Chapter 2: Assessment of the Pacific Cod Stock in the Gulf of Alaska

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EXECUTIVE SUMMARY

Summary of Major Changes

Relative to the November edition of last year's GOA SAFE report, the following substantive changes have been made in the Pacific cod stock assessment.

Changes in the Input Data

1) Catch data for 2005 were updated, and preliminary catch data for 2006 were incorporated.
2) Size composition data from the 2005 commercial fisheries were updated, and preliminary size composition data from the 2006 commercial fisheries were incorporated.
3) Age composition data from the 2005 GOA bottom trawl survey were incorporated.
4) Parameters governing the length-at-age and weight-at-length relationships were re-estimated based on all available data from the NMFS bottom trawl survey time series.

Changes in the Assessment Model

Now that a sufficient number of age data are available to estimate parameters of the length-at-age schedule outside the model, the values of these parameters have been set equal to their point estimates rather than estimated internally in the stock assessment model (as was already the case with parameters governing the weight-at-length relationship). No other substantive changes were made to the assessment model.

Changes in Assessment Results

1) The projected 2007 female spawning biomass is 127,000 t, up about 9% from last year's projection for 2006.
2) The projected 2007 age 3+ biomass is 375,000 t, up about 15% from last year's projection for 2006.
3) The maximum permissible 2007 ABC is 81,200 t, up about 18% from the actual 2006 ABC of 68,859 t. The recommended 2007 ABC is 68,859 t, equal to the actual ABC for 2006.
4) The estimated 2007 OFL is 97,600 t, up about 2% from the actual OFL for 2006.

Responses to Comments from the SSC and Plan Teams

SSC Comments Specific to the Pacific Cod Assessments

From the December, 2005 minutes: *"The Bering Sea model in particular suggests very high uncertainty about the true values of M and Q, and the SSC suggests that the authors try to estimate only one of these parameters at a time, while leaving the other parameter fixed."* The present BSAI Pacific cod assessment includes eight alternative models in which bottom trawl survey catchability (*Q*) is estimated. There was insufficient time to develop a similar set of runs for the present GOA Pacific cod assessment, however. For the present assessment, the GOA model leaves *Q* and the natural mortality rate (*M*) fixed at their traditional values of 1.0 and 0.37, respectively.

From the December, 2005 minutes: *"The SSC requests a brief update on stock structure of Pacific cod when new genetic data become available. Although the assessments for the Bering Sea and Gulf of Alaska have "converged" on the same model in this year's assessment, there is little a priori reason to emphasize the use of the same model or the same parameter values across regions."* A presentation to the SSC is planned for the coming year, perhaps as early as February (SSC minutes, October, 2005).

From the December, 2005 minutes: *"We endorse the Plan Team's recommendation to continue work on size-at-maturity. To reiterate, although we concur that sufficient justification was provided for adopting the new maturity schedule, there is some concern over the timing (GOA) and location (BSAI) of the samples that were used for histological examination. For example, maturity data for the BSAI were obtained only on the spawning grounds and may lead to an underestimation of length-at-maturity if small mature fish have a higher probability of entering the spawning grounds than immature fish of the same size."* A three-year study of Pacific cod maturity is currently underway. Results will be reported as soon as they become available.

From the December, 2005 minutes: *"The SSC encourages the authors to explore the use of longer time series of CPUE in the GOA using ADF&G and IPHC trawl survey data, similar to the GLM approach used in the GOA pollock assessment."* A preliminary investigation into the possible use of ADF&G survey data was presented in the 2004 GOA Pacific cod assessment. This year, efforts to expand the use of alternative survey data sets were concentrated in the BSAI assessment. Use of ADF&G survey data in the GOA assessment will be considered in the future.

From the December, 2005 minutes: *"In next year's assessment, the SSC would like to see a summary table of the overall likelihood of the models that were fit and the contribution to this likelihood of the various components, similar to tables provided in other assessments."* Table 2.14 includes the requested information.

From the September, 2006 minutes: *"The Plan Teams and SSC received a paper on estimating Pacific cod off-bottom distance from archival tag data that was collected for different purposes. The SSC encourages continued work along those lines, recognizing that such estimates could prove extremely valuable for improving survey estimates of abundance and stock assessments."* Work on alternative methods of estimating survey catchability and selectivity, including the use of archival tag data, will continue. However, as suggested at the September Plan Team meeting (see Plan Team minutes), it was not possible to complete the studies based on archival tag data in time for use in the present assessment.

SSC Comments on Assessments in General

From the December, 2005 minutes: *"The SSC appreciates the inclusion of phase-plane diagrams of relative harvest rate versus biomass, but we recommend standardization of units along the axes in all chapters to facilitate comparisons across species. The SSC suggests considering a quad plot based on* $F/F_{35\%}$ *versus* $B/B_{35\%}$*."* Figure 2.6 has been revised per the SSC's suggestion.

From the December, 2005 minutes: *"The SAFEs have been improved overall by expanded sections on ecosystem considerations to include discussion of predator-prey interactions. To this end, tables and* *figures have been added from ECOPATH models. One problem that has arisen is that there is some confusion about whether the information presented is stomach contents data, output from a single-species model, or output from an ECOPATH model. Figures and tables should more explicitly describe the source of the information presented. To avoid confusion between statistically-driven single species models and manually-adjusted ECOPATH models, the word "estimate" should be reserved for output from single-species models. In the absence of a statistical fitting procedure, outputs from ECOPATH/ECOSIM models should be referred to as adjusted parameters or just outputs. When ECOPATH/ECOSIM parameters are assumed to take on particular values, such assumptions should be stated explicitly. Care should be taken to avoid mixing results from different model structures."* The present assessment does not include outputs from ECOPATH or ECOSIM models.

Plan Team Comments

From the September, 2005 minutes: *"The Teams suggested using the longline survey data in the model."* This year, efforts to consider use of longline survey data were concentrated in the BSAI assessment. Use of longline survey data in the GOA assessment will be considered in the future.

From the November, 2005 minutes: *"For future assessments, the Teams recommend that the authors present a model where Q is estimated (and/or prior is provided) and M is fixed."* This recommendation is similar to one made by the SSC (see above). The BSAI Pacific cod assessment includes eight alternative models in which Q is estimated and M is fixed at its traditional value of 0.37. There was insufficient time to develop a similar set of runs for the present GOA Pacific cod assessment, however. For the present assessment, the GOA model leaves Q and M fixed at their traditional values of 1.0 and 0.37, respectively.

From the November, 2005 minutes: *"The Teams recommend exploring estimation of natural mortality from existing mark-recapture data."* Given the Teams' suggestion to leave M fixed for the time being (along with a similar SSC recommendation), this suggestion was not addressed in the present assessment.

INTRODUCTION

Pacific cod (*Gadus macrocephalus*) is a transoceanic species, occurring at depths from shoreline to 500 m. The southern limit of the species' distribution is about 34° N latitude, with a northern limit of about 63° N latitude. Pacific cod is distributed widely over Gulf of Alaska (GOA), as well as the eastern Bering Sea (EBS) and the Aleutian Islands (AI) area. Tagging studies (e.g., Shimada and Kimura 1994) have demonstrated significant migration both within and between the EBS, AI, and GOA. Although at least one previous genetic study (Grant et al. 1987) failed to show significant evidence of stock structure within these areas, current genetic research underway at the Alaska Fisheries Science Center may soon shed additional light on the issue of stock structure of Pacific cod within the BSAI (M. Canino, AFSC, pers. commun.). Pacific cod is not known to exhibit any special life history characteristics that would require it to be assessed or managed differently from other groundfish stocks in the GOA.

Fishery

During the two decades prior to passage of the Magnuson Fishery Conservation and Management Act (MFCMA) in 1976, the fishery for Pacific cod in the GOA was small, averaging around 3,000 t per year. Most of the catch during this period was taken by the foreign fleet, whose catches of Pacific cod were usually incidental to directed fisheries for other species. By 1976, catches had increased to 6,800 t. Catches of Pacific cod since 1978 are shown in Tables 2.1a and 2.1b. In Table 2.1a, catches for 1978-1990 are broken down by year, fleet sector, and gear type. In Table 2.1b, catches for 1991-2006 are broken down by year, jurisdiction, and gear type. The foreign fishery peaked in 1981 at a catch of nearly 35,000 t. A small joint venture fishery existed through 1988, averaging a catch of about 1,400 t per year. The domestic fishery increased steadily through 1986, then increased more than three-fold in 1987 to a catch of nearly 31,000 t as the foreign fishery was eliminated. Presently, the Pacific cod stock is exploited by a multiple-gear fishery, including trawl, longline, pot, and jig components. Trawl gear has traditionally accounted for the largest single-gear share of the catch (approximately 44% on average during the period 1997-2005), although pot gear has taken the largest single-gear share of the catch in each year since 2003. Figure 2.1 shows areas in which sampled hauls for each of the three main gear types (trawl, longline, and pot) were concentrated during 2005. To create this figure, the EEZ off Alaska was divided into 20 km × 20 km squares. A square is shaded if more than two hauls containing Pacific cod were sampled in it during 2005.

The history of acceptable biological catch (ABC) and total allowable catch (TAC) levels is summarized and compared with the time series of aggregate commercial catches in Table 2.2. For the first year of management under the MFCMA (1977), the catch limit for GOA Pacific cod was established at slightly less than the 1976 total reported landings. During the period 1978-1981, catch limits varied between 34,800 and 70,000 t, settling at 60,000 t in 1982. Prior to 1981 these limits were assigned for "fishing years" rather than calendar years. In 1981 the catch limit was raised temporarily to 70,000 t and the fishing year was extended until December 31 to allow for a smooth transition to management based on calendar years, after which the catch limit returned to 60,000 t until 1986, when ABC began to be set on an annual basis. Changes in ABC over time are typically attributable to three factors: 1) changes in resource abundance, 2) changes in management strategy, and 3) changes in the stock assessment model. From 1986 (the first year in which an ABC was set) through 1996, TAC averaged about 83% of ABC and catch averaged about 81% of TAC. In 8 of those 11 years, TAC equaled ABC exactly. In 2 of those 11 years (1992 and 1996), catch exceeded TAC. To understand the relationships between ABC, TAC, and catch for the period since 1997, it is important to understand that a substantial fishery for Pacific cod has been conducted during these years inside State of Alaska waters, mostly in the Western and Central Regulatory Areas. To accommodate the State-managed fishery, the Federal TAC was set well below ABC in each of those years (15% in 1997 and 1998; 20% in 1999; 23% in 2000-2003; and 24% in 2004-2006). Thus, although total (Federal plus State) catch has exceeded the Federal TAC in all but two years since 1997, this is basically an artifact of the bi-jurisdictional nature of the fishery and is not evidence of overfishing. At no time since the separate State waters fishery began in 1997 has total catch exceeded ABC.

Historically, the majority of the GOA catch has come from the Central regulatory area. To some extent the distribution of effort within the GOA is driven by regulation, as catch limits within this region have been apportioned by area throughout the history of management under the MFCMA. Changes in area-specific allocation between years have usually been traceable to changes in biomass distributions estimated by Alaska Fisheries Science Center trawl surveys or management responses to local concerns. Currently, the ABC allocation follows the average biomass distribution estimated by the three most recent trawl surveys, and the TAC allocation is within one percent of this distribution on an area-by-area basis. The complete history of allocation (in percentage terms) by regulatory area within the GOA is shown in Table 2.3.

In addition to area allocations, GOA Pacific cod is also allocated on the basis of processor component (inshore/offshore) and season. The inshore component is allocated 90% of the TAC and the remainder is allocated to the offshore component. Within the Central and Western Regulatory Areas, 60% of each component's portion of the TAC is allocated to the A season (January 1 through June 10) and the remainder is allocated to the B season (June 11 through December 31, although the B season directed fishery does not open until September 1). The longline and trawl fisheries are also associated with a Pacific halibut mortality limit which sometimes constrains the magnitude and timing of harvests taken by these two gear types.

The catches shown in Tables 2.1a-b and 2.2 include estimated discards for all years since 1980. Discard rates of Pacific cod in the various GOA target fisheries are shown for each year 1991-2002 in Table 2.4a and for the years 2003-2004 in Table 2.4b.

DATA

This section describes data used in the current assessment model. It does not attempt to summarize all available data pertaining to Pacific cod in the GOA.

Commercial Catch Data

Catch Biomass

Catches (including estimated discards) taken in the GOA since 1964 are shown in Table 2.5, broken down by the three main gear types and the following within-year time intervals, or "seasons": January-May, June-August, and September-December. This particular division, which was suggested by participants in the BSAI fishery, is intended to reflect actual intra-annual differences in fleet operation (e.g., fishing operations during the spawning season may be different than at other times of year). In years for which estimates of the distribution by gear or season were not available, proxies based on other years' distributions were used.

Catch Size Composition

Fishery size compositions are presently available, by gear, for the years 1977 through the first part of 2006. For ease of representation and analysis, length frequency data for Pacific cod can usefully be grouped according to the following set of 25 intervals or "bins," with the upper and lower boundaries shown in cm:

Bin Number:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Lower Bound:	9	12	15	18	21	24	27	30	33	36	39	42	45	50	55	60	65	70	75	80	85	90	95	100	105
Upper Bound:	11	14	17	20	23	26	29	32	35	38	41	44	49	54	59	64	69	74	79	84	89	94	99	104	115

Total length sample sizes for each year, gear, and season are shown in Table 2.6. The collections of relative length frequencies are shown by year, season, and size bin for the pre-1987, 1987-1999, and post-1999 trawl fisheries in Tables 2.7a, 2.7b, and 2.7c, respectively; the pre-1987, 1987-1999, and post-1999 longline fisheries in Tables 2.8a, 2.8b, and 2.8c, respectively; and the 1987-1999 and post-1999 pot fisheries in Tables 2.9a and 2.9b. Fishery length frequencies since 1997 include samples from the State-managed fishery.

Survey Data

Survey Size Composition

The relative size compositions from trawl surveys of the GOA conducted by the Alaska Fisheries Science Center since 1984 are shown in Table 2.10, using the same length bins defined above for the commercial catch size compositions. Total sample sizes are shown below:

Year:	1984	1987	1990	1993	1996	1999	2001	2003	2005
Sample size:	17413	19589	11440	17152	12190	8645	6772	9125	6844

Survey Age Composition

Following a decade-long hiatus in production ageing of Pacific cod, the Age and Growth Unit of the Alaska Fisheries Science Center began ageing samples of Pacific cod from the EBS shelf bottom trawl surveys a few years ago (Roberson 2001, Roberson et al. 2005). Last year, age data have become available for the 2003 bottom trawl survey in the GOA as well, and age data from the 2005 GOA bottom trawl survey became available this year. Age composition estimates for the 2003 and 2005 surveys are shown in Table 2.11 (sample sizes = 711 and 536, respectively). Age data are not yet available for any other year.

Abundance Estimates
Estimates of total abundance (both in biomass and numbers of fish) obtained from the trawl surveys are shown in Table 2.12, together with the standard errors and upper and lower 95% confidence intervals (CI) for the biomass estimates.

The highest biomass ever observed by the survey was the 1984 estimate of 550,971 t, and the low point is the 2001 estimate of 279,332 t (the 2001 estimate was obtained by summing the 2001 estimate for the Western and Central areas with the 1999 estimate for the Eastern area, because the 2001 survey did not cover the Eastern area). In terms of population numbers, the record high was observed in 1984, when the population was estimated to include over 320 million fish.

ANALYTIC APPROACH

Model Structure

History of Model Structures Developed Under Stock Synthesis 1 and 2
Beginning with the 1994 SAFE report (Thompson and Zenger 1994), a model using the Stock Synthesis 1 (SS1) assessment program (Methot 1986, 1990, 1998, 2000) and based largely on length-structured data formed the primary analytical tool used to assess the GOA Pacific cod stock.

SS1 is a program that used the parameters of a set of equations governing the assumed dynamics of the stock (the “model parameters”) as surrogates for the parameters of statistical distributions from which the data are assumed to be drawn (the “distribution parameters”), and varies the model parameters systematically in the direction of increasing likelihood until a maximum is reached. The overall likelihood is the product of the likelihoods for each of the model components. In part because the overall likelihood can be a very small number, SS1 uses the logarithm of the likelihood as the objective function. Each likelihood component is associated with a set of data assumed to be drawn from statistical distributions of the same general form (e.g., multinomial, lognormal, etc.). Typically, likelihood components are associated with data sets such as catch size (or age) composition, survey size (or age) composition, and survey biomass (either relative or absolute).

SS1 permits each data time series to be divided into multiple segments, resulting in a separate set of parameter estimates for each segment. In the base model for the GOA Pacific cod assessment, for example, possible differences in selectivity between the mostly foreign (also joint venture) and mostly domestic fisheries have traditionally been accommodated by splitting the fishery size composition time series into pre-1987 and post-1986 segments.

In the both the EBS and GOA Pacific cod models, each year has traditionally been partitioned into three seasons: January-May, June-August, and September-December (these seasonal boundaries were suggested by industry participants in the EBS fishery). Four fisheries have traditionally been defined: The January-May trawl fishery, the June-December trawl fishery, the longline fishery, and the pot fishery.

Following a series of modifications from 1993 through 1997, the base model for GOA Pacific cod remained completely unchanged from 1997 to 2001. During the late 1990s, a number of attempts were made to estimate the natural mortality rate *M* and the shelf bottom trawl survey catchability coefficient *Q*, but these were not particularly successful and the Plan Team and SSC always opted to retain the base model in which *M* and *Q* were fixed at their traditional values of 0.37 and 1.0, respectively.

A minor modification of the base model was suggested by the SSC in 2001, namely, that consideration be given to dividing the domestic era into pre-2000 and post-1999 segments. This modification was tested in the 2002 assessment (Thompson et al. 2002), where it was found to result in a statistically significant improvement in the model's ability to fit the data.

A major change took place in the 2005 assessment (Thompson and Dorn 2005), as the model was migrated to the newly developed Stock Synthesis 2 (SS2) program, which makes use of the ADMB modeling architecture (Fournier 2005) currently used in most age-structured assessments of BSAI and GOA groundfish. The move to SS2 facilitated improved estimation of model parameters as well as statistical characterization of the uncertainty associated with parameter estimates and derived quantities such as spawning biomass. Three alternative models were presented in the 2005 assessment. Model 1 was identical to the SS1-based model used in the 2004 assessment. Model 2 was very similar to Model 1, but was explicitly Bayesian (i.e., prior distributions were specified for all model parameters) and it was configured under SS2 rather than SS1. Model 3 was similar to Model 2, except that values of the shelf bottom trawl survey catchability coefficient Q and the natural mortality rate M were estimated rather than fixed at the traditional values of 1.0 and 0.37, respectively. The Plan Team and SSC both chose Model 2, feeling that moving from fixed values of Q and M to estimated values for both those parameters at the same time was too big a step. (It should be noted that fixing Q is not the same as fixing the entire selectivity schedule, as selectivity parameters are still typically estimated even when Q is fixed. However, fixing Q at a particular value will usually influence the values of the estimated selectivity parameters.)

The structure of the model used in the present assessment is identical to the model structure chosen by the Plan Team and SSC in last year's assessment, except that parameters governing the length-at-age schedule are now estimated independently rather than conditionally (see below).

Selectivity

As alluded to above, a total of eleven selectivity curves are specified by the GOA Pacific cod model. Three curves apiece are specified for the June-December trawl fishery and the longline fishery, corresponding to the time periods 1964-1986, 1987-1999, and 2000-2006. Two curves are specified for the January-May trawl fishery, corresponding to the time periods 1964-1999 and 2000-2006 (although a single selectivity curve is specified for the years 1964-1999 in the January-May trawl fishery, the parameters for this curve are estimated entirely from data collected during the 1987-1999 time period, because almost no size composition data were collected from the January-May trawl fishery during the 1964-1986 time period). Two curves are also specified for the pot fishery, corresponding to the time periods 1987-1999 and 2000-2006 (there was no significant pot fishery for Pacific cod prior to 1987). A single curve is specified for the GOA bottom trawl survey.

Although SS2 includes several options for specifying the functional form of the selectivity curve, the most flexible and commonly used option, the "double logistic" function, involves a pair of scaled logistic curves joined by a horizontal linear segment. The first (ascending) logistic curve begins at the minimum length specified in the data file (9 cm in the case of the GOA Pacific cod model), where the selectivity is less than 1.0, and ends at some intermediate length, where selectivity is exactly 1.0. A horizontal linear segment extends from the right-hand end of the first logistic to the left-hand end of the second logistic. Selectivity equals 1.0 throughout this linear segment. The second (descending) logistic curve begins at the end of the horizontal linear segment, where selectivity is still exactly 1.0, and ends at the maximum length specified in the data file (110 cm in the case of the GOA Pacific cod model), where the selectivity is less than 1.0.

Eight parameters are used to define the SS2 double logistic selectivity function: the size at which selectivity first reaches a value of 1.0 (*peak location*), the selectivity at the minimum length represented in the data ($S(Lmin)$), the logit transform of the size corresponding to the inflection of the ascending logistic curve (logit(*infl1*)), the relative slope of the ascending logistic curve (*slope1*), the logit transform of the size corresponding to the inflection of the descending logistic curve (logit(*infl2*)), the relative slope of the descending logistic curve (*slope2*), the logit transform of the selectivity at the maximum length represented in the data (logit(*S*(*Lmax*))), and the width of the length range at which selectivity equals 1 (*peak width*).

Prior Distributions
Because SS2 is explicitly cast in a Bayesian framework, specification of a prior distribution is required for each parameter. Of course, a noninformative prior can be chosen for any or all parameters if so desired. However, use of informative priors is probably appropriate for many of the parameters in the GOA Pacific cod model, because one or both Plan Teams and the SSC have indicated in the past that certain values, or ranges of values, of various parameters are either relatively likely or unlikely. For example, the BSAI Plan Team has expressed concern that previous assessments' estimates of large-fish selectivity in the EBS shelf bottom trawl survey may be too low (BSAI Plan Team minutes, November 2004), and the GOA Pacific cod assessment has typically produced survey selectivity patterns similar to those obtained in the BSAI assessment. By utilizing a Bayesian framework, SS2 provides a logical means of integrating perspectives such as these into the stock assessment model. Use of informative priors can also help to stabilize parameter estimates. The specific priors used in this assessment are described under "Parameters Estimated Conditionally" below.

Parameters Estimated Independently

Natural Mortality
In the 1993 BSAI Pacific cod assessment (Thompson and Methot 1993), the natural mortality rate *M* was estimated using SS1 at a value of 0.37. All subsequent assessments of the BSAI and GOA Pacific cod stocks (except the 1995 GOA assessment) have used this value for *M*. Other published estimates of *M* for Pacific cod are shown below:

Area	Author	Year	Value
Eastern Bering Sea	Low	1974	0.30-0.45
	Wespestad et al.	1982	0.70
	Bakkala and Wespestad	1985	0.45
	Thompson and Shimada	1990	0.29
	Thompson and Methot	1993	0.37
Gulf of Alaska	Thompson and Zenger	1993	0.27
	Thompson and Zenger	1995	0.50
British Columbia	Ketchen	1964	0.83-0.99
	Fournier	1983	0.65

As the above table indicates, the natural mortality rate for Pacific cod is either highly variable by time or area or it is very hard to estimate. In the present model, the traditional value of 0.37 is retained.

Trawl Survey Catchability
The base model used in all previous GOA Pacific cod assessments has fixed the catchability coefficient (*Q*) for the GOA bottom trawl survey independently of other parameters at a value of 1.0, and this value is retained in the present assessment. However, catchability remains an issue in both the BSAI and GOA Pacific cod assessments. In this year's BSAI Pacific cod assessment, several alternative models are proposed in which *Q* is estimated within the stock assessment. If, upon review by the Plan Team and SSC, these efforts are determined to be successful, similar attempts will likely be made in future assessments of the GOA Pacific cod stock.

Length at Age
Parameters of the Brody growth equation, as formulated in SS2, were re-estimated this year based on all available data. The curve described by the updated parameter values is close to last year's curve. The new parameter values are: length at 1 year = 13.8 cm, length at 12 years = 93.0 cm, and Brody's growth coefficient K = 0.108.

Variability in Length at Age
The method for estimating variability in length at age was substantially improved this year by developing a formal statistical model based on SS2's required assumption that the coefficient of variation in length at age is a linear function of mean length at age. A lognormal distribution of lengths at age was assumed. The new parameter estimates are: CV at age 1 = 0.14, CV at age 13 = 0.062.

Variability in Estimated Age
Variability in estimated age in SS2 is based on the standard deviation of estimated age. Weighted least squares regression was used in the 2005 assessment (Thompson and Dorn 2005) to estimate a proportional relationship between standard deviation and age. The regression was re-run this year based on all available data. The new relationship is close to last year's. The new estimated proportionality is 0.079 (i.e, the standard deviation of estimated age was modeled as 0.079 × age).

Weight at Length
Parameters governing the allometric relationship between weight (kg) and length (cm) were re-estimated this year by log-log regression from the same data used to estimate the parameters of the length-at-age relationship. The curve described by the updated parameter values is close to last year's curve. The new parameter values are: multiplicative constant = 6.242×10^{-6}, and exponent = 3.137.

Maturity at Length
A detailed history and evaluation of parameter values used to describe maturity at length for GOA Pacific cod was presented in the 2005 assessment (Thompson and Dorn 2005). The parameters used in last year's assessment, based on a study by Stark (2005), were as follows: length at 50% maturity = 50.2 cm and slope of linearized logistic equation = -0.222. The same parameter values are used for all models in this year's assessment.

Parameters Estimated Conditionally

Parameters estimated conditionally (i.e., within individual SS2 runs, based on the data and the parameters estimated independently) consist of the following:

1) log-scale mean recruitment for the post-1976 environmental regime
2) annual log-scale recruitment deviations
3) EBS slope bottom trawl survey catchability
4) initial fishing mortality rates (the population is assumed to be in equilibrium in 1964)
5) selectivity parameters (8 parameters for the trawl survey selectivity curve; 7 parameters for each of the 10 gear- and era-specific fishery selectivity curves, with $S(Lmin)$ fixed at 0.001 for each of the fishery selectivity curves)

For all parameters estimated within individual SS2 runs, the estimator used is the mode of the logarithm of the joint posterior distribution, which is in turn calculated as the sum of the logarithms of the parameter-specific prior distributions (see below) and the logarithm of the likelihood function.

In addition to the above, there are two other sets of parameters that are estimated conditionally, but not in the same sense as the above parameters. The first of these is the full set of year-, season-, and gear-specific fishing mortality rates. The fishing mortality rates are determined exactly rather than estimated statistically because SS2 assumes that the input total catch data are true values rather than estimates, so the fishing mortality rates can be computed algebraically given the other parameter values and the input catch data.

The second set of parameters that is estimated conditionally, but in a manner different from the other parameters, consists of two parameters that help to describe the distribution of individual recruitments. These are estimated iteratively (i.e., *between* SS2 runs rather than within an individual SS2 run). In SS2, log-scale recruitment is modeled in terms of a mean, a standard deviation (σ_R), and annual deviations from the mean. The parameters are automatically scaled so that the average annual deviation from the mean is zero. A problem arises, however, in attempting to model the effects of the major environmental regime shift that occurred in 1977 (e.g., Hare and Mantua 2000), because the available information indicates strongly that year classes of Pacific cod were much smaller (in magnitude) during the pre-1977 regime than during the post-1976 regime. Establishing different pre-1977 and post-1976 log-scale means is easily accomplished in SS2 by creating a regime shift "dummy variable" for each year in the time series and estimating a link between mean log-scale recruitment and the dummy variable. However, σ_R cannot be linked to the dummy variable in SS2. This implies that the mean recruitment deviation for each portion of the time series (pre-1977 and post-1976) will not necessarily equal zero, even though SS2 forces the mean recruitment deviation for the overall time series to equal zero. This, in turn, implies that the estimates of the pre- and post-regime shift means will be confounded with the estimate of σ_R.

To resolve the problem of confounding between the estimates of the pre-1977 and post-1976 recruitment log-scale means with the estimate of σ_R, the following iterative algorithm was adopted in last year's assessment (Thompson and Dorn 2005) and retained this year to implement the 1977 environmental regime shift in SS2:

1) Candidate values for the pre-1977 log-scale mean and σ_R were chosen.
2) SS2 was allowed to estimate the post-1976 log-scale mean and the recruitment deviations for the entire time series (deviations are expressed as the difference between the logarithm of annual recruitment at age 0 and the log-scale mean for the respective environmental regime), conditional on the candidate values for the pre-1977 log-scale mean and σ_R.
3) The mean of the estimated pre-1977 recruitment deviations and the standard deviation of the entire time series of recruitment deviations were computed.
4) If the absolute value of the mean computed in Step 3 was less than 0.005 and the standard deviation computed in Step 3 was equal to σ_R within three significant digits, the candidate values were determined to be the final estimates. If either of these conditions did not hold, the candidate value for the pre-1977 log-scale mean was set equal to the old value plus the mean computed in Step 3, the candidate value for σ_R was set equal to the standard deviation computed in Step 3, and the process returned to Step 2. (Occasionally, the change in candidate values between iterations deviated slightly from this algorithm if the prescribed changes seemed too small or too large.)

The above algorithm was tested many times under different initial candidate values and consistently returned the same final estimates, so long as the initial candidate values were feasible. It should also be noted that the path to convergence was not always smooth or rapid.

Prior Distributions

If an informative prior distribution was placed on a parameter, it is described in the following paragraphs (all distributions are normal). If a particular parameter is not listed, it is because a noninformative prior (i.e., a normal distribution with a very large variance) was used. All priors are identical to those used in last year's assessment (Thompson and Dorn 2005).

Parameters with priors based on a specified coefficient of variation (CV)

Initial fishing mortality: The mean was set at 0.1, reflecting the conventional wisdom that the stock was lightly exploited during the 1960s. The standard deviation was set at 0.03, corresponding to a CV of 30%.

Selectivity parameter *S*(*Lmin*): For the commercial fisheries, this was not an estimated parameter, but was set at a fixed value of 0.001. This choice was based on the fact that almost no fish in the sub-30 cm range are taken in the commercial fisheries and because preliminary model runs invariably resulted in this parameter being bound at whatever minimum value was specified. For the bottom trawl survey, the prior distribution was assigned a mean of 0.1 and a standard deviation of 0.03, corresponding to a 30% CV. In contrast to the commercial fisheries, 10% of the average bottom trawl survey size composition has consisted of fish smaller than 30 cm.

Selectivity parameters *slope1* and *slope2*: These two parameters had identical priors, with the mean set at 0.2 and the standard deviation set at 0.06, corresponding to a 30% CV. The choice of mean was based on a subjective examination of the shape of the selectivity curve under different values of these parameters.

Selectivity parameter *peak width*: The mean was set at 10 and the standard deviation was set at 3, corresponding to a 30% CV. The choice of mean was based on a subjective examination of the shape of the selectivity curve under different values of this parameter, in addition to results from preliminary model runs which indicated that values much higher than 10 tended to cause the model to get “stuck.”

Parameters with priors based on one or both endpoints of the 98% confidence interval

Selectivity parameters logit(*infl1*) and logit(*infl2*): These two parameters had identical priors, with the mean set at 0 and the standard deviation set at 0.944. The mean corresponds to an inflection point located midway between *Lmin* and *peak location*, in the case of *infl1*, or between *peak location* and *Lmax*, in the case of *infl2*. The mean and standard deviation together imply a 98% confidence interval extending from 10% to 90% of the difference between *Lmin* and *peak location*, in the case of *infl1*, or between *peak location* and *Lmax*, in the case of *infl2*. The choice of mean was based on a subjective examination of the shape of the selectivity curve under different values of these parameters.

Selectivity parameter logit(*S*(*Lmax*)): The mean was set at 2.197 and the standard deviation was set at 0.944. The mean corresponds to a selectivity of 0.9 at *Lmax*. The mean and standard deviation together imply a 1% chance of selectivity at *Lmax* being less than 0.5. These parameter values were chosen in part to reflect the Plan Team’s belief that selectivity of large fish in the bottom trawl survey should be fairly high.

Parameters with priors based on the data

Selectivity parameter *peak location* (used in both the double logistic and double normal functional forms): The mean and standard deviation were set individually for each selectivity curve by identifying the length associated with the maximum frequency in each length frequency record, then computing the mean and standard deviation (weighted by the square root of sample size) for each respective gear type and portion of the time series. This was done in order to give the model a reasonable starting value and place reasonable constraints on *peak location*, a parameter which is typically very difficult to estimate. Extensive testing during the 2005 assessment (Thompson and Dorn 2005) indicated that the value of this parameter can be quite important in determining model results and that free estimation (with a reasonably strong prior) was much more likely to find an optimal value than profiling manually over the range of possible integer values, especially considering the practical difficulty of manually tuning 11 such parameters (one *peak location* for each selectivity curve) at the same time. The resulting means (cm) and standard deviations (cm) for *peak location* in each of the 11 selectivity curves were as follow:

Fishery/Survey	Years	Mean	Std. Dev.
Jan-May Trawl	1964-1999	63.8	2.12
Jan-May Trawl	2000-2006	61.5	4.26
Jul-Dec Trawl	1964-1986	54.1	5.71
Jul-Dec Trawl	1987-1999	58.7	5.68
Jul-Dec Trawl	2000-2006	61.2	4.62
Longline	1964-1986	58.3	6.96
Longline	1987-1999	63.1	3.10
Longline	2000-2006	63.4	2.35
Pot	1987-1999	64.5	2.53
Pot	2000-2006	62.1	2.93
Bottom Trawl Survey	1984-2005	54.5	3.60

Likelihood Components

Likelihood components included in all three models are of four types: size composition, age composition, survey biomass, mean size at age, and recruitment deviations. There are five size composition components in the likelihood: one each for the January-May trawl fishery, the June-December trawl fishery, the longline fishery, the pot fishery, and the bottom trawl survey. There is only one age composition component and one size-at-age component in the likelihood, because all age data currently come from the trawl survey. There is one survey biomass component in the likelihood, corresponding to the bottom trawl survey.

In SS2, emphasis factors are specified to determine which likelihood components receive the greatest attention during the parameter estimation process. As in previous assessments, each likelihood component in each model was given an emphasis of 1.0 in the present assessment. The prior distributions are also assigned an emphasis. As in last year's assessment (the first assessment conducted in SS2), the prior distributions were also given an emphasis of 1.0 in the present assessment.

Use of Size Composition Data in Parameter Estimation

Size composition data are assumed to be drawn from a multinomial distribution specific to a particular year, gear/fishery, and season within the year. In the parameter estimation process, SS2 weights a given size composition observation (i.e., the size frequency distribution observed in a given year, gear/fishery, and season) according to the emphasis associated with the respective likelihood component and the sample size specified for the multinomial distribution from which the data are assumed to be drawn. In developing the model upon which SS1 was originally based, Fournier and Archibald (1982) suggested truncating the multinomial sample size at a value of 400 in order to compensate for contingencies which cause the sampling process to depart from the process that gives rise to the multinomial distribution. As in previous assessments, the present assessment uses a multinomial sample size equal to the square root of the true length sample size, rather than the true length sample size itself. Given the true length sample sizes observed in the present assessment, this procedure tends to give values somewhat below 400 while still providing SS2 with usable information regarding the appropriate effort to devote to fitting individual length samples. Multinomial length sample sizes derived by this procedure for the commercial fishery size compositions are shown in Table 2.13. In the case of GOA bottom trawl survey size composition data, the square root assumption was also used. The square roots (sqrt) of the true survey length sample sizes are shown below:

Year	sqrt(N)
1984	132
1987	140
1990	107
1993	131
1996	110
1999	93
2001	82
2003	96
2005	83

Use of Age Composition Data in Parameter Estimation

Like the size composition data, the age composition data are assumed to be drawn from a multinomial distribution specific to a particular year, gear/fishery (in this case, the GOA bottom trawl survey), and season within the year (in this case, the June-August season). However, selection of an appropriate input sample size is more complicated for age composition data than for length composition data, because age composition data are generated not only from the set of otolith readings but from the estimated size composition as well. Therefore, even if a square root transformation is appropriate for size composition data, taking the square root of the number of otoliths read may underestimate the weight that should be given to the age composition data. The 2004 BSAI Pacific cod assessment (Thompson and Dorn 2004) introduced a method for setting an input sample size appropriate to age composition, a method which has been retained in last year's and this year's GOA assessments. The steps are as follow:

1) The proportions of age at length are assumed to be approximately multivariate normally distributed, with a variance-covariance matrix determined by the matrix of proportions and the number of otoliths actually read at each length. A set of 10,000 random age-length keys was then simulated.
2) Survey numbers at each length are assumed to be approximately lognormally distributed with a mean equal to the point estimate and for that length and a constant (across lengths) coefficient of variation (CV) equal to the amount that sets the sum of the variances in numbers at length equal to the variance of the survey estimate of population size. A set 10,000 of random numbers-at-length distributions was then simulated.
3) For each combination of randomly simulated age-key and numbers-at-length distribution, an effective sample size was computed.

4) The input sample size was set equal to the harmonic mean of the distribution of randomly simulated effective sample sizes, based on the asymptotic equivalence of these two quantities. The following table was thereby obtained for the age composition data (the last row shows the value used as input sample sizes):

Year	2003	2005
Number of fish aged:	711	536
Square root of number of fish aged:	27	23
CV of numbers at length:	0.83	1.31
Harmonic mean effective sample size:	80	31

Note that this procedure gives an input sample size larger than would be achieved simply by taking the square root of the number of fish aged (third row in the above table). This reflects the added precision achieved by use of both age-at-length and numbers-at-length data in constructing a numbers-at-age estimate. To avoid double counting of the same data, the SS2 model ignores length composition data from the 2003 and 2005 GOA bottom trawl surveys.

It may be noted that the harmonic mean effective sample sizes computed above (80 and 31) is smaller than the sample size (96 and 83, respectively) obtained for the corresponding length composition using the square root method in the preceding subsection, suggesting that the two methods of computing sample sizes are not entirely consistent. This is not surprising, given that the square root method was adopted only as a simple approximation in the first place, but it does suggest a need for further work in this area.

Use of Size-at-Age Data in Parameter Estimation
Each size at age datum is assumed to be drawn from a normal distribution specific for that age and year. The model's estimate of mean size at age serves as the mean for that year's distribution, and the standard deviation is inversely proportional to the sample size (Methot 2000, Methot 2005a).

Use of Survey Biomass Data in Parameter Estimation
Each year's survey biomass datum is assumed to be drawn from a lognormal distribution specific to that year. The model's estimate of survey biomass in a given year serves as the geometric mean for that year's lognormal distribution, and the ratio of the survey biomass datum's standard error to the survey biomass datum itself serves as the distribution's coefficient of variation.

Use of Recruitment Deviation "Data" in Parameter Estimation
The recruitment deviations likelihood component is different from traditional likelihoods because it does not involve "data" in the same sense that traditional likelihoods do. Instead, the log-scale recruitment deviation plays the role of the datum and the log-scale recruitment mean and σ_R play the role of the parameters in a normal distribution, but, of course, all of these are treated as parameters by SS2.

MODEL EVALUATION

The model used in the present assessment is very similar to the model selected by the Plan Team and SSC in last year's assessment, and was evaluated at that time. Some key parameter estimates and management-related quantities as estimated by last year's model and this year's model, together with values for each likelihood component, the prior distributions, and the overall posterior distribution, are shown in Table 2.14. The table is structured as follows (values obtained from the SS2 model are shown in normal font and values obtained from the projection model are shown in bold font):

Row 1: Model names.

Rows 2-4: Parameters governing the distribution of recruitments. Row 2 shows the standard deviation of the distribution of log-scale recruitment deviations, row 3 shows the median log-scale recruitment for the post-1976 environmental regime, and row 4 shows the log of the ratio of median log-scale recruitments between the pre-1977 and post-1976 environmental regimes (i.e., a negative value in row 4 means that median recruitment was lower in the pre-1977 regime than in the post-1976 regime).

Rows 5-6: Parameters or function values characterizing trawl survey catchability and selectivity. Row 5 shows catchability, and row 6 shows the trawl survey selectivity for fish 90 cm in length.

Rows 7-8: Total (age 0+) biomass for 2005 and 2006.

Rows 9-12: Female spawning biomass for 2005-2008. Note that there is a mismatch between values obtained from SS2 and those obtained from the projection model, because SS2 computes spawning biomass at the start of the year whereas the projection model computes spawning biomass at the month of peak spawning.

Rows 13-16: Female spawning biomass for 2005-2008 expressed as a proportion of equilibrium unfished spawning biomass (again, there is a slight mismatch between the SS2 and projection model estimates of equilibrium unfished spawning biomass).

Rows 17-21: Current (2006) ABC and projected maximum permissible ABC for 2007-2008, with the proportional year-to-year changes implied by those ABCs.

Rows 22-26: Similar to rows 17-21, but for OFL instead of ABC.

Rows 27: Log likelihood value related to survey abundance index (by convention, all log likelihood, log prior, and log objective function values are multiplied by -1).

Rows 28-32: Log likelihood values related to size composition. These rows show the values of the log likelihoods pertaining to the size composition data from the January-May trawl fishery, June-December trawl fishery, longline fishery, pot fishery, and the trawl survey, respectively.

Rows 33-35: Other log likelihoods. Row 33 shows the log likelihood pertaining to the trawl survey age composition data, row 34 shows the log likelihood pertaining to the trawl survey size-at-age data, and row 35 shows the log likelihood pertaining to recruitment deviations.

Row 36: Log prior distributions.

Row 37: Log posterior distribution (the objective function). This row shows the sum of the previous 10 rows.

It should be noted that most of the likelihood components displayed in Table 2.14 are not comparable between years, because different amounts of data were used in the two years. One change between last year's model and this year's is the overall level of variability in recruitment (σ_R). Previous assessments have tended to show that recruitment variability in the GOA Pacific cod stock is much lower than the BSAI Pacific cod stock, and this year the disparity appears even greater, as the model's estimate of σ_R dropped from 0.47 to 0.24.

Evaluation Criteria

In previous GOA Pacific cod assessments, evaluation criteria have typically focused on effective sample sizes of the size composition data (and, since last year, the age composition data also) and the model's ability to fit the survey biomass data. These criteria are retained in the present assessment.

Effective Sample Size

Once maximum likelihood estimates of the model parameters have been obtained, SS2 computes an "effective" sample size for the size or age composition data specific to a particular year, gear/fishery, and time season within the year. Roughly, the effective sample size can be interpreted as the multinomial sample size that would typically be required in order to produce the given fit. More precisely, it is the sample size that sets the sum of the marginal variances of the proportions implied by the multinomial distribution equal to the sum of the squared differences between the sample proportions and the estimated proportions (McAllister and Ianelli 1997). As a function of a multinomial random variable, the effective sample size has its own distribution. The harmonic mean of the distribution is asymptotically equal to the true sample size in the multinomial distribution. Thus, if the effective sample size is less than the true sample size in the multinomial distribution, it is reasonable to conclude that the fit is not as good as expected. Table 2.15 shows the average of the input sample sizes, the average of the (output) effective sample sizes, and the ratio of the two for each of the size composition components and the trawl survey age composition component.

The model produces average effective sample sizes that are much larger than the average input values for all fishery length components. The model produces average effective sample sizes that are slightly larger than the average input values for the survey length component, and it produces average effective sample sizes that are slightly smaller than the average input values for the survey age component. The present model's average effective sample size for the age data is much better than last year's model, although the number of years with age data has doubled since last year (from 1 year's worth to 2 years' worth).

Fit to Survey Biomass Data

As with the model chosen last year by the Plan Team and SSC, the present model had difficulty fitting the high biomasses observed by the trawl survey in 1984 and 1996. Like last year's model, the present model's estimates of survey biomass fell within the 95% confidence intervals for all years except 1984. Not counting the two extremely high 1984 and 1996 survey observations, which neither last year's model nor this year's model was able to match, the highest survey observations came during the years 1987-1993. This year's model did not fit those high observations as well as last year's model did. The present model's poorer fit to those observations may be a result of the reduced estimated of recruitment variability, which would make it hard to generate the large year classes needed to produce the survey's high 1987-1993 survey observations. However, this year's model did fit the 1999-2005 survey observations almost perfectly (root-mean-squared-error = 4%).

Selection of Final Model

Although room remains for examining potential improvements to the present model (see this year's BSAI Pacific cod assessment for a list of possible modifications), the present model seems to perform very well in terms of the size composition data, the fit to the age composition data is improving, and the fit to the most recent survey abundance data is excellent. The model is therefore recommended for use in setting harvest specifications for 2007.

Final Parameter Estimates and Associated Schedules

Final estimates of some key scalar parameters (i.e., parameters that do not define length-specific schedules) corresponding to this year's model are shown in Table 2.14. Another scalar parameter estimated by SS2 is the equilibrium fishing mortality rate at the start of the time series (1964), which had a value of 0.004.

Estimates of fishing mortality rates are shown in Table 2.16, estimates of regime-specific median recruitments and annual recruitment deviations are shown in Table 2.17, and estimates of selectivity parameters are shown in Table 2.18.

Schedules of selectivity at length are shown for the commercial fisheries and bottom trawl survey in Table 2.19. The schedules in Table 2.19 are plotted in Figure 2.2.

Schedules of length at age, proportion mature at age, and weight at age are shown in Table 2.20.

RESULTS

Definitions

The biomass estimates presented here will be defined in three ways: 1) age 3+ biomass, consisting of the biomass of all fish aged three years or greater in January of a given year; 2) spawning biomass, consisting of the biomass of all spawning females in a given year; and 3) survey biomass, consisting of the biomass of all fish that the model estimates should have been observed by the survey in July of a given year. The recruitment estimates presented here will be defined as numbers of age 0 fish in a given year. The fishing mortality rates presented here will be defined as full-selection, instantaneous fishing mortality rates expressed on a per annum scale. In all comparisons involving last year's results, it is important to note that table entries labeled "Last Year's Values" do not correspond to the values given in last year's SAFE report, because the values given in last year's SAFE report corresponded to the authors' preferred model, not the model chosen by the Plan Team and SSC. Instead, table entries labeled "Last Year's Values" correspond to the results given last year under the model chosen by the Plan Team and SSC.

Biomass

Table 2.21 shows the time series of GOA Pacific cod female spawning biomass for the years 1977-2006 as estimated last year under the Plan Team's and SSC's preferred model and this year's model. Both estimated time series are accompanied by their respective 95% confidence intervals.

The estimated female spawning biomass time series and confidence intervals from this year's are shown, together with the model's estimated time series of age 3+ biomass, in Figure 2.3. Figure 2.3 also compares the observed and model-estimated time series from the bottom trawl survey. All three biomass trends estimated by the model are fairly flat from about 1999 onward.

Recruitment

Table 2.22 shows the time series of GOA Pacific cod age 0 recruitment (1000s of fish) for the years 1977-2004 as estimated last year under the Plan Team's and SSC's preferred model and this year's model. Both estimated time series are accompanied by their respective 95% confidence intervals.

The model's recruitment estimates for the entire time series (1964-2004) are shown in Figure 2.4, along with their respective 95% confidence intervals and regime-specific averages. For the time series since 1977, the largest year class appears to have been the 1977 cohorts. Other large cohorts include the 1984, 1987, 1989, 1995, 1999, and 2000 year classes. Of the four classes spawned after the strong 2000 year none appear to have been above average, with a mean strength approximately 22% below the post-1976 average. On the other hand, the relationship of these four year classes to the long-term average is still somewhat uncertain, as the 95% confidence interval for all but the 2001 year class extends above the long-term average. The 2004 year class is particularly uncertain, since the only data currently available to estimate its strength is the size composition data from the 2005 trawl survey.

To date, it has not been possible to estimate a reliable stock-recruitment relationship for this stock. With the move to SS2, prospects for future estimation of such a relationship should improve. In the interim, Figure 2.5 is provided to give some indication of the relationship between stock and recruitment. The Ricker (1954) curve shown in this figure (fit by maximum likelihood, ignoring process error) is intended to be illustrative only, and is not recommended for management purposes.

Exploitation

Table 2.23 shows the time series of GOA Pacific cod catch divided by age 3+ biomass for the years 1977-2006 as estimated last year under the Plan Team's and SSC's preferred model and this year's model.

The average value of this ratio over the entire time series is about 0.12, slightly higher than the average value of 0.10 obtained in the model chosen last year by the Plan Team and SSC. The estimated values exceed the average for every year after 1989 except 1993-1994 (last year's estimates) and 1994 (this year' estimates), whereas none of the estimated values exceed the average in any year prior to 1990 except for 1980-1981 (both year's assessments). This finding is similar to those obtained in past assessments.

Figure 2.6 plots the trajectory of relative fishing mortality and relative female spawning biomass from 1977 through 2006 based on the assessment model, overlaid with the current harvest control rules (fishing mortality rates in the figure are standardized relative to $F_{35\%}$ and biomasses are standardized relative to $B_{35\%}$, per SSC request). The entire trajectory lies underneath the F_{ABC} control rule.

PROJECTIONS AND HARVEST ALTERNATIVES

Amendment 56 Reference Points

Amendment 56 to the GOA Groundfish Fishery Management Plan (FMP) 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 cod 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. The following formulae apply under Tier 3:

3a) *Stock status:* $B/B_{40\%} > 1$
$F_{OFL} = F_{35\%}$
$F_{ABC} \leq F_{40\%}$

3b) *Stock status:* $0.05 < B/B_{40\%} \leq 1$
$F_{OFL} = F_{35\%} \times (B/B_{40\%} - 0.05) \times 1/0.95$
$F_{ABC} \leq F_{40\%} \times (B/B_{40\%} - 0.05) \times 1/0.95$

3c) *Stock status:* $B/B_{40\%} \leq 0.05$
$F_{OFL} = 0$
$F_{ABC} = 0$

Estimation of the $B_{40\%}$ reference point used in the above formulae 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 post-1976 average (i.e., the arithmetic mean of all estimated recruitments from year classes spawned in 1977 or later). Other useful biomass reference points which can be calculated using this assumption are $B_{100\%}$ and $B_{35\%}$, defined analogously to $B_{40\%}$. These reference points are estimated as follows:

Reference point:	$B_{35\%}$	$B_{40\%}$	$B_{100\%}$
Value:	90,500 t	103,000 t	259,000 t

For a stock exploited by multiple gear types, estimation of $F_{35\%}$ and $F_{40\%}$ requires an assumption regarding the apportionment of fishing mortality among those gear types. For this assessment, the apportionment was based on the model's estimates of fishing mortality by gear for the three most recent complete years of data (2003-2005). The average fishing mortality rates for those years implied that total fishing mortality was divided among the three main gear types according to the following percentages: trawl 28.6%, longline 16.9%, and pot 54.5%. This apportionment results in estimates of $F_{35\%}$ and $F_{40\%}$ equal to 0.57 and 0.46, respectively.

Specification of OFL and Maximum Permissible ABC

GOA Pacific cod spawning biomass for 2007 is estimated at a value of 136,000 t. This is about 31% above the $B_{40\%}$ value of 103,000 t, thereby placing Pacific cod in sub-tier "a" of Tier 3. Given this, the model estimates OFL, maximum permissible ABC, and the associated fishing mortality rates for 2007 as follows:

Quantity	Overfishing Level	Maximum Permissible ABC
Catch:	97,600 t	81,200 t
Fishing mortality rate:	0.57	0.46

The age 3+ biomass estimate for 2007 is 375,000 t.

ABC Recommendation

Review of Past Approaches

For the years 1997-1999, the GOA Pacific cod assessments advocated a harvest strategy that attempted to address some of the statistical uncertainty in the assessment model, namely the uncertainty surrounding parameters the natural mortality rate M and survey catchability Q (Thompson et al. 1997, 1998, 1999). For the 2000-2003 assessments, the strategy was simplified by assuming that the ratio between the recommended F_{ABC} and $F_{40\%}$ estimate given in the 1999 assessment (0.87) was an appropriate factor by which to multiply the current maximum permissible F_{ABC} to obtain a recommended F_{ABC} (Thompson et al. 2003). By the time of the 2004 assessment, however, concern arose that the 87% adjustment factor might have outlived its usefulness, given that the survey time series had changed appreciably since the adjustment factor was last estimated, most notably with the addition of two more survey biomass estimates in 2001 and 2003 and the recalibration of the entire time series in 2003. It was also noted, by way of comparison, that the 87% adjustment factor had not been used to set the ABC for BSAI Pacific cod since the 2002 fishery (Thompson and Dorn 2003). Therefore, the 2004 assessment based its recommendation for the 2005 ABC on a new method. This method, which focused on the mean-variance tradeoff associated with future catches predicted by the standard projection model, resulted in a 2005 ABC of 58,100 t. In the 2005 assessment, the Plan Team and SSC selected a model that resulted in a maximum permissible 2006 ABC of 79,618 t. However, the same model predicted that future ABCs would have to return quickly to values much closer to the 2005 ABC, so the SSC recommended an intermediate value of 68,859 t (the average of the 2005 ABC and the maximum permissible 2007 ABC), which was adopted as the 2007 ABC.

Recommendation for 2007

Based on this year's assessment model, the maximum permissible ABC (Tier 3a) for 2007 is 81,200 t. An ABC of this magnitude would represent an increase of 12,341 t, or 18%, relative to the 2006 ABC. However, it should be remembered that the 2001-2004 year classes appear to be below average, meaning that biomass is likely to decrease in coming years as these cohorts work their way through the age structure. For example, projections show that continued harvesting at the maximum permissible rate would be expected to result in a 2008 ABC 68,300 t. In other words, increasing the ABC by 12,000-

13,000 t in 2007 would likely be followed by a very similar decrease the following year. Given the existing issues surrounding the structure of the GOA Pacific cod model (see this year's BSAI Pacific cod assessment for discussion), it seems best to keep the 2007 ABC at the 2006 value of 68,859 t while work continues on refining the assessment model.

Area Allocation of Harvests

For the past several years, ABC has been allocated among regulatory areas on the basis of the three most recent surveys. The recent time series of area-specific biomass estimates are shown below, together with the proportions corresponding to a three-year weighted average (in keeping with past calculations, the 1999 estimate of biomass in the Eastern regulatory area is used as a proxy for the 2001 value, because the 2001 survey did not include the Eastern regulatory area):

Year	Western	Central	Eastern	Total
2001	133214	124400	21718	279332
2003	75632	207080	14689	297402
2005	134029	160118	13954	308102
Average	114292	163866	16787	294945
Proportion	0.39	0.55	0.06	1.00

Thus, if the previous approach for allocating ABC is retained for the 2007 fishery, the proportions would be 39% Western, 55% Central, and 6% Eastern.

Standard Harvest and Recruitment Scenarios and Projection Methodology

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

For each scenario, the projections begin with the vector of 2006 numbers at age estimated in the assessment. This vector is then projected forward to the beginning of 2007 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2006. 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 2007, 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*: For the present assessment, this scenario is implemented by setting the 2007 ABC equal to the 2006 ABC, then, in all future years, F is set equal to *max* F_{ABC}, (Rationale: This is the authors' recommended scenario.)

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 2002-2006 average F. (Rationale: For some stocks, TAC can be well below ABC, and recent average F may provide a better indicator of F_{TAC} than F_{ABC}.)

Scenario 5: In all future years, F is set equal to zero. (Rationale: In extreme cases, TAC may be set at a level close to zero.)

Two other scenarios are needed to satisfy the MSFCMA's requirement to determine whether a stock is currently in an overfished condition or is approaching an overfished condition. These two scenarios are as follow (for Tier 3 stocks, the MSY level is defined as $B_{35\%}$):

Scenario 6: In all future years, F is set equal to F_{OFL}. (Rationale: This scenario determines whether a stock is overfished. If the stock is expected to be 1) above its MSY level in 2007 or 2) above ½ of its MSY level in 2007 and above its MSY level in 2017 under this scenario, then the stock is not overfished.)

Scenario 7: In 2007 and 2008, F is set equal to *max* F_{ABC}, and in all subsequent years, F is set equal to F_{OFL}. (Rationale: This scenario determines whether a stock is approaching an overfished condition. If the stock is expected to be above its MSY level in 2019 under this scenario, then the stock is not approaching an overfished condition.)

Projections and Status Determination

Scenario Projections and Two-Year Ahead Overfishing Level
Projections corresponding to the standard scenarios are shown for this year's model in Tables 2.24-2.30.

In addition to the seven standard harvest scenarios, Amendments 48/48 to the BSAI and GOA Groundfish Fishery Management Plans require projections of the likely OFL two years into the future. While Scenario 6 gives the best estimate of OFL for 2007, it does not provide the best estimate of OFL for 2008, because the mean 2007 catch under Scenario 6 is predicated on the 2007 catch being equal to the 2007 OFL, whereas the actual 2007 catch will likely be less than the 2007 OFL. Table 2.14 contains the appropriate one- and two-year ahead projections for both maximum permissible ABC and OFL.

For the authors' recommended 2007 ABC of 68,859 t, the two-year ahead projections are as follow:

Year	F_{ABC}	ABC	F_{OFL}	OFL
2007	0.38	68,859 t	0.57	97,600 t
2008	0.46	71,400 t	0.57	86,000 t

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 2007:

a. If spawning biomass for 2007 is estimated to be below ½ $B_{35\%}$, the stock is below its MSST.

b. If spawning biomass for 2007 is estimated to be above $B_{35\%}$ the stock is above its MSST.

c. If spawning biomass for 2007 is estimated to be above ½ $B_{35\%}$ but below B35%, the stock's status relative to MSST is determined by referring to harvest Scenario #6 (Table 2.29). If the mean spawning biomass for 2017 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 2.30):

a. If the mean spawning biomass for 2009 is below ½ $B_{35\%}$, the stock is approaching an overfished condition.

b. If the mean spawning biomass for 2009 is above $B_{35\%}$, the stock is not approaching an overfished condition.

c. If the mean spawning biomass for 2009 is above ½ $B_{35\%}$ but below $B_{35\%}$, the determination depends on the mean spawning biomass for 2019. If the mean spawning biomass for 2019 is below $B_{35\%}$, the stock is approaching an overfished condition. Otherwise, the stock is not approaching an overfished condition.

In the case of GOA Pacific cod, spawning biomass for 2007 is estimated to be above $B_{35\%}$ under this year's model. Therefore, the stock is above its MSST and is not overfished. Mean spawning biomass for 2009 in Table 2.30 is above $B_{35\%}$. Therefore, the stock is not approaching an overfished condition.

ECOSYSTEM CONSIDERATIONS

The material in the present section is largely unchanged from last year's assessment.

Ecosystem Effects on the Stock

A primary ecosystem phenomenon affecting the Pacific cod stock seems to be the occurrence of periodic "regime shifts," in which central tendencies of key variables in the physical environment change on a scale spanning several years to a few decades (Boldt (ed.), 2005). One well-documented example of such a regime shift occurred in 1977, and shifts occurring in 1989 and 1999 have also been suggested (e.g., Hare and Mantua 2000). In the present assessment, an attempt was made to estimate the change in median recruitment of GOA Pacific cod associated with the 1977 regime shift. According to this year's model, pre-1977 median recruitment was only about 32% of post-1976 median recruitment. Establishing a link between environment and recruitment within a particular regime is more difficult. In the 2004 assessment (Thompson et al. 2004), for example, the correlations between age 1 recruits spawned since 1977 and monthly values of the Pacific Decadal Oscillation (Mantua et al. 1997) were computed and found to be very weak.

The prey and predators of Pacific cod have been described or reviewed by Albers and Anderson (1985), Livingston (1989, 1991), Lang et al. (2003), Westrheim (1996), and Yang (2004). The composition of Pacific cod prey varies to some extent by time and area. In terms of percent occurrence, some of the most important items in the diet of Pacific cod in the BSAI and GOA have been polychaetes, amphipods, and crangonid shrimp. In terms of numbers of individual organisms consumed, some of the most important dietary items have been euphausids, miscellaneous fishes, and amphipods. In terms of weight of organisms consumed, some of the most important dietary items have been walleye pollock, fishery offal, yellowfin sole, and crustaceans. Small Pacific cod feed mostly on invertebrates, while large Pacific cod are mainly piscivorous. Predators of Pacific cod include Pacific cod, halibut, salmon shark, northern fur seals, Steller sea lions, harbor porpoises, various whale species, and tufted puffin. Major trends in the most important prey or predator species could be expected to affect the dynamics of Pacific cod to some extent.

Fishery Effects on the Ecosystem

Potentially, fisheries for Pacific cod can have effects on other species in the ecosystem through a variety of mechanisms, for example by relieving predation pressure on shared prey species (i.e., species which serve as prey for both Pacific cod and other species), by reducing prey availability for predators of Pacific cod, by altering habitat, by imposing bycatch mortality, or by "ghost fishing" caused by lost fishing gear.

Bycatch of Nontarget and "Other" Species

Bycatch of nontarget species and members of the "other species" group are shown in the following set of tables (for the 2003-2005 tables, the "hook and line" gear type includes both longline and jig gear): Tables 2.31a and 2.31b show bycatch for the GOA Pacific cod trawl fishery in 1997-2002 and 2003-2005, respectively. Tables 2.32a and 2.32b show bycatch for the GOA Pacific cod longline fishery in 1997-2002 and the GOA Pacific cod hook and line fishery in 2003-2005, respectively. Tables 2.33a and 2.33b show bycatch for the GOA Pacific cod pot fishery in 1997-2002 and 2003-2005, respectively.

It is not clear how much bycatch of a particular species constitutes "too much" in the context of ecosystem concerns. As a first step toward possible prioritization of future investigation into this question, it might be reasonable to focus on those species groups for which a Pacific cod fishery had a bycatch in excess of 100 t and accounted for more than 10% of the total bycatch in at least two of the three most recent years. This criterion results in the following list of impacted species groups (an "X" indicates that the criterion was met for that area/species/gear combination).

Species group	Hook and Line	Pot
Large sculpins		X
Sea star	X	X
Skate	X	

Steller Sea Lions

Sinclair and Zeppelin (2002) showed that Pacific cod was one of the four most important prey items of Steller sea lions in terms of frequency of occurrence averaged over years, seasons, and sites, and was especially important in winter. Pitcher (1981) and Calkins (1998) also showed Pacific cod to be an important winter prey item in the GOA and BSAI, respectively. Furthermore, the size ranges of Pacific cod harvested by the fisheries and consumed by Steller sea lions overlap, and the fishery operates to some extent in the same geographic areas used by Steller sea lion as foraging grounds (Livingston (ed.), 2002).

The Fisheries Interaction Team of the Alaska Fisheries Science Center has been engaged in research to determine the effectiveness of recent management measures designed to mitigate the impacts of the Pacific cod fisheries (among others) on Steller sea lions. Results from studies conducted in 2002-2003 were summarized by Conners et al. (2004). These studies included a tagging feasibility study, which may evolve into an ongoing research effort capable of providing information on the extent and rate to which Pacific cod move in and out of various portions of Steller sea lion critical habitat. Nearly 6,000 cod with spaghetti tags were released, of which approximately 1,000 had been returned as of September, 2003.

Seabirds

The following is a summary of information provided by Livingston (ed., 2002): In both the BSAI and GOA, the northern fulmar (*Fulmarus glacialis*) comprises the majority of seabird bycatch, which occurs primarily in the longline fisheries, including the hook and line fishery for Pacific cod (Tables 2.36b and 2.39b). Shearwater (*Puffinus* spp.) distribution overlaps with the Pacific cod longline fishery in the Bering Sea, and with trawl fisheries in general in both the Bering Sea and GOA. Black-footed albatross (*Phoebastria nigripes*) is taken in much greater numbers in the GOA longline fisheries than the Bering Sea longline fisheries, but is not taken in the trawl fisheries. The distribution of Laysan albatross

(*Phoebastria immutabilis*) appears to overlap with the longline fisheries in the central and western Aleutians. The distribution of short-tailed albatross (*Phoebastria albatrus*) also overlaps with the Pacific cod longline fishery along the Aleutian chain, although the majority of the bycatch has taken place along the northern portion of the Bering Sea shelf edge (in contrast, only two takes have been recorded in the GOA). Some success has been obtained in devising measures to mitigate fishery-seabird interactions. For example, on vessels larger than 60 ft. LOA, paired streamer lines of specified performance and material standards have been found to reduce seabird incidental take significantly.

Fishery Usage of Habitat

The following is a summary of information provided by Livingston (ed., 2002): The longline and trawl fisheries for Pacific cod each comprise an important component of the combined fisheries associated with the respective gear type in each of the three major management regions (BS, AI, and GOA). Looking at each gear type in each region as a whole (i.e., aggregating across all target species) during the period 1998-2001, the total number of observed sets was as follows:

Gear	BS	AI	GOA
Trawl	240,347	43,585	68,436
Longline	65,286	13,462	7,139

In the BS, both longline and trawl effort was concentrated north of False Pass (Unimak Island) and along the shelf edge represented by the boundary of areas 513, 517 (in addition, longline effort was concentrated along the shelf edge represented by the boundary of areas 521-533). In the AI, both longline and trawl effort were dispersed over a wide area along the shelf edge. The catcher vessel longline fishery in the AI occurred primarily over mud bottoms. Longline catcher-processors in the AI tended to fish more over rocky bottoms. In the GOA, fishing effort was also dispersed over a wide area along the shelf, though pockets of trawl effort were located near Chirikof, Cape Barnabus, Cape Chiniak and Marmot Flats. The GOA longline fishery for Pacific cod generally took place over gravel, cobble, mud, sand, and rocky bottoms, in depths of 25 fathoms to 140 fathoms.

Impacts of the Pacific cod fisheries on essential fish habitat were further analyzed in an environmental impact statement by NMFS (2005).

Data Gaps and Research Priorities

Understanding of the above ecosystem considerations would be improved if future research were directed toward closing certain data gaps. Such research would have several foci, including the following: 1) ecology of the Pacific cod stock, including spatial dynamics, trophic and other interspecific relationships, and the relationship between climate and recruitment; 2) behavior of the Pacific cod fishery, including spatial dynamics; 3) determinants of trawl survey selectivity; 4) ecology of species taken as bycatch in the Pacific cod fisheries, including estimation of biomass, carrying capacity, and resilience; and 5) ecology of species that interact with Pacific cod, including estimation of biomass, carrying capacity, and resilience.

SUMMARY

The major results of the Pacific cod stock assessment are summarized in Table 2.34.

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Tables

Table 2.1a—Summary of catches (t) of Pacific cod by fleet sector and gear type, 1964-1990. All catches since 1980 include discards. Jt. Vent. = joint venture.

	Fleet Sector			Gear Type				
Year	Foreign	Jt. Vent.	Domestic	Trawl	Longline	Pot	Other	Total
1964	196	0	0	56	140	0	0	196
1965	599	0	0	172	427	0	0	599
1966	1,376	0	0	396	980	0	0	1,376
1967	2,225	0	0	640	1,585	0	0	2,225
1968	1,046	0	0	301	745	0	0	1,046
1969	1,335	0	0	384	951	0	0	1,335
1970	1,805	0	0	519	1,286	0	0	1,805
1971	523	0	0	150	373	0	0	523
1972	3,513	0	0	1,010	2,503	0	0	3,513
1973	5,963	0	0	1,715	4,248	0	0	5,963
1974	5,182	0	0	1,491	3,691	0	0	5,182
1975	6,745	0	0	1,940	4,805	0	0	6,745
1976	6,764	0	0	1,946	4,818	0	0	6,764
1977	2,267	0	0	652	1,615	0	0	2,267
1978	11,370	7	813	4,547	6,800	0	843	12,190
1979	13,173	711	1,020	3,629	9,545	0	1,730	14,904
1980	34,245	466	634	6,464	27,780	0	1,101	35,345
1981	34,969	58	1,104	10,484	25,472	0	175	36,131
1982	26,937	193	2,335	6,679	22,667	0	119	29,465
1983	29,777	2,426	4,337	9,512	26,756	0	272	36,540
1984	15,896	4,649	3,353	8,805	14,844	0	249	23,898
1985	9,086	2,266	3,076	4,876	9,411	2	139	14,428
1986	15,211	1,357	8,444	6,850	17,619	141	402	25,012
1987	0	1,978	30,961	22,486	8,261	642	1,550	32,939
1988	0	1,661	32,141	27,145	3,933	1,422	1,302	33,802
1989	0	0	43,293	37,637	3,662	376	1,618	43,293
1990	0	0	72,517	59,188	5,919	5,661	1,749	72,517

Table 2.1b—Summary of catches (t) of Pacific cod since 1991 by management jurisdiction and gear type. Longl. = longline, Subt. = subtotal. All entries include discards. Catches for 2006 are complete through early October.

	Federal					State			
Year	Trawl	Longl.	Pot	Other	Subt.	Pot	Other	Subt.	Total
1991	58,093	7,656	10,464	115	76,328	0	0	0	76,328
1992	54,593	15,675	10,154	325	80,746	0	0	0	80,746
1993	37,806	8,962	9,708	11	56,487	0	0	0	56,487
1994	31,446	6,778	9,160	100	47,484	0	0	0	47,484
1995	41,875	10,978	16,055	77	68,985	0	0	0	68,985
1996	45,991	10,196	12,040	53	68,280	0	0	0	68,280
1997	48,405	10,977	9,065	26	68,474	7,224	1,319	8,542	77,017
1998	41,569	10,011	10,510	29	62,120	9,088	1,316	10,404	72,524
1999	37,167	12,362	19,015	70	68,613	12,075	1,096	13,171	81,784
2000	25,457	11,667	17,351	54	54,528	10,388	1,643	12,031	66,559
2001	24,382	9,913	7,171	155	41,621	7,836	2,084	9,920	51,541
2002	19,809	14,666	7,694	176	42,345	10,423	1,714	12,137	54,483
2003	18,799	9,475	12,675	88	41,037	8,031	3,429	11,461	52,498
2004	17,351	10,337	13,671	310	17,351	10,117	2,804	12,922	54,591
2005	14,513	5,756	14,684	203	35,157	9,712	2,673	12,384	47,541
2006	12,930	7,314	12,624	107	32,975	9,168	590	9,758	42,734

Table 2.2—History of Pacific cod ABC, TAC, total catch, and type of stock assessment model used to recommend ABC. ABC was not used in management of GOA groundfish prior to 1986. Catch for 2006 is current through early October. The values in the column labeled "TAC" correspond to "optimum yield" for the years 1980-1986, "target quota" for the year 1987, and true TAC for the years 1988-2005. "SS1" refers to Stock Synthesis 1, and "SS2" refers to Stock Synthesis 2. Each cell in the "Stock Assessment Model" column lists the type of model used to recommend the ABC in the corresponding row, meaning that the model was produced in the year previous to the one listed in the corresponding row.

Year	ABC	TAC	Catch	Stock Assessment Model (from previous year)
1980	n/a	60,000	35,345	n/a
1981	n/a	70,000	36,131	n/a
1982	n/a	60,000	29,465	n/a
1983	n/a	60,000	36,540	n/a
1984	n/a	60,000	23,898	n/a
1985	n/a	60,000	14,428	n/a
1986	136,000	75,000	25,012	survey biomass
1987	125,000	50,000	32,939	survey biomass
1988	99,000	80,000	33,802	survey biomass
1989	71,200	71,200	43,293	stock reduction analysis
1990	90,000	90,000	72,517	stock reduction analysis
1991	77,900	77,900	76,328	stock reduction analysis
1992	63,500	63,500	80,746	stock reduction analysis
1993	56,700	56,700	56,487	stock reduction analysis
1994	50,400	50,400	47,484	stock reduction analysis
1995	69,200	69,200	68,985	SS1 model (length-based data)
1996	65,000	65,000	68,280	SS1 model (length-based data)
1997	81,500	69,115	77,017	SS1 model (length-based data)
1998	77,900	66,060	72,524	SS1 model (length-based data)
1999	84,400	67,835	81,784	SS1 model (length-based data)
2000	76,400	58,715	66,559	SS1 model (length-based data)
2001	67,800	52,110	51,541	SS1 model (length-based data)
2002	57,600	44,230	54,483	SS1 model (length-based data)
2003	52,800	40,540	52,498	SS1 model (length-based data)
2004	62,810	48,033	54,591	SS1 model (length-based data)
2005	58,100	44,433	47,541	SS1 model (length-based data)
2006	68,859	52,264	42,734	SS2 model (length- and age-based data)

Table 2.3—History of GOA Pacific cod allocations by regulatory area.

	Regulatory Area		
Year(s)	Western	Central	Eastern
1977-1985	28	56	16
1986	40	44	16
1987	27	56	17
1988-1989	19	73	8
1990	33	66	1
1991	33	62	5
1992	37	61	2
1993-1994	33	62	5
1995-1996	29	66	5
1997-1999	35	63	2
2000-2001	36	57	7
2002 (ABC)	39	55	6
2002 (TAC)	38	56	6
2003 (ABC)	39	55	6
2003 (TAC)	38	56	6
2004 (ABC)	36	57	7
2004 (TAC)	35.3	56.5	8.2
2005 (ABC)	36	57	7
2005 (TAC)	35.3	56.5	8.2
2006 (ABC)	39	55	6
2006 (TAC)	38.54	54.35	7.11

Table 2.4a—Pacific cod discard rates by area, target species/group, and year for the period 1991-2002 (see Table 2.4b for the period 2003-2004). The discard rate is the ratio of discarded Pacific cod catch to total Pacific cod catch for a given area/target/year combination. An empty cell indicates that no Pacific cod were caught in that area/target/year combination. Note that the absolute amount of discards may be small even if the discard rate is large.

Target species/group	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Arrowtooth flounder		0.98	0.59	0.00	0.10	0.09	0.00	1.00	0.63	0.06		0.00
Atka mackerel				0.81	1.00	0.00						
Deepwater Flat	1.00			0.43	0.00	0.68	0.53	0.00	0.36	0.00	0.75	
Flathead sole				1.00		0.07	0.99	0.00		0.29	0.75	0.00
Other species	1.00	0.15	0.63		0.10	0.91	0.00	0.00	0.96	0.01	0.00	0.00
Pacific cod	0.05	0.03	0.03	0.02	0.03	0.02	0.02	0.01	0.01	0.00	0.02	0.02
Pollock	0.82	0.59	0.15	0.15	0.95	0.17	0.98	0.75	0.89	0.44	0.00	1.00
Rex sole					0.16	0.25	0.61	0.57				1.00
Rockfish	0.15	0.11	0.13	0.16	0.11	0.13	0.14	0.17	0.17	0.17	0.00	0.04
Sablefish	0.84	0.72	0.72	0.77	0.55	0.78	0.54	0.66	0.52	0.25	0.27	0.22
Shallow-water flatfish	0.43	0.00	0.00	0.87	0.00	0.97	0.00	1.00	0.74	0.28		1.00
Unknown	0.01					1.00	1.00	1.00		1.00		
All targets	0.03	0.03	0.04	0.02	0.03	0.02	0.03	0.01	0.02	0.00	0.02	0.02

Table 2.4b—Pacific cod discard rates by area, target species/group, and year for the period 2003-2004 (see Table 2.4a for the period 1991-2002; note that the IFQ halibut target does not exist in Table 2.4a). The discard rate is the ratio of discarded Pacific cod catch to total Pacific cod catch for a given area/target/year combination. An empty cell indicates that no Pacific cod were caught in that area/target/year combination. Note that the absolute amount of discards may be small even if the discard rate is large.

Target species/group	2003	2004
Arrowtooth flounder	0.40	0.27
Atka mackerel		
Deepwater flatfish	0.01	0.25
Flathead sole	0.25	0.33
IFQ halibut	0.61	0.59
Other species	0.16	0.07
Pacific cod	0.01	0.01
Pollock	0.05	0.26
Rex sole	0.22	0.15
Rockfish	0.14	0.04
Sablefish	0.64	0.23
Shallowwater flatfish	0.61	0.53
Unknown		
All targets	0.05	0.02

Table 2.5—Catch of Pacific cod by year, gear, and season as used in the stock assessment model. Jig catches have been merged with other gear types. Catches for season 3 in 2006 are based on 2005.

	Trawl			Longline			Pot		
Year	Sea. 1	Sea. 2	Sea. 3	Sea. 1	Sea. 2	Sea. 3	Sea. 1	Sea. 2	Sea. 3
1964	16	14	27	82	16	42	0	0	0
1965	48	42	82	249	50	127	0	0	0
1966	111	96	189	572	115	293	0	0	0
1967	180	155	305	926	186	473	0	0	0
1968	84	73	144	435	88	222	0	0	0
1969	108	93	183	555	112	284	0	0	0
1970	146	126	248	751	151	384	0	0	0
1971	42	36	72	218	44	111	0	0	0
1972	284	245	482	1461	294	747	0	0	0
1973	481	415	819	2480	499	1268	0	0	0
1974	418	361	711	2156	434	1102	0	0	0
1975	544	470	926	2806	565	1434	0	0	0
1976	546	471	929	2814	566	1438	0	0	0
1977	183	158	311	943	190	482	0	0	0
1978	916	790	1558	4720	950	2413	0	0	0
1979	1063	917	1809	5480	1103	2801	0	0	0
1980	2764	2384	4702	14245	2868	7282	0	0	0
1981	387	3532	6565	10504	5312	9656	0	0	0
1982	1143	2041	3495	9912	2890	9865	0	0	0
1983	2861	2844	3807	10960	4651	11145	0	0	0
1984	3429	2008	3368	11840	425	2579	0	0	0
1985	2427	571	1878	9127	6	280	0	0	0
1986	2999	431	3420	15927	460	1373	0	0	0
1987	5377	7928	9181	5343	983	1935	219	141	282
1988	16021	6569	4555	2979	507	447	1081	23	318
1989	24614	12857	166	2378	356	928	241	103	32
1990	43279	7514	8395	5557	109	253	2577	1008	2076
1991	55977	631	1484	7296	332	142	9591	0	873
1992	51911	1189	1494	12946	802	2251	9672	14	468
1993	33632	2624	1550	8485	307	181	9689	18	0
1994	29152	1421	873	6696	48	133	8742	0	418
1995	38476	802	2597	10662	166	227	15419	43	592
1996	41450	3048	1493	9991	152	106	12014	27	0
1997	40727	1638	6040	10931	967	424	14007	475	1807
1998	34690	3679	3200	10566	510	280	18479	0	1119
1999	30124	1501	5542	12782	555	191	25167	3374	2548
2000	22133	2574	750	12758	436	169	26947	154	638
2001	15234	2035	7113	11199	662	291	13047	37	1923
2002	15829	2705	1276	12963	259	3334	13602	83	4431
2003	10996	2565	5239	8416	407	768	20997	24	3087
2004	9137	2091	6339	8236	109	2027	24250	4	4461
2005	9545	1831	3138	3774	115	1867	22118	4	5150
2006	10148	1703	3138	6124	115	1867	21941	51	5150

Table 2.6—Pacific cod length sample sizes from the commercial fisheries.

	Trawl Fishery			Longline Fishery			Pot Fishery		
Year	Sea. 1	Sea. 2	Sea. 3	Sea. 1	Sea. 2	Sea. 3	Sea. 1	Sea. 2	Sea. 3
1977	0	210	0	0	0	0	0	0	0
1978	0	0	634	0	0	18670	0	0	0
1979	0	0	0	0	0	14460	0	0	0
1980	0	0	783	0	0	18671	0	0	0
1981	0	0	461	0	0	19308	0	0	0
1982	0	0	1390	0	0	22856	0	0	0
1983	0	0	2896	0	0	127992	0	0	0
1984	0	0	1039	0	0	47485	0	0	0
1985	0	0	0	0	0	10141	0	0	0
1986	0	0	0	0	0	87304	0	0	0
1987	0	0	0	0	0	387	0	0	0
1988	0	0	0	0	0	2432	0	0	0
1989	660	0	312	0	0	0	0	0	0
1990	25396	10892	12025	9925	0	0	2783	2920	10711
1991	38514	0	131	12551	143	0	49453	139	0
1992	39683	0	2255	28817	577	3603	37177	664	5013
1993	26844	0	0	11748	0	0	20866	0	0
1994	12579	0	0	5201	0	0	16342	0	217
1995	26039	120	2402	24635	0	0	46625	0	1233
1996	17858	0	0	14706	0	0	35256	432	0
1997	22822	225	3746	7239	119	154	26880	252	1537
1998	52448	3465	6763	7981	410	148	31569	291	2902
1999	11550	232	1101	9013	86	396	33876	3719	3656
2000	6951	425	69	11426	47	20	28991	902	277
2001	6115	665	4560	12642	145	141	23290	0	3925
2002	6285	808	309	9583	134	3009	17235	0	4674
2003	4129	1187	1761	7941	375	2301	12019	9343	6168
2004	2598	471	2545	6647	337	2906	16676	0	4817
2005	1760	581	1759	5978	445	3312	17124	49	6867
2006	2190	43	0	7645	133	338	20445	0	427

Table 2.7a—Length frequencies of Pacific cod in the pre-1987 trawl fishery by year, season, and length bin.

		Length Bin																								
Yr.	Sea.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1977	2	0	0	0	0	0	0	0	0	0	4	16	21	38	49	38	8	6	16	10	3	1	0	0	0	0
1978	3	0	0	0	0	0	1	1	5	9	5	4	14	40	93	125	106	106	59	39	23	3	1	0	0	0
1980	3	0	0	0	0	0	0	1	0	0	0	1	6	60	162	96	71	91	134	93	48	17	3	0	0	0
1981	3	0	0	0	0	0	0	0	0	0	0	5	29	85	148	145	47	2	0	0	0	0	0	0	0	0
1982	3	0	0	0	0	0	0	0	0	1	3	26	39	118	255	280	294	174	111	52	14	15	5	2	1	0
1983	3	0	0	0	0	0	0	1	2	1	11	24	106	332	388	403	439	375	310	252	143	76	23	7	3	0
1984	3	0	0	0	0	0	0	0	0	1	7	49	135	265	127	140	122	70	47	23	19	13	10	6	4	1

Table 2.7b—Length frequencies of Pacific cod in the 1987-1999 trawl fishery by year, season, and length bin.

		Length Bin																								
Yr.	Sea.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1989	1	0	0	0	0	0	0	0	0	0	0	0	0	5	52	175	248	141	30	5	3	1	0	0	0	0
1989	3	0	0	0	0	0	6	28	41	29	17	3	3	16	37	50	39	14	4	6	2	7	4	4	2	0
1990	1	1	0	1	1	12	7	15	76	119	160	201	228	574	1322	3188	4903	4680	3357	2562	1572	1311	754	256	70	26
1990	2	41	36	15	0	0	1	0	1	3	31	81	169	419	954	1892	2562	2555	1323	510	181	90	24	3	0	1
1990	3	0	0	0	1	2	0	7	13	39	62	180	427	1447	1239	1240	1744	1726	1269	1101	860	434	133	67	18	16
1991	1	0	1	2	2	2	7	63	142	163	226	235	346	1905	3794	4421	5618	6609	5126	3629	2613	1621	1016	618	273	82
1991	3	0	0	0	0	0	0	0	0	0	0	0	0	2	5	15	15	24	28	24	6	9	3	0	0	0
1992	1	0	0	0	1	4	13	21	78	261	567	921	1084	1796	3160	4966	6796	5825	4257	3355	2548	1734	1143	749	280	124
1992	3	0	0	0	0	0	1	8	21	18	7	64	214	479	502	415	211	145	77	63	28	2	0	0	0	0
1993	1	0	0	1	4	2	5	4	58	234	469	547	544	2077	3445	3613	4744	4817	2832	1430	846	491	345	214	87	35
1994	1	0	0	0	0	0	0	0	7	31	83	115	138	499	1022	1734	2551	2642	1659	944	490	347	167	82	44	24
1995	1	0	0	0	0	0	0	1	8	60	91	204	316	1000	2363	3475	4628	5820	4040	1903	993	533	300	164	74	66
1995	2	0	0	0	0	0	1	1	0	0	1	1	9	26	15	20	19	19	6	2	0	0	0	0	0	0
1995	3	0	0	0	0	0	1	14	14	16	14	12	7	51	140	222	583	642	470	153	50	9	3	1	0	0
1996	1	0	0	0	1	6	28	39	64	105	187	250	230	290	690	1575	2924	3744	2948	1949	1237	793	437	217	96	48
1997	1	0	0	3	8	12	12	5	44	123	300	357	276	807	2271	2841	2945	4449	3874	2247	1140	562	288	174	67	17
1997	2	0	0	0	0	0	0	0	0	0	0	0	0	1	0	9	28	54	78	46	8	1	0	0	0	0
1997	3	0	0	0	1	3	8	29	49	100	62	56	96	318	374	477	823	589	342	262	100	46	10	1	0	0
1998	1	0	0	0	1	5	7	9	57	293	746	989	832	2009	4345	5676	9100	10443	8205	4970	2379	1278	652	327	98	27
1998	2	0	0	1	3	0	0	1	1	0	2	13	49	196	310	656	854	720	419	148	60	26	1	4	0	1
1998	3	3	4	0	0	5	35	112	133	209	209	146	225	1027	1139	906	1048	747	438	214	112	45	4	1	1	0
1999	1	0	0	1	4	4	4	4	21	73	144	184	215	453	1052	1797	2194	2226	1644	851	397	173	61	30	14	4
1999	2	0	0	0	0	0	5	0	0	0	0	0	1	5	8	34	52	65	36	18	6	2	0	0	0	0
1999	3	0	0	0	0	0	1	0	2	3	6	2	9	14	31	59	271	281	213	124	54	19	10	2	0	0

Table 2.7c—Length frequencies of Pacific cod in the post-1999 trawl fishery by year, season, and length bin.

		Length Bin																								
Yr.	Sea.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
2000	1	0	0	0	0	0	0	2	10	29	74	84	99	250	787	1091	1429	1310	806	475	243	163	72	20	6	1
2000	2	0	0	0	0	0	0	0	3	1	0	9	21	31	30	56	88	100	48	20	14	4	0	0	0	0
2000	3	0	0	0	0	0	0	0	0	0	0	2	6	13	11	7	6	9	9	5	1	0	0	0	0	0
2001	1	0	1	2	2	1	1	4	7	37	97	158	146	287	694	947	1166	1183	803	336	147	63	22	8	1	2
2001	2	0	0	0	0	0	5	5	5	0	2	6	18	48	45	68	144	147	99	31	20	16	6	0	0	0
2001	3	0	0	0	0	1	0	10	45	100	154	123	80	303	633	669	783	677	496	301	122	46	14	3	0	0
2002	1	0	0	0	0	1	3	5	7	36	118	232	298	497	441	756	975	1123	936	508	218	80	36	8	5	2
2002	2	0	0	0	0	0	0	0	1	3	1	5	24	145	195	101	114	117	55	24	19	3	1	0	0	0
2002	3	0	0	0	0	0	0	0	3	4	6	12	14	36	39	49	51	37	21	12	12	8	4	1	0	0
2003	1	0	0	0	0	0	1	4	13	34	99	150	130	214	609	963	645	433	358	221	133	85	20	10	6	1
2003	2	0	0	0	2	1	2	10	8	7	19	27	59	193	170	162	220	136	101	37	26	5	1	1	0	0
2003	3	0	0	0	0	0	1	9	5	9	11	12	43	193	303	291	405	249	139	53	25	8	4	1	0	0
2004	1	0	0	1	0	2	1	0	6	24	52	65	74	179	433	525	518	413	167	86	35	11	4	2	0	0
2004	2	0	0	0	0	0	0	0	2	0	0	1	6	9	24	83	124	106	62	30	16	5	2	1	0	0
2004	3	0	0	0	0	0	0	4	9	7	1	4	30	156	284	383	465	532	405	166	70	20	9	0	0	0
2005	1	0	0	0	0	0	0	0	2	5	7	26	24	58	98	177	318	437	300	143	75	51	21	8	8	2
2005	2	0	0	0	0	2	2	2	2	4	8	21	22	8	10	52	144	150	91	40	13	8	2	0	0	0
2005	3	0	0	0	0	0	0	3	2	5	4	15	34	34	21	57	275	485	420	229	113	44	14	4	0	0
2006	1	0	0	0	0	0	1	0	1	3	14	42	27	64	180	228	397	424	342	206	124	63	35	25	11	3
2006	2	0	0	0	0	0	0	0	0	2	1	0	1	4	4	4	7	9	3	3	5	0	0	0	0	0

Table 2.8a–Length frequencies of Pacific cod in the pre-1987 longline fishery by year, season, and length bin.

		Length Bin																								
Yr.	Sea.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1978	3	0	0	0	0	0	0	0	0	7	38	91	276	1160	2235	3077	4051	3359	2139	1261	696	224	49	6	1	0
1979	3	0	0	0	0	0	0	1	6	35	113	285	475	1124	1327	1744	2148	2534	2258	1401	651	271	75	12	0	0
1980	3	0	0	0	0	0	0	0	1	2	43	256	1184	3776	3199	1989	1555	1854	1998	1630	787	276	99	19	2	1
1981	3	0	0	0	0	0	0	0	0	9	29	83	263	1558	4685	5824	3243	1485	844	570	379	199	101	28	8	0
1982	3	0	0	0	0	0	0	0	5	40	106	280	498	1945	3992	5101	4586	3115	1729	815	351	181	80	26	6	0
1983	3	0	0	0	0	0	0	0	3	24	164	728	2661	11515	21037	24663	22224	17602	13130	7842	3868	1638	588	234	63	8
1984	3	0	0	0	0	0	1	1	5	40	135	341	885	4389	9372	10579	7666	4722	3612	2572	1666	958	380	134	23	4
1985	3	0	0	0	0	1	0	8	45	114	206	316	440	1036	990	1847	2170	1294	626	462	294	186	89	14	3	0
1986	3	0	0	0	0	0	0	0	10	133	387	487	681	2963	6979	11599	12075	10988	13158	12084	7943	4112	2254	1025	346	80

Table 2.8b—Length frequencies of Pacific cod in the 1987-1999 longline fishery by year, season, and length bin.

		Length Bin																								
Yr.	Sea.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1987	3	0	0	0	0	0	0	0	1	1	4	9	17	49	102	109	72	15	6	0	1	1	0	0	0	0
1988	3	0	0	0	0	0	0	0	1	2	17	58	76	252	580	662	412	165	115	39	27	13	3	6	1	3
1990	1	0	0	0	0	0	0	2	2	6	28	82	57	219	511	991	1633	1999	1535	1173	850	549	186	69	30	3
1991	1	0	0	0	0	0	0	0	1	3	8	56	155	670	1351	1839	2473	2486	1740	909	411	229	119	49	23	29
1991	2	0	0	0	0	0	0	0	0	0	0	0	0	0	1	16	34	50	22	12	4	1	0	3	0	0
1992	1	0	0	0	0	0	2	3	8	20	57	137	333	1078	2326	4103	5900	4910	3817	2585	1598	906	580	306	103	45
1992	2	0	0	0	0	0	0	0	0	1	2	6	8	13	76	84	119	145	71	28	11	11	2	0	0	0
1992	3	0	0	0	0	0	0	0	1	2	0	11	7	68	185	466	986	1130	541	142	43	15	1	2	2	1
1993	1	0	0	0	1	3	6	9	5	8	18	43	67	357	924	1503	2077	1959	1226	1036	947	856	413	163	75	52
1994	1	0	0	0	0	0	0	0	0	0	1	4	20	166	500	630	1000	1065	788	450	213	167	93	61	26	17
1995	1	0	0	0	0	1	0	3	2	3	24	96	173	692	1662	2521	4264	5252	4025	2628	1606	874	421	212	117	59
1996	1	0	0	0	0	0	0	1	4	21	42	54	79	260	516	1268	2763	3858	3178	1627	583	265	109	48	26	4
1997	1	0	0	0	0	0	0	0	0	3	3	10	12	159	559	925	1267	1575	1431	791	317	118	46	16	6	1
1997	2	0	0	0	0	0	0	0	0	0	0	0	0	0	4	19	27	24	28	15	2	0	0	0	0	0
1997	3	0	0	0	0	0	0	0	0	1	0	1	7	34	17	30	41	12	5	5	1	0	0	0	0	0
1998	1	0	0	0	0	0	0	0	0	2	9	18	53	277	748	1015	1458	1548	1197	833	473	243	78	27	2	0
1998	2	0	0	0	0	0	0	0	0	0	0	0	0	7	28	34	80	116	79	48	8	6	3	0	1	0
1998	3	0	0	0	0	0	0	0	0	0	0	1	0	0	6	18	29	35	38	12	7	1	1	0	0	0
1999	1	0	0	0	0	0	0	0	0	3	6	20	60	254	707	1385	1802	1679	1243	881	474	268	132	62	22	15
1999	2	0	0	0	0	0	0	0	0	0	0	0	0	0	21	36	15	8	6	0	0	0	0	0	0	0
1999	3	0	0	0	0	0	0	0	0	0	0	0	1	17	26	58	67	99	53	48	12	9	1	3	2	0

Table 2.8c–Length frequencies of Pacific cod in the post-1999 longline fishery by year, season, and length bin.

		Length Bin																								
Yr.	Sea.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
2000	1	0	0	0	0	0	0	0	1	2	3	2	25	197	797	1697	2548	2714	1747	946	422	179	97	36	10	3
2000	2	0	0	0	0	0	0	0	0	0	0	1	1	1	7	11	13	9	3	1	0	0	0	0	0	0
2000	3	0	0	0	0	0	0	0	0	0	0	0	0	1	0	7	10	2	0	0	0	0	0	0	0	0
2001	1	0	0	0	0	0	0	1	1	3	6	33	82	296	915	1969	2850	3074	1919	906	358	126	60	34	6	3
2001	2	0	0	0	0	0	0	0	0	0	0	1	4	3	9	8	24	43	18	14	12	6	2	1	0	0
2001	3	0	0	0	0	0	0	0	0	0	0	0	0	1	13	13	27	35	28	18	3	1	1	1	0	0
2002	1	0	0	0	0	1	0	0	5	3	13	32	77	246	542	1250	1849	2208	1712	939	447	161	69	21	7	1
2002	2	0	0	0	0	0	0	0	0	0	0	0	2	2	7	18	21	24	23	22	8	3	3	0	1	0
2002	3	0	0	0	0	1	2	9	24	16	16	18	38	103	279	424	618	622	440	263	95	31	8	0	2	0
2003	1	0	0	0	0	0	0	0	0	5	7	30	92	385	800	1337	1415	1523	1097	626	382	149	58	26	9	0
2003	2	0	0	0	0	0	0	0	0	0	1	3	1	5	18	47	47	76	60	45	37	27	7	0	1	0
2003	3	0	0	0	0	0	0	0	0	0	0	3	16	47	224	378	500	468	276	182	102	59	29	12	4	1
2004	1	0	0	0	0	0	0	0	0	0	1	4	16	149	654	1188	1563	1367	803	434	257	129	55	19	7	1
2004	2	0	0	0	0	0	0	0	0	0	1	1	3	12	35	46	74	60	34	40	17	8	2	2	1	1
2004	3	0	0	0	0	0	0	0	0	0	0	4	4	31	203	505	694	633	407	230	96	62	23	10	3	1
2005	1	0	0	0	0	0	0	0	0	0	1	2	7	75	386	917	1466	1428	796	410	235	152	75	26	2	0
2005	2	0	0	0	0	0	0	0	0	0	0	0	0	2	14	57	99	92	54	40	33	17	18	12	7	0
2005	3	0	0	0	0	0	0	0	0	0	2	2	8	39	153	394	719	845	563	236	139	83	65	48	12	4
2006	1	0	0	0	0	0	1	0	0	2	6	17	27	156	569	960	1685	1864	1177	529	248	185	104	69	35	11
2006	2	0	0	0	0	0	0	0	0	0	0	0	0	0	3	8	23	39	31	21	4	2	2	0	0	0
2006	3	0	0	0	0	0	0	0	0	0	0	1	1	9	25	46	94	93	45	17	3	4	0	0	0	0

Table 2.9a—Length frequencies of Pacific cod in the 1987-1999 pot fishery by year, season, and length bin.

		Length Bin																								
Yr.	Sea.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1990	1	0	0	0	0	0	0	0	0	0	0	0	0	30	141	351	679	766	426	208	76	54	33	12	6	1
1990	2	0	0	0	0	0	0	0	0	0	0	1	3	39	144	525	845	748	382	151	62	14	3	2	1	0
1990	3	0	0	0	0	0	0	0	0	0	2	42	167	438	630	1172	1994	2355	1732	1139	579	313	123	23	2	0
1991	1	0	0	0	0	0	0	0	1	2	16	44	87	799	2413	5253	11348	13970	9321	4071	1403	487	180	49	8	1
1991	2	0	0	0	0	0	0	0	0	0	0	0	0	1	8	11	23	31	45	11	6	2	1	0	0	0
1992	1	0	0	0	0	0	0	0	1	10	29	58	148	700	2092	5494	9467	9042	5461	2671	1248	509	190	45	11	1
1992	2	0	0	0	0	0	0	0	0	0	0	0	1	10	45	81	118	164	118	71	34	12	5	4	0	1
1992	3	0	0	0	0	0	0	0	0	0	1	7	24	91	191	489	1073	1337	898	545	222	93	35	7	0	0
1993	1	0	0	0	0	0	0	0	0	0	0	13	51	319	1173	2529	4897	5815	3641	1546	566	201	78	28	7	2
1994	1	0	0	0	0	0	0	0	0	0	0	3	26	196	943	2218	4052	4217	2759	1228	428	160	71	28	13	0
1994	3	0	0	0	0	0	0	0	0	0	0	0	1	16	59	56	32	19	14	6	4	2	4	2	2	0
1995	1	0	0	0	0	0	0	0	0	1	4	12	33	607	2329	4778	9405	12541	8610	4502	2120	1026	403	170	59	25
1995	3	0	0	0	0	0	0	0	0	0	0	0	0	8	51	200	394	274	152	74	40	26	8	5	1	0
1996	1	0	0	0	0	0	0	0	2	4	6	5	23	174	954	3199	6690	9720	8399	3889	1431	489	184	67	15	5
1996	2	0	0	0	0	0	0	0	0	0	0	0	0	7	24	105	130	55	36	31	20	12	8	1	2	1
1997	1	6	0	1	1	4	9	12	18	43	45	43	53	263	969	2843	6289	7541	5200	2299	750	268	151	50	19	3
1997	2	0	0	0	0	0	0	0	0	0	0	0	0	0	5	26	84	82	38	9	5	2	1	0	0	0
1997	3	0	0	0	0	0	0	0	0	0	0	0	4	18	46	90	228	440	390	206	64	29	16	5	1	0
1998	1	0	0	0	0	0	0	0	2	0	1	14	19	281	1081	2513	6362	8088	6459	4003	1699	660	257	97	24	9
1998	2	0	0	0	0	0	0	0	0	0	0	0	0	1	9	31	51	60	64	38	15	11	7	3	0	1
1998	3	0	0	0	0	0	0	0	3	2	7	7	9	62	126	259	477	623	640	362	184	74	33	15	18	1
1999	1	0	0	0	0	0	0	0	0	1	1	15	51	392	1769	4157	7042	8712	6480	2980	1313	586	216	102	42	17
1999	2	0	0	0	0	0	0	0	0	0	0	0	0	7	56	317	653	720	838	626	306	131	48	11	5	1
1999	3	0	0	0	1	0	0	0	1	0	1	0	8	65	188	402	824	858	648	339	166	75	48	24	6	2

Table 2.9b—Length frequencies of Pacific cod in the post-1999 pot fishery by year, season, and length bin.

		Length Bin																								
Yr.	Sea.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
2000	1	0	0	0	0	0	3	2	0	3	1	9	41	464	1839	3998	6894	6987	4694	2237	1055	454	203	73	25	9
2000	2	0	0	0	0	0	0	0	0	0	0	0	0	1	7	76	374	316	104	17	5	0	2	0	0	0
2000	3	0	0	0	0	0	0	0	0	0	0	0	0	3	7	17	73	105	55	13	2	1	1	0	0	0
2001	1	1	0	0	0	0	0	0	1	0	4	13	62	310	1339	3324	6205	6366	3540	1202	525	222	106	49	16	5
2001	3	0	0	0	0	0	0	0	0	0	0	3	10	104	389	730	956	954	553	134	56	26	3	4	1	2
2002	1	0	0	0	0	0	0	0	0	0	0	15	39	323	1192	2507	3864	4315	3048	1245	427	159	68	24	8	1
2002	3	0	0	0	0	0	0	0	1	0	2	2	17	133	312	580	926	982	841	479	217	106	53	16	6	1
2003	1	0	0	0	0	0	1	0	2	3	9	46	82	369	1203	2059	2566	2267	1750	945	442	167	63	28	14	3
2003	2	0	0	0	0	0	0	0	0	0	0	0	9	144	717	1682	2186	2040	1421	689	281	113	39	15	5	2
2003	3	0	0	0	0	0	0	0	0	0	0	2	15	204	744	1232	1416	1093	768	392	181	78	35	7	0	1
2004	1	0	0	0	0	0	0	0	0	0	1	2	26	422	1629	3197	3869	3233	1952	1132	599	344	177	64	29	0
2004	3	0	0	0	0	0	0	0	0	0	0	6	11	130	502	1147	1144	812	485	269	157	85	40	18	9	2
2005	1	0	0	0	0	0	0	0	0	0	1	3	10	249	1298	2984	4337	3695	2123	1010	662	340	253	113	33	13
2005	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	18	27	0	0	0	0	0	0	0
2005	3	0	0	0	0	0	0	0	0	0	0	0	4	67	321	1108	1794	1588	896	479	277	179	94	49	10	1
2006	1	0	0	0	0	0	0	0	0	0	0	5	21	216	1156	2725	4675	4932	3368	1583	767	424	313	180	62	18
2006	3	0	0	0	0	0	0	0	0	0	0	0	3	19	42	86	111	95	49	18	2	2	0	0	0	0

Table 2.10—Length frequencies of Pacific cod in the trawl survey by year (all surveys take place in season 2). Numbers shown are survey estimates of population numbers at length, rescaled so that the sum equals the total size of the actual survey length sample.

		Length Bin																								
Yr.	Sea.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1984	2	718	13	13	39	82	213	417	454	588	549	972	1124	2420	3577	2827	1631	772	329	299	233	96	34	11	1	1
1987	2	123	22	35	127	130	105	130	536	1128	1652	1823	1254	1721	3310	2947	2196	1300	597	273	96	57	14	10	3	2
1990	2	374	1	15	90	195	134	75	114	223	276	414	549	1645	1812	1928	1632	934	559	207	137	70	35	13	7	1
1993	2	46	20	307	372	233	284	191	261	445	513	800	1275	1998	2538	3079	2105	1476	694	294	109	59	22	17	10	1
1996	2	4	36	239	883	1177	891	240	91	193	314	459	458	732	1037	1378	1656	1388	604	225	86	40	30	15	12	2
1999	2	1	16	67	151	164	96	74	140	308	349	398	576	1085	1129	1432	1194	783	411	166	58	27	7	9	4	0
2001	2	6	57	105	192	233	320	229	187	183	310	455	437	749	753	726	764	534	302	133	52	19	15	5	5	0
2003	2	1	5	28	76	137	87	66	64	160	296	495	753	1280	1319	1624	1308	698	372	190	113	36	15	3	0	0
2005	2	10	10	106	182	195	113	69	101	188	242	203	216	422	847	1524	1257	485	214	103	72	45	88	98	45	7

Table 2.11—Age composition estimates from the 2003 and 2005 GOA bottom trawl surveys (expressed as numbers per 10,000).

Age	2003	2005
1	336	731
2	343	779
3	1810	1121
4	2676	1643
5	2735	2799
6	1327	2038
7	487	549
8	226	236
9	33	49
10	9	23
11	9	6
12+	9	27

Table 2.12—Biomass, standard error, 95% confidence interval (CI), and population numbers of Pacific cod estimated by NMFS' bottom trawl survey of the GOA. All figures except population numbers are expressed in metric tons. Population numbers are expressed in terms of individual fish.

Year	Biomass	Std. Error	Lower 95% CI	Upper 95% CI	Numbers
1984	550,971	80,385	393,417	708,525	320,524,532
1987	394,987	51,325	294,390	495,585	247,020,039
1990	416,788	63,706	291,925	541,651	212,131,668
1993	409,848	73,431	265,924	553,772	231,963,103
1996	538,154	107,736	326,991	749,316	319,068,011
1999	306,413	38,699	230,563	382,263	166,583,892
2001	257,614	52,457	154,799	360,429	158,424,464
2003	297,402	44,549	210,086	384,717	159,749,380
2005	308,102	80,862	149,613	466,591	139,860,010

Note: The 2001 survey did not cover the eastern GOA. To account for the missing stations, the 1999 survey estimates of biomass, biomass variance, and numbers for the eastern GOA were added to the respective 2001values to produce the figures shown in the above table.

Table 2.13—Pacific cod commercial fishery length sample sizes used in the multinomial distribution. (These values correspond to the square roots of the true sample sizes shown in Table 2.6.)

	Trawl Fishery			Longline Fishery			Pot Fishery		
Year	Sea. 1	Sea. 2	Sea. 3	Sea. 1	Sea. 2	Sea. 3	Sea. 1	Sea. 2	Sea. 3
1977	0	14	0	0	0	0	0	0	0
1978	0	0	25	0	0	137	0	0	0
1979	0	0	0	0	0	120	0	0	0
1980	0	0	28	0	0	137	0	0	0
1981	0	0	21	0	0	139	0	0	0
1982	0	0	37	0	0	151	0	0	0
1983	0	0	54	0	0	358	0	0	0
1984	0	0	32	0	0	218	0	0	0
1985	0	0	0	0	0	101	0	0	0
1986	0	0	0	0	0	295	0	0	0
1987	0	0	0	0	0	20	0	0	0
1988	0	0	0	0	0	49	0	0	0
1989	26	0	18	0	0	0	0	0	0
1990	159	104	110	100	0	0	53	54	103
1991	196	0	11	112	12	0	222	12	0
1992	199	0	47	170	24	60	193	26	71
1993	164	0	0	108	0	0	144	0	0
1994	112	0	0	72	0	0	128	0	15
1995	161	11	49	157	0	0	216	0	35
1996	134	0	0	121	0	0	188	21	0
1997	151	15	61	85	11	12	164	16	39
1998	229	59	82	89	20	12	178	17	54
1999	107	15	33	95	9	20	184	61	60
2000	83	21	8	107	7	4	170	30	17
2001	78	26	68	112	12	12	153	0	63
2002	79	28	18	98	12	55	131	0	68
2003	64	34	42	89	19	48	110	97	79
2004	51	22	50	82	18	54	129	0	69
2005	42	24	42	77	21	58	131	7	83
2006	47	7	0	87	12	18	143	0	21

Table 2.14—Summary of key parameter estimates, management-related quantities, and objective function values from last year's assessment and this year's assessment (note that the entries labeled "Last Yr." do not correspond to the values given in last year's SAFE report, because the values given in last year's SAFE report corresponded to the authors' preferred model, not the model chosen by the Plan Team and SSC). Results in normal font correspond to outputs from the SS2 assessment model, and results in bold font correspond to outputs from the standard projection model.

Item	Last Yr.	This Yr.
sigmaR	0.47	0.24
ln(post-76 Rmedian)	12.61	12.52
ln(pre-77 Rmedian)-ln(post-76 Rmedian)	-1.22	-1.14
trawl survey catchability	1.00	1.00
trawl survey selectivity at 90 cm	0.61	0.58
total biomass 2005	384,975	416,623
total biomass 2006	n/a	411641
female spawning biomass 2005	148,116	150,503
female spawning biomass 2006	**116,576**	148,963
female spawning biomass 2007	**89,608**	**126,903**
female spawning biomass 2008	**78,831**	**109,893**
proportion of B100% in 2005	0.53	0.55
proportion of B100% in 2006	**0.42**	0.54
proportion of B100% in 2007	**0.34**	**0.49**
proportion of B100% in 2008	**0.30**	**0.42**
ABC 2006 (adopted by Council)	68,859	68,859
maxABC 2007 (from model)	**49,473**	**81,176**
maxABC 2008 (from model)	**36,789**	**68,279**
relative change in ABC (2006 to 2007)	**-0.28**	**0.18**
relative change in ABC (2007 to 2008)	**-0.26**	**-0.16**
OFL 2006 (adopted by Council)	95,500	95,500
OFL 2007 (from model)	**59,145**	**97,624**
OFL 2008 (from model, assuming maxABC)	**44,315**	**82,290**
relative change in OFL (2006 to 2007)	**-0.38**	**0.02**
relative change in OFL (2007 to 2008)	**-0.25**	**-0.16**
trawl survey rel. abund. log like.	6.20	15.76
Jan-May trawl fishery size comp. log like.	78.01	72.67
Jun-Dec trawl fishery size comp. log like.	170.82	173.34
longline fishery size comp. log like.	200.16	205.45
pot fishery size comp. log like.	131.98	124.61
trawl survey size comp. log like.	87.13	116.33
trawl survey age comp. log like.	7.56	8.93
trawl survey size-at-age log like.	27.55	68.56
recruitment log like.	37.31	76.06
log priors	117.62	70.84
log posterior (sum of the above 10 lines)	864.32	932.56

Table 2.15—Summary of average input multinomial sizes and average output “effective” sample sizes.

Gear	Type	Input N	Output N	Ratio
Jan-May trawl fish.	Length	116	350	3.03
Jun-Dec trawl fish.	Length	37	77	2.09
longline fishery	Length	79	397	5.04
pot fishery	Length	92	334	3.64
trawl survey	Length	114	124	1.10
trawl survey	Age	56	51	0.93

Table 2.16—Estimates of Pacific cod fishing mortality rates, expressed on an annual time scale. Empty cells indicate that recorded catch was negligible or that no catch was recorded.

	Trawl			Longline			Pot		
Year	Sea. 1	Sea. 2	Sea. 3	Sea. 1	Sea. 2	Sea. 3	Sea. 1	Sea. 2	Sea. 3
1964	0.000	0.000	0.000	0.001	0.000	0.000	0	0	0
1965	0.000	0.000	0.000	0.002	0.000	0.001	0	0	0
1966	0.001	0.001	0.001	0.004	0.001	0.002	0	0	0
1967	0.001	0.001	0.002	0.006	0.001	0.003	0	0	0
1968	0.001	0.000	0.001	0.003	0.001	0.002	0	0	0
1969	0.001	0.001	0.001	0.004	0.001	0.002	0	0	0
1970	0.001	0.001	0.002	0.005	0.001	0.003	0	0	0
1971	0.000	0.000	0.000	0.002	0.000	0.001	0	0	0
1972	0.002	0.002	0.003	0.011	0.002	0.006	0	0	0
1973	0.004	0.003	0.006	0.020	0.004	0.011	0	0	0
1974	0.003	0.003	0.005	0.018	0.004	0.010	0	0	0
1975	0.005	0.003	0.007	0.025	0.005	0.013	0	0	0
1976	0.005	0.003	0.006	0.024	0.005	0.012	0	0	0
1977	0.002	0.001	0.002	0.008	0.001	0.004	0	0	0
1978	0.007	0.005	0.009	0.034	0.007	0.017	0	0	0
1979	0.008	0.006	0.011	0.038	0.008	0.020	0	0	0
1980	0.020	0.014	0.027	0.100	0.021	0.050	0	0	0
1981	0.003	0.018	0.031	0.069	0.033	0.055	0	0	0
1982	0.008	0.009	0.015	0.054	0.015	0.048	0	0	0
1983	0.016	0.011	0.015	0.052	0.022	0.049	0	0	0
1984	0.018	0.007	0.012	0.051	0.002	0.010	0	0	0
1985	0.011	0.002	0.006	0.035	0.000	0.001	0	0	0
1986	0.012	0.001	0.011	0.057	0.002	0.005	0	0	0
1987	0.021	0.034	0.039	0.022	0.004	0.008	0.001	0.001	0.002
1988	0.061	0.028	0.019	0.012	0.002	0.002	0.006	0.000	0.002
1989	0.090	0.052	0.001	0.009	0.001	0.004	0.001	0.001	0.000
1990	0.152	0.031	0.034	0.021	0.000	0.001	0.013	0.005	0.011
1991	0.206	0.003	0.007	0.029	0.002	0.001	0.049	0	0.005
1992	0.204	0.006	0.007	0.054	0.004	0.010	0.053	0.000	0.003
1993	0.138	0.012	0.007	0.037	0.001	0.001	0.054	0.000	0
1994	0.114	0.006	0.003	0.027	0.000	0.001	0.046	0	0.002
1995	0.139	0.003	0.010	0.040	0.001	0.001	0.073	0.000	0.003
1996	0.151	0.013	0.006	0.038	0.001	0.000	0.058	0.000	0
1997	0.155	0.008	0.027	0.044	0.005	0.002	0.071	0.003	0.010
1998	0.144	0.019	0.015	0.046	0.003	0.001	0.105	0	0.007
1999	0.132	0.008	0.028	0.059	0.003	0.001	0.151	0.024	0.017
2000	0.094	0.013	0.004	0.065	0.003	0.001	0.144	0.001	0.004
2001	0.066	0.010	0.034	0.057	0.004	0.002	0.070	0.000	0.011
2002	0.068	0.014	0.006	0.067	0.001	0.018	0.074	0.000	0.025
2003	0.046	0.012	0.023	0.043	0.002	0.004	0.115	0.000	0.017
2004	0.036	0.009	0.026	0.039	0.001	0.009	0.122	0.000	0.022
2005	0.036	0.008	0.013	0.017	0.001	0.008	0.103	0.000	0.024
2006	0.038	0.008	0.013	0.027	0.001	0.009	0.102	0.000	0.026

Table 2.17—Estimates of Pacific cod regime-specific median recruitments and recruitment deviations. Deviations are expressed as the difference between the logarithm of annual recruitment at age 0 and the logarithm of median recruitment for the respective environmental regime.

Year	ln(Median Recruitment)	Annual Deviation
1964	11.376	-0.078
1965	11.376	-0.106
1966	11.376	-0.142
1967	11.376	-0.180
1968	11.376	-0.211
1969	11.376	-0.214
1970	11.376	-0.166
1971	11.376	-0.030
1972	11.376	0.297
1973	11.376	0.590
1974	11.376	0.134
1975	11.376	-0.043
1976	11.376	0.199
1977	12.516	0.505
1978	12.516	-0.383
1979	12.516	-0.096
1980	12.516	0.164
1981	12.516	-0.312
1982	12.516	-0.306
1983	12.516	-0.188
1984	12.516	0.336
1985	12.516	0.073
1986	12.516	-0.219
1987	12.516	0.319
1988	12.516	-0.024
1989	12.516	0.382
1990	12.516	0.126
1991	12.516	0.055
1992	12.516	-0.057
1993	12.516	-0.033
1994	12.516	0.085
1995	12.516	0.243
1996	12.516	-0.166
1997	12.516	-0.190
1998	12.516	0.004
1999	12.516	0.393
2000	12.516	0.167
2001	12.516	-0.378
2002	12.516	-0.296
2003	12.516	-0.129
2004	12.516	-0.123

Table 2.18—Estimates of Pacific cod selectivity parameters. The first column lists the eight parameters of the selectivity function: the size at which selectivity first reaches a value of 1 ("*peak location*"), selectivity at the minimum length represented in the data ("*S*(*Lmin*)"), the logit transform of the size corresponding to the inflection of the ascending logistic curve ("logit(*infl1*)"), the relative slope of the ascending logistic curve ("*slope1*"), the logit transform of the size corresponding to the inflection of the descending logistic curve ("logit(*infl2*)"), the relative slope of the descending logistic curve ("*slope2*"), the logit transform of selectivity at the maximum length represented in the data ("logit(*S*(*Lmax*))"), and the width of the length range at which selectivity equals 1 ("*peak width*"). The middle portion of the table lists the portion of the time series ("era") to which each parameter value applies (FOR = pre-1987, DOM = 1987-1999, NEW = post-1999), for each of the four fisheries (TWL1 = January-May Trawl, TWL2 = June-December Trawl, LGL = longline, POT = pot). For the January-May trawl fishery, parameters for the pre-1987 selectivity curve were borrowed from the 1987-1999 estimates, because there were very few size composition data from the pre-1988 fishery. For the pot fishery, there were no significant catches prior to 1987, so no selectivity parameters are needed for that fishery during the pre-1987 portion of the time series. The right-most column lists the values of the selectivity parameters for the bottom trawl survey. Because the survey selectivity is assumed to be constant over the entire time series, the value of each survey selectivity parameter is shown in triplicate (once for each portion of the time series).

		Fishery Selectivity				
Parameter	Era	TWL1	TWL2	LGL	POT	Survey
peak location	FOR	67.401	58.180	64.776		55.384
peak location	DOM	67.401	66.940	66.904	66.466	55.384
peak location	NEW	66.523	66.560	65.717	64.558	55.384
S(Lmin)	FOR	0.001	0.001	0.001		0.093
S(Lmin)	DOM	0.001	0.001	0.001	0.001	0.093
S(Lmin)	NEW	0.001	0.001	0.001	0.001	0.093
logit(infl1)	FOR	1.904	1.481	1.214		1.038
logit(infl1)	DOM	1.904	1.540	1.873	2.252	1.038
logit(infl1)	NEW	1.560	1.547	1.987	2.081	1.038
slope1	FOR	0.086	0.244	0.284		0.186
slope1	DOM	0.086	0.115	0.170	0.181	0.186
slope1	NEW	0.139	0.126	0.200	0.228	0.186
logit(S(Lmax))	FOR	2.001	1.934	-0.653		0.148
logit(S(Lmax))	DOM	2.001	-0.600	0.330	-1.431	0.148
logit(S(Lmax))	NEW	1.590	0.047	0.026	-0.485	0.148
logit(infl2)	FOR	0.083	0.046	0.127		-0.490
logit(infl2)	DOM	0.083	-1.164	-0.517	-1.259	-0.490
logit(infl2)	NEW	-0.348	-1.037	-1.002	-1.363	-0.490
slope2	FOR	0.200	0.203	0.229		0.205
slope2	DOM	0.200	0.215	0.203	0.207	0.205
slope2	NEW	0.200	0.208	0.203	0.203	0.205
peak width	FOR	10.336	10.044	10.767		10.110
peak width	DOM	10.336	8.465	9.619	8.162	10.110
peak width	NEW	9.710	8.636	8.775	7.942	10.110

Table 2.19—Selectivities of Pacific cod selectivities at length in the commercial fisheries and bottom trawl survey (“Sur.”) as defined by final parameter estimates. Lengths (cm) correspond to mid-points of size bins. Len. = length, FOR = pre-1987, DOM = 1987-1999, NEW = post-1999.

	Jan-May Trawl		Jul-Dec Trawl Fishery			Longline Fishery			Pot Fishery		
Len.	DOM	NEW	FOR	DOM	NEW	FOR	DOM	NEW	DOM	NEW	Sur.
10.5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09
13.5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09
16.5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10
19.5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10
22.5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10
25.5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.11
28.5	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.13
31.5	0.00	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.16
34.5	0.01	0.01	0.02	0.02	0.02	0.01	0.00	0.00	0.00	0.00	0.22
37.5	0.01	0.03	0.04	0.03	0.03	0.01	0.01	0.00	0.00	0.00	0.30
40.5	0.03	0.05	0.09	0.06	0.05	0.03	0.01	0.01	0.00	0.00	0.42
43.5	0.05	0.08	0.18	0.09	0.09	0.08	0.02	0.01	0.01	0.01	0.56
47.5	0.09	0.15	0.39	0.17	0.16	0.21	0.06	0.04	0.02	0.03	0.75
52.5	0.20	0.31	0.74	0.32	0.32	0.54	0.17	0.15	0.07	0.14	0.93
57.5	0.38	0.55	0.98	0.54	0.55	0.84	0.40	0.40	0.26	0.43	1.00
62.5	0.66	0.81	1.00	0.79	0.81	0.98	0.72	0.78	0.63	0.85	1.00
67.5	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99
72.5	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.95
77.5	1.00	1.00	0.99	0.90	0.93	0.99	0.99	0.92	0.82	0.77	0.86
82.5	0.99	0.97	0.97	0.70	0.79	0.95	0.91	0.78	0.57	0.59	0.74
87.5	0.97	0.93	0.94	0.52	0.66	0.85	0.80	0.65	0.37	0.48	0.64
92.5	0.95	0.89	0.91	0.42	0.57	0.67	0.70	0.57	0.26	0.42	0.58
97.5	0.91	0.85	0.89	0.38	0.53	0.49	0.63	0.53	0.22	0.39	0.55
102.5	0.89	0.84	0.88	0.36	0.52	0.39	0.60	0.51	0.20	0.38	0.54
107.5	0.88	0.83	0.87	0.35	0.51	0.34	0.58	0.51	0.19	0.38	0.54

Table 2.20—Schedules of Pacific cod length (cm), proportion mature, and weight (kg) by season and age as defined by final parameter estimates. Pop. = population, Sea. 1 = Jan-Jun, Sea. 2 = Jul-Aug, Sea. 3 = Sep-Dec, Beg. = beginning of season, Mid. = middle of season, SDev. = standard deviation, Mat. = proportion mature, Twl. = trawl fishery, Lgl. = longline fishery, pot = pot fishery, survey = trawl survey.

		Length				Pop. Weight		Fishery/Survey Weight			
Sea.	Age	Beg.	Mid.	S.Dev.	Mat.	Beg.	Mid.	Twl.	Lgl.	Pot	Survey
1	1	13.80	16.33	3.405	0.000	0.026	0.043	0.046	0.043	0.043	0.044
1	2	25.46	27.73	4.502	0.006	0.171	0.223	0.289	0.247	0.236	0.246
1	3	35.93	37.97	5.277	0.069	0.498	0.594	0.805	0.905	0.933	0.701
1	4	45.33	47.16	5.804	0.328	1.031	1.165	1.477	1.675	1.727	1.275
1	5	53.76	55.41	6.141	0.653	1.739	1.910	2.232	2.397	2.409	1.964
1	6	61.33	62.81	6.334	0.841	2.612	2.815	3.039	3.116	3.087	2.811
1	7	68.13	69.46	6.419	0.915	3.616	3.842	3.934	3.920	3.847	3.775
1	8	74.23	75.42	6.425	0.944	4.716	4.957	4.959	4.848	4.720	4.807
1	9	79.71	80.77	6.372	0.957	5.878	6.128	6.082	5.890	5.747	5.906
1	10	84.62	85.58	6.279	0.964	7.073	7.328	7.253	7.034	6.931	7.082
1	11	89.03	89.90	6.157	0.970	8.278	8.531	8.445	8.254	8.209	8.315
1	12	93.00	93.77	6.019	0.975	9.469	9.715	9.633	9.497	9.492	9.555
1	13	96.55	97.24	6.219	0.979	10.62	10.85	10.77	10.68	10.69	10.73
1	14	99.74	100.3	6.399	0.983	11.66	11.86	11.80	11.74	11.75	11.77
2	1	18.81	20.27	3.405	n/a	0.085	0.085	0.100	0.085	0.085	0.087
2	2	29.96	31.27	4.502	n/a	0.325	0.325	0.434	0.413	0.392	0.377
2	3	39.97	41.14	5.277	n/a	0.766	0.766	1.016	1.189	1.240	0.892
2	4	48.95	50.01	5.804	n/a	1.397	1.397	1.722	1.944	1.986	1.495
2	5	57.02	57.96	6.141	n/a	2.200	2.200	2.502	2.651	2.647	2.236
2	6	64.25	65.11	6.334	n/a	3.150	3.150	3.324	3.385	3.340	3.126
2	7	70.75	71.52	6.419	n/a	4.210	4.210	4.210	4.223	4.127	4.113
2	8	76.58	77.27	6.425	n/a	5.348	5.348	5.187	5.184	5.041	5.164
2	9	81.82	82.44	6.372	n/a	6.531	6.531	6.260	6.258	6.119	6.287
2	10	86.52	87.07	6.279	n/a	7.735	7.735	7.428	7.430	7.342	7.485
2	11	90.74	91.23	6.157	n/a	8.934	8.934	8.661	8.664	8.632	8.727
2	12	94.52	94.97	6.019	n/a	10.10	10.10	9.898	9.901	9.902	9.957
2	13	97.92	98.32	6.219	n/a	11.20	11.20	11.05	11.05	11.06	11.09
2	14	100.9	101.3	6.399	n/a	12.16	12.16	12.05	12.05	12.06	12.08
3	1	21.71	23.60	3.405	n/a	0.136	0.136	0.173	0.141	0.138	0.144
3	2	32.56	34.26	4.502	n/a	0.432	0.432	0.592	0.635	0.629	0.517
3	3	42.30	43.83	5.277	n/a	0.934	0.934	1.225	1.437	1.495	1.065
3	4	51.05	52.42	5.804	n/a	1.617	1.617	1.960	2.173	2.201	1.701
3	5	58.90	60.13	6.141	n/a	2.467	2.467	2.750	2.873	2.856	2.487
3	6	65.94	67.05	6.334	n/a	3.453	3.453	3.583	3.627	3.567	3.409
3	7	72.27	73.26	6.419	n/a	4.540	4.540	4.489	4.496	4.381	4.413
3	8	77.95	78.83	6.425	n/a	5.694	5.694	5.489	5.486	5.334	5.482
3	9	83.04	83.84	6.372	n/a	6.887	6.887	6.589	6.588	6.456	6.627
3	10	87.62	88.33	6.279	n/a	8.091	8.091	7.779	7.781	7.708	7.843
3	11	91.72	92.36	6.157	n/a	9.284	9.284	9.020	9.023	9.002	9.087
3	12	95.41	95.98	6.019	n/a	10.43	10.43	10.24	10.24	10.25	10.30
3	13	98.72	99.23	6.219	n/a	11.50	11.50	11.36	11.36	11.37	11.40
3	14	101.6	102.1	6.399	n/a	12.40	12.40	12.30	12.30	12.32	12.34

Table 2.21—Time series of GOA Pacific cod female spawning biomass for the years 1977-2006 as estimated last year under the Plan Team's and SSC's preferred model and in this year's assessment, 1977-2006 (note that the entries labeled "Last Year's Values" do not correspond to the values given in last year's SAFE report, because the values given in last year's SAFE report corresponded to the authors' preferred model, not the model chosen by the Plan Team and SSC). The columns labeled "L95%CI" and "U95%CI" represent the lower and upper bounds of the 95% confidence interval.

	Last Year's Values			This Year's Values		
Year	Sp. Bio.	L95%CI	U95%CI	Sp. Bio.	L95%CI	U95%CI
1977	70,485	50,797	90,173	73,085	59,747	86,423
1978	84,115	62,221	106,009	79,925	66,025	93,825
1979	88,060	65,225	110,895	80,850	66,758	94,942
1980	90,390	67,447	113,333	81,330	67,289	95,371
1981	102,270	77,033	127,507	84,160	69,426	98,894
1982	124,875	95,520	154,230	96,945	80,294	113,596
1983	144,380	111,759	177,001	110,700	92,048	129,352
1984	161,225	125,632	196,818	121,050	100,613	141,487
1985	179,875	141,412	218,338	135,030	113,033	157,027
1986	191,700	151,769	231,631	147,765	124,908	170,622
1987	193,640	153,710	233,570	152,995	129,983	176,007
1988	202,360	162,268	242,452	158,965	136,059	181,871
1989	216,790	175,945	257,635	169,150	146,300	192,000
1990	221,100	180,507	261,693	173,780	151,166	196,394
1991	212,975	173,115	252,835	165,530	143,151	187,909
1992	205,565	166,317	244,813	158,055	135,590	180,520
1993	203,475	164,347	242,603	153,010	130,177	175,843
1994	214,960	175,177	254,743	161,185	137,652	184,718
1995	222,655	182,897	262,413	170,535	146,366	194,704
1996	213,540	174,980	252,100	165,845	141,312	190,378
1997	200,725	163,683	237,767	158,500	133,551	183,449
1998	183,835	148,216	219,454	148,105	122,296	173,914
1999	175,595	140,373	210,817	143,420	116,123	170,717
2000	165,085	130,188	199,982	135,655	107,031	164,279
2001	155,550	121,796	189,304	131,060	101,906	160,214
2002	150,675	118,055	183,295	131,925	102,588	161,262
2003	149,725	117,095	182,355	136,720	106,550	166,890
2004	153,105	118,864	187,346	147,005	115,043	178,967
2005	148,115	112,175	184,055	150,505	116,755	184,255
2006	n/a	n/a	n/a	148,965	114,086	183,844

Table 2.22—Time series of GOA Pacific cod age 0 recruitment (1000s of fish) as estimated last year under the Plan Team's and SSC's preferred model and this year's assessment, 1977-2004 (note that the entries labeled "Last Year's Values" do not correspond to the values given in last year's SAFE report, because the values given in last year's SAFE report corresponded to the authors' preferred model, not the model chosen by the Plan Team and SSC). The columns labeled "L95%CI" and "U95%CI" represent the lower and upper bounds of the 95% confidence interval for each cohort.

	Last Year's Values			This Year's Values		
Year	Recruits	L95%CI	U95%CI	Recruits	L95%CI	U95%CI
1977	689,650	521,782	911,538	438,779	354,819	542,579
1978	210,242	111,729	395,659	180,488	129,598	251,368
1979	224,094	126,326	397,537	240,515	180,205	321,005
1980	498,708	351,642	707,284	311,980	241,960	402,270
1981	215,126	125,028	370,177	193,887	143,107	262,687
1982	185,922	112,439	307,455	194,945	144,865	262,345
1983	193,160	111,355	335,011	219,354	162,574	295,964
1984	636,641	458,690	883,648	370,485	288,495	475,785
1985	297,876	181,432	489,016	284,807	216,907	373,957
1986	188,066	107,211	329,877	212,845	158,825	285,235
1987	503,886	372,793	681,100	364,291	293,401	452,311
1988	230,582	135,484	392,387	258,515	196,125	340,745
1989	572,240	419,552	780,463	388,069	309,589	486,439
1990	367,933	245,143	552,220	300,507	230,967	390,987
1991	237,916	143,303	394,987	279,940	214,710	364,990
1992	302,566	201,631	454,052	250,117	191,497	326,687
1993	272,435	176,212	421,195	256,261	196,421	334,331
1994	233,518	148,280	367,776	288,372	224,612	370,232
1995	494,330	375,922	650,045	337,740	271,240	420,550
1996	174,934	108,826	281,227	224,313	173,033	290,793
1997	205,647	140,860	300,238	219,034	169,864	282,434
1998	269,408	195,469	371,313	265,825	210,765	335,275
1999	369,701	273,455	499,808	392,405	316,715	486,175
2000	319,361	226,431	450,449	313,025	243,775	401,945
2001	115,873	71,236	188,457	181,555	132,545	248,685
2002	116,611	68,919	197,297	197,009	141,079	275,109
2003	106,709	60,846	187,148	232,720	156,600	345,820
2004	225,817	123,440	413,062	234,076	152,396	359,576

Table 2.23—Time series of GOA Pacific cod catch divided by age 3+ biomass as estimated last year under the Plan Team's and SSC's preferred model and this year's assessment, 1977-2006 (note that the entries labeled "Last Year's Values" do not correspond to the values given in last year's SAFE report, because the values given in last year's SAFE report corresponded to the authors' preferred model, not the model chosen by the Plan Team and SSC). The last entry in each column is based on partial catches for the respective year, because the year was/is still in progress at the time of the assessment.

Year	Last Year's Values	This Year's Values
1977	0.01	0.01
1978	0.06	0.06
1979	0.07	0.07
1980	0.12	0.14
1981	0.11	0.13
1982	0.08	0.10
1983	0.08	0.11
1984	0.05	0.07
1985	0.03	0.04
1986	0.05	0.07
1987	0.06	0.08
1988	0.06	0.08
1989	0.08	0.10
1990	0.12	0.16
1991	0.14	0.17
1992	0.14	0.18
1993	0.10	0.13
1994	0.08	0.11
1995	0.12	0.15
1996	0.12	0.16
1997	0.15	0.18
1998	0.14	0.17
1999	0.17	0.21
2000	0.15	0.18
2001	0.13	0.14
2002	0.13	0.14
2003	0.12	0.13
2004	0.13	0.14
2005	0.13	0.12
2006	n/a	0.11

Table 2.24—Projections for GOA Pacific cod catch (t), spawning biomass (t), and fishing mortality under the assumption that $F = max\ F_{ABC}$ in 2007-2019 (Scenario 1), with random variability in future recruitment.

Catch Projections					
Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2007	81175	81176	81176	81176	0
2008	68277	68279	68279	68282	1
2009	62574	62603	62605	62644	22
2010	61055	61531	61575	62245	370
2011	60167	63582	63543	66587	2023
2012	56096	65233	64645	72732	5134
2013	53114	66067	65336	77468	7624
2014	52144	66605	65898	78993	8368
2015	52143	66853	66173	79228	8363
2016	52778	66629	66235	79311	8253
2017	52474	67023	66160	78959	8088
2018	52607	66425	66068	78748	7961
2019	52848	66641	66062	78722	8007
Spawning Biomass Projections					
Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2007	126903	126903	126903	126903	0
2008	109893	109893	109893	109893	0
2009	102398	102424	102426	102463	20
2010	100502	101054	101104	101879	428
2011	98353	101927	102235	107226	2758
2012	94581	102806	103433	114937	6341
2013	92690	103395	104381	118807	8674
2014	91842	103864	105019	121244	9318
2015	91689	104137	105327	121535	9319
2016	92280	104223	105367	121395	9180
2017	92278	104345	105269	121528	9046
2018	92322	103608	105199	120738	8992
2019	92545	103903	105277	122004	9158
Fishing Mortality Projections					
Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2007	0.460	0.460	0.460	0.460	0.000
2008	0.460	0.460	0.460	0.460	0.000
2009	0.455	0.455	0.455	0.456	0.000
2010	0.446	0.449	0.449	0.453	0.002
2011	0.436	0.453	0.452	0.460	0.008
2012	0.419	0.457	0.449	0.460	0.015
2013	0.410	0.460	0.447	0.460	0.018
2014	0.406	0.460	0.447	0.460	0.019
2015	0.405	0.460	0.447	0.460	0.019
2016	0.408	0.460	0.448	0.460	0.019
2017	0.408	0.460	0.448	0.460	0.019
2018	0.408	0.460	0.448	0.460	0.018
2019	0.409	0.460	0.448	0.460	0.018

Table 2.25— Projections for GOA Pacific cod catch (t), spawning biomass (t), and fishing mortality under the assumption that 2007 ABC = 2006 ABC and $F = max\ F_{ABC}$ in 2008-2019 (Scenario 2), with random variability in future recruitment.

Catch Projections					
Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2007	68859	68859	68859	68859	0
2008	71359	71361	71361	71364	1
2009	64990	65004	65005	65024	10
2010	62741	63229	63267	63961	360
2011	60735	64165	64020	66839	1917
2012	56243	65388	64770	72852	5121
2013	53139	66056	65373	77534	7637
2014	52148	66593	65910	79032	8378
2015	52133	66876	66178	79251	8368
2016	52775	66631	66236	79325	8256
2017	52474	67020	66160	78961	8089
2018	52604	66435	66067	78746	7962
2019	52850	66640	66062	78724	8008
Spawning Biomass Projections					
Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2007	128062	128062	128062	128062	0
2008	114653	114653	114653	114653	0
2009	105327	105354	105357	105395	21
2010	102003	102559	102611	103392	434
2011	98937	102511	102830	107840	2777
2012	94789	103012	103684	115276	6392
2013	92762	103548	104495	119025	8715
2014	91864	103926	105074	121310	9341
2015	91692	104173	105352	121555	9330
2016	92278	104240	105378	121397	9186
2017	92276	104362	105273	121549	9049
2018	92320	103607	105200	120748	8993
2019	92543	103906	105277	122010	9158
Fishing Mortality Projections					
Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2007	0.381	0.381	0.381	0.381	0.000
2008	0.460	0.460	0.460	0.460	0.000
2009	0.460	0.460	0.460	0.460	0.000
2010	0.454	0.456	0.456	0.460	0.002
2011	0.439	0.456	0.454	0.460	0.007
2012	0.420	0.458	0.449	0.460	0.014
2013	0.410	0.460	0.447	0.460	0.018
2014	0.406	0.460	0.447	0.460	0.019
2015	0.405	0.460	0.447	0.460	0.019
2016	0.408	0.460	0.448	0.460	0.019
2017	0.408	0.460	0.448	0.460	0.019
2018	0.408	0.460	0.448	0.460	0.018
2019	0.409	0.460	0.448	0.460	0.018

Table 2.26—Projections for GOA Pacific cod catch (t), spawning biomass (t), and fishing mortality under the assumption that F = ½ *max* F_{ABC} in 2007-2019 (Scenario 3), with random variability in future recruitment.

Catch Projections					
Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2007	43727	43727	43727	43727	0
2008	41724	41725	41725	41727	1
2009	41604	41610	41611	41620	5
2010	42806	42895	42903	43027	69
2011	43930	44691	44761	45833	590
2012	43334	46192	46370	50107	2104
2013	42133	47175	47486	53925	3706
2014	41605	47981	48190	55747	4527
2015	41317	48285	48615	56654	4740
2016	41577	48559	48835	56627	4752
2017	41803	48630	48918	56921	4695
2018	41762	48709	48943	56772	4633
2019	41857	48643	48986	56893	4617
Spawning Biomass Projections					
Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2007	130284	130284	130284	130284	0
2008	127620	127620	127620	127620	0
2009	128420	128447	128450	128488	21
2010	131319	131903	131956	132777	453
2011	132080	135967	136283	141583	2949
2012	129920	139614	140108	152692	7090
2013	127876	142267	143042	160248	10450
2014	127201	144779	145151	165282	12147
2015	126790	146070	146570	167775	12790
2016	127128	146623	147426	169812	12949
2017	128084	147252	147899	170660	12906
2018	128004	147184	148199	170009	12796
2019	129042	147360	148500	170788	12859
Fishing Mortality Projections					
Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2007	0.230	0.230	0.230	0.230	0.000
2008	0.230	0.230	0.230	0.230	0.000
2009	0.230	0.230	0.230	0.230	0.000
2010	0.230	0.230	0.230	0.230	0.000
2011	0.230	0.230	0.230	0.230	0.000
2012	0.230	0.230	0.230	0.230	0.000
2013	0.230	0.230	0.230	0.230	0.000
2014	0.230	0.230	0.230	0.230	0.000
2015	0.230	0.230	0.230	0.230	0.000
2016	0.230	0.230	0.230	0.230	0.000
2017	0.230	0.230	0.230	0.230	0.000
2018	0.230	0.230	0.230	0.230	0.000
2019	0.230	0.230	0.230	0.230	0.000

Table 2.27—Projections for GOA Pacific cod catch (t), spawning biomass (t), and fishing mortality under the assumption that *F* = the 2002-2006 average in 2007-2019 (Scenario 4), with random variability in future recruitment.

Catch Projections					
Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2007	47177	47178	47178	47178	0
2008	44518	44519	44519	44520	1
2009	44075	44082	44083	44093	6
2010	45162	45259	45267	45402	74
2011	46212	47037	47113	48275	639
2012	45443	48526	48717	52751	2272
2013	44066	49502	49817	56716	3972
2014	43443	50243	50499	58511	4817
2015	43183	50579	50903	59400	5021
2016	43476	50817	51102	59377	5023
2017	43610	50864	51165	59678	4959
2018	43527	50922	51176	59441	4891
2019	43711	50854	51214	59619	4877
Spawning Biomass Projections					
Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2007	129990	129990	129990	129990	0
2008	125956	125956	125956	125956	0
2009	125815	125843	125845	125883	21
2010	128051	128635	128688	129509	453
2011	128309	132193	132508	137805	2946
2012	125768	135422	135921	148472	7067
2013	123513	137782	138521	155549	10363
2014	122735	139933	140368	160154	11974
2015	122180	141220	141588	162709	12549
2016	122367	141447	142298	163904	12668
2017	123338	142126	142666	164588	12604
2018	123266	141663	142894	164098	12488
2019	124242	142137	143150	165063	12554
Fishing Mortality Projections					
Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2007	0.250	0.250	0.250	0.250	0.000
2008	0.250	0.250	0.250	0.250	0.000
2009	0.250	0.250	0.250	0.250	0.000
2010	0.250	0.250	0.250	0.250	0.000
2011	0.250	0.250	0.250	0.250	0.000
2012	0.250	0.250	0.250	0.250	0.000
2013	0.250	0.250	0.250	0.250	0.000
2014	0.250	0.250	0.250	0.250	0.000
2015	0.250	0.250	0.250	0.250	0.000
2016	0.250	0.250	0.250	0.250	0.000
2017	0.250	0.250	0.250	0.250	0.000
2018	0.250	0.250	0.250	0.250	0.000
2019	0.250	0.250	0.250	0.250	0.000

Table 2.28—Projections for GOA Pacific cod catch (t), spawning biomass (t), and fishing mortality under the assumption that F = 0 in 2007-2019 (Scenario 5), with random variability in future recruitment.

Catch Projections					
Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2007	0	0	0	0	0
2008	0	0	0	0	0
2009	0	0	0	0	0
2010	0	0	0	0	0
2011	0	0	0	0	0
2012	0	0	0	0	0
2013	0	0	0	0	0
2014	0	0	0	0	0
2015	0	0	0	0	0
2016	0	0	0	0	0
2017	0	0	0	0	0
2018	0	0	0	0	0
2019	0	0	0	0	0
Spawning Biomass Projections					
Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2007	133768	133768	133768	133768	0
2008	149221	149221	149221	149221	0
2009	165160	165187	165190	165228	21
2010	180804	181389	181442	182265	454
2011	192606	196527	196843	202192	2975
2012	199877	209998	210477	223457	7367
2013	205150	221080	221978	241438	11557
2014	209731	230610	231339	255502	14550
2015	213355	238065	238705	266325	16471
2016	216785	243218	244306	274788	17616
2017	221079	247287	248460	279884	18239
2018	222920	250450	251532	283589	18505
2019	224345	252793	253868	285545	18701
Fishing Mortality Projections					
Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2007	0.000	0.000	0.000	0.000	0.000
2008	0.000	0.000	0.000	0.000	0.000
2009	0.000	0.000	0.000	0.000	0.000
2010	0.000	0.000	0.000	0.000	0.000
2011	0.000	0.000	0.000	0.000	0.000
2012	0.000	0.000	0.000	0.000	0.000
2013	0.000	0.000	0.000	0.000	0.000
2014	0.000	0.000	0.000	0.000	0.000
2015	0.000	0.000	0.000	0.000	0.000
2016	0.000	0.000	0.000	0.000	0.000
2017	0.000	0.000	0.000	0.000	0.000
2018	0.000	0.000	0.000	0.000	0.000
2019	0.000	0.000	0.000	0.000	0.000

Table 2.29—Projections for GOA Pacific cod catch (t), spawning biomass (t), and fishing mortality under the assumption that $F = F_{OFL}$ in 2007-2019 (Scenario 6), with random variability in future recruitment.

Catch Projections					
Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2007	97624	97624	97624	97625	0
2008	76697	76699	76699	76702	2
2009	63417	63448	63451	63494	24
2010	63024	63556	63605	64353	414
2011	62606	66420	66756	72127	2936
2012	58248	68348	68804	81601	7100
2013	55278	69074	69616	85389	9659
2014	54244	69288	69896	86891	10123
2015	54344	69443	69979	86341	10060
2016	54653	69178	69814	86304	9858
2017	54552	69085	69594	85782	9663
2018	54831	68286	69454	85997	9561
2019	55008	68797	69519	85938	9672
Spawning Biomass Projections					
Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2007	125274	125274	125274	125274	0
2008	102421	102421	102421	102421	0
2009	93173	93199	93202	93238	20
2010	92154	92702	92752	93522	425
2011	90446	93979	94258	99046	2674
2012	86851	94912	95310	105439	5839
2013	85066	95230	95775	108252	7541
2014	84475	95420	95946	109548	7762
2015	84551	95213	95946	108887	7613
2016	84566	95395	95808	109401	7430
2017	84554	95196	95650	108102	7304
2018	84920	94799	95590	108530	7262
2019	84971	94910	95696	108967	7424
Fishing Mortality Projections					
Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2007	0.574	0.574	0.574	0.574	0.000
2008	0.568	0.568	0.568	0.568	0.000
2009	0.514	0.514	0.514	0.514	0.000
2010	0.508	0.511	0.511	0.516	0.002
2011	0.498	0.518	0.520	0.548	0.015
2012	0.477	0.524	0.524	0.574	0.029
2013	0.466	0.526	0.525	0.574	0.035
2014	0.463	0.527	0.525	0.574	0.036
2015	0.463	0.526	0.525	0.574	0.037
2016	0.463	0.527	0.525	0.574	0.036
2017	0.463	0.525	0.524	0.574	0.035
2018	0.465	0.523	0.524	0.574	0.035
2019	0.466	0.524	0.524	0.574	0.035

Table 2.30—Projections for GOA Pacific cod catch (t), spawning biomass (t), and fishing mortality under the assumption that $F = max\ F_{ABC}$ in each year 2007-2008 and $F = F_{OFL}$ thereafter (Scenario 7), with random variability in future recruitment.

Catch Projections					
Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2007	81175	81176	81176	81176	0
2008	68277	68279	68279	68282	1
2009	74817	74850	74853	74899	26
2010	66893	67437	67487	68252	423
2011	63660	67495	67828	73231	2936
2012	58421	68527	68967	81592	7076
2013	55267	69058	69594	85369	9655
2014	54213	69254	69864	86858	10127
2015	54320	69420	69958	86342	10063
2016	54638	69163	69802	86292	9860
2017	54544	69077	69587	85776	9664
2018	54828	68281	69450	85993	9561
2019	55006	68795	69517	85936	9672
Spawning Biomass Projections					
Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2007	126903	126903	126903	126903	0
2008	109893	109893	109893	109893	0
2009	101304	101330	101332	101368	20
2010	95176	95723	95773	96541	424
2011	91445	94972	95252	100032	2671
2012	87142	95196	95597	105724	5841
2013	85151	95306	95856	108328	7551
2014	84493	95433	95968	109590	7770
2015	84552	95214	95950	108894	7617
2016	84562	95397	95806	109399	7431
2017	84550	95193	95647	108101	7304
2018	84918	94796	95588	108528	7262
2019	84969	94909	95694	108965	7424
Fishing Mortality Projections					
Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2007	0.460	0.460	0.460	0.460	0.000
2008	0.460	0.460	0.460	0.460	0.000
2009	0.561	0.561	0.561	0.561	0.000
2010	0.525	0.529	0.529	0.533	0.002
2011	0.504	0.524	0.526	0.554	0.015
2012	0.478	0.525	0.526	0.574	0.029
2013	0.467	0.526	0.525	0.574	0.035
2014	0.463	0.527	0.525	0.574	0.036
2015	0.463	0.526	0.525	0.574	0.037
2016	0.463	0.527	0.525	0.574	0.036
2017	0.463	0.525	0.524	0.574	0.035
2018	0.465	0.523	0.524	0.574	0.035
2019	0.466	0.524	0.524	0.574	0.035

Table 2.31a—Bycatch of nontarget and "other" species taken in the GOA Pacific cod trawl fishery, 1997-2002. The first part of the table ("Bycatch in...") shows the amount (t) of each species group taken as bycatch in the GOA Pacific cod trawl fishery, broken down by year. The second part of the table ("Proportion of...") shows the same quantity expressed relative to the total GOA catch (taken in all target categories with all gears) of that species group in that year. An empty cell in the second part of the table indicates that no catch of that group was observed in the GOA during that year.

	Bycatch in GOA Pacific cod trawl fishery						Proportion of total GOA catch					
Species group	1997	1998	1999	2000	2001	2002	1997	1998	1999	2000	2001	2002
Sculpin	201	109	127	124	69	75	0.22	0.20	0.23	0.13	0.12	0.08
Skates	476	411	385	219	272	120	0.15	0.09	0.19	0.07	0.15	0.02
Shark	11	7	4	1	1	0	0.09	0.00	0.12	0.02	0.01	0.00
Salmonshk	0	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
Dogfish	30	624	14	21	61	3	0.05	0.72	0.04	0.05	0.12	0.02
Sleepershk	17	6	5	11	0	26	0.12	0.07	0.01	0.02	0.00	0.12
Octopus	25	1	4	0	3	7	0.11	0.01	0.03	0.00	0.03	0.02
Squid	1	1	1	0	1	0	0.01	0.01	0.03	0.01	0.01	0.00
Smelts	0	1	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
Gunnel	0	0	0		0		0.00	0.00	0.00		1.00	
Sticheidae	0	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.56
Sandfish	0	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
Lanternfish	0	0	0		0	0	0.00		0.00		0.00	0.00
Sandlance	0	0	0	0	0	0	0.00	1.00	1.00	0.97	0.12	1.00
Grenadier	0	1	17	114	376	0	0.00	0.00	0.00	0.01	0.04	0.00
Otherfish	58	211	110	43	68	42	0.10	0.03	0.13	0.04	0.10	0.02
Crabs	1	12	1	0	0	0	0.08	0.47	0.06	0.03	0.06	0.04
Starfish	63	59	62	22	27	22	0.06	0.05	0.04	0.02	0.06	0.04
Jellyfish	7	5	1	1	13	1	0.18	0.03	0.01	0.02	0.05	0.00
Invertunid	2	28	0	5	1	0	0.22	0.65	0.10	0.31	0.13	0.00
seapen/whip	0	0	3	0	0	0	0.00	0.01	0.99	0.00	0.00	0.00
Sponge	0	1	1	1	1	0	0.04	0.24	0.10	0.12	0.26	0.09
Anemone	3	3	11	1	3	6	0.17	0.20	0.65	0.07	0.21	0.27
Tunicate	1	0	0	0	0	0	0.43	0.13	0.38	0.05	0.04	0.03
Benthinv	3	22	11	1	1	0	0.11	0.72	0.42	0.07	0.06	0.09
Snails	0	0	0	0	0	0						
echinoderm	3	23	2	2	1	2	0.13	0.72	0.24	0.31	0.12	0.26
Coral	0	0	0	0	0	0	0.00	0.01	0.01	0.01	0.00	0.01
Shrimp	0	0	0	0	0	0	0.00	0.08	0.02	0.01	0.03	0.01
Birds	0	0	0	0	0	0	0.00	0.07	0.00	0.00	0.00	0.00

Table 2.31b—Bycatch of nontarget and "other" species taken in the GOA Pacific cod trawl fishery, 2003-2005. The first part of the table ("Bycatch") shows the amount (t) of each species group taken as bycatch in the GOA Pacific cod trawl fishery, broken down by year. The second part of the table ("Proportion of total") shows the same quantity expressed relative to the total GOA catch (taken in all target categories with all gears) of that species group in that year. An empty cell in the second part of the table indicates that no catch of that group was observed in the GOA during that year. Note that the list of nontarget species groups used for 2003-2005 differs from that used for 1997-2002.

	Catch (t)			Proportion of total		
Species group	2003	2004	2005	2003	2004	2005
Benthic urochordata		0			0.02	
Birds						
Bivalves	1	0	1	0.33	0.18	0.22
Brittle star unidentified						
Capelin						
Corals Bryozoans		0			0.29	
Deep sea smelts (bathylagidae)						
Eelpouts			0			0.00
Eulachon	0		0	0.00		0.00
Giant Grenadier			0			0.00
Greenlings	1	5	0	0.11	0.36	0.03
Grenadier	5	0		0.00	0.00	
Gunnels						
Hermit crab unidentified	1	0	0	0.54	0.16	0.00
Invertebrate unidentified	0	2	0	0.01	0.20	0.25
Lanternfishes (myctophidae)						
Large Sculpins	11	20	88	0.09	0.03	0.16
Misc crabs	0	0	0	0.01	0.01	0.00
Misc crustaceans		0			0.06	
Misc deep fish						
Misc fish	32	108	35	0.07	0.36	0.11
Misc inverts (worms etc)						
Octopus	0	3	0	0.01	0.02	0.00
Other osmerids		0			0.00	
Other Sculpins	33	5	0	0.06	0.09	0.00
Pacific Sand lance		0			1.00	
Pandalid shrimp			0			0.00
Polychaete unidentified						
Scypho jellies	9	1	1	0.12	0.05	0.00
Sea anemone unidentified	0	1	0	0.02	0.06	0.00
Sea pens whips		0			0.05	
Sea star	19	9	3	0.03	0.01	0.00
Shark	6	5	7	0.02	0.04	0.03
Skate	151	49	26	0.04	0.02	0.01
Snails	0	0	0	0.01	0.17	0.00
Sponge unidentified	0	0		0.02	0.05	
Squid	1	0	0	0.01	0.00	0.00
Stichaeidae	0		0	0.00		0.00
Surf smelt			0			1.00
Urchins dollars cucumbers	1	0	1	0.11	0.18	0.26

Table 2.32a—Bycatch of nontarget and “other” species taken in the GOA Pacific cod longline fishery, 1997-2002. The first part of the table (“Bycatch in...”) shows the amount (t) of each species group taken as bycatch in the GOA Pacific cod longline fishery, broken down by year. The second part of the table (“Proportion of...”) shows the same quantity expressed relative to the total GOA catch (taken in all target categories with all gears) of that group in that year. An empty cell in the second part of the table indicates that no catch of that group was observed in the GOA during that year.

	Bycatch in GOA Pacific cod longline fishery						Proportion of total GOA catch					
Species group	1997	1998	1999	2000	2001	2002	1997	1998	1999	2000	2001	2002
Sculpin	63	181	207	203	197	291	0.07	0.33	0.38	0.22	0.33	0.31
Skates	478	461	789	1823	617	5005	0.15	0.10	0.39	0.56	0.34	0.77
Shark	2	4	8	2	1	5	0.02	0.00	0.25	0.03	0.01	0.19
Salmonshk	0	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
Dogfish	28	104	146	8	111	7	0.04	0.12	0.47	0.02	0.23	0.06
Sleepershk	42	14	501	366	66	40	0.31	0.19	0.90	0.60	0.26	0.18
Octopus	1	25	17	16	6	7	0.00	0.22	0.10	0.09	0.07	0.02
Squid	0	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
Smelts	0	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
Gunnel	0	0	0		0		0.00	0.00	0.00		0.00	
Sticheidae	0	0	4	0	0	0	0.00	0.00	1.00	0.00	0.01	0.00
Sandfish	0	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
Lanternfish	0	0	0		0	0	0.00		0.00		0.00	0.00
Sandlance	0	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
Grenadier	191	0	423	0	0	92	0.02	0.00	0.04	0.00	0.00	0.01
Otherfish	15	50	36	39	2	128	0.03	0.01	0.04	0.04	0.00	0.06
Crabs	0	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
Starfish	304	162	765	199	347	207	0.31	0.13	0.51	0.22	0.74	0.40
Jellyfish	0	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
Invertunid	0	0	0	5	0	4	0.05	0.00	0.17	0.34	0.05	0.32
seapen/whip	0	3	0	1	0	0	0.00	0.99	0.00	0.87	0.00	0.07
Sponge	0	0	0	0	0	0	0.00	0.00	0.01	0.01	0.01	0.01
Anemone	0	8	5	5	0	1	0.02	0.52	0.27	0.33	0.02	0.06
Tunicate	0	0	0	1	0	0	0.00	0.00	0.00	0.17	0.00	0.00
Benthinv	0	1	1	1	5	0	0.00	0.03	0.03	0.07	0.40	0.07
Snails	0	0	0	0	0	0						
echinoderm	0	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.04
Coral	0	0	0	0	0	0	0.00	0.00	0.05	0.00	0.00	0.02
Shrimp	0	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
Birds	0	1	1	1	1	0	0.13	0.12	0.16	0.21	0.43	0.40

Table 2.32b—Bycatch of nontarget and "other" species taken in the GOA Pacific cod hook-and-line (including jigs) fishery, 2003-2005. The first part of the table ("Bycatch") shows the amount (t) of each species group taken as bycatch in the GOA Pacific cod hook-and-line fishery, broken down by year. The second part of the table ("Proportion of total") shows the same quantity expressed relative to the total GOA catch (taken in all target categories with all gears) of that species group in that year. An empty cell in the second part of the table indicates that no catch of that group was observed in the GOA during that year. Note that the list of nontarget species groups used for 2003-2005 differs from that used for 1997-2002.

	Catch (t)			Proportion of total		
Species group	2003	2004	2005	2003	2004	2005
Benthic urochordata						
Birds	0	0		0.01	0.03	
Bivalves	0	0	0	0.11	0.00	0.02
Brittle star unidentified		0			0.30	
Capelin						
Corals Bryozoans			0			0.00
Deep sea smelts (bathylagidae)						
Eelpouts	0	0		0.00	0.00	
Eulachon						
Giant Grenadier						
Greenlings	1	1	1	0.05	0.06	0.16
Grenadier		0			0.00	
Gunnels						
Hermit crab unidentified						
Invertebrate unidentified	0	2		0.00	0.27	
Lanternfishes (myctophidae)						
Large Sculpins	39	129	49	0.33	0.20	0.09
Misc crabs	0	0	0	0.00	0.02	0.01
Misc crustaceans						
Misc deep fish						
Misc fish	11	6	2	0.03	0.02	0.01
Misc inverts (worms etc)						
Octopus	2	1	0	0.05	0.01	0.00
Other osmerids						
Other Sculpins	90	7	7	0.17	0.14	0.15
Pacific Sand lance						
Pandalid shrimp						
Polychaete unidentified						
Scypho jellies						
Sea anemone unidentified	1	1	0	0.06	0.09	0.02
Sea pens whips	0		0	0.40		0.05
Sea star	110	246	170	0.20	0.23	0.17
Shark	59	13	10	0.17	0.11	0.04
Skate	464	472	108	0.12	0.21	0.06
Snails	0	0	0	0.00	0.00	0.00
Sponge unidentified		0	1		0.07	0.34
Squid	10	0	0	0.13	0.00	0.00
Stichaeidae						
Surf smelt						
Urchins dollars cucumbers		0			0.00	

Table 2.33a—Bycatch of nontarget and “other” species taken in the GOA Pacific cod pot fishery, 1997-2002. The first part of the table (“Bycatch in...”) shows the amount (t) of each species group taken as bycatch in the GOA Pacific cod pot fishery, broken down by year. The second part of the table (“Proportion of...”) shows the same quantity expressed relative to the total GOA catch (taken in all target categories with all gears) of that species group in that year. An empty cell in the second part of the table indicates that no catch of that group was observed in the GOA during that year.

	Bycatch in GOA Pacific cod pot fishery						Proportion of total GOA catch					
Species group	1997	1998	1999	2000	2001	2002	1997	1998	1999	2000	2001	2002
Sculpin	106	61	106	357	29	79	0.12	0.11	0.19	0.38	0.05	0.09
Skates	1	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
Shark	0	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
Salmonshk	0	0	1	0	0	0	0.00	0.00	0.01	0.00	0.00	0.00
Dogfish	0	0	0	0	1	0	0.00	0.00	0.00	0.00	0.00	0.00
Sleepershk	0	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
Octopus	168	74	142	137	63	252	0.72	0.66	0.85	0.78	0.71	0.84
Squid	0	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
Smelts	0	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
Gunnel	0	0	0		0		0.00	0.00	0.00		0.00	
Sticheidae	0	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
Sandfish	0	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
Lanternfish	0	0	0		0	0	0.00		0.00		0.00	0.00
Sandlance	0	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
Grenadier	0	0	0	0	1	0	0.00	0.00	0.00	0.00	0.00	0.00
Otherfish	30	4	92	19	52	43	0.05	0.00	0.11	0.02	0.07	0.02
Crabs	6	10	9	10	2	1	0.41	0.42	0.81	0.84	0.36	0.19
Starfish	468	210	633	566	35	66	0.47	0.17	0.42	0.63	0.08	0.13
Jellyfish	0	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
Invertunid	0	0	0	0	0	0	0.00	0.00	0.00	0.01	0.01	0.03
seapen/whip	0	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
Sponge	0	0	5	0	0	0	0.03	0.00	0.39	0.04	0.01	0.01
Anemone	0	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
Tunicate	0	0	0	0	0	0	0.00	0.03	0.41	0.02	0.00	0.00
Benthinv	10	2	10	4	1	2	0.40	0.08	0.40	0.34	0.08	0.28
Snails	0	0	0	0	0	0						
echinoderm	1	0	1	1	1	1	0.06	0.00	0.09	0.14	0.16	0.09
Coral	0	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
Shrimp	0	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
Birds	0	0	0	0	0	0	0.00	0.00	0.01	0.00	0.02	106

Table 2.33b—Bycatch of nontarget and "other" species taken in the GOA Pacific cod pot fishery, 2003-2005. The first part of the table ("Bycatch") shows the amount (t) of each species group taken as bycatch in the GOA Pacific cod pot fishery, broken down by year. The second part of the table ("Proportion of total") shows the same quantity expressed relative to the total GOA catch (taken in all target categories with all gears) of that species group in that year. An empty cell in the second part of the table indicates that no catch of that group was observed in the GOA during that year. Note that the list of nontarget species groups used for 2003-2005 differs from that used for 1997-2002.

	Catch (t)			Proportion of total		
Species group	2003	2004	2005	2003	2004	2005
Benthic urochordata		0			0.01	
Birds	0	0	0	0.02	0.09	0.08
Bivalves	0	0	0	0.14	0.00	0.01
Brittle star unidentified	0	0	0	0.03	0.65	0.53
Capelin						
Corals Bryozoans	0	0		0.00	0.01	
Deep sea smelts (bathylagidae)						
Eelpouts	0		7	0.13		0.34
Eulachon						
Giant Grenadier						
Greenlings	1	1	0	0.10	0.04	0.04
Grenadier						
Gunnels						
Hermit crab unidentified	0	0	0	0.05	0.08	0.45
Invertebrate unidentified	0			0.02		
Lanternfishes (myctophidae)						
Large Sculpins	14	262	157	0.11	0.41	0.28
Misc crabs	1	0	2	0.44	0.23	0.54
Misc crustaceans						
Misc deep fish						
Misc fish	43	20	80	0.10	0.07	0.26
Misc inverts (worms etc)						
Octopus	42	135	88	0.88	0.86	0.96
Other osmerids						
Other Sculpins	195	7	8	0.38	0.15	0.18
Pacific Sand lance						
Pandalid shrimp						
Polychaete unidentified						
Scypho jellies	0	0	0	0.00	0.01	0.00
Sea anemone unidentified		0	0		0.01	0.01
Sea pens whips	0			0.01		
Sea star	341	756	748	0.61	0.71	0.73
Shark						
Skate	1	0	1	0.00	0.00	0.00
Snails	5	0	5	0.56	0.34	0.68
Sponge unidentified	0	0		0.00	0.00	
Squid		0	0		0.00	0.00
Stichaeidae						
Surf smelt						
Urchins dollars cucumbers	0	0	0	0.03	0.09	0.12

Table 2.34—Summary of major results for the stock assessment of Pacific cod in the GOA region.

Tier		3a
Reference mortality rates		
	M	0.37
	$F_{40\%}$	0.46
	$F_{35\%}$	0.57
Equilibrium spawning biomass		
	$B_{35\%}$	90,500 t
	$B_{40\%}$	103,000 t
	$B_{100\%}$	259,000 t
Projected biomass for 2007		
	Spawning (at max FABC)	127,000 t
	Age 3+	375,000 t
ABC for 2007		
	FABC (maximum permissible)	0.46
	FABC (recommended)	0.38
	ABC (maximum permissible)	81,200 t
	ABC (recommended)	68,859 t
Overfishing level for 2007		
	Fishing Mortality	0.57
	Catch	97,600 t

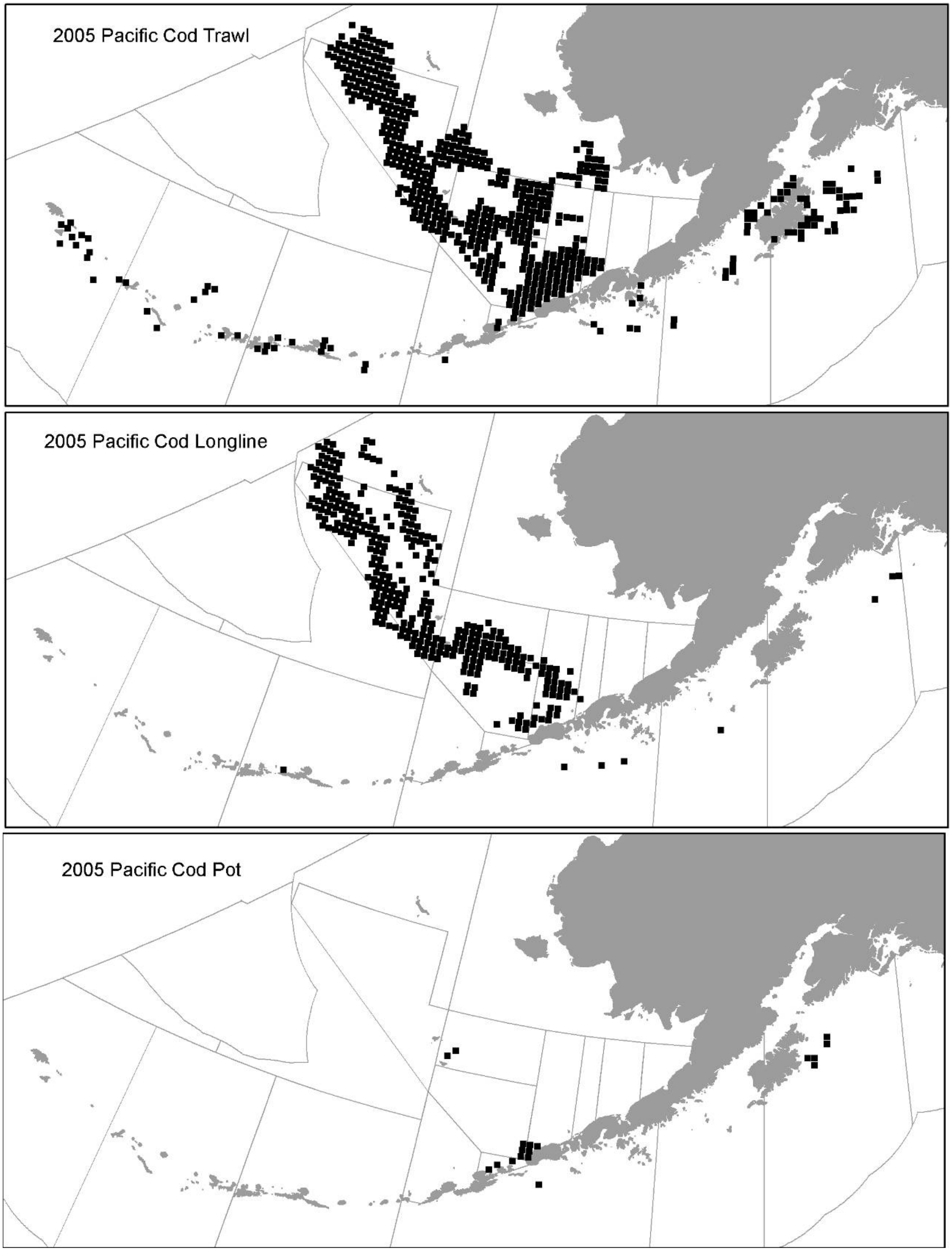

Figure 2.1—Maps showing each 400 square kilometer cell with at least 3 observed hauls/sets containing Pacific cod in 2005, by gear type, overlaid against NMFS 3-digit statistical areas.

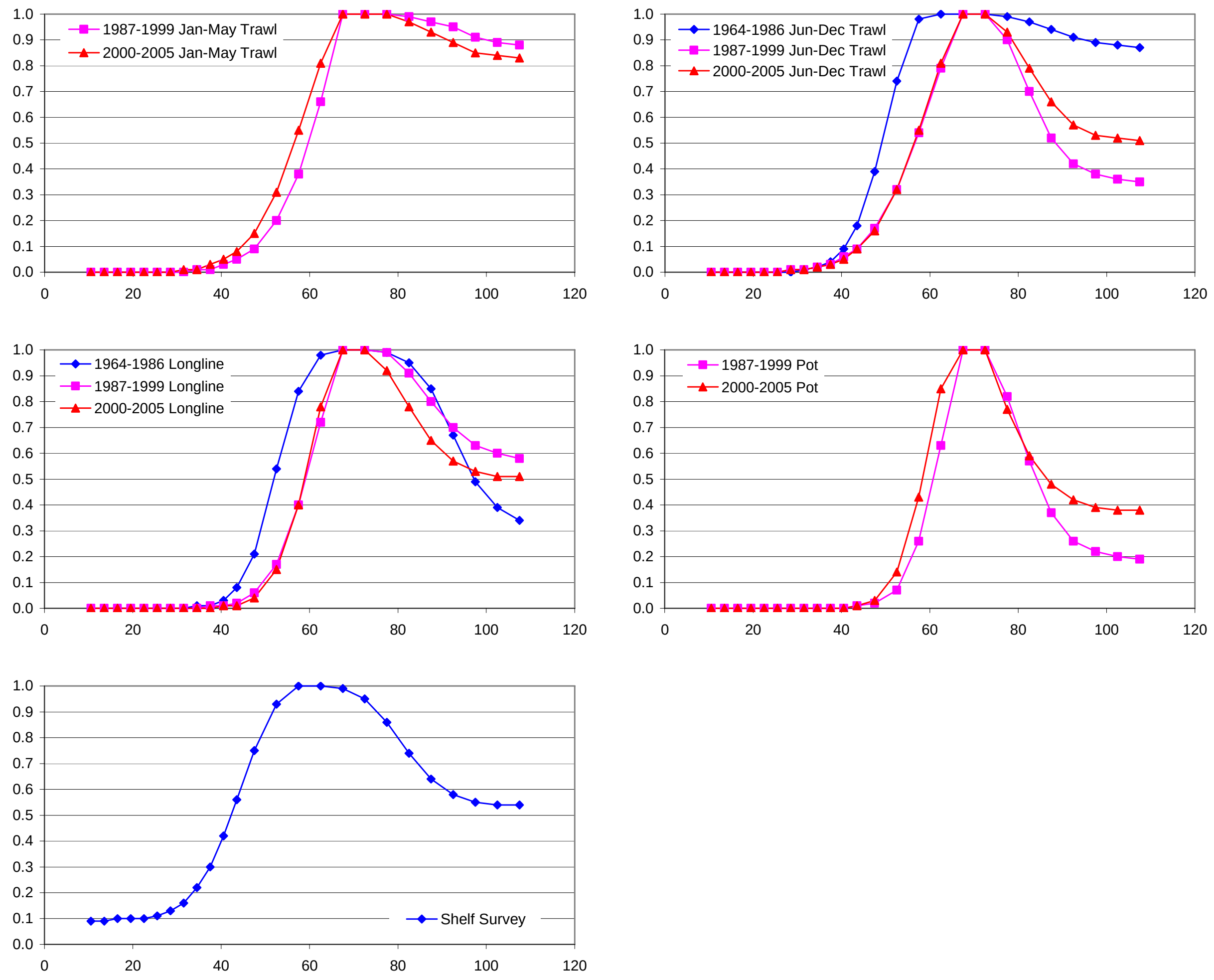

Figure 2.2—Selectivity at length (cm, evaluated at midpoints of length bins) as determined by final parameter estimates.

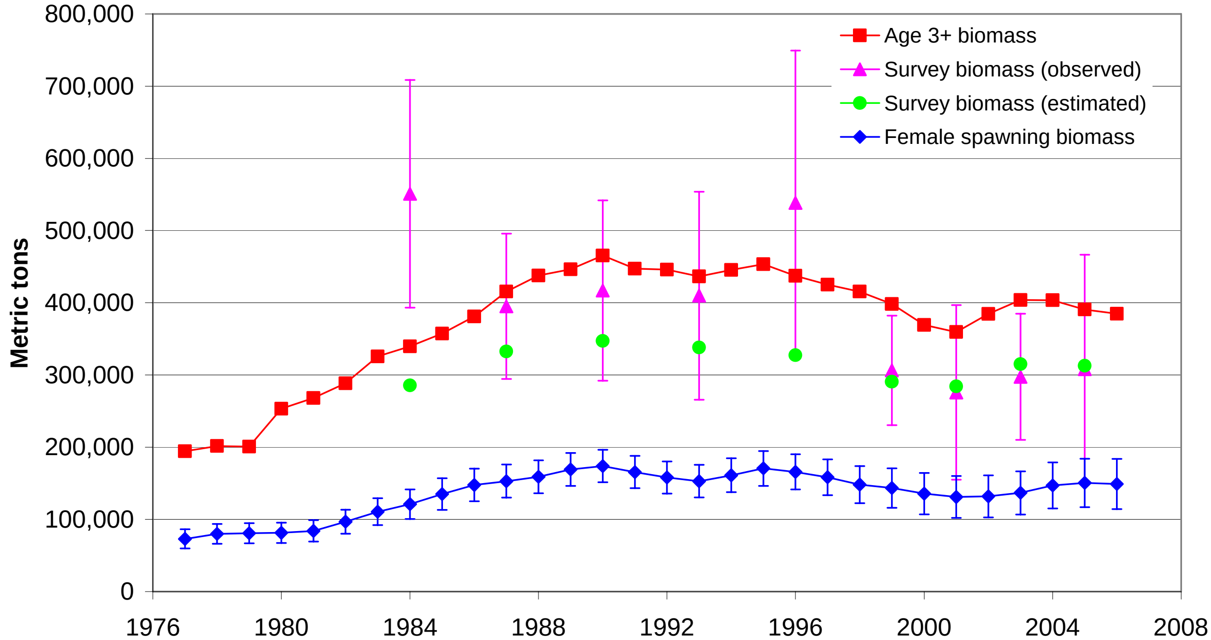

Figure 2.3—Biomass time trends (age 3+ biomass, female spawning biomass, survey biomass) of GOA Pacific cod as determined by final parameter estimates.

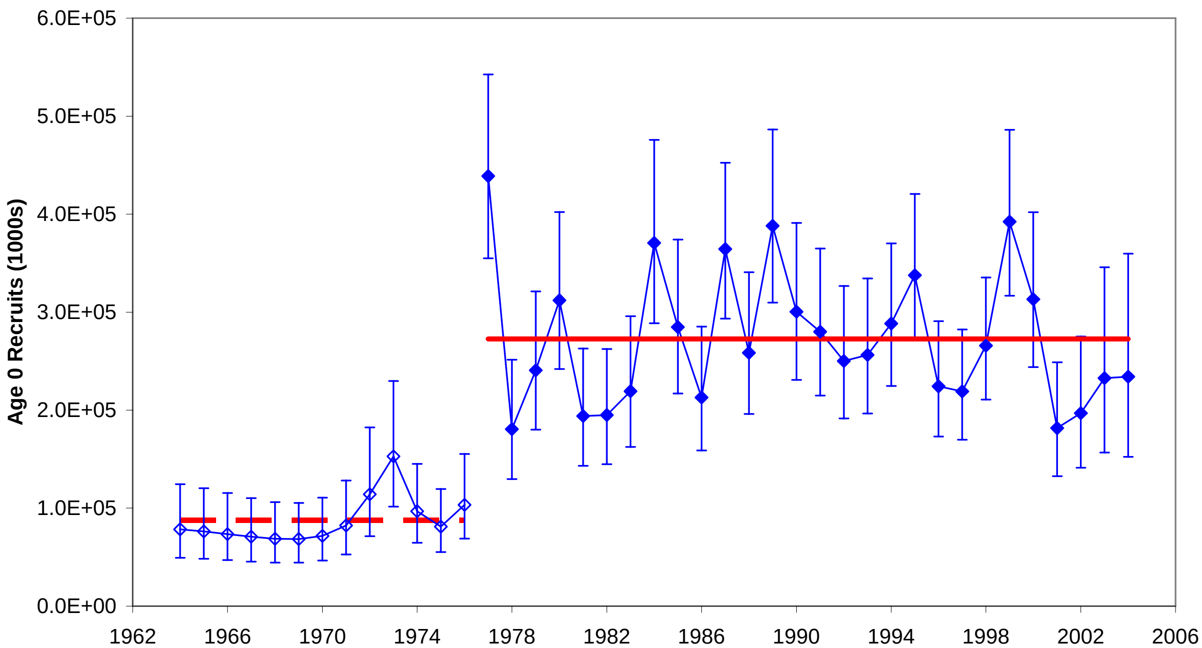

Figure 2.4—Time series of GOA Pacific cod recruitment at age 0, with 95% confidence intervals, as determined by final parameter estimates.

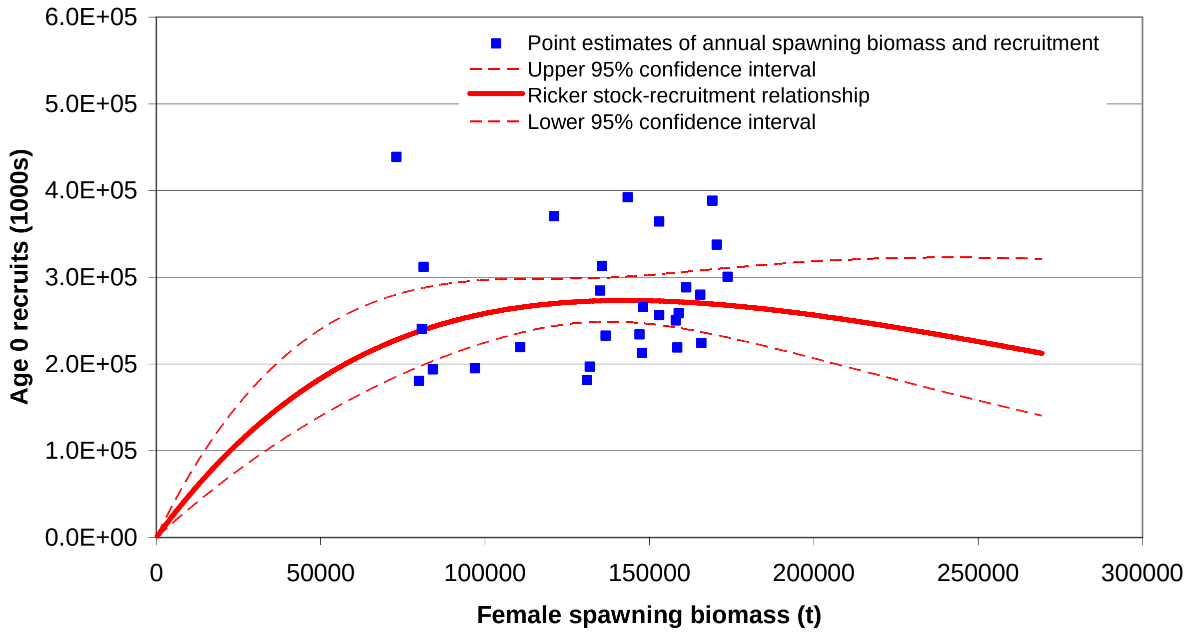

Figure 2.5—Age 0 recruitment versus female spawning biomass for Pacific cod during the years 1977-2004, with Ricker stock-recruitment curve (for illustrative purposes only).

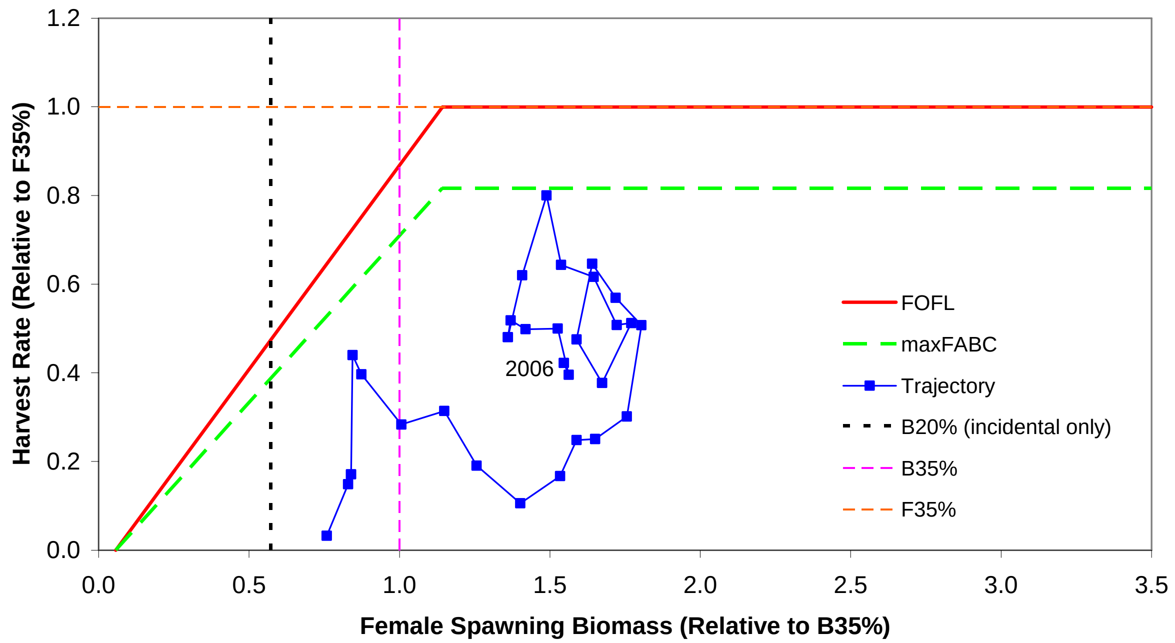

Figure 2.6—Trajectory of GOA Pacific cod fishing mortality and female spawning biomass as determined by final parameter estimates, 1977-2006. Because Pacific cod is a key prey of Steller sea lions, harvests of Pacific cod would be restricted to incidental catch in the event that spawning biomass fell below $B_{20\%}$.