8. Gulf of Alaska Pacific ocean perch

by

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8.0 Executive Summary

We continue to use the generic rockfish model as the primary assessment tool. This model was 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 is adaptable to several rockfish species. The data sets used included total catch biomass for 1961-2004, size compositions from the fishery for 1963-77 and 1991-97, survey age compositions for 1984, 1987, 1990, 1993, 1996, 1999 and 2003, fishery age composition for 1990, 1998-2002, 2004 and survey biomass estimates for 1984, 1987, 1990, 1993, 1996, 1999, 2001 2003 and 2005. New data in the model included the 2003 survey age composition, 2004 fishery age composition, estimated 2005 fishery catch and 2005 survey biomass estimates. Consecutive surveys' biomass estimates that have come in relatively high compared with estimates in the early 1990s with more precision have begun to influence the model estimates upward. The projected ABC for 2006 is 14,261 t which is 5% higher than last year's ABC of 13,575 t. The corresponding reference values for Pacific ocean perch are summarized below. The stock is not overfished, nor is it approaching overfishing status.

	2006	2007*
$B_{40\%}$ (t)	90,022	-
Female Spawning Biomass (t)	93,108	95,185
$F_{40\%}$	0.062	0.062
F_{ABC} (maximum allowable)	0.062	0.062
ABC (t; maximum allowable)	14,261	14,726
F_{OFL}	0.074	0.074
OFL (t)	16,927	17,152

*** Projected ABCs and OFLs for 2007 are derived using an expected catch value of 11,930 mt for 2006 based on recent ratios of catch to ABC.** The projection results of this method are listed under Author's F in Table 8.10. 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

> *"The Bayesian spawner-recruit analysis suggests that the current harvest rate is reasonable. However, as noted in the past by both the SSC and authors, the resiliency of GOA POP is largely influenced by several large recruitments in the late 1980's. The SSC supports further analyses and encourages authors to explore alternative spawner-recruit analyses based on subsets of the data and contrast those with an analysis using all of the data."*

We ran eight more trials of the Bayesian spawner-recruit analysis with updated recruitment data. In these trials we used Ricker and Beverton-Holt with the full data set, the full data set without the large 1988 recruitment, post-1977 recruitment, and post-1977 recruitment without the large 1988 recruitment. Spawner-per-recruit values at MSY remained in the range of 20-28%. The results were robust to different recruitment scenarios.

> *"We also request that an evaluation of the actual degree of loss of older aged females be provided, including an evaluation of how to adjust for early fishery data where there may have been intense fishing prior to historic age collections."*

Several figures are provided to help answer this question. It does appear that the amount of older fish in the Gulf POP age distribution has been slowly declining since the collection of reliable age samples in 1984. For more discussion, see section 8.2.3.

> *"The SSC requests that additional analysis be provided for rockfish regarding:*
> *a. A listing of species of rockfish which are most likely to be subject to local depletions either because of life-history characteristics or fishing practices;*
> *b. The availability of data for those species which could be used to evaluate the occurrence of local depletion; and*
> *c. The quality of data that would be needed to detect local depletion with reasonable certainty*."

We discuss several studies performed to detect local depletion in the Gulf of Alaska and the Aleutian Islands in section 8.24.

8.1 Introduction

8.1.1 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 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 very 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. Stock assessments for Alaska groundfish have assumed that the reproductive success of mature fish is independent of age. The AFSC has funded a project to determine if this relationship occurs for Pacific ocean perch in the Central Gulf of Alaska.

8.1.2 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.

8.1.3 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.

8.1.4 Fishery

8.1.4.1 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 8-1a). 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 8-1b). 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 8-1a for the commercial fishery and in Table 8-1b 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 8-1). Pacific ocean perch make up the majority of catches from this complex. The acceptable biological catches and quotas in Table 8-1 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 the last paragraph of section 8.1, the Eastern area for Pacific ocean perch has been subdivided into two areas, so there are now a total of four regulatory areas for these two management groups.)

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. The following table shows the percent of the total catch of Pacific ocean perch in the Central area that shore-based trawlers have taken since 1998[1]:

Percent of catch taken by shore-based trawlers in the Central area

1998	1999	2000	2001	2002	2003	2004	2005
32	41	52	43	58	54	48	44

Factory trawlers continued to take nearly all the catch in the Western and Eastern areas.

8.1.4.2 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[1]) 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[1].

8.1.4.3 Discards

Gulfwide discard rates[1] (% discarded) for Pacific ocean perch in the commercial fishery for 1994-2005 are listed as follows:

Year	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
% Discard	59.7	19.7	17.2	14.5	14.0	13.8	11.3	8.6	7.2	15.1	7.4	5.6

[1] National Marine Fisheries Service, Alaska Region, Fishery Management Section, P.O. Box 21668, Juneau, AK 99802-1688. Data are from weekly production and observer reports through October 4, 2005.

The high discard rates for Pacific ocean perch in 1994 can be attributed to its "bycatch only" status for most of this time period. Since then, discard rates for Pacific ocean perch have steadily decreased.

8.2 Data

The following table summarizes the data used for this assessment:

Source	Data	Years
NMFS Groundfish survey	Survey biomass	1984, 1987, 1990, 1993, 1996, 1999, 2001, 2003, 2005
	Age	1984, 1987, 1990, 1993, 1996, 1999, 2003
U.S. trawl fisheries	Catch	1961-2005
	Age	1990,1998-2002, 2004
	Length	1963-1977, 1991-1997

8.2.1 Fishery Data

8.2.1.1 Catch

Catches range from 2,500 t to 350,000 t from 1961 to 2005. Detailed catch information for Pacific ocean perch is listed in Table 8-1a and shown graphically in Figure 8-1.

8.2.1.2 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 8-2 summarizes the length compositions from 1990-2005. Table 8-3 summarizes age compositions from 1990, 1998-2002 and 2004 for the fishery. Figures 8-2 and 8-3 show the distributions graphically along with the model predictions. The age compositions in all seven 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 new 2004 fishery data show the presence of potentially 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 shows high correlation when lagged, indicating ages and collections are consistent.

8.2.2 Survey Data

8.2.2.1 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 these surveys became biennial for the 1999-2005 surveys. 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 8-4.

8.2.2.2 Comparison of Trawl Surveys in 1984-2005

Gulfwide biomass estimates for Pacific ocean perch are shown in Table 8-4. Gulfwide biomass estimates for 2005 and 95% confidence intervals are also shown graphically in Figure 8-4. 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 2003 and 2005 were more precise (Figure 8-4). 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 2005 and 1999 Figures 8-5 a, b). The 2005 survey had more stations than most of the previous surveys due to few problems and good weather. 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. Ongoing 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.

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 8-4. 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.

8.2.2.3 Age Compositions

Ages were determined from the break-and-burn method (Chilton and Beamish 1982). The survey age compositions from 1984-2003 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 8-5). 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 8-6). 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 data 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 indicates that 1994-1995 may also have been strong year classes.

8.2.2.4 Survey Size Compositions

Gulfwide population size compositions for Pacific ocean perch are shown in Figure 8-7. 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 is used in constructing the age-length transition matrix, but not used as data to be fit in the stock assessment model.

8.2.3 Age truncation

According to recent survey age data collected for Pacific ocean perch, the amount of very old fish (age 34+) has been declining since 1984 (34 was chosen as the age that is 40% of the maximum observed age, Figure 8-8.). These effects, though not as clear, are present in the absolute terms, where the abundance of old fish has declined while abundance for all ages has increased. Naturally, some age-truncation will occur in the presence of fishing. The individual age samples are too small and noisy to compare the sampled age-distributions with what is expected by fishing at $F_{40\%}$. However, we can examine the unweighted average age distribution over time (1984-2003) and compare what we would expect if the population had been fished at $F_{40\%}$ until equilibrium. When we examine the aggregate age structure, it appears the population age-structure corresponds more closely to an average fishing mortality of 0.11, which is about twice the fishing mortality recently recommended for Gulf of Alaska Pacific ocean perch (Figure 8-9). Of course, Pacific ocean perch have been fished at rates that are far higher than currently are recommended, such as values above F=0.5 in the 1960s and values as high as F=0.2 as recently as 1990. Therefore, these age effects, if real, could be residual from historic fishing.

The converse explanation starts with most evidence showing that the Gulf of Alaska Pacific ocean perch total biomass has been expanding since the early 1990s. Presumably this is from several year classes in the late 1980s, especially 1986, that have recruited to the survey and fishery. If these younger fish comprise most of the biomass, the proportion of older fish must go down to compensate.

In general, older fish make up a smaller proportion of the population than in 1984 and the proportion is less than would be expected at equilibrium fishing at $F_{40\%}$. However, populations like Pacific ocean perch with highly variable recruitment can be expected to be at disequilibrium and show fluctuations in age distribution that are unrelated to fishing.

8.2.4 Localized depletion

Localized depletion is defined here as the reduction of population size over a relatively small spatial area as a result of intensive fishing. Localized depletion is a potential conservation issue for rockfish because several species have been observed to be patchily distributed and stock structure could occur at relatively small spatial scales. Thus, intensive fishing upon local spawning populations could potentially lead to significant losses in stock productivity even if the exploitation rate over a broad management area is within management guidelines.

Declines in fishery CPUE within small spatial areas could be indicative of population declines and thus localized depletion. In a report presented to the SSC in January, 2005, Pacific ocean perch (POP) catch-per-unit-effort (CPUE) from the Aleutian Islands POP fishery in recent years were used to examine the extent to which CPUE has declined during the course of the fishery. The POP fishery in the Aleutian Islands is characterized by relatively few vessels fishing for a few weeks in July; data were obtained from three areas (two areas near Buldir Island, and one area near Atka Island) where large POP catches have recently occurred.

A total of 10 datasets from the three areas were examined, ranging from 2000-2004. Of these 10 datasets, 8 did not show a significant decline in CPUE that would be expected with a fishery-induced localized depletion. The two area-year combinations where declines in CPUE were significant were northwest Buldir in 2003 and 2004. If localized depletion occurs at temporal scales longer than one year, one would expect the CPUE in 2004 to be consistent with estimates observed near the end of the 2003 fishery. However, CPUE in 2004 was consistent with most of the days in 2003, suggesting that localized depletion does not seem to have carried over between years. Apparently the 2003 fishery caused a localized decline in the population, but the population replenished by movement and/or recruitment before the 2004 fishery. For these area-year combinations, the available data do not indicate significant declines in CPUE that would suggest localized depletion. However, one of the features of the POP fishery is that it is limited to only a few days each year in any given area, and the total number of hauls from which a daily CPUE can be computed may be limited to three or less for some area-day combinations. The observed lack of local depletion is consistent with the limited number of hauls in the fishery; conversely, statistically significant declines in CPUE will more difficult to observe with a limited number of hauls.

In an analogous study prepared for the Lowell-Wakefield Pacific rockfish symposium (Hanselman et al. *in review*[3]), larger areas were examined for localized depletion. In this study, 18 blocks were selected with regular rockfish harvest in the Gulf of Alaska and Aleutian Islands with areas of ~10,000 km^2. These areas were further divided in half to make 36 ~5,000 km^2 blocks. Two block sizes were used to try to further understand scale in the detection of localized depletion.

A total of 113 regressions were performed across 14 of the 18 selected areas. In both block sizes, regression slopes were mainly negative and approximately 26% of these negative slopes were significant ($p<0.05$). Only one regression had a significant positive slope. Intercepts were mainly significant. Depletions were detectable at both scales of block sizes and significant results occurred in similar areas and years between block sizes. Areas with the most consistent depletion were in the Eastern Aleutian Islands between Seguam Island and Yunaska Island. Regressions in area one block near Seguam Island showed depletions in the last three consecutive fishing seasons (2002-2004). The estimates of initial biomass suggested that much of the Pacific ocean perch biomass in this area was being depleted over the fishing season. However, these depletions did not seem to proceed where they left off in the following year. The area seems to be replenished by new fish or the fishery shifts to an aggregation nearby in the same area because the CPUE at the start of the fishery each year is similar and the estimate of initial biomass is also similar. In an adjacent block near Yunaska Island there were four significant depletions, but not in consecutive years. Several depletion events in the 1990s were found around Yakutat; however, this area is no longer fished for rockfish, mainly due to the Eastern Gulf of Alaska bottom trawling closure.

The same area was found to be depleted at all three spatial scales examined in the two studies presented here for the Buldir Reef area of the Aleutian Islands, indicating that depletion can be detected at different scales. The appropriate spatial and temporal scales at which localized depletion becomes important for rockfish is a subject for future research. Localized depletion becomes problematic if it diminishes the ability of rockfish to replenish fished areas such that local spawning populations are not eliminated. Thus,

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[2] Hanselman, D.H., P.D. Spencer, S.K. Shotwell, R. Reuter. Localized Depletion of Three Alaskan Rockfish Species. In Review. Lowell-Wakefield Symposium on Pacific Rockfish. September 2005.

evaluations of localized depletion for rockfish should reflect the spatial scale characterizing fish movement within a year and the location and spatial extent of spawning populations, and this information can be obtain from research on early life history and genetic stock structure. From a management perspective, localized aggregations of rockfish are logical candidate areas for spatial management measures, and identification of such areas can be aided if rockfish are observed to associate with certain habitat features.

8.3 Analytic Approach

8.3.1 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[4]. 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). 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 is 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.

8.3.2 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 8-6:

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

[4] Rockfish Modeling Workshop, NMFS Auke Bay Laboratory, 11305 Glacier Hwy., Juneau, AK. February, 2001.

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.

8.3.3 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 1%. 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), we assign it a less precise CV of 20%. 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 20%.

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. Other parameters are described in Box 1.

8.3.4 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 135. 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

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

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
$L_7 = \frac{1}{2\sigma_M^2} \left(\ln\left(M \middle/ M_{prior} \right) \right)^2$	Penalty on deviation from prior distribution of natural mortality
$L_8 = \frac{1}{2\sigma_q^2} \left(\ln\left(q \middle/ q_{prior} \right) \right)^2$	Penalty on deviation from prior distribution of catchability coefficient
$L_9 = \frac{1}{2\sigma_{\sigma_r}^2} \left(\ln\left(\sigma_r \middle/ \sigma_{r(prior)} \right) \right)^2$	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

8.4 Model Evaluation

This model is the same model adopted in 2003 and used in 2004, 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.

8.5 Model Results

Key results have been summarized in Tables 8-7 and 8-8. Model predictions continue to fit the data well (Figures 8-2, 8-4, 8-5, and 8-6) 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.

8.5.1 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 around 300,000 t for 2005 (Figure 8-10). 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 8-11). 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 8-12). Fish are fully selected by both fishery and survey by about age 8. Fishery selectivity has a slight dome-shape, this is because we place a very small penalty on dome-shapedness in the selectivity curve.

Fully-selected fishing mortality (fishing mortality including fishery selectivity) shows that fishing mortality has decreased dramatically from historic rates and has leveled out in the last decade (Figure 8-13). 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. In a management path we plot estimated fishing mortality relative to the (current) target value and the estimated spawning biomass relative to the (current) target spawning biomass. The plot in Figure 8-14 suggests that management is on track and the stock is in the 'optimum' quadrant where $B_{now}/B_{40\%}$ has recently exceeded one for the first time since the 1960s. $F_{now}/F_{40\%}$ continues to stay below one.

8.5.2 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 8-15). Recruitment appears to have increased since the early 1970s, with the 1986 year class becoming progressively more important. 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, particularly the first survey ages since 1999, has increased recruitment estimates for the 1994 and 1995 year classes and shows potential higher recruitments for the 1999 and 2000 year classes when compared to results from last year's model (Figure 8-16). However, these recruitments, especially recently, are still highly uncertain as indicated by the MCMC confidence intervals in Figure 8-15.

8.5.3 Uncertainty results

From the MCMC chains described in Section 8.5.3, we summarize the posterior densities of key parameters for the recommended model using histograms (Figure 8-17) and confidence intervals (Table 8-8). We also use these posterior distributions to show uncertainty around time series estimates such as total biomass, spawning biomass and recruitment (Figs. 8-10, 8-11, 8-15).

Table 8-8 shows the maximum likelihood estimate (MLE) of key parameters with their corresponding standard deviation derived from the Hessian matrix. Also shown is the MCMC standard deviation and the corresponding Bayesian 95% confidence intervals (BCI). The MLE and MCMC standard deviations are similar for *q, M* and F_{40}, but the MCMC standard deviations are larger for the estimates of current female spawning biomass, 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. The distribution of ABC and spawning biomass are skewed, indicating possibilities of higher biomass estimates (also see Figure 8-11). 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.

8.6 Projections and Harvest Alternatives

8.6.1 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 1979-2001 (year classes between 1977 and 1999). Other useful biomass reference points which can be calculated using this assumption are $B_{100\%}$ and $B_{35\%}$, defined analogously to $B_{40\%}$. 2005 estimates of these reference points are:

$B_{100\%}$	$B_{40\%}$	$B_{35\%}$	$F_{40\%}$	$F_{35\%}$
225,056	90,022	78,770	0.062	0.074

8.6.2 Specification of OFL and Maximum Permissible ABC

Female spawning biomass for 2006 is estimated at 93,108 t. This is above the $B_{40\%}$ value of 90,022 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 2006, yields the following ABC and OFL:

$F_{40\%}$	0.062
ABC	14,261
$F_{35\%}$	0.074
OFL	16,927

8.6.3 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 2005 numbers at age estimated in the assessment. This vector is then projected forward to the beginning of 2006 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2005. 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 2006, 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 2006 recommended in the assessment to the *max* F_{ABC} for 2006. (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 three year average of the ratio of catch to TAC and multiply it against future ABCs predicted by Scenario 1 to estimate catches for 2006 and 2007. 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 2001-2005 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 *FOFL*. (Rationale: This scenario determines whether a stock is overfished. If the stock is expected to be 1) above its MSY level in 2006 or 2) above ½ of its MSY level in 2006 and above its MSY level in 2016 under this scenario, then the stock is not overfished.)

Scenario 7: In 2006 and 2007, *F* is set equal to *max FABC*, 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 2018 under this scenario, then the stock is not approaching an overfished condition.)

8.6.4 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 2006:

a) If spawning biomass for 2006 is estimated to be below ½ $B_{35\%}$, the stock is below its MSST
b) If spawning biomass for 2006 is estimated to be above $B_{35\%}$, the stock is above its MSST.
c) If spawning biomass for 2006 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 8-10). If the mean spawning biomass for 2016 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 8-10):

a) If the mean spawning biomass for 2006 is below ½ $B_{35\%}$, the stock is approaching an overfished condition.
b) If the mean spawning biomass for 2006 is above $B_{35\%}$, the stock is not approaching an overfished condition.
c) If the mean spawning biomass for 2006 is above ½ $B_{35\%}$ but below $B_{35\%}$, the determination depends on the mean spawning biomass for 2016. If the mean spawning biomass for 2016 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 8-10. For Pacific ocean perch the stock is not overfished and is not approaching an overfished condition.

8.6.5 Area Allocation 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 2001, 2003, and 2005 surveys, respectively and apportionments of 29% for the Western area, 52% for the Central area, and 19% for the Eastern area (Table 8-11). This results in recommended ABC's of 4,155 t for the Western area, 7,418, t for the Central area, and 2,688 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 1999, 2003 and 2005 (2001 did not sample the Eastern Gulf). We calculated the approximate upper 95% confidence interval using the weighted variance of the 1999-2005 ratios for our weighted ratio estimate. This resulted in slightly higher ratio than last year of 0.41. This results in the following apportionment to the W. Yakutat area:

ABC (t)	1,101
OFL (t)	1,314

which would leave 1,587 t unharvested in the Eastern Gulf.

8.6.6 Overfishing Definition

Based on the definitions for overfishing in Amendment 44 in tier 3a (i.e., $F_{OFL} = F_{35\%}$=0.074), overfishing is set equal to 16,927 t for Pacific ocean perch. The overfishing level is apportioned by area for Pacific ocean perch. Using the apportionment in Section 8.8.5, results in overfishing levels by area of 4,931 t in the Western area, 8,805 t in the Central area, and 3,190 t in the Eastern area.

8.7 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 8-12.

8.7.1 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. Changes in the abundance of walleye pollock could lead to a corollary change in the availability of euphausiids, which would then have an impact on Pacific ocean perch.

Predator population trends: Pacific ocean perch are preyed on 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 have effect on prey item abundance and success of transition of rockfish from 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.

8.7.2 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 8-13).

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: Proportion of older fish has declined since 1984, whether this is a result of fishing or large year-classes of younger fish coming into the population is unknown.

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 8-14, 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.

8.8 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 and age-reading. Further work to verify the reasonableness of a catchability estimate near 2 would also be useful.

8.9 Summary

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

Year	2006	2007*
Tier	3a	3a
Total Biomass (Age 2+)	312,968	315,507
Female spawning biomass (t)	93,108	95,185
$B_{0\%}$ (t)	225,056	-
$B_{40\%}$ (t)	90,022	-
$B_{35\%}$ (t)	78,770	-
M	0.060	0.060
$F_{40\%}$	0.062	0.062
F_{ABC} (maximum allowable)	0.062	0.062
ABC (t; maximum allowable)	14,261	14,726
F_{OFL}	0.074	0.074
OFL (t)	16,927	17,152

*** Projected ABCs and OFLs for 2007 are derived using an expected catch value of 11,930 mt for 2006 based on recent ratios of catch to ABC.** The projection results of this method are listed under Author's F in Table 8.10. This was done in response to management requests to obtain a more accurate one-year projection.

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Tables

Table 8-1a. 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), 1977-2005. Catches in 2005 updated through October 1, 2005.

			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 8-1a (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	11,356	13,575	13,580

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); 2001-2005, NMFS Alaska Regional Office catch reports (http://www.fakr.noaa.gov).

Table 8-1b. Catch (t) of Pacific ocean perch taken during research cruises in the Gulf of Alaska, 1977-2005. (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

Table 8-2. Fishery length frequency data for Pacific ocean perch in the Gulf of Alaska.

Length								**Year**								
Class(cm)	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
<13	35	0	9	0	0	0	0	34	0	0	0	0	0	0	0	0
13-15	127	14	24	0	0	1	1	11	0	0	1	1	0	0	0	0
16	33	16	20	0	0	0	0	23	0	0	2	0	0	0	0	0
17	21	31	29	0	0	0	0	35	0	1	2	0	0	1	1	0
18	54	17	24	0	0	0	0	69	0	0	0	2	0	2	2	0
19	15	56	33	0	0	0	0	25	1	0	1	0	0	1	3	0
20	41	118	26	0	0	1	0	25	4	3	2	7	0	2	2	3
21	64	145	50	0	0	0	2	27	7	2	5	6	3	8	2	2
22	66	149	62	0	0	1	1	30	4	0	2	9	6	5	3	7
23	148	232	65	0	1	9	4	37	8	6	2	7	8	4	4	6
24	214	253	82	0	0	21	6	34	23	13	8	5	15	3	11	6
25	239	252	106	0	0	36	18	52	30	13	9	14	32	8	17	6
26	375	339	116	0	0	65	27	80	48	20	24	11	28	9	19	22
27	473	265	134	0	1	50	38	120	37	21	48	20	32	24	19	18
28	596	204	134	0	2	46	42	126	54	22	40	26	41	41	34	44
29	931	217	193	1	4	67	68	164	69	42	55	42	43	47	80	58
30	1450	187	283	3	2	68	103	227	79	29	61	49	47	53	103	90
31	2121	291	446	5	3	132	197	259	117	43	91	61	59	72	70	124
32	3158	442	697	14	11	255	327	345	165	71	88	91	102	103	100	172
33	4454	651	1262	17	40	535	740	641	298	156	141	163	213	156	144	221
34	5386	1048	1777	25	94	844	1392	1074	799	328	345	263	359	372	232	290
35-38	21455	5394	5463	60	610	3389	6672	7861	9040	2698	3535	2695	2537	3084	2567	2101
>38	10180	3252	1270	5	128	1060	1502	3312	3327	1182	1695	1304	1455	1890	1621	1163
Total	51636	13573	12305	130	896	6580	11140	14611	14110	4650	6157	4776	4980	5885	5034	4333

Table 8-3. Fishery age compositions for GOA Pacific ocean perch 1990-2004.

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

Table 8-4. Biomass estimates (t) and Gulfwide confidence intervals for Pacific ocean perch in the Gulf of Alaska based on the 1984-2005 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

*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 8-5. 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
2-	0.007	0.009	0.014	0.027	0.010	0.046	0.019
3	0.002	0.085	0.059	0.046	0.031	0.099	0.057
4	0.061	0.101	0.116	0.050	0.063	0.099	0.053
5	0.029	0.058	0.095	0.071	0.070	0.111	0.071
6	0.052	0.061	0.114	0.102	0.111	0.060	0.040
7	0.115	0.115	0.097	0.102	0.058	0.061	0.054
8	0.386	0.047	0.073	0.090	0.075	0.058	0.107
9	0.028	0.056	0.063	0.114	0.111	0.065	0.115
10	0.016	0.084	0.058	0.064	0.130	0.030	0.057
11	0.007	0.104	0.037	0.034	0.077	0.058	0.053
12	0.013	0.021	0.025	0.039	0.058	0.072	0.044
13	0.010	0.013	0.026	0.032	0.025	0.040	0.036
14	0.012	0.012	0.070	0.020	0.022	0.036	0.057
15	0.005	0.012	0.015	0.029	0.019	0.021	0.047
16	0.003	0.016	0.012	0.013	0.007	0.025	0.042
17	0.008	0.018	0.006	0.044	0.015	0.012	0.032
18	0.005	0.010	0.008	0.010	0.011	0.009	0.029
19	0.002	0.006	0.006	0.003	0.018	0.003	0.016
20	-	0.009	0.007	0.003	0.017	0.008	0.015
21	0.004	0.007	0.007	0.003	0.007	0.005	0.010
22	0.003	0.003	0.002	0.005	0.006	0.009	0.005
23	0.002	0.004	0.003	0.003	0.003	0.014	0.006
24	0.006	0.003	0.005	0.005	-	0.005	0.007
25+	0.224	0.147	0.083	0.091	0.056	0.052	0.031
Total	2575	1824	1766	1492	718	963	1003

Table 8-6. Estimated numbers (thousands) in 2005, 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 2005 (1000's)	Percent mature	Weight (g)	Fishery selectivity	Survey selectivity
2	42,884	0	46	0	5
3	40,356	0	106	1	13
4	42,765	0	180	2	22
5	58,461	0	261	4	35
6	57,879	0	342	8	59
7	43,122	12	420	29	98
8	27,198	20	493	100	100
9	28,446	30	559	93	100
10	52,901	42	619	93	100
11	30,934	56	672	93	100
12	15,599	69	718	93	100
13	13,177	79	758	93	100
14	10,193	87	792	93	100
15	9,167	92	822	93	100
16	10,975	95	847	93	100
17	13,833	97	868	93	100
18	14,787	98	886	93	100
19	55,596	99	902	93	100
20	8,314	99	915	93	100
21	12,459	100	926	93	100
22	4,650	100	935	93	100
23	2,791	100	943	93	100
24	2,257	100	950	93	100
25+	13,907	100	970	93	100

Table 8-7. Summary of results from 2005 compared with 2004 results

	2005		2004	
Likelihoods	**Value**	**Weight**	**Value**	**Weight**
Catch	0.09	50	0.13	50
Survey Biomass	8.10	1	7.23	1
Fishery Ages	24.40	1	14.35	1
Survey Ages	44.25	1	40.19	1
Fishery Sizes	49.73	1	54.36	1
Data-Likelihood	126.58		116.26	
Penalties/Priors				
Recruitment Devs	23.83	1	24.12	1
Fishery Selectivity	1.96	1	0.99	1
Survey Selectivity	0.38	1	0.25	1
Fish-Sel Domeshape	0.01	1	0.00	1
Survey-Sel Domeshape	0.00	1	0.00	1
Average Selectivity	0.00	1	0.00	1
F Regularity	4.89	0.1	4.94	0.1
σ_r prior	1.06		0.00	
q prior	1.03		1.03	
M prior	1.81		1.80	
Objective Fun Total	161.53		149.39	
Parameter Ests.		LN Prior (μ,σ)		LN Prior (μ,σ)
q	1.90	(1,0.2)	1.85	(1,0.2)
M	0.06	(0.05,0.01)	0.06	(0.05,0.01)
σ_r	0.89	(1.7,0.2)	0.90	(1.7,0.2)
log-mean-recruitment	3.76		3.76	
$F_{40\%}$	0.062		0.060	
Total Biomass	312,968		286,370	
B_{2006}	93,108		90,572*	
$B_{0\%}$	225,056		215,405	
$\mathbf{B_{40\%}}$	90,022		86,162	
$\mathbf{ABC_{F40\%}}$	14,261		13,575	
$F_{35\%}$	0.074		0.072	
$OFL_{F35\%}$	16,927		16,266	
$F_{50\%}$	0.044		0.044	
$ABC_{F50\%}$	10,071		9,330	

*As predicted by the 2004 projection model

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

Parameter	μ	σ	σ(MCMC)	BCI-Lower	BCI-Upper
q	1.90	0.50	0.55	1.21	3.40
M	0.060	0.006	0.006	0.046	0.067
$F_{40\%}$	0.062	0.015	0.016	0.041	0.102
Female Sp. Biomass	93,108	28,973	37,843	46,266	172,602
ABC	14,261	2,834	3,261	9,063	21,606
σ_r	0.90	0.114	0.33	1.52	2.80

Table 8-9. 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	27,339	24,722	90,490	84,906	0.239	0.254	15,327	15,607
1978	22,552	20,028	73,253	67,806	0.109	0.118	27,499	25,836
1979	22,012	19,466	69,311	64,015	0.120	0.130	55,717	35,867
1980	20,972	18,484	64,786	59,671	0.167	0.181	19,030	20,634
1981	18,609	16,241	58,172	53,257	0.181	0.197	17,954	23,655
1982	16,156	13,876	55,197	49,956	0.098	0.108	25,780	44,760
1983	15,779	13,535	65,657	55,106	0.043	0.051	23,635	35,567
1984	17,135	14,550	70,606	59,719	0.039	0.046	23,973	33,529
1985	18,681	15,822	75,026	65,147	0.011	0.012	31,520	47,067
1986	21,307	18,143	83,199	78,267	0.026	0.028	70,956	43,298
1987	23,989	20,808	89,266	88,312	0.050	0.051	41,065	41,062
1988	26,142	23,123	92,845	95,560	0.092	0.089	248,869	215,184
1989	26,747	24,344	94,028	102,114	0.125	0.115	61,247	150,695
1990	25,941	24,801	102,538	104,640	0.128	0.125	52,591	48,745
1991	25,278	25,027	103,676	105,587	0.064	0.063	37,915	33,688
1992	26,971	27,474	166,983	159,495	0.037	0.039	28,608	32,176
1993	33,307	33,632	189,340	203,884	0.011	0.010	28,760	29,448
1994	41,252	42,963	212,428	228,144	0.009	0.008	33,432	32,631
1995	51,140	53,373	230,036	246,119	0.025	0.023	35,574	43,009
1996	61,129	63,940	238,680	256,535	0.035	0.033	63,270	54,262
1997	70,651	74,379	242,094	260,687	0.039	0.037	96,762	46,526
1998	78,584	83,518	243,524	262,111	0.037	0.034	46,747	39,267
1999	84,468	90,590	244,707	265,143	0.043	0.039	39,979	39,674
2000	87,859	94,898	250,794	268,733	0.040	0.038	58,775	40,832
2001	89,909	97,460	266,657	270,432	0.041	0.040	73,951	41,779
2002	91,423	98,208	270,252	269,097	0.043	0.044	70,178	42,470
2003	92,093	97,707	270,300	266,313	0.040	0.041	48,286	42,764
2004	93,167	97,197	275,346	264,334	0.042	0.044	42,878	42,786
2005	94,600		283,787		0.040		42,884	

Table 8-10. 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 section 8.8.1. All units in t. $B_{40\%}$ = 90,022 t, $B_{35\%}$ = 78,770 t, $F_{40\%}$ = 0.062, and $F_{35\%}$ = 0.074.

Year	Maximum permissible F	Author's F (prespecificed catch)	Half maximum F	5-year average F	No fishing	Overfished	Approaching overfished
		Spawning biomass (t)					
2005	91,283	91,283	91,283	91,283	91,283	91,283	91,283
2006	92,811	93,108	93,702	93,106	94,602	92,469	92,811
2007	93,992	95,185	97,603	95,177	101,355	92,632	93,992
2008	94,704	96,485	101,093	96,781	107,922	92,345	94,353
2009	95,244	96,984	104,443	98,207	114,554	91,913	93,853
2010	95,484	97,159	107,458	99,304	120,984	91,230	93,078
2011	95,734	97,328	110,178	100,413	127,489	90,652	92,390
2012	95,499	96,990	112,342	100,917	133,230	89,649	91,241
2013	94,975	96,354	114,005	101,145	138,501	88,585	89,985
2014	94,374	95,635	115,078	101,119	143,271	87,499	88,700
2015	93,726	94,868	115,717	100,980	147,668	86,518	87,535
2016	93,196	94,216	116,543	100,853	151,853	85,727	86,579
2017	92,795	93,695	117,010	100,682	155,750	85,051	85,760
2018	92,534	93,322	117,021	100,561	159,471	84,549	85,135
		Fishing mortality					
2005	0.051	0.051	0.051	0.051	0.051	0.051	0.051
2006	0.062	0.052	0.031	0.052	-	0.074	0.074
2007	0.062	0.052	0.031	0.052	-	0.074	0.074
2008	0.062	0.062	0.031	0.052	-	0.074	0.074
2009	0.062	0.062	0.031	0.052	-	0.074	0.074
2010	0.062	0.062	0.031	0.052	-	0.074	0.074
2011	0.062	0.062	0.031	0.052	-	0.074	0.074
2012	0.062	0.062	0.031	0.052	-	0.074	0.074
2013	0.062	0.062	0.031	0.052	-	0.073	0.073
2014	0.062	0.062	0.031	0.052	-	0.072	0.072
2015	0.062	0.062	0.031	0.052	-	0.071	0.071
2016	0.062	0.062	0.031	0.052	-	0.070	0.070
2017	0.061	0.062	0.031	0.052	-	0.069	0.069
2018	0.061	0.061	0.031	0.052	-	0.069	0.069
		Yield (t)					
2005	11,356	11,356	11,356	11,356	11,356	11,356	11,356
2006	14,261	14,261	7,230	11,945	-	16,927	14,261
2007	14,597	14,726	7,599	12,334	-	17,152	14,597
2008	14,762	15,015	7,876	12,576	-	17,181	17,522
2009	14,595	14,829	7,978	12,534	-	16,831	17,143
2010	14,370	14,586	8,037	12,436	-	16,430	16,714
2011	14,207	14,404	8,117	12,385	-	16,124	16,382
2012	14,177	14,356	8,257	12,448	-	15,882	16,237
2013	14,122	14,284	8,350	12,447	-	15,528	15,888
2014	14,039	14,187	8,449	12,466	-	15,204	15,516
2015	13,978	14,133	8,504	12,424	-	14,850	15,114
2016	13,834	13,993	8,559	12,392	-	14,552	14,773
2017	13,730	13,878	8,614	12,371	-	14,327	14,506
2018	13,685	13,817	8,669	12,360	-	14,169	14,314

Table 8-11. Allocation of ABC and OFL for 2006 Pacific ocean perch in the Gulf of Alaska.

		Western	Central		Eastern		
Year	Weights	Shumagin	Chirikof	Kodiak	Yakutat	Southeast	Total
2001	4	32%	5%	45%	5%	12%	100%
2003	6	16%	25%	36%	6%	16%	100%
2005	9	33%	10%	39%	10%	8%	100%
Weighted Mean	19	29%	12%	40%	8%	11%	100%
Area Allocation		29%	52%		19%		
Area ABC		**4,155**	**7,418**		**2,688**		**14,261**
Area OFL		**4,931**	**8,805**		**3,190**		**16,927**

Table 8-12. 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 being initiated in 2005

Table 8-13. Bycatch (kg) and bycatch rates during 1997 - 2005 of living substrates in the Gulf of Alaska for combined rockfish fisheries, all gears. Source: Alaska Regional Office Data prepared by Gaichas and Ackley, unpublished data. Rockfish catch for 2005 is an estimate.

	1997	1998	1999	2000	2001	2002	2003	2004	2005	Average
Non-target species	Bycatch (kg)									
Sea Pens/Whips	0	0	23	12	30	18	0	2	43	14
Sponges	1,504	643	5,393	1,482	1,887	1,951	3,815	1,140	1,130	2,105
Anemones	459	15	673	1,438	255	335	3,304	2,940	296	1,079
Tunicates	14	45	6	481	8	38	2	130	0	80
Echinoderms	2,023	532	2,016	773	2,952	683	3,467	2,103	1,514	1,785
Coral	1,636	330	766	10,005	4,317	15,143	1,904	65	6,125	4,477
Rockfish Catch (tons)	13,083	13,592	18,333	15,947	15,672	16,977	20,144	20,012	20,000	17,084
	Bycatch rate (kg/t target)									
Sea Pens/Whips	0.000	0.000	0.001	0.001	0.002	0.001	0.000	0.000	0.002	0.001
Sponges	0.115	0.047	0.294	0.093	0.120	0.115	0.189	0.057	0.057	0.121
Anemones	0.035	0.001	0.037	0.090	0.016	0.020	0.164	0.147	0.015	0.058
Tunicates	0.001	0.003	0.000	0.030	0.001	0.002	0.000	0.006	0.000	0.005
Echinoderms	0.155	0.039	0.110	0.049	0.188	0.040	0.172	0.105	0.076	0.104
Coral	0.125	0.024	0.042	0.627	0.276	0.892	0.095	0.003	0.306	0.266

Table 8-14. Estimates of non-target bycatch in the Gulf of Alaska rockfish fisheries from 2003-2005. Data are from the NMFS Regional Office prepared by Gaichas and Ackley as of Oct 4, 2005.

	Estimated Catch (kg)			Estimated Proportions		
Group Name	2003	2004	2005	2003	2004	2005
Benthic urochordata	2	130		0.0%	0.0%	0.0%
Birds (fulmar)	215			0.0%	0.0%	0.0%
Bivalves	5			0.0%	0.0%	0.0%
Brittle star unidentified	161	2	47	0.0%	0.0%	0.0%
Corals Bryozoans unidentified	1,903	60	6,125	0.2%	0.0%	1.3%
Red Tree Coral	0	5		0.0%	0.0%	0.0%
Eelpouts	30	222	11,511	0.0%	0.0%	2.5%
Eulachon	11	197	87	0.0%	0.0%	0.0%
Giant Grenadier	139,262	418	134,077	16.1%	0.0%	28.7%
Greenlings	8,372	6,923	3,542	1.0%	0.2%	0.8%
Grenadier Unidentified	480,913	2,835,239	95,760	55.6%	92.2%	20.5%
Hermit crab unidentified	13	10	40	0.0%	0.0%	0.0%
Invertebrate unidentified	441	938	98	0.1%	0.0%	0.0%
Lanternfishes (myctophidae)		0		0.0%	0.0%	0.0%
Large Sculpins	123	42,999	16,478	0.0%	1.4%	3.5%
Misc crabs	28	338	705	0.0%	0.0%	0.2%
Misc crustaceans		24		0.0%	0.0%	0.0%
Misc fish	145,399	116,116	117,559	16.8%	3.8%	25.2%
Octopus	654	425	18	0.1%	0.0%	0.0%
Other osmerids	553	141	15	0.1%	0.0%	0.0%
Other Sculpins	24,076	15,019	14,506	2.8%	0.5%	3.1%
Pandalid shrimp	916	293	261	0.1%	0.0%	0.1%
Polychaete unidentified	4			0.0%	0.0%	0.0%
Scypho jellies	660	2,920	150	0.1%	0.1%	0.0%
Sea anemone unidentified	3,304	2,940	296	0.4%	0.1%	0.1%
Sea pens whips		2	43	0.0%	0.0%	0.0%
Sea star	3,306	2,102	1,468	0.4%	0.1%	0.3%
Shark (other)	199	221	178	0.0%	0.0%	0.0%
pacific sleeper		70	150	0.0%	0.0%	0.0%
salmon	12	120	500	0.0%	0.0%	0.1%
spiny dogfish	1,083	1,249	1,036	0.1%	0.0%	0.2%
Skate (big)		6,635	4,622	0.0%	0.2%	1.0%
Longnose	30	16,270	9,348	0.0%	0.5%	2.0%
Other	39,662	10,380	45,017	4.6%	0.3%	9.6%
Snails	423	302	157	0.0%	0.0%	0.0%
Sponge unidentified	3,815	1,140	1,130	0.4%	0.0%	0.2%
Squid	8,767	11,741	1,458	1.0%	0.4%	0.3%
urchins dollars cucumbers	353	606	160	0.0%	0.0%	0.0%
Grand Total	864,697	3,076,198	466,544	100.0%	100.0%	100.0%

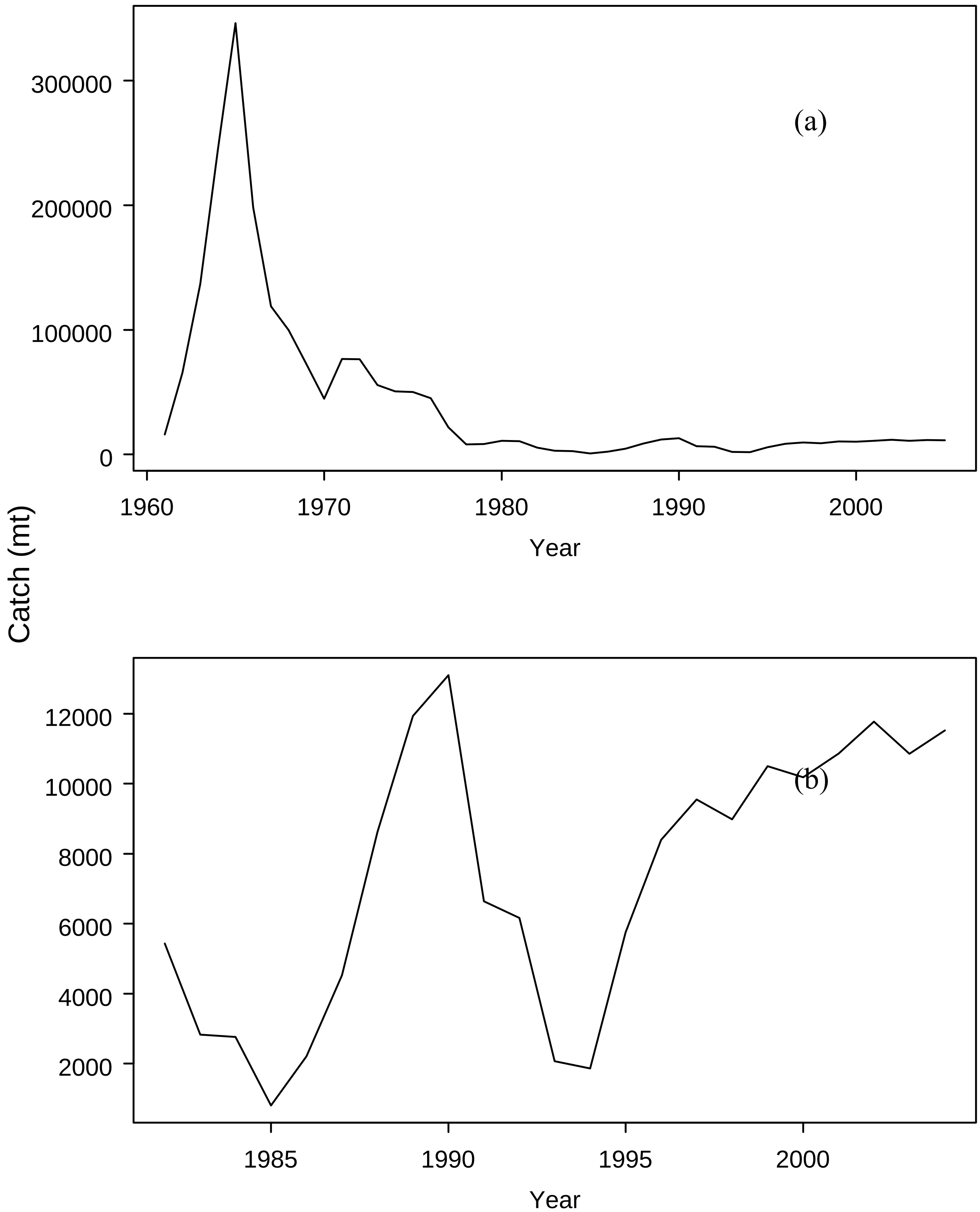

Figure 8-1. Estimated long-term (a) and short-term (b) catch history for Gulf of Alaska Pacific ocean perch.

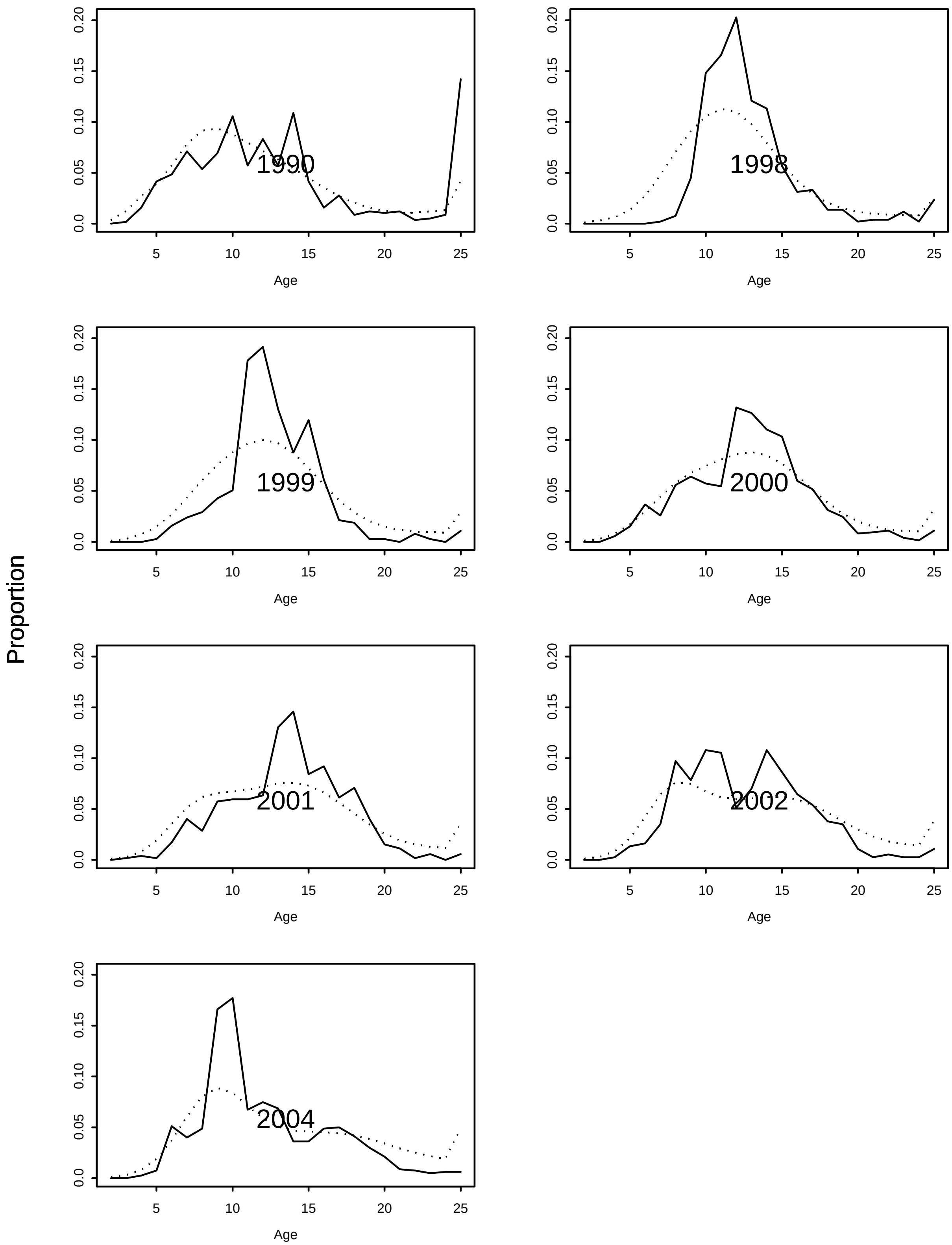

Figure 8-2. Fishery age compositions for GOA Pacific ocean perch. Observed=solid line, predicted=dotted line.

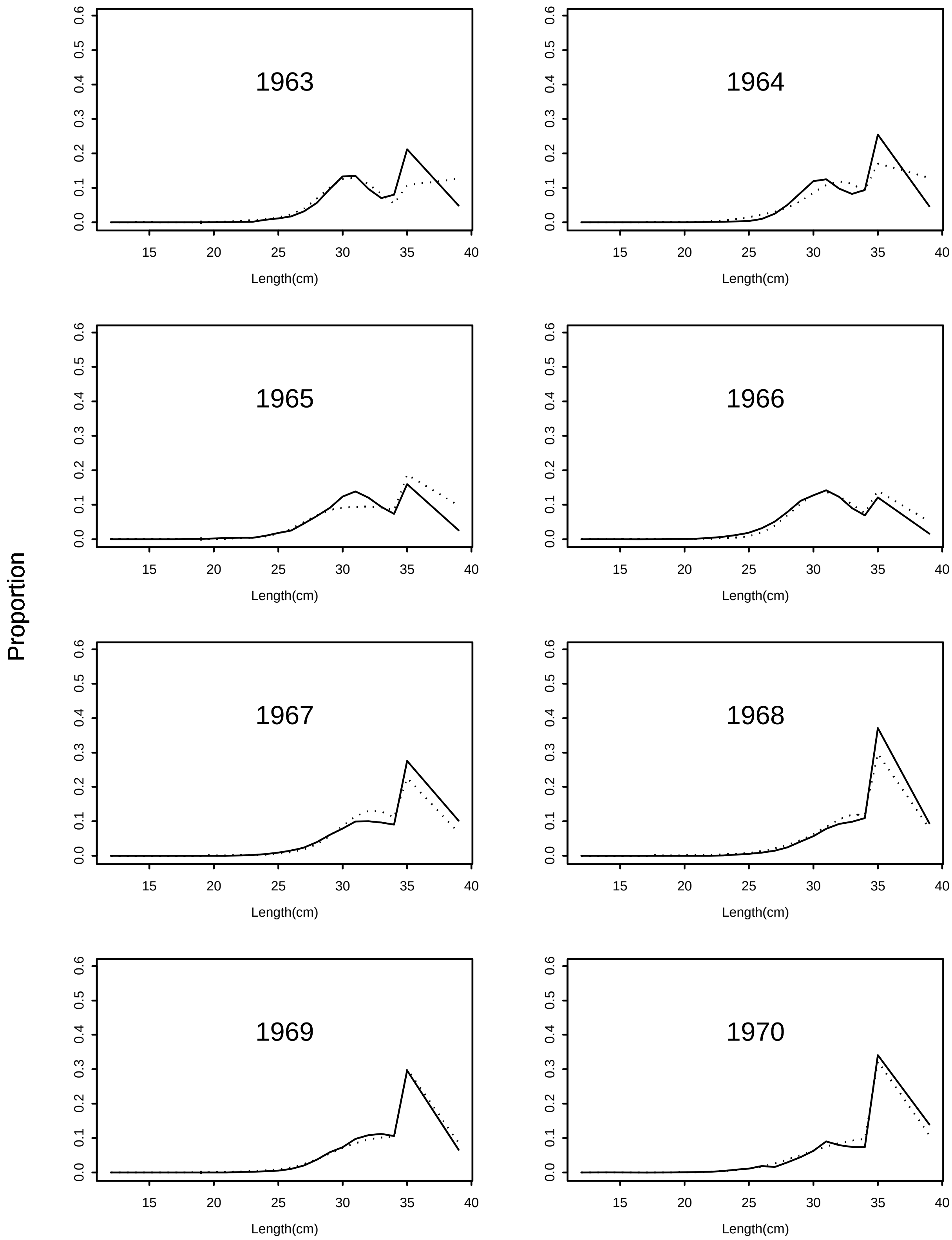

Figure 8-3. Fishery length compositions for GOA Pacific ocean perch. Observed=solid line, predicted=dotted line.

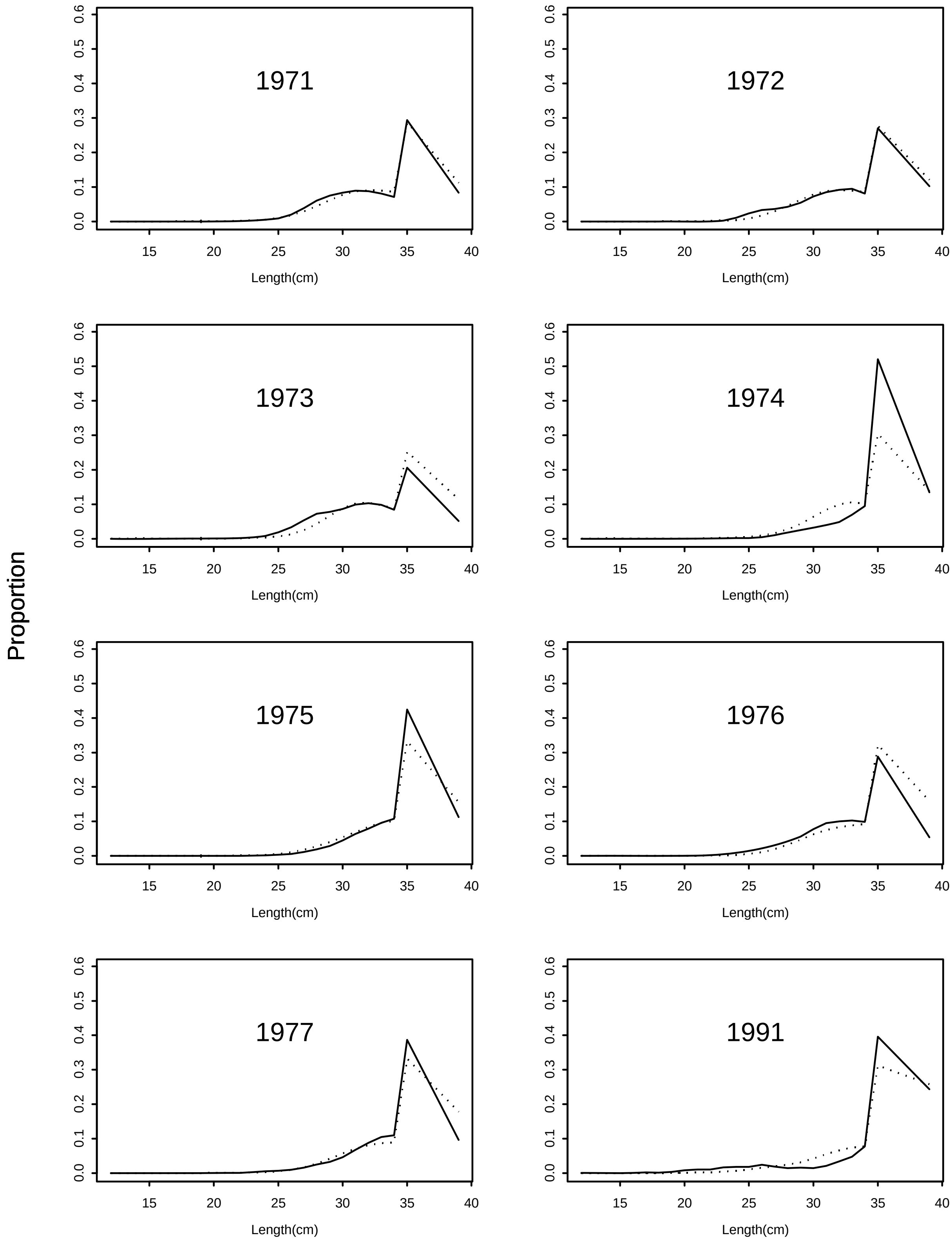

Figure 8-3 (continued). Fishery length compositions for GOA Pacific ocean perch. Observed=solid line, predicted=dotted line.

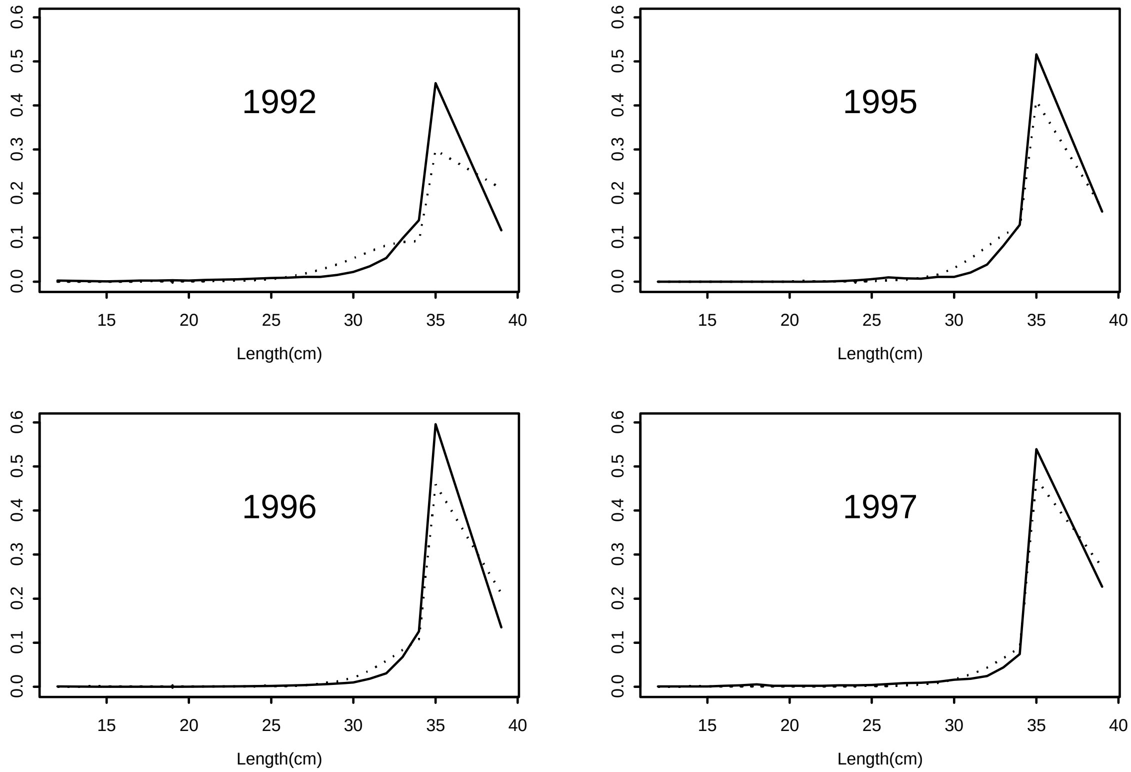

Figure 8-3 (continued). Fishery length compositions for GOA Pacific ocean perch. Observed=solid line, predicted =dotted line.

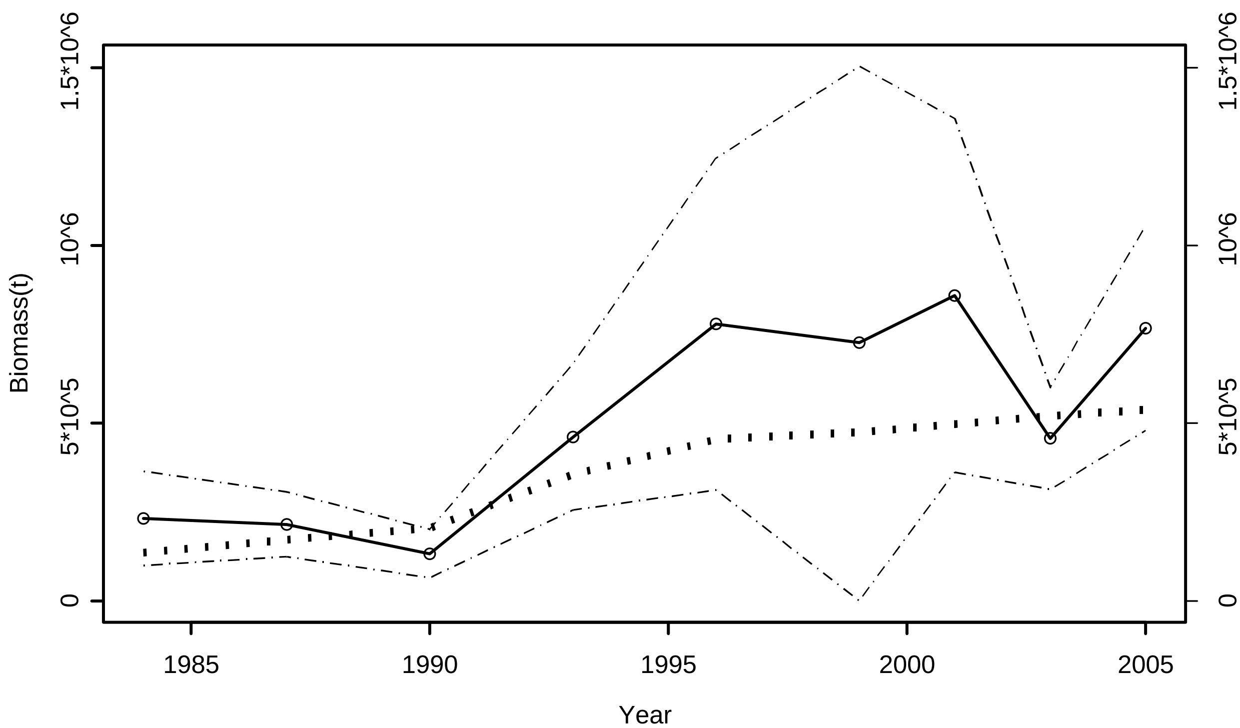

Figure 8-4. NMFS Groundfish Survey biomass estimates (solid line), with 95% sampling error confidence intervals (dashed line) and model fit (dotted line) for Gulf of Alaska Pacific ocean perch.

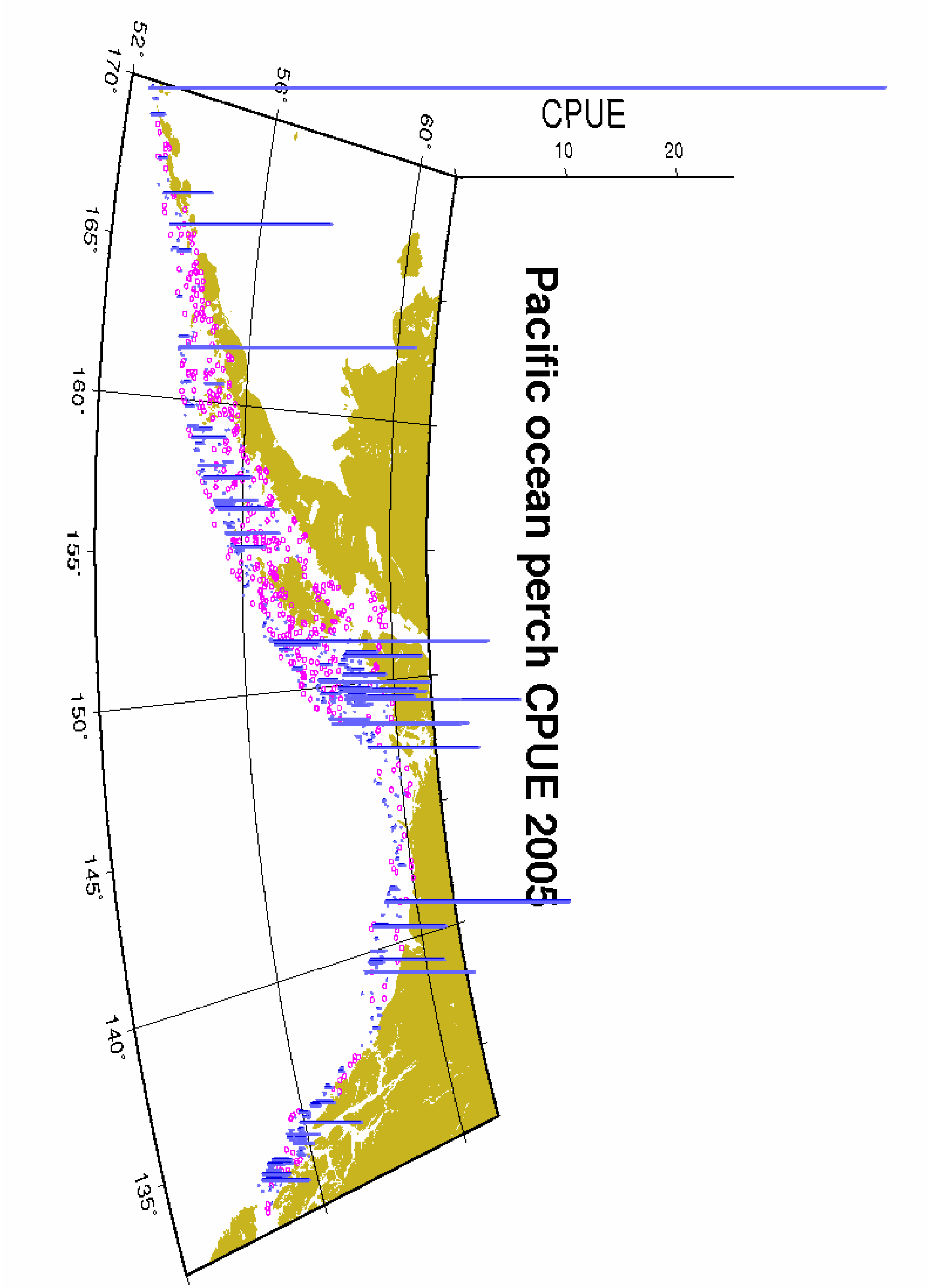

Figure 8-5a. Distribution of Gulf of Alaska Pacific ocean perch catches in the 2005 Gulf of Alaska groundfish survey.

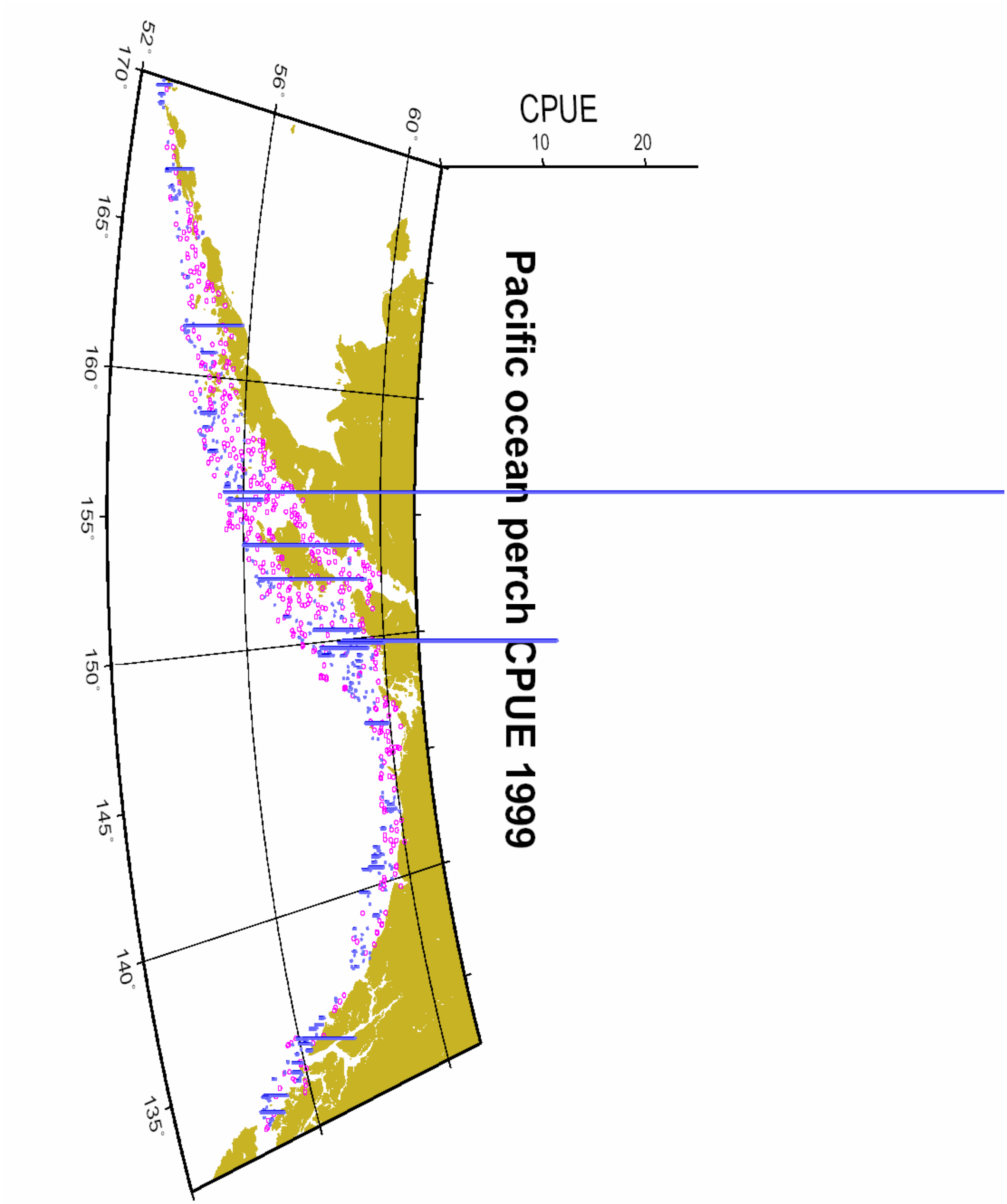

Figure 8-5b. Distribution of Gulf of Alaska Pacific ocean perch catches in the 1999 Gulf of Alaska groundfish survey.

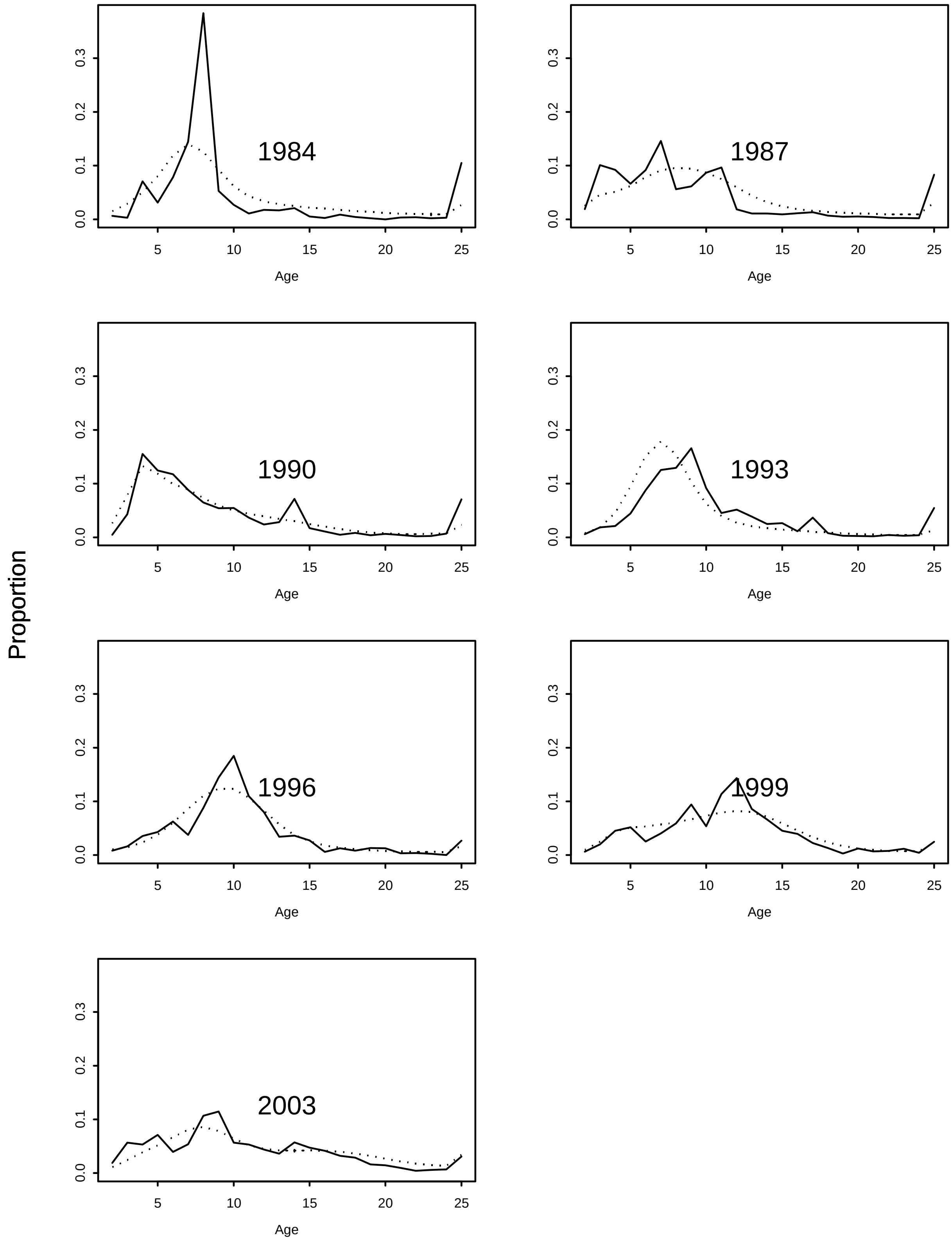

Figure 8-6. Groundfish survey age compositions for GOA Pacific ocean perch. Observed=solid line, predicted=dashed line.

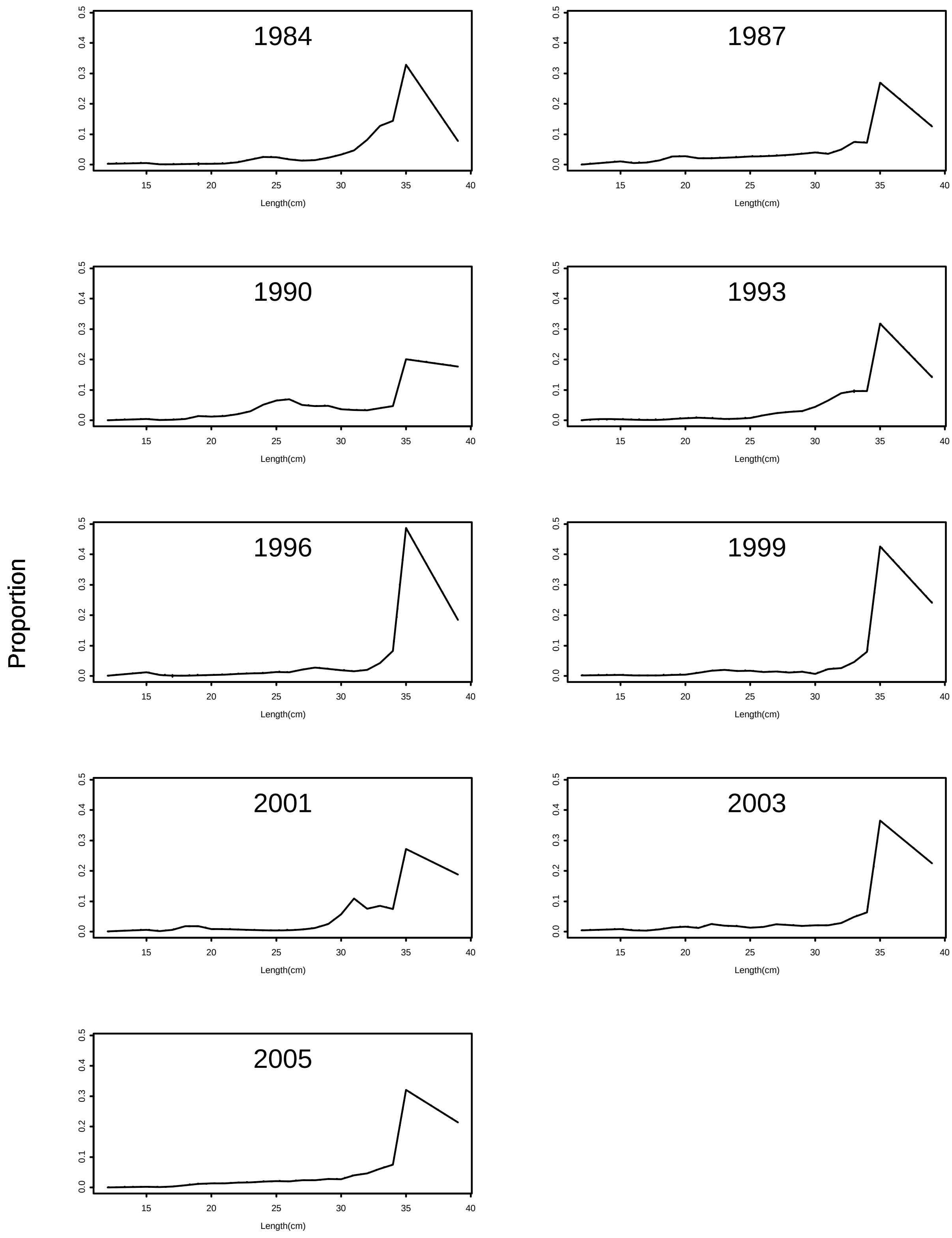

Figure 8-7. Groundfish trawl survey length compositions for Gulf of Alaska Pacific ocean perch.

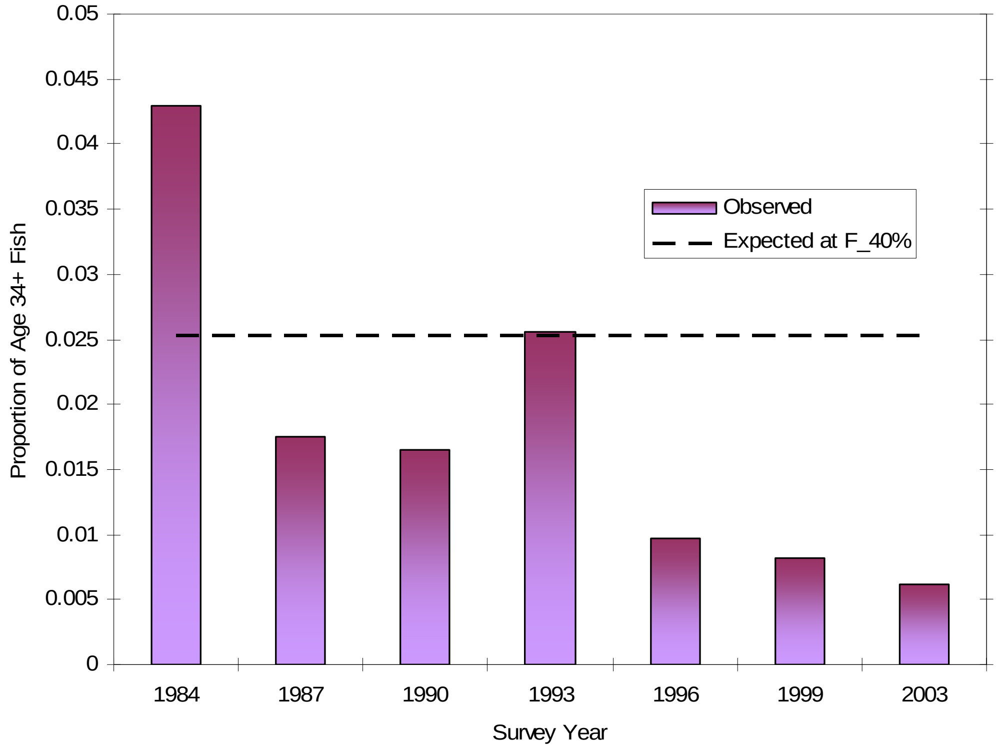

Figure 8-8. Proportion of fish in survey age collections greater than 40% of maximum observed survey age (fish over 34 years old) over time for Gulf of Alaska Pacific ocean perch.

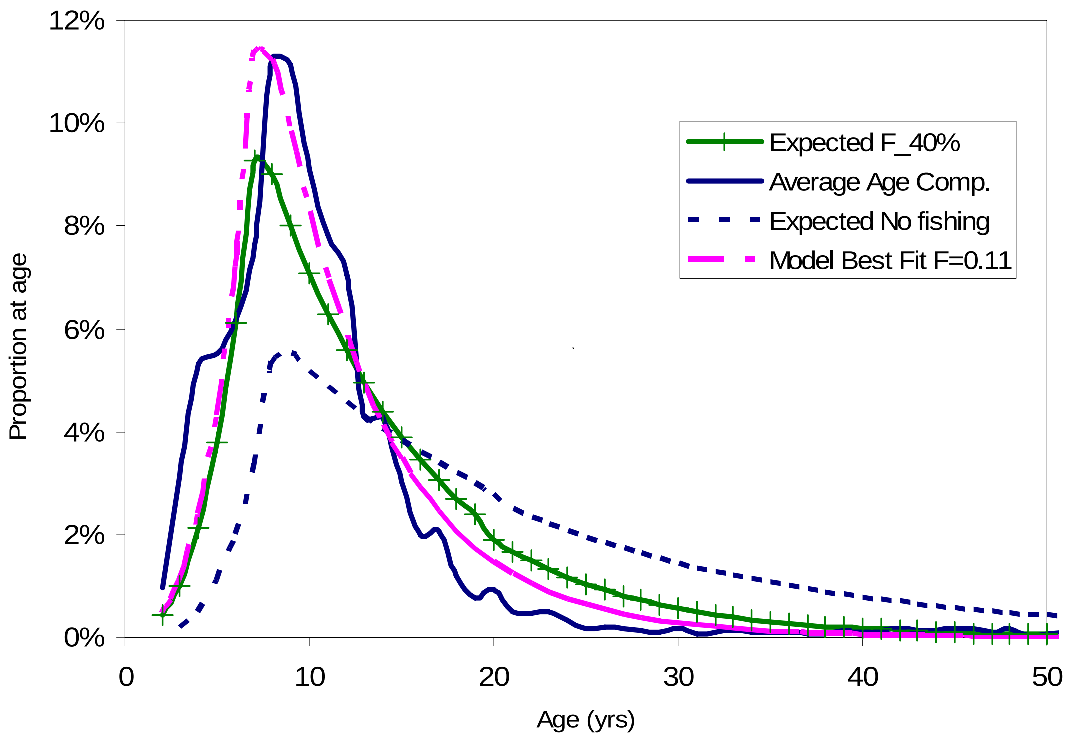

Figure 8-9. Average age composition for GOA Pacific ocean perch from 1984-2003 (solid blue), expected age composition at equilibrium fishing at $F_{40\%}$ (green w/ pluses), expected ages with no fishing (dashed blue), and the best model fit to average age comp predicting F=0.11 (double-dash pink).

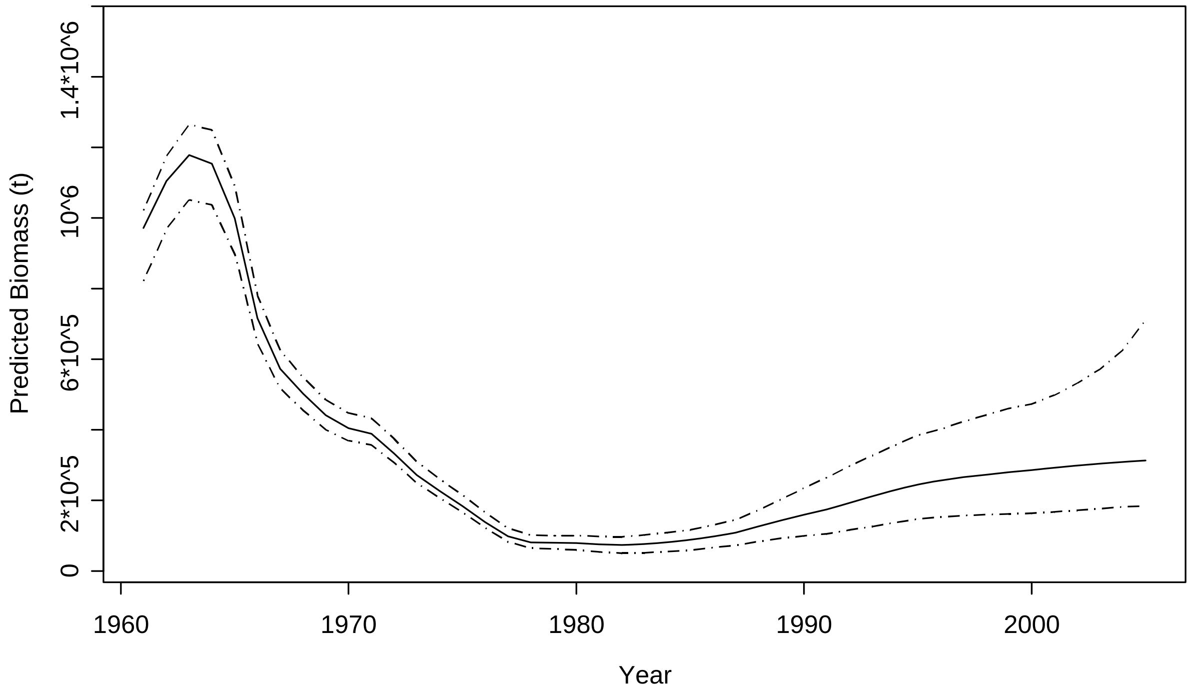

Figure 8-10. Model estimated total biomass (solid line) with 95% confidence intervals determined by MCMC (dashed line) for Gulf of Alaska Pacific ocean perch.

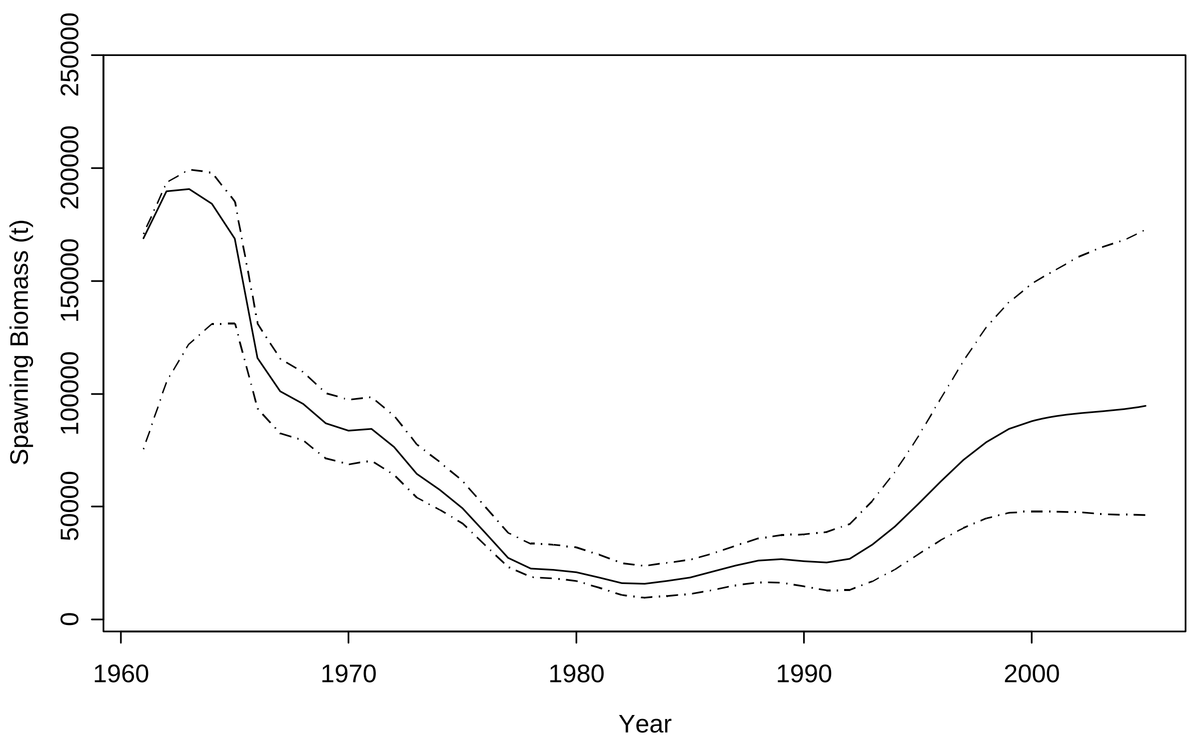

Figure 8-11. Model estimated spawning biomass (solid line) with 95% confidence intervals determined by MCMC (dashed line) for Gulf of Alaska Pacific ocean perch.

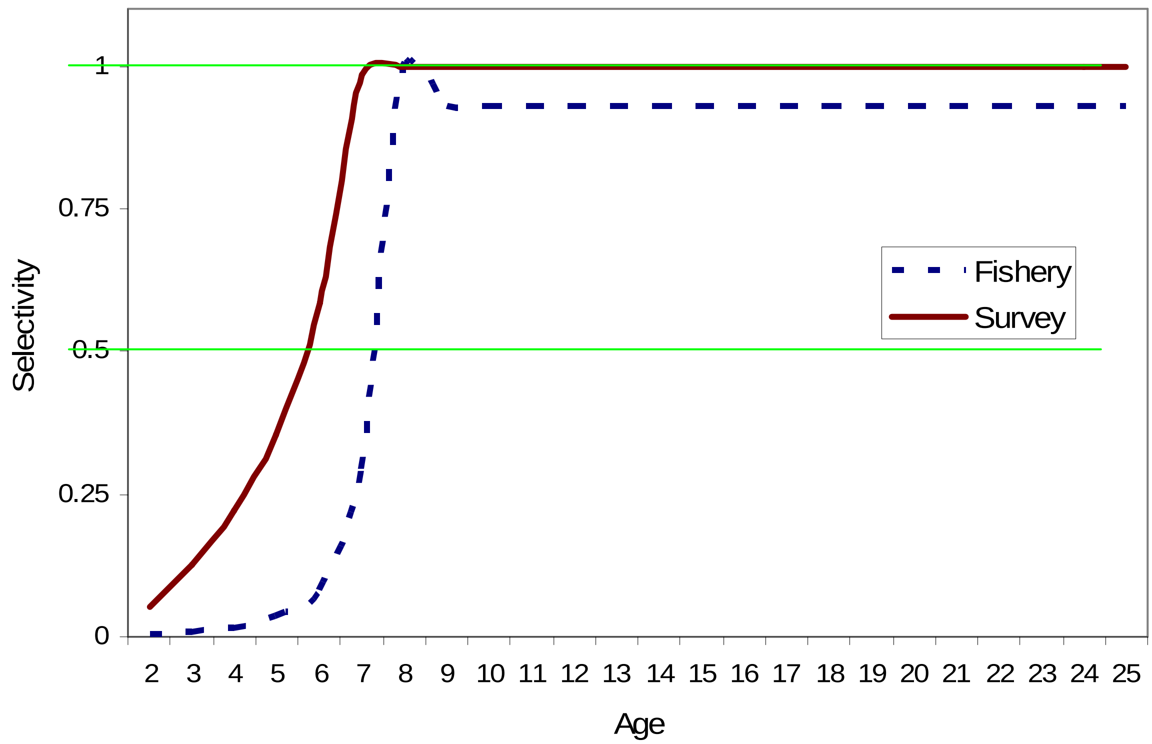

Figure 8-12. Estimated selectivities for the fishery and groundfish survey for Gulf of Alaska Pacific ocean perch.

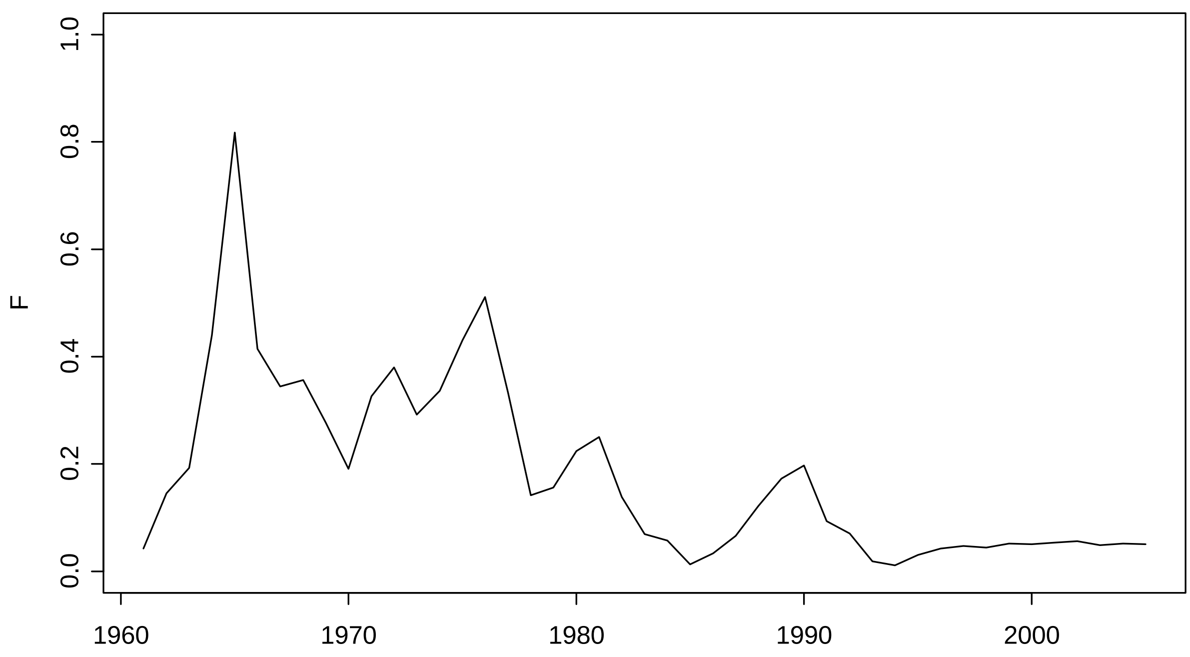

Figure 8-13. Estimated fully selected fishing mortality over time for GOA Pacific ocean perch.

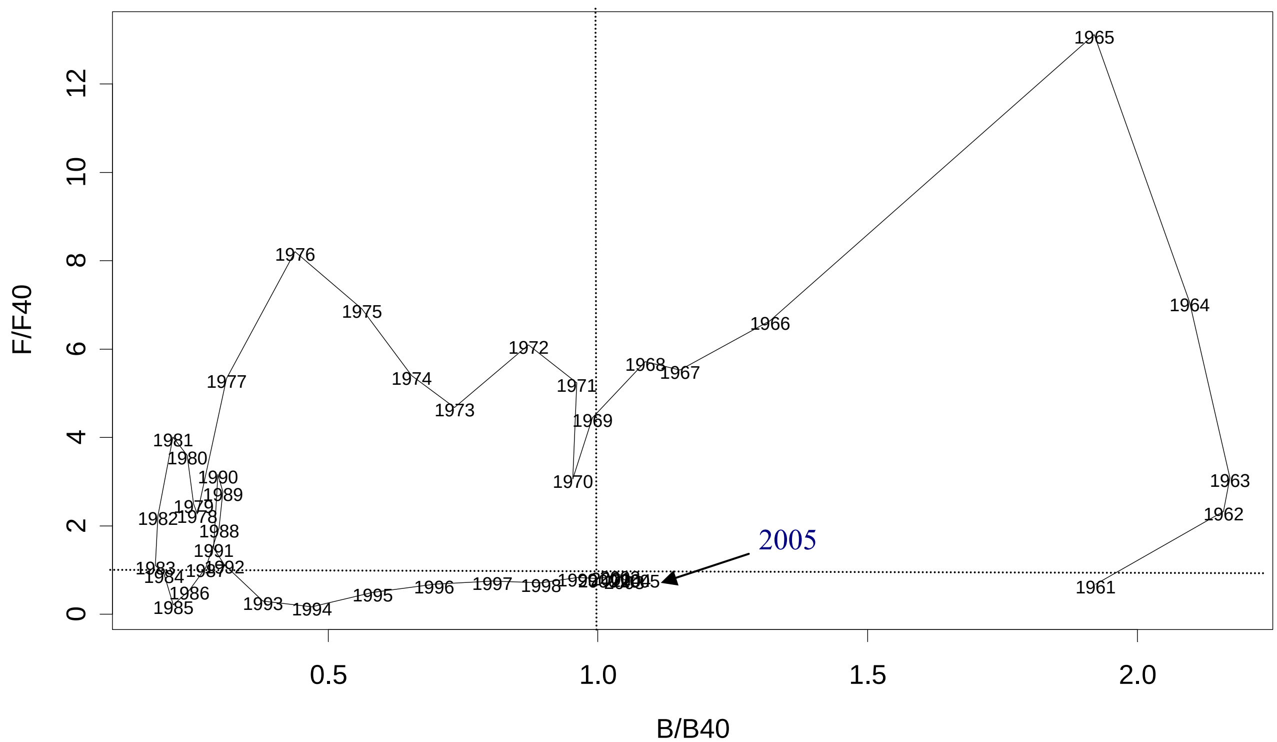

Figure 8-14. Time series of estimated fishing mortality over F40% versus estimated spawning biomass over B40% for Model 3.

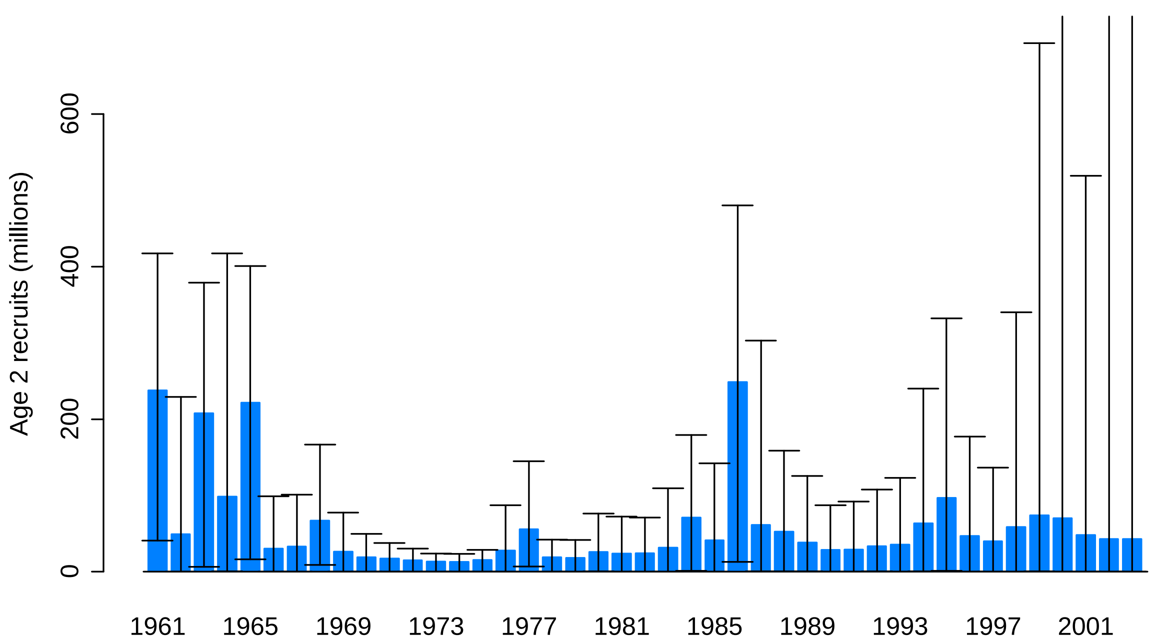

Figure 8-15. Estimated recruitment of Gulf of Alaska Pacific ocean perch (age 2) by year class with 95% confidence intervals derived from MCMC.

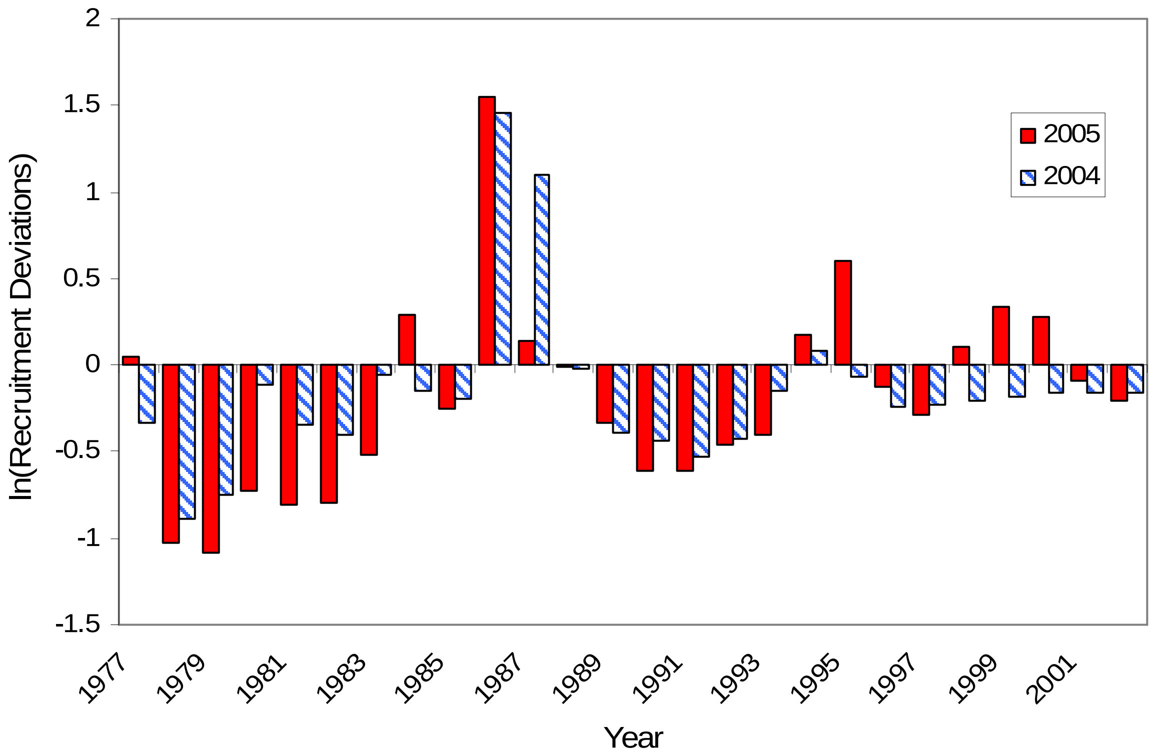

Figure 8-16. Recruitment deviations from average on the log-scale comparing last year's model to current for Gulf of Alaska Pacific ocean perch.

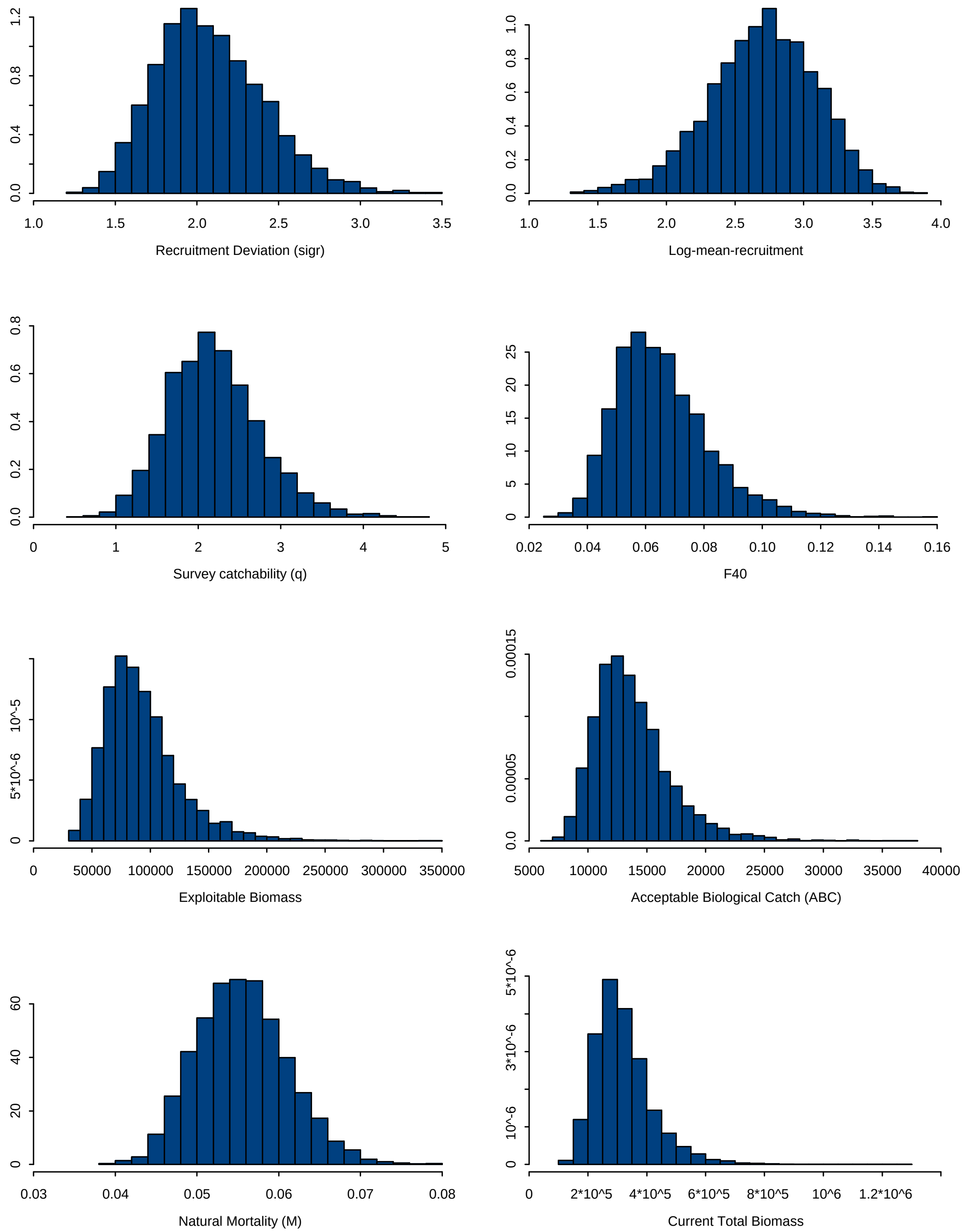

Figure 8-17. Histograms of estimated posterior distributions of key parameters derived from MCMC for Gulf of Alaska Pacific ocean perch.