9. Gulf of Alaska Pacific ocean perch

by

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Executive Summary

We continue to use a modified version of the generic rockfish model template developed in a workshop held at the Auke Bay Laboratory in February 2001. The model was constructed with AD Model Builder software. The model is a separable age-structured model with allowance for size composition data that are adaptable to several rockfish species. The data sets used included total catch biomass for 1961-2007, size compositions from the fishery for 1963-77 and 1991-97, survey age compositions for 1984, 1987, 1990, 1993, 1996, 1999, 2003, and 2005, fishery age composition for 1990, 1998-2002, and 2004- 2006, and survey biomass estimates for 1984, 1987, 1990, 1993, 1996, 1999, 2001 2003, 2005 and 2007. New data in the model include the 2005 survey age composition, 2006 fishery age composition, 2006 and estimated 2007 fishery catch and 2007 survey biomass estimates. The 2005 and 2007 survey biomass estimates are relatively large and have greater precision than the estimates in the early 1990s, and have begun to influence the model estimates upward. The projected ABC for 2008 is 14,999 t which is 3% higher than last year's ABC of 14,636 t. The corresponding reference values for Pacific ocean perch are summarized below. The stock is not overfished, nor is it approaching overfishing status.

Summary	**2008**	2009*
Tier	3a	3a
Total Biomass (Age 2+)	317,511	317,615
Female spawning biomass (t)	90,898	94,149
$B_{0\%}$ (t)	222,987	-
$B_{40\%}$ (t)	89,195	-
$B_{35\%}$ (t)	78,045	-
M	0.060	0.060
$F_{40\%}$	0.061	0.061
F_{ABC} (maximum allowable)	0.061	0.061
ABC (t; maximum allowable)	**14,999**	15,072
F_{OFL}	0.073	0.073
OFL (t)	17,807	17,893

*** Projected ABCs and OFLs for 2009 are derived using an expected catch value of 13,500 t for 2008 based on recent ratios of catch to ABC.** The projection results of this method are listed under Author's F in Table 9-10. This was done in response to management requests to obtain a more accurate one-year projection.

Summary of Major Changes to Model, Data and Results

The assessment methodology is the same and only a new catch, survey biomass estimate, and one year of survey and fishery age data were added. The results of the model yielded a slightly higher ABC, primarily because of another large survey biomass estimate. Female spawning biomass remains above $B_{40\%}$, with projected biomass stable.

Responses to SSC Comments for Pacific ocean perch

There were no SSC comments in 2005 or 2006 for Pacific ocean perch.

Responses to SSC comments in general.

"Phase-plane diagram. The SSC appreciates the addition of phase-plane diagrams to most stock assessments and reiterates interest in these diagrams for all stock assessments in which it is possible to

do so using standardized axes (i.e., X axis of B/B_{target}; and Y axis of F_{catch}/F_{OFL}), formatted relative to harvest control rules. In addition, values from the most recent year should be provided annually by the assessment authors to the plan team. The plan teams are requested to provide a figure summarizing all stocks in the introduction section of the SAFE documents. This figure would show the most recent year's status for all stocks possible by plotting realized F relative to F_{OFL} versus biomass relative to target biomass. One point for each stock from the most recent year plotted relative to the harvest control rules would provide a snapshot of relative stock management performance for the group (see figure below as a potential example). One option could be to plot the last two years values as a line with an arrow head to show the change in each stock's performance from the prior year."

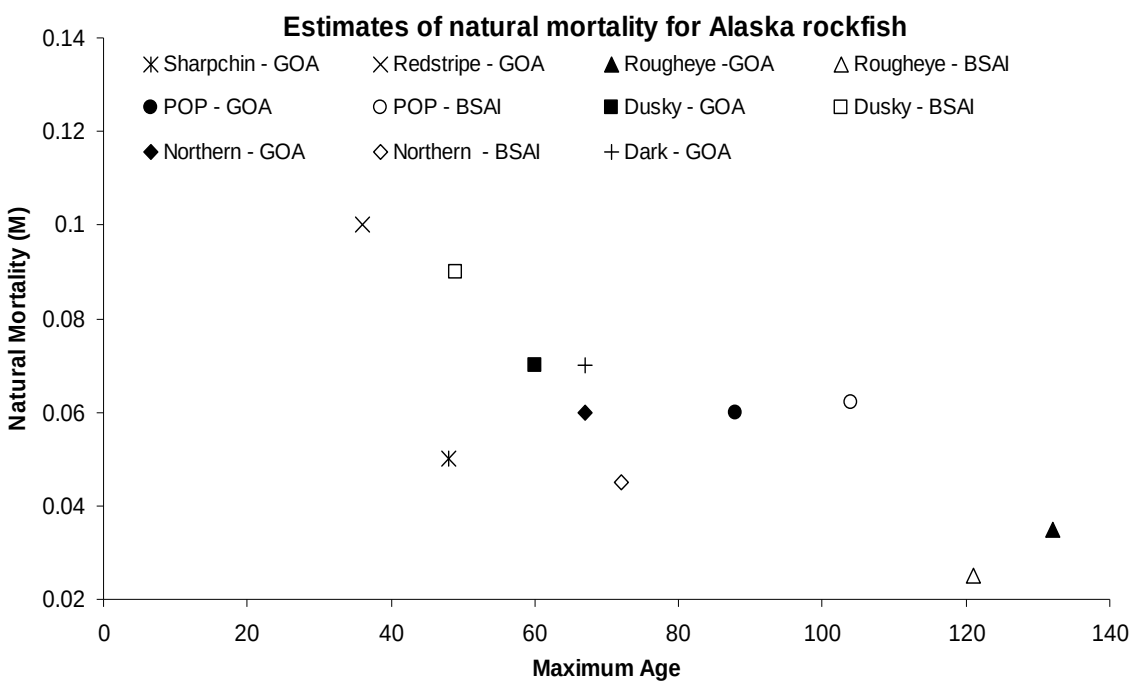
In this assessment we moved from the Goodman et al. (2002) style management path plot to one that incorporates the harvest control rules in Figure 9-14.

Responses to CIE Review

In June, 2006, the Alaska Fisheries Science Center (AFSC) arranged for a review of Alaska rockfish harvest strategies and stock assessment methods by the Center of Independent Experts (CIE). Three reviewers participated and each produced a separate review without collaboration with other panelists or NMFS staff. The reviews can be found at: http://www.afsc.noaa.gov/refm/docs/2006/rf_CIE.pdf. The AFSC prepared a draft response to the review and presented several discussion points at the February, 2007 SSC meeting. The draft response can be found at: ftp://ftp.afsc.noaa.gov/afsc/public/rockfish/RWG response to CIE review.pdf. The draft response focused on specific comments and recommendations regarding rockfish assessments in Alaska. Comments that pertained to Pacific ocean perch include:

"Estimation of M is problematic, whether it is via a maximum age assumption, an early catch-curve, or is estimated within a stock assessment model. How ever it is done, the objective should be to attain a "best" estimate of M – not a conservative estimate of M."

A description of methods available for estimating M is provided in the draft response to the CIE. Estimates of natural mortality currently in use for Alaska rockfish stock assessments have been derived from a variety of different literature references and vary among species and between areas.



The natural mortality value used for Pacific ocean perch in this assessment is estimated in the model to be 0.06. This estimate is derived using an informative prior with a mean of 0.05 and a CV of 10%. The estimated value parallels the estimated value in the BSAI POP assessment. An overview of the methodology and justification for using this value of M is provided in the ***Model Structure*** section of this document. The authors will monitor new research regarding maximum age of rockfish species and alternative methods for estimating natural mortality. We will also continue to experiment with model derived estimates of natural mortality as more data become available for use in the model.

"Trawl survey indices take no account of the proportion of untrawlable ground in each stratum (a particular problem for the GOA survey)."

A center-wide initiative is underway to estimate the effect of untrawlable areas on groundfish stock assessments. Retrospective studies of untrawlable stations during past surveys, development of split-beam acoustic methods to estimate untrawlable areas, analysis of existing echosounder data, and submersible video, and alternative methods to trawl surveys that will allow estimation of fish abundance in untrawlable areas, are all being investigated to address the problem.

"Develop informative priors for the trawl q's. Changes in gear setup and operation (e.g., length of trawl, standardization of methods) should be considered for each time series. More than one q will probably be needed for each time series."

Several simulations were presented in the draft response to the CIE which addressed how well standard stock assessment models estimate catchability under different scenarios. Another simulation was presented which modeled the trawl survey sampling and estimation procedures under a variety of situations. The question of trawl survey catchability is an important component to rockfish assessments and will likely be an ongoing research effort at the AFSC. Pacific ocean perch has had several studies specifically address catchability and estimated it to be near 2. We will develop a more formal prior using these studies and the results of the center-wide initiative on trawlable/untrawlable ground. As suggested by the CIE we show graphical representations of our assumed priors.

The CIE also stated that the projection model should incorporate the full uncertainty of the stock assessment as opposed to only recruitment uncertainty at the end point of the model. We briefly show an alternate method of projection in ***Projections and Harvest Alternatives***.

Responses to internal review

Reviewer comments (paraphrased)

1) You might consider fixing sigma-r to match closely the estimated recruitment variability rather than using a relatively high prior mean.

It is a priority for the Gulf of Alaska rockfish assessment authors to come up with a standardized procedure to either determine a value to fix sigma-r by species or a way to formulate an appropriate prior for estimating the value, if sufficient age data exist to do so.

2) You might consider using the 2007 survey size compositions in the model because the age composition are not available

We believe that while it would provide more current information to include the latest survey size compositions, the Pacific ocean perch model does not use survey size compositions in the model at this time. This is because we have survey age compositions that are derived from those same compositions. We could add the new size composition where we do not yet have the survey ages, but that would involve adding data in one year and removing them in the following assessment, which is likely not good for model stability.

3) One graph that would really help would be a scatterplot of recruits against SSB, labeled by year class. Just looking at the time series of recruits doesn't give you information on the stock size these recruits came from.

A graph of spawner-recruits was added as the bottom panel of Figure 9-15.

4) I think there is the potential for bias when we treat the survey specimen data as random samples from the population when, in fact, they are collected with a size-stratified sampling program. My thinking now is that the best way to handle this is to run the raw data through the age-length key to get an unbiased estimate of size at age (with variance), then fit the VB curve to these estimates.

We agree with the reviewer, and this is something we need to examine for all our Gulf of Alaska rockfish assessments because each species' growth has been estimated treating the length-stratified estimates as if they were randomly collected. The effect is likely small in slow-growing species like rockfish, but nevertheless should not be ignored.

5) Why do you not project with recruitments to 2007?

Because of uncertainty in very recent recruitment estimates, we lag two years behind model estimates in our projection. This is an effort to prevent retrospective trends in the projection caused by recent recruitment estimates changing as new data are added.

Summaries for Plan Team

Species	Year	Biomass[1]	OFL	ABC	TAC	Catch
Pacific ocean perch	2006	312,968	16,927	14,261	14,261	13,590
	2007	315,521	17,157	14,636	14,635	12,410
	2008	317,511	17,807	14,999		
	2009	317,615	17,893	15,072		

[1]Total biomass from the age-structured model

Stock/		2007				2008		2009	
Assemblage	Area	OFL	ABC	TAC	Catch	OFL	ABC	OFL	ABC
Pacific ocean perch	W	4,976	4,244	4,244	4,380	4,376	3,686	4,397	3,704
	C	8,922	7,612	7,612	6,788	9,717	8,185	9,764	8,225
	WYAK		1,140	1,140	1,242		1,100		1,105
	SEO		1,640	1,640	0		2,028		2,038
	E	3,260	2,781	2,780		3,714	3,128	3,732	3,143
	Total	17,157	14,636	14,635	12,410	17,807	14,999	17,893	15,072

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 2001). 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). 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). It has been suggested that Pacific ocean perch and walleye pollock compete for the same euphausiid prey. 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, the fish is relatively fecund with number of eggs/female in Alaska ranging from 10,000-300,000, depending upon size of the fish (Leaman 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 length and larval survival (Waschak 2007[1]). However, younger maturing fish were not examined where much of the relationship was found in black rockfish

Evidence of stock structure

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, preliminary analysis using mitochondrial DNA techniques suggest that genetically distinct populations of Pacific ocean perch exist (A. J. Gharrett pers. commun., University of Alaska Fairbanks, October 2000). 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.

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

[1] Waschak, E. 2007. An analysis of larval survival rates and maternal parameters for the deepwater rockfish, Pacific ocean perch, *Sebastes alutus*, in the Gulf of Alaska. Poster. AFS National Meeting, San Francisco, CA, Sep. 2007.

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. As of, September 2007, 87% of the Central GOA had been taken, while 103% of the Western Gulf quota had been taken, indicating at least some spreading of the harvest over time in the Central GOA. The authors will pay close attention to the benefits and consequences of this action.

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 1960's. 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 1960's. Catches continued to decline in the 1970's, and by 1978 catches were only 8,000 t (Figure 9-1a). 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) reducing levels 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 is listed in Table 9-1a for the commercial fishery and in Table 9-1b for research cruises. 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 4 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. In the years 1999-2002, the amount caught in pelagic trawls has remained moderately high, with annual percentages of 17.6, 10.3, 11.7 and 11.0, respectively.

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 since 1998. Factory trawlers continue to take nearly all the catch in the Western and Eastern areas.

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 which receive exclusive harvest privileges for rockfish management groups. The primary rockfish management groups are northern rockfish, Pacific ocean perch, and pelagic shelf rockfish. Potential effects of this program on Pacific ocean perch include: 1) Extended fishing season lasting from May 1 – November 15, 2) changes in spatial distribution of fishing effort within the Central GOA, 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. Future analyses regarding the effect of the Pilot Project upon Pacific ocean perch will be possible as more data become available.

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, shortraker/rougheye rockfish, sablefish, 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). More recent data (Gaichas and Ackley estimates[2]) from 1997-2004 show that the largest bycatch groups in the combined rockfish trawl fishery are Pacific cod (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 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[2].

Discards

Gulfwide discard rates[2] (% discarded) for Pacific ocean perch in the commercial fishery for 1996-2007 are listed as follows:

Year	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
% Discard	17.2	14.5	14.0	13.8	11.3	8.6	7.2	15.1	7.4	5.6	8.2	6.0

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

Data

The following table summarizes the data used for this assessment:

The following table summarizes the data used for this assessment: Source	Data	Years
NMFS Groundfish survey	Survey biomass	1984-1999 (triennial), 2001-2007 (biennial)
	Age Composition	1984, 1987, 1990, 1993, 1996, 1999, 2003, 2005
U.S. trawl fisheries	Catch	1961-2007
	Age Composition	1990,1998-2002, 2004-2006
	Length Composition	1963-1977, 1991-1997

Fishery Data

Catch

Catches range from 2,500 t to 350,000 t from 1961 to 2007. Detailed catch information for Pacific ocean perch is listed in Table 9-1a 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 1994-2007. Table 9-3 summarizes age compositions from 1990, 1998-2002, and 2004-2006 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 fishery age data show high correlation when lagged, indicating ages and collections are consistent.

[2] 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.

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 2005 surveys are provided in Table 9-4.

Comparison of Trawl Surveys in 1984-2007

Gulfwide biomass estimates for Pacific ocean perch are shown in Table 9-4. Gulfwide biomass estimates for 2005 and 95% confidence intervals are also shown graphically in 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. Also, 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 2007 (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. 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).

Age Compositions

Ages were determined from the break-and-burn method (Chilton and Beamish 1982). The survey age compositions from 1984-2005 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 survey age compositions suggested that 1998 may have been a 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 90's, 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 fit in the stock assessment model. 2005-2007 size compositions return to the same patterns as the 1996-1999 surveys, where the biomass was mainly adults.

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 developed in a workshop held in February 2001 (Courtney et al. 2007). The generic rockfish model builds from the northern rockfish model (Courtney et al., 1999). Four changes were made to the northern rockfish model during construction of the generic rockfish model: 1) Fishery age compositions and associated likelihood components were added; 2) The spawner-recruit relationship was removed from the estimation of beginning biomass (B_0); 3) Survey catchability, q, was computed relative to survey selectivity standardized to a maximum of one (full selectivity), rather than to survey

selectivity standardized to an average of one (average selectivity); and 4) The penalties for deviations from reasonable fishing mortality parameter estimates were modified. These fishing mortality deviation and regularity penalties are part of the internal model structure and are designed to speed up model convergence. The result is a separable age-structured model with allowance for size composition data that are adaptable to several rockfish species.

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.

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 2000). 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. 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).

Other parameters estimated conditionally include, but are not limited to: selectivity (up to full selectivity) for survey and fishery, mean recruitment, fishing mortality, and spawners per recruit levels. The numbers of estimated parameters 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	69
Average fishing mortality	μ_f	1
Fishing mortality deviations	ϕ_y	47
Fishery selectivity coefficients	fs_a	8
Survey selectivity coefficients	ss_a	7
Total		139

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 139. 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 500,000 iterations out of 5,000,000 and "thinned" the chain to one value out of every 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% confidence intervals for some parameters.

BOX 1. AD Model Builder POP Model Description

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

BOX 1 (Continued)

Equations describing the observed data

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

Catch equation

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

Survey biomass index (t)

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

Survey age distribution
Proportion at age

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

Survey length distribution
Proportion at length

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

Fishery age composition
Proportion at age

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

Fishery length composition
Proportion at length

Equations describing population dynamics

Start year

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

Number at age of recruitment

Number at ages between recruitment and pooled age class

Number in pooled age class

Subsequent years

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

Number at age of recruitment

Number at ages between recruitment and pooled age class

Number in pooled age class

Formulae for likelihood components	**BOX 1 (Continued)**
$L_1 = \lambda_1 \sum_y \left(\ln\left[\frac{C_y + 0.01}{\hat{C}_y + 0.01} \right] \right)^2$	Catch likelihood
$L_2 = \lambda_2 \sum_y \frac{\left(I_y - \hat{I}_y\right)^2}{2 * \hat{\sigma}^2\left(I_y\right)}$	Survey biomass index likelihood
$L_3 = \lambda_3 \sum_{styr}^{endyr} -n^*_y \sum_a^{a+} \left(P_{y,a} + 0.001\right) * \ln\left(\hat{P}_{y,a} + 0.001\right)$	Fishery age composition likelihood (n^*_y =sample size, standardized to maximum of 100)
$L_4 = \lambda_4 \sum_{styr}^{endyr} -n^*_y \sum_l^{l+} \left(P_{y,l} + 0.001\right) * \ln\left(\hat{P}_{y,l} + 0.001\right)$	Fishery length composition likelihood
$L_5 = \lambda_5 \sum_{styr}^{endyr} -n^*_y \sum_a^{a+} \left(P_{y,a} + 0.001\right) * \ln\left(\hat{P}_{y,a} + 0.001\right)$	Survey age composition likelihood
$L_6 = \lambda_6 \sum_{styr}^{endyr} -n^*_y \sum_l^{l+} \left(P_{y,l} + 0.001\right) * \ln\left(\hat{P}_{y,l} + 0.001\right)$	Survey size composition likelihood
$L_7 = \frac{1}{2\sigma_M^2} \left(\ln\left(M / M_{prior} \right) \right)^2$	Penalty on deviation from prior distribution of natural mortality
$L_8 = \frac{1}{2\sigma_q^2} \left(\ln\left(q / q_{prior} \right) \right)^2$	Penalty on deviation from prior distribution of catchability coefficient
$L_9 = \frac{1}{2\sigma_{\sigma_r}^2} \left(\ln\left(\sigma_r / \sigma_{r(prior)} \right) \right)^2$	Penalty on deviation from prior distribution of recruitment deviations
$L_{10} = \lambda_{10} \left[\frac{1}{2 * \sigma_r^2} \sum_y \tau_y^2 + n_y * \ln\left(\sigma_r\right) \right]$	Penalty on recruitment deviations
$L_{11} = \lambda_{11} \sum_y \varepsilon_y^2$	Fishing mortality regularity penalty
$L_{12} = \lambda_{12} \bar{s}^2$	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

Model Evaluation

This model is the same model adopted in 2003 and has been used since, with the addition of some additional data. The model is producing stable and reasonable results at this time with minimal convergence and parameter penalties. In general, fits to the data are good. At this time modifications do not appear to be necessary. Ongoing research into model performance and rockfish biology may warrant changes to the Pacific ocean perch model in the future.

Model Results

Key results have been summarized in Tables 9-7 and 9-8. Model predictions continue to fit the data well (Figures 9-2, 9-4, 9-5, and 9-6) and parameter estimates have remained similar to the last several years using this model. The objective function value has increased slightly from last year's data, primarily due to the addition of new data.

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 300,000 t for 2007 (Figure 9-10). MCMC confidence 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 9-11). 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% selection are about 5 and 6.5 years for survey and fishery, respectively (Figure 9-12). Fish are fully selected by both fishery and survey by about age 8. Fishery selectivity has a slight descending right limb; this is because we place a very small penalty on dome-shapedness in the selectivity curve. Catchability is near two, which is supported by several empirical studies using line transects densities counted from a submarine compared to trawl survey densities (Keiger 1993, Krieger and Sigler 1996, Hanselman et al. 2006[3]).

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 9-13). 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 the target level ($B_{40\%}$). 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 9-14a). However, since 1998, Pacific ocean perch have been above $B_{40\%}$ and below $F_{40\%}$ (Figure 9-14b).

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 9-15). 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 1977-2003). The addition of new age data in this year's model, has increased the recruitment estimate for the 1995 year class and shows potential higher recruitments for the 1998-2000 year classes when compared to results from last year's model (Figure 9-16). However, these recruitments, especially recently, are still highly uncertain as indicated by the MCMC confidence intervals in Figure 9-15. Pacific ocean perch do not seem to exhibit

[3] 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.

much of a stock-recruitment relationship because large recruitments have occurred during periods of high and low biomass (Figure 9-15, 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 9-17) and confidence 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. 9-10, 9-11, 9-15).

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 MLE 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 confidence 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 9-11).

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 recruits from 1979-2005. 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 $B_{40\%}$. 2007 estimates of these reference points are:

$B_{0\%}$	$B_{40\%}$	$B_{35\%}$	$F_{40\%}$	$F_{35\%}$
222,987	89,195	78,045	0.061	0.073

Specification of OFL and Maximum Permissible ABC

Female spawning biomass for 2008 is estimated at 90,898 t. This is above the $B_{40\%}$ value of 89,195 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 2008, yields the following ABC and OFL:

$F_{40\%}$	0.061
ABC	14,999
$F_{35\%}$	0.073
OFL	17,807

Projections

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

For each scenario, the projections begin with the vector of 2007 numbers at age estimated in the assessment. This vector is then projected forward to the beginning of 2008 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2007. 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. For the first year, catch is estimated from available data at the time of the assessment. In subsequent years, total catch is assumed to equal the catch associated with the respective harvest scenario in all years. This projection scheme is run 1000 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 2008, 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 F_{ABC} value for 2008 recommended in the assessment to the *max* F_{ABC} for 2008. (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 case we use the most recent ratio of catch to TAC and multiply it against future ABCs predicted by Scenario 1 to estimate catches for 2008 and 2009. This was suggested to 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 2003-2007 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 1) above its MSY level in 2008 or 2) above ½ of its MSY level in 2008 and above its MSY level in 2018 under this scenario, then the stock is not overfished.)

Scenario 7: In 2008 and 2009, F is set equal to $max\ F_{ABC}$, and in all subsequent years, F is set equal to *FOFL*. (Rationale: This scenario determines whether a stock is approaching an overfished condition. If the stock is expected to be above its MSY level in 2020 under this scenario, then the stock is not approaching an overfished condition.)

Status Determination

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 overfished? This depends on the stock's estimated spawning biomass in 2008:

a) If spawning biomass for 2008 is estimated to be below ½ $B_{35\%}$, the stock is below its MSST
b) If spawning biomass for 2008 is estimated to be above $B_{35\%}$, the stock is above its MSST.
c) If spawning biomass for 2008 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 2018 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 (Table 9-10):

a) If the mean spawning biomass for 2008 is below ½ $B_{35\%}$, the stock is approaching an overfished condition.
b) If the mean spawning biomass for 2008 is above $B_{35\%}$, the stock is not approaching an overfished condition.
c) If the mean spawning biomass for 2008 is above ½ $B_{35\%}$ but below $B_{35\%}$, the determination depends on the mean spawning biomass for 2018. If the mean spawning biomass for 2018 is below $B_{35\%}$, the stock is approaching an overfished condition. Otherwise, the stock is not approaching an overfished condition.

A summary of the results of these scenarios for Pacific ocean perch is in Table 9-10. For Pacific ocean perch 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. For this assessment we present an alternative projection scenario using the full recruitment time series, always harvesting at $F_{40\%}$ (or maxABC). This is the least conservative scenario. This projection propagates uncertainty throughout the entire assessment procedure and is based on 10,000,000 MCMC. The projection shows wide confidence bounds on future spawning biomass (Figure 9-18). The $B_{35\%}$ and $B_{40\%}$ reference points are based on the 1977-2003 year classes, and this projection predicts that the median spawning biomass will eventually dip

below these reference points at harvesting at $F_{40\%}$.. This is because spawning biomass is positively skewed; the mean is moving toward equilibrium ($B_{40\%}$).

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. These results in weights of 4:6:9 for the 2003, 2005, and 2007 surveys, respectively and apportionments of 25% for the Western area, 55% for the Central area, and 20% for the Eastern area (Table 9-11). This results in recommended ABC's of 3,686 t for the Western area, 8,185 t for the Central area, and 3,128 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 2003, 2005 and 2007. 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 0.35. This results in the following apportionment to the W. Yakutat area:

ABC (t)	1,100
OFL (t)	1,312

which would leave 2,029 t unharvested in the Eastern Gulf.

Overfishing Definition

Based on the definitions for overfishing in Amendment 44 in tier 3a (i.e., $F_{OFL} = F_{35\%}$=0.073), overfishing is set equal to 17,807 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 4,376 t in the Western area, 9,717 t in the Central area, and 3,714 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.

Fishery Effects 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 begin in July concentrated in known areas of abundance and typically lasts only a few weeks. 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 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.

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.

Summary

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

Year	2008	2009*
Tier	3a	3a
Total Biomass (Age 2+)	317,511	317,615
Female spawning biomass (t)	90,898	94,149
$B_{0\%}$ (t)	222,987	-
$B_{40\%}$ (t)	89,195	-
$B_{35\%}$ (t)	78,045	-
M	0.060	0.060
$F_{40\%}$	0.061	0.061
F_{ABC} (maximum allowable)	0.061	0.061
ABC (t; maximum allowable)	14,999	15,072
F_{OFL}	0.073	0.073
OFL (t)	17,807	17,893

*** Projected ABCs and OFLs for 2009 are derived using an expected catch value of 13,500 t for 2008 based on recent ratios of catch to ABC.** The projection results of this method are listed under Author's F in Table 9-10. This was done in response to management requests to obtain a more accurate one-year projection.

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Tables

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

Table 9-1a (continued)

		Regulatory Area			Gulfwide		Gulfwide value
Year	Fishery	Western	Central	Eastern	Total	ABC	Quota
1989	U.S.	4,339	8,315	6,348	19,002	20,000	20,000
1990	U.S.	5,203	9,973	5,938	21,114	17,700	17,700
1991	U.S.	1,589	2,956	2,087	6,631	5,800	5,800
1992	U.S.	1,266	2,658	2,234	6,159	5,730	5,200
1993	U.S.	477	1,140	443	2,060	3,378	2,560
1994	U.S.	165	920	768	1,853	3,030	2,550
1995	U.S.	1,422	2,598	1,722	5,742	6,530	5,630
1996	U.S.	987	5,145	2,246	8,378	8,060	6,959
1997	U.S.	1,832	6,720	979	9,531	12,990	9,190
1998	U.S.	850	7,501	610	8,961	12,820	10,776
1999	U.S.	1,935	7,910	627	10,472	13,120	12,590
2000	U.S.	1,160	8,379	618	10,157	13,020	13,020
2001	U.S.	944	9,249	624	10,817	13,510	13,510
2002	U.S.	2,720	8,261	748	11,729	13,190	13,190
2003	U.S.	2,149	8,106	606	10,861	13,663	13,660
2004	U.S.	2,196	8,455	877	11,528	13,336	13,340
2005	U.S.	2,339	8,145	872	11,272	13,575	13,580
2006	U.S.	4,050	8,282	1,258	13,590	14,261	14,261
2007*	U.S.	4,380	6,788	1,242	12,410	14,636	14,635

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). *2007 catch as of 9/22/07.

Table 9-1b. Catch (t) of Pacific ocean perch taken during research cruises in the Gulf of Alaska, 1977-2007. (Does not include catches in longline surveys before 1995; tr=trace)

Year	Catch
1977	13.0
1978	5.7
1979	12.2
1980	12.6
1981	57.1
1982	15.2
1983	2.4
1984	76.5
1985	35.2
1986	14.4
1987	68.8
1988	0.3
1989	1.0
1990	25.5
1991	0.1
1992	0.0
1993	59.2
1994	tr
1995	tr
1996	81.2
1997	tr
1998	305.0
1999	330.2
2000	0.0
2001	42.5
2002	tr
2003	50.4
2004	tr
2005	84.4
2006	tr
2007	92.7

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

Length Class (cm)	1994	1995	1996	1997	1998	1999	Year 2000	2001	2002	2003	2004	2005	2006	2007
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	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
16	0.000	0.000	0.000	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
17	0.000	0.000	0.000	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
18	0.000	0.000	0.000	0.005	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
19	0.000	0.000	0.000	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.001
20	0.000	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
21	0.000	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
22	0.000	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
23	0.001	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
24	0.000	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
25	0.000	0.005	0.002	0.004	0.002	0.003	0.001	0.003	0.006	0.001	0.003	0.002	0.003	0.005
26	0.000	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
27	0.001	0.008	0.003	0.008	0.003	0.005	0.008	0.004	0.006	0.004	0.004	0.004	0.005	0.010
28	0.002	0.007	0.004	0.009	0.004	0.005	0.006	0.005	0.008	0.007	0.007	0.010	0.010	0.010
29	0.004	0.010	0.006	0.011	0.005	0.009	0.009	0.009	0.009	0.008	0.016	0.013	0.016	0.015
30	0.002	0.010	0.009	0.016	0.006	0.006	0.010	0.010	0.009	0.009	0.020	0.020	0.024	0.017
31	0.003	0.020	0.018	0.018	0.008	0.009	0.015	0.013	0.012	0.012	0.014	0.029	0.033	0.030
32	0.012	0.039	0.029	0.024	0.012	0.015	0.014	0.019	0.020	0.018	0.020	0.040	0.063	0.049
33	0.045	0.081	0.066	0.044	0.021	0.034	0.023	0.034	0.043	0.027	0.029	0.050	0.084	0.077
34	0.105	0.128	0.125	0.074	0.057	0.071	0.056	0.055	0.072	0.063	0.046	0.065	0.098	0.108
35-38	0.681	0.515	0.599	0.538	0.641	0.580	0.574	0.564	0.509	0.524	0.510	0.486	0.412	0.461
>38	0.143	0.161	0.135	0.227	0.236	0.254	0.275	0.273	0.292	0.321	0.322	0.271	0.244	0.202
Total	896	6,580	11,140	14,611	14,110	4,650	6,157	4,776	4,980	5,885	5,034	4,572	5,206	7,760

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

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

Table 9-4. Biomass estimates (t) and Gulfwide confidence intervals for Pacific ocean perch in the Gulf of Alaska based on the 1984-2007 trawl surveys. (Biomass estimates and confidence intervals for 2001 have been slightly revised from those listed in previous SAFE reports for slope rockfish.)

	Western		Central		Eastern		
	Shumagin	Chirikof	Kodiak	Yakutat	Southeast	Total	95% Confidence interval
1984	59,710	9,672	36,976	94,055	32,280	232,694	101,550 - 363,838
1987	62,906	19,666	44,441	35,612	52,201	214,827	125,499 - 304,155
1990	24,375	15,991	15,221	35,635	46,780	138,003	70,993 - 205,013
1993	75,416	103,224	153,262	50,048	101,532	483,482	260,553 - 706,411
1996	92,618	140,479	326,280	50,394	161,641	771,413	355,756 - 1,187,069
1999	38,196	402,293	209,675	32,733	44,367	727,263	0 - 1,566,566
2001*	275,210	39,819	385,126	44,392	102,514	847,061	364,570 - 1,275,552
2003	72,851	116,231	166,815	27,762	73,737	457,394	313,363 - 601,426
2005	250,912	75,433	300,153	77,682	62,239	766,418	479,078 - 1,053,758
2007	158,100	77,002	301,712	52.569	97,798	688,180	459,836 – 916,524

*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.

	1984	1987	1990	1993	1996	1999	2003	2005
2	0.006	0.019	0.005	0.006	0.008	0.006	0.016	0.002
3	0.003	0.101	0.043	0.018	0.016	0.020	0.056	0.037
4	0.071	0.092	0.155	0.021	0.036	0.045	0.053	0.051
5	0.031	0.066	0.124	0.044	0.043	0.052	0.071	0.077
6	0.078	0.091	0.117	0.088	0.063	0.026	0.040	0.072
7	0.145	0.146	0.089	0.125	0.038	0.041	0.054	0.118
8	0.385	0.056	0.065	0.129	0.088	0.059	0.107	0.069
9	0.053	0.061	0.054	0.166	0.144	0.095	0.115	0.087
10	0.027	0.087	0.055	0.092	0.185	0.054	0.057	0.091
11	0.010	0.096	0.036	0.045	0.110	0.114	0.053	0.063
12	0.017	0.018	0.024	0.052	0.080	0.144	0.044	0.034
13	0.017	0.011	0.028	0.038	0.034	0.086	0.036	0.027
14	0.021	0.011	0.072	0.025	0.036	0.067	0.057	0.030
15	0.005	0.009	0.017	0.026	0.028	0.045	0.047	0.039
16	0.002	0.011	0.011	0.011	0.006	0.040	0.042	0.022
17	0.009	0.013	0.005	0.036	0.013	0.023	0.032	0.027
18	0.004	0.007	0.008	0.007	0.009	0.013	0.029	0.036
19	0.002	0.005	0.004	0.003	0.014	0.003	0.016	0.024
20	0.000	0.005	0.006	0.002	0.013	0.012	0.015	0.021
21	0.003	0.004	0.004	0.002	0.003	0.007	0.010	0.013
22	0.004	0.003	0.002	0.004	0.004	0.008	0.005	0.018
23	0.002	0.002	0.002	0.002	0.003	0.012	0.006	0.004
24	0.003	0.002	0.006	0.004	0.000	0.004	0.007	0.008
25+	0.102	0.083	0.070	0.054	0.027	0.025	0.031	0.030
Total	1,427	1,824	1,766	1,492	718	963	1,003	1,023

Table 9-6. Estimated numbers (thousands) in 2007, 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 2007 (1000's)	Percent mature	Weight (g)	Fishery selectivity	Survey selectivity
2	42,324	0	46	0	5
3	39,737	0	106	1	12
4	35,119	0	180	1	22
5	39,297	0	261	3	35
6	42,985	0	342	8	57
7	61,807	12	420	29	98
8	52,196	20	493	100	100
9	49,154	30	559	94	100
10	26,144	42	619	94	100
11	22,979	56	672	94	100
12	51,979	69	718	94	100
13	20,676	79	758	94	100
14	10,935	87	792	94	100
15	9,146	92	822	94	100
16	7,216	95	847	94	100
17	6,489	97	868	94	100
18	7,635	98	886	94	100
19	9,786	99	902	94	100
20	10,884	99	915	94	100
21	35,625	100	926	94	100
22	6,043	100	935	94	100
23	8,176	100	943	94	100
24	3,076	100	950	94	100
25+	11,995	100	970	94	100

Table 9-7. Summary of results from 2007 compared with 2005 results

	2005		**2007**	
Likelihoods	**Value**	**Weight**	**Value**	**Weight**
Catch	0.09	50	0.10	50
Survey Biomass	8.1	1	8.03	1
Fishery Ages	24.4	1	27.99	1
Survey Ages	44.25	1	45.75	1
Fishery Sizes	49.73	1	49.71	1
Data-Likelihood	126.58		131.57	
Penalties/Priors				
Recruitment Devs	23.83	1	24.75	1
Fishery Selectivity	1.96	1	1.97	1
Survey Selectivity	0.38	1	0.42	1
Fish-Sel Domeshape	0.01	1	0.00	1
Survey-Sel Domeshape	0	1	0	1
Average Selectivity	0	1	0	1
F Regularity	4.89	0.1	4.65	0.1
σ_r prior	1.06		0.89	
q prior	1.03		1.43	
M prior	1.81		1.80	
Objective Fun Total	161.53		167.64	
Parameter Ests.		LN Prior (μ,σ)		LN Prior (μ,σ)
q	1.9	(1,0.45)	2.1	(1,0.45)
M	0.06	(0.05,0.1)	0.06	(0.05,0.1)
σ_r	0.89	(1.7,0.45)	0.89	(1.7,0.45)
log-mean-recruitment	3.76		3.73	
$F_{40\%}$	0.062		0.061	
Total Biomass	312,968		317,511	
B_{2008}	93,108*		90,898	
$B_{0\%}$	225,056		222,987	
$\mathbf{B_{40\%}}$	90,022		89,195	
$\mathbf{ABC_{F40\%}}$	14,261		14,999	
$F_{35\%}$	0.074		0.073	
$OFL_{F35\%}$	16,927		17,807	
$F_{50\%}$	0.044		0.043	
$ABC_{F50\%}$	10,071		10,588	

As predicted by the 2005 projection model

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	2.13	2.36	2.32	0.51	0.56	1.35	3.46
M	0.060	0.056	0.056	0.002	0.006	0.046	0.068
$F_{40\%}$	0.061	0.067	0.067	0.019	0.021	0.038	0.123
Female Sp. Biomass	90,898	88,399	79,189	25,974	30,553	51,317	167,935
ABC	14,999	17,138	15,609	3,750	7,654	7,372	38,791
σ_r	0.89	2.09	2.05	0.10	0.34	1.53	2.81

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	26,362	27,339	87,806	90,490	0.246	0.239	14,497	15,327
1978	21,542	22,552	70,446	73,253	0.114	0.109	26,072	27,499
1979	20,952	22,012	66,371	69,311	0.125	0.120	50,501	55,717
1980	19,861	20,972	61,683	64,786	0.175	0.167	17,833	19,030
1981	17,448	18,609	54,851	58,172	0.191	0.181	16,794	17,954
1982	14,932	16,156	51,488	55,197	0.105	0.098	23,590	25,780
1983	14,473	15,779	60,525	65,657	0.047	0.043	21,802	23,635
1984	15,664	17,135	64,950	70,606	0.042	0.039	22,132	23,973
1985	17,043	18,681	68,889	75,026	0.012	0.011	28,787	31,520
1986	19,464	21,307	76,342	83,199	0.029	0.026	63,291	70,956
1987	21,892	23,989	81,779	89,266	0.055	0.050	40,114	41,065
1988	23,755	26,142	84,741	92,845	0.101	0.092	213,328	248,869
1989	24,059	26,747	85,084	94,028	0.138	0.125	60,152	61,247
1990	22,941	25,941	91,408	102,538	0.143	0.128	49,453	52,591
1991	21,878	25,278	91,951	103,676	0.072	0.064	34,880	37,915
1992	23,214	26,971	145,554	166,983	0.042	0.037	26,618	28,608
1993	28,549	33,307	166,077	189,340	0.012	0.011	26,602	28,760
1994	35,583	41,252	187,205	212,428	0.010	0.009	30,114	33,432
1995	44,362	51,140	203,191	230,036	0.028	0.025	32,131	35,574
1996	53,129	61,129	210,777	238,680	0.040	0.035	54,072	63,270
1997	61,367	70,651	213,375	242,094	0.045	0.039	120,620	96,762
1998	68,136	78,584	213,914	243,524	0.042	0.037	47,642	46,747
1999	73,111	84,468	214,324	244,707	0.049	0.043	48,433	39,979
2000	75,786	87,859	218,210	250,794	0.047	0.040	81,530	58,775
2001	77,249	89,909	240,575	266,657	0.045	0.041	76,886	73,951
2002	78,862	91,423	245,787	270,252	0.048	0.043	84,269	70,178
2003	79,722	92,093	249,514	270,300	0.044	0.040	54,924	48,286
2004	81,463	93,167	262,349	275,346	0.044	0.042	47,172	42,878
2005	84,111	94,600	274,041	283,787	0.041	0.040	39,651	42,884
2006	87,536		288,305		0.047		42,219	
2007	90,947		292,800		0.042		42,324	

Table 9-10. Set of projections of spawning biomass (SB) 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. $B_{40\%}$ = 89,195 t, $B_{35\%}$ = 78,045 t, $F_{40\%}$ = 0.061, and $F_{35\%}$ = 0.073.

Year	Maximum permissible F	Author's F (prespecified catch)	Half maximum F	5-year average F	No fishing	Overfished	Approaching overfished
			Spawning biomass (t)				
2007	87,682	87,682	87,682	87,682	87,682	87,682	87,682
2008	90,898	91,077	91,776	91,090	92,661	90,561	90,898
2009	93,409	94,149	97,033	94,193	100,799	92,043	93,409
2010	95,270	96,403	101,776	96,661	108,734	92,865	94,915
2011	96,579	97,701	106,033	98,578	116,433	93,152	95,162
2012	96,949	98,041	109,287	99,530	123,242	92,564	94,496
2013	96,713	97,755	111,584	99,830	129,286	91,460	93,283
2014	96,027	97,005	113,359	99,626	134,588	90,012	91,701
2015	95,021	95,926	114,456	99,044	139,188	88,383	89,902
2016	94,083	94,912	115,348	98,482	143,520	86,993	88,306
2017	93,204	93,955	116,225	97,930	147,566	85,819	86,933
2018	92,500	93,172	116,925	97,502	151,484	84,931	85,866
2019	92,044	92,637	117,968	97,264	155,396	84,351	85,131
2020	91,790	92,310	118,704	97,177	159,278	84,009	84,656
			Fishing mortality				
2007	0.053	0.053	0.053	0.053	0.053	0.053	0.053
2008	0.061	0.055	0.031	0.055	-	0.073	0.073
2009	0.061	0.055	0.031	0.055	-	0.073	0.073
2010	0.061	0.061	0.031	0.055	-	0.073	0.073
2011	0.061	0.061	0.031	0.055	-	0.073	0.073
2012	0.061	0.061	0.031	0.055	-	0.073	0.073
2013	0.061	0.061	0.031	0.055	-	0.073	0.073
2014	0.061	0.061	0.031	0.055	-	0.073	0.073
2015	0.061	0.061	0.031	0.055	-	0.072	0.072
2016	0.061	0.061	0.031	0.055	-	0.071	0.071
2017	0.061	0.061	0.031	0.055	-	0.070	0.070
2018	0.061	0.061	0.031	0.055	-	0.069	0.069
2019	0.061	0.061	0.031	0.055	-	0.068	0.068
2020	0.060	0.060	0.031	0.055	-	0.068	0.068
			Yield (t)				
2007	12,410	12,410	12,410	12,410	12,410	12,410	12,410
2008	14,999	14,999	7,606	13,393	-	17,807	14,999
2009	14,988	15,072*	7,810	13,464	-	17,608	14,988
2010	14,830	14,996	7,930	13,398	-	17,249	17,606
2011	14,571	14,725	7,986	13,235	-	16,787	17,115
2012	14,327	14,468	8,034	13,078	-	16,363	16,662
2013	14,120	14,249	8,085	12,947	-	16,001	16,271
2014	14,075	14,193	8,204	12,955	-	15,826	16,089
2015	14,014	14,121	8,304	12,944	-	15,463	15,829
2016	13,933	14,030	8,382	12,910	-	15,075	15,421
2017	13,873	13,973	8,473	12,912	-	14,785	15,080
2018	13,727	13,832	8,535	12,875	-	14,514	14,757
2019	13,619	13,717	8,606	12,866	-	14,354	14,552
2020	13,577	13,664	8,694	12,897	-	14,289	14,451

*** Projected ABCs and OFLs for 2009 are derived using an expected catch value of 13,500 t for 2008 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 2008 Pacific ocean perch in the Gulf of Alaska.

		Western	Central		Eastern		
Year	Weights	Shumagin	Chirikof	Kodiak	Yakutat	Southeast	Total
2003	4	16%	25%	36%	6%	16%	100%
2005	6	33%	10%	39%	10%	8%	100%
2007	9	23%	11%	44%	8%	14%	100%
Weighted Mean	19	25%	14%	41%	8%	12%	100%
Area Apportionment		**25%**	**55%**			**20%**	
Area ABC		**3,686**	**8,185**		**3,128**		**14,999**
Area OFL		**4,376**	**9,717**		**3,714**		**17,807**

Table 9-12. Summary of ecosystem considerations for slope rockfish.

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 2003-2007. Source: Alaska Regional Office, data prepared by Olav Orsmeth.

	Estimated Catch (kg)				
Group Name	**2003**	**2004**	**2005**	**2006**	**2007**
Benthic urochordata	2	130		44	30
Birds	215				82
Birds Total	215				82
Bivalves	5			6	
Brittle star unidentified	161	2	47	93	8
Corals Bryozoans	1,903	60	6,125	360	2,259
Red Tree Coral	0	5		44	
Corals Bryozoans Total	1,904	65	6,125	404	2,259
Eelpouts	30	222	11,406	32	121
Eulachon	11	197	87	321	21
Giant Grenadier	139,261	418	134,043	277,147	122,516
Greenlings	8,372	6,923	3,541	5,959	6,821
Grenadier	480,913	2,835,239	95,761	65,538	70,296
Grenadier Total	480,913	2,835,239	95,761	65,538	70,296
Hermit crab unidentified	13	10	40	49	5
Invertebrate unidentified	441	938	98	43	
Lanternfishes (myctophidae)		0			0
Large Sculpins	123	42,999	16,476	28,465	26,486
Misc crabs	28	338	705	414	104
Misc crustaceans		24			
Misc fish	145,399	116,116	117,541	182,333	175,303
Misc inverts (worms etc)				10	
Octopus	654	425	193	468	46
Other osmerids	553	141	15	268	83
Other Sculpins	24,076	15,019	14,506	3,904	4,315
Pandalid shrimp	916	293	261	175	96
Polychaete unidentified	4				
Scypho jellies	660	2,920	150	438	204
Sea anemone unidentified	3,304	2,940	296	622	195
Sea pens whips		2	43		
Sea star	3,306	2,102	1,467	2,231	477
Shark, Other	208	221	178	1,614	327
Shark, pacific sleeper	275	628	150	386	39
Shark, salmon	12	120	500	620	693
Shark, spiny dogfish	35,460	2,107	2,760	2,002	1,826
Skate, Big		6,635	4,622	4,210	111
Skate, Longnose	864	16,270	9,348	8,093	14,363
Skate, Other	106,607	10,380	45,017	35,787	16,166
Snails	423	302	157	801	65
Sponge unidentified	3,815	1,140	1,130	949	610
Squid	9,139	11,905	1,526	9,844	2,955
Stichaeidae				13	
urchins dollars cucumbers	353	606	160	306	139
Grand Total	967,508	3,077,777	468,351	633,590	446,762

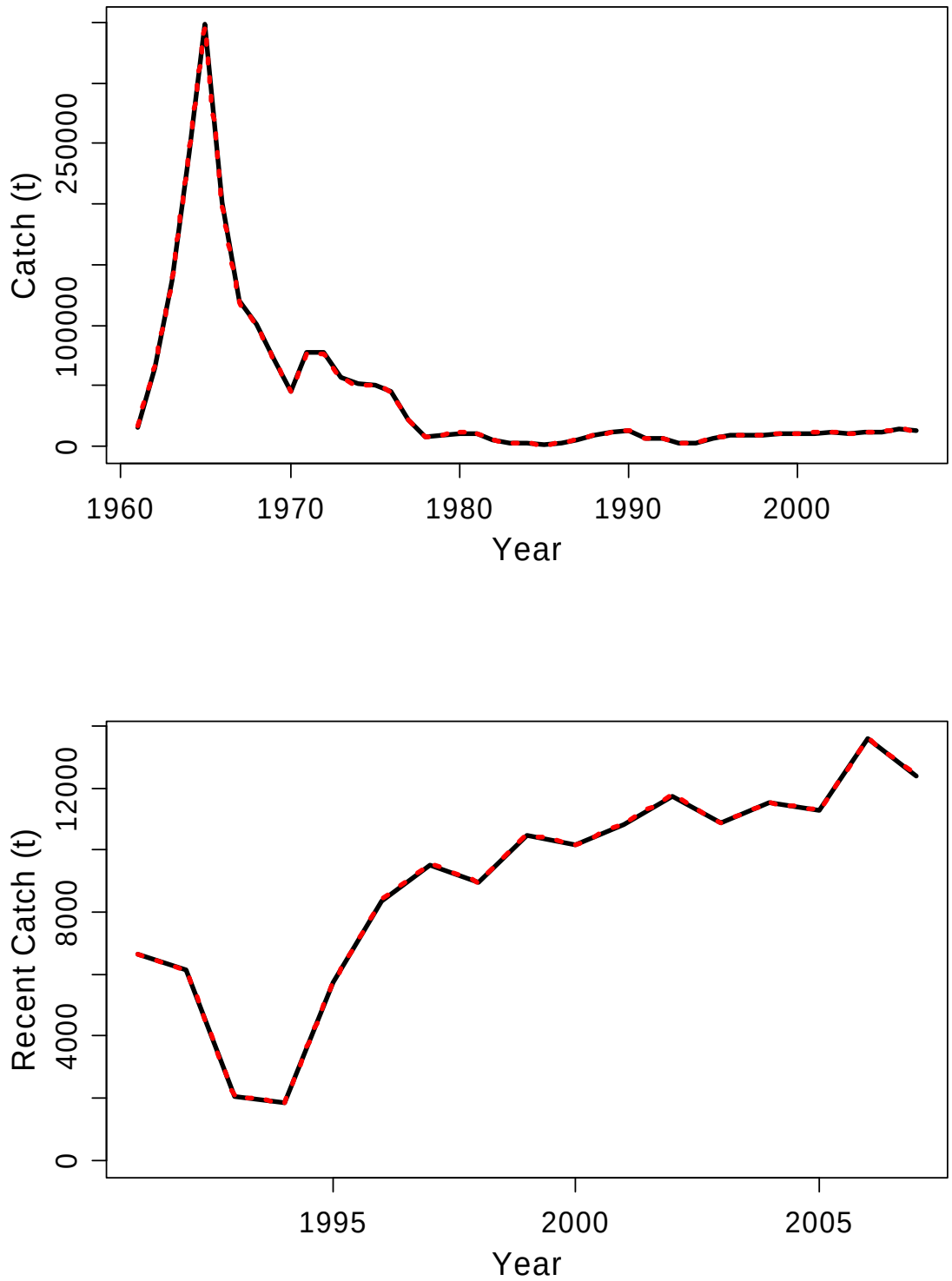


Figure 9-1. Estimated and observed long-term (a) and short-term (b) catch history for Gulf of Alaska Pacific ocean perch.

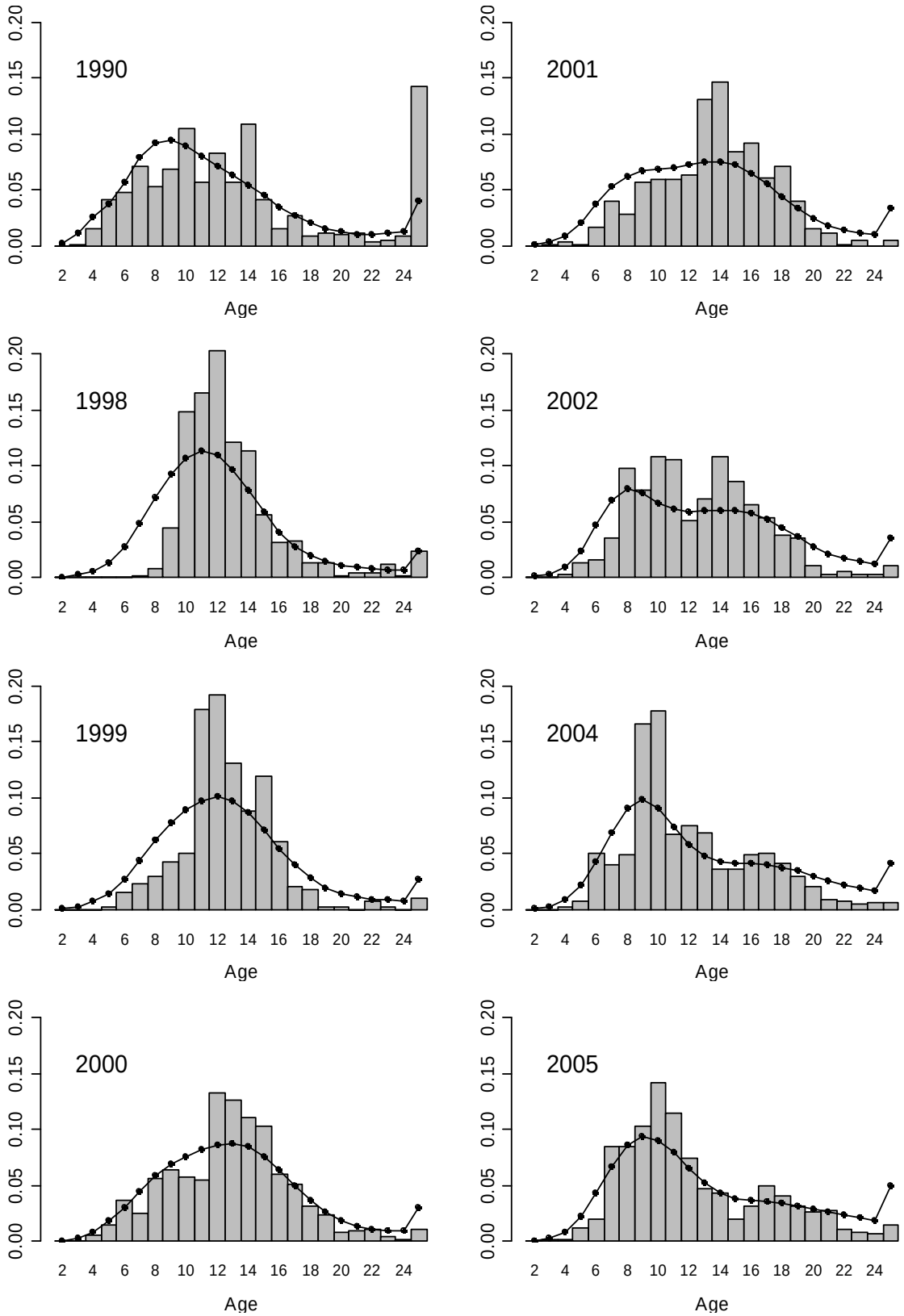


Figure 9-2. Fishery age compositions for GOA Pacific ocean perch. Observed = bars, predicted from author recommended model = line with circles.

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

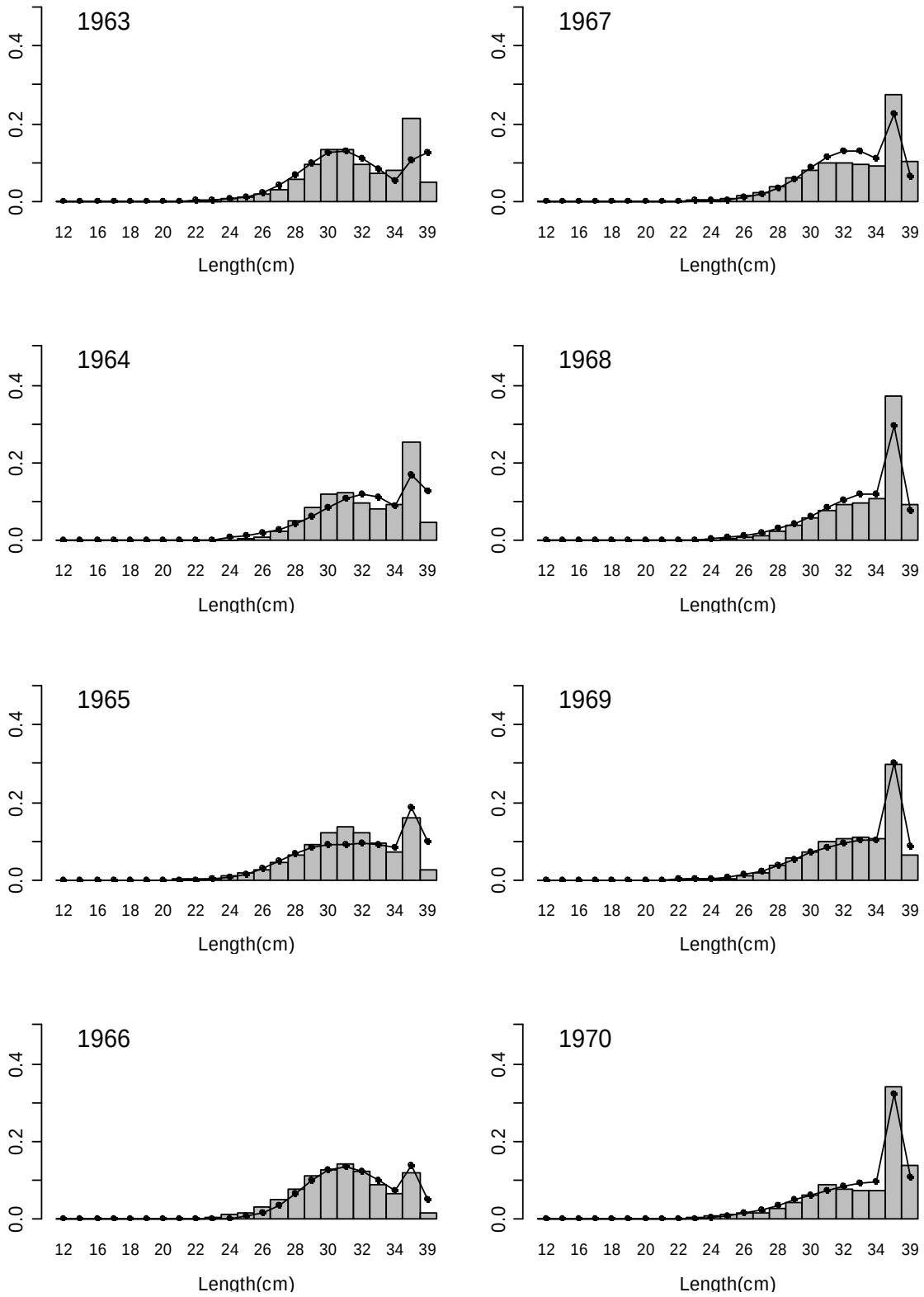


Figure 9-3. Fishery length compositions for GOA Pacific ocean perch. Observed = bars, predicted from author recommended model = line with circles.

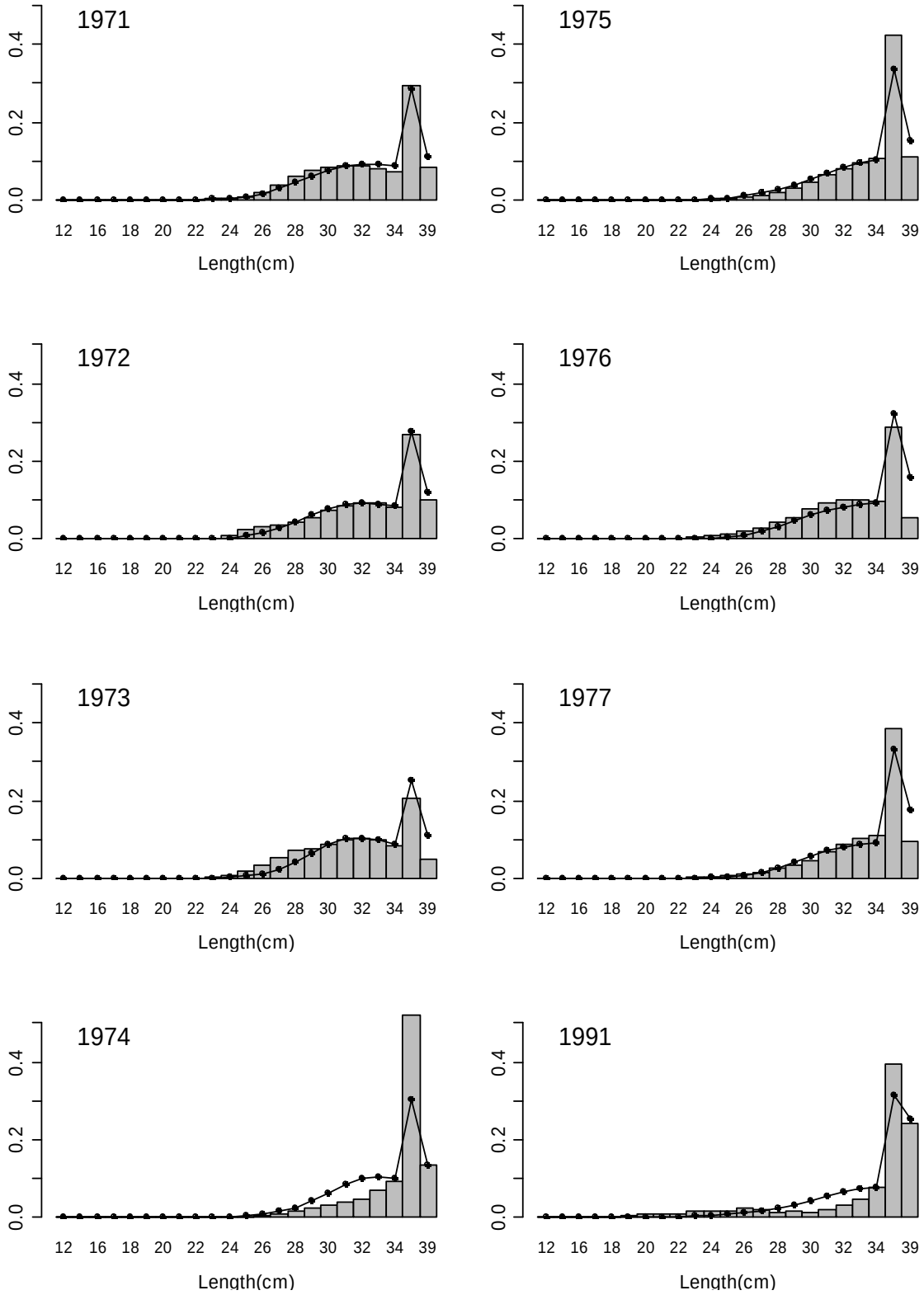


Figure 9-3 (continued). Fishery length compositions for GOA Pacific ocean perch. Observed = bars, predicted from author recommended model = line with circles.

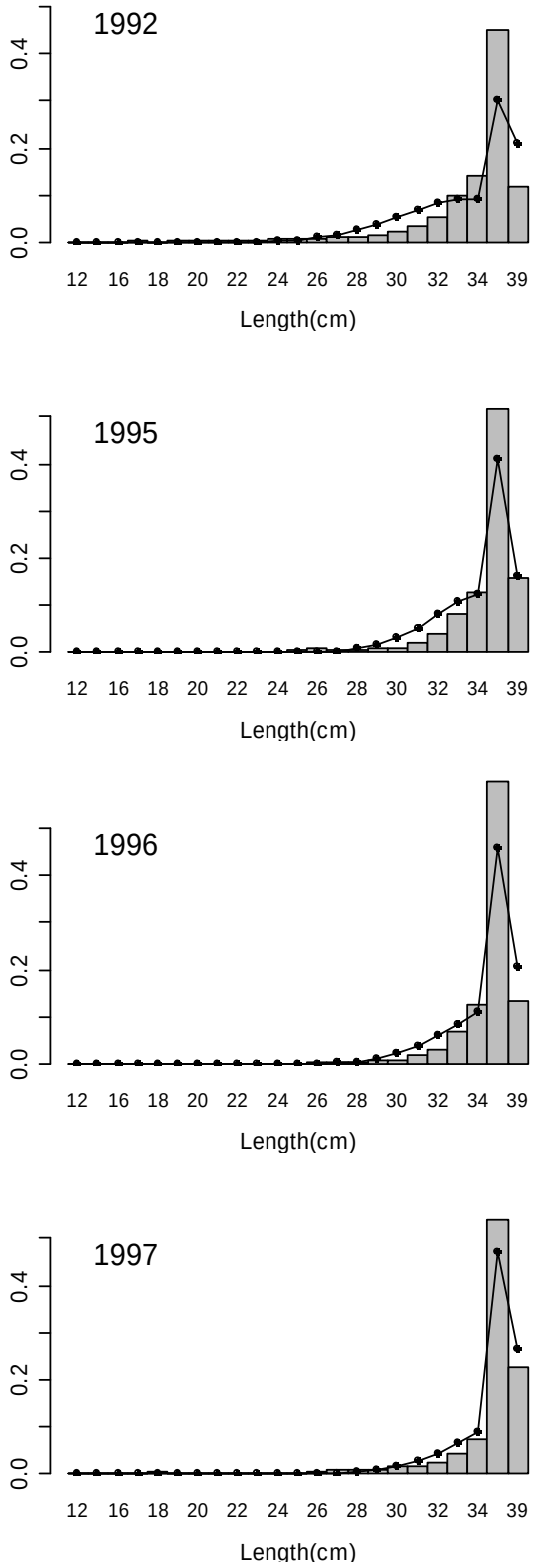


Figure 9-3 (continued). Fishery length compositions for GOA Pacific ocean perch. Observed = bars, predicted from author recommended model = line with circles.

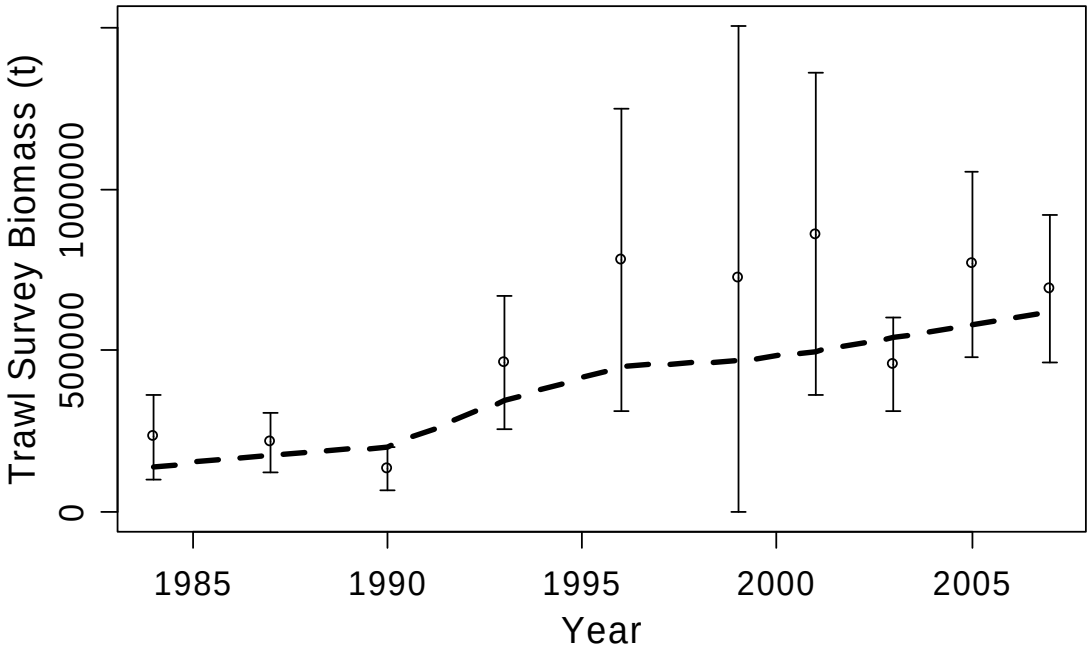


Figure 9-4. NMFS Groundfish Survey biomass estimates (solid line), with 95% sampling error confidence intervals (dashed line) and model fit (dotted line) for Gulf of Alaska Pacific ocean perch.

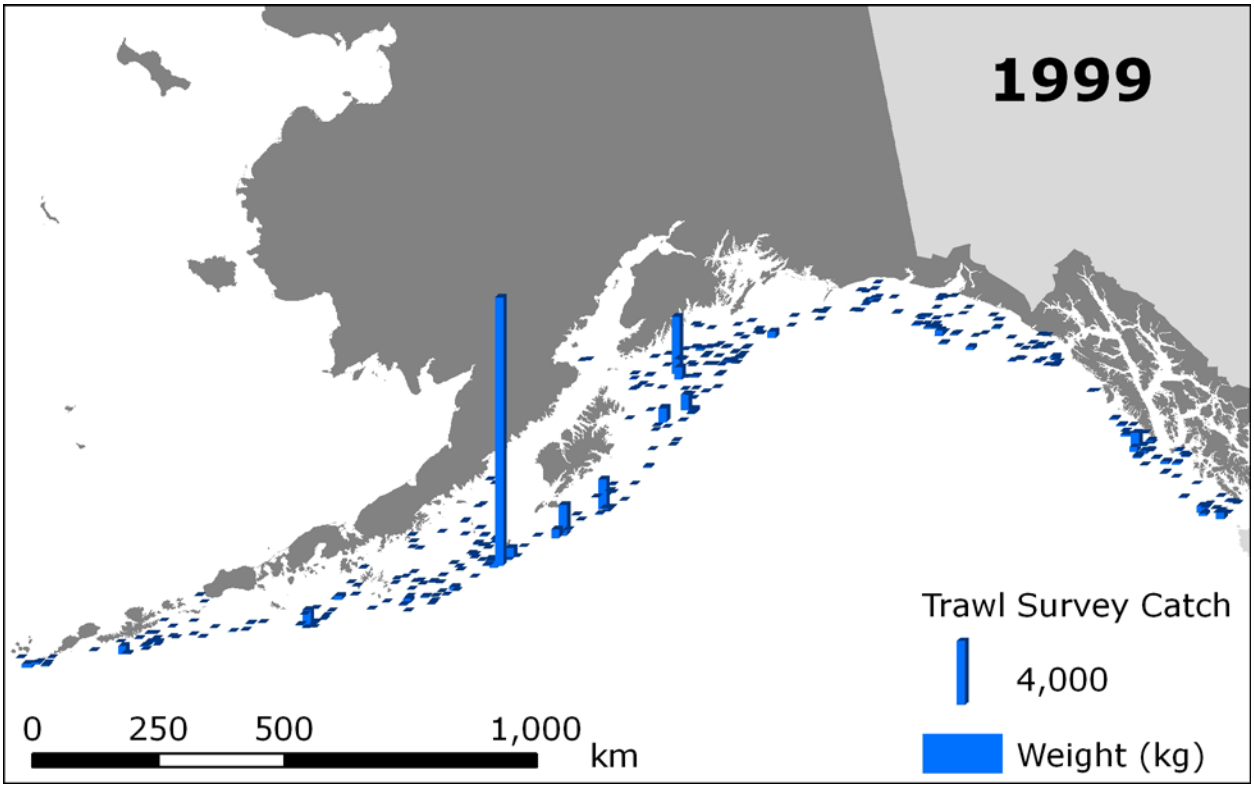


Figure 9-5a. Distribution of Gulf of Alaska Pacific ocean perch catches in the 1999 Gulf of Alaska groundfish survey.

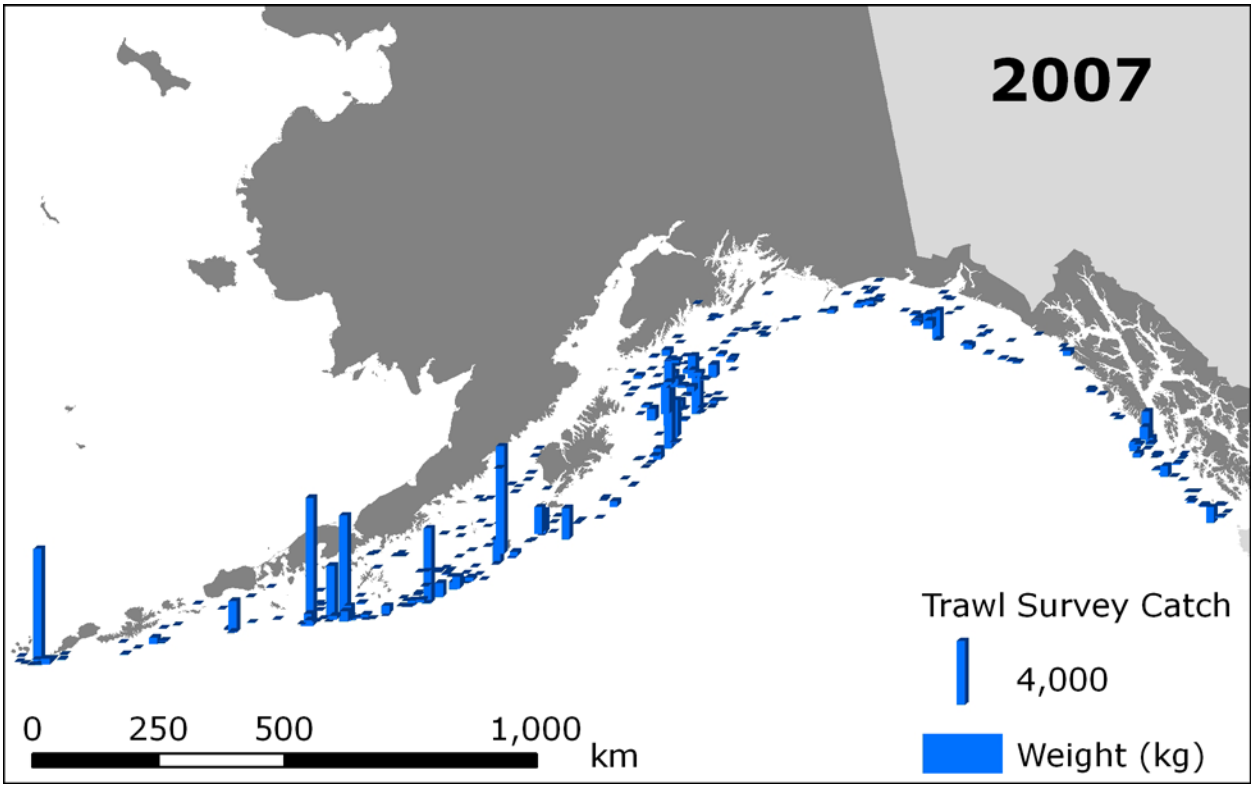


Figure 9-5b. Distribution of Gulf of Alaska Pacific ocean perch catches in the 2007 Gulf of Alaska groundfish survey.

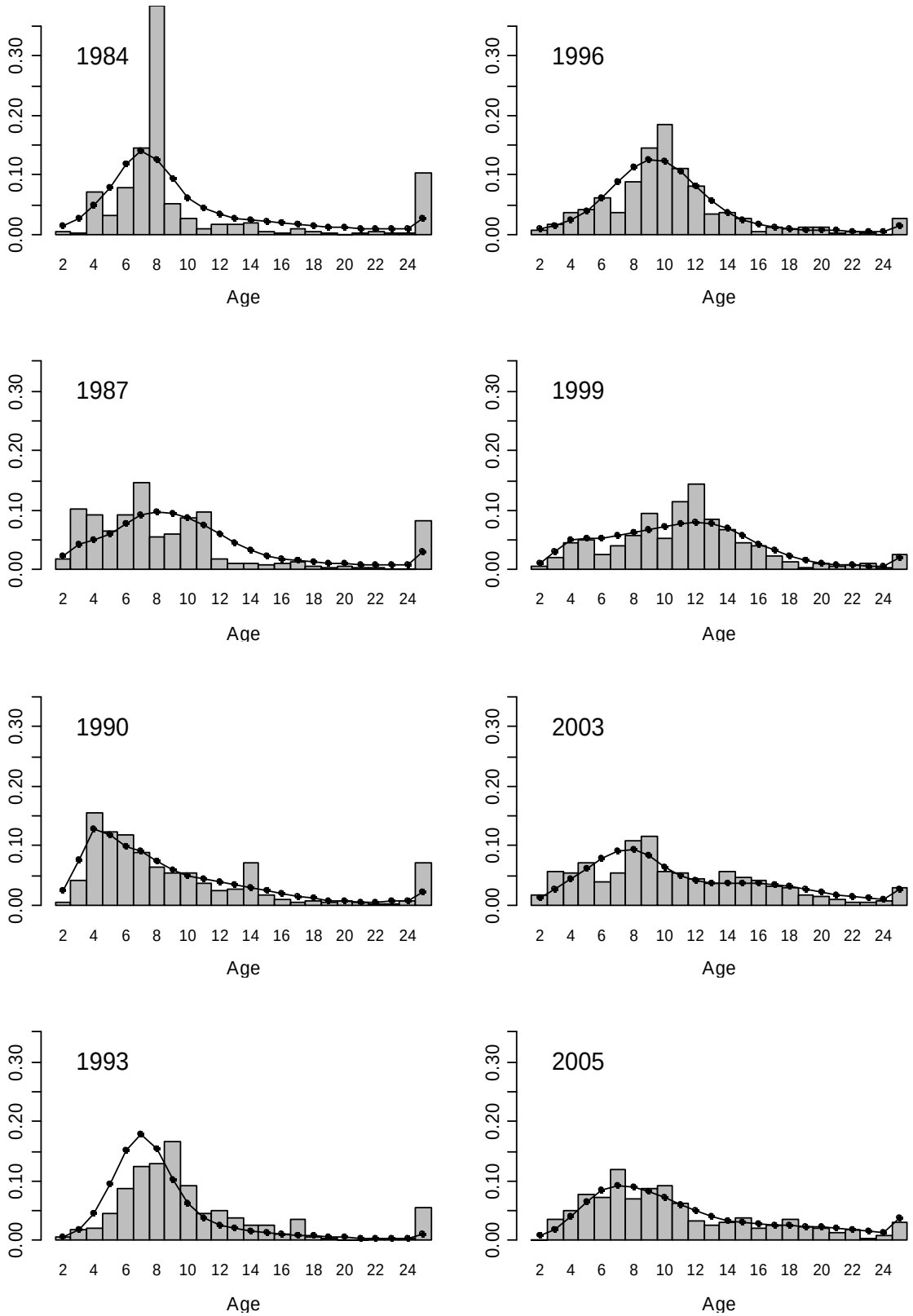


Figure 9-6. Groundfish survey age compositions for GOA Pacific ocean perch. Observed = bars, predicted from author recommended model = line with circles.

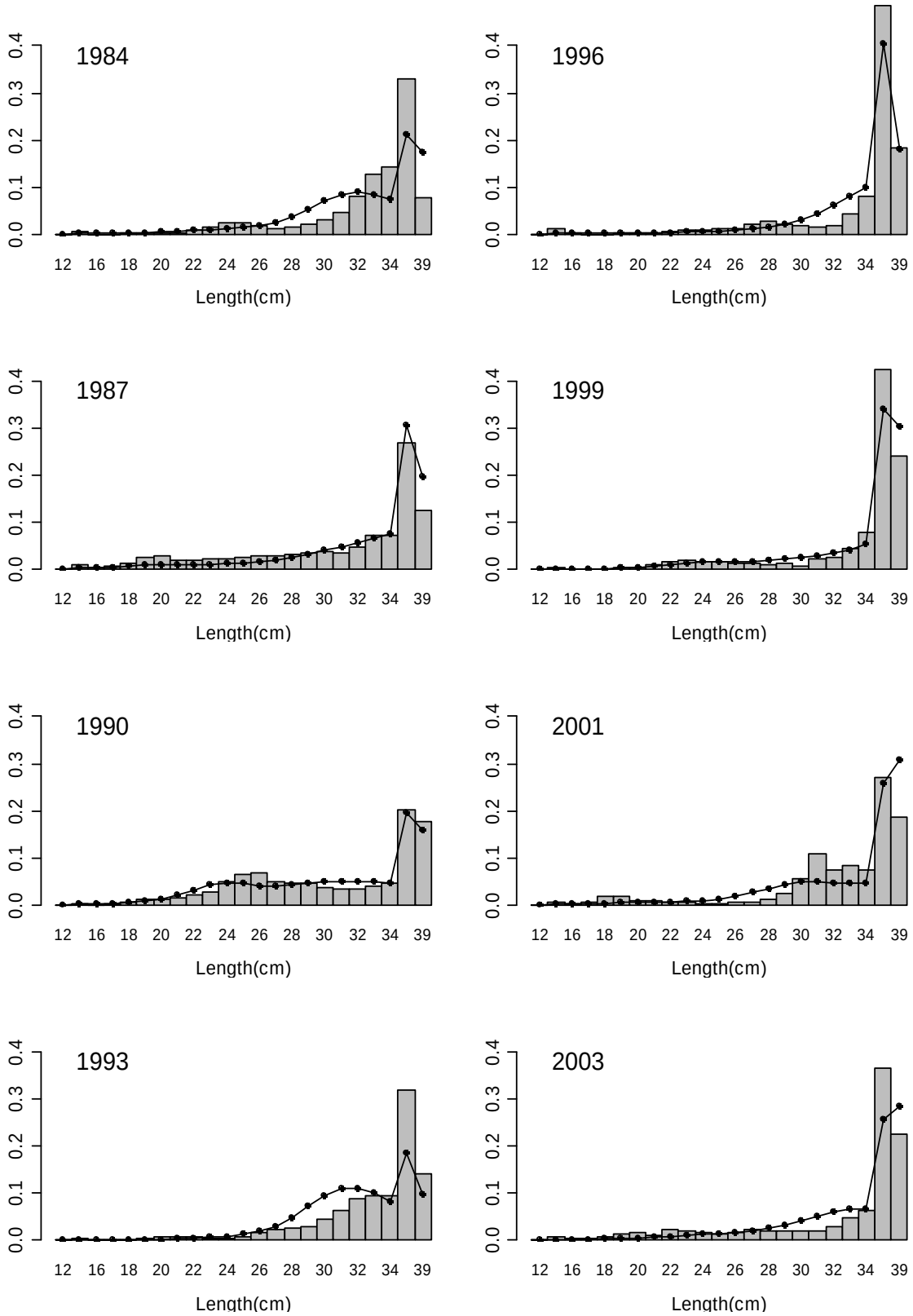


Figure 9-7. Groundfish survey length compositions for GOA Pacific ocean perch. Observed = bars, predicted from author recommended model = line with circles. Survey size distributions not used in Pacific ocean perch model because survey ages are available for these years.

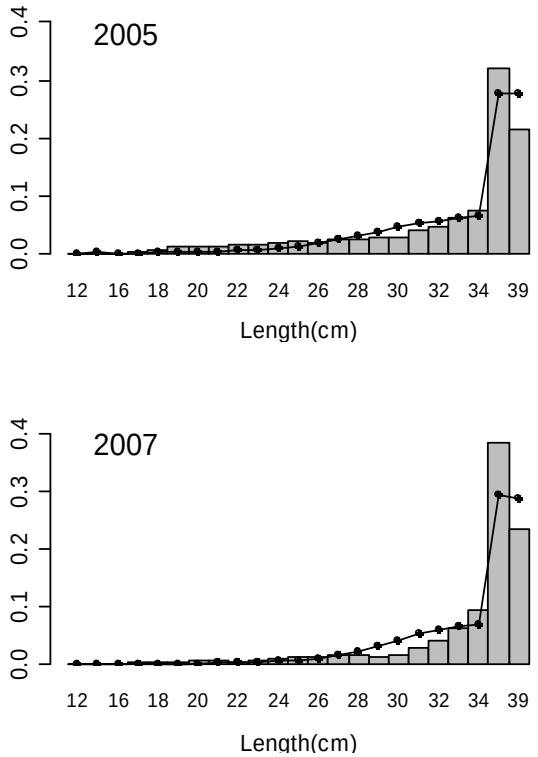


Figure 9-7 (continued). Groundfish survey length compositions for GOA Pacific ocean perch. Observed = bars, predicted from author recommended model = line with circles. Survey size distributions not used in Pacific ocean perch model because survey ages are available for these years.

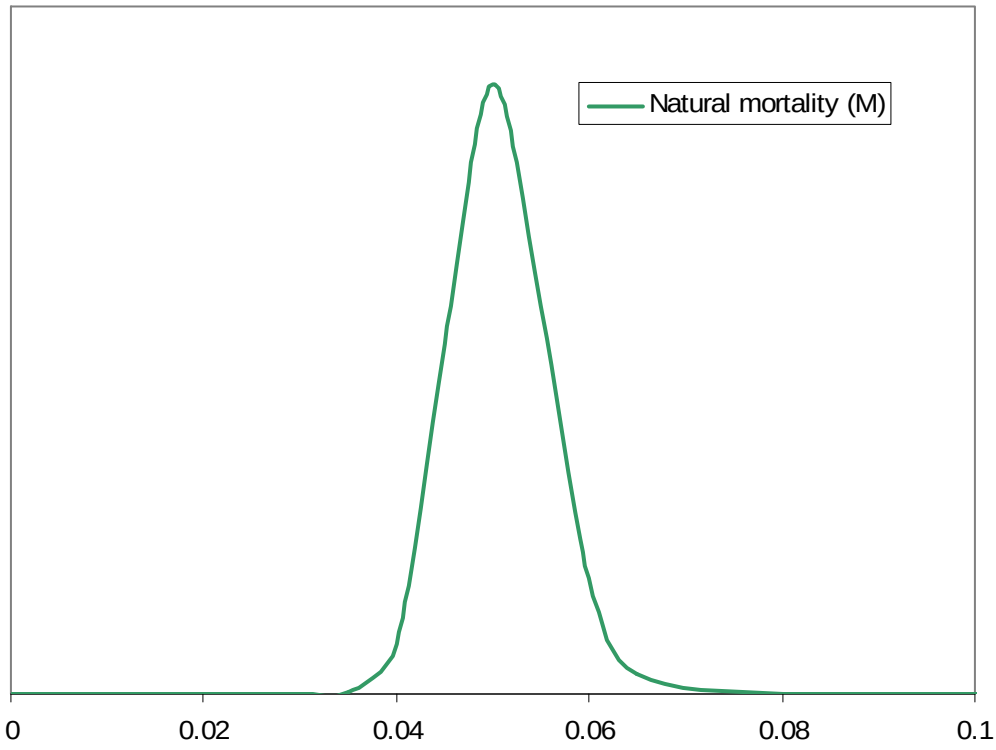


Figure 9-8. Prior distribution for natural mortality (*M*) of Pacific ocean perch, μ=0.05, CV=10%.

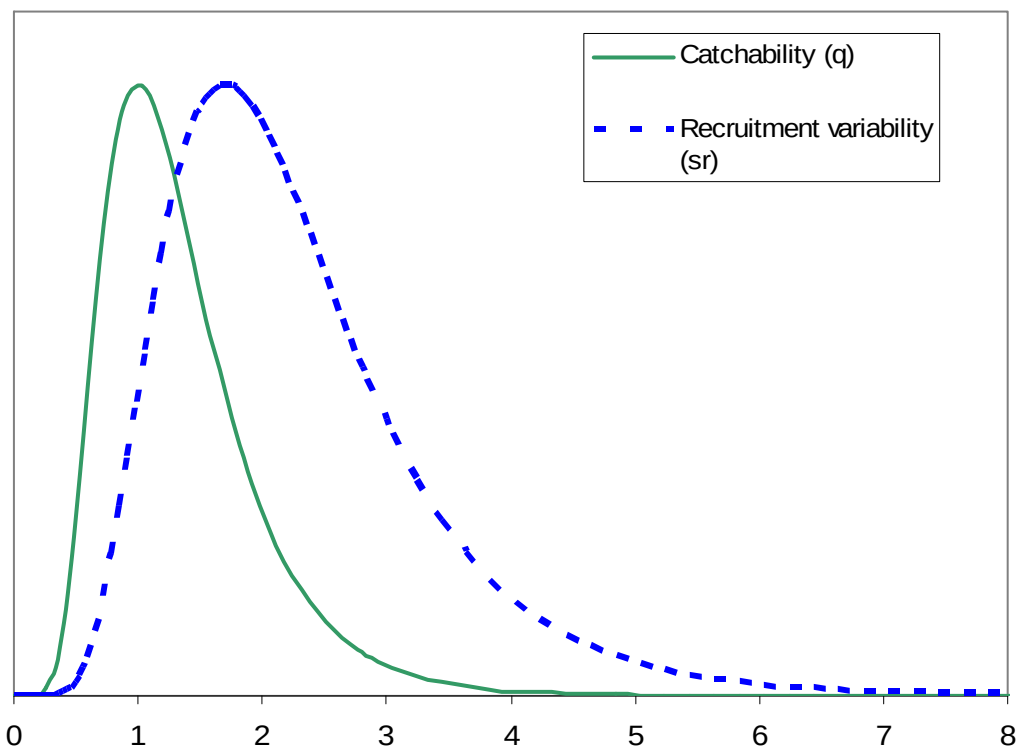


Figure 9-9. Prior distributions for catchability (*q,* μ=1, CV=45%) and recruitment variability (σ_r, μ=1.7, CV=45%) of Pacific ocean perch.

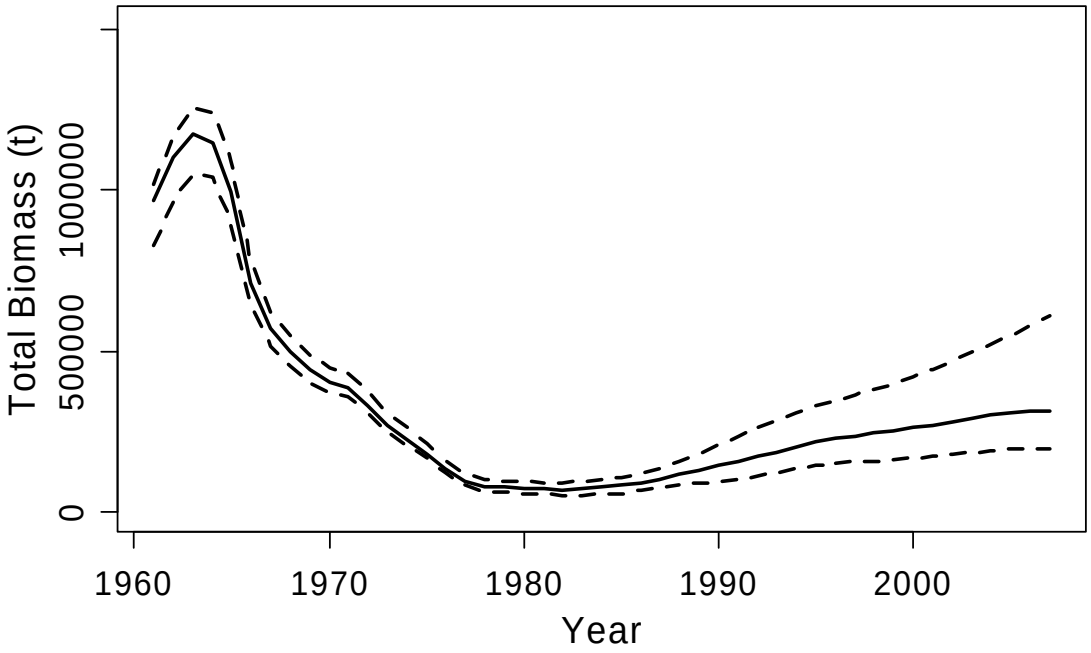


Figure 9-10. Model estimated total biomass (solid line) with 95% confidence intervals determined by MCMC (dashed line) for Gulf of Alaska Pacific ocean perch.

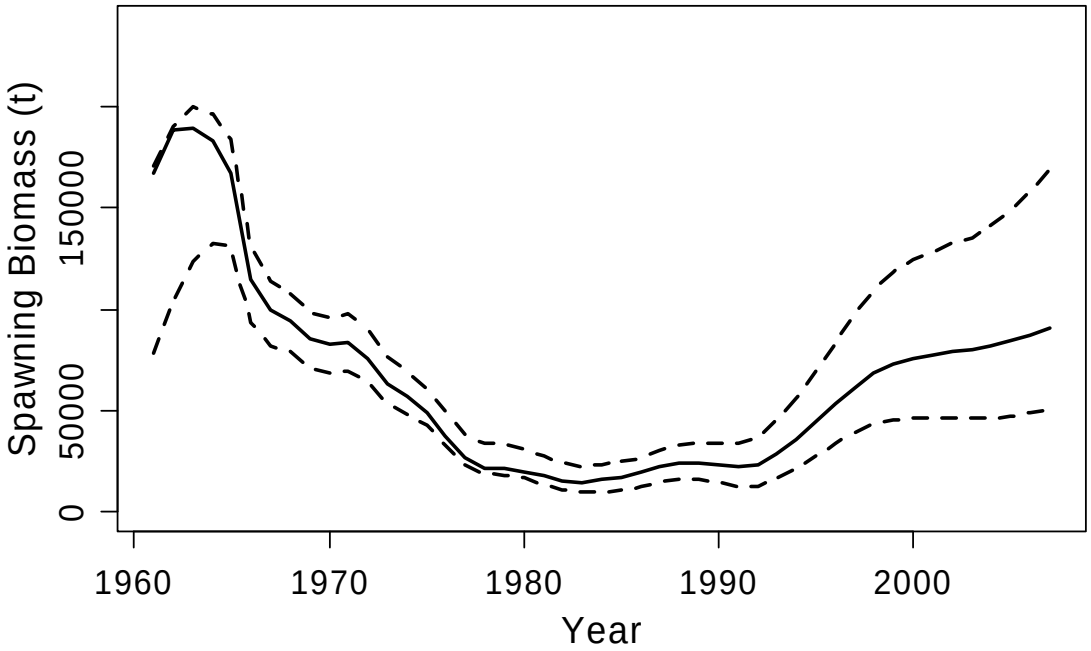


Figure 9-11. Model estimated spawning biomass (solid line) with 95% confidence intervals determined by MCMC (dashed line) for Gulf of Alaska Pacific ocean perch.

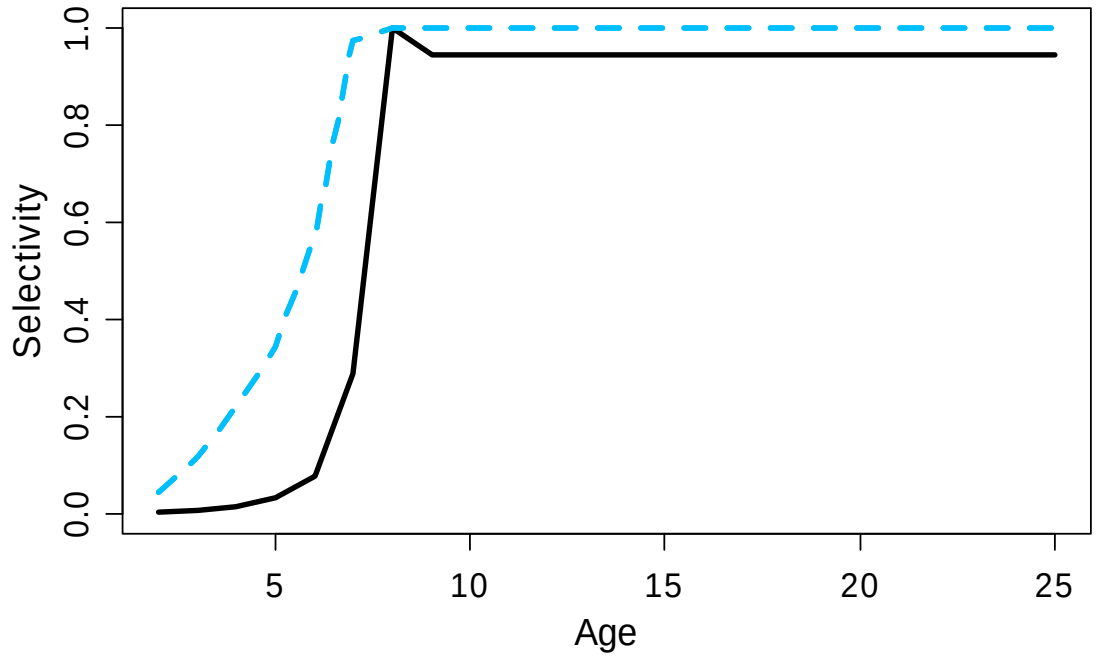


Figure 9-12. Estimated selectivities for the fishery (solid black line) and groundfish survey (blue dashed line) for Gulf of Alaska Pacific ocean perch.

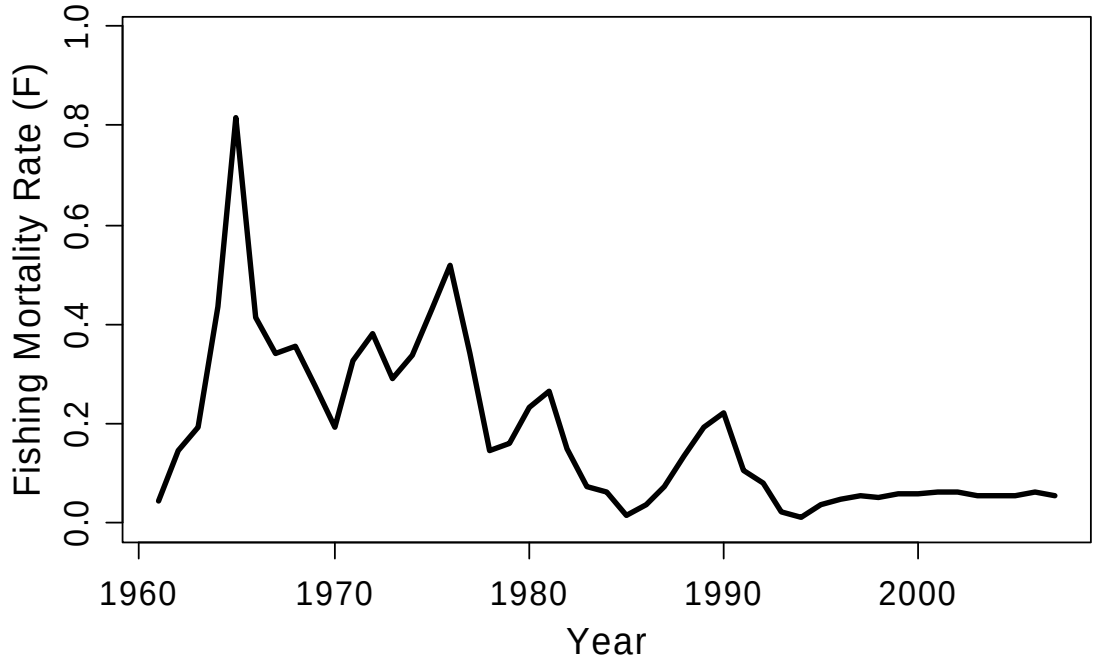
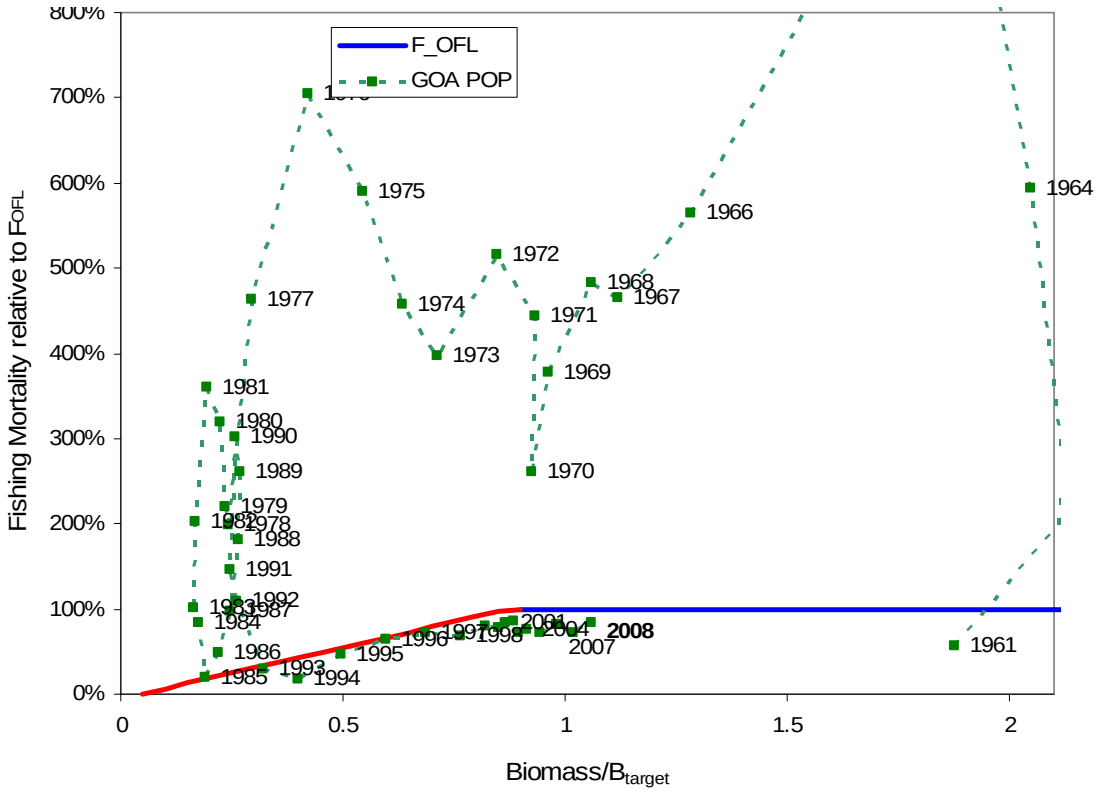


Figure 9-13. Estimated fully selected fishing mortality over time for GOA Pacific ocean perch.



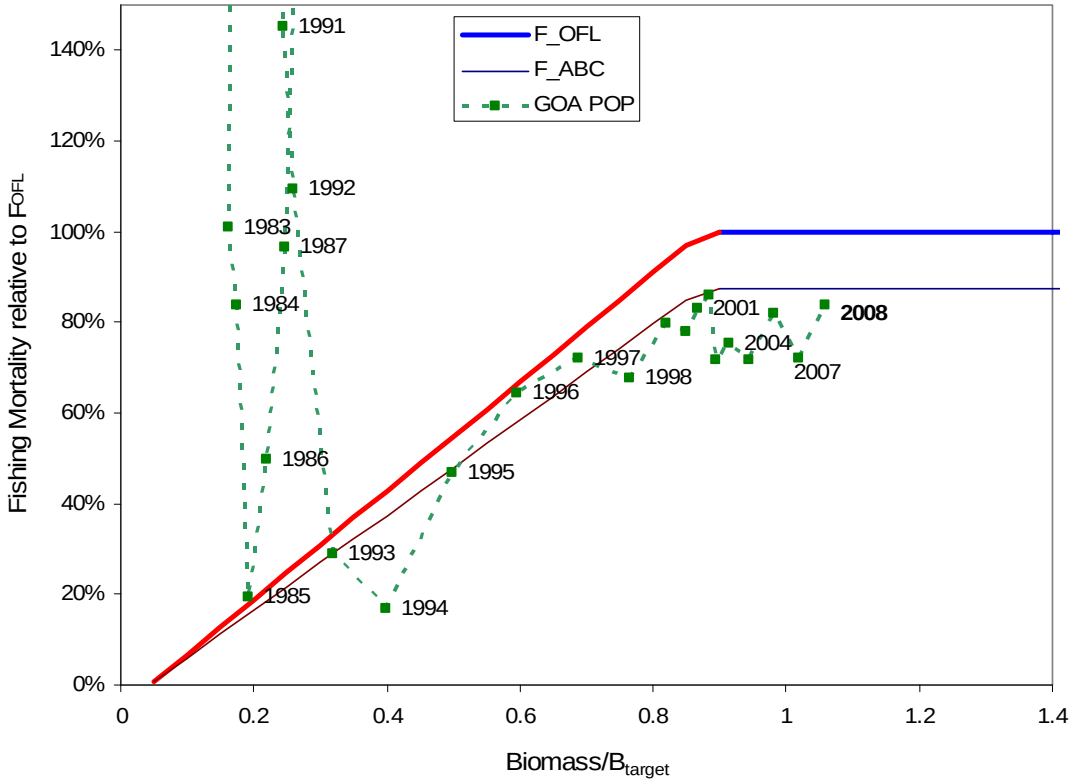
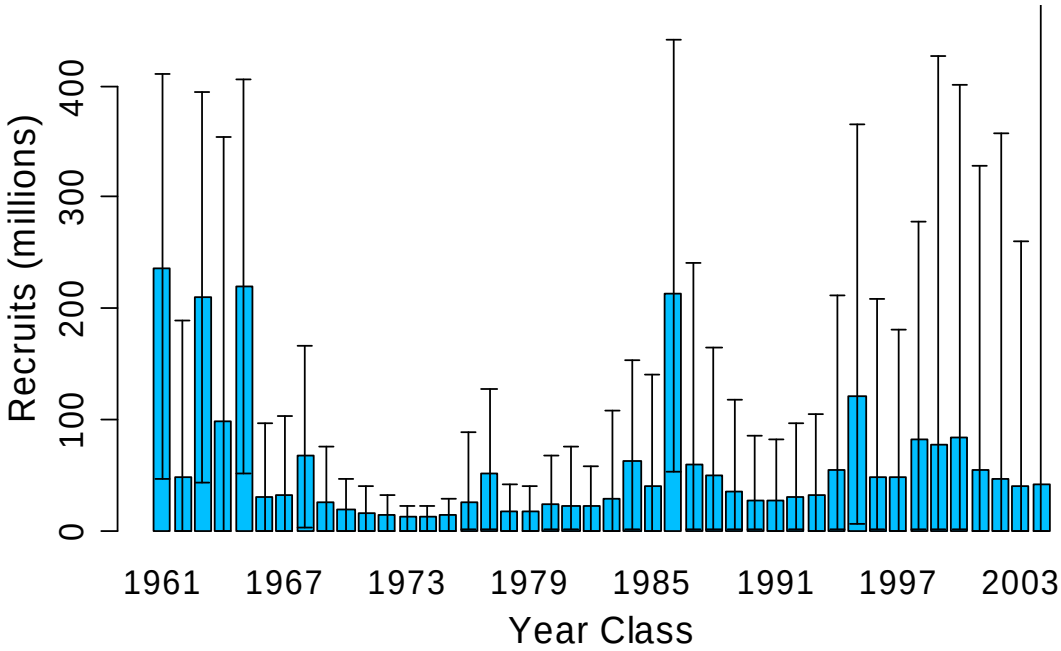


Figure 9-14. Time series of Pacific ocean perch estimated spawning biomass relative to the target level $B_{40\%}$ level and fishing mortality relative to F_{OFL} for author recommended model. Top shows whole time series. Bottom shows close up on more recent management path.



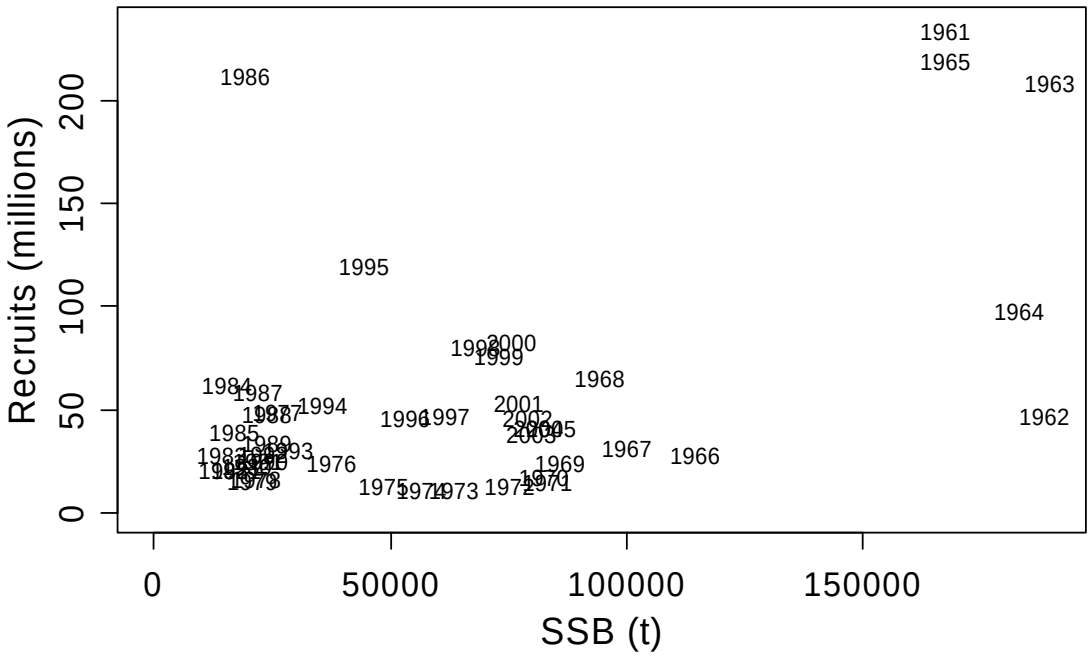


Figure 9-15. Estimated recruitment of Gulf of Alaska Pacific ocean perch (age 2) by year class with 95% confidence intervals derived from MCMC (top). Estimate recruits per spawning stock biomass (bottom).

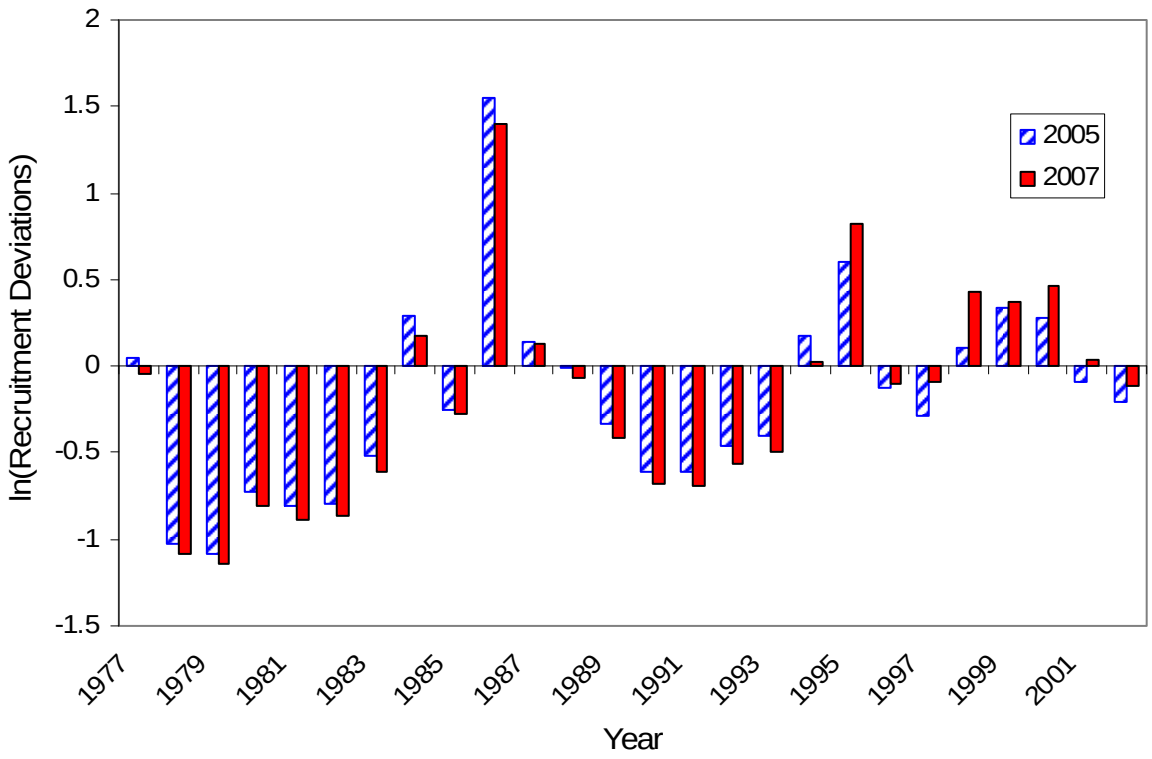


Figure 9-16. Recruitment deviations from average on the log-scale comparing last cycle's model to current for Gulf of Alaska Pacific ocean perch.

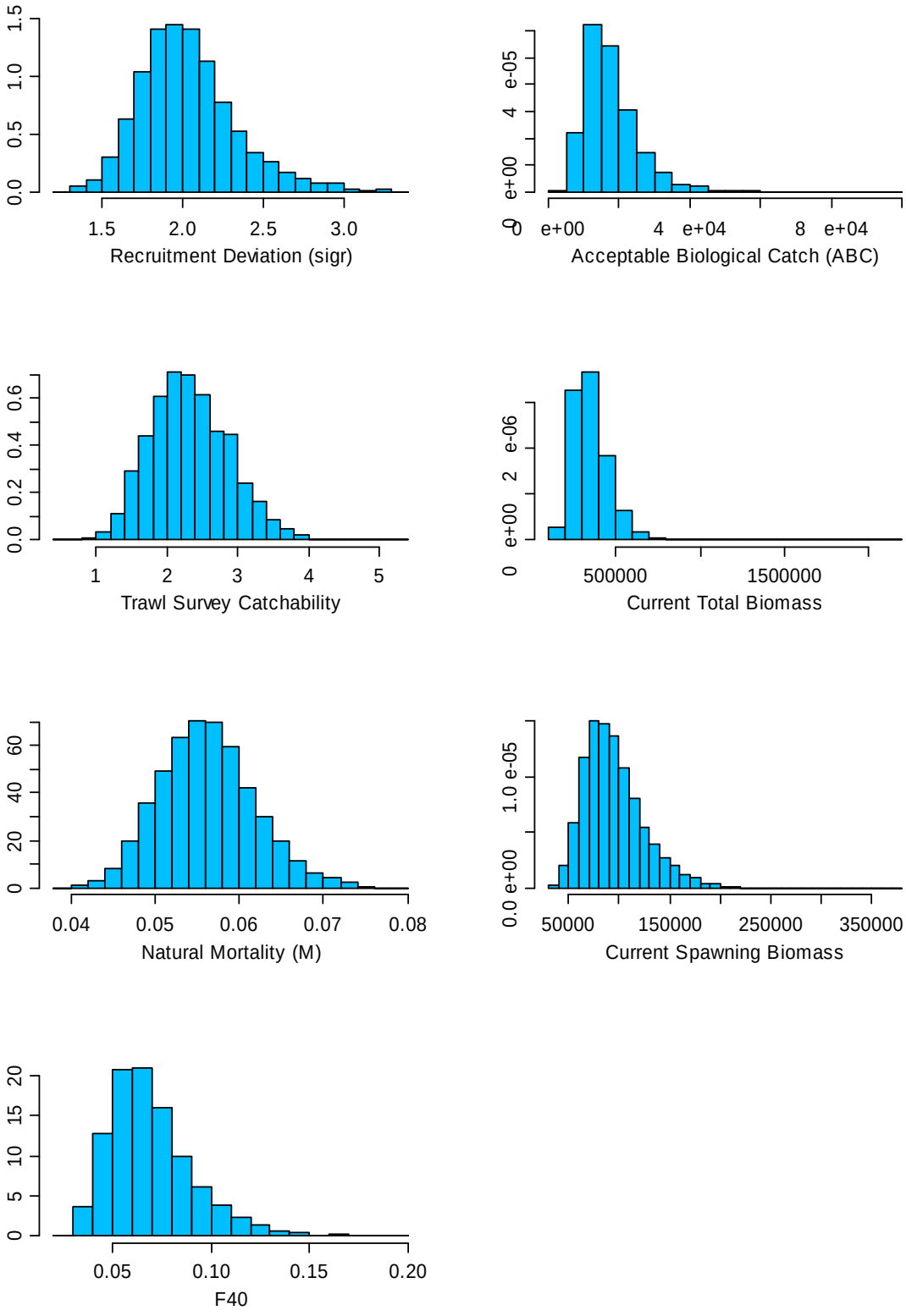


Figure 9-17. Histograms of estimated posterior distributions of key parameters derived from MCMC for Gulf of Alaska Pacific ocean perch.

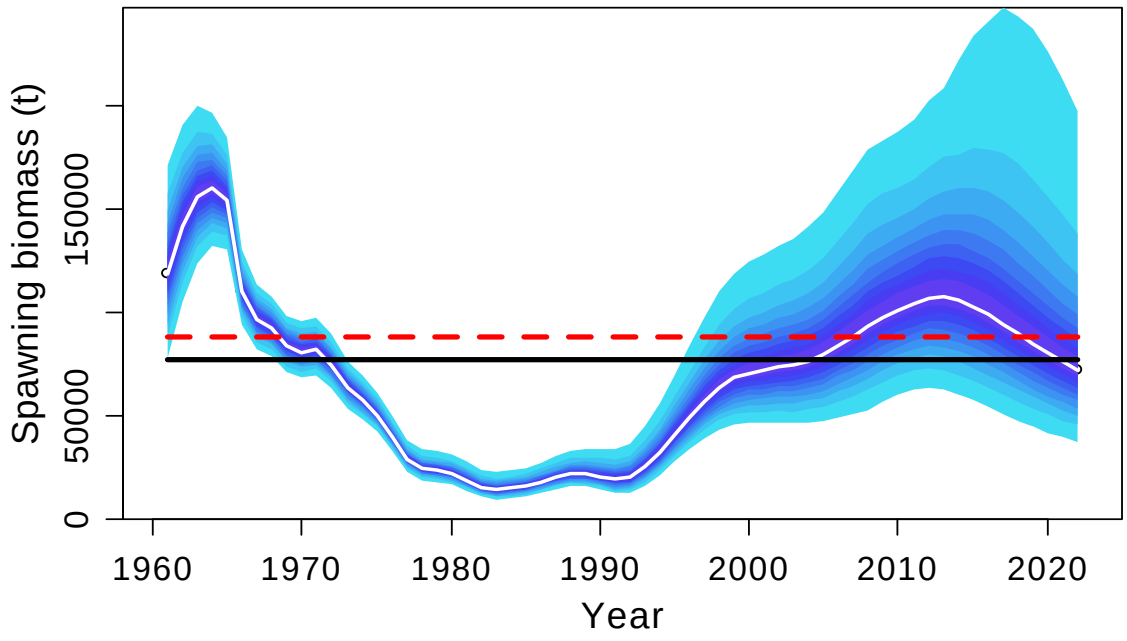


Figure 9-18. Bayesian credible intervals for entire spawning stock biomass series including projections through 2020. Red dashed line is $B_{40\%}$ and black solid line is $B_{35\%}$ based on recruitments from 1977-2003. The white line is the median of MCMC simulations.