Gulf of Alaska Pacific ocean perch

by

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7.0 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 1961-2003, size compositions from the fishery for 1963-77 and 1990-97, survey age compositions for 1984, 1987, 1990, 1993, 1996 and 1999, fishery age composition for 1998-2002, and survey biomass estimates for 1984, 1987, 1990, 1993, 1996, 1999, 2001 and 2003. New data in the model included the 1998, 1999 and 2002 fishery age composition, estimated 2003 fishery catch and 2003 survey biomass estimates. A preliminary assessment of uncertainty in last year's SAFE document indicated some potential model specification problems. Because of this, models this year were evaluated using Markov Chain Monte Carlo (MCMC) simulations to estimate posterior distributions of key parameters. The base model from last year is contrasted with four alternative models. The key differences are a new length-age transition matrix and a relaxation of the fishing mortality regularity penalty. Based on improved fits to the data and more realistic posterior distributions we recommend that the ABC of 13,340 mt from a new model be used for the 2004 fishery. This ABC is similar to last year's ABC of 13,660 mt. The corresponding reference values for Pacific ocean perch are summarized below. The stock is not overfished, nor is it approaching overfishing status.

$B_{40\%}$ (mt)	89,699
B_{2004} (mt)	95,760
$F_{40\%}$	0.06
F_{ABC} (maximum allowable)	0.06
ABC (mt; maximum allowable)	13,340
OFL (mt)	15,840

Summary of Major Changes

The Pacific ocean perch assessment is now reported separately from other members of the slope rockfish complex. In the model we recommend this year, there are a number of substantive changes. Changes in input data include: Addition of 1998, 1999, and 2002 fishery ages, 2003 survey biomass estimate, removal of the 1978 fishery size data, revised weight at age, and a revised length at age matrix. The assessment methodology is the same, but the model is more stable and many constraints were reduced or eliminated. The results of the model are essentially the same with the main features being a much better fit to the data, a similar ABC as last year, B_{2004} remaining above $B_{40\%}$, with projected biomass decreasing slightly.

Responses to SSC Comments

The SSC was concerned that our estimate of catchability was much closer to 1.0 than the BSAI perch assessment, but looked underestimated when examining our survey biomass figures. The 2002 model was somewhat constrained to produce a catchability near 1.0. This year's recommended model allows the catchability parameter more freedom and does produce a higher estimate of q than last year.

7.1 Introduction

Pacific ocean perch (POP), *Sebastes alutus*, is the dominant fish in the slope rockfish assemblage and has been extensively fished along its North American range since 1940 (Westrheim et al. 1970). The species has a wide geographic range in the North Pacific from California, to the Bering Sea and Southwest to the Kuril Islands. Pacific ocean perch are viviparous, with internal fertilization and release of live young. Spawning takes place in relatively deep water (>250m) in early winter. Fertilization takes place after the sperm is held in the female for a short time, followed by several months of gestation with larval release in April-May. This parturition time corresponds with the large plankton blooms that occur in the spring in the Gulf of Alaska. Dependency on the timing of this bloom could be a reason for their sporadic recruitment.

Identification of the larvae of POP is difficult and infrequent (Gharrett et al. 2001). Consequently there is considerable uncertainty about the early life history of the species. POP larvae are hypothesized to stay at depth of release for extended periods, then move to shallower waters over several months. Larvae feed on varying sizes of copepods and larvae as they grow. During this stage, larvae are pelagic and do not settle into demersal existence for 2-3 years (Gunderson 1977, Haldorson and Love 1991). Among rockfish, POP juveniles have one of the lower daily growth rates of rockfish juveniles. Upon recruitment, juveniles settle on hard low-relief sediments (Love et al. 1991). Older fish are generally found between 150-350 meters in the summer time and deeper in the winter (Love et al. 2002). Pacific ocean perch are very slow growing and long lived with natural mortality rates estimated to be ~ 0.05. Maximum age has been estimated to be in excess of 90 years (Leaman 1991). However, 90% of maximum size (~48 cm) is usually reached by 20-25 years of age.

Few studies have been conducted on the stock structure of Pacific ocean perch. Based on allozyme variation, Seeb and Gunderson (1988) concluded that Pacific ocean perch are genetically quite similar throughout their range, and genetic exchange may be the result of dispersion at early life stages. In contrast, preliminary analysis using mitochondrial DNA techniques suggest that genetically distinct populations of Pacific ocean perch exist (A. J. Gharrett pers. commun., University of Alaska Fairbanks, October 2000). Withler et al. 2001 found distinct genetic populations on a small scale in British Columbia. Currently, genetic studies are underway that should clarify the genetic stock structure of Pacific ocean perch.

In 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. These subgroups were established to protect Pacific ocean perch, shortraker/rougheye, 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 1998, 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.

7.1.1 Fishery

Historical Background

A Pacific ocean perch trawl fishery by the U.S.S.R. and Japan began in the Gulf of Alaska in the early 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 (mt) 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 mt (Figure 7-1a). 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 7-1b). Much of the expansion of the domestic fishery was apparently related to increasing annual quotas; quotas increased from 3,702 mt in 1986 to 20,000 mt 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 7-1a for the commercial fishery and in Table 7-1b 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 four other rockfish species), Pacific ocean perch alone, or all *Sebastes* rockfish, depending upon the year (see Footnote in Table 7-1). Pacific ocean perch make up the majority of catches from this complex. The acceptable biological catches and quotas in Table 7-1 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 7.1, the Eastern area for Pacific ocean perch has been subdivided into two areas, so there is 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 1996[1]:

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

1996	1997	1998	1999	2000	2001	2002
49	28	32	41	52	43	58

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

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 Ianelli summaries of NMFS Observer data) from 1997-2002 show that the largest bycatch groups in the combined rockfish trawl fishery are arrowtooth flounder, Pacific cod, and sablefish in that order. The same data set shows that the only major non-rockfish fishery that catches substantial Pacific ocean perch is the rex sole fishery, averaging 280 mt per year. Small amounts of Pacific ocean perch are also taken in other flatfish, pacific cod and sablefish fisheries (Gaichas and Ianelli summaries of NMFS Observer data).

Discards

Gulfwide discard rates[2] (% discarded) for Pacific ocean perch in the commercial fishery for 1991-2002 are listed as follows:

Year	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
%Discard	18.4	29.4	79.2	59.7	19.7	17.2	14.5	14.0	13.8	11.3	8.6	7.2

The high discard rates for Pacific ocean perch in 1993 and 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.

[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 28, 2003.

[2] Source: National Marine Fisheries Service, Alaska Region, Fishery Management Section, P.O. Box 21688, Juneau, AK 99802-1688. Data are from weekly production and observer reports through October 28, 2003.

7.2 Data

7.2.1 Fishery Data

Catch

Catches range from 2500 mt to 350,000 mt from 1961 to 2003. Detailed catch information for Pacific ocean perch is listed in Table 7-1a and shown graphically in Figure 7-1.

Age and Size composition

Observers aboard fishing vessels and at onshore processing facilities have provided data on size and age composition of the commercial catch of Pacific ocean perch. Ages were determined from the break-and-burn method (Chilton and Beamish 1982). Table 7-2 summarizes the length compositions from 1977-2003 (with several gaps). Table 7-3 summarizes age compositions from 1998-2002 for the fishery. Figures 7-3 and 7-4 show the distributions graphically along with the recommended model predictions. The age compositions in all five years of the fishery data show strong 1987 and 1988 year classes. These year classes were also strong in age compositions from the 1996 and 1999 trawl surveys. The 1993 and previous surveys show more strength in the 1986 year class. The fishery age data shows high correlation when lagged, indicating ages and collections are consistent.

7.2.2 Survey Data

Biomass Estimates from Trawl Surveys

Bottom trawl surveys were conducted on a triennial basis in the Gulf of Alaska in 1984, 1987, 1990, 1993, 1996 and these surveys became biennial for the 1999-2003 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 triennial 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. Other, less comprehensive trawl surveys were periodically conducted before 1984 in the Gulf of Alaska, and these have also provided information on age and size composition of slope rockfish. Summaries of biomass estimates from the 2003 trawl survey and comparative estimates from the 1984 to 2003 surveys are provided in Table 7-4.

Comparison of Trawl Surveys in 1984, 1987, 1990, 1993, 1996, 1999, 2001 and 2003

Gulfwide biomass estimates for Pacific ocean perch are shown in Table 7-4. Gulfwide biomass estimates and 95% confidence intervals are also shown graphically in Figure 7-2. 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 reader should be aware that 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 have been extremely variable in recent surveys (Figure 7-2). Such wide fluctuations in biomass do not seem reasonable given the slow growth and low natural mortality rates of POP. 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. In past SAFE reports, we have also 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. It seems prudent to repeat this speculation in the present report, while acknowledging 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 using hydroacoustics to gain 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. 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 7-4. 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 tenfold, from 15,221 mt in 1990 to 154,013 mt 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.

Age Compositions

Ages were determined from the break-and-burn method (Chilton and Beamish 1982). The survey age compositions from 1984-1999 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 7-5). 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 7-5). 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 became more abundant than the 1986 year class. 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.

Survey Size Compositions

Gulfwide population size compositions for Pacific ocean perch are shown in Figure 7-6. 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 matrix, but not used in the model fitting phase.

7.3 Analytic Approach

7.3.1 Model Structure

For the third year, we present results for Pacific ocean perch based on an age-structured model using AD Model Builder software (Otter Research Ltd 2000). Previously 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[3]. 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. Fishery age compositions and associated likelihood components were added. The spawner-recruit relationship was removed from the estimation of beginning biomass (B_0). 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). 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 several new changes are proposed below.

7.3.2 Parameters Estimated Independently

The estimate of natural mortality (*M*) 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. In some model scenarios we estimate *M*, but use 0.05 as the mean of a prior distribution.

Recently, new information on female age and size at 50% maturity has become available 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 7-6:

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

A von Bertalanffy growth curve was fitted to survey length at age data from 1984-1999. Sexes were combined. A length at 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. Two new matrices were constructed for the two alternate models considered in this year's SAFE. A second matrix was constructed to represent a lower growth rate in the 1960s. The estimated parameters for the growth curve are shown below:

L_∞=41.4 cm κ=0.19 t_0=-0.47 n=9336

Weight-at-age was constructed with weight at age data from the same data set as the length at age. The estimated growth parameters are shown below. A correction of $(W_\infty - W_a)/2$ was used for the weight of the pooled ages (Schnute et al. 2001).

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

7.3.3 Parameters estimated conditionally

Parameters estimated conditionally include but are not limited to: catchability, selectivity (up to full selectivity) for survey and fishery, recruitment deviations, mean recruitment, fishing mortality, and spawners per recruit levels. Other parameters are described in Box 1.

7.3.4 Uncertainty

Evaluation of model uncertainty has recently become an integral part of the "precautionary approach" in fisheries management. 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 models presented in this SAFE report, the number of parameters estimated is between 131 and 134. In a low-dimensional model, an analytical solution might be possible, but in one with this many parameters, an analytical solution is intractable. Therefore, we use MCMC methods to estimate the Bayesian posterior distribution for these parameters. The basic premise is to use a Markov chain to simulate a random walk through the parameter space which will eventually converge to a stationary distribution which approximates the posterior distribution. Determining whether a particular chain has converged to this stationary distribution can be complicated, but generally if allowed to run long enough, it will converge. The "burn-in" is a set of iterations removed at the beginning of the chain. In our simulations we removed the first 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 and to show examples of key parameter posterior distributions (Figures 7-7, 7-8).

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

Equation	Description
$\hat{C}_y = \sum_a \frac{N_{y,a} * F_{y,a} * \left(1 - e^{-Z_{y,a}}\right)}{Z_{y,a}} * w_a$	Catch equation
$\hat{I}_y = q * \sum_a N_{y,a} * \frac{s_a}{\max(s_a)} * w_a$	Survey biomass index (mt)
$\hat{P}_{y,a'} = \sum_a \left(\frac{N_{y,a} * s_a}{\sum_a N_{y,a} * s_a} \right) * T_{a,a'}$	Survey age distribution Proportion at age
$\hat{P}_{y,l} = \sum_a \left(\frac{N_{y,a} * s_a}{\sum_a N_{y,a} * s_a} \right) * T_{a,l}$	Survey length distribution Proportion at length
$\hat{P}_{y,a'} = \sum_a \left(\frac{\hat{C}_{y,a}}{\sum_a \hat{C}_{y,a}} \right) * T_{a,a'}$	Fishery age composition Proportion at age
$\hat{P}_{y,l} = \sum_a \left(\frac{\hat{C}_{y,a}}{\sum_a \hat{C}_{y,a}} \right) * T_{a,l}$	Fishery length composition Proportion at length

Equations describing population dynamics

Start year

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

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
$L_7 = \frac{1}{2\sigma_M^2} \left(M / M_{prior} \right)^2$	Penalty on deviation from prior distribution of natural mortality
$L_8 = \frac{1}{2\sigma_q^2} \left(q / q_{prior} \right)^2$	Penalty on deviation from prior distribution of catchability coefficient
$L_9 = \frac{1}{2\sigma_{\sigma_r}^2} \left(\sigma_r / \sigma_{r(prior)} \right)^2$	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
$L_{12} = \lambda_{12} \overline{s}^2$	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

7.4 Model Evaluation

7.4.1 Alternative Models

Base Model

This model is the base model that has been used in the previous two slope rockfish SAFE documents for Pacific ocean perch. Except for catch data, our base model was run with all data components given a likelihood weight of one and both survey and fishery selectivity patterns constrained to be approximately asymptotic. The catch likelihood was given a weight of 50 in all model runs. Each year of data components is weighted within a likelihood component by computing the square root of the sample size and scaling it to a maximum of 100. Table 7-7 summarizes the results from the base model and the new alternative models. Figures 7-9 to 7-14 show some of the results for the base model. For this base model the fit to survey biomass was poor for the more recent surveys. In addition the fits to some of the survey age compositions were not very good. The predicted fits to fishery length compositions are poor (Fig. 7-11) and have a large influence on overall model fits. This is partly because the length compositions are the longest time series in the model. We surmise that this poor fit is also due to an inaccurate length at age transition matrix. The base model also relies heavily on penalties that caused peculiar distributions in the Markov Chain Monte Carlo (MCMC) outputs explored in last year's SAFE (Heifetz et al. 2002). An example of this is in Figure 7-10 where the predicted total biomass from the model is outside of the 95% MCMC confidence interval. Further discussion of MCMC methods used for assessing uncertainty was presented in Section 7.3.4. The next model also explores lowering or removing these constraints.

Model 2

In model two we made extensive changes to the base model. The large likelihood component of the length frequency data in the base model led to further examination of the current length at age matrix. This revealed some unlikely components of the base model matrix. Primarily, the matrix predicts that an older fish would fall into an unrealistically small size class. This matrix was based on limited age data from when the stock synthesis approach was used. In model two, a new length at age matrix is constructed using a slightly different method than the previous SAFEs that alleviates this unreasonable probability distribution. A new LVB model is fit to the data using survey data from 1984-1999. The matrix is then constructed using the predicted lengths at age and observed standard deviation at age. The new matrix lowers the effect of the size data on the objective function (Table 7-7) and provides much better fits to the data. We remove one year of size data (1978) which has an unusual distribution (Table 7-2) and exerts much leverage on the model even though it has a small sample size.

We estimate natural mortality (M) but use an informative prior (lognormal, mean=0.05, σ=0.01) which admits a little uncertainty, but constrains it from extreme values. Figure 7-12 of the base model predicts that fishing mortality was too low in the past, considering that 1.7 million mts were removed between 1963 and 1978. The fully-selected F of 0.4 predicted in the base model for 1965 with a 350,000 mt catch translates to 1.1 million mts, while the base model predicts that there were only ~800,000 mts of exploitable biomass. Hence, we lower the fishing mortality regularity penalty from 1 to 0.1 which is consistent with other AD Model Builder assessments (e.g., sablefish and BSAI Pacific ocean perch). Figure 7-13 shows that estimated recruitments over time have been reasonably consistent according to the base model. This regularity is unexpected for rockfish considering that it is commonly believed that their populations are characterized by rare large recruitment levels. The prior mean for the recruitment deviation parameter (σ_r) in the current model is 0.9. This value, which implies a CV for log-recruitment of 25%, seems low considering the current theory of sporadic recruitment. Additionally, Figure 7-7 shows the MCMC distribution of the recruitment deviation parameter and shows the previous bound set on it was unreasonable, with much of the mass truncated at two. Therefore, we set the mean of the σ_r

prior distribution to be 1.7 with a CV of 0.2 in this model (1.7 is roughly the mode of the MCMC distributions in Figure 7-8 and other rockfish species) and increase the upper boundary on σ_r to ten from two. A correction factor was added to the weight at age relationship to compensate for the pooling of ages after age 25 using a method suggested by Schnute et al. 2001. Other penalties in the model were lowered to one from the base model as can be seen in Table 7-7.

Models 3-5

Models 3-5 add an additional length at age matrix. The biomass in the 1960s was likely much larger than present. Since POP seem to inhabit small optimum areas, we suspect this substantial reduction in the population caused a concurrent density dependent increase in growth. Evidence of this suspicion can be seen when examining the fishery size data. In the size data from 1963-1977, the weighted-average size was 34 cm while the second set of size data from 1990-1999 has a weighted-average of 36.5 cm, representing approximately a ~6% increase in average growth. Since the length at age matrix applied to this data is based only on recent length at age data, this matrix will give poor results when applied to the older size data. We constructed a slower-growth length at age matrix to use for the size data from 1963-1977 that reflects that older fish have a smaller size. The method here was simple: decrease the length-at-age by six percent, then refit the LVB model and use the resulting matrix for predicting those years. This resulted in a better fit to the fishery size data, survey age data and a better overall fit of the model. For comparison Model 3 shows a fixed natural mortality at 0.05, Model 4 shows a fixed M $(M=0.05)$ and q constrained to one. Model 5 is the "full" model that estimates q and M simultaneously.

7.4.2 Model Comparison

We compare stock assessment results for the five different model configurations above:

Model 1 - Base model from 2002 SAFE

Model 2 - New length at age transition matrix applied, penalties reduced, new weight-at-age

Model 3 – 2^{nd} length at age transition matrix applied to fishery lengths 1963-77, M fixed at 0.05

Model 4 – Model 3 with M fixed at 0.05 and q constrained to equal 1.

Model 5 –Model 3 with q and M both estimated.

Models 2-5 all have significantly better fits than the base model. The changes made in Model 2 make it a reasonable choice, but does not fit the data as well as Models 3-5. The objective function is reduced significantly for this model and the results in general are more appealing than the base model but some results are unexpected (e.g. a recruitment of ~1 billion fish in the first year of the model and an equivalent spawning biomass at the beginning of the time series as at the end.)

Model 4 produced a better fit to the data than the base model and model 2, but was less stable, requiring the fishing mortality regularity penalty to be raised to 0.2 from 0.1 for convergence. Models 3 and 5 have the best overall fit, with 5 fitting slightly better and providing more reasonable estimates of q and B_{2004} than Model 3. Even though the penalties for selectivity smoothness were lowered, selectivities in model 5 were still reasonable (Table 7-6). Models 3 and 5 produced reasonable estimates after lowering all the penalties to quantities that have little effect on the model, indicating increased stability. Overall, model 5 has the best properties of the alternatives and we recommend model 5 for setting the ABC in 2004.

7.5 Model Results

Model 5 shows a much improved fit to age and length data (Figures 7-3 to 7-6). An example of the improved fit is provided by comparing the length predictions in Figure 7-4 with the base model predictions in Figure 7-11. MCMC confidence intervals around predicted biomass (Figure 7-15 and 7-16) show a more realistic reflection of uncertainty around recent biomass predictions than the base model

(Figure 7-9 and 7-10). There are very tight confidence intervals around recent estimates from the base model, with the model estimate outside of the confidence intervals. This model, when compared to the base model has a 55% smaller objective function value and 63% smaller portion of the objective function attributed to the data fits. Table 7-7 shows a summary of the main results for model 5. Additional results for model 5 are shown in Figures 7-15 to 7-21; fits to the data are shown in Figures 7-2 to 7-6.

Model 5 suggests that there was a group of stronger recruitments in the late 1980s, peaking with a very large recruitment (age-2) in 1989. Before then, the model suggests there were no other major recruitment events since the 1960s. MCMC confidence intervals around recruitments reflect much uncertainty around these estimated recruitments, particularly in recent years (Figure 7-20). Marginal posterior distributions from the MCMC integration suggest that the estimates could be quite different from the mode and that prior distributions did not particularly affect the estimates except for M (Figure 7-8). The tight posterior distribution of natural mortality is due to its prior CV of 0.01 which was necessary to prevent very large estimates of M, which in turn would produce low estimates of q.

We suggest that in the face of uncertainty, it is preferable to be more conservative and accept a moderately high estimate of q rather than move to a much higher estimate of natural mortality. In a model with this many parameters q cannot be considered as a true measure of trawl catchability, but as a scaling factor that is affected by other data in the model. One possibility is that in the years the trawl survey has one or two tows that are an order of magnitude larger than the rest of the tows, these tows are translated into unexpected jumps in certain age or length classes. This would lead to q rising to compensate for this increase in catchability. In model 5, if the natural mortality is allowed to rise to 0.075, this equates to a q of about 1.

From the MCMC chains described in Section 7.5.3, we summarize the posterior densities of key parameters for the recommended model using histograms (Figure 7-8) and confidence regions (Table 7-8). We also use these posterior distributions to show uncertainty around time series estimates such as total biomass, spawning biomass and recruitment (Figs. 7-9, 7-10, 7-15, 7-16).

Table 7-8 shows the maximum likelihood estimate (MLE) of key parameters with their corresponding MLE 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 much larger for the estimates of B_{2004}, 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 highly skewed, indicating possibilities of much higher biomass estimates (also see Figure 7-8).

We selected the results from Model 5, a new model, as the basis for our recommendations for ABC and overfishing. The ABC for this year's assessment is similar to last year's assessment using $F_{40\%}$. Recently, the use of $F_{40\%}$ has come into question for rockfish in a NPFMC harvest strategy review (Goodman et al. 2002). Adoption of a more conservative harvest strategy such as $F_{50\%}$ has been suggested for West Coast rockfish in recent literature (Dorn 2002, Ianelli 2002, Hilborn et al. 2002). We do not feel these papers apply particularly well to Gulf of Alaska rockfish, which likely are healthier and more productive than West Coast stocks (Dorn 2002). Therefore we recommend continuing to harvest at $F_{40\%}$ unless new information suggests otherwise.

7.6 Projections and Harvest Alternatives

7.6.1 Harvest Alternatives

Several alternate model configurations were evaluated in section 7.7.1. ABCs from these alternative models ranged from 9,400 – 19,877 mt. We recommend that the ABC from model 5 be used for the 2004 fishery. The management path from Model 5 in Figure 7-20 suggests that management is on track and moving the stock into the 'optimum' quadrant where $B_{now}/B_{40\%}$ has recently exceeded one again for the first time since the 1960s. $F_{now}/F_{40\%}$ continues to stay below one. Based on model 5, the spawning biomass in 2004, B_{2004}, is 95,760 mt. $B_{40\%}$ is 89,699 mt which is determined from average recruitment of the 1977-97 year-classes (Table 7-9). Since B_{2004} is greater than $B_{40\%}$, the computation in tier 3a [i.e., $F_{ABC} = F_{40\%}$] is used to determine the maximum value of F_{ABC} resulting in an ABC of 13,340 mt. We expected to recommend a larger ABC this year before receiving the 2003 survey biomass estimate. Using last survey's biomass estimate as a placeholder, the recommended model was predicting a much higher ABC (18,112). This year's survey biomass estimate came in much lower and more precise than recent years, resulting in a return to approximately the base model's ABC from last year. We recommend that the ABC for Pacific ocean perch for 2004 fishery in the Gulf of Alaska be set at 13,340 mt.

7.6.2 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 2003 numbers at age estimated in the assessment. This vector is then projected forward to the beginning of 2004 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2003. In each subsequent year, the fishing mortality rate is prescribed on the basis of the spawning biomass in that year and the respective harvest scenario. In each year, recruitment is drawn from an inverse Gaussian distribution whose parameters consist of maximum likelihood estimates determined from recruitments estimated in the assessment. Spawning biomass is computed in each year based on the time of peak spawning and the maturity and weight schedules described in the assessment. Total catch 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 2004, 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 2004 recommended in the assessment to the *max* F_{ABC} for 2004. (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.) We do not recommend a fraction of F_{ABC}, so we do not present this scenario.

Scenario 3: In all future years, F is set equal to 50% of *max FABC*. (Rationale: This scenario provides a likely lower bound on *FABC* 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 1999-2003 average *F*. (Rationale: For some stocks, TAC can be well below ABC, and recent average *F* may provide a better indicator of *FTAC* than *FABC*.)

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 *B35%*):

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 2004 or 2) above ½ of its MSY level in 2004 and above its MSY level in 2014 under this scenario, then the stock is not overfished.)

Scenario 7: In 2004 and 2005, *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 2016 under this scenario, then the stock is not approaching an overfished condition.)

7.6.3 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 2003:

a) If spawning biomass for 2004 is estimated to be below ½ *B35%*, the stock is below its MSST.

b) If spawning biomass for 2004 is estimated to be above *B35%*, the stock is above its MSST.

c) If spawning biomass for 2004 is estimated to be above ½ *B35%* but below *B35%*, the stock's status relative to MSST is determined by referring to harvest scenario #6 (Table 7-10). If the mean spawning biomass for 2014 is below *B35%*, 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 7-10):

a) If the mean spawning biomass for 2006 is below ½ *B35%*, the stock is approaching an overfished condition.

b) If the mean spawning biomass for 2006 is above *B35%*, the stock is not approaching an overfished condition.

c) If the mean spawning biomass for 2006 is above ½ *B35%* but below *B35%*, the determination depends on the mean spawning biomass for 2016. If the mean spawning biomass for 2016 is below *B35%*, 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 7-10. For Pacific ocean perch the stock is not overfished and is not approaching an overfished condition.

7.6.4 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. This results in weights of 4:6:9 for the 1999, 2001, and 2003 surveys, respectively and apportionments of 19% for the Western area, 63 % for the Central area, and 18% for the Eastern area (Table 7-11). This results in recommended ABC's of 2,520 mt for the Western area, 8,390 mt for the Central area, and 2,430 mt 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 1996, 1999 and 2003. We calculated the upper 95% confidence interval using the variance of the 1996-2003 ratios for our weighted variance estimate. This resulted in a similar ratio as last year of 0.34. This results in an apportionment to the W. Yakutat area of 830 mt which would leave 1600 mt unharvested in the Eastern Gulf.

7.6.5 Overfishing Definition

Based on the definitions for overfishing in Amendment 44 in tier 3a (i.e., $F_{OFL} = F_{35\%}$=0.071), overfishing is set equal to 15,840 mt for Pacific ocean perch. The overfishing level is apportioned by area for Pacific ocean perch. Using the apportionment in Section 7.8.3, results in overfishing levels by area of 3,000 mt in the Western area, 9,960 mt in the Central area, and 2,880 mt in the Eastern area.

7.7 Ecosystem Considerations

In general, a determination of ecosystem considerations for slope rockfish is hampered by the lack of biological and habitat information. A summary of the ecosystem considerations presented in this section is listed in Table 7-12.

7.7.1 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 a strong 1987-88 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.

7.7.2 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 7-13).

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.

Fishery-specific effects on amount of large size target fish: There is no evidence for targeting large fish since the size-at-age has increased since the beginning of the fishery.

Fishery contribution to discards and offal production: Fishery discard rates for the whole rockfish trawl fishery has declined from 35% in 1997 to 19% in 2002. Arrowtooth flounder comprised 22-46% of these discards.

Fishery-specific effects on age-at-maturity and fecundity of the target fishery: Speculatively, we would expect that if the size-at-age is getting larger, than fecundity is rising and age-at-maturity is decreasing. However, no studies have been conducted to provide evidence of this.

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.

7.7.3 Data Gaps and Research Priorities

There is little information on larval, post-larval, or early stages slope rockfish. Habitat requirements for larval, post-larval, and early 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.

7.8 Summary

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

	Model				
	1 Base	2 New size-age matrix, low penalties	3 Model 2 with M fixed @ 0.05 and two size-age matrices	4 Model 3 with *q* constrained to = 1	5* Full model, estimating *M* and *q*
Tier			3a		
Total Biomass (Age 2+)	360,650	384,060	250,510	508,230	285,070
B_{2004} (mt)	120,090	138,385	95,567	166,100	95,765
$B_{0\%}$ (mt)	280,254	290,955	238,918	366406	224,248
$B_{40\%}$ (mt)	112,102	116,382	85,840	146,562	89,699
$B_{35\%}$ (mt)	98,089	101,834	83,622	128,242	78,486
M	0.05	0.06	0.05	0.05	0.06
$F_{40\%}$	0.05	0.06	0.05	0.05	0.06
F_{ABC} (maximum allowable)	0.05	0.06	0.05	0.05	0.06
ABC (mt; maximum allowable)	14,761	18,519	9,406	19,877	13,340

* Recommended for ABC calculation

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Table 7-1a. Commercial catch[a] (mt) of fish of Pacific ocean perch in the Gulf of Alaska, with Gulfwide values of acceptable biological catch (ABC) and fishing quotas[b] (mt), 1977-2002. Catches in 2003 updated through October 1, 2003.

				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 7-1a (continued)

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.	2,073	7,848	606	10,627	13,663	13,660

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; 1989-2003, 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); 2001-2003, Heifetz et. Al (2002).

Table 7-1b. Catch (mt) of Pacific ocean perch taken during research cruises in the Gulf of Alaska, 1977-2003. (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

Table 7-2. Fishery length frequency data for Pacific ocean perch in the Gulf of Alaska.

Length Class(cm)	Year 1977	1978	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
<13	0	0	5	0	14	0	0	1	0	34	0	0	0	0	0	0
13-15	0	0	26	11	22	3	0	3	2	11	1	1	2	1	1	0
16	2	0	13	16	16	2	0	1	0	23	0	1	2	0	1	0
17	2	0	19	13	13	2	0	2	0	35	2	1	3	0	1	1
18	2	0	31	17	13	6	0	2	6	69	2	3	2	7	1	1
19	3	0	46	26	20	9	2	3	5	25	3	4	1	7	3	1
20	9	0	72	38	23	20	3	4	6	25	12	3	3	8	7	0
21	14	0	124	37	32	35	2	5	7	27	19	5	14	9	16	2
22	20	0	177	50	54	60	9	7	11	30	21	11	14	15	21	3
23	56	1	235	66	81	96	19	18	22	37	17	13	15	15	29	5
24	100	2	321	81	112	129	31	20	25	34	44	30	30	15	33	6
25	134	4	412	97	167	166	64	34	44	53	61	37	24	26	50	10
26	198	12	512	123	239	198	85	56	83	89	90	47	45	23	71	12
27	314	33	642	158	303	250	97	80	158	143	88	44	70	41	83	22
28	484	67	724	156	338	315	125	110	272	191	117	40	80	49	123	30
29	630	130	836	240	416	359	137	158	427	287	201	94	92	66	135	36
30	890	263	951	263	496	398	167	174	666	499	312	83	101	92	133	47
31	1306	415	1089	319	531	440	179	225	948	855	516	147	160	114	207	62
32	1710	484	1259	382	584	472	192	254	1443	1312	860	271	229	176	234	71
33	2026	429	1374	439	644	490	212	283	2353	1995	1420	463	340	320	404	102
34	2131	286	1418	485	674	523	216	306	3646	2508	2338	739	665	479	671	194
35-38	7492	172	5601	1918	2477	1767	746	1158	17318	14246	17214	4967	5785	4390	4689	1755
>38	1866	0	4249	1567	2019	1051	563	783	5329	5554	7481	2250	3016	2612	2992	1242
Total	19382	2294	20136	6502	9288	6791	2849	3687	32771	28082	30819	9254	10693	8465	9905	3602

Table 7-3. Fishery age compositions for GOA Pacific ocean perch 1998-2002.

Age Class	Year 1998	1999	2000	2001	2002
2	0.001	-	-	-	-
3	-	-	-	0.004	-
4	0.002	-	0.008	0.003	0.002
5	0.001	0.002	0.014	0.004	0.008
6	0.001	0.014	0.029	0.011	0.011
7	0.005	0.024	0.018	0.029	0.029
8	0.031	0.045	0.046	0.025	0.085
9	0.076	0.045	0.051	0.051	0.072
10	0.180	0.054	0.063	0.041	0.106
11	0.122	0.173	0.066	0.052	0.091
12	0.132	0.189	0.130	0.075	0.058
13	0.106	0.128	0.103	0.139	0.071
14	0.120	0.090	0.095	0.112	0.114
15	0.052	0.116	0.102	0.088	0.111
16	0.029	0.054	0.079	0.086	0.071
17	0.051	0.019	0.050	0.069	0.058
18	0.020	0.021	0.040	0.071	0.042
19	0.014	0.002	0.030	0.046	0.032
20	0.008	0.002	0.012	0.019	0.014
21	0.011	-	0.017	0.019	0.008
22	0.004	0.009	0.014	0.006	0.006
23	0.008	0.002	0.006	0.012	0.003
24	0.003	-	0.003	0.006	0.002
25	0.022	0.009	0.024	0.032	0.008
Sample size	1336	423	1312	1234	624

Table 7-4. Biomass estimates (mt) and Gulfwide confidence intervals for Pacific ocean perch in the Gulf of Alaska based on the 1984-2003 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*	275210	39819	385,126	44,392	102,514	820,061	364,570 – 1,275,552
2003	72,851	116,231	166,815	27,762	73,737	457,394	313,363 – 601,426

*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 7-5. 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
2	0.007	0.009	0.014	0.027	0.010	0.046
3	0.002	0.085	0.059	0.046	0.031	0.099
4	0.061	0.101	0.116	0.050	0.063	0.099
5	0.029	0.058	0.095	0.071	0.070	0.111
6	0.052	0.061	0.114	0.102	0.111	0.060
7	0.115	0.115	0.097	0.102	0.058	0.061
8	0.386	0.047	0.073	0.090	0.075	0.058
9	0.028	0.056	0.063	0.114	0.111	0.065
10	0.016	0.084	0.058	0.064	0.130	0.030
11	0.007	0.104	0.037	0.034	0.077	0.058
12	0.013	0.021	0.025	0.039	0.058	0.072
13	0.010	0.013	0.026	0.032	0.025	0.040
14	0.012	0.012	0.070	0.020	0.022	0.036
15	0.005	0.012	0.015	0.029	0.019	0.021
16	0.003	0.016	0.012	0.013	0.007	0.025
17	0.008	0.018	0.006	0.044	0.015	0.012
18	0.005	0.010	0.008	0.010	0.011	0.009
19	0.002	0.006	0.006	0.003	0.018	0.003
20	-	0.009	0.007	0.003	0.017	0.008
21	0.004	0.007	0.007	0.003	0.007	0.005
22	0.003	0.003	0.002	0.005	0.006	0.009
23	0.002	0.004	0.003	0.003	0.003	0.014
24	0.006	0.003	0.005	0.005	-	0.005
25	0.224	0.147	0.083	0.091	0.056	0.052
Total	2575	1824	1788	1492	718	963

Table 7-6. Estimated numbers (thousands) in 2003, 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 2003 (1000's)	Percent mature	Weight (g)	Fishery selectivity	Survey selectivity
2	37,024	0	46	0	2
3	34,159	0	106	1	6
4	30,592	0	180	2	18
5	27,904	0	261	3	33
6	25,496	0	342	8	48
7	23,834	12	420	29	97
8	33,051	20	493	100	100
9	40,633	30	559	95	100
10	11,453	42	619	95	100
11	12,336	56	672	95	100
12	8,528	69	718	95	100
13	6,483	79	758	95	100
14	10,497	87	792	95	100
15	13,564	92	822	95	100
16	84,867	95	847	95	100
17	41,663	97	868	95	100
18	10,839	98	886	95	100
19	15,793	99	902	95	100
20	7,027	99	915	95	100
21	5,308	100	926	95	100
22	3,324	100	935	95	100
23	5,557	100	943	95	100
24	1,492	100	950	95	100
25+	10,702	100	970	95	100

Table 7-7. Summary of results from five alternative *S. alutus* models

	Base Model		Model 2		Model 3		Model 4		Model 5	
Likelihoods	**Value**	**Weight**	**Value**	**Weight**	**Value**	**Weight**	**Value**	**Weight**	**Value**	**Weight**
Catch	1.71	50	0.17	50	0.10	50	0.16	50	0.09	50
Survey Biomass	9.34	1	7.42	1	6.72	1	11.24	1	6.82	1
Fishery Ages	53.79	1	37.32	1	32.10	1	35.13	1	32.87	1
Survey Ages	77.58	1	80.77	1	67.76	1	69.55	1	67.59	1
Fishery Sizes	213.61	1	62.71	1	54.40	1	58.68	1	50.82	1
Data-Likelihood	356.03		188.39		161.08		174.76		158.20	
Penalties/Priors										
Recruitment Devs	7.93	50	31.03	1	31.53	1	35.69	1	32.50	1
Fishery Selectivity	4.60	12.5	2.40	1	2.34	1	1.37	1	1.92	1
Survey Selectivity	1.72	12.5	1.48	1	0.92	1	0.71	1	0.84	1
Fish-Sel Domeshape	0.06	1,000	0.00	1	0.04	1	0.00	1	0.00	1
Survey-Sel Domeshape	0.19	1,000	0.00	1	0.01	1	0.00	1	0.00	1
Average Selectivity	0.00	10	0.00	1	0.00	1	0.00	1	0.00	1
F Regularity	49.26	1	7.28	0.1	4.40	0.1	12.26	0.2	4.74	0.1
σ_r prior	0.17		0.71		0.69		0.01		0.65	
q prior	0.10		0.27		1.82		0.02		0.99	
Objective Fun Total	420.07		231.56		202.83		224.81		199.84	
Parameter Ests.		LN Prior (μ,σ)		LN Prior (μ,σ)		LN Prior (μ,σ)		LN Prior (μ,σ)		LN Prior (μ,σ)
q	1.22	(1,0.2)	1.39	(1,0.2)	2.35	(1,0.2)	1.00	(1, 0.00001)	1.88	(1,0.2)
M	0.05	Fixed	0.06	(0.05,0.01)	0.05	Fixed	0.05	Fixed	0.06	(0.05,0.01)
σ_r	0.69	(0.9,0.2)	1.00	(1.7,0.2)	1.01	(1.7,0.2)	1.05	(1.7,0.2)	1.02	(1.7,0.2)
log-mean-rec	4.17		3.82		3.38		3.61		3.61	
$F_{40\%}$	0.05		0.06		0.05		0.05		0.06	
Total Biomass	360,650		384,060		250,510		508,230		285,070	
B_{2004}	120,090		138,385		85,840		166,100		95,762	
$B_{0\%}$	280,254		290,955		238,918		366,406		224,248	
$\mathbf{B_{40\%}}$	***112,102***		***116,382***		***95,567***		***146,562***		***89,699***	
$\mathbf{ABC_{F40}}$	***14,761***		***18,519***		***9,406***		***19,877***		***13,336***	
$F_{50\%}$	0.04		0.04		0.04		0.04		0.04	
$ABC_{F50\%}$	10,405		13,132		6,608		13,958		9,410	

Table 7-8. Estimates of key parameters with MLE estimates of standard error and 95% Bayesian confidence intervals (BCI) derived from MCMC simulations.

Parameter	μ	σ	σ(MCMC)	BCI-Lower	BCI-Upper
q	1.88	0.508	0.560	1.127	3.330
M	0.059	0.006	0.005	0.045	0.066
$F_{40\%}$	0.060	0.015	0.015	0.042	0.100
B_{2003}	101,380	32,465	37,843	50,462	193,829
ABC	13,363	4,732	5,923	5,713	28298
σ_r	1.02	0.114	0.419	1.64	3.25

Table 7-9. 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.

Year	Spawning biomass (mt)		6+ Biomass (mt)		Catch/6+ biomass		Age 2 recruits (1000's)	
	Current	Previous	Current	Previous	Current	Previous	Current	Previous
1977	39,481	48,907	130,740	141,950	0.348	0.152	9,169	22,517
1978	28,010	43,760	88,930	125,765	0.243	0.064	11,166	38,014
1979	22,888	43,432	70,370	123,057	0.114	0.068	25,273	60,901
1980	22,029	42,761	65,106	120,099	0.127	0.091	44,380	26,518
1981	20,540	40,900	59,212	115,668	0.182	0.092	14,192	26,667
1982	17,619	39,041	51,184	116,290	0.205	0.047	15,698	47,485
1983	14,558	39,482	47,324	129,758	0.114	0.022	51,844	34,679
1984	13,679	41,747	54,578	137,442	0.052	0.021	26,420	29,138
1985	14,429	44,259	57,716	144,924	0.048	0.006	34,333	36,849
1986	15,374	47,989	61,049	160,221	0.013	0.014	35,957	49,830
1987	17,390	52,157	75,919	170,829	0.029	0.027	68,177	50,326
1988	19,972	55,888	83,767	177,172	0.054	0.049	40,740	159,199
1989	22,075	58,139	91,216	181,092	0.094	0.066	142,264	80,177
1990	23,249	59,069	94,916	185,422	0.124	0.070	268,167	45,291
1991	23,379	59,642	103,941	189,242	0.126	0.035	39,487	42,186
1992	23,797	62,590	105,798	232,133	0.063	0.027	27,923	36,468
1993	26,344	68,233	141,489	257,436	0.044	0.008	15,680	32,123
1994	31,459	76,017	215,674	277,060	0.010	0.007	18,759	28,812
1995	42,237	84,788	241,154	294,249	0.008	0.020	24,560	26,614
1996	53,458	93,210	260,376	303,904	0.022	0.028	20,615	33,679
1997	65,267	101,074	268,391	307,698	0.031	0.031	65,941	42,751
1998	76,809	107,773	270,578	307,613	0.035	0.030	48,124	43,633
1999	87,391	112,964	270,082	305,958	0.033	0.035	32,253	47,125
2000	95,610	115,830	266,981	303,597	0.039	0.034	32,396	60,147
2001	99,941	117,186	272,777	303,634	0.037	0.036	33,361	62,901
2002	102,503	117,090	274,761	303,281	0.039	0.039	34,449	63,966
2003	102,644	112,269	271,652	298,816	0.043		36,246	47,840
2004*	95,760		266,963				37,024	

* projection based on an average recruitment 1977-1997 year class.

Table 7-10. 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 7.8.1. All units in mt. $B_{40\%}$ = 89,699 mt, $B_{35\%}$ = 78,486 mt, $F_{40\%}$ = 0.060, and $F_{35\%}$ = 0.071.

Year	Maximum permissible F	Half maximum F	5-year average F	No fishing	Overfished	Approaching overfished
			Spawning biomass (mt)			
2003	97,765	97,765	97,765	97,765	97,765	97,765
2004	95,762	96,675	96,123	97,596	95,411	95,762
2005	93,397	96,983	94,800	100,708	92,042	93,397
2006	91,110	97,270	93,499	103,852	88,848	90,776
2007	88,789	97,371	92,078	106,820	85,793	87,535
2008	86,749	97,544	90,797	109,859	83,206	84,731
2009	84,988	97,704	89,607	112,807	81,020	82,339
2010	83,600	97,978	88,633	115,783	79,304	80,432
2011	82,763	98,623	88,102	119,079	78,205	79,160
2012	82,467	99,686	88,047	122,760	77,689	78,491
2013	82,419	100,854	88,186	126,435	77,467	78,130
2014	82,739	102,328	88,677	130,380	77,625	78,169
2015	83,321	104,038	89,434	134,549	78,047	78,489
2016	84,089	105,915	90,390	138,860	78,651	79,008
			Fishing mortality			
2003	0.052	0.052	0.052	0.05	0.052	0.052
2004	0.060	0.030	0.048	-	0.071	0.060
2005	0.060	0.030	0.048	-	0.071	0.060
2006	0.060	0.030	0.048	-	0.071	0.071
2007	0.059	0.030	0.048	-	0.068	0.070
2008	0.058	0.030	0.048	-	0.066	0.067
2009	0.057	0.030	0.048	-	0.064	0.065
2010	0.056	0.030	0.048	-	0.063	0.064
2011	0.055	0.030	0.048	-	0.062	0.063
2012	0.055	0.030	0.048	-	0.061	0.062
2013	0.055	0.030	0.048	-	0.061	0.062
2014	0.055	0.030	0.048	-	0.061	0.062
2015	0.055	0.030	0.048	-	0.061	0.062
2016	0.055	0.030	0.048	-	0.062	0.062
			Yield (mt)			
2003	12,001	12,001	12,001	12,001	12,001	12,001
2004	13,336	6,761	10,756	-	15,838	13,336
2005	12,949	6,746	10,557	-	15,218	12,949
2006	12,592	6,732	10,371	-	14,510	14,955
2007	12,152	6,725	10,211	-	13,536	14,078
2008	11,628	6,735	10,088	-	12,776	13,228
2009	11,251	6,776	10,027	-	12,227	12,603
2010	11,142	6,913	10,128	-	12,013	12,327
2011	11,131	7,054	10,239	-	11,933	12,195
2012	11,209	7,199	10,362	-	11,972	12,188
2013	11,300	7,330	10,472	-	12,049	12,226
2014	11,435	7,463	10,590	-	12,189	12,332
2015	11,583	7,587	10,701	-	12,354	12,468
2016	11,734	7,705	10,805	-	12,525	12,615

Table 7-11. Allocation of ABC for 2004 Pacific ocean perch in the Gulf of Alaska.

		Western	Central		Eastern		
Year	Weights	Shumagin	Chirikof	Kodiak	Yakutat	Southeast	Total
1999	4	5%	55%	29%	5%	6%	100%
2001	6	32%	5%	45%	5%	12%	100%
2003	9	16%	25%	36%	6%	16%	100%
Weighted Mean	19	19%	25%	38%	5%	13%	100%
Area Allocation		19%	63%		18%		
Area ABC		**2,522**	**8,384**		**2,430**		**13,336**

Table 7-12.Summary of ecosystem considerations for slope rockfish.

Indicator	*Observation*	*Interpretation*	*Evaluation*
ECOSYSTEM EFFECTS ON STOCK			
Prey availability or abundance trends	important for larval and post-larval survival, but no information known	may help to determine year class strength	possible concern if some information available
Predator population trends	unknown		little concern for adults
Changes in habitat quality	variable	variable recruitment	possible concern
FISHERY EFFECTS ON ECOSYSTEM			
Fishery contribution to bycatch			
Prohibited species	unknown		
Forage (including herring, Atka mackerel, cod, and pollock)	Minimal, with Pacific cod being the most affected	Amount discarded is small compared to fishery take.	little concern
HAPC biota (seapens/whips, corals, sponges, anemones)	fishery disturbs hardbottom biota: e.g. corals, sponges	Could harm the ecosystem by reducing shelter for some species	concern
Marine mammals and birds	few taken		little concern
Sensitive non-target species	corals and sponges	Occasional large amounts taken in specific areas	concern
Fishery concentration in space and time	little overlap between fishery and reproductive activities	Fishery does not hinder reproduction	little concern
Fishery effects on amount of large size target fish	no evidence for tar-getting large fish	large fish and small fish are both in population	little concern
Fishery contribution to discards and offal production	discard rates moderate to high for some species of slope rockfish	little unnatural input of food into the ecosystem	some concern
Fishery effects on age-at-maturity and fecundity	**fishery is catching some immature fish**	**could reduce spawning potential and yield**	possible concern

Table 7-13. Bycatch (kg) and bycatch rates during 1997 - 2002 of living substrates in the Gulf of Alaska for combined rockfish fisheries, all gears. Source: Gaichas and Ianelli, unpublished data.

	1997	1998	1999	2000	2001	2002	Average
Non-target species	Bycatch (kg)						
Sea Pens/Whips	0	0	23	12	30	18	14
Sponges	1,504	643	5,393	1,482	1,887	1,951	2,143
Anemones	459	15	673	1,438	255	335	529
Tunicates	14	45	6	481	8	38	99
Echinoderms	2,023	532	2,016	773	2,952	683	1,496
Coral	1,636	330	766	10,005	4,317	15,143	5,366
Rockfish Catch (tons)	13,083	13,592	18,333	15,947	15,672	16,977	15,601
	Bycatch rate (kg/mt target)						
Sea Pens/Whips	0.0000	0.0000	0.0012	0.0007	0.0019	0.0010	0.0009
Sponges	0.1150	0.0473	0.2941	0.0929	0.1204	0.1149	0.1374
Anemones	0.0351	0.0011	0.0367	0.0902	0.0163	0.0197	0.0339
Tunicates	0.0011	0.0033	0.0003	0.0301	0.0005	0.0022	0.0063
Echinoderms	0.1546	0.0391	0.1099	0.0485	0.1883	0.0402	0.0959
Coral	0.1251	0.0242	0.0418	0.6274	0.2755	0.8920	0.3440

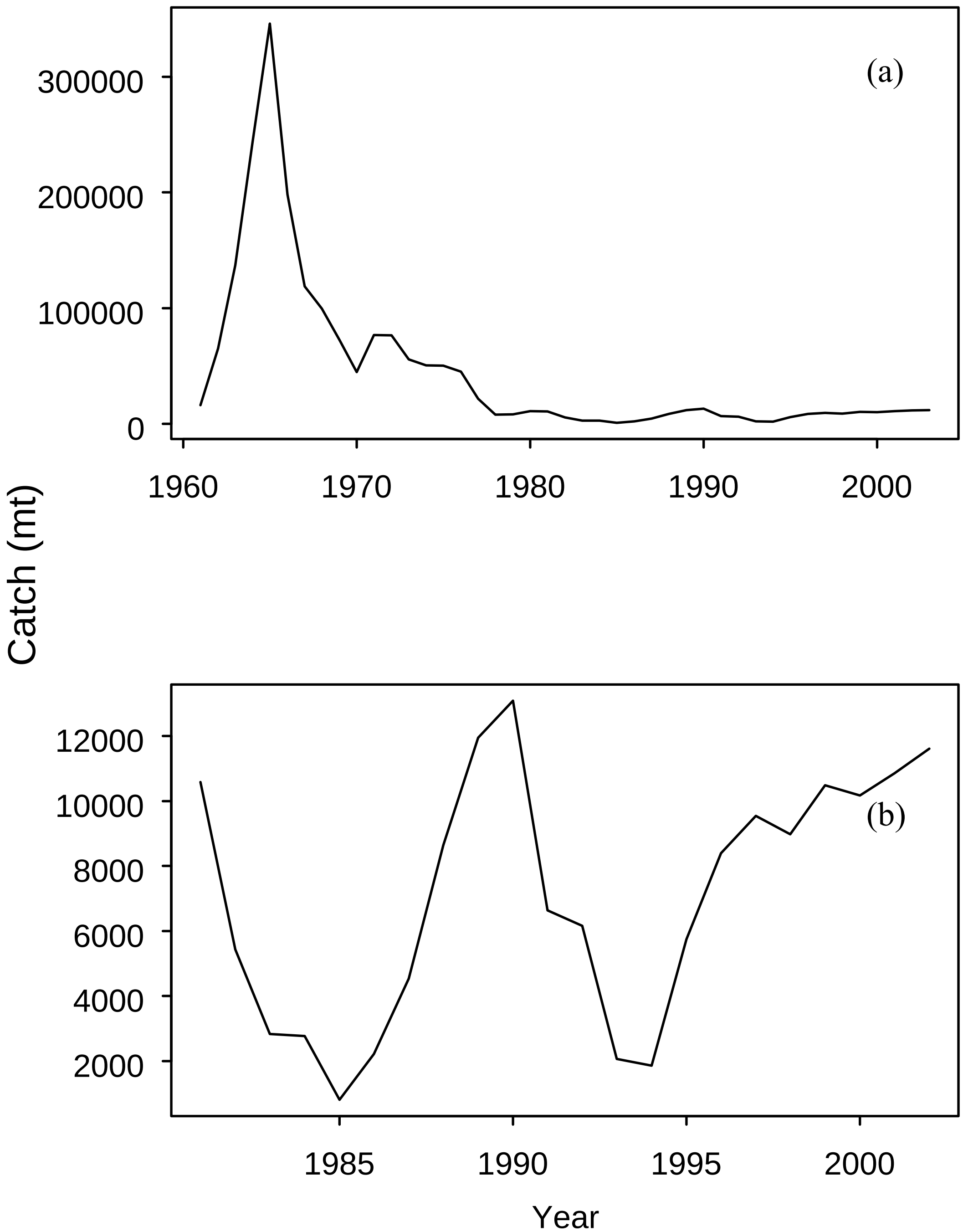

Figure 7-1. Long-term and short-term catch for GOA Pacific ocean perch.

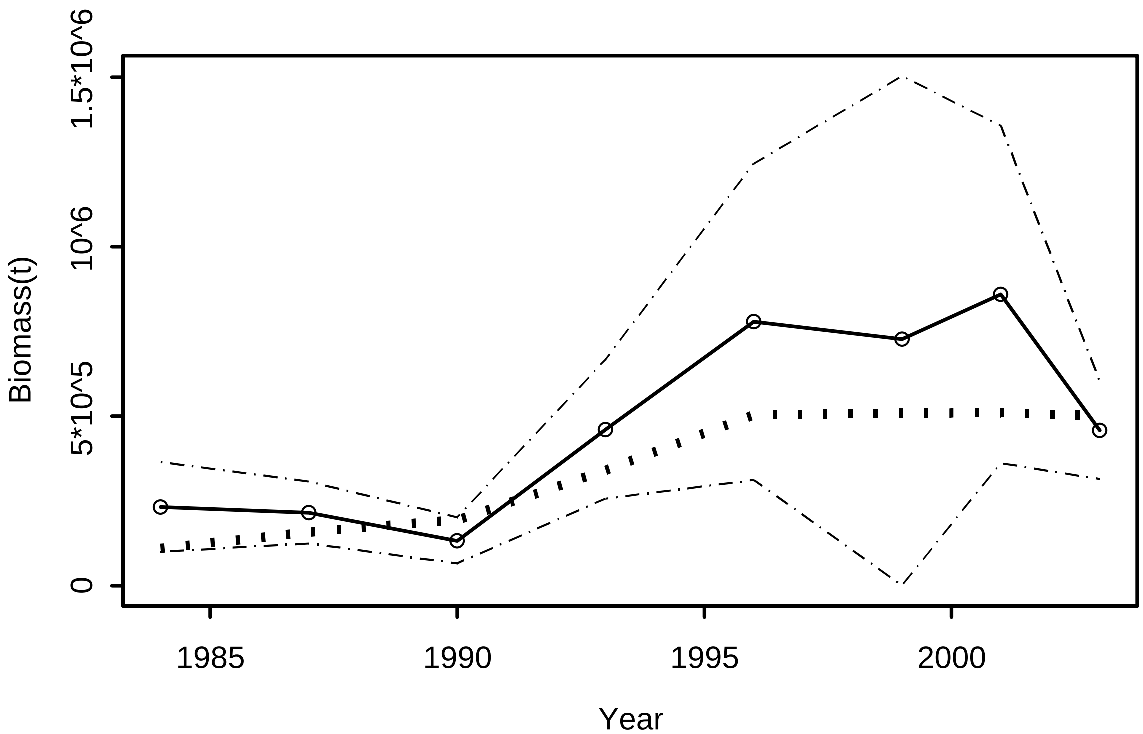

Figure 7-2. Observed and predicted GOA POP survey biomass. Observed =solid line and recommended model predicted=dotted line. Outer dashed lines represent 95% CIs of sampling error of observed biomass.

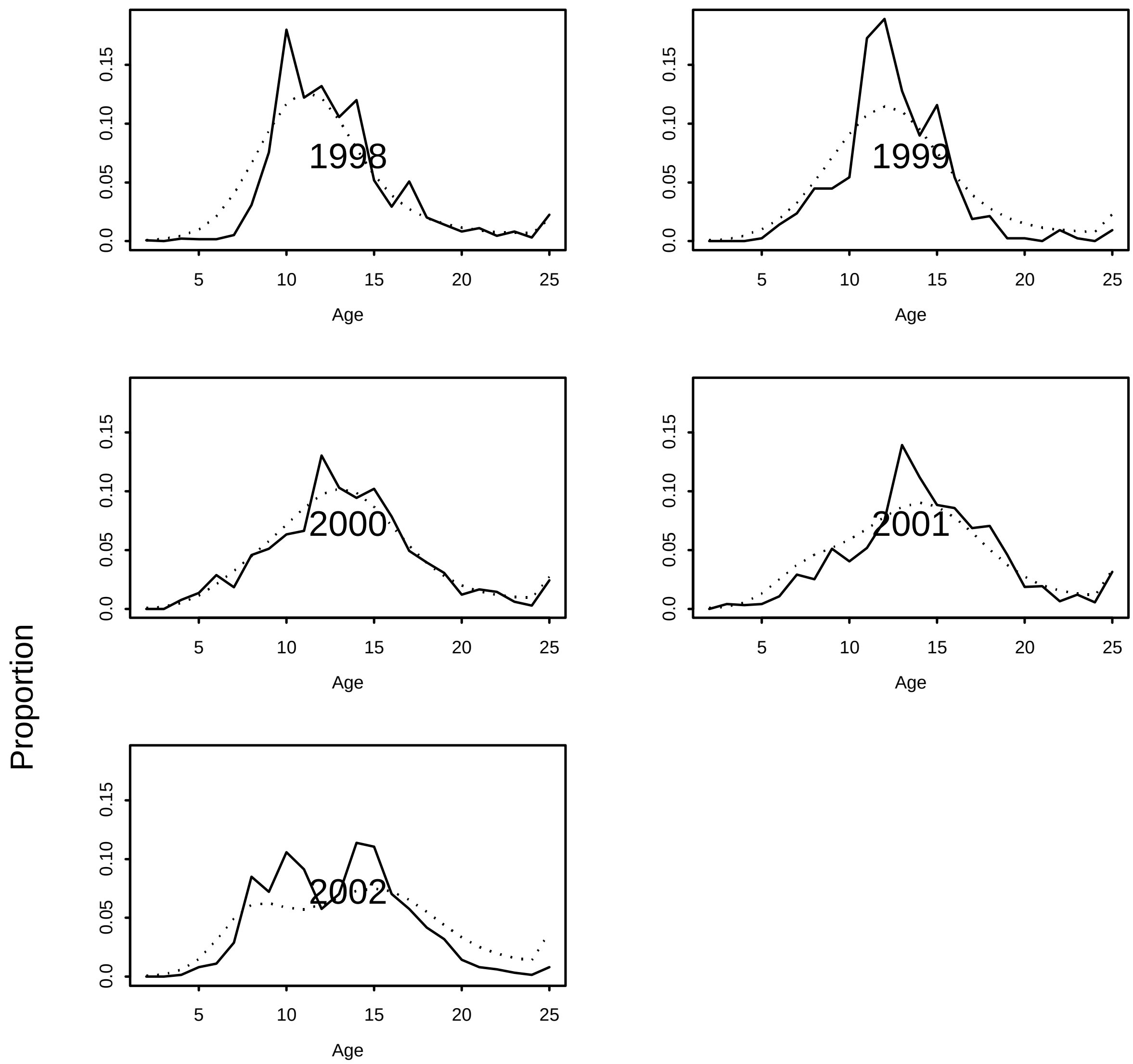

Figure 7-3. Fishery age composition by year (solid line = observed, dotted line = predicted from recommended model.)

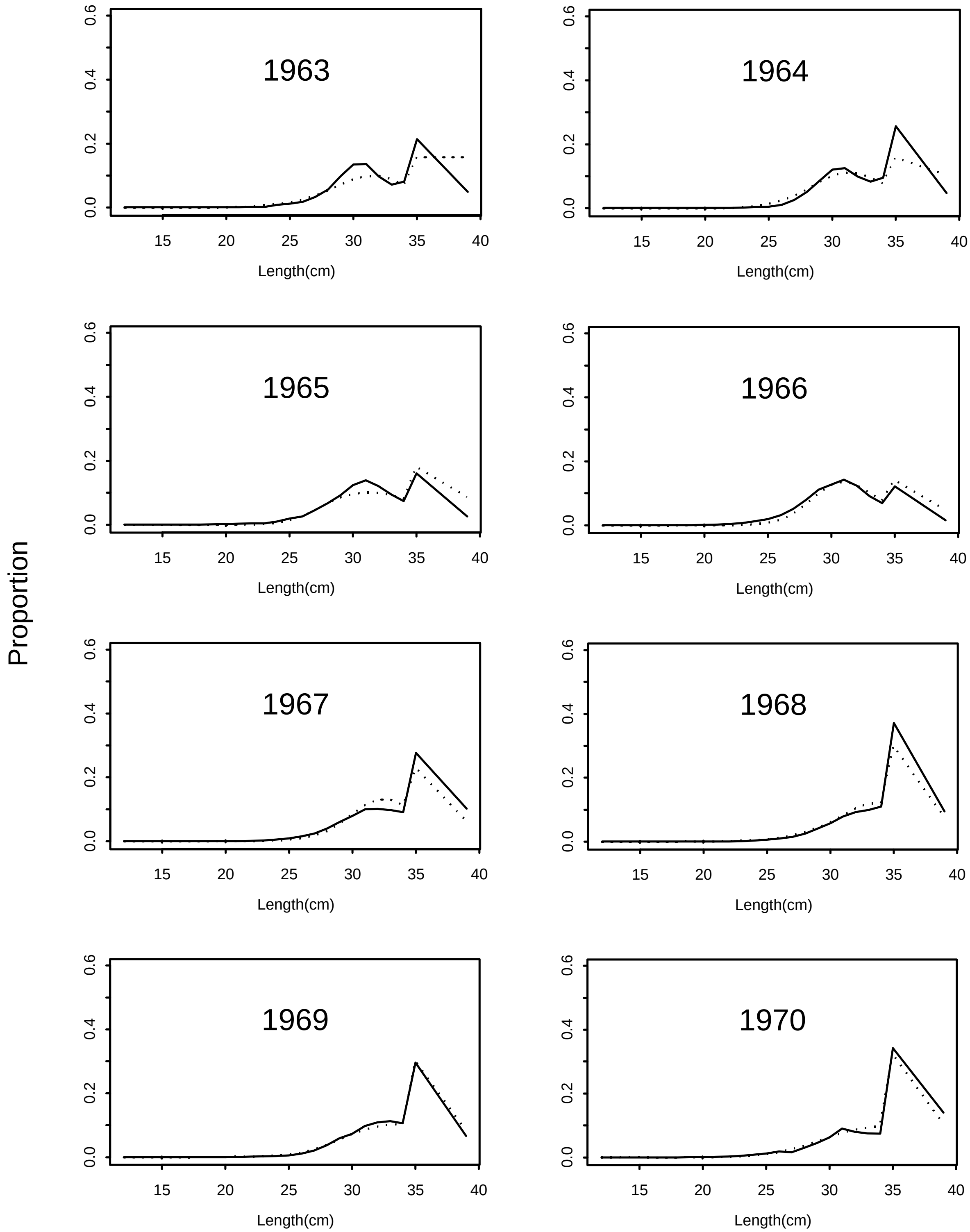

Figure 7-4. Fishery length composition by year (solid line = observed, dotted line = predicted from recommended model.)

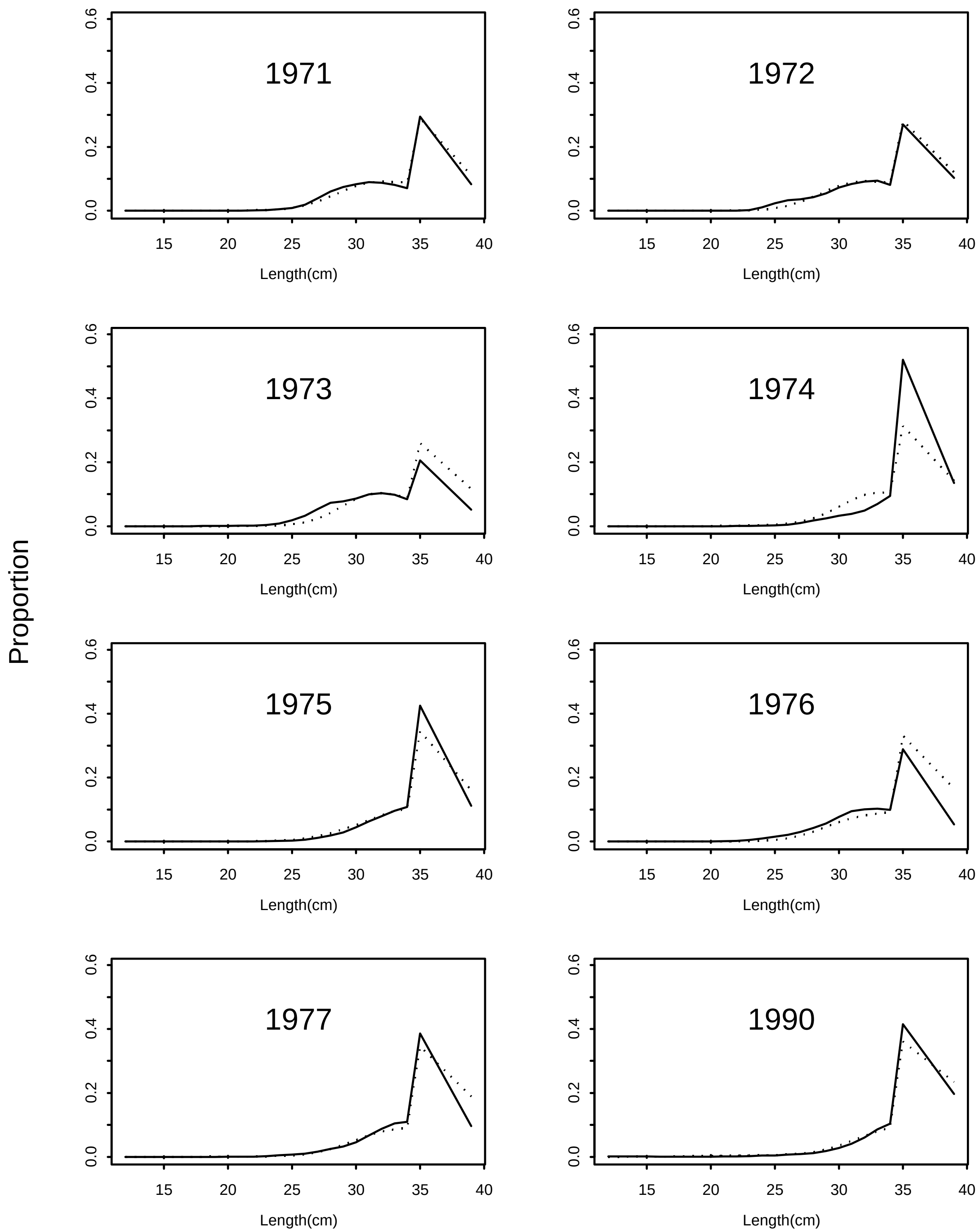

Figure 7-4 (continued). Fishery length composition by year (solid line = observed, dotted line = predicted from recommended model.)

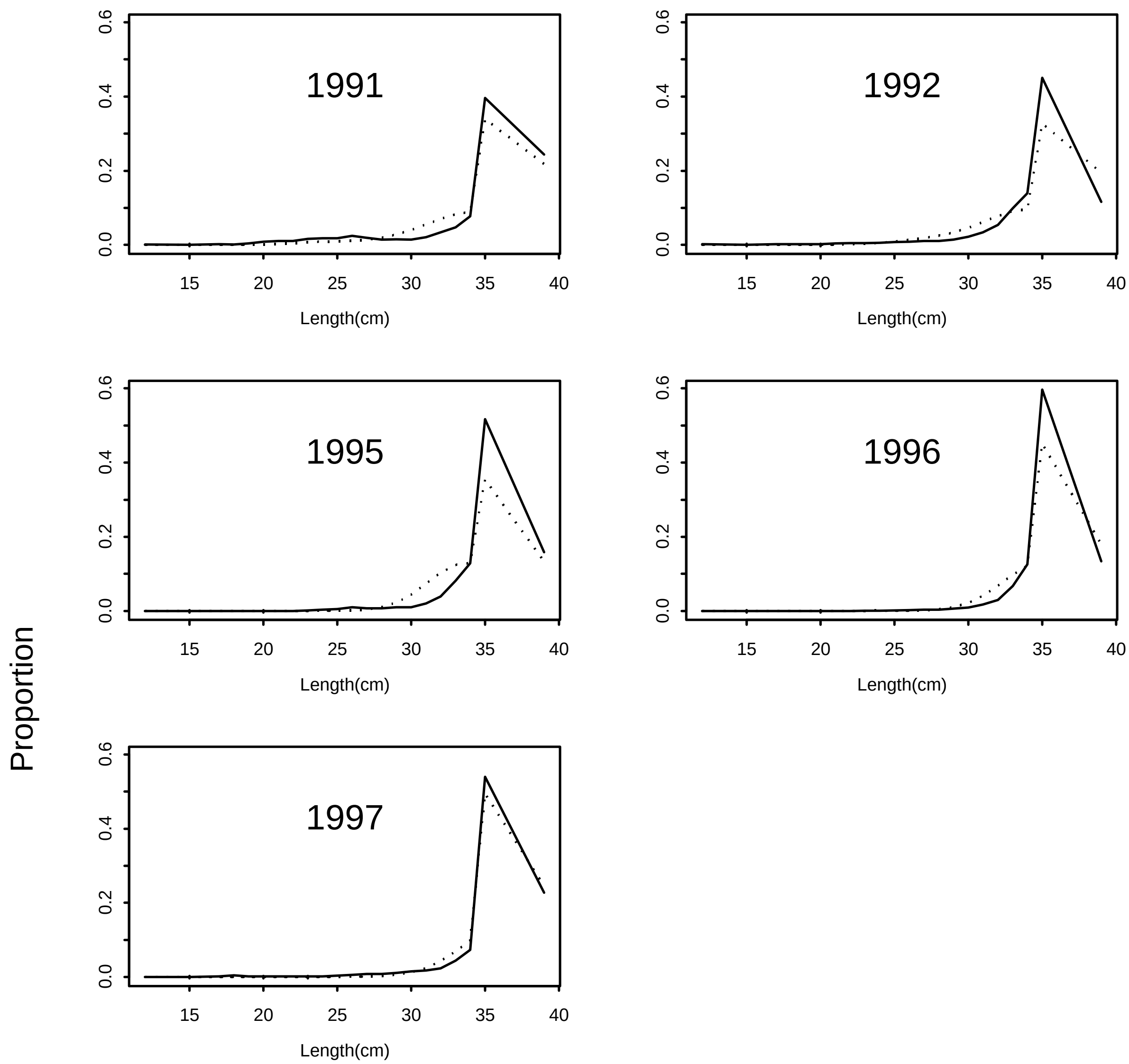

Figure 7-4 (continued). Fishery length composition by year (solid line = observed, dotted line = predicted from recommended model.)

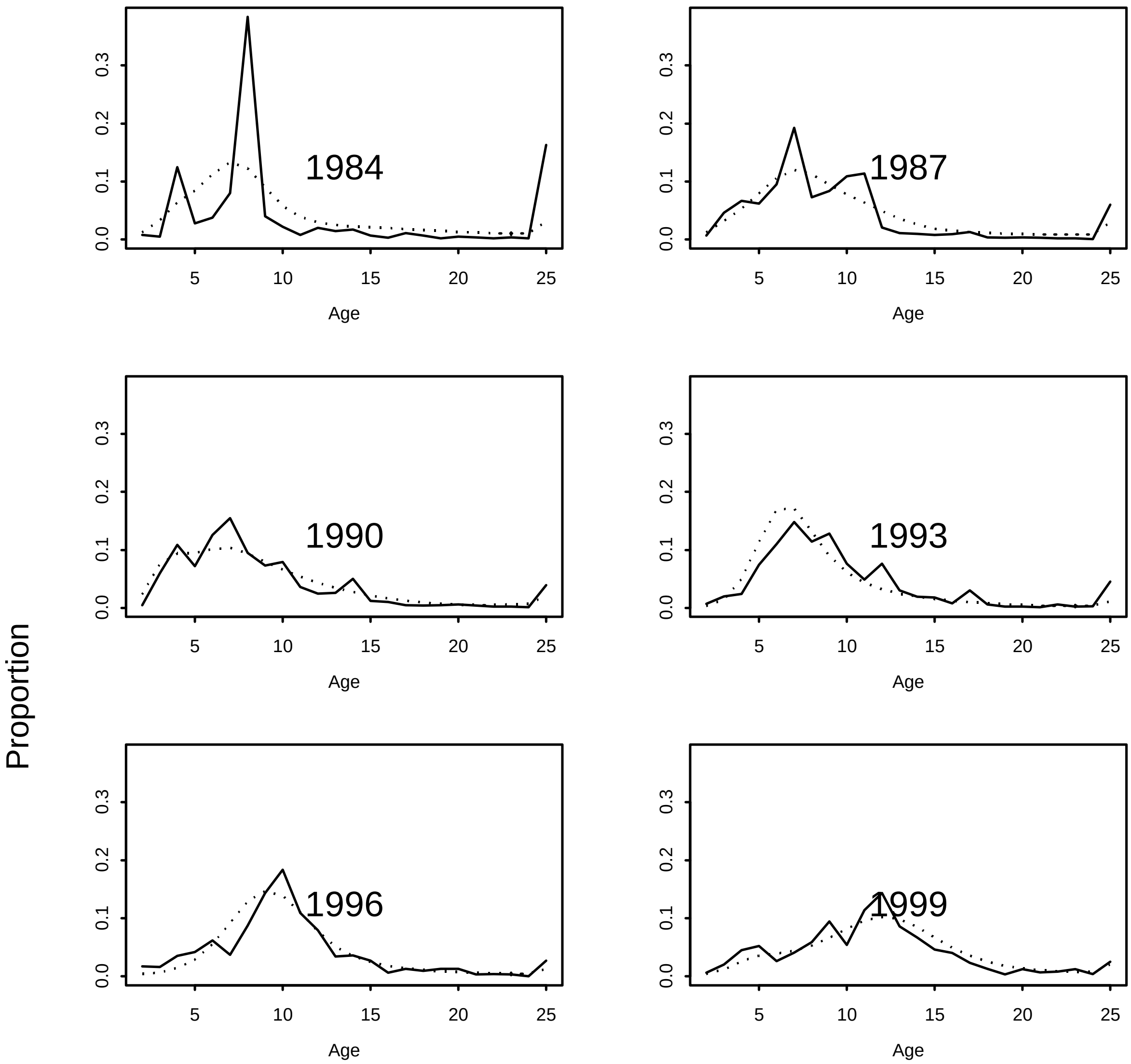

Figure 7-5. GOA Survey age composition by year (solid line = observed, dotted line = predicted from recommended model.)

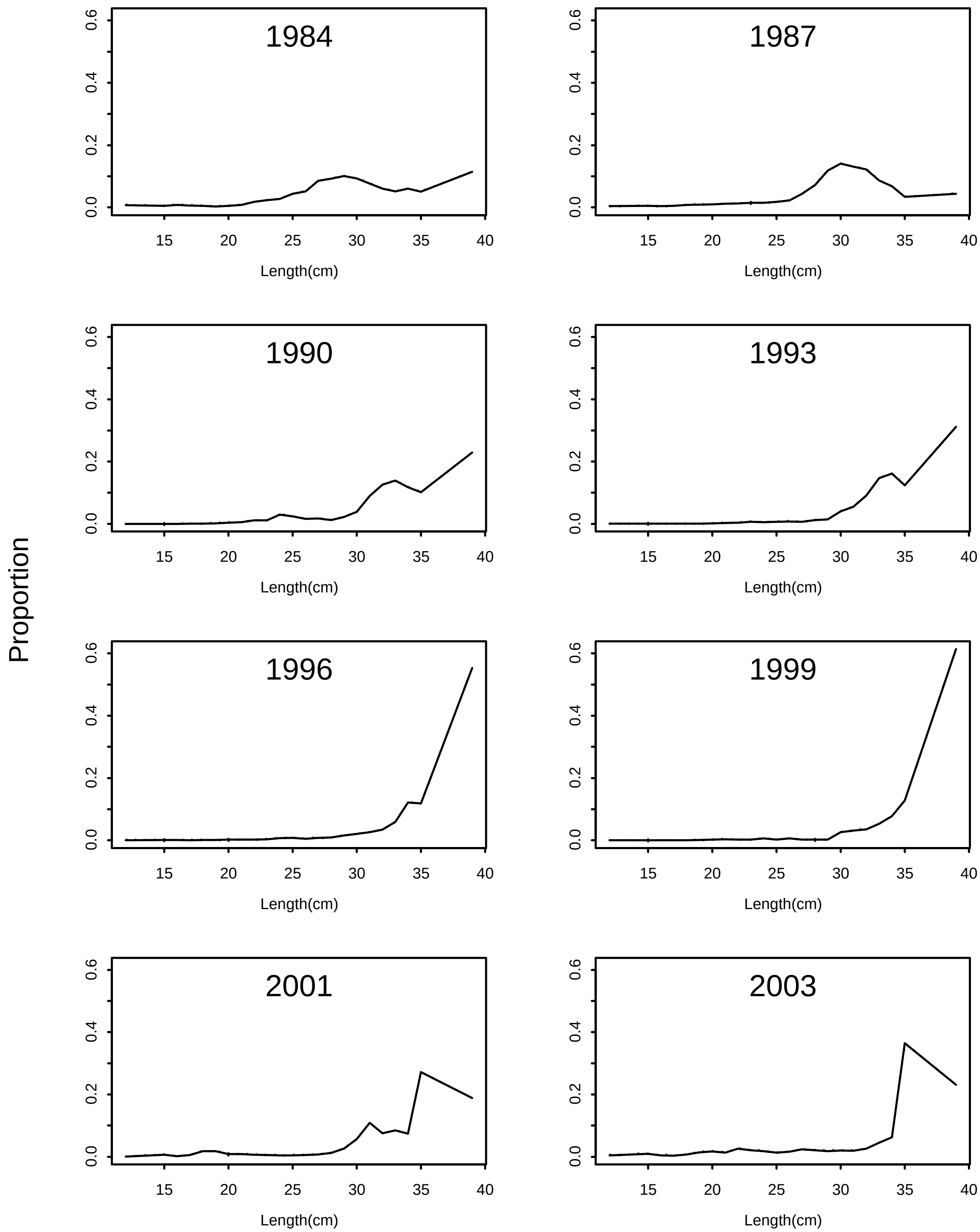

Figure 7-6. GOA Survey length composition by year.

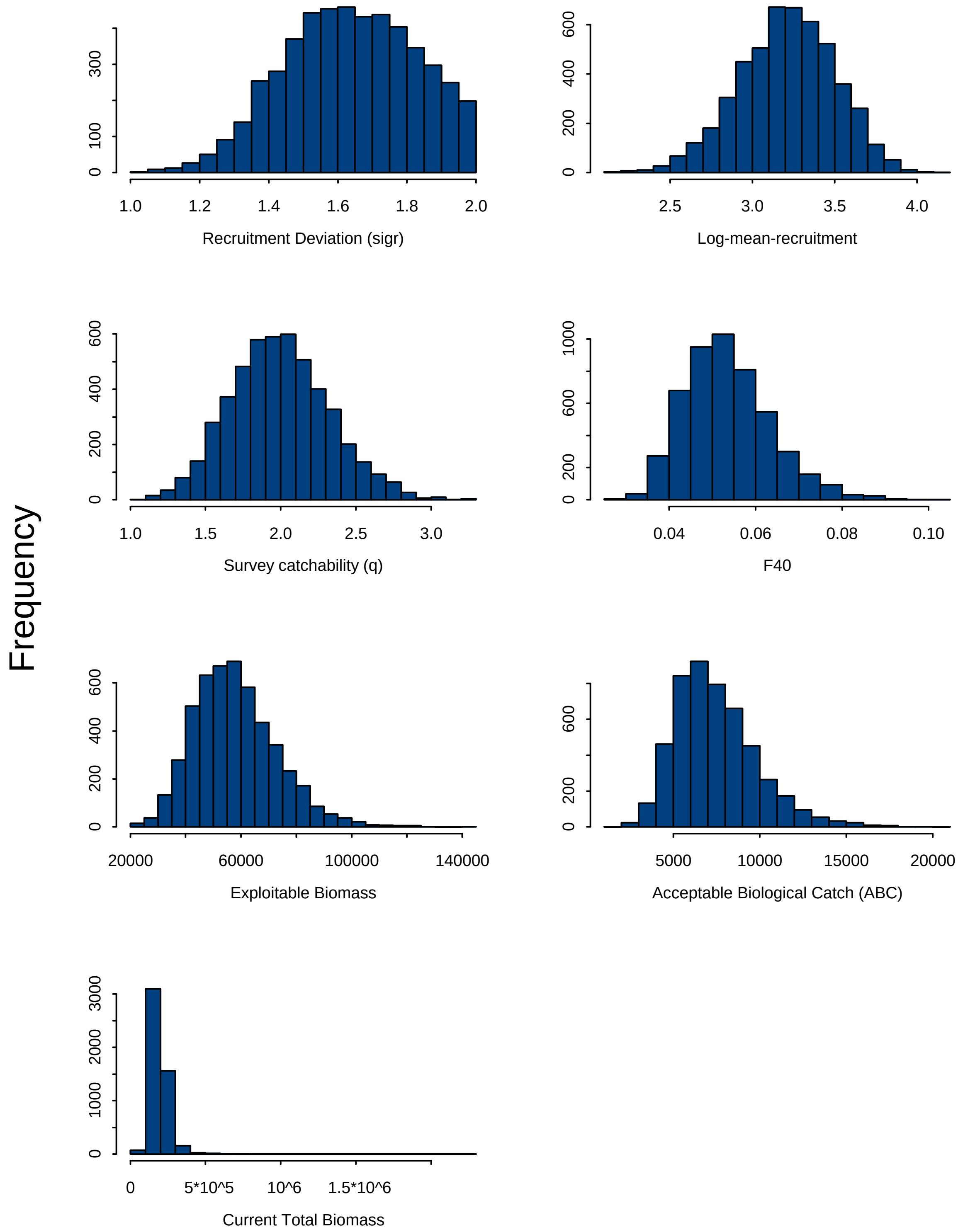

Figure 7-7. MCMC distributions of key parameters from sample of 4500 from 5 million runs for base model (1).

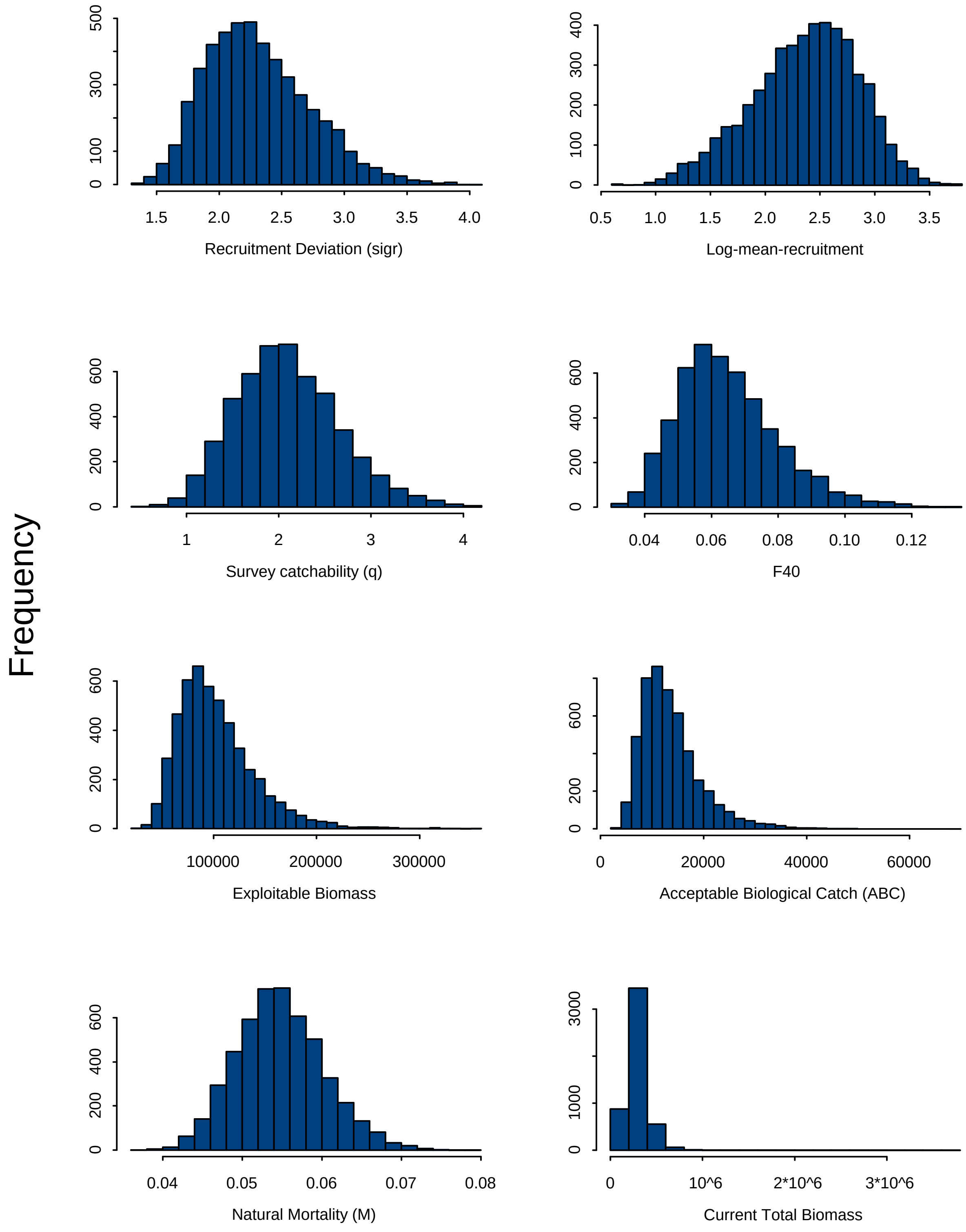

Figure 7-8. MCMC distributions of key parameters from sample of 4500 from 5 million runs for recommended model (5).

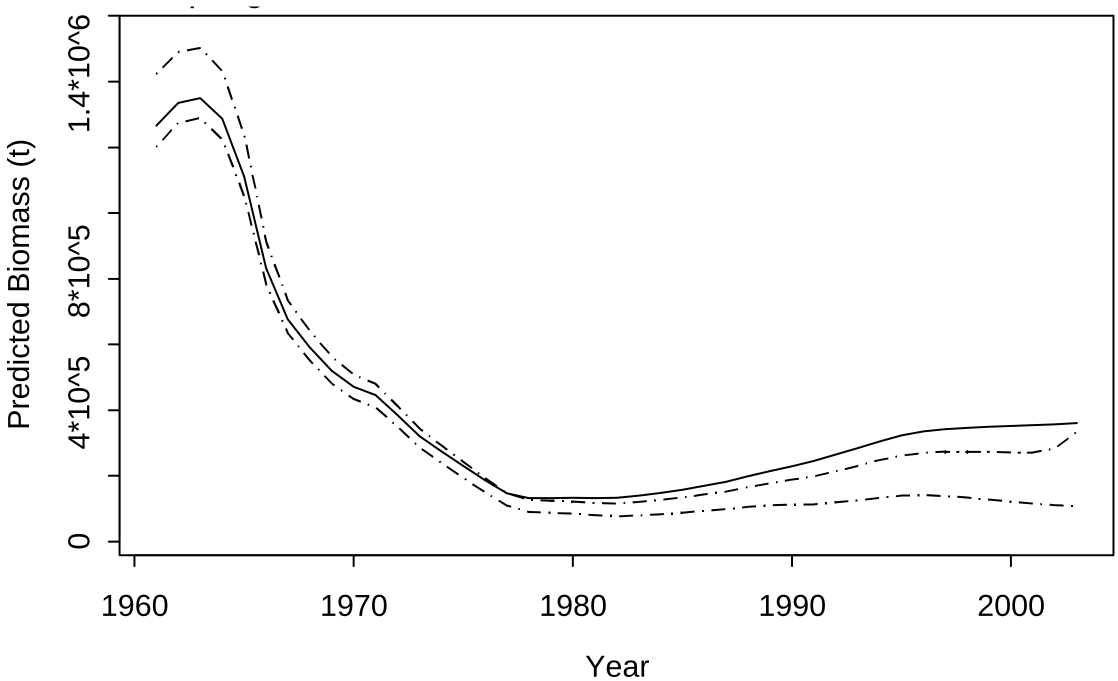

Figure 7-9. Predicted total biomass for GOA Pacific ocean perch.
Dashed lines are 95% confidence intervals
from 5,000,000 MCMC runs for Base Model (1).

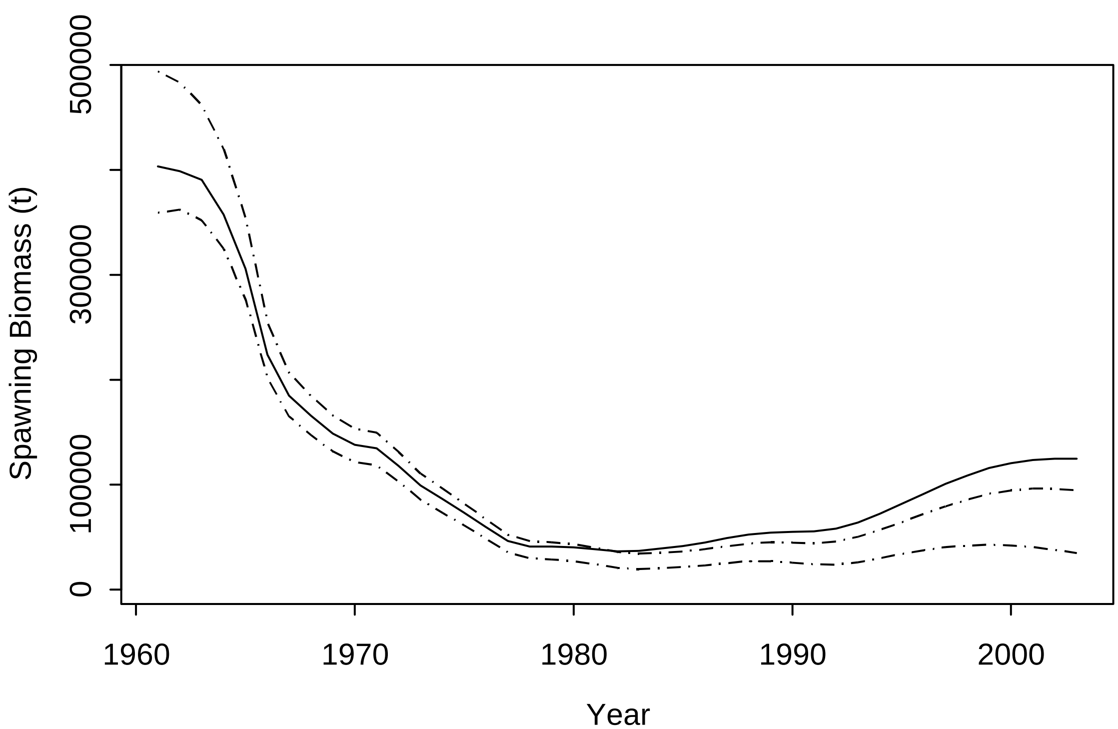

Figure 7-10. Predicted total biomass for GOA Pacific ocean perch.
Dashed lines are 95% confidence intervals
from 5,000,000 MCMC runs for Base Model (1).

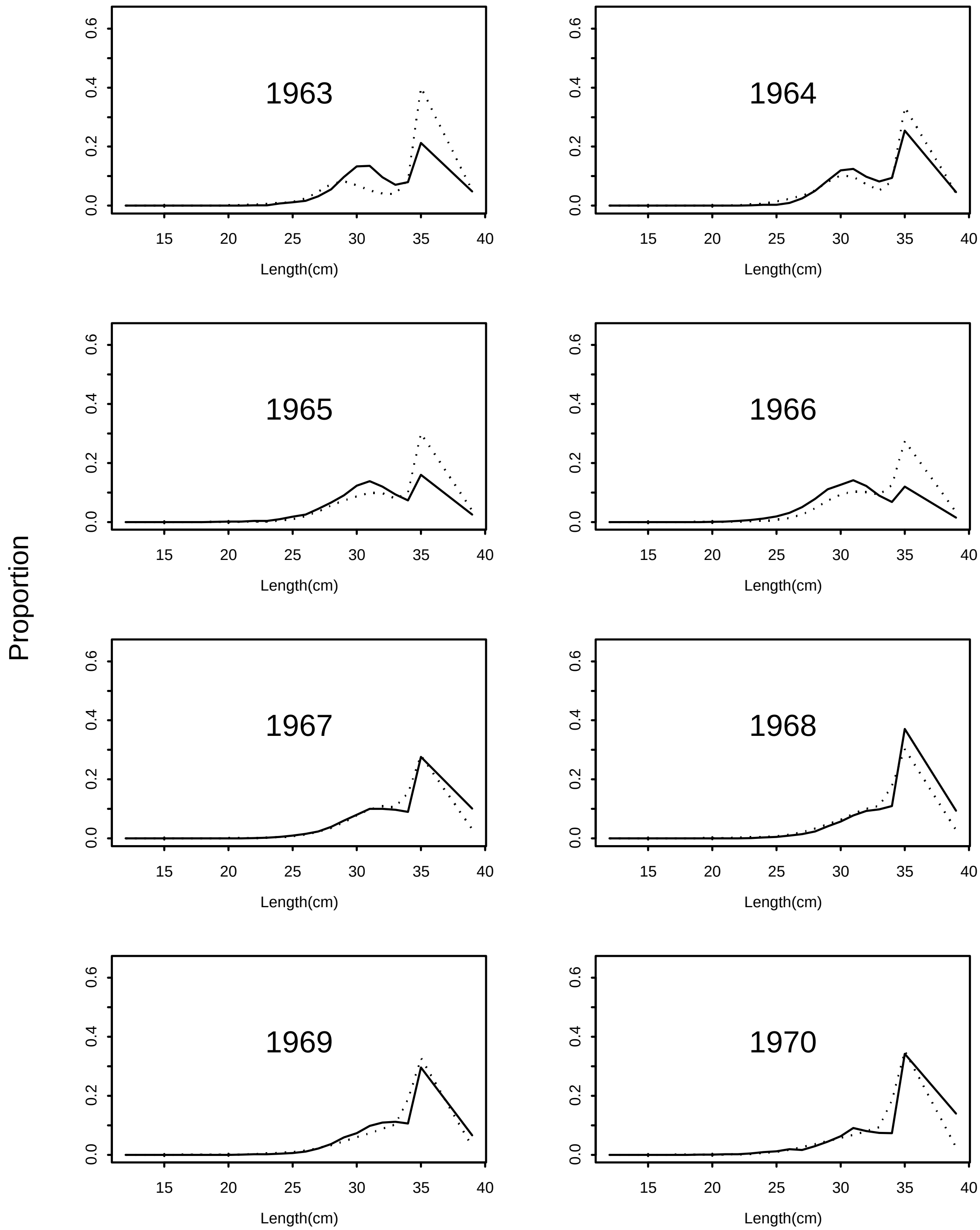

Figure 7-11. Fishery length composition by year (solid line = observed, dotted line = predicted). Base Model Fits.

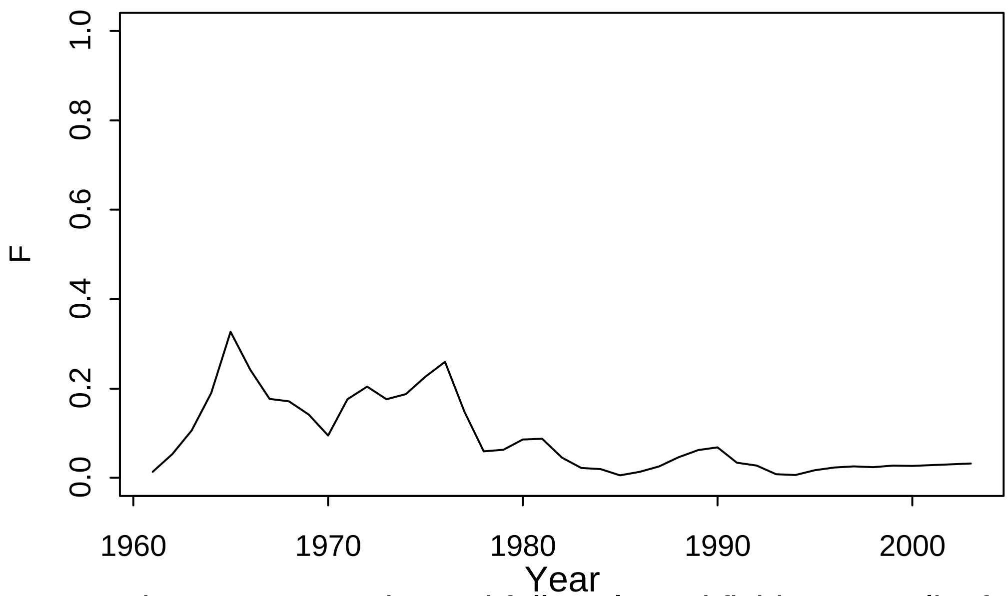

Figure 7-12. Estimated fully selected fishing mortality for GOA POP. Base Model.

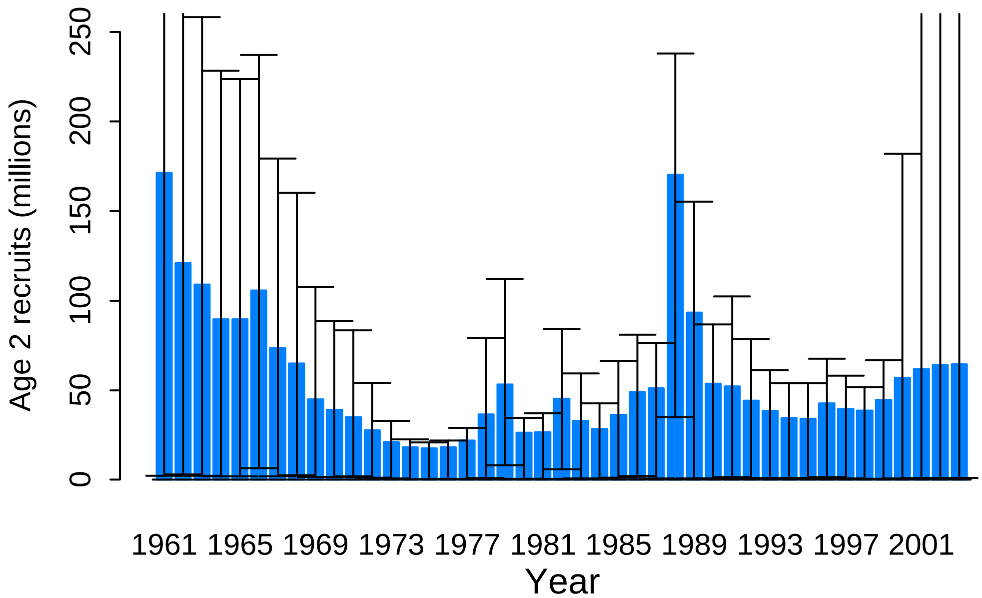

Figure 7-13. Estimated recruitment (age 2) of GOA POP
Error bars represent 95% MCMC confidence intervals. Base Model

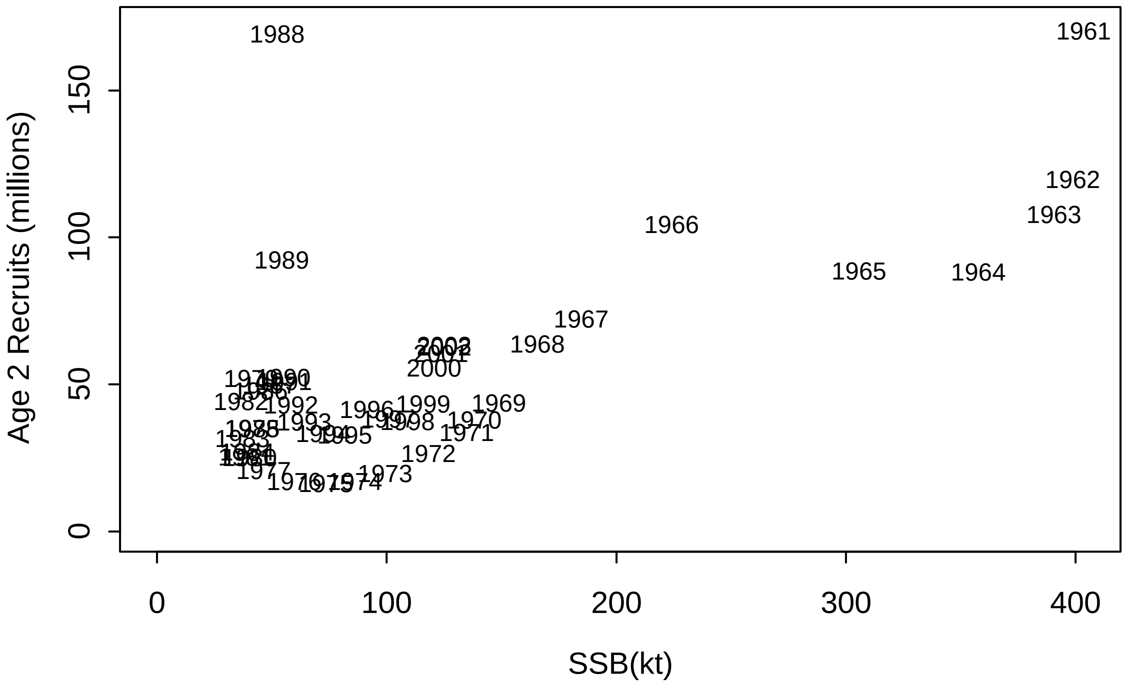

Figure 7-14. Scatterplot of GOA POP spawner-recruit data; label is year of age-2 recruits for Base Model

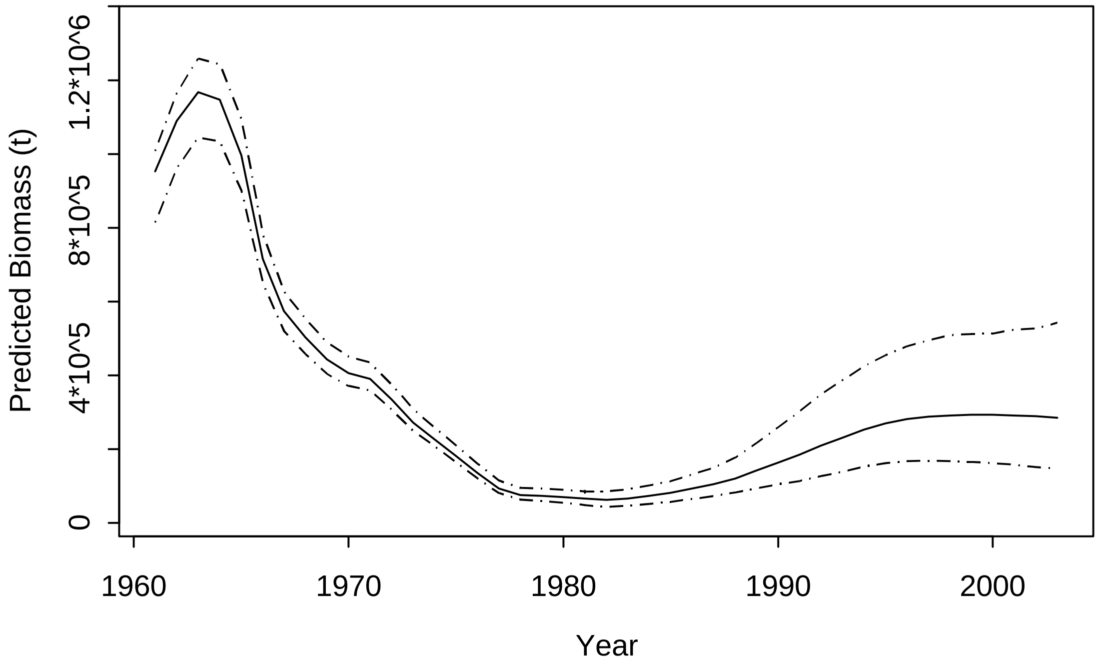

Figure 7-15. Predicted total biomass for GOA Pacific ocean perch. Dashed lines are 95% confidence intervals from 5,000,000 MCMC runs. Recommended model (5).

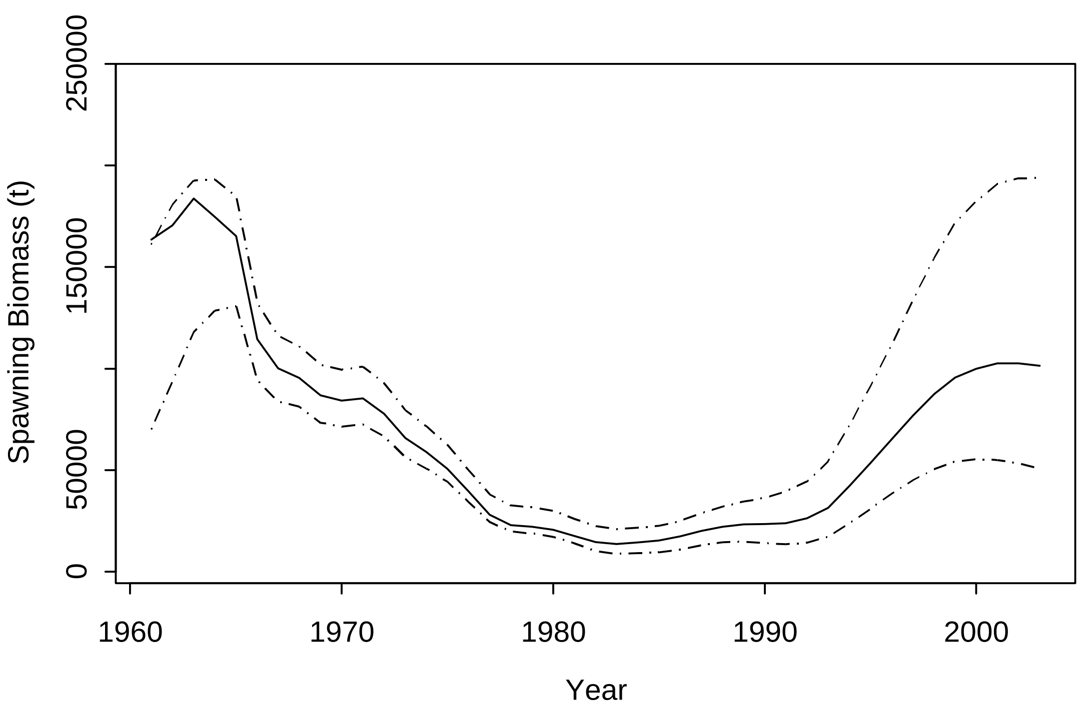

Figure 7-16. Predicted spawning biomass for GOA Pacific ocean perch. Dashed lines are 95% confidence intervals from 5,000,000 MCMC runs. Recommended model (5).

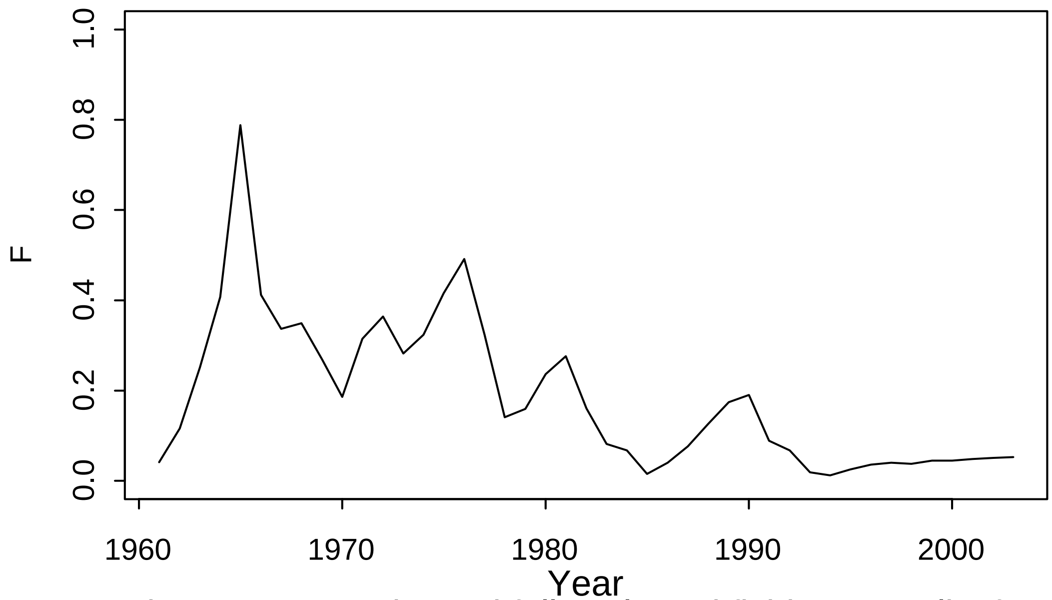

Figure 7-17. Estimated fully selected fishing mortality for GOA POP. Recommended model (5).

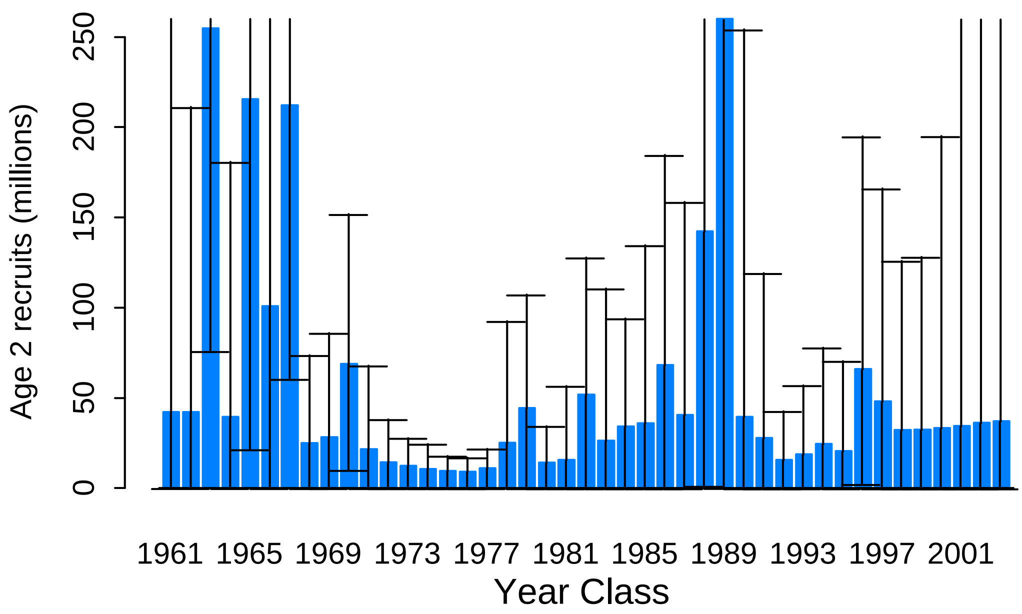

Figure 7-18. Estimated recruitment (age 2) of GOA POP
Error bars represent 95% MCMC CIs. Recommended model (5).

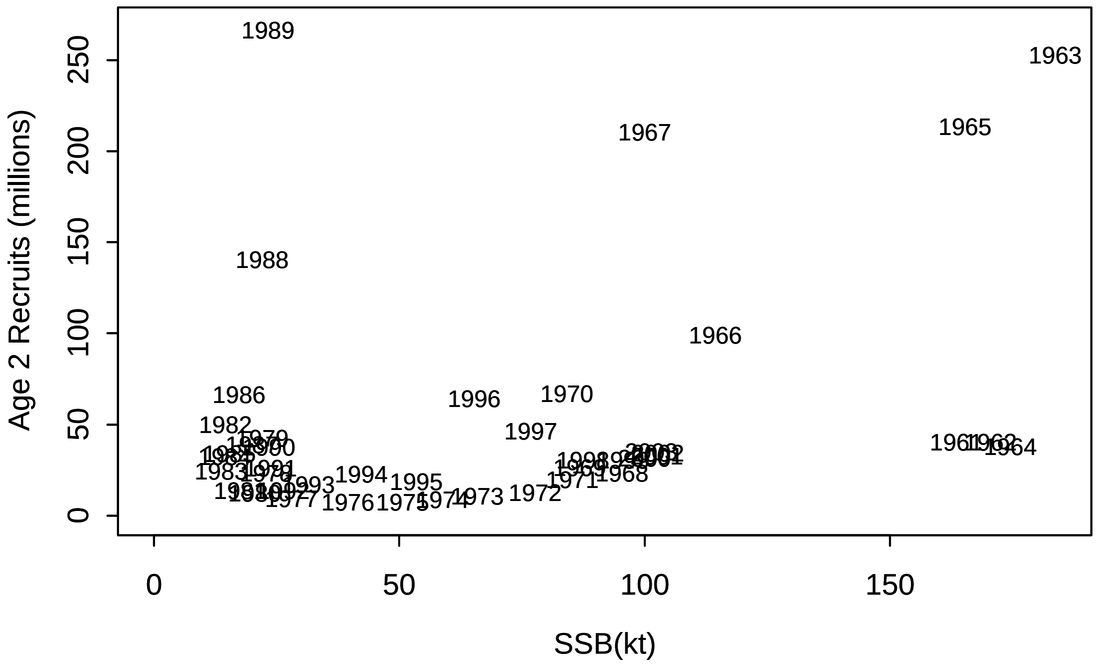

Figure 7-19. Scatterplot of GOA POP spawner-recruit data; label is year of age-2 recruits for recommended model (5).

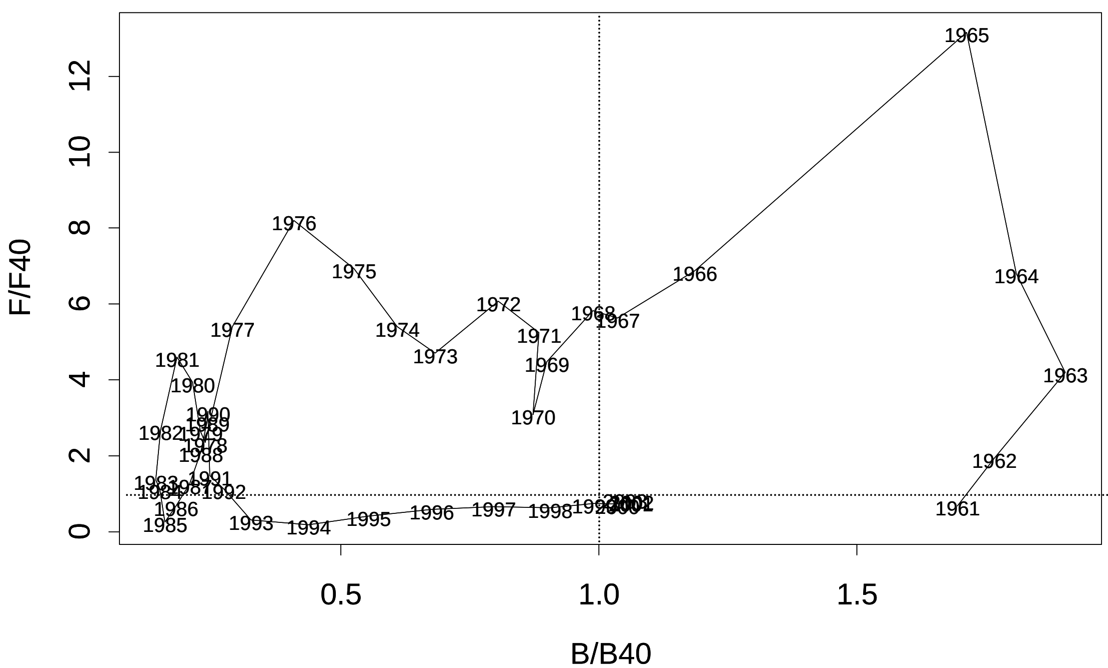

Figure 7-20. Time series of estimated fishing mortality over F40 versus estimated spawning biomass over B40 for recommended model (5).

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