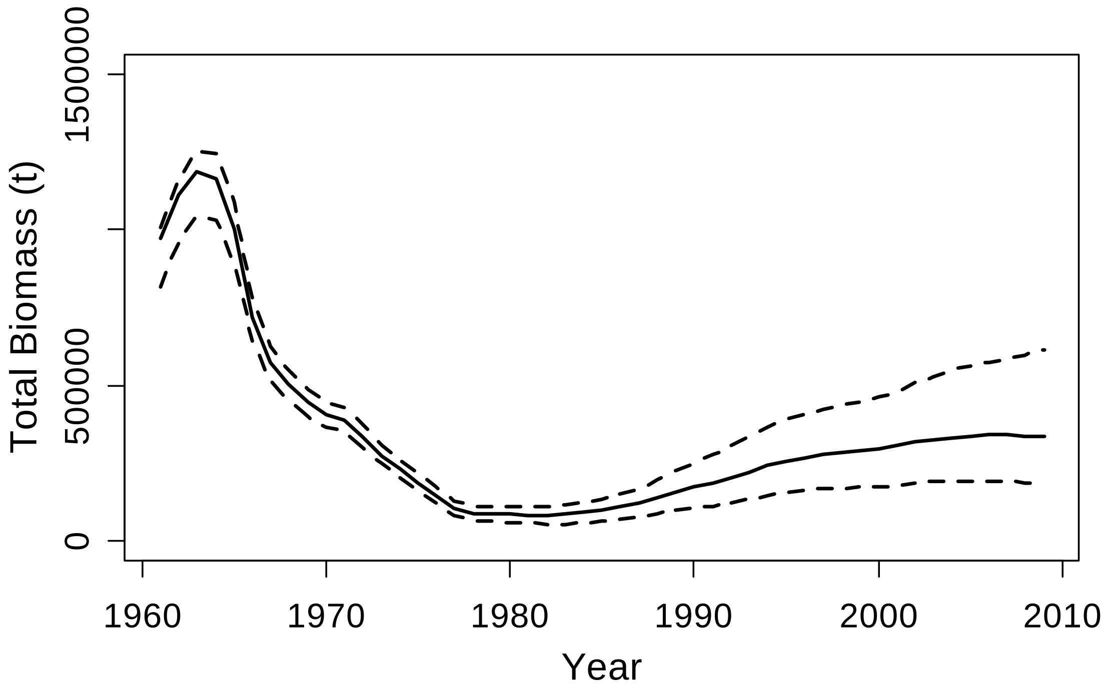


Figure 9-19. Model estimated total biomass (solid line) with 95% credible intervals determined by MCMC (dashed line) for Gulf of Alaska Pacific ocean perch.

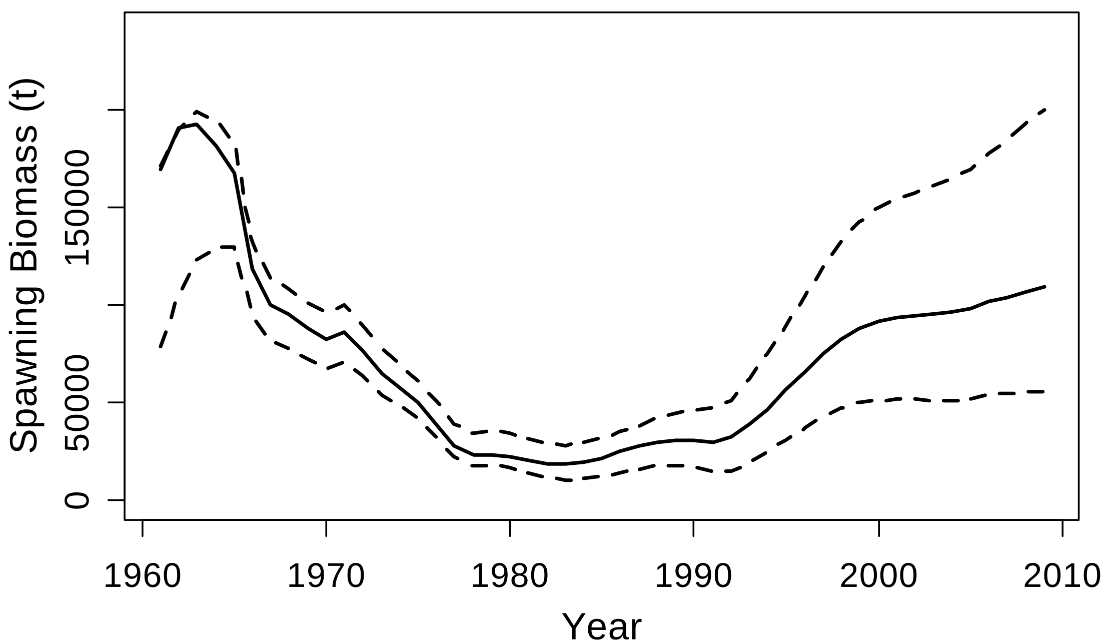


Figure 9-20. Model estimated spawning biomass (solid line) with 95% credible intervals determined by MCMC (dashed line) for Gulf of Alaska Pacific ocean perch.

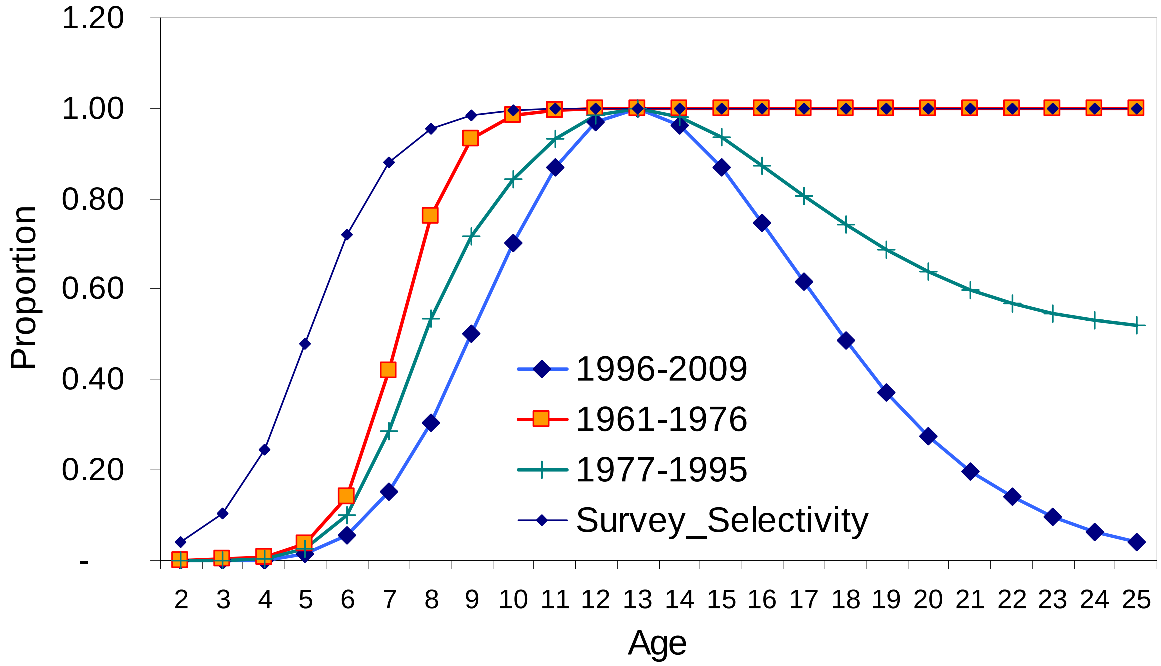


Figure 9-21. Estimated selectivities for the fishery for three periods and groundfish survey for Gulf of Alaska Pacific ocean perch.

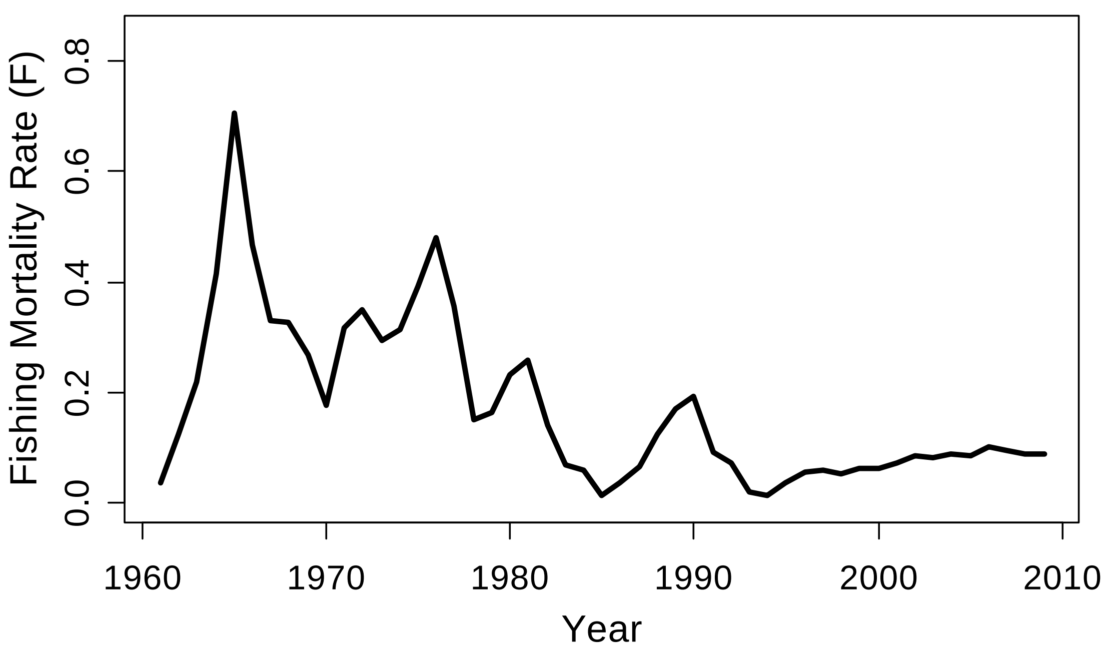


Figure 9-22. Estimated fully selected fishing mortality over time for GOA Pacific ocean perch.

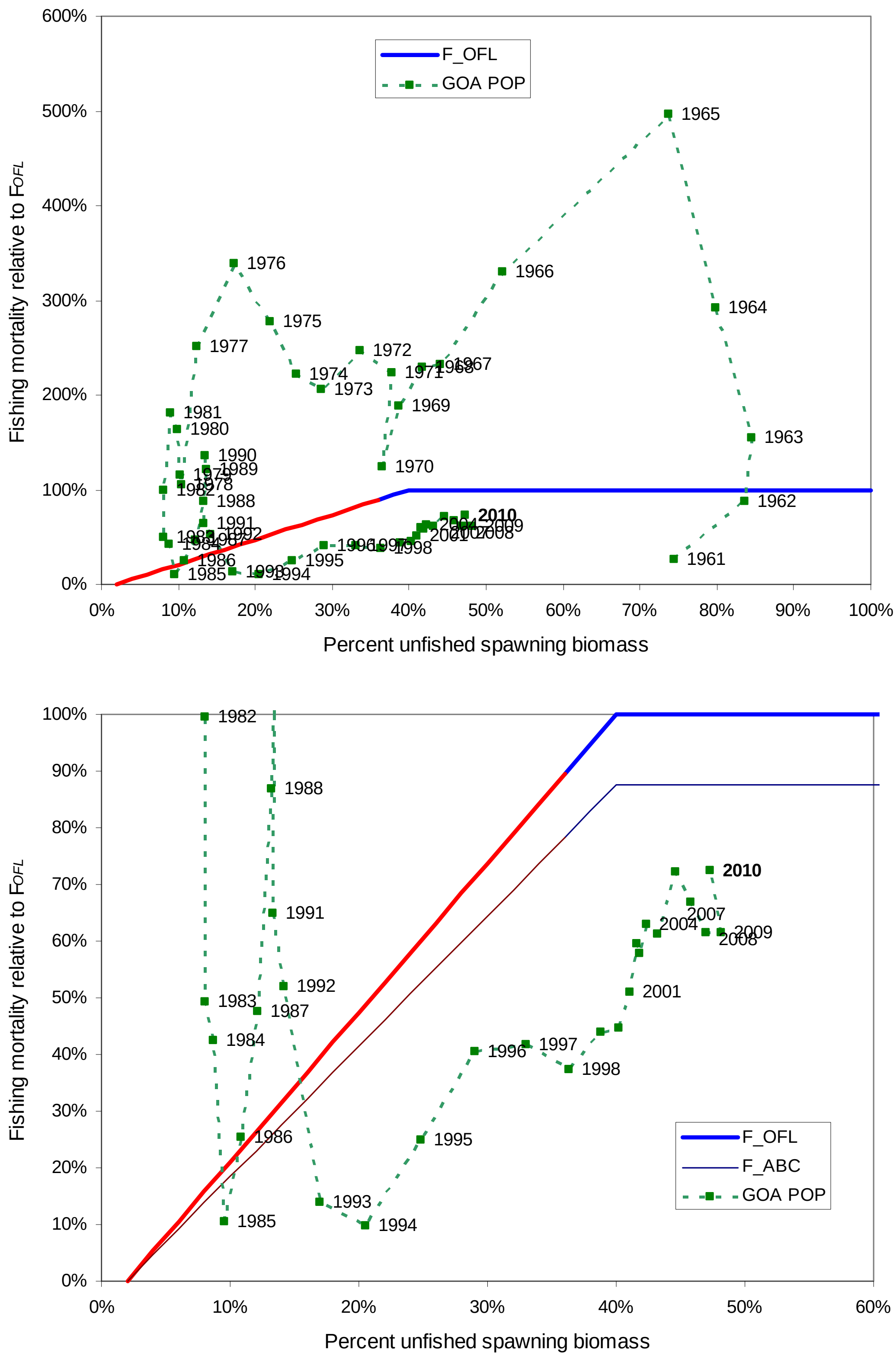


Figure 9-23 Time series of Pacific ocean perch estimated spawning biomass relative to the target level $B_{40\%}$ level and fishing mortality relative to F_{OFL} for author recommended model. Top shows whole time series. Bottom shows close up on more recent management path.

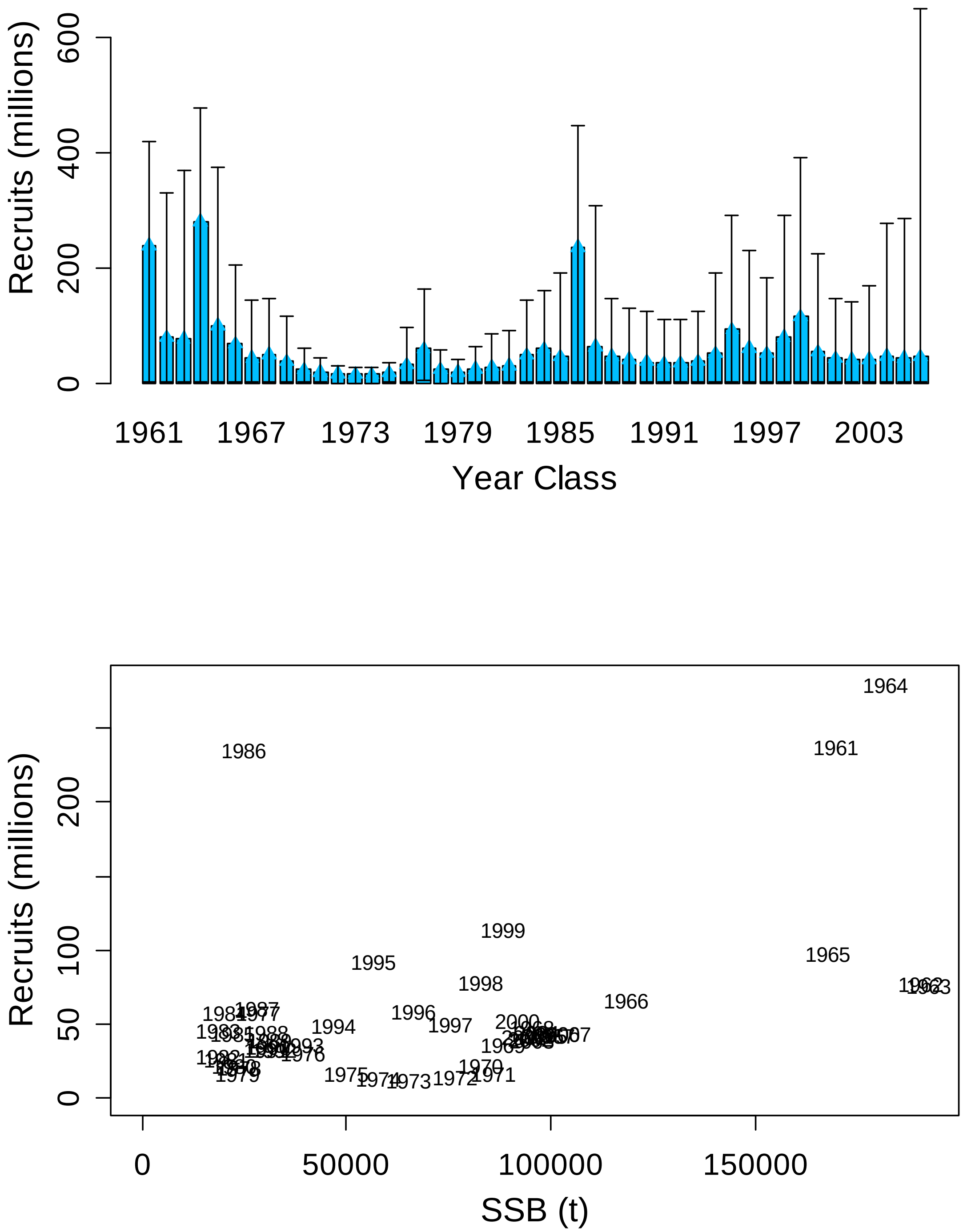


Figure 9-24. Estimated recruitment of Gulf of Alaska Pacific ocean perch (age 2) by year class with 95% credible intervals derived from MCMC (top). Estimate recruits per spawning stock biomass (bottom).

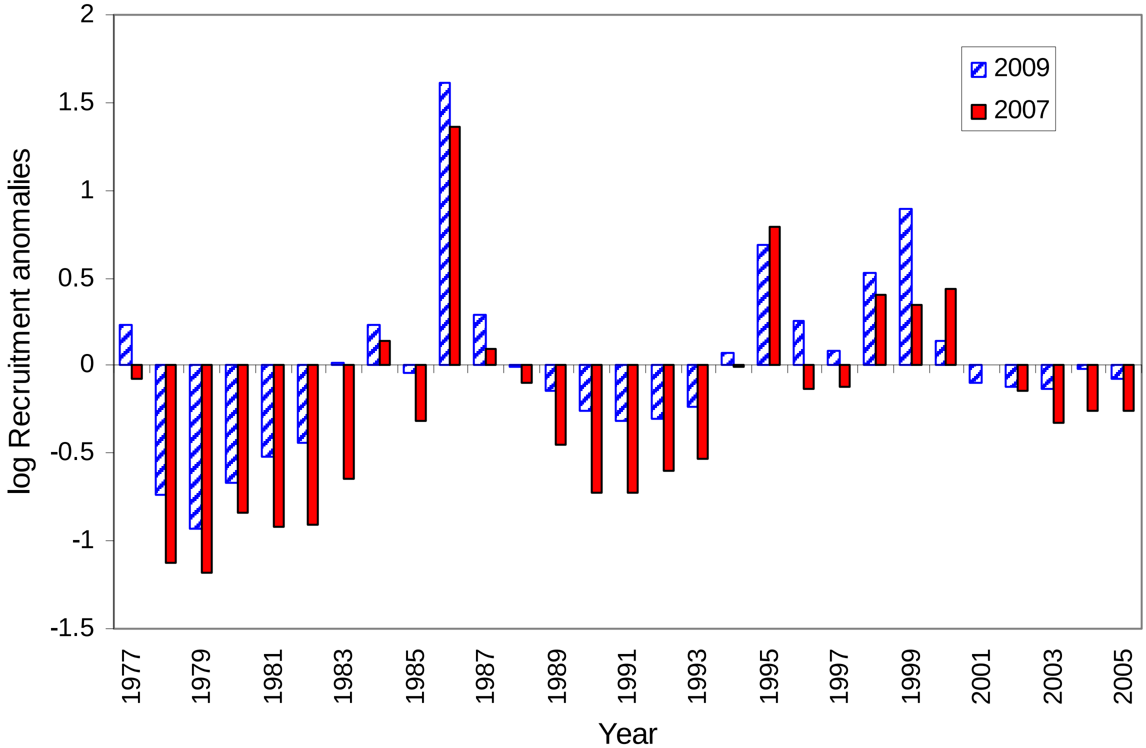


Figure 9-25. Recruitment deviations from average on the log-scale comparing last cycle's model to current for Gulf of Alaska Pacific ocean perch.

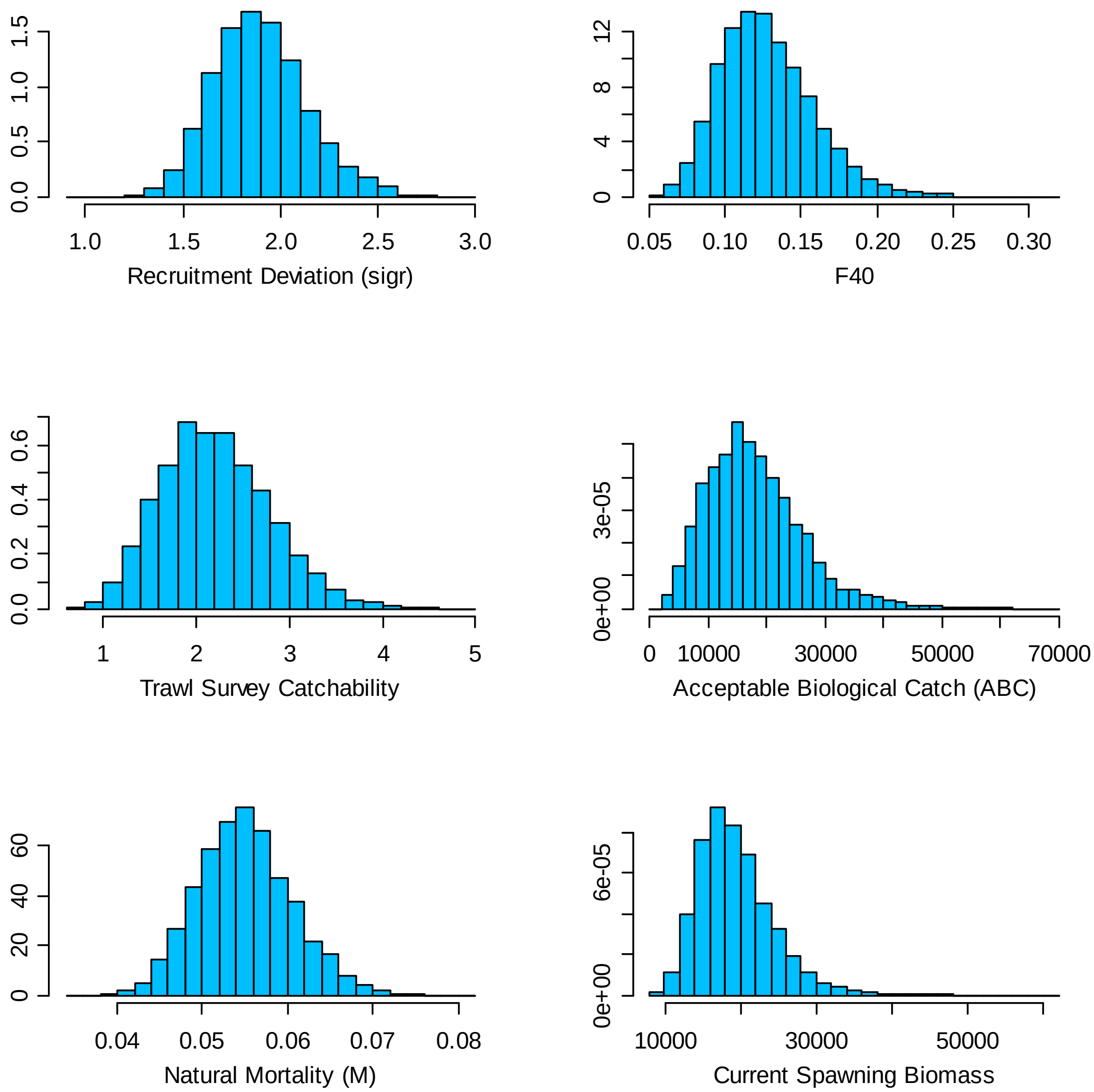


Figure 9-26. Histograms of estimated posterior distributions of key parameters derived from MCMC for Gulf of Alaska Pacific ocean perch.

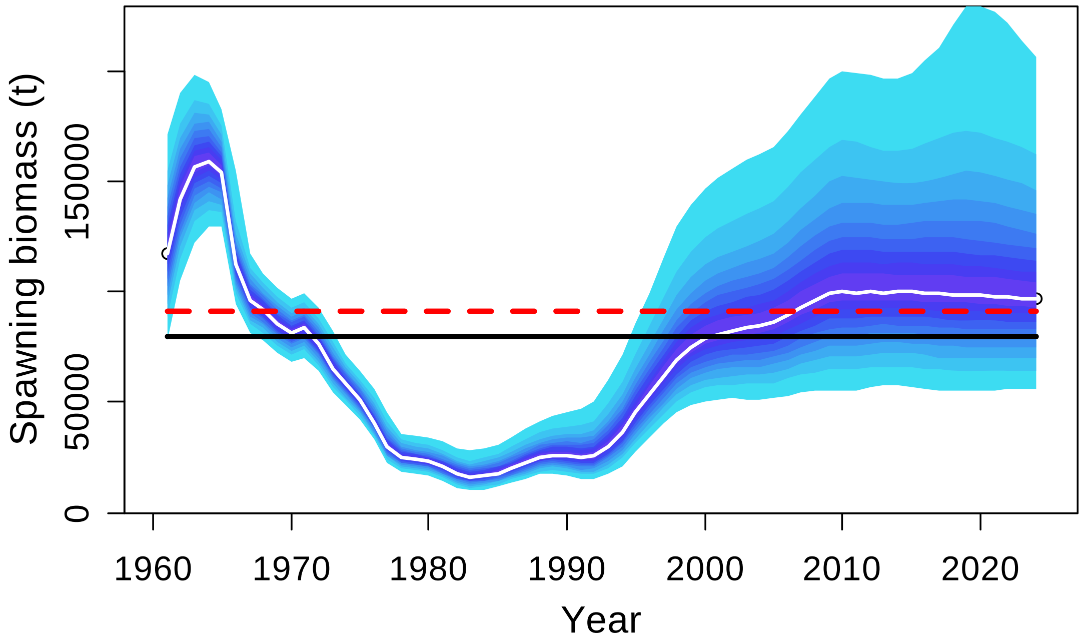


Figure 9-27. Bayesian credible intervals for entire spawning stock biomass series including projections through 2023. Red dashed line is $B_{40\%}$ and black solid line is $B_{35\%}$ based on recruitments from 1979-2007. The white line is the median of MCMC simulations. Each shade is 5% of the posterior distribution.

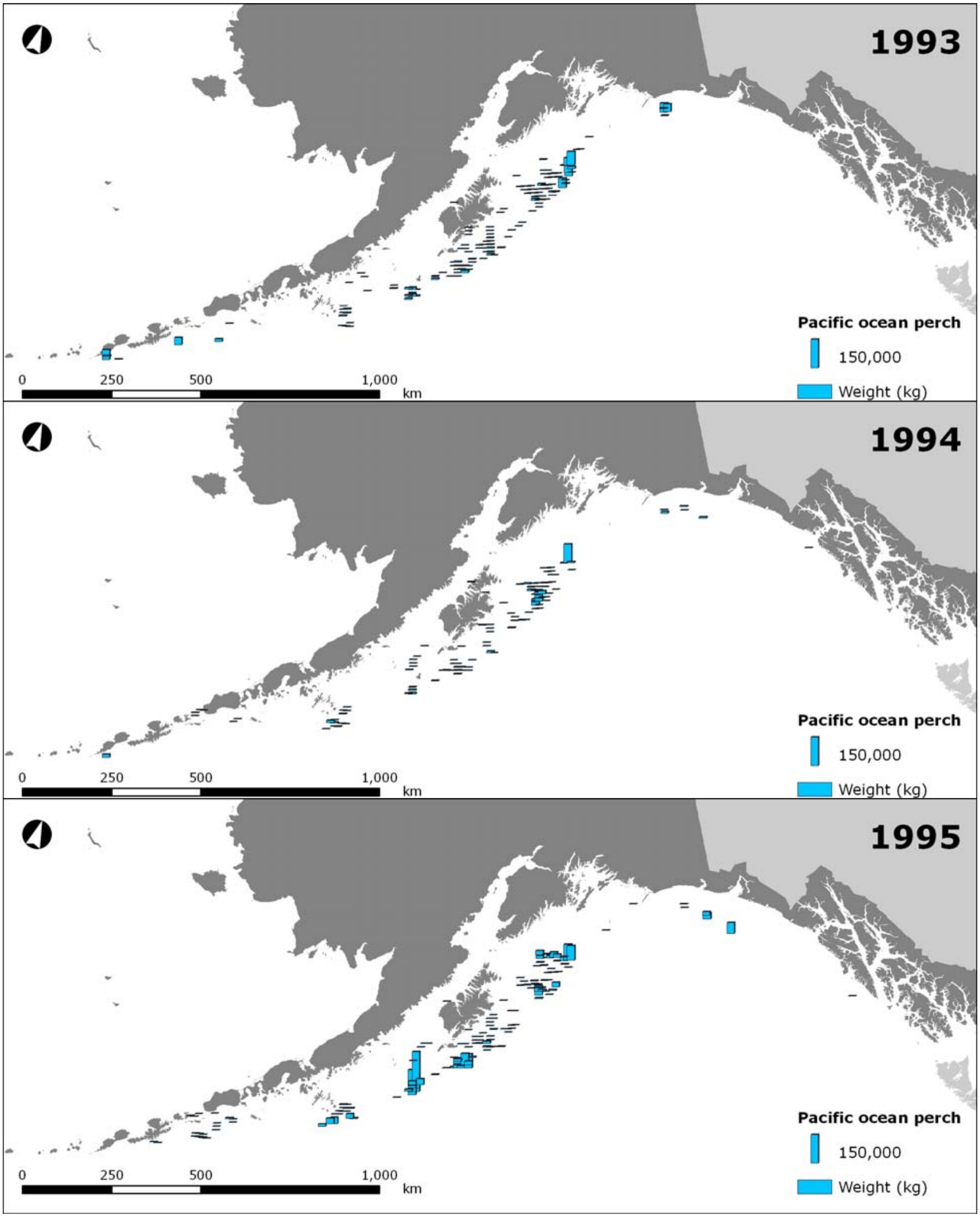


Figure 9-28. Maps of fishery catch based on observer data by 100 km^2 blocks for Pacific ocean perch from 1993-1995.

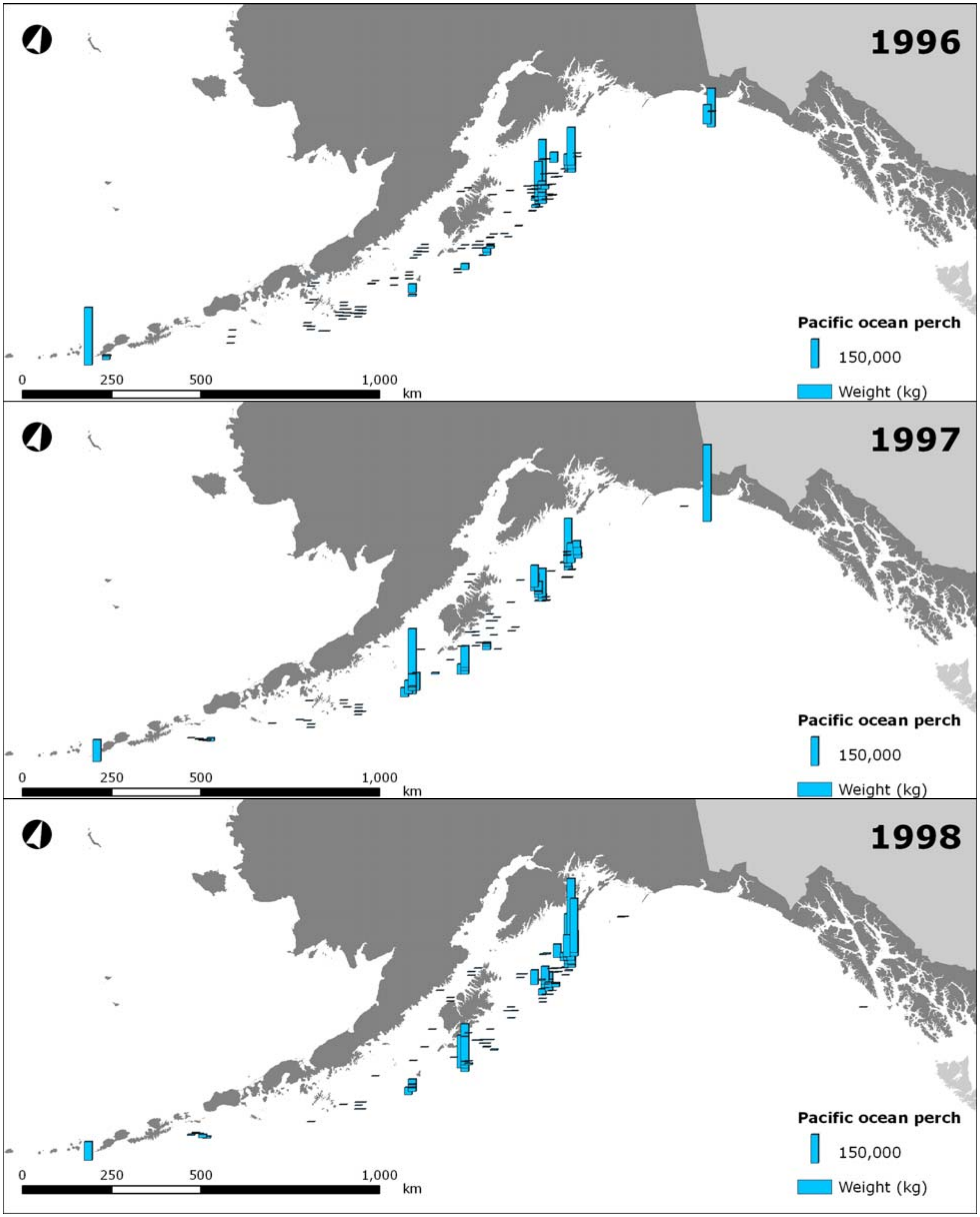


Figure 9-29. Maps of fishery catch based on observer data by 100 km^2 blocks for Pacific ocean perch from 1996-1998.

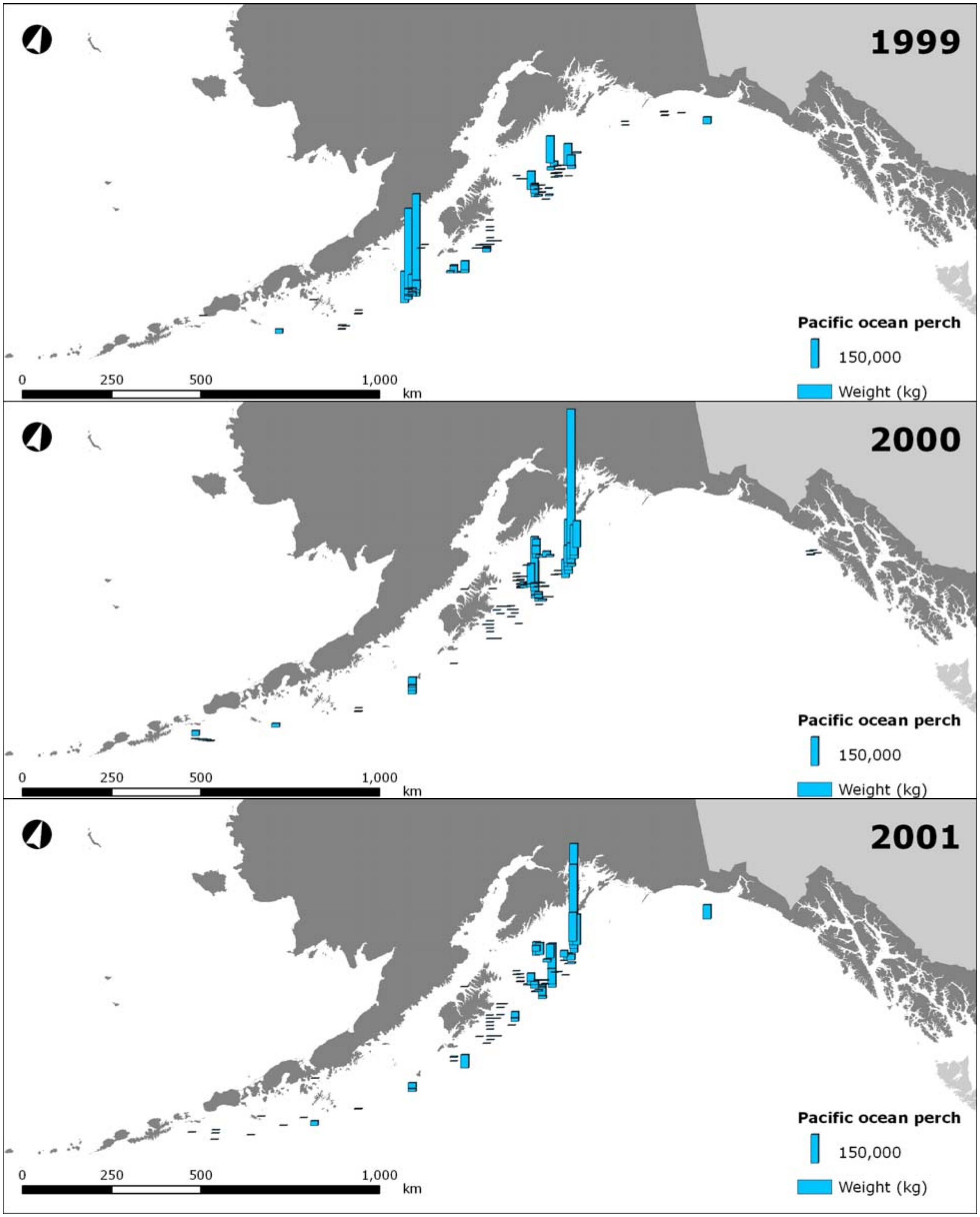


Figure 9-30. Maps of fishery catch based on observer data by 100 km^2 blocks for Pacific ocean perch from 1999-2001.

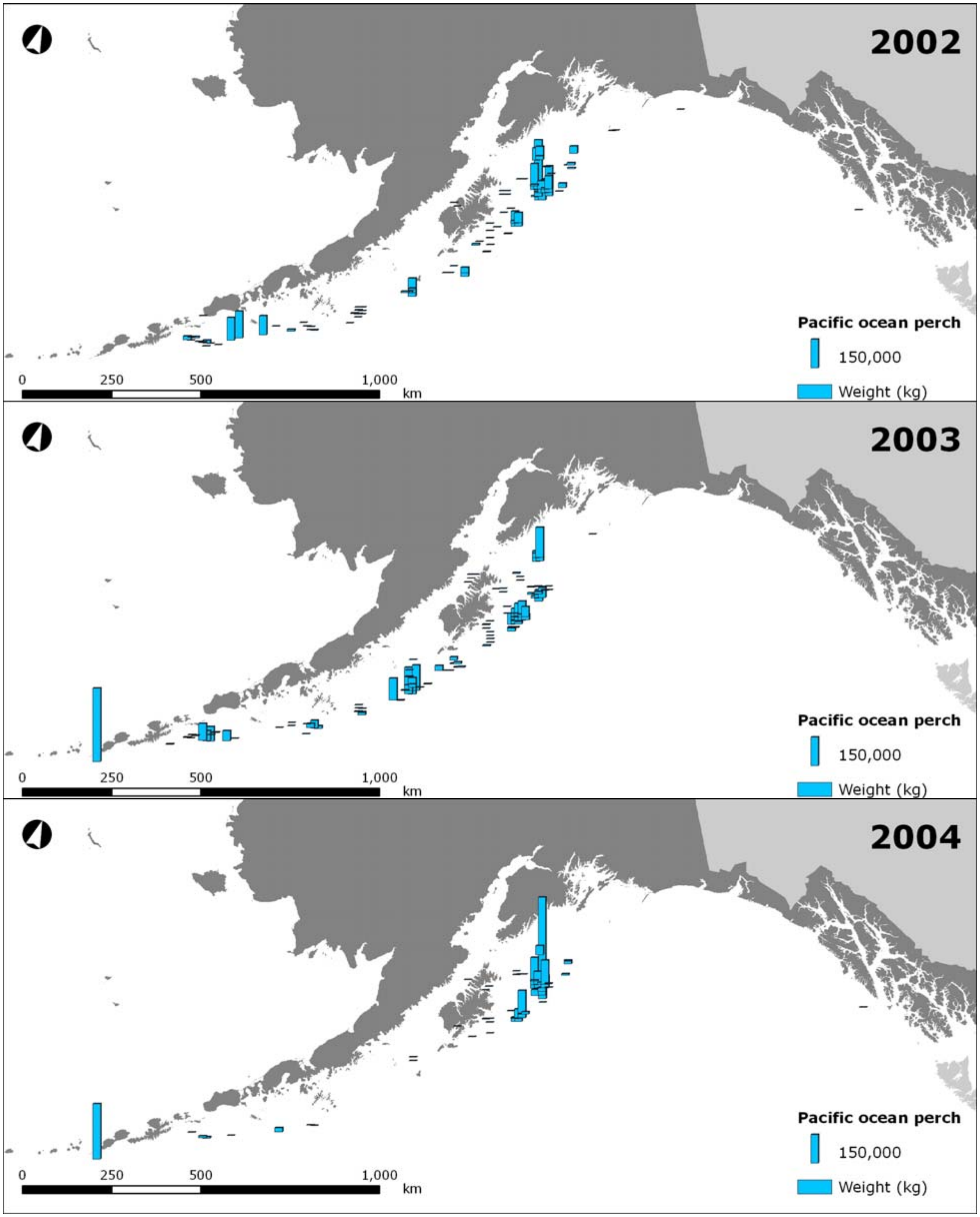


Figure 9-31. Maps of fishery catch based on observer data by 100 km^2 blocks for Pacific ocean perch from 2002-2004.

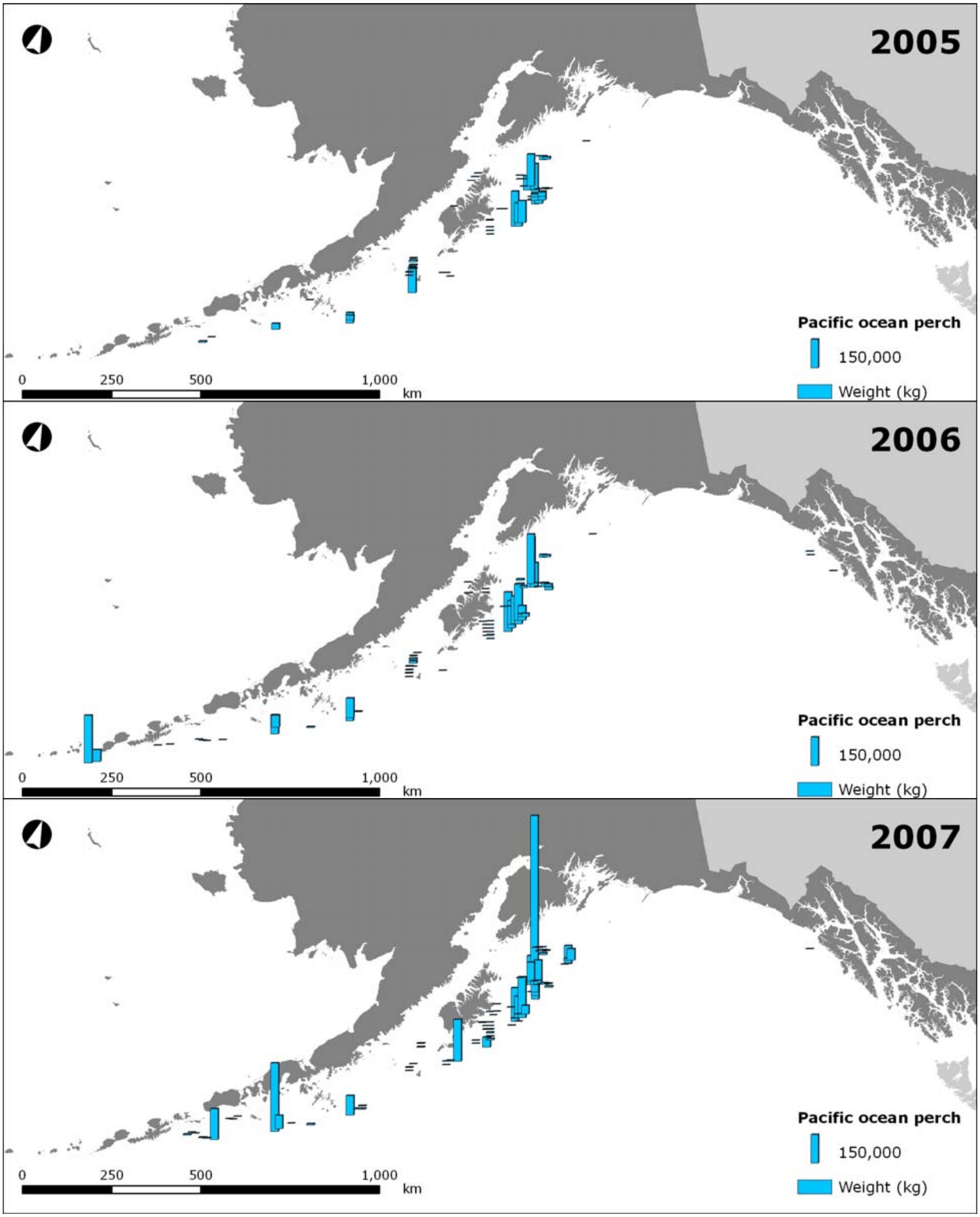


Figure 9-32. Maps of fishery catch based on observer data by 100 km^2 blocks for Pacific ocean perch from 2005-2007.

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