Chapter 2: Assessment of the Pacific Cod Stock in the Eastern Bering Sea and Aleutian Islands Area

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EXECUTIVE SUMMARY

Summary of Major Changes

Relative to the November edition of last year's BSAI 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) Commercial fishery size composition data were recompiled for all years.
3) Size composition data from the 1982-2005 EBS shelf bottom trawl surveys were recompiled.
4) Size composition data from the 2006 EBS shelf bottom trawl survey were incorporated.
5) The biomass estimate from the 2006 EBS shelf bottom trawl survey was incorporated (the 2006 estimate of 517,698 t was down about 14% from the 2005 estimate).
6) The biomass estimate from the 2006 AI bottom trawl survey was incorporated (the 2006 estimate of 92,526 t was down about 19% from the 2004 estimate).
7) Age composition data from the 1994 and 2004-2005 EBS shelf bottom trawl surveys were incorporated.
8) Length-at-age and weight-at-length data from the 1994 and 2004-2005 EBS shelf bottom trawl surveys were incorporated.
9) Relative abundance indices and size composition data from the Japanese longline survey (annual from 1982 through 1994) and the U.S. longline survey (biennial from 1997 through 2005) were incorporated into some models, but not others.

Changes in the Assessment Model

The model selected last year by the Plan Team and SSC is presented again, basically unchanged except for updated estimates of parameters governing life history schedules that can be reliably estimated outside of the stock assessment model (e.g., length-at-age parameters, weight-at-length parameters). In addition, eight alternative models are presented. Unlike the base model, in which the catchability coefficient for the EBS shelf bottom trawl survey is fixed at a value of 1.0, the eight alternative models all attempt to estimate this parameter. The eight alternative models are distinguished from one another via a factorial design based on the following three questions:

1) Should data from the longline surveys be excluded or included?

2) Should the selectivity function be of the "double logistic" or "double normal" form?
3) Should the prior distributions receive full (1.0) or partial (0.5) weight in the objective function?

The model recommended by the authors is Model B1, in which the data from the longline surveys are excluded, the selectivity function is of the "double normal" form, and the prior distributions receive full weight in the objective function (Model B2, which is the same as Model B1 except with down-weighted priors, gives very similar results).

Changes in Assessment Results

Free estimation of shelf trawl survey catchability by all of the alternative models (except those incorporating data from the longline surveys) tended to result in estimates of biomass somewhat higher than the estimates from last year's assessment (using the model selected by the Plan Team and SSC).

1) Based on Model B1, the projected 2007 female spawning biomass for the BSAI stock is 307,000 t, up about 10% from last year's estimate for 2006 and up about 25% from last year's F_{ABC} projection for 2007.
2) Based on Model B1, the projected 2007 total age 3+ biomass for the BSAI stock is 960,000 t, up about 4% from last year's estimate for 2006.
3) Based on Model B1, the recommended 2007 ABC for the BSAI stock is 176,000 t, down about 9% from the actual 2006 ABC and up about 19% from last year's F_{ABC} projection for 2007.
4) Based on Model B1, the estimated 2007 OFL for the BSAI stock is 207,000 t, down about 10% from the actual 2006 OFL and up about 17% from last year's F_{ABC} projection for 2007.

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 assessment includes eight alternative models in which EBS shelf bottom trawl survey catchability (Q) is estimated. All of the models leave the natural mortality rate (M) fixed at its traditional value of 0.37.

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. For this year's assessment, priority for inclusion of additional survey time series was given to the Japanese longline survey and U.S. longline survey, per Plan Team request (see below).

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."* The table of likelihood component values (Table 2.17 in last year's assessment) has been restructured (Table 2.16 in the present assessment) so as to be more similar to its counterparts in some other assessments.

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 2.10 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 includes an attachment describing recent results from ecosystem models. Special attention was paid to use of appropriate terminology so as to avoid confusion regarding the sources of the information presented.

Plan Team Comments

From the September, 2005 minutes: *"The Teams suggested using the longline survey data in the model."* The present assessment includes four alternative models that use data from the Japanese longline survey and the U.S. longline survey.

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 present assessment includes eight alternative models in which EBS shelf bottom trawl survey catchability (Q) is estimated. All of the models leave the natural mortality rate (M) fixed at its traditional value of 0.37. A prior distribution for Q is specified for all eight alternative models, but the prior distribution is relaxed in four of those models.

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.

From the November, 2005 minutes: *"In September, the Plan Teams recommended that stock assessment authors continue to work on incorporating ecosystem assessment information into their chapters as much as possible, and that the ecosystem modelers also try to work with specific stock assessments each year to better incorporate the information to the assessments. … The Teams agreed and noted that the following priorities for next year might be useful: GOA arrowtooth, AI Pollock, AI Pacific cod."* An attachment to the present assessment summarizes results from ecosystem models on the role of Pacific cod in the Eastern Bering Sea and Aleutian Islands ecosystems.

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 the eastern Bering Sea (EBS) as well as in the Aleutian Islands (AI) area. The resource in these two areas (BSAI) is managed as a single unit. Tagging studies (e.g., Shimada and Kimura 1994) have demonstrated significant migration both within and between the EBS, AI, and Gulf of Alaska (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 EBS or AI areas.

FISHERY

Catches of Pacific cod taken in the EBS, AI, and BSAI for the periods 1964-1980 and 1981-2006 are shown in Tables 2.1a and 2.1b, 2.2a and 2.2b, and 2.3a and 2.3b, respectively. The catches in Tables 2.1a, 2.2a, and 2.3a are broken down by year and fleet sector (foreign, joint venture, domestic annual processing), while the catches in Tables 2.1b, 2.2b, and 2.3b are broken down by gear type as well. During the early 1960s, a Japanese longline fishery harvested BSAI Pacific cod for the frozen fish market. Beginning in 1964, the Japanese trawl fishery for walleye pollock (*Theragra chalcogramma*) expanded and cod became an important bycatch species and an occasional target species when high concentrations were detected during pollock operations. By the time that the Magnuson Fishery Conservation and Management Act went into effect in 1977, foreign catches of Pacific cod had consistently been in the 30,000-70,000 t range for a full decade. In 1981, a U.S. domestic trawl fishery and several joint venture fisheries began operations in the BSAI. The foreign and joint venture sectors dominated catches through 1988, but by 1989 the domestic sector was dominant and by 1991 the foreign and joint venture sectors had been displaced entirely. Presently, the Pacific cod stock is exploited by a multiple-gear fishery, including trawl, longline, pot, and jig components. Figure 2.1 shows areas in which sampled hauls or sets for each of the three main gear types (trawl, longline, and pot) were concentrated during 2005. To create these figures, the EEZ off Alaska was divided into 20 km × 20 km squares. For each gear type, a square is shaded if more than two hauls/sets 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 (i.e., all-gear, combined area) commercial catches in Table 2.4. From 1980 through 2006, TAC averaged about 78% of ABC, and aggregate commercial catch averaged about 88% of TAC. In 10 of these 27 years (37%), TAC equaled ABC exactly, and in 5 of these 27 years (19%), catch exceeded TAC (by an average of 4%). 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. For example, in the assessments for fishery years 1980 through 2005, seven different assessment models were used (Table 2.4). All assessments from 1993 through 2004 used the Stock Synthesis 1 modeling software with primarily length-based data, albeit with some changes in model structure from time to time. The assessment was migrated to Stock Synthesis 2 last year (Thompson and Dorn 2005). Historically, the great majority of the BSAI catch has come from the EBS area. During the most recent complete five-year period (2001-2005), the EBS accounted for an average of about 85% of the BSAI catch.

Current regulations specify that the BSAI Pacific cod TAC will be allocated initially according to gear type as follows: the trawl fishery will be allocated 47%, the fixed gear (longline and pot) fishery will be allocated 51%, and the jig fishery will be allocated 2%; of the fixed gear allocation, the longline fishery will be allocated 80.3% (not counting catcher vessels less than 60 ft LOA), the pot fishery will be allocated 18.3% (not counting catcher vessels less than 60 ft. LOA), and fixed-gear catcher vessels less than 60 ft. LOA will be allocated 1.4%. Typically, as the harvest year progresses, it becomes apparent that one or more gear types will be unable to harvest their full allotment(s) by the end of the year. This is addressed by reallocating TAC between gear types in September of each year. Most often, such reallocations shift TAC from the trawl, jig, and sometimes pot components of the fishery to the longline catcher/processors. The longline catcher-processors typically receive 15,000-20,000 t per year through such transfers.

The catches shown in Tables 2.1b, 2.2b, 2.3b, and 2.4 include estimated discards. Discard rates of Pacific cod in the various EBS and AI target fisheries are shown for each year 1991-2002 in Table 2.5a and for each year 2003-2004 in Table 2.5b.

DATA

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

Commercial Catch Data

Catch Biomass

Catches (which may not include discards) taken in the EBS for the period 1964-1980 are shown in Table 2.6a and catches (including estimated discards) taken in the EBS for the period 1981-2005 are shown in Table 2.6b. Catches in these tables are broken down by the three main gear types and intra-annual periods consisting of the months January-May, June-August, and September-December. This particular division, which was suggested by participants in the EBS fishery, is intended to reflect actual intra-annual differences in fleet operation (e.g., fishing operations during the spawning period may be different than at other times of year). In years for which estimates of the distribution by gear or period were not available, proxies based on other years' distributions were used.

Catch Size Composition

Fishery size compositions are presently available, by gear, for at least one gear type in every year from 1974 through the first part of 2006, with the exception of 1976. 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:

BinNumber:	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
LowerBound:	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
UpperBound:	11	14	17	20	23	26	29	32	35	38	41	44	49	54	59	64	69	74	79	84	89	94	99	104	110

The collections of relative length frequencies are shown by year, period, and size bin for the trawl fishery in Tables 2.7a, 2.7b, and 2.7c; the longline fishery in Tables 2.8a, 2.8b, and 2.8c; and the pot fishery in Tables 2.9a and 2.9b. Input sample sizes (N) for the multinomial distribution used in the stock assessment model are also shown. These are set equal to the square root of the total sample size.

Survey Data

EBS Shelf Bottom Trawl Survey

The relative size compositions from bottom trawl surveys of the EBS shelf conducted by the Alaska Fisheries Science Center since 1979 are shown in Tables 2.10a for the years 1979-1981 and 2.10b for the years 1982-2006, using the same length bins defined above for the commercial catch size compositions. The survey is shown as two separate time series because of a gear change that was instituted in 1982. Input sample sizes (N) for the multinomial distribution used in the stock assessment model are also shown. These are set equal to the square root of the total sample size in years 1982-1987 and 1990-2006. For other years, N was set equal to 100, approximating the square root of the average average of the 10 known true sample sizes from the years 1986-1997.

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). To date, the otolith collections from the 1994 and 1996-2005 surveys have been read. The relative age compositions from these surveys are shown in Table 2.11. The number of fish aged for each of these years is shown below:

Year:	1994	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
N:	715	252	719	635	860	864	950	947	1360	1040	609

Estimates of total abundance (both in biomass and numbers of fish) obtained from the trawl surveys are shown in Table 2.12a (1979-1981) and 2.12b (1982-2006), together with the standard errors and upper and lower 95% confidence intervals (CI) for the biomass estimates. Survey results indicate that biomass increased steadily from 1978 through 1983, then remained relatively constant from 1983 through 1988. The highest biomass ever observed by the survey was the 1994 estimate of 1,368,120 t. Following the high observation in 1994, the survey biomass estimate declined steadily through 1998. The survey biomass estimates have remained in the 510,000-620,000 t range from 1997 through the present, except for 2001, when the estimate was 833,626 t. The biomass estimate from 2001 appears likely to be an overestimate, given the magnitude of the implied increases relative to the 2000 survey (57%) and the fact that the 2002-2006 estimates were much closer to the preceding estimates. The 2006 estimate was 517,698 t, a 14% drop from the 2005 value and the second lowest estimate in the post-1981 time series.

EBS Slope Bottom Trawl Survey

The Alaska Fisheries Science Center conducted bottom trawl surveys of the EBS slope in 2002 and 2004. The relative size compositions from these surveys are shown in Table 2.13, using the same length bins defined above for the commercial catch size compositions. Input sample sizes (N) for the multinomial distribution used in the stock assessment model are also shown. These are set equal to the square root of the total sample size. A total of 468 fish were measured in the 2002 survey and a total of 531 fish were measured in the 2004 survey (note that these sample sizes are only about one-twentieth of the average sample size from the shelf survey). The biomass estimates and standard errors from the 2002 and 2004 surveys are shown below (all figures are in t):

Year	Biomass	Standard Error
2002	7511	1944
2004	5756	968

Japanese and U.S. Longline Surveys

The Japanese longline survey was conducted annually from 1982-1994, and the U.S. longline survey has been conducted in the EBS biennially starting in 1997. These surveys are designed primarily to assess the abundance of sablefish (*Anoplopoma fimbria*), but Pacific cod are also captured in these surveys. Pacific cod size compositions from the Japanese and U.S. longline surveys are shown in Tables 2.14a and 2.14b.

Input sample sizes (N) for the multinomial distribution used in the stock assessment model are also shown. These are set equal to the square root of the total sample size.

A problem arises in use of the longline survey catch rates as an index of abundance, however, in that most of the Pacific cod catches take place in the shallowest depth strata, where few sablefish are caught. Because few sablefish are caught in these strata, appropriate area expansion factors have not been computed, so the only index of abundance available for Pacific cod is a simple average catch per station. The time series of average Pacific cod catch (number of fish caught per station) and associated coefficients of variation are shown for the two surveys in Table 2.15. To make the abundance indices as meaningful as possible, the averages were computed only for those stations that were successfully sampled in every year. The numbers of stations that qualify under this criterion are not large. For the Japanese survey, 32 stations were successfully sampled every year, but only 11 stations were successfully sampled every year in the U.S. survey.

It should be emphasized that the abundance indices in Table 2.15 are relative indices at best. The Japanese survey in particular shows an enormous degree of year-to-year variability. Of the 12 year-to-year changes present in the Japanese time series, there were two one-year increases of well over 200% (i.e., the index more than tripled) and two other annual changes showed decreases of more than 50%.

Aleutian Bottom Trawl Survey

Biomass estimates for the Aleutian Islands region were derived from U.S.-Japan cooperative bottom trawl surveys conducted during the summers of 1980, 1983, and 1986, and by U.S. bottom trawl surveys of the same area in 1991, 1994, 1997, 2000, 2002, 2004, and 2006. These surveys covered both the Aleutian management area (170 degrees east to 170 degrees west) and a portion of the Bering Sea management area ("Southern Bering Sea") not covered by the EBS shelf bottom trawl surveys. The time series of biomass estimates from the overall Aleutian survey area are shown together with their sum below (all figures are in t):

Year	Survey Type	Aleutian Survey Area
1980	U.S.-Japan	148,272
1983	U.S.-Japan	215,755
1986	U.S.-Japan	255,072
1991	U.S.	191,049
1994	U.S.	184,068
1997	U.S.	83,416
2000	U.S.	136,028
2002	U.S.	82,970
2004	U.S.	114,161
2006	U.S.	92,526

For many years, the assessments of Pacific cod in the BSAI used a weighted average formed from EBS and Aleutian survey biomass estimates to provide a conversion factor which was used to translate model projections of EBS catch and biomass into BSAI equivalents. Prior to the 2004 assessment, the weighted average was based on the sums of the biomass estimates from the EBS shelf and AI survey biomass time series. However, in December of 2003 the SSC requested that alternative methods of estimating relative biomass between the EBS and AI be explored. Following a presentation of some possible alternatives, the SSC recommended that an approach based on a simple Kalman filter be used (SSC Minutes, October, 2004). Applying the Kalman filter approach to the updated (through 2006) time series indicates that the best estimate of the current biomass distribution is 84% EBS and 16% AI (the previous proportions were 85% and 15%, respectively). Because the 83-112 net (with no roller gear) used in the EBS survey generally tends the bottom better than the polyethylene Noreastern net (with roller gear) used in the AI survey, this ratio should tend to err on the conservative side (that is, the AI survey would be expected to miss more fish than the EBS survey, so the true portion in the AI should be higher than the ratio of the AI to AI+EBS survey estimates).

ANALYTIC APPROACH

Model Structure

History of Model Structures Developed Under Stock Synthesis 1 and 2

Beginning with the 1993 SAFE report (Thompson and Methot 1993) and continuing through the 2004 SAFE report (Thompson and Dorn 2004), 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 EBS Pacific cod stock. It should be emphasized that the model has always been intended to assess only the EBS portion of the BSAI stock. Conversion of model estimates of EBS biomass and catch to BSAI equivalents has traditionally been accomplished by application of an expansion factor based on the relative survey biomasses between the EBS and AI.

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. The EBS Pacific cod assessments, for example, have usually divided the shelf bottom trawl survey size composition time series into pre-1982 and post-1981 segments to account for the effects of a change in the trawl survey gear instituted in 1982. Also, to account for possible differences in selectivity between the mostly foreign (also joint venture) and mostly domestic fisheries, the fishery size composition time series have traditionally been split into pre-1989 and post-1988 segments.

In the EBS Pacific cod model, each year has traditionally been partitioned into three seasons: January-May, June-August, and September-December (these seasonal boundaries were suggested by industry participants). 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 EBS Pacific cod remained completely unchanged from 1997 through 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 and Dorn 2002), where it was found to result in a statistically significant improvement in the model's ability to fit the data. In the 2004 assessment (Thompson and Dorn 2004), further modifications were made to the base model. The 2004 model included a set of selectivity parameters for the EBS slope bottom trawl survey and added new likelihood components for the age compositions and length-at-age data from the 1998-2003 EBS shelf bottom trawl surveys and the size composition and biomass data from the 2002 and 2004 EBS slope bottom trawl surveys. Incorporation of age data and slope survey data had been suggested by the SSC (SSC minutes, December 2003).

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.)

Current Issues in Model Structure

Estimation of EBS Shelf Bottom Trawl Survey Catchability

The SSC has requested that the 2006 assessment focus on estimating either *Q* or *M* (not both) while leaving the other parameter fixed at its traditional value of 1.0 or 0.37, respectively (SSC minutes, December, 2005). The Plan Team was more explicit in its recommendation, suggesting that the 2006 assessment focus on estimating *Q* while leaving *M* fixed at its traditional value (Plan Team minutes, November, 2005).

Estimates of the selectivity schedule for the EBS shelf bottom trawl survey obtained in previous BSAI Pacific cod assessments have often tended to show a pronounced “kink,” with survey selectivity increasing rapidly from a low value for the smallest fish up to a peak at some intermediate length, then decreasing rapidly as length increased further. It has been conjectured that this behavior was a result of fixing *Q* at an artificially high level, thereby forcing a sharp kink in the selectivity curve so that, overall, the product of catchability and selectivity is approximately correct.

Although direct experimental evidence (as opposed to the types of indirect evidence coming from length compositions, age compositions, and abundance indices used in stock assessments) pertaining to the value of *Q* for Pacific cod in the EBS shelf bottom trawl survey is becoming more available, it is still insufficient to enable estimation of this parameter outside the context of a full stock assessment model. Two types of direct experimental evidence are available: results of studies pertaining specifically to Pacific cod, and results of studies pertaining to closely related species.

Available experimental evidence regarding the value of *Q* for Pacific cod in the EBS shelf bottom trawl survey includes the following: Munro and Somerton (2002) and Weinberg et al. (2002) showed that Pacific cod within the path of the net do not tend to escape under the footrope. Somerton (2004) showed that Pacific cod neither tend to escape around the sides of the net nor tend to be herded into the net by the doors. Von Szalay and Somerton (2005) showed that catch efficiency of Pacific cod decreased with increases in net spread and presumed decreases in net height, leaving open the possibility that some fish occur in the water column above the headrope or are initially within the path of the net but escape over the headrope. Recently, Nichol et al. (unpubl. manuscr.) and Thompson and Nichol (unpubl. manuscr.) proposed methods for estimating the vertical distribution of Pacific cod relative to the bottom based on archival tag data. However, neither of these studies has been completed.

Available experimental evidence from closely related species includes the following: Winger et al. (2000) showed that catchability of Atlantic cod (*Gadus morhua*) may be highly sensitive to changes in towing speed. If the same holds true for Pacific cod, it is possible that some fish may be out-swimming the trawl survey net. Handegard et al. (2003) and Handegard and Tjostheim (2005) showed that some other gadids, including Atlantic cod, may tend to dive as a behavioral response to an approaching vessel or net, meaning that even a highly accurate estimate of "typical" vertical distribution may provide a biased picture of catchability.

Not only is the available experimental evidence regarding survey catchability of Pacific cod less than conclusive in some respects, the results of existing studies tend to obscure the distinction between age- or size-specific selectivity (a measure of how *relative* susceptibility to capture differs with age or size) and overall catchability (a measure of *absolute* susceptibility to capture for the most-selected age or size).

In summary, considering the indirect evidence from past stock assessments along with the available direct evidence from field experiments, it seems that enough uncertainty about the true value of Q exists to warrant exploration of the possibility that Q does not equal the traditional value of 1.0.

Use of Longline Survey Data

For many years, data from the Japanese longline survey and U.S. longline survey have been a primary input to the BSAI and GOA assessments of sablefish. In 2005, the Plan Teams suggested using data from the longline surveys in the Pacific cod assessments as well (Plan Team minutes, September, 2005). There are some issues involved with use of the Pacific cod data from these surveys, as discussed under "Data" above. Nevertheless, relative abundance estimates (though not expanded by area) and size composition data are available annually from the Japanese longline survey from 1982 through 1994 and biennially from the U.S. longline survey from 1997 through 2005.

Functional Form of the Selectivity Curve

Several options are included in SS2 for specifying the functional form of the selectivity curve. The most flexible and commonly used of these is the "double logistic" function, which the BSAI Pacific cod assessments have used ever since the first length-based SS1 version of the assessment in 1993 (Thompson and Methot 1993). This function has grown increasingly complicated over the years, starting from a four-parameter form in its original incarnation in SS1 and evolving to an eight-parameter form as currently implemented in SS2. The double logistic function consists of 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 EBS 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 EBS Pacific cod model), where the selectivity is less than 1.0. Eight parameters are used to define the 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 1.0 (*peak width*).

Another option provided by SS2 for the functional form of the selectivity curve is the "double normal" function, which involves a pair of curves reminiscent of the left and right halves of a pair of normal probability density functions joined by a horizontal linear segment. Like the double logistic function, the double normal function involves an ascending curve that reaches a maximum value of 1.0 at some point (*peak location*), a horizontal linear segment extending for some distance (*peak width*), and a descending curve that begins at the end of the horizontal linear segment. Contrasted with the double logistic function, the double normal function is simpler but less flexible, in that a single parameter defines the shape of the ascending curve and a single parameter defines the shape of the descending curve (as opposed to three parameters apiece in the double logistic). The parameters governing the shapes of the ascending and descending curves in the double normal are the log variances (*lnvar1* and *lnvar2*, respectively) of the associated normal curves. Using the ascending curve as an example, selectivity at length *len* is given by:

$$S(len) = \exp\left(-\frac{(len - peak\ location)^2}{\exp(lnvar1)} \right)$$

Estimating or otherwise specifying eight parameters for each selectivity function (there are either 14 or 16 selectivity functions in the Pacific cod model, depending on whether the longline survey data are excluded or included), as required by use of the double logistic function, is a challenging undertaking, and it is worth exploring the possibility that a simpler functional form may not change the point estimates of the most important model outputs appreciably but may make those estimates less uncertain.

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 at least some of the parameters in the EBS Pacific cod model, because both the Plan Team and the SSC have indicated in the past that certain values, or ranges of values, for various parameters are either relatively likely or unlikely. For example, the Plan Team has expressed concern that the estimates of large-fish selectivity in the EBS shelf bottom trawl survey obtained in many previous assessments may be too low (Plan Team minutes, November 2004). 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.

Last year's assessment contained a thorough description of the prior distributions used, but the sensitivity of the results to those distributions was not made explicit in the SAFE report. One way to make such sensitivity more explicit would be to include model runs in which the contribution of the prior distributions to the overall objective function is downweighted.

Model Structures Considered in This Year's Assessment

This year's BSAI Pacific cod assessment includes nine alternative models for the EBS portion of the stock. Model 0, the base model, is the same as the model selected last year by the Plan Teams and SSC. In addition to the base model, eight other models are presented as possible alternatives. All models, including the base model and the eight alternatives, use the latest estimates of parameters governing the length-at-age and weight-at-length relationships, as well as the latest estimates of parameters governing variability in length at age and variability in estimated age (ageing error). Parameters governing the maturity-at-length schedule have not changed since last year. The eight alternative models differ from the base model in various respects, but two of these differences are consistent across all of the alternative models:

1) In all of the alternative models, catchability of the EBS shelf bottom trawl survey is estimated, rather than assumed to equal 1.0 as in the base model. Separate catchability coefficients are estimated for the pre-1982 and post-1981 portions of the time series because of a change in the survey gear instituted in 1982.
2) In all of the alternative models, all selectivity parameters are estimated, except that *S*(*Lmin*) in models using the double logistic selectivity function is set equal to 0.001 for all gear types other than the EBS shelf bottom trawl surveys (*S*(*Lmin*) is estimated for the EBS shelf bottom trawl surveys). Last year, it was not possible to estimate all remaining selectivity parameters statistically in the model chosen by the Plan Team and SSC, so the value of each *peak location* parameter in that model was chosen by other methods. The same (fixed) *peak location* values are used in this year's base model, but not the alternative models.

Although the eight alternative models share the above pair of features in common, they are distinguished from one another via a factorial design based on the following three questions:

1) Should data from the longline surveys be excluded or included?
2) Should the selectivity function be of the "double logistic" or "double normal" form?
3) Should the prior distributions receive full (1.0) or partial (0.5) weight in the objective function?

The eight alternative models address all possible combinations of answers to the above as follow:

Model	Longline survey data	Selectivity function	Prior weight
Model A1	Exclude	Double logistic	1.0
Model A2	Exclude	Double logistic	0.5
Model B1	Exclude	Double normal	1.0
Model B2	Exclude	Double normal	0.5
Model C1	Include	Double logistic	1.0
Model C2	Include	Double logistic	0.5
Model D1	Include	Double normal	1.0
Model D2	Include	Double normal	0.5

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. Although attempts have been made to re-estimate *M* in some years (during the late 1990s and, most recently, in the 2005 assessment (Thompson and Dorn 2005)), all models of the BSAI Pacific cod stock accepted by the Plan Team and SSC since 1993 have ultimately retained a value of 0.37 for *M*, as have all subsequent assessments of the GOA Pacific cod stock (with one exception, in 1995). 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

All models in the present assessment fix *M* at the traditional value of 0.37.

Trawl Survey Catchability

In Model 0, catchability for the EBS shelf bottom trawl survey is fixed at a value of 1.0 for both the pre-1982 and post-1981 portions of the time series. In all other models, these parameters are estimated freely and separately for both portions of the time series.

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 = 11.1 cm, length at 12 years = 93.3 cm, and Brody's growth coefficient K = 0.113.

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 = 0.16, CV at age 13 = 0.065.

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 0.103 (i.e, the standard deviation of estimated age was modeled as 0.103 × 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 = 3.86×10^{-6}, and exponent = 3.266.

Maturity at Length

A detailed history and evaluation of parameter values used to describe maturity at length for BSAI 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 = 58 cm and slope of linearized logistic equation = -0.132. 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) by all nine models 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)

Estimation of catchability coefficients for surveys other than the EBS slope bottom trawl survey varies by survey as follows:

1) Pre-1982 EBS shelf bottom trawl survey catchability: all models except Model 0
2) Post-1981 EBS shelf bottom trawl survey catchability: all models except Model 0
3) Japanese longline survey catchability: Models C1, C2, D1, and D2 only
4) U.S. longline survey catchability: Models C1, C2, D1, and D2 only

Recall that all models consider three bottom trawl surveys (pre-1982 shelf trawl survey, post-1981 shelf trawl survey, slope trawl survey) and a total of 11 gear- and era-specific fisheries (four gears, consisting of the January-May trawl fishery, June-December trawl fishery, longline fishery, and pot fishery; and three eras, consisting of the years 1964-1988, 1989-1999, and 2000-2006, except that there was no significant pot fishery during the 1964-1988 era). In addition, Models C1, C2, D1, and D2 consider two longline surveys (Japan and U.S.). The total number of selectivity parameters estimated conditionally therefore varies by model as follows:

1) Model 0 uses the 8-parameter double logistic function to describe selectivity for 3 surveys and 11 fisheries, which would total 112 selectivity parameters, except that $S(Lmin)$ is fixed at a value of 0.001 for the slope trawl survey and all fisheries and *peak location* is fixed at various values for all surveys and fisheries, bringing the total of estimated selectivity parameters down to 86.
2) Models A1 and A2 use the 8-parameter double logistic function to describe selectivity for 3 surveys and 11 fisheries, which would total 112 selectivity parameters, except that that $S(Lmin)$ is fixed at a value of 0.001 for the slope trawl survey and all fisheries, bringing the total of estimated selectivity parameters down to 100.
3) Models B1 and B2 use the 4-parameter double normal function to describe selectivity for 3 surveys and 11 fisheries, with no parameters fixed, giving a total of 56 estimated selectivity parameters.
4) Models C1 and C2 use the 8-parameter double logistic function to describe selectivity for 5 surveys and 11 fisheries, which would total 128 selectivity parameters, except that that $S(Lmin)$ is fixed at a value of 0.001 for the slope trawl survey, the Japanese and U.S. longline surveys, and all fisheries, bringing the total of estimated selectivity parameters down to 114.
5) Models D1 and D2 use the 4-parameter double normal function to describe selectivity for 5 surveys and 11 fisheries, with no parameters fixed, giving a total of 64 estimated selectivity parameters.

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 to 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. Except for the prior distribution for shelf bottom trawl survey catchability, 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)

Log shelf bottom trawl survey catchability ln(Q): A mean of zero and a standard deviation of 0.294 were specified, corresponding to a lognormal prior distribution on Q with a mean of 1.0 and a CV of 30%, corresponding to the mean and CV used to specify a prior distribution for Q during the late 1990s.

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%.

Double logistic selectivity parameter *S*(*Lmin*): For the EBS slope bottom trawl survey, the Japanese and U.S. longline surveys, and all 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-18 cm range are taken by these gears and because preliminary model runs invariably resulted in this parameter being bound at whatever minimum value was specified. For the EBS shelf bottom trawl surveys, the prior distribution was assigned a mean of 0.2 and a standard deviation of 0.06, corresponding to a 30% CV. In contrast to the commercial fisheries, 12% of the average shelf bottom trawl survey size composition since 2000 has consisted of fish smaller than 18 cm.

Double logistic 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.

Double logistic 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, for the double logistic form at least, indicated that values much higher than 10 tended to cause the model to get "stuck." Although the *peak width* parameter is also used in the double normal functional form, an informative prior was not specified when the parameter was used in that context.

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

Double logistic 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* + *peak width* 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* + *peak width* 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.

Double logistic 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 14-16 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 potential 16 selectivity curves were as follow:

Fishery/Survey	Years	Mean	Std. Dev.
Jan-May Trawl Fishery	1964-1988	60.7	9.4
Jan-May Trawl Fishery	1989-1999	58.9	10.6
Jan-May Trawl Fishery	2000-2006	64.1	26.8
Jul-Dec Trawl Fishery	1964-1988	61.5	9.2
Jul-Dec Trawl Fishery	1989-1999	62.7	12.7
Jul-Dec Trawl Fishery	2000-2006	60.6	10.2
Longline Fishery	1964-1988	63.4	6.4
Longline Fishery	1989-1999	62.6	4.6
Longline Fishery	2000-2006	59.2	3.2
Pot Fishery	1989-1999	63.9	4.3
Pot Fishery	2000-2006	61.2	3.2
Shelf Bottom Trawl Survey	1979-1981	41.7	6.9
Shelf Bottom Trawl Survey	1982-2006	35.4	11.8
Slope Bottom Trawl Survey	2002-2004	55.1	5.0
Japanese Longline Survey	1982-1994	64.2	4.3
U.S. Longline Survey	1997-2005	62.9	2.5

Likelihood Components

Likelihood components included in all nine models were of five types: size composition, age composition, survey abundance, mean size at age, and recruitment deviations. All nine models included at least seven 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, the pre-1982 shelf trawl survey, the post-1981 shelf trawl survey, the slope trawl survey. In addition, Models C1, C2, D1, and D2 included size composition components for the Japanese longline survey and the U.S. longline survey. Only one age composition component and one size-at-age component appear in the likelihood, because all age data currently come from the post-1982 shelf trawl survey. All nine models included at least three survey abundance components in the likelihood: one each for the pre-1982 shelf trawl survey, the post-1981 shelf trawl survey, and the slope trawl survey. In addition, Models C1, C2, D1, and D2 included survey abundance components for the Japanese longline survey and the U.S. longline survey.

In SS2, emphasis factors are specified to determine which likelihood components receive the greatest attention during the parameter estimation process. The prior distributions are also assigned an emphasis. As in previous assessments, each likelihood component in each model was given an emphasis of 1.0 in the present assessment. The prior distributions were given an emphasis of 1.0 in Models 0, A1, B1, C1, and D1 and an emphasis of 0.5 in Models A2, B2, C2, and D2.

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 time period 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 period) 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 EBS Pacific cod data, 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 Tables 2.7-2.9, for the shelf bottom trawl surveys in Tables 2.10a and 2.10b, for the slope bottom trawl survey in Table 2.13, for the Japanese longline survey in Table 2.14a, and for the U.S. longline survey in Table 2.14b.

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 EBS shelf bottom trawl survey), and time period within the year (in this case, the June-August period). 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 assessment (Thompson and Dorn 2004) introduced a method for setting an input sample size appropriate to age composition, a method which has been retained since. 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 values used as input sample sizes):

Year	1994	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Number of fish aged:	715	252	719	635	860	864	950	947	1360	1040	609
Sqrt. of no, fish aged:	27	16	27	25	29	29	31	31	37	32	25
CV of nos. at length:	0.78	0.93	1.12	0.51	0.60	0.63	0.63	0.65	0.87	0.64	1.06
Harmonic mean:	67	43	47	107	131	136	111	108	77	157	53

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, all nine models ignore length composition data from the EBS shelf bottom trawl surveys in years where age data are available.

It may be noted that all but one of the harmonic mean effective sample sizes computed above is smaller than the sample sizes obtained for the corresponding length compositions 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 Abundance Data in Parameter Estimation

Each year's survey abundance datum is assumed to be drawn from a lognormal distribution specific to that year. The model's estimate of survey abundance in a given year serves as the geometric mean for that year's lognormal distribution, and the ratio of the survey abundance 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

As described in the preceding section, nine models are evaluated in the present assessment. Model 0 is very similar to the model selected last year by the Plan Team and SSC, except for use of updated values for those parameters that are estimated independently (i.e., outside of the SS2 model). Model 0 fixes the catchability coefficient for the EBS shelf bottom trawl survey at the traditional value of 1.0. The eight alternative models attempt to estimate catchability for all surveys, and differ from one another with respect to use or exclusion of longline survey data, choice of functional form for selectivity, and the weight assigned to prior distributions in the objective function. All models appeared to converge successfully and the Hessian matrices from all models were positive definite. However, it should be noted that it was typically more difficult to achieve convergence for the models associated with de-emphasized prior distributions (Models A2, B2, C2, and D2). To achieve convergence, those models were initialized with the parameter estimates from their respective "full prior" counterparts. Even then, convergence was sometimes achieved only after considerable trial and error, particularly in the case of models utilizing the double logistic selectivity function (Models A2 and C2). Also, models using the longline survey data (Models C1, C2, D1, and D2) had a difficult time converging unless estimation of the longline survey selectivity parameters was moved to the last phases in the estimation routine.

Overall Conclusions Common to All Models

Before choosing a preferred model, it is important to note that, in many respects, the descriptions of the stock provided by all of the models are, qualitatively at least, very similar. For example, Figure 2.2 compares numbers of age 0 fish for the years 1977-2005 as estimated by all the models. All the models are in basic agreement as to which year classes appear to be strong and which appear to be weak (of course, there is estimation error associated with all of the points shown in Figure 2.2, but to keep the figure legible, only the point estimates are shown). In particular, all the models agree that the 2000-2004 year classes currently appear to be weak. Figure 2.3 compares female spawning biomass for the years 1977-2006 as estimated by all the models. The overall shapes of all the estimated time series are again qualitatively similar, with the main difference being one of scale. From about 1993 to the present, all models indicate that female spawning biomass has been fairly stable, although the trend over the last couple of years is downward in all models. As far as the prognosis for the future is concerned, again the models are in qualitative agreement, with all models projecting continued declines for the next 2-3 years, as shown in Figure 2.4 (note that the spawning biomasses in Figure 2.3 are from the assessment model, which is configured for the EBS portion of the stock only, whereas the spawning biomasses in Figure 2.4 are from the projection model, which is configured for the overall BSAI stock, so the endpoints of the two time series do not match). It should be emphasized that the projections shown in Figure 2.4 represent the average of a large number of stochastic projections. The averages rather than the ranges are plotted because of the large number of models being compared.

Comparing and Contrasting the Models

Table 2.16 presents a summary of some key results from last year's assessment (based on the model chosen by the Plan Team and SSC) and compares them with the corresponding results from Model 0 and the eight alternative models. The table is structured as follows:

Row 1: Model names.

Rows 2-4: Factors that distinguish the eight alternative models from each other.

Rows 5-7: Parameters governing the distribution of recruitments. Row 5 shows the standard deviation of the distribution of log-scale recruitment deviations, row 6 shows the median log-scale recruitment for the post-1976 environmental regime, and row 7 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 7 means that median recruitment was lower in the pre-1977 regime than in the post-1976 regime).

Rows 8-10: Parameters or function values characterizing shelf trawl survey catchability and selectivity. Row 8 shows the catchability for the pre-1982 portion of the time series, row 9 shows the catchability for the post-1981 portion of the time series, and row 10 shows the estimated post-1981 shelf trawl survey selectivity for fish 90 cm in length. The full selectivity schedules for the post-1981 shelf trawl survey are compared in Figure 2.5.

Rows 11-15: Log likelihood values related to survey abundance indices (by convention, all log likelihood, log prior, and log objective function values are multiplied by -1). These rows show the values of the log likelihoods pertaining to the abundance data from the pre-1982 shelf trawl survey, post-1981 shelf trawl survey, slope trawl survey, Japanese longline survey, and U.S. longline survey, respectively.

Rows 16-24: 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, pre-1982 shelf trawl survey, post-1981 shelf trawl survey, slope trawl survey, Japanese longline survey, and U.S. longline survey, respectively.

Rows 25-27: Other log likelihoods. Row 25 shows the log likelihood pertaining to the post-1981 shelf trawl survey age composition data, row 26 shows the log likelihood pertaining to the post-1981 shelf trawl survey size-at-age data, and row 27 shows the log likelihood pertaining to recruitment deviations.

Row 28: Log prior distributions.

Row 29: Log posterior distribution (the objective function). This row shows the sum of the previous 18 rows, except that the log prior distribution is weighted by a factor of 0.5 in Models A2, B2, C2, and D2.

Table 2.17 continues the comparison by presenting results for several management-related quantities. Values obtained from the SS2 model are shown in normal font and values obtained from the projection model are shown in bold font. All values pertain to the overall BSAI stock, not just the EBS portion of the stock assessed by the SS2 model. The table is structured as follows:

Rows 1-4: Same as Table 2.16.

Rows 5-6: BSAI total biomass for 2005 and 2006.

Rows 7-10: BSAI 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 11-14: BSAI 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 15-19: Current (2006) BSAI ABC and projected maximum permissible ABC for 2007-2008, with the proportional year-to-year changes implied by those ABCs.

Rows 20-24: Similar to rows 15-19, but for OFL instead of ABC.

For the length composition and age composition components of the likelihood, past assessments have included a comparison of input sample sizes and "effective" output sample sizes. The rationale is as follows: Once maximum likelihood estimates of the model parameters have been obtained, SS2 computes an "effective" sample size for the length or age composition data specific to a particular year, gear, and 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. The following table shows the average of the input sample sizes (Input N) for each length or age composition component and the ratio between the average effective sample size and the average input sample size under each model (a higher ratio implies a better fit):

			Model								
Gear	Type	Input N	0	A1	A2	B1	B2	C1	C2	D1	D2
Jan-May trawl fish.	Length	169	1.55	1.74	1.86	1.52	1.52	1.91	2.00	1.50	1.51
Jun-Dec trawl fish.	Length	42	1.96	2.07	2.12	1.99	1.94	1.97	1.97	1.97	1.94
longline fishery	Length	191	1.58	1.57	1.61	1.79	1.80	1.54	1.56	1.74	1.76
pot fishery	Length	100	2.33	2.29	2.40	2.44	2.45	2.31	2.45	2.55	2.57
pre-82 shelf survey	Length	100	0.72	0.70	0.69	0.64	0.64	0.57	0.56	0.54	0.54
post-81 shelf survey	Length	104	1.11	1.12	1.11	0.93	0.93	1.08	1.07	0.93	0.93
slope survey	Length	23	5.00	4.68	5.85	10.27	9.91	5.56	6.98	11.21	10.65
Japan LL survey	Length	140	n/a	n/a	n/a	n/a	n/a	1.22	1.19	1.23	1.23
U.S. LL survey	Length	88	n/a	n/a	n/a	n/a	n/a	2.17	2.21	1.95	2.12
post-81 shelf survey	Age	94	0.63	0.62	0.61	0.60	0.60	0.61	0.61	0.62	0.61

Two points should be noted regarding the shelf survey length composition components: 1) The true input sample sizes for the pre-1982 portion of the time series are unknown, so the assumed value of 100 is only a guess. 2) To avoid double-counting, results for the post-1981 shelf survey length composition component do not include years for which age data are available.

Evaluation Criteria

The values of the various components of the objective function are often fairly close across models, or involve tradeoffs that make it difficult to choose one model over another. The same conclusion holds for the effective sample sizes associated with the length and age composition data. Because all of the models seem to perform reasonably well in terms of fitting the data, the following criteria are therefore proposed:

1) The model should describe a plausible selectivity schedule for the post-1981 shelf trawl survey.
2) The model should not depend on data that require further validation before they can be considered ready for use in the stock assessment.
3) The model should converge well (e.g., not be too dependent on initial parameter estimates).
4) The model should not depend too strongly on the prior distributions.

Selection of Final Model

Criterion #1 argues against choosing Model 0. As Figure 2.5 shows, Model 0's selectivity schedule for the post-1981 shelf trawl survey shows a pronounced kink that is very difficult to justify on theoretical grounds. The eight alternative models all result in much more plausible selectivity schedules for this survey.

Criterion #2 argues against choosing Models C1, C2, D1, and D2, which are the models that utilize data from the Japanese longline survey and the U.S. longline survey. While it may be possible to develop usable indices from these surveys in the future, the present indices seem too problematic, for the following reasons: 1) the available abundance indices for Pacific cod (unlike those for sablefish) do not include appropriate area expansion factors, 2) the interannual variability in the available abundance indices from the Japanese longline survey is extreme, and 3) the sample size in the U.S. longline survey is small (only 11 stations have been successfully sampled in every year).

Criterion #3 argues against Models A2, B2, C2, and D2, which are the models with de-emphasized priors and that typically had to be initiated with the converged parameter estimates from their respective "full prior" counterparts in order to converge successfully. Also, the models that used the longline survey data (Models C1, C2, D1, and D2) had difficulty converging unless estimation of longline survey selectivity parameters was delayed until other parameters had been estimated (i.e., moved to a later phase).

Criterion #4 argues against Model A1. Using relative change in estimated 2006 spawning biomass as an indicator of sensitivity, Model A1 is seen to be much more sensitive to the emphasis assigned to the prior distributions than any of the other "full prior" models (Models B1, C1, and D1). The relative change in 2006 spawning biomass between Model A1 (full prior) and Model A2 (de-emphasized prior) was 16%, compared to -3%, 3%, and -2% for the relative changes between Models B1 and B2, C1 and C2, and D1 and D2, respectively.

By process of elimination, then, Model B1 is therefore recommended as the preferred model. If Model A1, which has many more parameters, were to have given results substantially different from Model B1, it might be argued that Model B1 is under-parameterized. However, results from Models A1 and B1 are fairly similar, indicating that the more parsimonious parameterization used in Model B1 does not cause the model to overlook key details. It may also be noted that Model B2 gives results extremely similar to those from Model B1, suggesting that this model could also be a viable candidate, particularly in a future assessment if further work confirms the stability of the model when less informative priors are specified. Another consideration pertaining to future assessment work is that Model B1 may have potential to overcome some of the past difficulties encountered in attempting to estimate *M* and *Q* for Pacific cod using models based on the double logistic selectivity function.

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 Model B1 are shown in Table 2.16. Another scalar parameter estimated by SS2 is the equilibrium fishing mortality rate at the start of the time series, which had a value of 0.075 in Model B1.

Estimates of year-, season-, and gear-specific fishing mortality rates from Model B1 are shown in Table 2.18, estimates of regime-specific median recruitments and annual recruitment deviations from Model B1 are shown in Table 2.19, and estimates of selectivity parameters from Model B1 are shown in Table 2.20.

Schedules of selectivity at length from Model B1 are shown for the commercial fisheries in Table 2.21a and for the bottom trawl surveys in Table 2.21b. The schedules in Tables 2.21a and 2.21b are plotted in Figure 2.6.

Schedules of length at age, proportion mature at age, and weight at age from Model B1 are shown in Table 2.22.

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 2.23 shows the time series of EBS (not expanded to BSAI) 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 under Model B1. Both estimated time series are accompanied by their respective 95% confidence intervals.

The estimated EBS female spawning biomass time series and confidence intervals from Model B1 are shown, together with the Model B1's estimated time series of EBS age 3+ biomass, in Figure 2.7. Figure 2.7 also compares the observed and model-estimated time series from the EBS shelf bottom trawl survey. All three biomass trends estimated by Model B1 are fairly flat from about 1992 through about 2004, but all three show a declining trend for at least the last couple of years.

Recruitment

Table 2.24 shows the time series of EBS (not expanded to BSAI) Pacific cod age 0 recruitment (1000s of fish) for the years 1977-2005 as estimated last year under the Plan Team's and SSC's preferred model and this year under Model B1. Both estimated time series are accompanied by their respective 95% confidence intervals.

Model B1's recruitment estimates for the entire time series (1964-2005) are shown in Figure 2.8, along with their respective 95% confidence intervals and regime-specific averages. For the time series as a whole, the largest year classes appear to have been the 1976-1977 cohorts. Other large cohorts include the 1978, 1982, 1984, 1989, 1992, 1996, and 1999 year classes. Of the five classes spawned immediately after the strong 1999 year class, however, none have 95% confidence intervals that extend above the 1977-2005 average. One potential bright spot on the horizon is the 2005 year class, whose point estimate is just below the 1977-2005 average. However, its confidence interval is fairly large, since the only data currently available to estimate its strength is the size composition data from the 2006 shelf 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 2.9 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 2.25 shows the time series of EBS 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 under Model B1.

The average value of this ratio over the entire time series is about 0.12, slightly less than the average value of 0.13 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, whereas none of the estimated values exceed the average in any year prior to 1990. This finding is similar to that obtained in past assessments.

Figure 2.10 plots the trajectory of relative fishing mortality and relative female spawning biomass from 1977 through 2006 based on Model B1, 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_{OFL} control rule except for the years 1977-1979. For the period since 1980, the entire trajectory also fell below the $maxF_{ABC}$ control rule, except for 1995 and 1997, when the fishing mortality rate appears to have exceeded the retroactively calculated $maxF_{ABC}$. It should also be noted that the current harvest control rules did not go into effect until 1999.

PROJECTIONS AND HARVEST ALTERNATIVES

Amendment 56 Reference Points

Amendment 56 to the BSAI 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 BSAI 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, based on Model B1:

Reference point:	$B_{35\%}$	$B_{40\%}$	$B_{100\%}$
BSAI:	280,000 t	320,000 t	800,000 t
EBS:	235,000 t	269,000 t	672,000 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 Model B1'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 31.0%, longline 58.8%, and pot 10.2%. This apportionment results in estimates of $F_{35\%}$ and $F_{40\%}$ equal to 0.42 and 0.34, respectively.

Specification of OFL and Maximum Permissible ABC

BSAI spawning biomass for 2007 is estimated by Model B1 at a value of 307,000 t (EBS value = 258,000 t). This is about 4% below the BSAI $B_{40\%}$ value of 320,000 t (EBS value = 269,000 t), thereby placing Pacific cod in sub-tier "b" of Tier 3. Given this, Model B1 estimates OFL, maximum permissible ABC, and the associated fishing mortality rates for 2007 as follows:

Quantity	Overfishing Level	Maximum Permissible ABC
EBS catch:	174,000 t	148,000 t
BSAI catch:	207,000 t	176,000 t
Fishing mortality rate:	0.39	0.33

The age 3+ biomass estimates for 2007 from Model B1 are 960,000 t and 807,000 t for the BSAI and EBS, respectively.

ABC Recommendation

Review of Past Approaches

BSAI Pacific cod ABCs for the years 1998-2002 were based on 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 and Dorn 1997, 1998, 1999). For the 2001-2002 ABCs, 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 and Dorn 2001). For the 2003 and 2004 ABCs, concerns regarding the performance of the assessment model led to a decision that kept ABC constant at the 2002 level of 223,000 t, well below the maximum permissible level estimated in the respective assessments (Thompson and Dorn 2002, 2003). In the 2004 assessment (Thompson and Dorn 2004), the maximum permissible value for the 2005 ABC was estimated to be 227,000 t, only slightly higher than the 2003-2004 ABCs of 223,000 t. Because the 2003-2004 "constant catch" ABCs were intended to provide a precautionary alternative to the model's maximum permissible ABCs, it seemed appropriate in the 2004 assessment to consider another method for recommending ABC. This method was based on a consideration of the mean-variance tradeoff associated with future catches predicted by the standard projection model, and resulted in a 2005 ABC of 206,000 t. In the 2005 assessment, the Plan Team and SSC selected a model that resulted in a maximum permissible ABC of 194,000 t, which was adopted as the 2006 ABC.

Recommendation for 2007

Based on Model B1, the maximum permissible ABC (Tier 3b) for 2007 is 176,000 t. To provide some context for this value, the time series of ABCs for the 16 years following 1990 shows that ABC has ranged from a low of 164,500 t to a high of 328,000 t, with an average of about 221,000 t, (Table 2.4). A 2007 ABC of 176,000 t would be the second lowest ABC since 1990, and the decrease from the 2006 ABC (14,000 t) would represent the seventh largest one-year decrease in the time series since 1990. Given the magnitude of this decrease and the fact that it follows immediately on the heels of two consecutive decreases of similar magnitude, there does not seem to be any compelling reason to recommend an ABC lower than the maximum permissible value for 2007. Therefore, 176,000 t is the recommended ABC for 2007. It should be noted that all models considered in this year's assessment, including Model B1, project the maximum permissible ABC to continue declining for at least the next couple of years while the weak 2000-2004 year classes work their way through the age structure.

Area Allocation of Harvests

At present, ABC of BSAI Pacific cod is not allocated by area. However, the Council is presently considering the possibility of specifying separate harvests in the EBS and AI.

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*: In all future years, F is set equal to a constant fraction of *max* F_{ABC}, where this fraction is equal to the ratio of the F_{ABC} value for 2007 recommended in the assessment to the *max* F_{ABC} for 2007. (Rationale: When F_{ABC} is set at a value below *max* F_{ABC}, it is often set at the value recommended in the stock assessment.)
>
> *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 Model B1 in Tables 2.26-2.31 (Table 2.26 combines scenarios 1 and 2, which are redundant).

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 2.17 contains the appropriate one- and two-year ahead projections for both ABC and OFL under any of the nine models considered in the present assessment.

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 2.30). 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 2.31):

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 BSAI Pacific cod, spawning biomass for 2007 is estimated to be above $B_{35\%}$ under Model B1. Therefore, the stock is above its MSST and is not overfished. Mean spawning biomass for 2009 in Table 2.31 is above ½ $B_{35\%}$ but below $B_{35\%}$, and mean spawning biomass for 2019 is above $B_{35\%}$. Therefore, the stock is not approaching an overfished condition.

ECOSYSTEM CONSIDERATIONS

Attachment 2.1 contains a summary of new results from ecosystem models on the role of Pacific Cod in the Eastern Bering Sea and Aleutian Islands ecosystems. 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 EBS Pacific cod associated with the 1977 regime shift. According to Model B1, pre-1977 median recruitment was only about 31% of post-1976 median recruitment. Establishing a link between environment and recruitment within a particular regime is more difficult. In the 2004 assessment (Thompson and Dorn 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 2.32a and 2.32b show bycatch for the EBS Pacific cod trawl fishery in 1997-2002 and 2003-2005, respectively. Tables 2.33a and 2.33b show bycatch for the EBS Pacific cod longline fishery in 1997-2002 and the EBS Pacific cod hook and line fishery in 2003-2005, respectively. Tables 2.34a and 2.34b show bycatch for the EBS Pacific cod pot fishery in 1997-2002 and 2003-2005, respectively. Tables 2.35a and 2.35b show bycatch for the AI Pacific cod trawl fishery in 1997-2002 and 2003-2005, respectively. Tables 2.36a and 2.36b show bycatch for the AI Pacific cod longline fishery in 1997-2002 and the AI Pacific cod hook and line fishery in 2003-2005, respectively. Tables 2.37 shows bycatch for the AI Pacific cod pot fishery in 1997-2002 (no data exist for this fishery in 2003-2005).

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).

Area	Species group	Trawl	Hook and Line
EBS	Grenadier		X
EBS	Large sculpins	X	X
EBS	Misc. fish	X	
EBS	Other sculpins		X
EBS	Shark		X
EBS	Skate		X
AI	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 2.33b and 2.36b). 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 catchability and 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 2.38.

ACKNOWLEDGMENTS

Jim Stark provided maturity data. Bob Lauth, Gary Walters, Dan Nichol, and Mark Wilkins provided trawl survey data. Chris Lunsford and Cara Rodgveller provided longline survey data. Chris Johnston and Delsa Anderl provided age data. Andy Smoker, Josh Keaton, Steve Kocsis, and Mary Furuness provided fishery data. Angie Greig provided fishery data and produced Figure 2.1. David Ackley, Sarah Gaichas, and Terry Hiatt provided bycatch data. Jim Ianelli answered provided assistance with ADMB and wrote the projection model. Rick Methot, David Sampson, and Mark Maunder provided advice on SS2. Anne Hollowed and the BSAI Groundfish Plan Team provided reviews of this assessment. Many NMFS survey personnel and countless fishery observers collected most of the raw data that were used in this assessment.

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Table 2.1a—Summary of 1964-1980 catches (t) of Pacific cod in the Eastern Bering Sea by fleet sector. Catches by gear are not available for these years. Catches may not always include discards.

Eastern Bering Sea only:

Year	Foreign	Joint Venture	Domestic	Total
1964	13408	0	0	13408
1965	14719	0	0	14719
1966	18200	0	0	18200
1967	32064	0	0	32064
1968	57902	0	0	57902
1969	50351	0	0	50351
1970	70094	0	0	70094
1971	43054	0	0	43054
1972	42905	0	0	42905
1973	53386	0	0	53386
1974	62462	0	0	62462
1975	51551	0	0	51551
1976	50481	0	0	50481
1977	33335	0	0	33335
1978	42512	0	31	42543
1979	32981	0	780	33761
1980	35058	8370	2433	45861

Table 2.1b—Summary of 1981-2005 catches (t) of Pacific cod in the Eastern Bering Sea by fleet sector and gear type. All catches include discards. LLine = longline, Subt. = sector subtotal. Catches for 2006 are through early October.

Eastern Bering Sea only:

	Foreign			Joint Venture		Domestic Annual Processing					
Year	Trawl	LLine	Subt.	Trawl	Subt.	Trawl	LLine	Pot	Other	Subt.	Total
1981	30347	5851	36198	7410	7410	12884	1	0	14	12899	56507
1982	23037	3142	26179	9312	9312	23893	5	0	1715	25613	61104
1983	32790	6445	39235	9662	9662	45310	4	21	569	45904	94801
1984	30592	26642	57234	24382	24382	43274	8	0	205	43487	125103
1985	19596	36742	56338	35634	35634	51425	50	0	0	51475	143447
1986	13292	26563	39855	57827	57827	37646	48	62	167	37923	135605
1987	7718	47028	54746	47722	47722	46039	1395	1	0	47435	149903
1988	0	0	0	106592	106592	93706	2474	299	0	96479	203071
1989	0	0	0	44612	44612	119631	13935	145	0	133711	178323
1990	0	0	0	8078	8078	115493	47114	1382	0	163989	172067
1991	0	0	0	0	0	129392	76734	3343	0	209469	209469
1992	0	0	0	0	0	77259	80174	7512	33	164978	164978
1993	0	0	0	0	0	81790	49295	2098	2	133185	133185
1994	0	0	0	0	0	84931	78566	8037	730	172264	172264
1995	0	0	0	0	0	110956	97665	19275	599	228496	228496
1996	0	0	0	0	0	91910	88882	28006	267	209064	209064
1997	0	0	0	0	0	93924	117008	21493	173	232598	232598
1998	0	0	0	0	0	60780	84323	13232	192	158526	158526
1999	0	0	0	0	0	51902	81463	12399	100	145865	145865
2000	0	0	0	0	0	53815	81640	15849	68	151372	151372
2001	0	0	0	0	0	35655	90360	16385	52	142452	142452
2002	0	0	0	0	0	51065	100269	15051	166	166552	166552
2003	0	0	0	0	0	47580	106967	21957	155	176659	176659
2004	0	0	0	0	0	57784	109692	17238	231	184945	184945
2005	0	0	0	0	0	52604	112994	17104	104	182807	182807
2006	0	0	0	0	0	54844	88254	17578	78	158753	158753

Table 2.2a—Summary of 1964-1980 catches (t) of Pacific cod in the Aleutian Islands region by fleet sector. Catches by gear are not available for these years. Catches may not always include discards.

Aleutian Islands region only:

Year	Foreign	Joint Venture	Domestic	Total
1964	241	0	0	241
1965	451	0	0	451
1966	154	0	0	154
1967	293	0	0	293
1968	289	0	0	289
1969	220	0	0	220
1970	283	0	0	283
1971	2078	0	0	2078
1972	435	0	0	435
1973	977	0	0	977
1974	1379	0	0	1379
1975	2838	0	0	2838
1976	4190	0	0	4190
1977	3262	0	0	3262
1978	3295	0	0	3295
1979	5593	0	0	5593
1980	5788	0	0	5788

Table 2.2b—Summary of 1981-2006 catches (t) of Pacific cod in the Aleutian Islands region by fleet sector and gear type. All catches include discards. LLine = longline, Subt. = sector subtotal. Catches for 2006 are through early October.

Aleutian Islands region only:

	Foreign			Joint Venture		Domestic Annual Processing					
Year	Trawl	LLine	Subt.	Trawl	Subt.	Trawl	LLine	Pot	Other	Subt.	Total
1981	2680	235	2915	1749	1749	2744	26	0	0	2770	7434
1982	1520	476	1996	4280	4280	2121	0	0	0	2121	8397
1983	1869	402	2271	4700	4700	1459	0	0	0	1459	8430
1984	473	804	1277	6390	6390	314	0	0	0	314	7981
1985	10	829	839	5638	5638	460	0	0	0	460	6937
1986	5	0	5	6115	6115	784	1	1	0	786	6906
1987	0	0	0	10435	10435	2662	22	88	0	2772	13207
1988	0	0	0	3300	3300	1698	137	30	0	1865	5165
1989	0	0	0	6	6	4233	284	19	0	4536	4542
1990	0	0	0	0	0	6932	602	7	0	7541	7541
1991	0	0	0	0	0	3414	3203	3180	0	9797	9797
1992	0	0	0	0	0	14558	22108	6317	84	43068	43068
1993	0	0	0	0	0	17312	16860	0	33	34204	34204
1994	0	0	0	0	0	14382	7009	147	0	21539	21539
1995	0	0	0	0	0	10574	4935	1024	0	16534	16534
1996	0	0	0	0	0	21179	5819	4611	0	31609	31609
1997	0	0	0	0	0	17349	7151	575	89	25164	25164
1998	0	0	0	0	0	20531	13771	424	0	34726	34726
1999	0	0	0	0	0	16437	7874	3750	69	28130	28130
2000	0	0	0	0	0	20362	16183	3107	33	39684	39684
2001	0	0	0	0	0	15826	17817	544	19	34207	34207
2002	0	0	0	0	0	27929	2865	7	0	30801	30801
2003	0	0	0	0	0	31478	974	2	0	32455	32455
2004	0	0	0	0	0	25766	3099	0	0	28865	28865
2005	0	0	0	0	0	19613	3001	0	13	22627	22627
2006	0	0	0	0	0	19843	3214	189	6	23252	23252

Table 2.3a—Summary of 1964-1980 catches (t) of Pacific cod in the combined Eastern Bering Sea and Aleutian Islands region by fleet sector. Catches by gear are not available for these years. Catches may not always include discards.

Eastern Bering Sea and Aleutian Islands region combined:

Year	Foreign	Joint Venture	Domestic	Total
1964	13649	0	0	13649
1965	15170	0	0	15170
1966	18354	0	0	18354
1967	32357	0	0	32357
1968	58191	0	0	58191
1969	50571	0	0	50571
1970	70377	0	0	70377
1971	45132	0	0	45132
1972	43340	0	0	43340
1973	54363	0	0	54363
1974	63841	0	0	63841
1975	54389	0	0	54389
1976	54671	0	0	54671
1977	36597	0	0	36597
1978	45807	0	31	45838
1979	38574	0	780	39354
1980	40846	8370	2433	51649

Table 2.3b—Summary of 1981-2006 catches (t) of Pacific cod in the combined Eastern Bering Sea and Aleutian Islands region by fleet sector and gear type. All catches include discards. LLine = longline, Subt. = sector subtotal. Catches for 2006 are through early October.

Eastern Bering Sea and Aleutian Islands region combined:

	Foreign			Joint Venture		Domestic Annual Processing					
Year	Trawl	LLine	Subt.	Trawl	Subt.	Trawl	LLine	Pot	Other	Subt.	Total
1981	33027	6086	39113	9159	9159	15628	27	0	14	15669	63941
1982	24557	3618	28175	13592	13592	26014	5	0	1715	27734	69501
1983	34659	6847	41506	14362	14362	46769	4	21	569	47363	103231
1984	31065	27446	58511	30772	30772	43588	8	0	205	43801	133084
1985	19606	37571	57177	41272	41272	51885	50	0	0	51935	150384
1986	13297	26563	39860	63942	63942	38430	49	63	167	38709	142511
1987	7718	47028	54746	58157	58157	48701	1417	89	0	50207	163110
1988	0	0	0	109892	109892	95404	2611	329	0	98344	208236
1989	0	0	0	44618	44618	123864	14219	164	0	138247	182865
1990	0	0	0	8078	8078	122425	47716	1389	0	171530	179608
1991	0	0	0	0	0	132806	79937	6523	0	219266	219266
1992	0	0	0	0	0	91818	102282	13829	117	208046	208046
1993	0	0	0	0	0	99102	66155	2098	35	167389	167389
1994	0	0	0	0	0	99313	85575	8184	730	193802	193802
1995	0	0	0	0	0	121530	102600	20299	599	245029	245029
1996	0	0	0	0	0	113089	94701	32617	267	240673	240673
1997	0	0	0	0	0	111273	124159	22068	262	257762	257762
1998	0	0	0	0	0	81310	98094	13657	192	193253	193253
1999	0	0	0	0	0	68339	89337	16150	169	173995	173995
2000	0	0	0	0	0	74177	97823	18956	101	191056	191056
2001	0	0	0	0	0	51482	108177	16929	71	176659	176659
2002	0	0	0	0	0	78994	103134	15058	166	197352	197352
2003	0	0	0	0	0	79059	107941	21959	156	209114	209114
2004	0	0	0	0	0	83550	112790	17239	231	213810	213810
2005	0	0	0	0	0	72217	115995	17104	117	205434	205434
2006	0	0	0	0	0	74687	91468	17767	84	182005	182005

Table 2.4—History of Pacific cod ABC, TAC, total BSAI catch, and type of stock assessment model used to recommend ABC. Catch for 2006 is current through early October. “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	148,000	70,700	45,947	projection of 1979 survey numbers at age
1981	160,000	78,700	63,941	projection of 1979 survey numbers at age
1982	168,000	78,700	69,501	projection of 1979 survey numbers at age
1983	298,200	120,000	103,231	projection of 1979 survey numbers at age
1984	291,300	210,000	133,084	projection of 1979 survey numbers at age
1985	347,400	220,000	150,384	projection of 1979-1985 survey numbers at age
1986	249,300	229,000	142,511	separable age-structured model
1987	400,000	280,000	163,110	separable age-structured model
1988	385,300	200,000	208,236	separable age-structured model
1989	370,600	230,681	182,865	separable age-structured model
1990	417,000	227,000	179,608	separable age-structured model
1991	229,000	229,000	219,266	separable age-structured model
1992	182,000	182,000	208,046	SS1 model (age-based data)
1993	164,500	164,500	167,389	SS1 model (length-based data)
1994	191,000	191,000	193,802	SS1 model (length-based data)
1995	328,000	250,000	245,029	SS1 model (length-based data)
1996	305,000	270,000	240,673	SS1 model (length-based data)
1997	306,000	270,000	257,762	SS1 model (length-based data)
1998	210,000	210,000	193,253	SS1 model (length-based data)
1999	177,000	177,000	173,995	SS1 model (length-based data)
2000	193,000	193,000	191,056	SS1 model (length-based data)
2001	188,000	188,000	176,659	SS1 model (length-based data)
2002	223,000	200,000	197,352	SS1 model (length-based data)
2003	223,000	207,500	209,114	SS1 model (length-based data)
2004	223,000	215,500	213,810	SS1 model (length-based data)
2005	206,000	206,000	164,404	SS1 model (length- and age-based data)
2006	194,000	194,000	182,005	SS2 model (length- and age-based data)

Table 2.5a—Pacific cod discard rates by area, target species/group, and year for the period 1991-2002 (see Table 2.5b 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.

Eastern Bering Sea

Target species/group	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Arrowtooth flounder	0.61	0.00	0.94		0.66	0.08	0.07	1.00	1.00	0.99	1.00	0.22
Atka mackerel	1.00		0.70	1.00		0.23		0.51	0.00	0.00	1.00	
Flathead sole					0.39	0.58	0.10	0.75	0.87	0.75	0.00	1.00
Greenland turbot	0.01	0.00	0.12	0.04	0.35	0.09	0.03	0.04	0.13	0.10	0.01	0.18
Other flatfish	0.63	0.31	0.47	0.88	0.22	0.28	0.91	0.28	0.33	0.32	0.00	0.00
Other species	0.04	0.99	0.38		1.00	1.00	0.01	0.95	0.07	0.92	0.08	0.00
Pacific cod	0.03	0.04	0.08	0.06	0.07	0.04	0.03	0.02	0.01	0.02	0.01	0.02
Pollock	0.70	0.85	0.73	0.68	0.21	0.41	0.24	0.42	0.49	0.68	0.84	0.52
Rock sole	1.00	0.00	0.08	0.87	0.25	0.90		1.00	0.02	0.16	1.00	1.00
Rockfish	1.00	0.00	0.89	0.01	0.84	0.69	0.16		0.00	0.03	0.00	0.00
Sablefish	0.00	0.12	0.42	0.40	0.96	0.94	0.78	0.93	0.61	0.98	0.12	0.48
Unknown	0.00	1.00	1.00	1.00	1.00	1.00	1.00	0.49	0.04	0.02		
Yellowfin sole		0.74	0.72	0.50	0.08	1.00	0.24	0.77	0.50	0.60	0.39	0.77
All targets	0.03	0.04	0.08	0.06	0.07	0.04	0.03	0.02	0.01	0.02	0.01	0.02

Aleutian Islands

Target species/group	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Arrowtooth flounder	1.00										0.00	0.00
Atka mackerel								1.00		1.00	1.00	1.00
Flathead sole		0.35										
Greenland turbot	0.11	0.00	0.73	0.58	0.40	0.89	0.04	0.01	0.18	0.40	0.00	0.00
Other species		1.00			0.00				0.14	0.08	0.00	0.06
Pacific cod	0.02	0.03	0.12	0.09	0.04	0.04	0.05	0.02	0.02	0.02	0.01	0.02
Pollock	0.76	0.00	0.29	0.00	0.47	0.74	0.75	0.61	0.00			
Rock sole			0.00									
Rockfish	0.83		0.75	0.28	0.18	0.80	0.91	1.00	0.64	0.12	0.22	0.03
Sablefish	1.00	0.04	0.49	0.52	0.97	0.53	0.70	0.88	0.51	0.31	0.06	0.76
Unknown	0.09				1.00	1.00		0.03		1.00	1.00	
All targets	0.04	0.03	0.12	0.09	0.12	0.04	0.06	0.02	0.02	0.02	0.01	0.02

Table 2.5b—Pacific cod discard rates by area, target species/group, and year for the period 2003-2004 (see Table 2.5a for the period 1991-2002; note that the IFQ halibut target does not exist in Table 2.5a). 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.

	Eastern Bering Sea			Aleutian Islands	
Target species/group	2003	2004		2003	2004
Arrowtooth flounder	0.01	0.00			
Atka mackerel	0.02	0.00		0.03	0.02
Flathead sole	0.00	0.02			
Greenland turbot	0.07	0.05		0.00	
IFQ halibut	0.28	0.28		0.58	0.38
Other flatfish	0.02	0.00			
Other species	0.02	0.04		0.00	
Pacific cod	0.01	0.01		0.01	0.01
Pollock	0.00	0.02			
Rock sole	0.08	0.03		0.11	
Rockfish	0.00	0.00		0.00	0.02
Sablefish	0.44	0.03		0.37	0.06
Unknown					
Yellowfin sole	0.06	0.02			
All targets	0.02	0.01		0.01	0.01

Table 2.6a—EBS catch (t) of Pacific cod by year, gear, and period for the years 1964-1980. Because direct estimates of gear- and period-specific catches are not available for these years, the figures shown here are estimates derived by distributing each year's total catch according to the average proportion observed for each gear/period combination during the years 1981-1988.

Year	Trawl Fishery			Longline Fishery			Pot Fishery		
	Period 1	Period 2	Period 3	Period 1	Period 2	Period 3	Period 1	Period 2	Period 3
1964	6007	2469	2759	744	105	1324	0	0	0
1965	6595	2711	3028	817	115	1453	0	0	0
1966	8154	3352	3744	1011	142	1797	0	0	0
1967	14366	5905	6597	1780	250	3166	0	0	0
1968	25942	10663	11913	3215	452	5718	0	0	0
1969	22559	9272	10359	2796	393	4972	0	0	0
1970	31404	12908	14421	3892	547	6922	0	0	0
1971	19289	7929	8858	2391	336	4252	0	0	0
1972	19223	7901	8827	2382	335	4237	0	0	0
1973	23918	9831	10984	2964	417	5272	0	0	0
1974	27985	11503	12851	3468	487	6168	0	0	0
1975	23096	9493	10606	2862	402	5091	0	0	0
1976	22617	9296	10386	2803	394	4985	0	0	0
1977	14935	6139	6858	1851	260	3292	0	0	0
1978	19710	8101	9051	2443	343	4344	0	0	0
1979	16131	6630	7407	1999	281	3555	0	0	0
1980	18387	7558	8444	2279	320	4053	0	0	0

Table 2.6b—EBS catch (t) of Pacific cod by year, gear, and period for the years 1981-2006. Period 3 catch values for 2006 are extrapolations based on the average values from the previous three years.

Year	Trawl Fishery			Longline Fishery			Pot Fishery		
	Period 1	Period 2	Period 3	Period 1	Period 2	Period 3	Period 1	Period 2	Period 3
1981	15067	14087	21486	1286	624	3942	0	0	0
1982	21742	18151	16348	363	475	2308	0	0	0
1983	40757	24300	22705	2941	748	2756	0	0	0
1984	48237	24964	25045	5012	2128	19508	0	0	0
1985	55673	28673	22310	13703	1710	21379	0	0	0
1986	59786	26598	22382	8895	438	17278	0	0	0
1987	64413	15604	21462	20947	723	26752	0	0	0
1988	127470	25662	47166	444	646	1385	90	51	160
1989	127459	16986	19798	3810	4968	5157	33	63	49
1990	101645	11402	10524	13171	16643	17299	0	986	395
1991	107979	15549	5863	25470	21472	29792	12	1042	2288
1992	59460	11840	5959	49696	24201	6276	2622	4632	258
1993	67148	5362	9280	49244	27	23	2073	24	0
1994	61009	5806	18115	57968	13	20585	4923	0	3113
1995	90366	8543	12047	68458	26	29180	12484	3469	3322
1996	78194	3126	10590	62011	26	26845	18143	6401	3462
1997	81313	3927	8684	70676	43	46290	14584	3576	3333
1998	45008	5603	10169	54234	18	30071	9022	2779	1432
1999	44904	3312	3686	55180	1923	24360	9346	1001	2052
2000	44508	4578	4730	40180	1375	40086	15742	0	107
2001	22849	7025	5781	38368	6700	45291	11645	442	4298
2002	37008	9554	4503	50024	12132	38113	10852	401	3799
2003	34515	9986	3079	53156	11032	42773	15452	74	6586
2004	42181	12407	3197	56050	10459	43183	12560	521	4388
2005	45014	6664	926	53556	12773	46665	12147	0	4957
2006	46045	5966	926	51072	14564	46665	14333	0	4957

Table 2.7a--Length frequencies of Pacific cod in the pre-1989 trawl fisheries, by year, season (S), and length bin. N = input sample size.

Yr.	S	N	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
1974	1	8	0	0	0	0	0	0	0	0	0	1	4	0	7	9	13	8	5	1	2	1	1	4	1	1	0
1974	3	10	0	0	0	0	0	0	0	0	0	0	1	3	13	16	39	19	3	4	1	0	0	0	0	0	0
1975	1	16	0	0	0	0	0	0	0	4	10	16	19	20	33	31	29	30	30	15	9	3	0	2	2	0	0
1975	2	8	0	0	0	0	0	0	0	1	2	3	1	1	1	0	2	2	3	16	13	11	0	0	1	1	0
1977	1	19	0	0	0	0	0	0	3	9	36	79	35	9	15	26	25	53	32	17	11	4	1	3	0	0	0
1977	2	42	0	0	0	0	0	0	0	0	6	12	22	39	40	273	331	367	355	188	104	38	12	3	2	0	0
1977	3	12	0	0	0	0	0	0	0	0	3	7	22	33	13	10	7	10	15	12	6	1	1	3	1	0	0
1978	1	23	0	0	0	1	1	0	1	0	3	16	19	73	220	103	29	19	13	4	5	4	0	1	2	0	0
1978	3	56	0	0	0	0	0	6	35	79	37	21	19	5	62	387	999	882	337	159	81	37	13	2	0	0	0
1979	1	39	0	0	0	0	0	0	1	21	45	94	204	315	329	77	122	147	144	37	5	4	3	1	1	0	0
1979	3	27	0	0	0	0	0	0	0	3	5	24	74	150	220	78	38	47	58	31	14	4	0	0	0	1	1
1980	1	91	0	0	0	0	0	0	2	36	75	235	635	1014	1560	1038	971	714	497	632	485	197	86	49	17	5	2
1980	2	9	0	0	0	0	0	0	0	0	0	0	0	0	1	16	45	8	3	0	0	0	0	0	0	0	0
1980	3	18	0	0	0	0	0	0	0	1	0	0	9	16	33	78	69	53	29	6	8	6	2	0	1	0	0
1981	1	12	0	0	0	0	0	0	0	0	0	0	0	8	33	44	40	22	5	0	0	0	0	0	0	0	0
1981	2	69	0	0	0	1	2	3	10	71	398	675	423	365	1109	1006	448	152	34	13	1	0	0	0	0	0	0
1981	3	38	0	0	0	0	0	0	0	2	1	0	2	7	21	111	315	353	284	179	103	27	13	7	2	0	0
1982	1	63	0	0	0	0	0	2	1	6	58	113	64	73	294	386	518	729	731	534	241	104	51	41	21	3	3
1982	2	17	0	0	0	0	0	0	0	0	0	2	1	10	22	18	26	50	48	40	34	21	6	5	3	1	0
1982	3	41	0	0	0	0	0	0	1	0	0	1	4	27	70	143	215	196	302	346	215	90	18	9	5	1	0
1983	1	101	0	0	0	0	0	1	1	50	154	93	95	176	492	758	1626	2344	2071	1307	644	211	77	36	21	12	6
1983	2	37	0	0	0	0	0	1	0	1	4	15	42	71	77	81	200	284	248	186	83	28	6	3	4	0	0
1983	3	120	0	0	0	0	1	15	24	26	15	8	35	205	421	508	1450	1996	2482	2430	2220	1546	742	272	64	21	5
1984	1	128	0	1	2	1	0	15	194	401	367	220	105	223	709	779	1264	2262	3195	2930	2027	1039	434	144	24	13	2
1984	2	97	0	1	4	51	201	206	313	556	455	357	339	305	679	695	891	1109	959	817	597	453	312	120	41	8	1
1984	3	65	0	0	0	0	0	7	21	15	114	434	372	190	140	126	235	375	502	506	437	363	210	92	29	11	0
1985	1	173	0	0	2	0	4	0	2	39	116	257	720	1752	2234	1079	1388	2440	4999	5563	4288	2630	1385	594	221	67	23
1985	2	35	0	0	0	0	0	0	0	3	24	74	68	119	404	256	66	35	39	58	46	23	9	5	7	2	1
1985	3	41	0	0	0	0	0	0	0	1	0	5	43	104	389	168	98	63	144	212	187	148	76	39	2	0	0
1986	1	169	0	4	16	8	34	60	118	249	635	761	683	783	2228	3560	3287	2095	2631	3469	3357	2442	1346	454	168	58	17
1986	2	26	0	0	0	0	0	0	7	2	2	3	5	7	15	62	92	72	67	95	98	84	46	30	8	4	0
1986	3	38	0	0	0	0	0	0	2	1	13	15	25	24	69	111	153	184	209	156	179	133	92	59	22	4	5
1987	1	202	0	0	3	13	15	58	192	440	477	592	1161	2054	3898	2890	3326	5470	5461	4306	3650	3106	1953	1076	440	198	63
1987	2	74	0	0	0	0	0	1	2	5	9	4	8	22	116	204	333	592	974	1093	720	525	385	248	133	68	25
1987	3	141	0	0	0	0	0	0	0	0	6	10	56	60	198	929	1639	1957	2591	3113	2678	2055	1930	1548	802	306	53
1988	1	310	1	0	1	1	6	29	92	580	1448	1956	2185	4311	11135	10599	10194	9103	10096	12012	10395	5807	3010	1686	814	346	92
1988	3	54	0	0	0	0	0	0	0	0	5	0	13	52	257	326	284	348	348	373	332	305	166	56	20	6	6

Table 2.7b--Length frequencies of Pacific cod in the 1989-1999 trawl fisheries, by year, season (S), and length bin. N = input sample size.

Yr.	S	N	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	241	0	0	3	3	1	0	28	217	494	795	720	954	3110	4341	4654	5664	7033	8561	8246	6265	3826	1867	919	388	144
1989	3	18	0	0	0	0	1	6	7	13	32	53	48	30	82	32	6	0	0	0	0	0	0	0	0	0	0
1990	1	253	0	0	3	4	14	84	308	708	942	885	712	536	1141	2564	4397	7314	9868	10274	9356	6385	4171	2251	1266	477	167
1990	2	88	0	0	0	0	0	0	0	1	1	2	5	14	69	268	622	834	1200	1191	1248	1042	582	420	184	77	29
1990	3	10	0	0	0	0	0	0	0	0	1	0	1	2	1	7	6	8	39	10	13	7	6	1	0	0	0
1991	1	296	0	1	5	6	15	70	457	1224	1325	1224	1283	1704	5124	6055	6459	9063	12143	12515	10775	7626	5003	2893	1509	759	278
1991	2	33	1	0	1	1	2	2	5	7	11	20	16	16	60	94	166	142	135	146	92	87	77	30	3	1	2
1992	1	258	0	3	9	15	21	67	200	625	1278	1577	2356	4432	8944	6722	6052	5900	6847	6025	5515	4074	2723	1624	910	400	179
1993	1	264	0	0	5	8	23	56	251	1142	1629	1723	4421	7656	11477	9881	9348	6655	4288	3408	2771	2000	1334	840	479	211	94
1993	2	7	0	0	0	3	0	0	1	3	5	1	5	6	10	7	8	1	1	0	0	1	0	0	0	0	0
1993	3	10	0	0	0	0	0	1	0	0	0	2	3	2	21	17	15	12	10	3	2	1	1	1	0	2	0
1994	1	314	0	1	2	4	24	106	610	2147	3791	3226	1929	2963	9871	14218	14269	11410	11301	9353	5752	3408	2074	1165	677	340	177
1995	1	253	0	0	12	28	38	91	158	281	361	664	2571	5781	9060	5920	6982	8042	8517	6661	3825	2204	1332	735	367	191	64
1995	3	26	0	0	0	0	0	0	0	0	0	0	26	24	65	79	40	17	36	63	67	91	57	51	41	8	2
1996	1	314	1	6	13	25	26	49	359	1048	1295	1080	1083	2352	8627	14582	13606	9698	10723	11524	9049	5953	3376	2027	1044	535	294
1996	2	22	0	0	0	0	0	0	2	2	5	10	11	35	110	149	94	28	12	7	8	3	2	0	0	0	0
1996	3	57	0	0	0	0	0	0	1	0	3	1	13	50	124	127	268	318	283	277	286	406	405	358	199	92	32
1997	1	306	1	4	17	80	98	69	307	1205	2289	2311	1741	1976	7253	8302	11127	15435	15210	10904	6382	4004	2558	1334	664	289	125
1997	2	17	0	1	0	4	5	1	4	4	8	8	12	13	31	42	38	34	20	24	15	8	2	1	0	0	0
1998	1	312	0	1	7	4	7	114	747	1448	1360	1037	925	1462	5621	6684	7605	11929	17524	18355	11124	5592	2697	1589	876	390	170
1998	2	54	0	0	0	0	1	0	1	1	37	66	81	63	195	425	588	526	382	237	195	78	20	20	14	12	9
1998	3	46	0	0	0	0	0	0	1	2	3	14	38	67	169	253	355	285	246	178	144	115	69	47	47	27	11
1999	1	190	3	0	1	6	5	8	104	409	383	338	991	2416	4722	2851	2939	3653	4745	4814	3466	2205	1092	536	219	103	52
1999	2	12	0	0	0	0	0	0	0	0	0	0	1	5	29	23	27	25	14	7	8	2	2	1	0	0	0
1999	3	27	0	0	0	0	0	0	0	1	1	0	1	15	40	87	118	93	100	78	61	52	40	24	20	8	3

Table 2.7c--Length frequencies of Pacific cod in the post-1999 trawl fisheries, by year, season (S), and length bin. N = input sample size.

Yr.	S	N	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	183	0	0	0	2	2	6	60	174	157	229	508	965	2756	3992	4293	3995	3965	4098	3229	2219	1353	750	383	182	85
2000	2	17	0	0	0	0	0	0	1	4	2	4	13	18	40	76	66	31	14	4	3	6	1	0	0	0	0
2000	3	8	0	0	0	0	0	0	0	0	0	0	0	0	3	13	20	12	8	6	3	0	1	1	0	0	0
2001	1	130	0	0	2	1	3	4	8	29	87	158	103	155	887	1372	1853	2785	2985	2416	1535	1115	679	424	186	93	39
2001	2	52	0	0	5	12	10	14	5	10	23	57	91	81	211	507	430	379	344	233	124	60	59	30	30	14	2
2001	3	36	0	0	0	0	0	1	2	8	12	8	21	33	80	108	202	206	202	169	101	59	26	13	6	5	1
2002	1	154	0	0	0	5	12	25	71	315	518	514	453	571	1671	1935	2020	3362	4287	3786	2177	1011	478	219	102	44	24
2002	2	67	0	0	0	6	8	3	12	68	201	263	305	288	415	593	740	524	387	229	175	124	57	35	18	8	3
2002	3	49	0	0	0	0	0	0	0	1	10	9	60	143	245	250	346	264	226	240	203	182	118	54	26	11	3
2003	1	157	0	0	2	4	1	2	5	82	266	333	355	647	1786	1867	2066	2749	3703	4240	3047	1799	895	379	170	78	30
2003	2	91	0	1	0	1	2	3	9	24	44	141	217	266	683	1106	1035	1046	1069	886	704	509	281	116	37	18	7
2003	3	44	0	0	0	0	0	0	0	0	0	1	7	31	94	190	200	221	225	246	237	232	156	92	35	7	1
2004	1	139	0	1	1	0	1	0	4	56	216	332	316	282	1295	2226	2490	2955	2947	2331	1575	998	535	339	197	113	48
2004	2	82	0	0	2	4	1	12	57	106	103	93	106	154	301	582	730	791	734	665	623	586	461	290	169	66	16
2004	3	39	0	0	0	0	0	0	0	0	0	0	3	14	55	103	198	169	134	133	164	219	161	94	61	11	1
2005	1	151	0	0	0	1	9	10	15	108	255	339	298	277	954	1579	2362	3351	4138	3778	2360	1496	809	466	220	90	34
2005	2	57	0	0	0	0	0	0	1	5	10	27	46	69	127	228	307	340	372	396	415	371	255	162	73	39	14
2005	3	14	0	0	0	0	0	0	0	0	0	0	1	8	16	20	17	22	28	21	16	14	13	2	5	1	0
2006	1	151	0	0	1	4	13	7	11	60	194	313	342	373	1219	1877	2123	2542	3157	3364	2784	2040	1238	621	285	83	55
2006	2	20	0	0	0	0	0	0	1	0	3	9	6	9	16	37	28	28	35	36	37	51	50	42	13	7	0

Table 2.8a--Length frequencies of Pacific cod in the pre-1989 longline fisheries, by year, season (S), and length bin. N = input sample size.

Yr.	S	N	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	1	54	0	0	0	0	0	0	0	0	1	4	23	124	623	812	435	269	216	160	110	58	36	7	7	0	0
1978	2	59	0	0	0	0	0	0	0	0	0	0	3	2	78	444	1093	783	436	328	170	64	30	6	1	1	0
1978	3	49	0	0	0	0	0	0	0	0	0	0	2	0	54	344	719	770	275	94	49	32	16	7	2	0	0
1979	1	99	0	0	0	0	0	0	0	8	83	377	683	434	337	1135	2126	2432	1356	465	233	128	56	27	3	6	0
1979	2	48	0	0	0	0	0	0	0	0	2	14	49	90	155	93	302	604	628	274	74	33	14	3	3	0	0
1979	3	53	0	0	0	0	0	0	0	0	0	4	11	51	252	263	195	401	705	605	220	44	11	9	2	0	0
1980	1	51	0	0	0	0	0	0	0	0	5	15	66	212	591	604	320	182	199	244	111	36	11	4	0	0	0
1980	2	37	0	0	0	0	0	0	0	0	0	0	1	29	169	334	293	185	148	140	67	17	4	2	0	0	0
1980	3	54	0	0	0	0	0	0	0	0	0	0	1	18	235	558	679	652	350	194	138	76	25	5	0	1	0
1981	1	47	0	0	0	0	5	18	7	7	10	0	18	48	285	496	448	335	197	153	89	70	36	9	4	0	0
1981	2	36	0	0	0	0	0	0	0	0	2	1	8	29	88	160	265	292	228	108	35	32	24	3	1	0	0
1981	3	36	0	0	0	0	0	0	0	0	0	0	0	2	8	86	230	318	300	220	89	29	15	2	0	1	0
1982	1	42	0	0	0	0	0	0	0	1	0	9	13	18	131	184	266	334	314	211	101	61	44	31	10	1	1
1982	2	32	0	0	0	0	0	0	0	0	0	9	42	17	98	190	128	161	130	117	74	38	11	5	3	2	0
1982	3	69	0	0	0	0	0	0	0	1	0	1	14	33	92	235	460	773	1149	1066	614	235	77	27	6	2	2
1983	1	132	0	0	0	0	0	0	0	0	3	16	48	170	1116	1525	2035	2732	3421	3065	1838	792	334	163	88	36	7
1983	2	61	0	0	0	0	0	0	0	0	1	2	14	13	91	319	383	504	623	675	505	355	150	50	18	10	0
1983	3	98	0	0	0	0	0	0	1	0	0	0	4	28	129	459	1162	1260	1544	1776	1561	991	476	148	37	9	6
1984	1	122	0	0	0	0	0	1	0	6	19	40	41	46	416	800	1323	2414	3163	3015	2012	1015	437	155	70	24	6
1984	2	100	0	0	0	0	0	2	0	0	2	7	14	17	102	376	750	1602	2167	1873	1405	891	567	203	59	16	3
1984	3	289	0	0	0	0	0	0	1	3	14	55	293	764	1721	2467	6595	12255	15779	15982	12816	8397	4192	1528	407	91	24
1985	1	189	0	0	0	0	0	0	0	1	12	34	186	550	1367	958	1828	3877	7018	8009	5977	3362	1591	537	175	44	7
1985	2	73	0	0	0	0	0	0	0	0	0	1	3	28	246	368	206	418	775	1000	823	590	429	245	105	23	2
1985	3	362	0	0	0	0	0	1	0	0	4	23	116	605	5449	16095	14240	10594	17780	24998	19637	11586	6071	2786	920	215	51
1986	1	182	0	0	0	0	0	0	0	8	30	81	121	385	1765	3055	3578	3014	3739	5900	5622	3348	1554	654	237	63	13
1986	2	37	0	0	0	0	0	0	0	0	0	0	0	1	15	94	247	306	175	162	205	104	60	24	13	0	0
1986	3	325	0	0	0	0	0	0	0	0	0	18	158	616	2233	5154	14368	23612	20725	10897	10483	9006	4991	2308	881	326	85
1987	1	304	0	0	0	0	0	2	0	5	18	88	425	1362	4950	5219	8337	14661	16709	12862	11421	9132	4689	1828	519	180	31
1987	2	17	0	0	0	0	0	0	0	0	0	0	0	0	7	24	25	55	79	51	28	11	13	3	1	0	0
1987	3	420	0	0	0	3	0	0	0	3	9	30	147	593	4503	18418	29582	24338	25914	28336	20972	10694	6630	3800	1532	414	134

Table 2.8b--Length frequencies of Pacific cod in the 1990-1999 longline fisheries, by year, season (S), and length bin. N = input sample size.

Yr.	S	N	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	137	0	0	0	0	0	0	0	0	0	0	4	12	162	780	1688	2789	3515	3071	2482	1587	1215	721	480	217	92
1990	2	273	0	0	0	0	0	0	6	6	23	55	131	225	769	2356	5901	10124	12987	12636	10206	7291	5046	3238	2168	884	314
1990	3	246	0	0	0	0	0	0	1	3	1	12	18	56	347	1624	5113	9278	11494	10815	8609	5752	3410	2028	1269	583	277
1991	1	226	0	0	0	0	0	0	0	4	14	29	113	299	1018	2340	4652	8431	10647	8943	6336	3565	2133	1203	739	298	130
1991	2	260	0	0	0	0	0	0	0	2	2	10	32	137	742	2079	4500	7909	10294	11451	10371	8410	5876	3153	1759	787	288
1991	3	291	0	0	0	1	3	18	33	38	58	107	185	396	1533	3750	6541	10028	12271	13086	12430	9961	6816	3885	2249	1012	418
1992	1	366	0	0	0	2	0	3	5	40	85	291	1131	3030	9842	13958	14564	17640	20796	18195	13121	9376	5922	3322	1814	790	289
1992	2	313	0	0	0	0	3	2	3	21	64	161	492	1076	5712	11463	11718	12967	13825	11925	8736	6950	5221	3594	2221	1219	418
1992	3	142	0	0	0	0	0	0	0	1	6	19	52	154	765	2375	2564	2390	2741	2412	1943	1595	1267	897	565	298	106
1993	1	348	0	0	1	0	1	6	14	70	172	414	1409	3110	9108	17361	23321	20379	14246	10806	7984	5839	3584	1934	827	412	110
1993	2	6	0	0	0	0	0	0	0	0	0	0	0	0	1	1	5	3	7	3	5	8	4	2	0	0	3
1994	1	391	0	0	0	3	3	12	20	28	78	183	490	1300	6598	16608	27623	35676	29844	16422	7682	4388	2661	1679	824	412	142
1994	3	203	0	0	0	0	0	0	2	6	11	57	140	236	745	2605	5322	7663	8939	6760	3892	2084	1192	745	449	260	120
1995	1	372	0	0	0	2	5	6	13	22	55	181	1053	3021	8157	13821	23425	29986	28142	17330	7399	2940	1396	712	363	193	88
1995	2	10	0	0	0	0	0	0	0	0	0	0	0	0	0	4	10	19	15	8	11	12	9	5	4	0	0
1995	3	258	0	0	0	0	0	0	2	21	24	47	210	515	2857	6911	7994	9242	11222	10274	7535	4520	2508	1391	804	387	130
1996	1	385	0	0	0	0	0	0	1	14	49	146	521	1512	8322	18562	24961	27766	26151	19048	11119	5431	2445	1204	669	296	143
1996	3	271	0	0	0	0	0	1	0	4	14	83	180	390	1523	5326	11475	14333	11034	8119	7117	5751	4074	2259	1041	424	128
1997	1	413	0	0	0	0	0	1	4	17	79	204	521	1612	8223	16931	29230	38525	33998	19962	10360	5475	3087	1386	557	194	67
1997	2	10	0	0	0	0	0	0	0	0	0	0	1	1	4	6	18	18	15	16	5	8	6	4	4	3	1
1997	3	380	0	0	1	2	3	13	20	89	160	288	621	1673	4814	9358	15198	20854	26965	25031	17322	8992	6073	3677	1977	853	361
1998	1	354	0	0	0	0	0	4	4	33	134	287	731	2105	6959	11401	16819	24275	25752	18942	9790	4249	1912	1021	418	149	72
1998	2	8	0	0	0	0	0	0	0	0	1	1	1	6	22	4	9	7	4	1	2	3	0	2	1	0	0
1998	3	416	1	0	0	1	32	22	46	45	88	333	1755	3717	8601	13692	20625	25081	28930	26157	19469	12038	6147	3232	1938	810	349
1999	1	276	0	0	0	2	2	0	4	22	54	208	1211	3601	8274	8267	9798	11745	11498	9679	6032	3123	1326	630	268	133	85
1999	2	96	0	0	0	0	0	0	0	0	6	13	44	130	943	1449	1164	1218	1260	1111	757	531	305	162	69	34	12
1999	3	217	1	0	0	0	0	1	10	27	61	112	361	666	3565	7611	6607	6008	6435	5846	4012	2777	1598	836	371	187	93

Table 2.8c--Length frequencies of Pacific cod in the post-1999 longline fisheries, by year, season (S), and length bin. N = input sample size.

Yr.	S	N	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	230	2	0	0	0	0	1	5	15	47	175	600	1419	5881	9645	9944	8241	6755	4738	2758	1403	687	275	140	51	16
2000	2	83	0	0	0	0	0	0	0	0	0	3	6	19	182	529	1058	1597	1244	869	581	408	213	135	52	26	5
2000	3	294	1	8	0	0	0	1	2	4	8	39	354	1166	3906	9291	15331	19838	15390	8759	5366	3308	1934	1055	497	187	83
2001	1	251	0	0	0	0	2	2	5	22	108	320	469	1018	4563	8794	12111	13587	10723	5665	2800	1399	697	376	164	84	37
2001	2	139	0	0	0	0	0	0	2	5	19	54	116	253	1037	2488	3593	3782	3560	2460	1007	455	207	110	64	25	11
2001	3	296	0	0	0	1	4	0	5	17	43	176	873	1854	5294	9164	14663	16806	16030	12007	5533	2478	1156	645	373	150	67
2002	1	261	1	2	5	5	7	14	20	85	183	312	1043	2684	6143	7166	10284	14302	12797	7764	3051	1276	571	325	230	49	29
2002	2	176	0	0	0	0	1	2	3	27	74	185	327	633	2559	4528	5121	5225	5107	3549	2070	918	401	213	104	57	11
2002	3	291	2	0	0	0	0	2	17	49	159	415	1029	2250	7432	12148	13736	13588	12757	9996	5814	2857	1239	546	220	97	46
2003	1	308	0	0	2	0	3	1	9	40	233	528	1469	3627	10878	15728	16306	15084	13262	9552	4839	2150	775	312	123	53	14
2003	2	192	0	0	0	0	0	1	1	5	10	54	185	571	2478	5601	7083	6687	5653	4235	2311	1204	532	214	102	31	7
2003	3	321	1	0	0	0	0	0	0	4	23	91	269	1181	6401	13746	18801	18771	16306	12049	7757	4265	1892	740	287	116	42
2004	1	279	0	1	0	0	2	0	2	8	55	155	330	954	4834	10937	16754	18365	12760	6674	3390	1713	703	268	112	43	13
2004	2	180	0	0	0	0	0	1	0	0	10	20	46	198	1044	2832	5247	6471	6058	4522	2648	1749	873	383	122	48	10
2004	3	297	1	0	0	1	1	3	4	22	49	162	366	929	3948	8110	12938	17249	16959	12732	7120	4017	2145	938	356	111	31
2005	1	259	0	0	0	1	0	2	5	27	84	199	528	1157	3953	6466	9408	13667	14874	10195	3945	1517	699	279	100	24	7
2005	2	195	0	0	0	1	1	1	0	5	13	22	110	255	1271	2649	4075	5289	6464	6344	4951	3257	1789	966	364	89	17
2005	3	293	1	0	2	1	4	4	12	24	60	149	395	1018	4544	7970	11523	12325	12264	11915	10011	6756	3633	1984	776	249	58
2006	1	236	0	0	0	0	1	0	0	10	37	116	270	570	2898	7229	9183	9466	8979	7718	5164	2524	981	409	164	55	18
2006	2	133	0	0	0	0	0	0	0	1	1	7	53	156	615	1485	2169	2284	2261	1992	1820	1838	1471	956	470	175	42
2006	3	77	0	0	0	0	0	0	0	0	0	3	28	48	137	305	510	914	916	1027	633	490	376	268	154	67	15

Table 2.9a--Length frequencies of Pacific cod in the 1989-1999 pot fisheries, by year, season (S), and length bin. N = input sample size.

Yr.	S	N	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	2	39	0	0	0	0	0	0	0	0	0	0	0	1	7	43	75	141	234	296	227	230	139	82	45	3	3
1990	3	76	0	0	0	0	0	0	0	0	0	0	0	1	3	10	116	512	1149	1146	1360	701	391	260	109	12	2
1991	2	82	0	0	0	0	0	0	0	0	0	0	0	0	39	237	545	975	1298	1315	991	681	329	189	59	16	4
1991	3	85	0	0	0	0	0	0	0	0	0	0	0	6	26	149	382	712	1193	1508	1424	911	491	262	124	45	21
1992	1	115	0	0	0	0	0	1	0	1	0	8	6	21	158	365	685	1747	3468	2854	1768	966	608	321	203	81	29
1992	2	137	0	0	0	0	0	0	1	2	5	34	82	275	1412	2419	2362	2726	2928	2376	1560	1066	685	425	196	96	37
1992	3	57	0	0	0	0	0	0	0	0	2	21	68	117	472	751	618	458	364	192	66	71	40	29	11	2	0
1993	1	112	0	0	0	0	0	0	0	0	0	0	9	29	350	923	1763	2384	2259	1983	1278	757	441	265	111	50	18
1994	1	170	0	0	0	0	0	0	0	0	0	1	21	126	758	3052	4939	5352	5172	3937	2601	1415	801	457	268	122	31
1994	3	80	0	0	0	0	0	0	0	0	5	3	10	25	152	576	1095	1255	1050	808	601	364	229	136	71	39	16
1995	1	220	0	0	0	0	0	0	0	0	1	4	48	251	1255	3298	7553	10763	9549	6607	4013	2228	1338	782	377	163	76
1995	2	117	0	0	0	0	0	0	0	0	0	0	4	33	399	793	1579	2527	2468	1815	1343	982	672	479	295	152	67
1995	3	102	0	0	0	0	0	0	0	0	0	1	0	10	225	676	1158	1822	2056	1587	1041	749	504	296	156	80	21
1996	1	271	0	0	0	0	0	3	5	11	14	39	84	251	2216	6984	11621	13669	13851	10926	6386	3538	1904	1173	638	285	103
1996	2	131	0	0	0	0	0	0	0	0	1	1	4	23	243	1085	2558	3219	2777	2079	1602	1361	928	642	362	193	103
1996	3	106	0	0	0	0	0	0	0	0	0	2	5	25	176	463	982	1875	1950	1478	1042	979	921	686	408	212	79
1997	1	212	0	0	0	0	1	0	0	1	3	15	39	83	667	2211	5414	10164	11131	7151	3776	1877	1043	633	398	187	84
1997	2	123	0	0	0	0	0	0	0	1	5	2	7	22	219	858	1793	3043	3852	2334	1129	683	423	312	180	105	56
1997	3	108	0	0	0	0	0	0	0	1	0	1	7	22	163	453	972	1661	2418	2501	1431	702	473	390	266	140	69
1998	1	185	0	0	0	0	1	0	0	0	2	4	19	105	855	1837	3037	6318	8140	6974	3987	1684	650	424	183	90	44
1998	2	98	0	0	0	0	0	0	0	0	0	0	5	12	175	615	1121	1527	1977	1864	1172	578	290	198	82	39	19
1998	3	56	0	0	0	0	0	0	0	1	0	3	8	10	67	235	356	534	603	615	380	167	91	39	40	23	16
1999	1	131	0	0	0	0	0	0	1	2	2	6	15	100	855	1329	2031	3154	3317	2836	1784	971	458	255	96	46	20
1999	2	30	0	0	0	0	0	0	0	0	0	0	2	7	52	105	117	174	152	121	69	48	28	9	4	3	2
1999	3	61	0	0	0	0	0	0	0	0	0	1	3	16	93	456	637	500	560	543	295	235	141	90	49	36	29

Table 2.9b--Length frequencies of Pacific cod in the post-1999 pot fisheries, by year, season (S), and length bin. N = input sample size.

Yr.	S	N	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	144	0	0	0	0	0	0	0	1	2	1	12	97	867	2375	3670	3687	3366	3027	1827	1028	482	215	95	34	17
2000	3	14	0	0	0	0	0	0	0	0	0	0	0	0	3	26	62	67	27	13	3	0	1	0	0	0	0
2001	1	121	0	0	1	0	0	0	0	0	0	0	3	13	230	791	2183	3947	3814	2027	848	341	190	106	48	17	7
2001	2	21	0	0	0	0	0	0	0	0	0	0	0	0	0	12	45	77	103	93	61	33	5	7	4	6	1
2001	3	80	0	0	0	0	0	0	2	2	1	4	3	11	130	528	1140	1279	1374	977	435	263	160	98	40	19	6
2002	1	105	0	0	0	0	0	0	0	0	0	1	4	15	131	600	1554	2841	2843	1781	765	297	134	78	39	20	14
2002	2	19	0	0	0	0	0	0	0	0	0	0	1	2	3	20	45	72	65	62	41	32	9	12	2	0	1
2002	3	79	0	0	0	0	0	1	0	0	0	0	5	26	165	578	1237	1348	1021	726	482	311	144	107	43	19	11
2003	1	111	0	0	0	0	0	0	0	2	3	3	6	54	267	766	1391	2203	2788	2360	1328	655	259	97	41	19	9
2003	3	88	0	0	0	0	0	0	0	0	1	0	2	19	236	920	1472	1403	1227	951	607	449	291	153	60	26	4
2004	1	94	0	0	0	0	0	0	0	0	0	0	1	15	253	895	1493	1870	1709	1185	668	375	188	105	43	17	5
2004	2	18	0	0	0	0	0	0	0	0	0	0	0	0	2	22	53	56	60	46	32	15	16	18	3	0	0
2004	3	77	0	0	0	0	0	0	1	2	2	2	4	18	105	510	1039	1101	904	660	420	389	330	188	127	47	14
2005	1	86	0	0	0	0	0	0	0	0	1	0	6	13	119	426	1088	1709	1600	1117	554	309	180	118	62	26	4
2005	3	80	0	0	0	0	1	0	0	1	0	2	7	14	114	434	1006	1308	1117	719	459	374	294	207	155	92	41
2006	1	107	0	0	0	0	0	0	0	0	0	2	7	8	218	767	1610	2346	2473	1783	1022	610	324	175	104	44	19
2006	3	56	0	0	0	0	0	0	0	0	0	0	0	2	68	252	557	557	546	357	248	189	131	96	84	47	27

Table 2.10a--Length frequencies of Pacific cod in the 1979-1981 EBS shelf trawl survey, by year and length bin. N = input sample size.

Yr.	S	N	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
1979	2	100	0	5	44	186	374	457	694	1764	2393	1884	1171	618	202	70	44	51	29	8	0	3	1	1	0	0	0
1980	2	100	0	6	85	241	82	42	224	687	929	1320	1542	2062	1364	893	333	100	33	31	19	6	2	0	0	0	0
1981	2	100	0	20	156	330	278	32	100	330	653	724	511	1063	1396	1746	1215	812	398	156	39	27	13	1	0	0	0

Table 2.10b--Length frequencies of Pacific cod in the post-1981 EBS shelf trawl survey, by year and length bin. N = input sample size.

Yr.	S	N	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
1982	2	103	17	97	234	148	37	28	132	403	766	750	416	520	1512	1326	1288	1178	874	474	210	90	29	9	4	0	0
1983	2	115	393	1396	1289	622	147	32	135	370	551	380	209	393	1367	1289	1341	1128	921	650	325	151	31	19	4	1	0
1984	2	110	70	129	82	142	282	920	1653	1712	1041	485	249	261	536	579	864	961	880	590	381	173	94	38	9	1	0
1985	2	130	162	540	964	1537	1761	664	298	595	880	942	1154	1528	1879	678	480	543	687	674	496	253	111	38	17	5	0
1986	2	124	154	465	501	154	114	692	1775	1908	1585	1083	553	425	1069	1338	1203	628	416	453	370	264	119	74	21	13	0
1987	2	103	18	69	250	398	267	185	440	899	779	606	617	957	1478	827	598	654	632	413	211	166	71	49	16	7	0
1988	2	100	8	49	76	88	109	233	279	384	641	625	491	660	1418	1306	1114	849	570	420	293	244	74	32	25	7	4
1989	2	100	24	154	298	205	70	34	82	87	139	348	339	366	871	1193	1294	1143	945	858	666	338	247	145	90	62	0
1990	2	75	201	488	699	355	133	122	249	292	321	276	175	123	194	223	346	419	283	266	182	128	82	33	26	11	3
1991	2	85	131	389	432	369	229	272	620	898	932	631	346	193	301	312	250	215	207	178	110	112	49	20	22	7	2
1992	2	98	18	456	517	698	556	435	854	1075	856	542	451	622	915	546	242	222	176	103	97	86	51	37	28	15	3
1993	2	102	114	924	1088	981	677	213	247	614	847	666	489	615	1071	665	399	267	230	85	62	48	37	20	23	14	6
1994	2	-118	19	145	291	363	326	445	956	1922	2081	1121	444	522	1216	961	1059	920	565	288	92	46	34	60	16	22	9
1995	2	96	30	73	135	208	77	173	460	691	579	705	1064	1233	1360	616	434	484	326	253	132	84	40	27	19	9	3
1996	2	-97	14	65	164	198	110	103	357	699	677	526	499	744	1477	1404	908	499	288	237	148	109	71	25	16	7	3
1997	2	-96	91	473	601	728	507	140	215	481	628	451	407	399	919	809	842	583	436	215	105	60	40	26	10	4	1
1998	2	-98	30	262	334	74	46	311	1151	1837	1396	655	379	367	659	458	378	391	333	244	132	64	33	29	9	10	1
1999	2	-108	71	334	286	113	141	415	760	874	667	718	1169	1648	1854	768	493	447	337	252	132	89	62	37	24	7	2
2000	2	-112	175	918	1310	505	54	141	488	785	604	564	749	958	1720	1419	894	537	266	188	99	79	57	33	19	3	0
2001	2	-141	95	646	1828	2113	1010	408	903	1990	2543	1614	705	486	1192	1277	1077	818	514	257	123	71	34	22	14	4	5
2002	2	-111	31	190	374	352	105	209	664	1459	1449	1005	792	1216	1578	878	609	545	367	208	103	49	19	16	15	3	2
2003	2	-111	19	283	633	774	682	489	182	252	682	837	974	1192	1974	1218	770	516	340	261	142	86	35	14	2	1	0
2004	2	-104	24	275	483	562	318	218	484	729	931	979	712	578	806	925	844	714	474	283	211	111	82	34	15	5	4
2005	2	-106	5	153	589	891	1017	1051	488	419	576	729	652	632	859	702	518	525	490	355	288	180	102	46	21	7	0
2006	2	110	478	1288	1076	885	317	165	266	605	754	867	707	533	729	856	643	494	395	321	259	238	144	76	35	14	3

Table 2.11—Age composition estimates from the 1994 and 1996-2005 EBS shelf bottom trawl surveys (expressed as numbers per 10,000).

Age	1994	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
1	536	32	2355	664	715	2240	2598	794	1487	1421	1834
2	4015	2306	1841	4546	1992	1162	2469	1869	1633	1622	2567
3	1844	2469	1737	2020	3090	1675	2052	3105	2546	2805	1880
4	1259	3568	1610	1137	2409	2476	941	2444	2212	1301	1387
5	1241	941	1225	589	806	1563	915	734	1220	1333	619
6	837	541	898	596	575	595	703	575	412	908	837
7	195	144	227	284	266	108	236	390	291	346	478
8	50	0	81	140	103	120	56	65	151	177	240
9	20	0	9	22	36	28	14	18	33	62	104
10	1	0	10	0	0	26	9	5	3	11	16
11	2	0	6	2	7	7	6	0	3	14	39
12+	0	0	0	0	0	0	1	1	7	0	0

Table 2.12a—Biomass, standard error, 95% confidence interval (CI), and population numbers of Pacific cod estimated by NMFS' annual bottom trawl survey of the EBS shelf, 1979-1981. All figures except population numbers are expressed in metric tons. Population numbers are expressed in terms of individual fish.

Year	Biomass	Standard Error	Lower 95% CI	Upper 95% CI	Numbers
1979	754,314	97,844	562,539	946,089	1,530,429,650
1980	905,344	87,898	733,063	1,077,624	1,084,147,540
1981	1,034,629	123,849	791,885	1,277,373	794,619,624

Table 2.12b—Biomass, standard error, 95% confidence interval (CI), and population numbers of Pacific cod estimated by NMFS' annual bottom trawl survey of the EBS shelf, 1982-2006. All figures except population numbers are expressed in metric tons. Population numbers are expressed in terms of individual fish.

Year	Biomass	Standard Error	Lower 95% CI	Upper 95% CI	Numbers
1982	1,012,856	73,588	867,151	1,158,562	583,715,842
1983	1,185,419	120,868	941,146	1,429,692	751,066,723
1984	1,048,595	63,643	922,583	1,174,608	680,914,697
1985	1,001,108	55,845	890,536	1,111,681	841,108,075
1986	1,117,774	69,604	979,957	1,255,590	838,123,105
1987	1,106,621	68,682	970,630	1,242,612	728,956,963
1988	959,000	76,265	807,996	1,110,004	508,065,276
1989	836,177	62,981	711,475	960,878	292,210,905
1990	691,255	51,455	589,375	793,136	423,835,267
1991	517,209	38,158	441,657	592,761	488,861,768
1992	551,369	45,780	460,725	642,013	601,795,262
1993	690,535	54,380	582,862	798,208	851,863,422
1994	1,368,120	250,044	868,032	1,868,209	1,237,758,281
1995	1,003,096	91,739	821,453	1,184,740	757,657,482
1996	890,793	87,552	717,439	1,064,146	609,304,214
1997	604,881	69,250	466,382	743,380	487,429,700
1998	558,419	45,182	468,960	647,879	537,278,347
1999	583,891	50,621	483,662	684,120	500,915,139
2000	528,466	43,037	443,253	613,679	481,358,109
2001	833,626	76,247	681,133	986,119	985,568,802
2002	618,680	69,082	480,516	756,845	566,471,072
2003	595,826	62,099	471,628	720,024	499,925,561
2004	596,464	35,191	526,787	666,142	424,075,921
2005	603,788	43,150	517,488	690,089	452,075,840
2006	517,698	28,341	461,583	573,813	393,993,981

Table 2.13--Length frequencies of Pacific cod in the 2002-2004 EBS slope trawl survey, by year and length bin. N = input sample size.

Yr.	S	N	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
2002	2	22	0	0	0	0	0	0	0	0	1	0	5	18	69	105	86	62	55	39	21	7	1	0	0	0	0
2004	2	23	0	0	0	0	0	0	0	0	0	1	1	2	32	94	114	128	93	44	10	7	3	2	0	0	0

Table 2.14a--Length frequencies of Pacific cod in the Japanese longline survey, by year and length bin. N = input sample size.

Yr.	S	N	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
1982	2	177	0	0	0	0	0	0	0	0	12	50	271	125	1445	2048	4054	4321	7416	4607	4400	1252	748	316	205	35	14
1983	2	170	0	0	0	0	0	0	0	0	0	5	17	37	514	2527	3062	4174	4691	4504	4104	2922	1419	509	231	86	17
1984	2	177	0	0	0	0	0	0	0	0	5	23	60	64	415	2000	3033	5608	6407	5018	3601	2452	1552	736	258	70	12
1985	2	193	0	0	0	0	0	0	0	0	2	7	90	508	3292	3157	2270	3822	5245	6049	5015	3205	2272	1302	699	164	17
1986	2	212	0	0	0	0	0	0	0	0	0	31	113	232	1598	4740	8267	8191	5006	4183	4372	3464	2518	1252	675	268	31
1987	2	210	0	0	0	0	0	0	0	0	0	1	13	104	1415	3570	4593	7155	9199	6638	3606	2650	2354	1590	846	339	64
1988	2	109	0	0	0	0	0	0	0	0	2	3	20	44	318	987	2114	2691	2146	1437	928	482	256	226	129	44	7
1989	2	140	0	0	0	0	0	0	0	0	0	0	8	34	183	825	1619	2611	3538	3735	2901	1788	1053	642	396	212	63
1990	2	89	0	0	0	0	0	0	0	0	0	0	0	7	59	292	701	1257	1655	1635	1008	650	314	168	85	29	11
1991	2	80	0	0	0	0	0	0	0	0	0	4	3	10	58	388	638	1053	1254	1130	712	496	313	164	101	24	11
1992	2	77	0	0	0	0	0	0	0	0	0	0	1	28	361	1024	967	1089	1116	656	344	192	109	52	35	11	8
1993	2	87	0	0	0	0	0	0	0	0	0	0	7	28	391	1051	1404	1996	1411	662	318	137	72	47	31	17	5
1994	2	100	0	0	0	0	0	0	0	0	0	0	2	16	176	716	1409	2645	2648	1532	526	164	67	32	20	8	5

Table 2.14b--Length frequencies of Pacific cod in the U.S. longline survey, by year and length bin. N = input sample size.

Yr.	S	N	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
1997	2	90	0	0	0	0	0	0	0	0	0	0	0	11	93	499	982	1531	2344	1691	598	186	87	50	36	10	3
1999	2	91	0	0	0	0	0	0	0	0	0	1	11	82	735	1107	1386	1712	1619	913	420	133	49	26	6	10	3
2001	2	96	0	0	0	0	0	0	0	0	0	0	9	26	216	681	1495	2077	2332	1490	522	169	63	21	10	9	1
2003	2	90	0	0	0	0	0	0	0	0	0	1	9	68	661	1694	1842	1905	1185	484	164	82	31	18	5	2	0
2005	2	74	0	0	0	0	0	0	0	0	0	0	8	26	123	522	855	1137	1195	902	448	207	72	34	4	2	1

Table 2.15—Japanese and U.S. longline survey abundance indices. Mean = average catch (in numbers of fish) per station. CV = coefficient of variation.

	Japanese Survey	
Year	Mean	CV
1982	315.31	0.14
1983	258.56	0.12
1984	250.72	0.10
1985	928.66	0.13
1986	1086.31	0.11
1987	540.19	0.17
1988	365.16	0.12
1989	1252.28	0.12
1990	686.03	0.15
1991	567.25	0.13
1992	208.00	0.19
1993	328.81	0.15
1994	439.16	0.18

	U.S. Survey	
Year	Mean	CV
1997	758.45	0.21
1999	718.73	0.24
2001	777.18	0.19
2003	733.73	0.22
2005	510.55	0.21

Table 2.16—Summary of key parameter estimates and objective function values from last year, from last year's model updated with new data (Model 0), and from eight alternative models.

Item	Last Yr.	Model0	ModelA1	ModelA2	ModelB1	ModelB2	ModelC1	ModelC2	ModelD1	ModelD2
Longline survey data:	excluded	excluded	excluded	excluded	excluded	excluded	included	included	included	included
Selectivity function:	dbl. log.	dbl. log.	dbl. log.	dbl. log.	dbl. nor.	dbl. nor.	dbl. log.	dbl. log.	dbl. nor.	dbl. nor.
Weight assigned to log priors:	1.0	1.0	1.0	0.5	1.0	0.5	1.0	0.5	1.0	0.5
sigmaR	0.69	0.62	0.63	0.65	0.62	0.61	0.61	0.61	0.59	0.59
ln(post76 Rmed)	13.50	13.53	13.60	13.69	13.62	13.61	13.51	13.53	13.51	13.49
ln(pre77 Rmed)-ln(post76 Rmed)	-1.31	-1.19	-1.21	-1.19	-1.18	-1.18	-1.23	-1.22	-1.21	-1.21
pre82 shelf trawl surv. catchability	1.00	1.00	0.90	0.87	0.97	0.99	1.10	1.19	1.24	1.28
post81 shelf trawl surv. catchability	1.00	1.00	0.61	0.55	0.57	0.59	0.67	0.66	0.68	0.70
post81 shelf trawl surv. sel. at 90 cm	0.55	0.64	0.95	0.93	1.00	1.00	0.98	0.99	1.00	1.00
pre82 shelf trawl surv. abund. ln(like)	n/a	0.92	0.71	0.30	0.40	0.42	0.64	0.33	0.36	0.36
post81 shelf trawl surv. abund. ln(like)	46.38	49.71	47.57	48.12	45.29	45.03	51.15	50.50	47.91	47.78
slope trawl surv. abund. ln(like)	0.59	0.28	0.29	0.27	0.22	0.24	0.31	0.31	0.25	0.26
Japan longline surv. abund. ln(like)	n/a	n/a	n/a	n/a	n/a	n/a	142.96	144.48	145.17	144.13
U.S. longline surv. abund. ln(like)	n/a	n/a	n/a	n/a	n/a	n/a	0.80	0.82	0.87	0.95
Jan-May trawl fishery size comp. ln(like)	296.21	273.60	270.37	265.18	266.07	266.46	275.08	270.60	272.81	273.41
Jun-Dec trawl fishery size comp. ln(like)	323.57	448.09	445.95	443.72	440.95	440.87	442.23	440.70	438.74	438.38
longline fishery size comp. ln(like)	571.88	587.42	585.81	578.79	489.07	488.12	587.37	583.33	479.77	478.73
pot fishery size comp. ln(like)	217.37	204.86	202.91	200.10	172.44	172.13	203.32	200.69	169.61	169.53
pre82 shelf trawl surv. size comp. ln(like)	n/a	36.96	35.97	34.80	35.18	35.19	42.11	40.72	40.65	40.68
post81 shelf trawl surv. size comp. ln(like)	246.86	177.66	173.33	175.54	188.30	187.76	179.23	179.31	194.69	194.47
slope trawl surv. size comp. ln(like)	3.65	3.54	3.83	3.36	1.17	1.16	3.30	2.87	1.13	1.13
Japan longline surv. size comp. ln(like)	n/a	n/a	n/a	n/a	n/a	n/a	103.83	104.18	89.62	89.21
U.S. longline surv. size comp. ln(like)	n/a	n/a	n/a	n/a	n/a	n/a	26.87	27.04	24.01	23.73
post81 shelf trawl surv. age comp. ln(like)	70.20	88.31	87.84	92.55	94.91	94.17	83.70	84.89	90.08	89.52
post81 shelf trawl surv. size-at-age ln(like)	204.14	411.36	386.15	376.58	420.83	422.62	397.94	394.23	433.58	435.53
recruitment ln(like)	29.48	30.17	30.22	29.37	30.04	30.18	31.32	31.09	31.54	31.62
log priors	106.56	79.87	87.48	115.76	18.59	19.85	87.76	108.82	24.07	26.35
log posterior (weighted sum of the above)	2,116.89	2,392.74	2,358.42	2,306.55	2,203.47	2,194.25	2,659.93	2,610.49	2,484.86	2,472.59

Table 2.17—Summary of management-related quantities as estimated last year, as estimated using last year's model updated with new data (Model 0), and as estimated by eight alternative models. 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.	Model0	ModelA1	ModelA2	ModelB1	ModelB2	ModelC1	ModelC2	ModelD1	ModelD2
Longline survey data:	excluded	excluded	excluded	excluded	excluded	excluded	included	included	included	included
Selectivity function:	dbl. log.	dbl. log.	dbl. log.	dbl. log.	dbl. nor.	dbl. nor.	dbl. log.	dbl. log.	dbl. nor.	dbl. nor.
Weight assigned to log priors:	1.0	1.0	1.0	0.5	1.0	0.5	1.0	0.5	1.0	0.5
BSAI total biomass 2005	1,073,901	1,130,968	1,264,702	1,425,857	1,318,952	1,291,488	1,108,749	1,134,506	1,119,163	1,099,939
BSAI total biomass 2006	n/a	979,815	1,110,143	1,257,202	1,169,095	1,145,140	966,200	990,648	982,092	965,839
BSAI female spawning biomass 2005	333,028	362,914	411,634	475,793	428,882	417,148	349,905	359,992	352,192	343,696
BSAI female spawning biomass 2006	**278,665**	322,305	370,004	429,826	388,571	378,228	311,854	321,839	315,130	307,879
BSAI female spawning biomass 2007	**246,178**	**247,860**	**289,029**	**337,705**	**306,790**	**298,766**	**241,216**	**249,661**	**245,508**	**240,106**
BSAI female spawning biomass 2008	**224,295**	**221,620**	**252,250**	**285,396**	**266,134**	**260,735**	**219,645**	**225,409**	**223,904**	**220,351**
Proportion of B100% in 2005	0.40	0.43	0.46	0.48	0.46	0.46	0.42	0.43	0.43	0.42
Proportion of B100% in 2006	**0.34**	0.38	0.41	0.44	0.42	0.42	0.38	0.38	0.38	0.38
Proportion of B100% in 2007	**0.33**	**0.34**	**0.37**	**0.40**	**0.38**	**0.38**	**0.33**	**0.34**	**0.34**	**0.34**
Proportion of B100% in 2008	**0.30**	**0.30**	**0.32**	**0.34**	**0.33**	**0.33**	**0.30**	**0.31**	**0.31**	**0.31**
BSAI ABC 2006 (Council adopted)	194,000	194,000	194,000	194,000	194,000	194,000	194,000	194,000	194,000	194,000
BSAI maxABC 2007 (from model)	**148,297**	**132,544**	**162,172**	**193,186**	**176,482**	**172,080**	**129,126**	**135,242**	**133,536**	**130,660**
BSAI maxABC 2008 (from model)	**121,390**	**104,447**	**121,971**	**135,858**	**130,876**	**129,146**	**105,690**	**108,732**	**109,609**	**108,618**
rel. change in ABC (2006 to 2007)	**-0.24**	**-0.32**	**-0.16**	**0.00**	**-0.09**	**-0.11**	**-0.33**	**-0.30**	**-0.31**	**-0.33**
rel. change in ABC (2007 to 2008)	**-0.18**	**-0.21**	**-0.25**	**-0.30**	**-0.26**	**-0.25**	**-0.18**	**-0.20**	**-0.18**	**-0.17**
BSAI OFL 2006 (Council adopted)	230,000	230,000	230,000	230,000	230,000	230,000	230,000	230,000	230,000	230,000
BSAI OFL 2007 (from model)	**176,135**	**156,515**	**190,609**	**225,845**	**206,861**	**201,918**	**152,651**	**159,669**	**157,630**	**154,438**
BSAI OFL 2008 (from model)	**144,805**	**123,719**	**143,934**	**159,624**	**154,061**	**152,162**	**125,285**	**128,756**	**129,736**	**128,709**
rel. change in OFL (2006 to 2007)	**-0.23**	**-0.32**	**-0.17**	**-0.02**	**-0.10**	**-0.12**	**-0.34**	**-0.31**	**-0.31**	**-0.33**
rel. change in OFL (2007 to 2008)	**-0.18**	**-0.21**	**-0.24**	**-0.29**	**-0.26**	**-0.25**	**-0.18**	**-0.19**	**-0.18**	**-0.17**

Table 2.18—Estimates of Pacific cod fishing mortality rates, expressed on an annual time scale (Model B1). 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	0.018	0.007	0.008	0.003	0.000	0.004			
1965	0.020	0.008	0.008	0.003	0.000	0.005			
1966	0.024	0.009	0.010	0.003	0.000	0.006			
1967	0.042	0.016	0.018	0.006	0.001	0.011			
1968	0.080	0.032	0.037	0.011	0.002	0.021			
1969	0.079	0.032	0.036	0.011	0.002	0.022			
1970	0.129	0.054	0.063	0.018	0.003	0.038			
1971	0.102	0.041	0.047	0.014	0.002	0.029			
1972	0.119	0.048	0.055	0.017	0.003	0.034			
1973	0.168	0.070	0.080	0.024	0.004	0.048			
1974	0.221	0.097	0.110	0.032	0.005	0.063			
1975	0.206	0.091	0.100	0.030	0.005	0.056			
1976	0.206	0.091	0.096	0.031	0.005	0.054			
1977	0.120	0.049	0.049	0.019	0.002	0.028			
1978	0.110	0.045	0.044	0.018	0.002	0.024			
1979	0.060	0.024	0.023	0.009	0.001	0.013			
1980	0.042	0.017	0.016	0.007	0.001	0.009			
1981	0.022	0.020	0.027	0.002	0.001	0.005			
1982	0.022	0.019	0.016	0.000	0.001	0.002			
1983	0.034	0.021	0.019	0.003	0.001	0.002			
1984	0.037	0.020	0.020	0.004	0.002	0.017			
1985	0.044	0.023	0.018	0.012	0.002	0.020			
1986	0.050	0.022	0.018	0.008	0.000	0.017			
1987	0.056	0.013	0.018	0.021	0.001	0.027			
1988	0.114	0.023	0.042	0.001	0.001	0.002			
1989	0.125	0.016	0.019	0.004	0.005	0.005	0.000	0.000	0.000
1990	0.110	0.012	0.011	0.013	0.019	0.020		0.001	0.000
1991	0.135	0.020	0.008	0.030	0.029	0.042	0.000	0.001	0.003
1992	0.090	0.018	0.009	0.074	0.040	0.010	0.004	0.008	0.000
1993	0.110	0.009	0.014	0.079	0.000	0.000	0.004	0.000	
1994	0.095	0.009	0.026	0.086	0.000	0.030	0.008		0.005
1995	0.133	0.013	0.017	0.096	0.000	0.043	0.018	0.006	0.005
1996	0.116	0.005	0.015	0.087	0.000	0.039	0.027	0.010	0.005
1997	0.122	0.006	0.013	0.100	0.000	0.070	0.022	0.006	0.005
1998	0.073	0.009	0.016	0.084	0.000	0.049	0.015	0.005	0.002
1999	0.074	0.006	0.006	0.089	0.003	0.039	0.016	0.002	0.004
2000	0.078	0.008	0.007	0.060	0.002	0.056	0.025		0.000
2001	0.037	0.011	0.008	0.052	0.009	0.059	0.017	0.001	0.006
2002	0.056	0.014	0.006	0.065	0.016	0.049	0.015	0.001	0.005
2003	0.051	0.014	0.004	0.068	0.015	0.055	0.021	0.000	0.009
2004	0.062	0.018	0.005	0.072	0.014	0.058	0.017	0.001	0.006
2005	0.070	0.010	0.001	0.074	0.019	0.071	0.017		0.008
2006	0.079	0.011	0.002	0.081	0.026	0.085	0.023		0.009

Table 2.19—Estimates of Pacific cod regime-specific median recruitments and recruitment deviations (Model B1). 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	12.443	-0.366
1965	12.443	-0.447
1966	12.443	-0.512
1967	12.443	-0.520
1968	12.443	-0.406
1969	12.443	-0.157
1970	12.443	-0.222
1971	12.443	-0.295
1972	12.443	-0.157
1973	12.443	0.433
1974	12.443	1.343
1975	12.443	-0.941
1976	12.443	2.296
1977	13.623	0.861
1978	13.623	0.398
1979	13.623	0.330
1980	13.623	-0.407
1981	13.623	0.263
1982	13.623	0.795
1983	13.623	-0.576
1984	13.623	0.575
1985	13.623	-0.489
1986	13.623	-0.553
1987	13.623	-0.776
1988	13.623	0.286
1989	13.623	0.514
1990	13.623	-0.035
1991	13.623	0.308
1992	13.623	0.384
1993	13.623	-0.603
1994	13.623	-0.187
1995	13.623	0.369
1996	13.623	0.484
1997	13.623	-0.126
1998	13.623	0.198
1999	13.623	0.407
2000	13.623	-0.254
2001	13.623	-0.387
2002	13.623	-0.462
2003	13.623	-0.546
2004	13.623	-0.809
2005	13.623	-0.009

Table 2.20—Estimates of Pacific cod selectivity parameters (Model B1). The first column lists the years defining the era for which the parameter values in that row are applicable. The eras for the commercial fisheries are 1964-1988, 1989-1999, and 2000-2006 (no eras *per se* are defined for the surveys, although separate shelf bottom trawl surveys are defined for the years prior to 1982 and after 1981). The second column lists the particular parameter being described. Four parameters define the shape of the selectivity function: the size at which selectivity first reaches a value of 1.0 ("*peak location*"), the logit transform of the region (within the range from *peak location* to the maximum length in the model) over which selectivity remains at a value of 1.0 ("logit(*peak width*)"), the log of the variance term in the ascending curve ("ln(*asc. variance*)"), and the log of the variance term in the descending curve ("ln(*des. variance*)"). See text for further description of these parameters and how they are used to define the selectivity function. The remaining columns correspond to the fishery or survey to which the values are applicable, using the following notation: TWL1 = January-May trawl fishery, TWL2 = June-December trawl fishery, LGL = longline fishery, POT = pot fishery, SRV1 = pre-1982 shelf trawl survey, SRV2 = post-1981 shelf trawl survey, and SRV3 = slope trawl survey.

Years	Parameter	TWL1	TWL2	LGL	POT
1964-1988	peak location	76.519	80.324	72.835	
1989-1999	peak location	79.197	78.482	69.926	70.626
2000-2006	peak location	81.159	83.026	66.386	66.059
1964-1988	logit(peak width)	-8.007	-0.040	-3.641	
1989-1999	logit(peak width)	-1.872	1.742	-0.446	0.040
2000-2006	logit(peak width)	-7.936	1.391	-2.728	-7.983
1964-1988	ln(asc. variance)	6.329	6.419	5.526	
1989-1999	ln(asc. variance)	6.373	6.303	5.336	5.135
2000-2006	ln(asc. variance)	6.283	6.558	5.294	4.746
1964-1988	ln(des. variance)	6.327	5.674	6.284	
1989-1999	ln(des. variance)	5.986	3.946	6.011	5.541
2000-2006	ln(des. variance)	6.427	3.800	6.729	7.392

Years	Parameter	SRV1	SRV2	SRV3
n/a	peak location	40.245	45.071	55.825
n/a	logit(peak width)	-8.842	3.678	-1.388
n/a	ln(asc. variance)	5.257	7.103	4.225
n/a	ln(des. variance)	7.034	2.670	5.555

Table 2.21a—Schedules of Pacific cod selectivities at length in the commercial fisheries as defined by final parameter estimates (Model B1). Lengths (cm) correspond to mid-points of size bins. Len. = length, FOR = 1964-1988, DOM = 1989-1999, NEW = 2000-2006.

	Jan-May Trawl Fishery			Jun-Dec Trawl Fishery			Longline Fishery			Pot Fishery	
Len.	FOR	DOM	NEW	FOR	DOM	NEW	FOR	DOM	NEW	DOM	NEW
10.5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13.5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16.5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
19.5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22.5	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
25.5	0.01	0.01	0.00	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00
28.5	0.02	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00
31.5	0.03	0.02	0.01	0.02	0.02	0.02	0.00	0.00	0.00	0.00	0.00
34.5	0.04	0.03	0.02	0.03	0.03	0.04	0.00	0.00	0.01	0.00	0.00
37.5	0.07	0.05	0.03	0.05	0.05	0.05	0.01	0.01	0.02	0.00	0.00
40.5	0.10	0.08	0.05	0.08	0.07	0.08	0.02	0.02	0.03	0.00	0.00
43.5	0.14	0.11	0.07	0.11	0.11	0.11	0.03	0.03	0.07	0.01	0.01
47.5	0.22	0.18	0.12	0.17	0.17	0.17	0.08	0.09	0.17	0.04	0.05
52.5	0.36	0.30	0.22	0.28	0.29	0.27	0.19	0.23	0.38	0.14	0.20
57.5	0.52	0.45	0.35	0.43	0.45	0.40	0.39	0.48	0.67	0.36	0.53
62.5	0.70	0.62	0.52	0.60	0.63	0.55	0.65	0.77	0.93	0.68	0.90
67.5	0.86	0.79	0.71	0.76	0.80	0.71	0.89	0.97	1.00	0.94	1.00
72.5	0.97	0.93	0.87	0.91	0.94	0.85	1.00	1.00	0.98	1.00	0.97
77.5	1.00	1.00	0.98	0.99	1.00	0.96	0.97	1.00	0.91	1.00	0.92
82.5	0.94	1.00	1.00	1.00	1.00	1.00	0.86	1.00	0.80	1.00	0.85
87.5	0.81	0.94	0.94	1.00	1.00	1.00	0.70	0.96	0.65	1.00	0.75
92.5	0.63	0.78	0.81	1.00	1.00	1.00	0.51	0.81	0.51	0.91	0.65
97.5	0.46	0.57	0.65	0.90	1.00	1.00	0.35	0.61	0.37	0.68	0.54
102.5	0.30	0.37	0.48	0.68	0.90	0.85	0.21	0.40	0.25	0.42	0.44

Table 2.21b—Schedules of Pacific cod selectivities at length in the bottom trawl surveys as defined by final parameter estimates (Model B1). Lengths (cm) correspond to lower bounds of size bins.

	Shelf Survey		
Length	pre-1982	post-1981	Slope
10.5	0.01	0.37	0.00
13.5	0.02	0.44	0.00
16.5	0.05	0.51	0.00
19.5	0.11	0.58	0.00
22.5	0.19	0.66	0.00
25.5	0.32	0.73	0.00
28.5	0.49	0.80	0.00
31.5	0.67	0.86	0.00
34.5	0.84	0.91	0.00
37.5	0.96	0.95	0.01
40.5	1.00	0.98	0.03
43.5	0.99	1.00	0.11
47.5	0.95	1.00	0.36
52.5	0.88	1.00	0.85
57.5	0.77	1.00	1.00
62.5	0.65	1.00	1.00
67.5	0.52	1.00	0.98
72.5	0.40	1.00	0.82
77.5	0.29	1.00	0.57
82.5	0.21	1.00	0.32
87.5	0.14	1.00	0.15
92.5	0.09	1.00	0.06
97.5	0.06	1.00	0.02
102.5	0.03	1.00	0.00

Table 2.22—Schedules of Pacific cod length (cm), proportion mature, and weight (kg) by season and age as estimated by Model B1. 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, shelf = shelf survey, slope = slope survey.

		Length				Pop. Weight		Fishery Weight			Survey Wt.	
Sea.	Age	Beg.	Mid.	S.Dev.	Mat.	Beg.	Mid.	Twl.	Lgl.	Pot	Shelf	Slope
1	1	11.10	13.79	3.54	0.00	0.01	0.02	0.03	0.04	0.06	0.02	0.07
1	2	23.44	25.85	4.87	0.01	0.13	0.17	0.24	0.31	0.42	0.18	0.45
1	3	34.47	36.61	5.80	0.05	0.43	0.53	0.73	0.87	1.08	0.55	1.01
1	4	44.32	46.23	6.42	0.18	0.98	1.13	1.45	1.56	1.78	1.13	1.52
1	5	53.11	54.82	6.80	0.38	1.75	1.94	2.35	2.32	2.49	1.94	2.13
1	6	60.97	62.50	7.00	0.59	2.72	2.95	3.36	3.17	3.26	2.95	2.93
1	7	67.99	69.35	7.07	0.75	3.86	4.12	4.44	4.14	4.19	4.12	3.84
1	8	74.25	75.47	7.05	0.85	5.12	5.40	5.58	5.24	5.31	5.40	4.75
1	9	79.85	80.94	6.97	0.90	6.47	6.76	6.76	6.42	6.54	6.76	5.66
1	10	84.85	85.82	6.83	0.93	7.86	8.16	7.96	7.63	7.83	8.14	6.59
1	11	89.31	90.18	6.67	0.95	9.27	9.56	9.16	8.86	9.13	9.49	7.53
1	12	93.30	94.08	6.49	0.96	10.65	10.94	10.36	10.09	10.43	10.73	8.47
1	13	96.86	97.55	6.71	0.97	11.98	12.24	11.48	11.20	11.64	11.72	9.20
1	14	100.04	100.66	6.90	0.98	13.16	13.38	12.52	12.26	12.75	12.49	9.87
2	1	16.41	17.96	3.54	n/a	0.05	0.05	0.07	0.10	0.15	0.06	0.17
2	2	28.19	29.57	4.87	n/a	0.27	0.27	0.36	0.48	0.64	0.28	0.65
2	3	38.71	39.94	5.80	n/a	0.71	0.71	0.92	1.11	1.33	0.72	1.19
2	4	48.10	49.21	6.42	n/a	1.38	1.38	1.69	1.83	2.04	1.38	1.72
2	5	56.49	57.48	6.80	n/a	2.26	2.26	2.63	2.61	2.75	2.26	2.39
2	6	63.99	64.87	7.00	n/a	3.33	3.33	3.69	3.49	3.57	3.33	3.23
2	7	70.68	71.47	7.07	n/a	4.54	4.54	4.83	4.50	4.56	4.54	4.13
2	8	76.66	77.36	7.05	n/a	5.86	5.86	6.04	5.63	5.71	5.86	5.03
2	9	82.00	82.63	6.97	n/a	7.23	7.23	7.32	6.81	6.96	7.23	5.94
2	10	86.77	87.33	6.83	n/a	8.63	8.63	8.62	8.03	8.26	8.61	6.85
2	11	91.03	91.53	6.67	n/a	10.03	10.03	9.89	9.25	9.56	9.92	7.78
2	12	94.83	95.28	6.49	n/a	11.39	11.39	11.04	10.46	10.84	11.09	8.72
2	13	98.23	98.63	6.71	n/a	12.64	12.64	11.98	11.56	12.02	12.00	9.43
2	14	101.27	101.62	6.90	n/a	13.71	13.71	12.76	12.59	13.09	12.70	10.08
3	1	19.48	21.48	3.54	n/a	0.10	0.10	0.13	0.19	0.26	0.10	0.30
3	2	30.93	32.72	4.87	n/a	0.37	0.37	0.50	0.67	0.87	0.39	0.84
3	3	41.16	42.75	5.80	n/a	0.88	0.88	1.14	1.33	1.56	0.89	1.36
3	4	50.29	51.72	6.42	n/a	1.62	1.62	1.97	2.07	2.27	1.62	1.91
3	5	58.45	59.72	6.80	n/a	2.56	2.56	2.95	2.87	3.00	2.56	2.63
3	6	65.73	66.87	7.00	n/a	3.68	3.68	4.03	3.78	3.85	3.68	3.49
3	7	72.24	73.26	7.07	n/a	4.93	4.93	5.19	4.82	4.89	4.93	4.38
3	8	78.05	78.96	7.05	n/a	6.26	6.26	6.42	5.96	6.07	6.26	5.27
3	9	83.24	84.05	6.97	n/a	7.65	7.65	7.71	7.15	7.33	7.64	6.17
3	10	87.88	88.60	6.83	n/a	9.05	9.05	9.00	8.37	8.63	9.00	7.08
3	11	92.02	92.67	6.67	n/a	10.44	10.44	10.23	9.58	9.92	10.27	8.00
3	12	95.72	96.30	6.49	n/a	11.77	11.77	11.33	10.79	11.19	11.38	8.93
3	13	99.02	99.54	6.71	n/a	12.98	12.98	12.22	11.87	12.35	12.22	9.62
3	14	101.97	102.43	6.90	n/a	13.98	13.98	12.96	12.87	13.37	12.88	10.26

Table 2.23—Time series of EBS (not expanded to BSAI) 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 under Model B1, 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	32,871	23,372	42,369	56,590	39,103	74,077
1978	48,058	36,761	59,354	78,325	57,381	99,269
1979	76,760	60,268	93,252	114,795	87,281	142,309
1980	134,915	109,848	159,982	181,760	144,358	219,162
1981	243,335	205,705	280,965	290,795	239,529	342,061
1982	381,235	330,376	432,094	424,045	357,133	490,957
1983	501,700	441,912	561,488	544,850	465,244	624,456
1984	567,600	504,904	630,296	613,850	527,493	700,207
1985	577,950	516,926	638,974	630,500	542,936	718,064
1986	565,500	508,045	622,955	622,950	537,388	708,512
1987	564,550	510,416	618,684	619,300	537,036	701,564
1988	564,450	513,092	615,808	607,300	529,182	685,418
1989	543,900	495,219	592,582	564,850	491,797	637,903
1990	513,600	468,179	559,021	516,550	449,321	583,779
1991	456,835	415,863	497,807	454,815	394,277	515,353
1992	375,875	339,795	411,955	378,065	324,193	431,937
1993	337,610	305,129	370,091	344,165	295,331	392,999
1994	346,000	315,330	376,670	351,985	306,049	397,921
1995	354,910	325,102	384,718	360,540	315,910	405,170
1996	344,020	314,354	373,686	350,860	306,281	395,439
1997	333,220	303,174	363,266	343,040	297,689	388,391
1998	296,725	266,672	326,778	314,645	268,605	360,685
1999	275,280	245,114	305,446	308,685	261,600	355,770
2000	266,385	235,573	297,197	319,535	270,639	368,431
2001	268,275	236,733	299,817	342,440	291,318	393,562
2002	275,295	243,594	306,996	366,965	314,358	419,572
2003	277,895	246,138	309,652	376,425	323,431	429,419
2004	284,915	252,345	317,485	376,585	323,995	429,175
2005	283,075	249,153	316,997	360,260	308,790	411,730
2006	n/a	n/a	n/a	326,400	276,697	376,103

Table 2.24—Time series of EBS (not expanded to BSAI) 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 under Model B1, 1977-2005 (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	2,087,960	1,727,781	2,523,294	1,611,960	1,292,760	2,009,960
1978	522,535	312,677	873,249	1,014,290	755,490	1,361,690
1979	1,074,910	834,512	1,384,544	947,821	723,421	1,241,821
1980	370,327	233,561	587,207	453,442	302,942	678,742
1981	482,648	339,877	685,403	886,610	704,310	1,116,110
1982	1,637,790	1,407,769	1,905,306	1,508,730	1,280,230	1,778,030
1983	315,147	205,383	483,561	383,242	263,542	557,342
1984	1,494,730	1,285,365	1,738,179	1,210,830	1,030,230	1,423,130
1985	428,535	314,820	583,336	418,040	315,040	554,740
1986	286,273	206,672	396,524	392,177	299,587	513,377
1987	200,418	134,291	298,974	313,653	227,433	432,553
1988	658,175	544,584	795,467	906,898	766,798	1,072,598
1989	1,224,710	1,061,143	1,413,498	1,139,520	975,220	1,331,520
1990	657,983	532,483	813,062	658,085	534,385	810,485
1991	640,898	524,260	783,476	926,882	787,582	1,090,882
1992	1,031,550	898,553	1,184,225	1,000,980	858,580	1,166,980
1993	280,836	212,685	370,814	373,064	285,674	487,164
1994	351,743	280,394	441,241	565,069	460,369	693,569
1995	627,883	531,606	741,596	985,921	844,021	1,151,721
1996	878,950	767,880	1,006,078	1,106,130	960,530	1,273,830
1997	411,017	340,031	496,831	600,909	500,609	721,309
1998	631,846	539,514	739,979	830,782	710,482	971,382
1999	943,613	820,365	1,085,367	1,023,880	890,480	1,177,280
2000	693,481	586,035	820,616	528,671	442,611	631,471
2001	300,762	234,407	385,904	462,633	381,223	561,433
2002	411,992	323,510	524,669	429,282	342,522	537,982
2003	272,626	193,079	384,942	394,653	298,673	521,453
2004	435,093	279,269	677,917	303,430	193,130	476,630
2005	n/a	n/a	n/a	675,083	448,783	1,015,383

Table 2.25—Time series of EBS 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 under Model B1, 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	0.16	0.11
1978	0.18	0.12
1979	0.08	0.05
1980	0.05	0.04
1981	0.05	0.04
1982	0.04	0.04
1983	0.06	0.05
1984	0.08	0.07
1985	0.08	0.08
1986	0.08	0.07
1987	0.09	0.08
1988	0.12	0.12
1989	0.12	0.11
1990	0.13	0.13
1991	0.17	0.17
1992	0.14	0.14
1993	0.12	0.11
1994	0.15	0.14
1995	0.19	0.18
1996	0.19	0.18
1997	0.23	0.21
1998	0.17	0.15
1999	0.16	0.13
2000	0.17	0.13
2001	0.16	0.12
2002	0.17	0.13
2003	0.18	0.14
2004	0.19	0.16
2005	0.21	0.17
2006	n/a	0.19

Table 2.26—Projections for BSAI Pacific cod catch (t), spawning biomass (t), and fishing mortality under the assumption that $F = max\ F_{ABC}$ in 2007-2019 (Scenarios 1 and 2), with random variability in future recruitment.

Catch Projections					
Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2007	176482	176482	176482	176482	0
2008	130874	130876	130876	130879	2
2009	112823	112928	112951	113155	110
2010	119780	121578	121951	125418	1885
2011	137288	149589	152036	175137	12907
2012	142863	179072	184434	237710	31529
2013	139315	198970	202011	271842	43446
2014	138648	209000	209525	288995	48424
2015	136339	213074	212460	297573	49877
2016	134168	214000	212948	295017	50477
2017	130585	215360	212735	296951	50374
2018	132485	214179	212568	296138	49711
2019	134790	212231	212703	294603	49481
Spawning Biomass Projections					
Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2007	306790	306790	306790	306790	0
2008	266129	266133	266134	266140	3
2009	246408	246580	246616	246949	180
2010	247692	249682	250055	253788	2028
2011	259440	269530	271219	288794	9938
2012	264890	291408	295471	337235	24702
2013	263146	306330	312557	380843	39215
2014	262217	314329	322391	406002	47908
2015	260860	318157	327356	426511	51489
2016	258451	319368	329367	424301	52803
2017	256819	322538	330002	428346	52984
2018	257637	321676	330283	428222	52615
2019	259754	320427	330705	424271	52600
Fishing Mortality Projections					
Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2007	0.330	0.330	0.330	0.330	0.000
2008	0.284	0.284	0.284	0.284	0.000
2009	0.261	0.261	0.261	0.262	0.000
2010	0.263	0.265	0.265	0.270	0.002
2011	0.276	0.287	0.289	0.309	0.011
2012	0.282	0.312	0.314	0.345	0.020
2013	0.280	0.329	0.323	0.345	0.023
2014	0.279	0.338	0.325	0.345	0.023
2015	0.278	0.343	0.327	0.345	0.024
2016	0.275	0.344	0.327	0.345	0.025
2017	0.273	0.345	0.327	0.345	0.025
2018	0.274	0.345	0.327	0.345	0.025
2019	0.276	0.345	0.327	0.345	0.024

Table 2.27—Projections for BSAI 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	93127	93127	93127	93127	0
2008	83988	83989	83989	83991	1
2009	80014	80078	80092	80217	67
2010	86845	87945	88173	90292	1152
2011	99701	106595	106831	115299	5033
2012	105824	118961	121142	142404	12597
2013	105656	129048	132226	168277	20735
2014	106975	136625	139901	183197	25577
2015	106646	140876	144613	194583	27648
2016	106650	143599	147145	196444	28470
2017	105368	146017	148414	199035	28642
2018	107034	146524	149134	198258	28359
2019	109316	146552	149686	198024	28186
Spawning Biomass Projections					
Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2007	312884	312884	312884	312884	0
2008	300303	300306	300307	300314	4
2009	293991	294165	294202	294540	182
2010	301388	303412	303791	307587	2062
2011	317522	327934	329764	348209	10391
2012	328519	357557	362400	408849	27631
2013	332456	386405	393385	474562	47710
2014	337674	409392	418470	525680	62885
2015	339846	427673	436960	563421	71627
2016	340821	439588	449732	583264	76108
2017	343889	449275	458344	593009	78075
2018	345309	457062	464311	603655	78523
2019	353270	460440	468698	605962	78583
Fishing Mortality Projections					
Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2007	0.165	0.165	0.165	0.165	0.000
2008	0.158	0.158	0.158	0.158	0.000
2009	0.155	0.155	0.155	0.155	0.000
2010	0.159	0.160	0.160	0.162	0.001
2011	0.168	0.172	0.171	0.172	0.002
2012	0.172	0.172	0.172	0.172	0.000
2013	0.172	0.172	0.172	0.172	0.001
2014	0.172	0.172	0.172	0.172	0.001
2015	0.172	0.172	0.172	0.172	0.001
2016	0.172	0.172	0.172	0.172	0.002
2017	0.172	0.172	0.172	0.172	0.002
2018	0.172	0.172	0.172	0.172	0.002
2019	0.172	0.172	0.172	0.172	0.001

Table 2.28—Projections for BSAI 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	142355	142355	142355	142355	0
2008	126101	126101	126101	126101	0
2009	117417	117444	117450	117505	29
2010	122044	122899	123077	124720	889
2011	132185	138739	139992	151943	6669
2012	135310	154971	158116	189284	18537
2013	133744	167377	171783	222896	29384
2014	134544	175892	180526	240880	34986
2015	134146	180743	185403	253582	36915
2016	134045	182597	187696	253732	37506
2017	132500	185365	188662	255484	37455
2018	133651	185381	189147	255445	37063
2019	136148	184942	189621	252896	36958
Spawning Biomass Projections					
Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2007	309351	309351	309351	309351	0
2008	279042	279045	279046	279053	4
2009	259241	259418	259456	259801	186
2010	257319	259396	259785	263681	2117
2011	267007	277736	279568	298358	10594
2012	272975	302415	307063	353114	27451
2013	273220	325462	331859	410662	45685
2014	275830	341799	350431	448735	57979
2015	274931	354149	362960	477048	63997
2016	275960	363226	370775	484384	66597
2017	276880	368476	375540	493276	67447
2018	278403	371516	378662	493772	67318
2019	282597	373292	381018	495003	67174
Fishing Mortality Projections					
Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2007	0.260	0.260	0.260	0.260	0.000
2008	0.260	0.260	0.260	0.260	0.000
2009	0.260	0.260	0.260	0.260	0.000
2010	0.260	0.260	0.260	0.260	0.000
2011	0.260	0.260	0.260	0.260	0.000
2012	0.260	0.260	0.260	0.260	0.000
2013	0.260	0.260	0.260	0.260	0.000
2014	0.260	0.260	0.260	0.260	0.000
2015	0.260	0.260	0.260	0.260	0.000
2016	0.260	0.260	0.260	0.260	0.000
2017	0.260	0.260	0.260	0.260	0.000
2018	0.260	0.260	0.260	0.260	0.000
2019	0.260	0.260	0.260	0.260	0.000

Table 2.29—Projections for BSAI 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	319108	319108	319108	319108	0
2008	340897	340900	340901	340908	4
2009	362981	363159	363197	363541	186
2010	393148	395229	395619	399520	2120
2011	430208	441064	442932	462007	10741
2012	464007	495258	500089	549150	29146
2013	490667	551014	558557	647290	53081
2014	514955	602199	612237	743683	75333
2015	533675	645942	658038	818593	92243
2016	547035	683346	695057	881167	103831
2017	561236	711336	723966	915900	111149
2018	573798	736203	746163	943696	115212
2019	590222	749743	763066	967657	117293
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 2.30—Projections for BSAI 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	206861	206861	206861	206861	0
2008	142693	142695	142695	142699	2
2009	119744	119862	119887	120116	124
2010	127325	129345	129765	133664	2121
2011	146585	160382	163159	189113	14640
2012	151534	191551	198795	269243	37767
2013	146437	210632	218508	306107	52538
2014	145624	219162	225469	320973	57253
2015	142783	221312	227147	326327	58156
2016	139461	220826	226482	324021	58583
2017	135291	219871	225559	322843	58321
2018	137372	220287	224847	321089	57609
2019	139397	219695	224882	321543	57581
Spawning Biomass Projections					
Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2007	304427	304427	304427	304427	0
2008	254137	254140	254141	254148	3
2009	231568	231739	231776	232107	179
2010	232263	234243	234614	238329	2018
2011	243572	253572	255244	272651	9843
2012	247954	273966	277888	317987	24020
2013	245253	286928	292226	355132	36622
2014	244018	292270	298808	373316	42774
2015	241907	294603	301037	383590	44536
2016	239695	294503	301151	382626	44926
2017	237445	294710	300643	383097	44692
2018	238495	294042	300312	383892	44187
2019	239929	293153	300484	378550	44136
Fishing Mortality Projections					
Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2007	0.395	0.395	0.395	0.395	0.000
2008	0.326	0.326	0.326	0.326	0.000
2009	0.295	0.295	0.295	0.296	0.000
2010	0.296	0.299	0.299	0.304	0.003
2011	0.311	0.325	0.327	0.351	0.013
2012	0.317	0.353	0.357	0.413	0.028
2013	0.314	0.371	0.370	0.416	0.034
2014	0.312	0.378	0.374	0.416	0.036
2015	0.309	0.381	0.376	0.416	0.037
2016	0.306	0.381	0.375	0.416	0.038
2017	0.303	0.381	0.375	0.416	0.039
2018	0.304	0.380	0.375	0.416	0.038
2019	0.306	0.379	0.375	0.416	0.038

Table 2.31—Projections for BSAI 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	176482	176482	176482	176482	0
2008	130874	130876	130876	130879	2
2009	133192	133315	133342	133581	129
2010	134346	136413	136843	140834	2170
2011	149805	163733	166529	192716	14741
2012	152493	192578	199770	270355	37664
2013	146466	210589	218429	305669	52431
2014	145442	218884	225206	320735	57226
2015	142603	221080	226946	326118	58158
2016	139336	220761	226365	323904	58588
2017	135227	219828	225499	322806	58324
2018	137342	220253	224818	321060	57610
2019	139379	219679	224868	321535	57581
Spawning Biomass Projections					
Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2007	306790	306790	306790	306790	0
2008	266129	266133	266134	266140	3
2009	244994	245164	245201	245532	179
2010	239659	241635	242006	245713	2015
2011	247245	257229	258899	276275	9828
2012	249480	275451	279372	319381	23995
2013	245780	287365	292703	355548	36628
2014	244160	292402	298934	373476	42805
2015	241926	294614	301067	383800	44565
2016	239684	294507	301161	382692	44945
2017	237432	294708	300649	383100	44704
2018	238486	294043	300316	383899	44193
2019	239926	293155	300485	378553	44139
Fishing Mortality Projections					
Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2007	0.330	0.330	0.330	0.330	0.000
2008	0.284	0.284	0.284	0.284	0.000
2009	0.313	0.314	0.314	0.314	0.000
2010	0.306	0.309	0.309	0.314	0.003
2011	0.316	0.330	0.332	0.356	0.013
2012	0.319	0.355	0.359	0.415	0.027
2013	0.314	0.371	0.371	0.416	0.034
2014	0.312	0.378	0.375	0.416	0.036
2015	0.309	0.381	0.376	0.416	0.037
2016	0.306	0.381	0.375	0.416	0.038
2017	0.303	0.381	0.375	0.416	0.039
2018	0.304	0.380	0.375	0.416	0.038
2019	0.306	0.379	0.375	0.416	0.038

Table 2.32a—Bycatch of nontarget and "other" species taken in the EBS 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 EBS 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 EBS 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 EBS during that year.

	Bycatch in EBS Pacific cod trawl fishery						Proportion of total EBS catch					
Species group	1997	1998	1999	2000	2001	2002	1997	1998	1999	2000	2001	2002
Sculpin	1508	1365	893	1280	749	925	0.22	0.26	0.20	0.23	0.12	0.12
Skates	678	676	946	981	583	1303	0.04	0.04	0.07	0.06	0.03	0.05
Shark	0	0	0	9	2	3	0.00	0.00	0.00	0.15	0.09	0.08
Salmonshk	0	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
Dogfish	0	0	0	0	0	1	0.00	0.00	0.00	0.00	0.04	0.08
Sleepershk	8	33	4	0	12	10	0.03	0.10	0.01	0.00	0.02	0.01
Octopus	29	19	17	68	17	30	0.14	0.13	0.13	0.19	0.09	0.08
Squid	7	1	0	2	4	1	0.00	0.00	0.00	0.00	0.00	0.00
Smelts	1	0	1	0	0	0	0.03	0.00	0.03	0.00	0.00	0.00
Gunnel	0	0	0	0	0	0		0.00	0.00	0.00	0.71	0.00
Sticheidae	0	0	0	0	0	0	0.00	0.03	0.00	0.00	0.01	0.00
Sandfish	0	0	3	0	0	1	0.27	0.08	0.91	0.02	0.05	0.36
Lanternfish	0	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
Sandlance	0	0	0	0	0	0	0.00		0.00	0.00	0.90	0.01
Grenadier	1	6	0	3	0	0	0.00	0.00	0.00	0.00	0.00	0.00
Otherfish	231	232	195	302	220	157	0.16	0.21	0.20	0.24	0.18	0.14
Crabs	10	6	5	8	3	6	0.03	0.03	0.05	0.06	0.02	0.04
Starfish	133	63	83	109	57	98	0.02	0.02	0.03	0.03	0.01	0.02
Jellyfish	948	213	416	413	112	93	0.11	0.03	0.06	0.04	0.03	0.05
Invertunid	1	9	3	11	1	51	0.00	0.02	0.02	0.01	0.00	0.05
seapen/whip	0	0	0	0	0	0	0.10	0.09	0.01	0.06	0.00	0.00
Sponge	73	34	39	28	9	13	0.23	0.09	0.22	0.30	0.05	0.08
Anemone	14	5	18	10	6	9	0.08	0.05	0.11	0.03	0.03	0.03
Tunicate	6	10	0	67	5	1	0.00	0.01	0.00	0.06	0.00	0.00
Benthinv	25	18	11	23	6	12	0.04	0.03	0.05	0.06	0.01	0.03
Snails	0	0	0	0	0	0					0.00	0.00
echinoderm	13	4	13	13	20	14	0.31	0.20	0.54	0.33	0.50	0.46
Coral	0	0	0	4	0	0	0.02	0.01	0.04	0.37	0.00	0.00
Shrimp	0	0	0	0	0	0	0.07	0.03	0.01	0.00	0.01	0.00
Birds	0	0	0	0	0	0	0.00	0.01	0.00	0.00	0.00	0.00

Table 2.32b—Bycatch of nontarget and "other" species taken in the EBS 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 EBS 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 EBS 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 EBS 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	14	4	9	0.01	0.00	0.01
Birds	0	0	0	0.00	0.01	0.00
Bivalves	1	10	0	0.05	0.52	0.03
Brittle star unidentified	1	1	0	0.02	0.03	0.00
Capelin		0			0.02	
Corals Bryozoans	1	1	0	0.28	0.25	0.06
Deep sea smelts (bathylagidae)						
Eelpouts	62	27	1	0.27	0.30	0.02
Eulachon		0	0		0.00	0.00
Giant Grenadier						
Greenlings	4	2	1	0.43	0.40	0.23
Grenadier	14	9	0	0.01	0.00	0.00
Gunnels						
Hermit crab unidentified	5	3	1	0.04	0.05	0.01
Invertebrate unidentified	5	4	0	0.01	0.01	0.00
Lanternfishes (myctophidae)		0			0.07	
Large Sculpins	547	1422	897	0.39	0.32	0.22
Misc crabs	7	3	2	0.13	0.09	0.07
Misc crustaceans	0	0	0	0.24	0.20	0.07
Misc deep fish						
Misc fish	174	152	149	0.35	0.30	0.31
Misc inverts (worms etc)	0	0	0	0.07	0.02	0.00
Octopus	14	44	12	0.10	0.12	0.05
Other osmerids	0	0		0.01	0.09	
Other Sculpins	854	95	58	0.22	0.18	0.12
Pacific Sand lance	0	0	0	0.45	0.40	0.59
Pandalid shrimp	0	0	0	0.15	0.18	0.01
Polychaete unidentified		0	0		0.01	0.08
Scypho jellies	727	699	391	0.11	0.10	0.06
Sea anemone unidentified	14	16	12	0.10	0.09	0.12
Sea pens whips	0	1	0	0.01	0.05	0.01
Sea star	118	91	81	0.03	0.03	0.03
Shark	10	29	11	0.03	0.08	0.05
Skate	1010	1355	570	0.06	0.07	0.03
Snails	14	13	3	0.07	0.05	0.02
Sponge unidentified	3	7	3	0.01	0.08	0.04
Squid	5	4	1	0.00	0.00	0.00
Stichaeidae	0	0	0	0.12	0.07	0.14
Surf smelt						
Urchins dollars cucumbers	11	10	12	0.36	0.43	0.48

Table 2.33a—Bycatch of nontarget and "other" species taken in the EBS 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 EBS 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 EBS 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 EBS during that year.

	Bycatch in EBS P. cod longline fishery						Proportion of total EBS catch					
Species group	1997	1998	1999	2000	2001	2002	1997	1998	1999	2000	2001	2002
Sculpin	706	931	821	801	1142	1383	0.11	0.18	0.18	0.14	0.19	0.18
Skates	12961	12808	9178	11578	11932	17507	0.77	0.70	0.69	0.68	0.66	0.66
Shark	27	48	18	47	17	22	0.50	0.40	0.11	0.78	0.70	0.48
Salmonshk	0	1	1	0	1	10	0.00	0.05	0.04	0.01	0.05	0.22
Dogfish	4	5	5	8	11	8	1.00	0.90	0.99	0.98	0.83	0.92
Sleepershk	67	114	99	114	240	250	0.24	0.34	0.35	0.33	0.37	0.30
Octopus	15	15	13	29	15	76	0.07	0.10	0.10	0.08	0.08	0.19
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	0		0.60	0.00	0.80	0.00	0.00
Sticheidae	0	0	0	0	0	0	0.01	0.00	0.00	0.00	0.00	0.56
Sandfish	0	0	0	0	0	0	0.00	0.00	0.01	0.00	0.00	0.00
Lanternfish	0	0	0	0	0	0	0.00	0.00	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
Grenadier	437	604	356	364	162	336	0.15	0.12	0.08	0.09	0.07	0.06
Otherfish	43	27	38	38	71	122	0.03	0.03	0.04	0.03	0.06	0.11
Crabs	1	0	0	1	1	3	0.00	0.00	0.00	0.00	0.01	0.01
Starfish	136	141	250	132	319	384	0.02	0.04	0.08	0.04	0.08	0.08
Jellyfish	5	7	24	2	2	5	0.00	0.00	0.00	0.00	0.00	0.00
Invertunid	10	12	1	6	10	11	0.01	0.02	0.01	0.01	0.01	0.01
seapen/whip	2	2	4	3	6	41	0.83	0.79	0.87	0.63	0.79	0.95
Sponge	1	1	2	1	0	5	0.00	0.00	0.01	0.01	0.00	0.03
Anemone	76	58	123	200	115	195	0.42	0.51	0.73	0.58	0.55	0.59
Tunicate	1	1	0	2	0	1	0.00	0.00	0.00	0.00	0.00	0.00
Benthinv	7	5	10	11	12	12	0.01	0.01	0.04	0.03	0.02	0.03
Snails	0	0	0	0	0	0					1.00	0.00
echinoderm	1	0	3	0	0	0	0.02	0.00	0.11	0.00	0.00	0.01
Coral	1	0	0	3	1	2	0.07	0.02	0.04	0.30	0.01	0.03
Shrimp	0	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
Birds	26	33	17	24	13	13	0.98	0.86	0.81	0.97	0.88	0.96

Table 2.33b—Bycatch of nontarget and "other" species taken in the EBS 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 EBS 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 EBS 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 EBS during that year. Note that the list of nontarget species groups used for 2003-2005 differs from that used for 1997-2002.

	Byatch (t)			Proportion of total		
Species group	2003	2004	2005	2003	2004	2005
Benthic urochordata	0	0	0	0.00	0.00	0.00
Birds	6	6	2	0.93	0.93	0.44
Bivalves	4	6	5	0.36	0.33	0.68
Brittle star unidentified	0	0	0	0.01	0.00	0.01
Capelin						
Corals Bryozoans	1	1	1	0.23	0.23	0.30
Deep sea smelts (bathylagidae)						
Eelpouts	4	8	16	0.02	0.09	0.25
Eulachon						
Giant Grenadier	1	16	91	0.01	0.08	0.08
Greenlings	3	1	1	0.28	0.23	0.20
Grenadier	221	202	158	0.08	0.10	0.12
Gunnels		0	0		1.00	1.00
Hermit crab unidentified	1	0	0	0.01	0.00	0.00
Invertebrate unidentified	14	2	3	0.02	0.00	0.01
Lanternfishes (myctophidae)						
Large Sculpins	194	1087	865	0.14	0.24	0.21
Misc crabs	1	1	9	0.01	0.02	0.24
Misc crustaceans	0	0	0	0.02	0.00	0.43
Misc deep fish						
Misc fish	44	58	26	0.09	0.12	0.05
Misc inverts (worms etc)		0	0		0.00	0.01
Octopus	41	37	20	0.30	0.10	0.08
Other osmerids			0			0.00
Other Sculpins	993	234	163	0.25	0.44	0.33
Pacific Sand lance						
Pandalid shrimp						
Polychaete unidentified	0	0	0	0.13	0.01	0.64
Scypho jellies	16	4	1	0.00	0.00	0.00
Sea anemone unidentified	79	94	69	0.58	0.53	0.69
Sea pens whips	6	10	19	0.86	0.84	0.88
Sea star	288	288	202	0.07	0.10	0.08
Shark	140	146	128	0.50	0.42	0.55
Skate	13519	13863	13219	0.74	0.75	0.78
Snails	5	6	6	0.03	0.02	0.05
Sponge unidentified	3	1	2	0.01	0.01	0.02
Squid	0	0	0	0.00	0.00	0.00
Stichaeidae	0			0.05		
Surf smelt						
Urchins dollars cucumbers	0	0	0	0.00	0.00	0.00

Table 2.34a—Bycatch of nontarget and "other" species taken in the EBS 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 EBS 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 EBS 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 EBS during that year.

	Bycatch in EBS Pacific cod pot fishery						Proportion of total EBS catch					
Species group	1997	1998	1999	2000	2001	2002	1997	1998	1999	2000	2001	2002
Sculpin	351	267	438	494	315	384	0.05	0.05	0.10	0.09	0.05	0.05
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	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
Dogfish	0	0	0	0	0	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	79	95	80	199	140	254	0.38	0.65	0.64	0.56	0.75	0.65
Squid	0	0	0	0	1	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	0		0.00	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	0.02	0.00	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
Grenadier	0	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
Otherfish	27	44	32	12	48	23	0.02	0.04	0.03	0.01	0.04	0.02
Crabs	1	1	4	2	1	2	0.00	0.00	0.04	0.01	0.01	0.01
Starfish	64	14	15	35	31	11	0.01	0.00	0.01	0.01	0.01	0.00
Jellyfish	11	1	16	0	6	2	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	0.00	0.00	0.00
seapen/whip	0	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
Sponge	0	0	0	0	0	1	0.00	0.00	0.00	0.00	0.00	0.00
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	0.00	0.00	0.00	0.00	0.00
Benthinv	8	3	4	11	4	9	0.01	0.01	0.02	0.03	0.01	0.02
Snails	0	0	0	0	0	0					0.00	0.00
echinoderm	1	0	0	2	1	0	0.02	0.02	0.02	0.04	0.02	0.01
Coral	0	0	0	0	0	0	0.02	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	0.00	0.00

Table 2.34b—Bycatch of nontarget and "other" species taken in the EBS 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 EBS 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 EBS 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 EBS during that year. Note that the list of nontarget species groups used for 2003-2005 differs from that used for 1997-2002.

	Byatch (t)			Proportion of total		
Species group	2003	2004	2005	2003	2004	2005
Benthic urochordata	0	0	0	0.00	0.00	0.00
Birds	0	0	0	0.01	0.00	0.01
Bivalves	0	0	0	0.01	0.02	0.01
Brittle star unidentified	0	0	0	0.00	0.00	0.00
Capelin						
Corals Bryozoans	0		0	0.01		0.01
Deep sea smelts (bathylagidae)						
Eelpouts	0			0.00		
Eulachon						
Giant Grenadier						
Greenlings	1	0	0	0.06	0.07	0.14
Grenadier						
Gunnels						
Hermit crab unidentified	0	0	0	0.00	0.00	0.00
Invertebrate unidentified	0	0	0	0.00	0.00	0.00
Lanternfishes (myctophidae)						
Large Sculpins	122	191	109	0.09	0.04	0.03
Misc crabs	0	1	1	0.01	0.02	0.04
Misc crustaceans	0	0		0.00	0.01	
Misc deep fish						
Misc fish	30	13	14	0.06	0.03	0.03
Misc inverts (worms etc)						
Octopus	49	57	187	0.35	0.15	0.76
Other osmerids						
Other Sculpins	133	13	2	0.03	0.03	0.00
Pacific Sand lance						
Pandalid shrimp						
Polychaete unidentified						
Scypho jellies	2	1	3	0.00	0.00	0.00
Sea anemone unidentified	0	0	0	0.00	0.00	0.00
Sea pens whips	0			0.00		
Sea star	41	30	27	0.01	0.01	0.01
Shark						
Skate	0	0	0	0.00	0.00	0.00
Snails	7	1	2	0.04	0.00	0.02
Sponge unidentified	1	1	0	0.00	0.01	0.00
Squid			1			0.00
Stichaeidae						
Surf smelt						
Urchins dollars cucumbers	1	1	0	0.04	0.06	0.01

Table 2.35a—Bycatch of nontarget and "other" species taken in the AI 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 AI 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 AI 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 AI during that year.

	Bycatch in AI Pacific cod trawl fishery						Proportion of total AI catch					
Species group	1997	1998	1999	2000	2001	2002	1997	1998	1999	2000	2001	2002
Sculpin	107	146	131	257	102	131	0.14	0.14	0.14	0.18	0.06	0.12
Skates	37	95	38	72	49	97	0.04	0.08	0.05	0.04	0.02	0.14
Shark	0	0	0	0	0	0	0.00	0.00	0.00	0.03	0.00	0.00
Salmonshk	0	0	0	4	0	0	0.00	0.00	0.00	1.00	0.00	
Dogfish	0	0	0	0	0	0	0.04	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	0.01	0.01
Octopus	2	2	9	2	1	9	0.06	0.05	0.04	0.03	0.03	0.38
Squid	1	0	0	1	2	4	0.01	0.01	0.01	0.07	0.30	0.25
Smelts	0	0	0	0	0	0	0.00	0.95	0.00	1.00	1.00	0.00
Gunnel	0	0	0	0	0	0			1.00		1.00	
Sticheidae	0	0	0	0	0	0	0.00			0.00		
Sandfish	0	0	0	0	0	0	0.00			0.00		
Lanternfish	0	0	0	0	0	0	0.00	0.00				
Sandlance	0	0	0	0	0	0					0.00	0.00
Grenadier	0	0	0	0	0	9	0.00	0.00	0.00	0.00	0.00	0.00
Otherfish	6	38	29	25	26	15	0.04	0.14	0.09	0.12	0.11	0.07
Crabs	1	1	0	0	1	2	0.13	0.44	0.27	0.22	0.42	0.88
Starfish	2	3	5	5	5	5	0.12	0.15	0.29	0.20	0.17	0.46
Jellyfish	0	0	0	0	0	0	0.01	0.17	0.00	0.99	0.01	0.44
Invertunid	0	2	3	6	2	0	0.00	0.03	0.34	0.40	0.36	0.02
seapen/whip	0	0	0	0	0	0	0.85	0.23	0.54	0.33	0.08	0.16
Sponge	4	52	15	15	13	28	0.02	0.47	0.10	0.21	0.18	0.16
Anemone	0	0	1	0	0	0	0.09	0.08	0.41	0.17	0.05	0.17
Tunicate	0	0	0	0	1	0	0.63	0.75	0.08	0.58	0.40	0.07
Benthinv	4	3	1	2	3	6	0.90	0.68	0.16	0.73	0.76	0.92
Snails	0	0	0	0	0	0						
echinoderm	0	1	1	1	1	2	0.16	0.26	0.23	0.35	0.44	0.75
Coral	2	8	2	8	3	11	0.07	0.48	0.03	0.24	0.15	0.52
Shrimp	0	0	0	0	0	0	0.01	0.05	0.00	0.11	0.19	0.10
Birds	0	1	0	0	0	0	0.02	0.11	0.02	0.04	0.01	0.16

Table 2.35b—Bycatch of nontarget and “other” species taken in the AI 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 AI 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 AI 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 AI 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	0	0.05	0.16	0.37
Birds	0	0	0	0.21	0.01	0.38
Bivalves	15	1	0	0.99	0.92	0.81
Brittle star unidentified		0	0		0.05	0.01
Capelin						
Corals Bryozoans	24	11	12	0.40	0.35	0.24
Deep sea smelts (bathylagidae)						
Eelpouts	0	1	0	0.08	0.51	0.00
Eulachon			0			0.68
Giant Grenadier						
Greenlings	1	0	0	0.66	0.05	0.01
Grenadier		4	0		0.01	0.00
Gunnels						
Hermit crab unidentified	0	0	0	0.80	0.98	0.09
Invertebrate unidentified	0	0	0	0.09	0.00	0.02
Lanternfishes (myctophidae)						
Large Sculpins	78	159	88	0.37	0.23	0.18
Misc crabs	1	1	0	0.73	0.59	0.52
Misc crustaceans	0	0	0	0.99	0.29	0.98
Misc deep fish						
Misc fish	28	15	19	0.23	0.10	0.12
Misc inverts (worms etc)		0	0		0.29	1.00
Octopus	6	5	3	0.36	0.28	0.40
Other osmerids						
Other Sculpins	122	1	3	0.31	0.01	0.04
Pacific Sand lance	0		0	1.00		1.00
Pandalid shrimp	0	0	0	0.06	0.01	0.03
Polychaete unidentified		0	0		0.13	0.97
Scypho jellies	0	0	1	0.17	0.49	0.44
Sea anemone unidentified	0	0	0	0.61	0.31	0.32
Sea pens whips	0	0	0	0.34	0.91	0.42
Sea star	5	3	2	0.49	0.27	0.17
Shark	0	2	2	0.01	0.43	0.10
Skate	72	76	65	0.13	0.09	0.11
Snails	1	1	0	0.52	0.50	0.21
Sponge unidentified	24	18	22	0.30	0.13	0.28
Squid	3	2	1	0.10	0.11	0.07
Stichaeidae			0			0.00
Surf smelt						
Urchins dollars cucumbers	1	1	0	0.40	0.43	0.15

Table 2.36a—Bycatch of nontarget and "other" species taken in the AI 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 AI 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 AI 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 AI during that year.

	Bycatch in AI Pacific cod longline fishery						Proportion of total AI catch					
Species group	1997	1998	1999	2000	2001	2002	1997	1998	1999	2000	2001	2002
Sculpin	334	597	356	662	1004	214	0.43	0.55	0.37	0.47	0.63	0.19
Skates	338	727	473	1397	2184	246	0.39	0.64	0.59	0.77	0.87	0.35
Shark	0	1	0	0	0	0	0.78	0.04	0.05	0.03	0.00	0.00
Salmonshk	0	0	0	0	0	0	0.00	0.02	0.00	0.00	0.00	
Dogfish	0	0	0	0	1	0	0.96	0.55	0.84	0.85	0.31	0.54
Sleepershk	0	0	1	0	1	2	0.00	0.00	0.02	0.00	0.03	0.49
Octopus	10	21	9	13	21	8	0.27	0.47	0.05	0.20	0.51	0.32
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	0			0.00		0.00	
Sticheidae	0	0	0	0	0	0	0.00			0.00		
Sandfish	0	0	0	0	0	0	0.00			0.00		
Lanternfish	0	0	0	0	0	0	0.00	0.00				
Sandlance	0	0	0	0	0	0					0.00	0.00
Grenadier	397	83	215	151	6	88	0.14	0.05	0.07	0.05	0.00	0.03
Otherfish	2	5	2	6	10	3	0.02	0.02	0.01	0.03	0.04	0.01
Crabs	0	0	0	0	0	0	0.00	0.01	0.01	0.01	0.04	0.00
Starfish	3	7	4	13	16	3	0.22	0.41	0.28	0.51	0.59	0.25
Jellyfish	0	0	0	0	0	0	0.00	0.00	0.00	0.01	0.00	0.00
Invertunid	0	1	0	1	0	0	0.00	0.01	0.02	0.06	0.08	0.02
seapen/whip	0	0	0	0	0	0	0.00	0.21	0.44	0.54	0.92	0.56
Sponge	0	4	3	11	4	1	0.00	0.04	0.02	0.15	0.06	0.00
Anemone	0	0	1	1	0	1	0.34	0.57	0.32	0.59	0.47	0.69
Tunicate	0	0	0	0	0	0	0.01	0.00	0.00	0.24	0.00	0.00
Benthinv	0	0	0	0	0	0	0.02	0.00	0.02	0.06	0.04	0.03
Snails	0	0	0	0	0	0						
echinoderm	0	0	0	0	0	0	0.10	0.04	0.00	0.09	0.04	0.02
Coral	0	1	2	6	3	1	0.02	0.03	0.04	0.17	0.16	0.03
Shrimp	0	0	0	0	0	0	0.09	0.00	0.00	0.01	0.00	0.00
Birds	2	2	2	2	1	0	0.75	0.45	0.55	0.66	0.48	0.16

Table 2.36b—Bycatch of nontarget and "other" species taken in the AI 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 AI 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 AI 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 AI 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	0	0.09	0.00	0.01
Birds	0	0	0	0.03	0.21	0.29
Bivalves	0	0	0	0.00	0.02	0.18
Brittle star unidentified	0	0	0	0.00	0.00	0.00
Capelin						
Corals Bryozoans	1	1	0	0.01	0.05	0.01
Deep sea smelts (bathylagidae)						
Eelpouts	0	0	0	0.01	0.00	0.00
Eulachon						
Giant Grenadier	0	0	0	0.30	0.00	0.00
Greenlings	0	0	0	0.08	0.16	0.02
Grenadier	46	8	0	0.01	0.01	0.00
Gunnels			0			0.00
Hermit crab unidentified	0	0	0	0.01	0.00	0.00
Invertebrate unidentified	0	1	0	0.00	0.12	0.03
Lanternfishes (myctophidae)						
Large Sculpins	28	133	91	0.14	0.19	0.18
Misc crabs	0	0	0	0.00	0.01	0.01
Misc crustaceans	0	0	0	0.00	0.00	0.00
Misc deep fish						
Misc fish	1	3	1	0.01	0.02	0.00
Misc inverts (worms etc)		0	0		0.00	0.00
Octopus	8	8	4	0.54	0.49	0.55
Other osmerids			0			0.00
Other Sculpins	31	63	1	0.08	0.41	0.01
Pacific Sand lance						
Pandalid shrimp						
Polychaete unidentified	0	0	0	1.00	0.00	0.03
Scypho jellies	0	0	0	0.01	0.00	0.00
Sea anemone unidentified	0	0	0	0.24	0.23	0.58
Sea pens whips	0	0	0	0.46	0.09	0.15
Sea star	1	6	3	0.10	0.47	0.25
Shark	0	0	0	0.01	0.08	0.02
Skate	105	402	245	0.20	0.48	0.43
Snails	0	0	0	0.01	0.03	0.05
Sponge unidentified	2	5	2	0.02	0.04	0.03
Squid		0			0.00	
Stichaeidae	0			0.00		
Surf smelt						
Urchins dollars cucumbers	0	0	0	0.02	0.11	0.01

Table 2.37—Bycatch of nontarget and “other” species taken in the AI 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 AI 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 AI 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 AI during that year.

	Bycatch in AI Pacific cod pot fishery						Proportion of total AI catch					
Species group	1997	1998	1999	2000	2001	2002	1997	1998	1999	2000	2001	2002
Sculpin	7	12	221	211	42	0	0.01	0.01	0.23	0.15	0.03	0.00
Skates	0	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	0	0	0	0	0.00	0.00	0.00	0.00	0.00	
Dogfish	0	0	0	0	0	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	24	18	182	47	17	0	0.62	0.40	0.90	0.75	0.41	0.00
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	0			0.00		0.00	
Sticheidae	0	0	0	0	0	0	0.00			0.00		
Sandfish	0	0	0	0	0	0	0.00			0.00		
Lanternfish	0	0	0	0	0	0	0.00	0.00				
Sandlance	0	0	0	0	0	0					0.00	0.00
Grenadier	0	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
Otherfish	0	0	7	1	4	0	0.00	0.00	0.02	0.01	0.02	0.00
Crabs	0	0	1	1	0	0	0.00	0.06	0.51	0.61	0.31	0.00
Starfish	0	0	1	1	0	0	0.00	0.00	0.05	0.05	0.00	0.00
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	0.01	0.00	0.00	0.00
seapen/whip	0	0	0	0	0	0	0.00	0.00	0.00	0.07	0.00	0.00
Sponge	0	0	0	4	0	0	0.00	0.00	0.00	0.06	0.00	0.00
Anemone	0	0	0	0	0	0	0.00	0.01	0.00	0.00	0.00	0.00
Tunicate	0	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
Benthinv	0	0	1	0	0	0	0.00	0.01	0.09	0.12	0.00	0.00
Snails	0	0	0	0	0	0						
echinoderm	0	0	1	1	0	0	0.01	0.00	0.20	0.18	0.00	0.00
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	0.02	0.00	0.00	0.00

Table 2.38—Summary of major results for the stock assessment of Pacific cod in the BSAI region.

Tier	3b
Reference mortality rates	
M	0.37
$F_{40\%}$	0.34
$F_{35\%}$	0.42
Equilibrium spawning biomass	
$B_{35\%}$	280,000 t
$B_{40\%}$	320,000 t
$B_{100\%}$	800,000 t
Projected biomass for 2007	
Spawning (at max FABC)	307,000 t
Age 3+	960,000 t
ABC for 2007	
F_{ABC} (maximum permissible)	0.33
F_{ABC} (recommended)	0.33
ABC (maximum permissible)	176,000 t
ABC (recommended)	176,000 t
Overfishing level for 2007	
Fishing Mortality	0.39
Catch	207,000 t

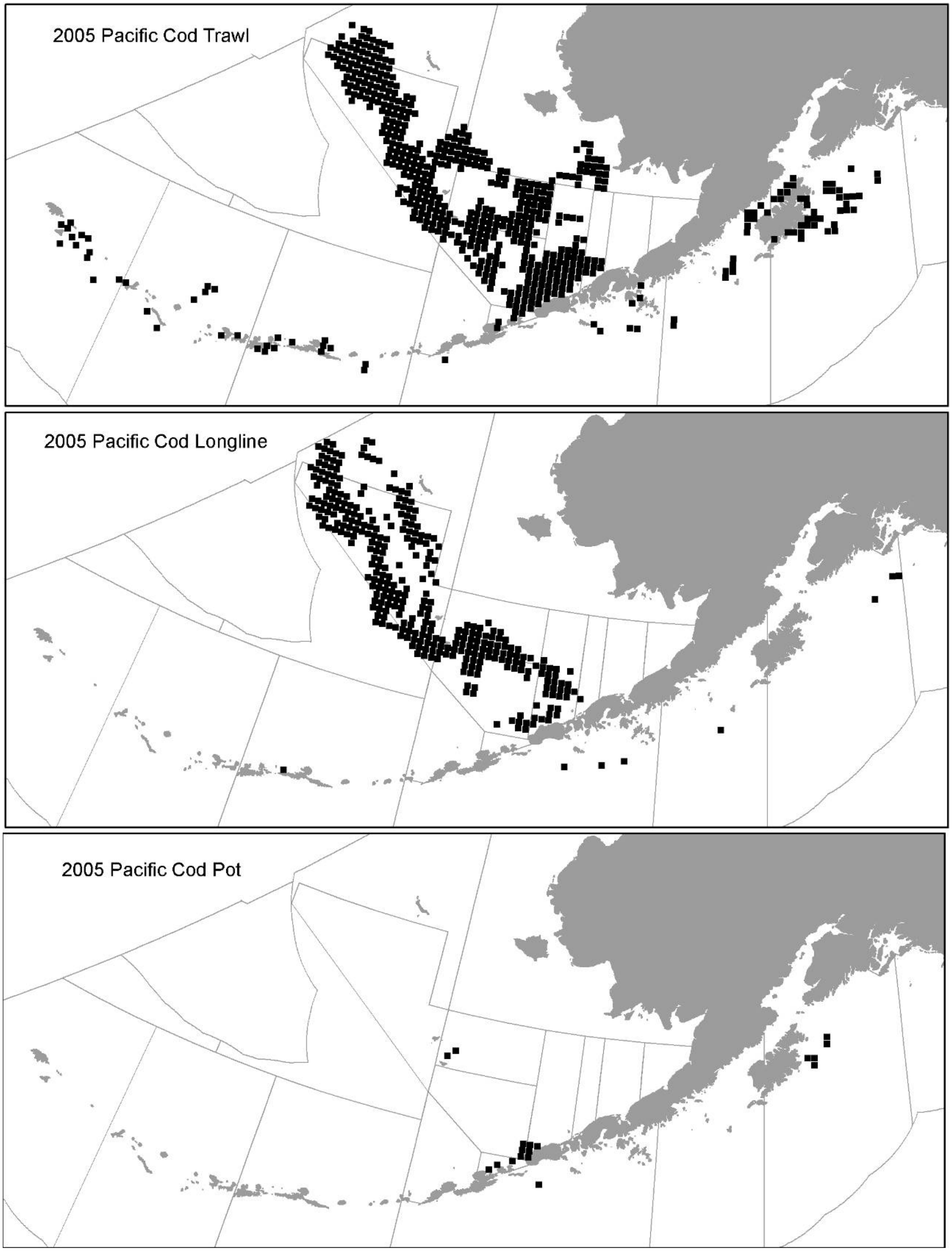


Figure 2.1—Maps showing each 400 square kilometer cell with at least 3 observed hauls/sets containing Pacific cod in 2005, by gear type, overlaid against NMFS 3-digit statistical areas.

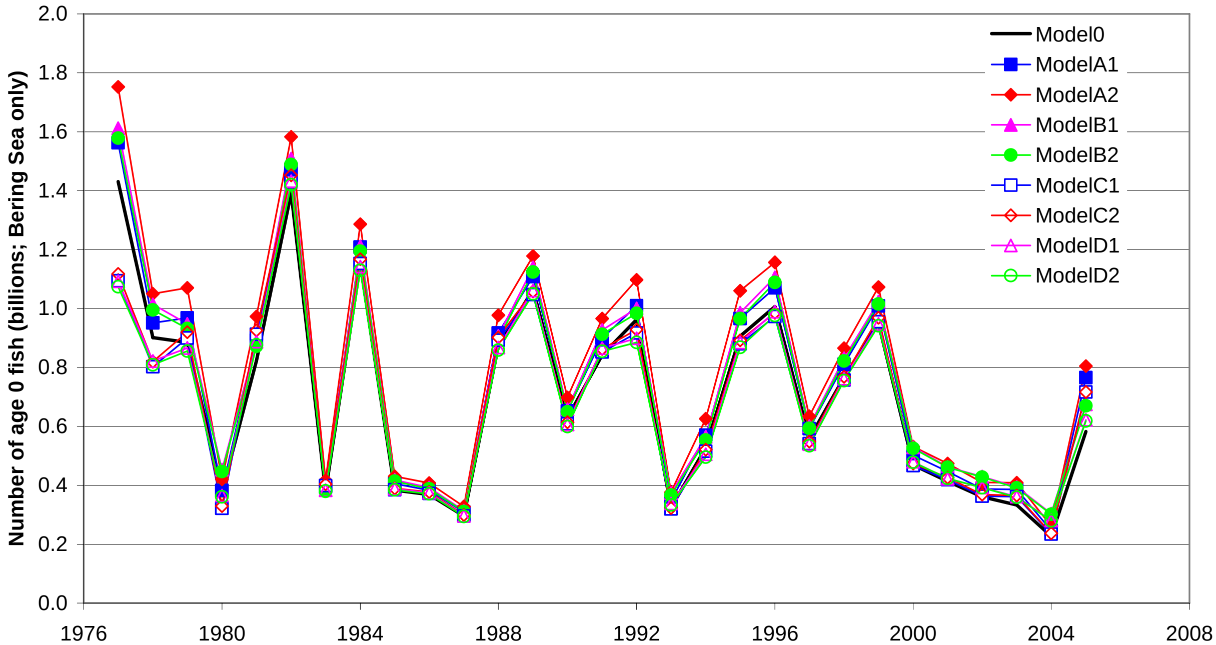


Figure 2.2—Comparison of numbers of age 0 EBS Pacific cod under last year's model updated with new data (Model 0) and eight alternative models.

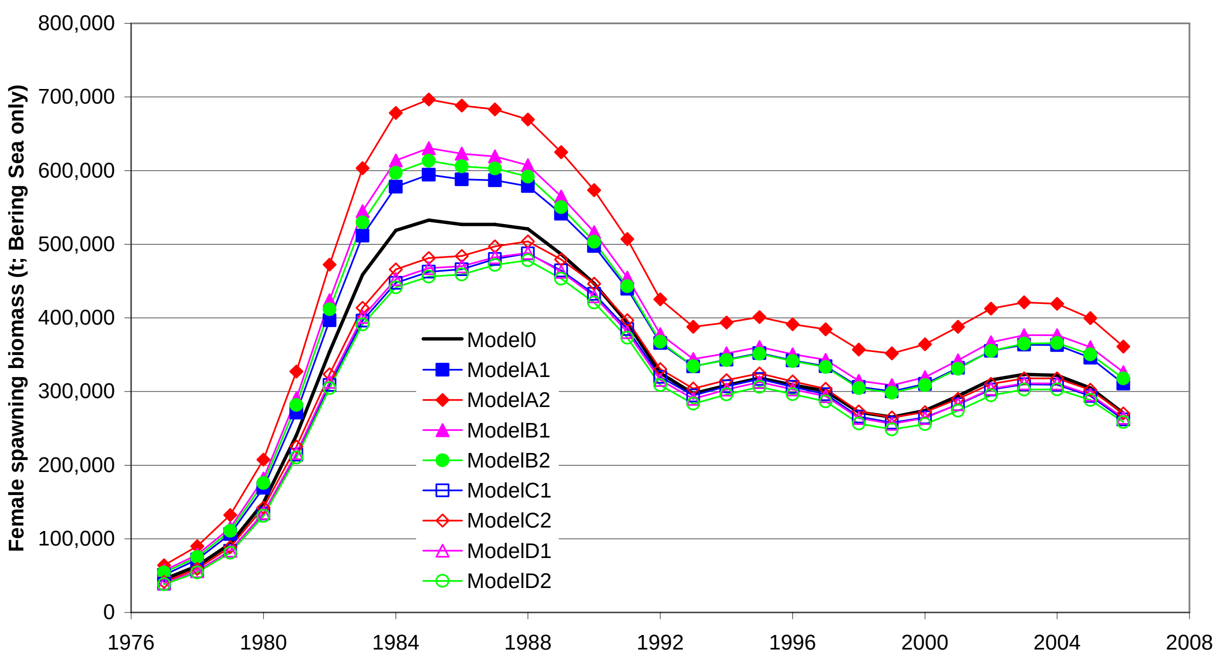


Figure 2.3— Comparison of female spawning biomass of EBS Pacific cod under last year's model updated with new data (Model 0) and eight alternative models.

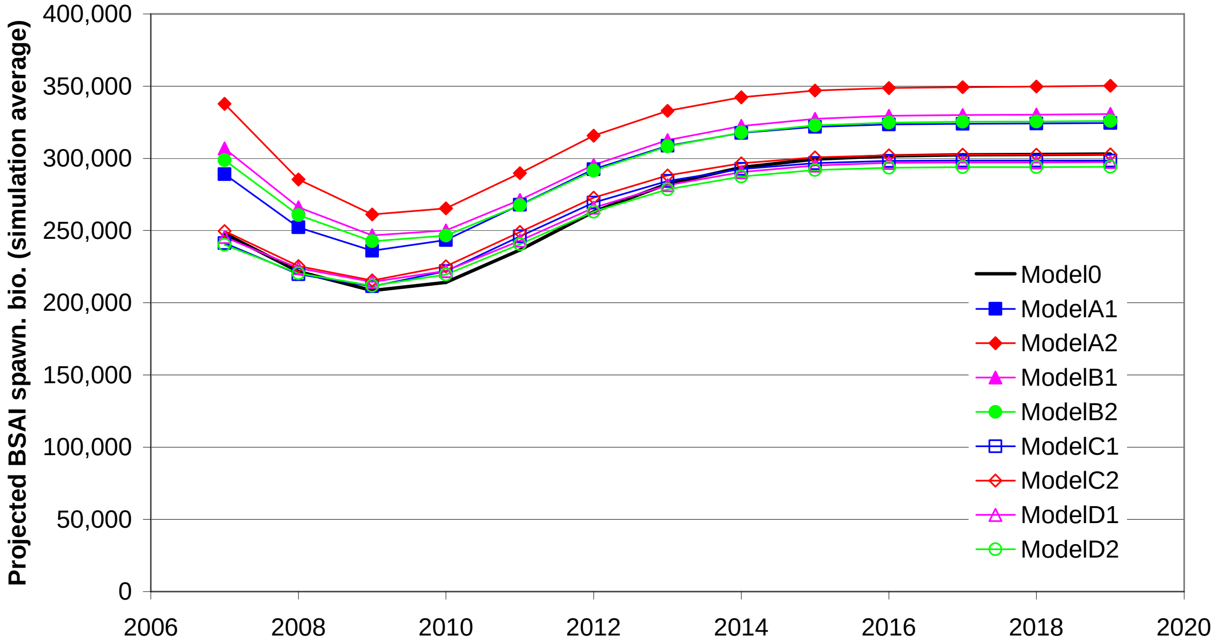


Figure 2.4— Comparison of projected female spawning biomass of BSAI Pacific cod under last year's model updated with new data (Model 0) and eight alternative models.

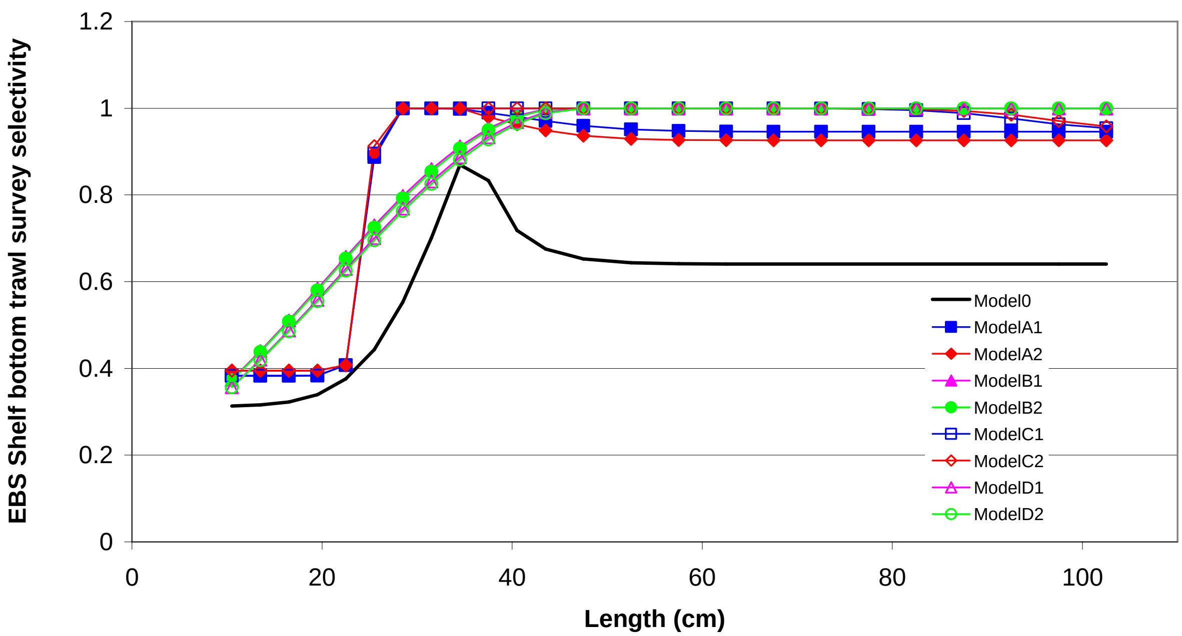


Figure 2.5— Comparison of estimated selectivity at length in the EBS shelf bottom trawl survey under last year's model updated with new data (Model 0) and eight alternative models.

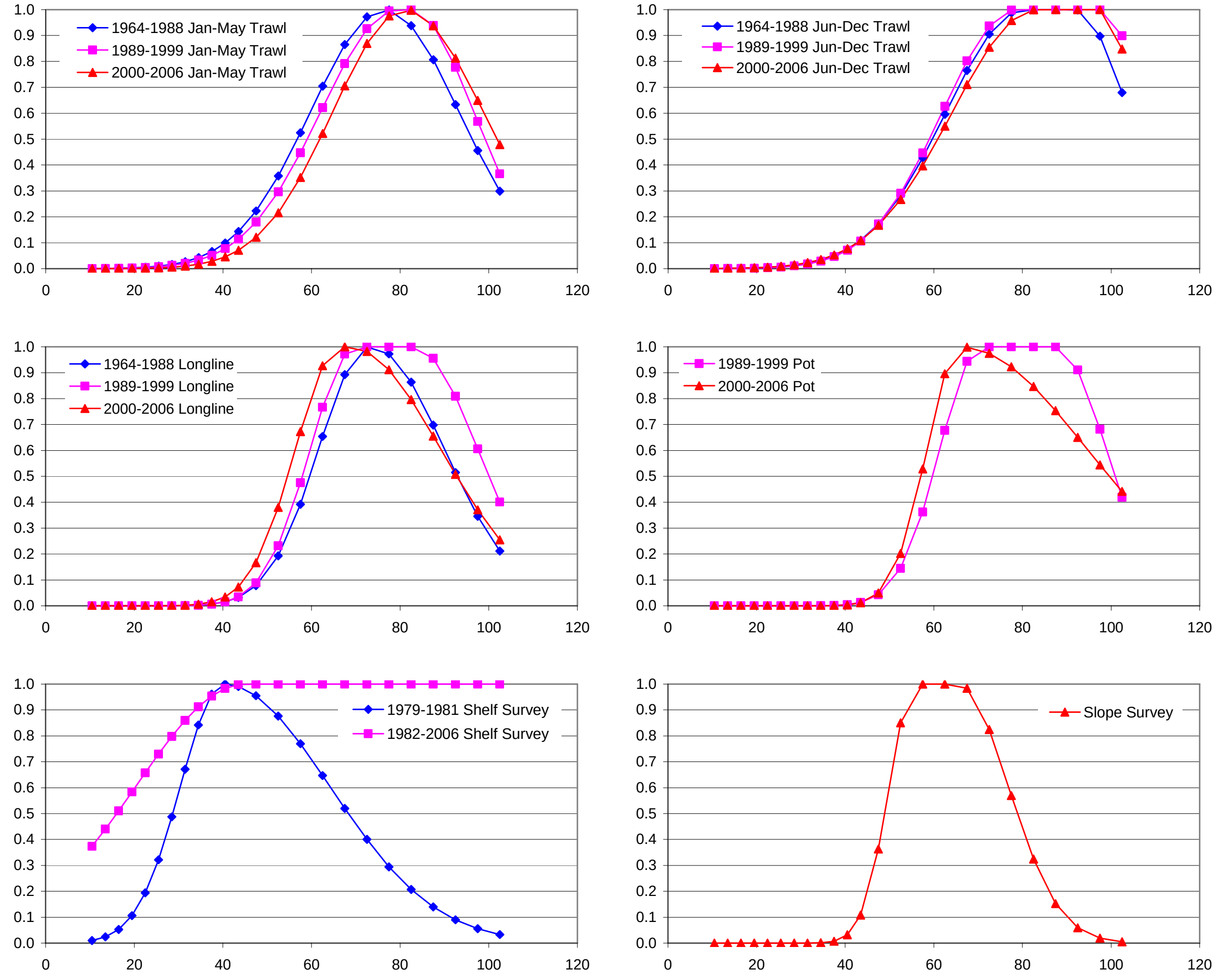


Figure 2.6—Selectivity at length (cm, evaluated at midpoints of length bins) as estimated by Model B1.

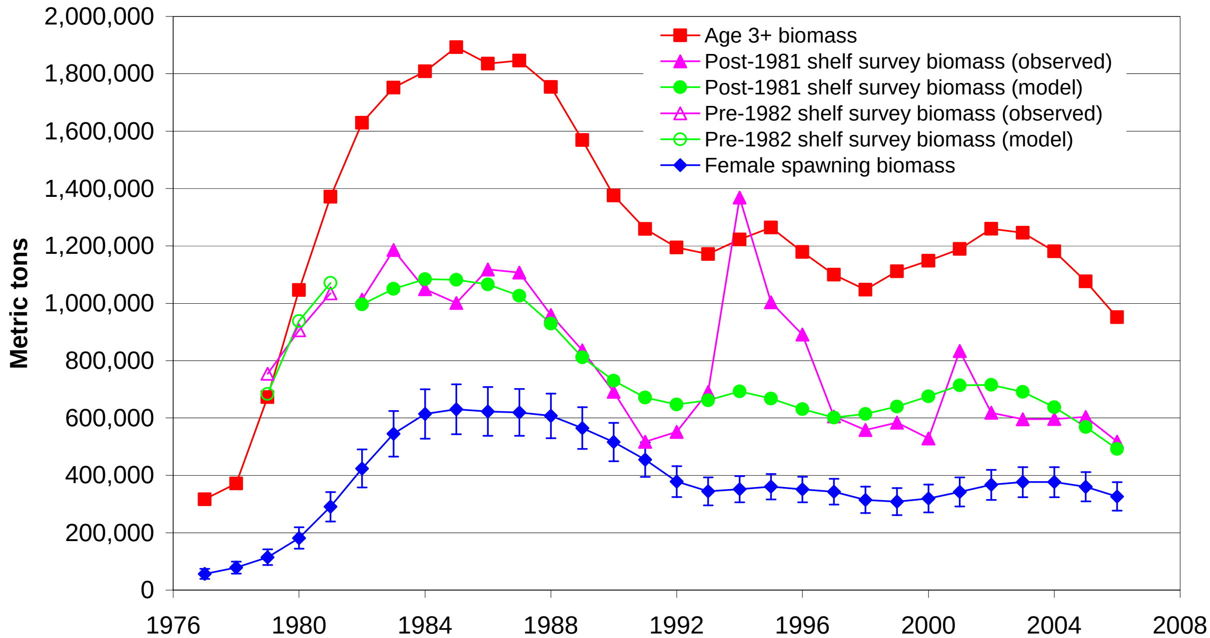


Figure 2.7—Biomass time trends (age 3+ biomass, female spawning biomass, survey biomass) of EBS Pacific cod as estimated by Model B1.

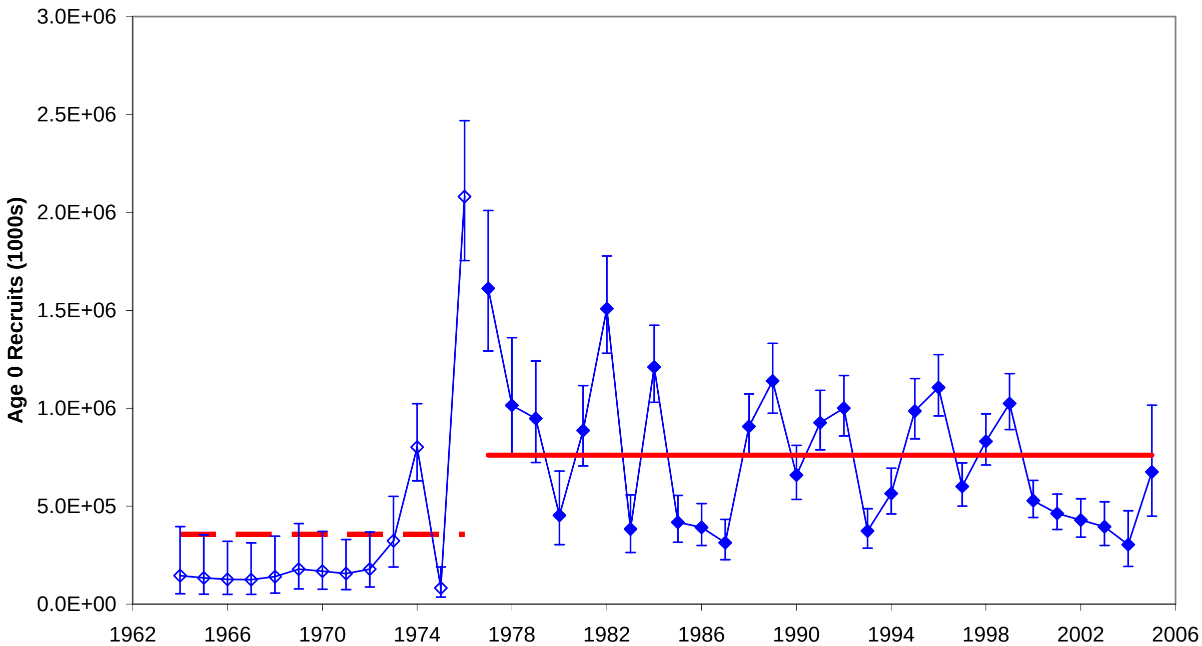


Figure 2.8—Time series of EBS Pacific cod recruitment at age 0, with 95% confidence intervals, as estimated by Model B1.

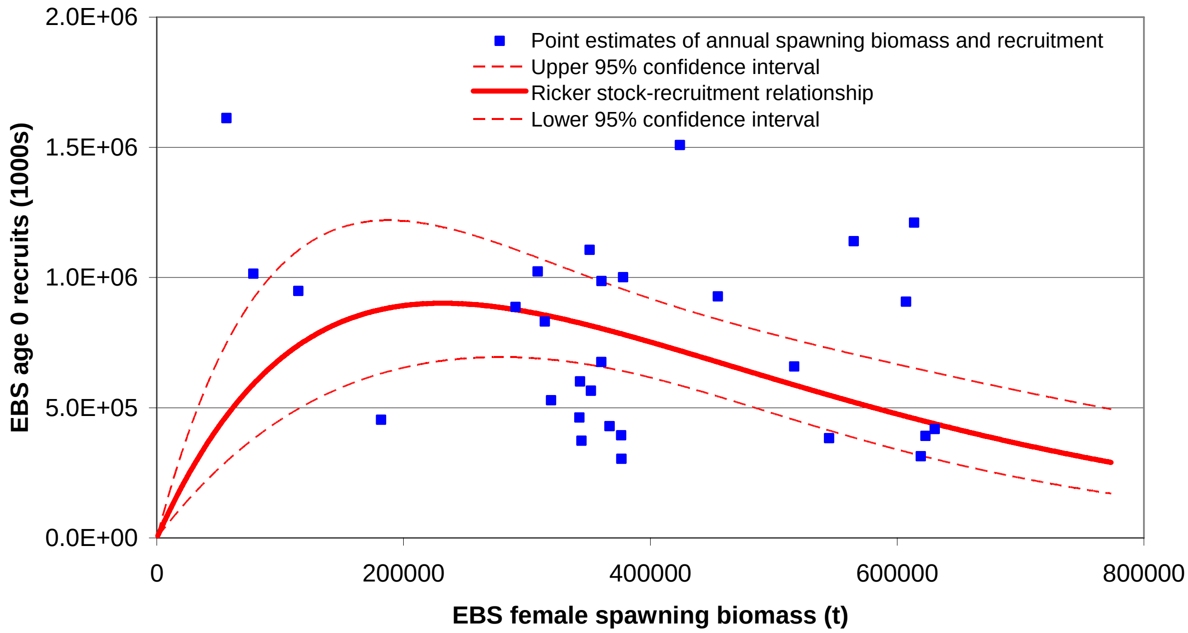


Figure 2.9—Age 0 recruitment versus female spawning biomass for Pacific cod during the years 1977-2005 as estimated by Model B1, with Ricker stock-recruitment curve (for illustrative purposes only).

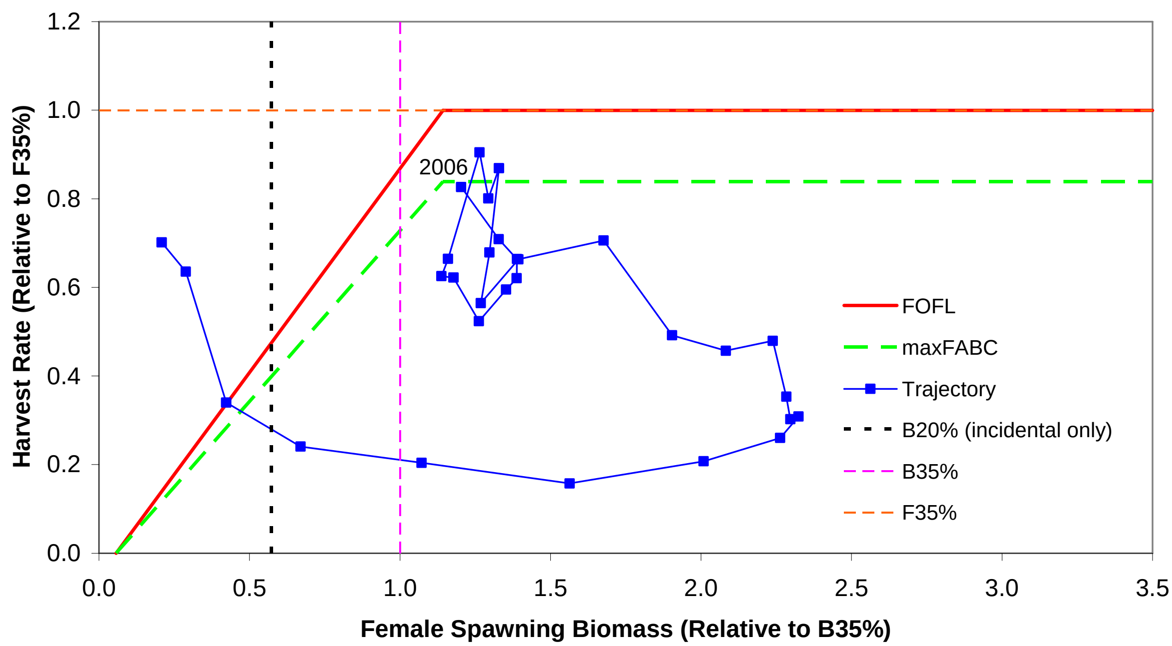


Figure 2.10—Trajectory of Pacific cod fishing mortality and female spawning biomass as estimated by Model B1, 1977-present. Because Pacific cod is a key prey of Steller sea lions, harvests of Pacific cod would be restricted to incidental catch in the event that spawning biomass fell below $B_{20\%}$.

Attachment 2.1: Results from Ecosystem Models on the Role of Pacific Cod In the Eastern Bering Sea and Aleutian Islands Ecosystems

Sarah Gaichas and Kerim Aydin

Pacific cod are important predators in the EBS and AI ecosystems. While they are managed similarly in both ecosystems, food web modeling suggests key differences in cod's ecosystem role in the AI and EBS. The first key difference between ecosystems relates to cod's relative density in its continental shelf habitats in each system: because the AI has a much smaller area of shelf relative to the EBS (and the Gulf of Alaska, GOA), the smaller survey biomass estimate of cod in this area translates into a higher density in tons per square kilometer relative to the density in the EBS (Figure 1, left panel). Although the density of cod differs between systems, the relative effects of fishing and predation mortality as estimated within food web models constructed for each ecosystem (Aydin et al in review) are similar between the AI, EBS, and GOA. Here, sources of mortality are compared against the total production of cod as estimated in the BSAI and GOA cod stock assessment models (see Annex 2.1.A, "Production rates," for detailed methods). The "unknown" mortality in Figure 1 (left) represents the difference between the stock assessment estimated cod production and the known sources of fishing and predation mortality. While nearly half of cod production as estimated by the stock assessment appears to be "unused" in all three ecosystems, it is also clear that cod have relatively more fishing mortality than predation mortality in all three ecosystems (Figure 1, right panel). This suggests that changing fishing mortality is likely to affect cod population trajectories; therefore, we may ask what ecosystem effects changes in cod mortality might cause in each ecosystem.

To determine the potential ecosystem effects of changing total cod mortality, we first examine the diet data collected for cod. Diet data are collected aboard NMFS bottom trawl surveys in both the EBS and AI ecosytems during the summer (May – August); this comparison uses diet data collected in the early 1990's in each ecosystem. In the EBS, 2436 cod stomachs were collected during the 1991 bottom trawl survey and used in this analysis. In the AI, a total of 1181 cod stomachs were collected between the 1991 and 1994 bottom trawl surveys (n=659 and 533, respectively) and used in this analysis. The diet compositions reported here reflect the size and spatial distribution of cod in each survey (see Annex 2.1.A, "Diet calculations" for detailed methods). While the diet compositions reported here most accurately reflect early 1990's conditions in the BSAI, it is possible to update this information and examine changes in cod diets over time; that more extensive analysis is planned for a future assessment.

Food habits data show that Pacific cod have an extremely varied diet in both ecosystems (Figure 2). In the EBS, pollock are a major diet item for cod (26% of diet), but in the AI Atka mackerel and sculpins are the predominant fish prey for cod (15% of diet each), with pollock comprising less than 5% of the diet. In both ecosystems, Pandalid and non-Pandalid (NP) shrimp and various crabs are important prey, but other major prey items differ by ecosystem and seem to relate to the relative importance of benthic and pelagic pathways in each ecosystem as discussed in Aydin et al (in review). Commerically important crab species such as snow crab (C. opilio) and tanner crab (C. bairdi) make up 9% of cod diets in the EBS, but less than 3% in the AI, reflecting the stronger benthic energy flow in the EBS. In contrast, squids make up over 6% of cod diets in the AI, but are very small proportions of diets in the EBS, reflecting the stronger pelagic energy flow in the AI. Myctophids are also found in cod diets only in the AI, reflecting the oceanic nature of the food web there. Cod are clearly opportunistic predators in both ecosystems, feeding on a variety of fish and invertebrates, and scavenging as well. Fishery offal makes up 5-7% of cod diets in both systems, indicating that while fishing causes cod mortality, it also contributes to cod production (although much fishery offal comes from fisheries directed at pollock, not cod).

Using diet data for all predators of cod and consumption estimates for those predators, as well as fishery catch data, we next estimate the sources of cod mortality in the AI and EBS (see detailed methods in Annex 2.1.A). As described above, sources of mortality are compared against the total production of cod as estimated in the BSAI cod stock assessment model. Mortality sources for cod are similar when comparing fisheries, but different when comparing predators between the EBS and AI. In both ecosystems, the trawl and longline fisheries for cod were the largest mortality sources for cod in the early 1990s (Figure 3). The next largest source of cod mortality is the pollock trawl fishery in the EBS and the directed Atka mackerel ("Other groundfish") fishery in the AI, which retains incidentally caught cod. In the EBS, pollock predation ranks next, and in the AI, adult and juvenile Steller sea lion predation represents the largest single source of predation mortality for cod. Cod cannibalism is a significant source of cod mortality only in the EBS, and flatfish trawl fisheries round out the large cod mortality sources in that ecosystem. Therefore, we see groundfish-dominated predation mortality sources for cod in the EBS, but sea-lion dominated predation mortality in the AI.

After comparing the different diet compositions and mortality sources of cod in each ecosystem, we shift focus slightly to view cod within the context of the larger EBS and AI food webs (Figure 4). Visually, it is apparent that cod's direct trophic relationships in each ecosystem include a majority of species groups; there are few boxes not connected to cod. However, comparing these food webs show further differences in cod trophic relationships between ecosystems. In the EBS, the significant predators of cod (blue boxes joined by blue lines) include the cod fisheries, the pollock fishery, and resident seals (upper panel of Figure 4). Significant prey of cod (green boxes joined by green lines) include the many species shown in Figure 2. Light blue boxes in the EBS food web represent species which are both predators and prey of cod at some stage of life, with the most significant predator/prey of cod being pollock. In contrast, there are no species groups in the AI which are both predator and prey to cod (Figure 4, lower panel).

We can investigate whether these differences in cod diet, mortality, and relationships between the EBS and AI might suggest different ecosystem roles for cod in these areas. We use the diet and mortality results integrated with information on uncertainty in the food web using the Sense routines (Aydin et al in review) and a perturbation analysis with each model food web to explore the ecosystem relationships of cod further. Two questions are important in determining the ecosystem role of cod: which species groups are cod important to, and which species groups are important to cod? First, the importance of cod to other groups within the EBS and AI ecosystems was assessed using a model simulation analysis where cod survival was decreased (mortality was increased) by a small amount, 10%, over 30 years to determine the potential effects on other living groups. This analysis also incorporated the uncertainty in model parameters using the Sense routines, resulting in ranges of possible outcomes which are portrayed as 50% confidence intervals (boxes in Figure 5) and 95% confidence intervals (error bars in Figure 5). Species showing the largest median changes from baseline conditions are presented in descending order from left to right. Therefore, the largest change resulting from a 10% decrease in cod survival in both ecosystems is a decrease in adult cod biomass, as might have been expected from such a perturbation. However, the decrease in biomass resulting from the same perturbation is different between the EBS and AI: the 50% intervals range from a 7-11% decrease in the AI, to a 7-17% decrease in the EBS (Figure 5).

The simulated decrease in cod survival affects the fisheries for cod similarly in the EBS and AI. After the decreased adult cod biomass, the next largest effect of the perturbation predicted by the models is a decrease in the "biomass" (catch) of the pot, longline, and trawl fisheries targeting adult cod in the EBS (Figure 5, top panel). In the AI ecosystem model, adult sablefish are predicted to have a larger change from the cod manipulation than the fisheries, although the predicted increase in sablefish biomass is much more uncertain than the predicted decrease in fishery catch in the AI (bottom panel, Figure 5). We discuss the sablefish result in detail below; for this discussion, we note that the cod fisheries in the AI are behaving similarly to the cod fisheries in the EBS after the simulated decrease in cod survival. Since cod fisheries are extremely specialized predators of cod, it makes sense that they are most sensitive to changes in the survival of cod in each ecosystem. It is notable that none of the other predators of cod showed a significant sensitivity to a 10% decrease in cod survival. Pollock and sea lions ranked highest as non-fishery mortality sources of cod in the EBS and AI, respectively, but neither of these species were predicted to have significant changes in biomass in either ecosystem in this analysis: neither EBS pollock nor AI sea lions showed enough change from the baseline condition to be included in the plots. While these predators may cause significant cod mortality in each system, this analysis suggests that none of them are dependent on cod to the extent that small changes in cod survival affect their biomass in a predictable manner. It may be that these predator species would react more strongly to larger changes in cod survival; this could be further analyzed with different perturbation analyses.

In contrast with the predators of cod, a 10% decrease in cod survival is predicted to change the biomass of some cod prey, and even some species not directly connected to cod. In the EBS, greenling biomass is predicted to increase as a result of the perturbation, as are tanner crab and king crab biomass, albeit wth less certainty (Figure 5, top panel). In the AI, a larger set of species appear to react more strongly to increases in cod mortality than in the other two systems: sablefish, rex sole, arrowtooth flounder, and sleeper sharks are all predicted to increase in biomass in addition to greenlings and small sculpins (Figure 5). Of these, only rex sole, greenlings and other sculpins are direct cod prey; the change in adult sablefish and adult arrowtrooth biomass apparently arises from reduced cod predation mortality on the juveniles of each species in the AI ecosystem model: cod cause 80% of juvenile sablefish and juvenile arrowtooth mortality in the AI model. Sleeper sharks are neither predators nor prey of cod in the AI, suggesting that decreased cod survival has strong indirect effects in this ecosystem. Some of these differences in species sensitivity to cod mortality arise from the differences in cod diet in each system, but it seems likely that the higher sensitivity of multiple species to cod in the AI may also be due to cod's higher biomass per unit area there relative to the EBS. This in turn suggests that in the AI there may be stronger potential ecosystem effects of cod fishing than in the other two systems.

To determine which groups were most important to cod in each ecosystem, we conducted the inverse of the analysis presented above. In this simulation, each species group in the ecosystem had survival reduced by 10% and the system was allowed to adjust over 30 years. The strongest median effects on EBS and AI adult cod are presented in Figure 6. The largest effect on adult cod was the reduction in biomass resulting from the reduced survival of juvenile cod, followed by the expected direct effect, reduced biomass of adult cod in response to reduced survival of adult cod, in both ecosystems (Figure 6). Beyond these direct single species effects, cod appear most sensitive in all ecosystems to bottom up effects from both pelagic and benthic production pathways (small phytoplankton and benthic detritus). However, the bottom up effect is most pronounced in the AI, where the upper 95% intervals for the percent change of cod indicate that cod biomass will almost certainly decrease as a result of decreased survival of small phytoplankton, benthic detritus, and large phytoplankton (Figure 6). In contrast, the EBS model prediction is that cod biomass is likely to decrease from decreased survival of small phytoplankton and benthic detritus, but the detritus 95% intervals cross the x axis indicating that no change is also a possible outcome.

While decreased survival of primary producers appears to hurt cod, there are few species groups in either ecosystem which appear to benefit cod through reduced survival. In other words, they have no obvious single competitor or predator supressing cod biomass in the AI or EBS. In general, reduced "survival" (lower catch) of fisheries means more cod in the EBS and AI. In the EBS, reduced survival of other sculpins may increase cod biomass to some extent (Figure 6), which may seem counterintuitive given that reduced cod survival appeared to increase other sculpin biomass in the AI (Figure 5). While adult cod eat other sculpins, other sculpins in turn eat juvenile cod in the EBS (Figure 7), likely accounting for the results shown in Figure 6.

The results of these perturbation analyses suggest that the regional level of management applied to Pacific cod should be modified to account for differences between ecosystems. The food web relationships of cod are demonstrably different between the EBS and AI ecosystems, where they are currently assessed and managed identically. The impacts of changing cod survival (and by extension, fishing mortality) differ by ecosystem as well, with the impacts felt most strongly and with highest certainty in the AI ecosystem according to this analysis. Therefore, it seems that the cod fishery in the AI should be managed separately from that in the EBS to ensure that any potential ecosystem effects of changing fishing mortality might be monitored at the appropriate scale.

References

Aydin, K., S. Gaichas, I. Ortiz, D. Kinzey, and N. Friday. In review. A comparison of the Bering Sea, Gulf of Alaska, and Aleutian Islands large marine ecosystems through food web modeling. NOAA NMFS Tech Memo. 233 p.

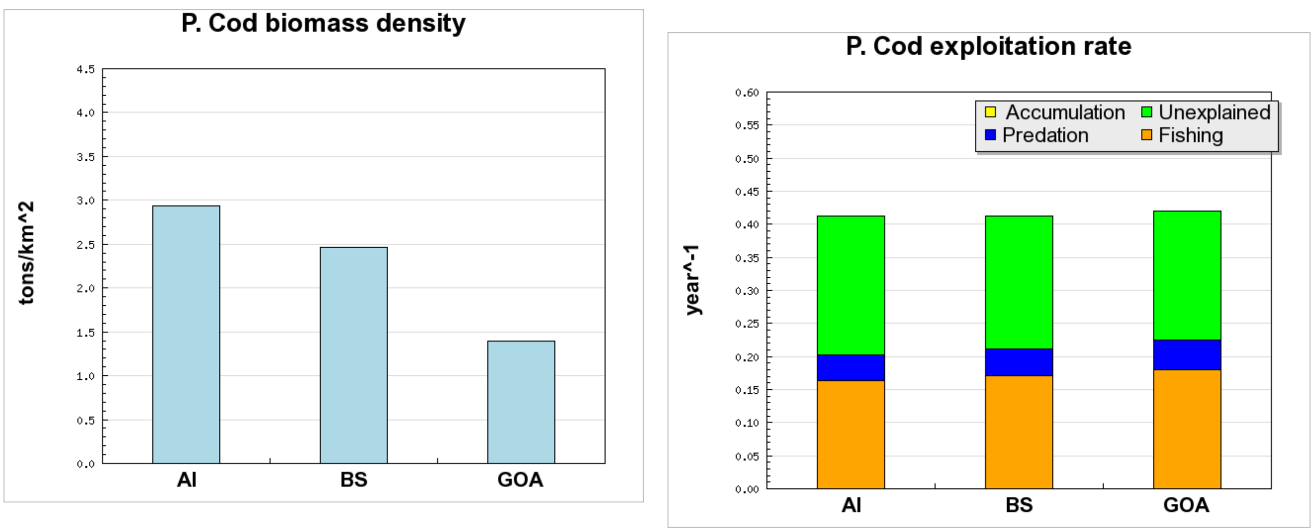


Figure 1. Comparative biomass density (left) and mortality sources (right) for Pacific cod in the AI, EBS, and GOA ecosystems. For the AI and GOA, biomass density (left) is the average biomass from early 1990s NMFS bottom trawl surveys divided by the total area surveyed. For the EBS, biomass density is the stock assessment estimated adult (age 3+) biomass for 1991 (Thompson and Dorn 2005) divided by the total area covered by the EBS bottom trawl survey. Total cod production (right) is derived from cod stock assessments for the early 1990's, and partitioned according to fishery catch data and predation mortality estimated from cod predator diet data (Aydin et al in review). See Annex 2.1.A for detailed methods.

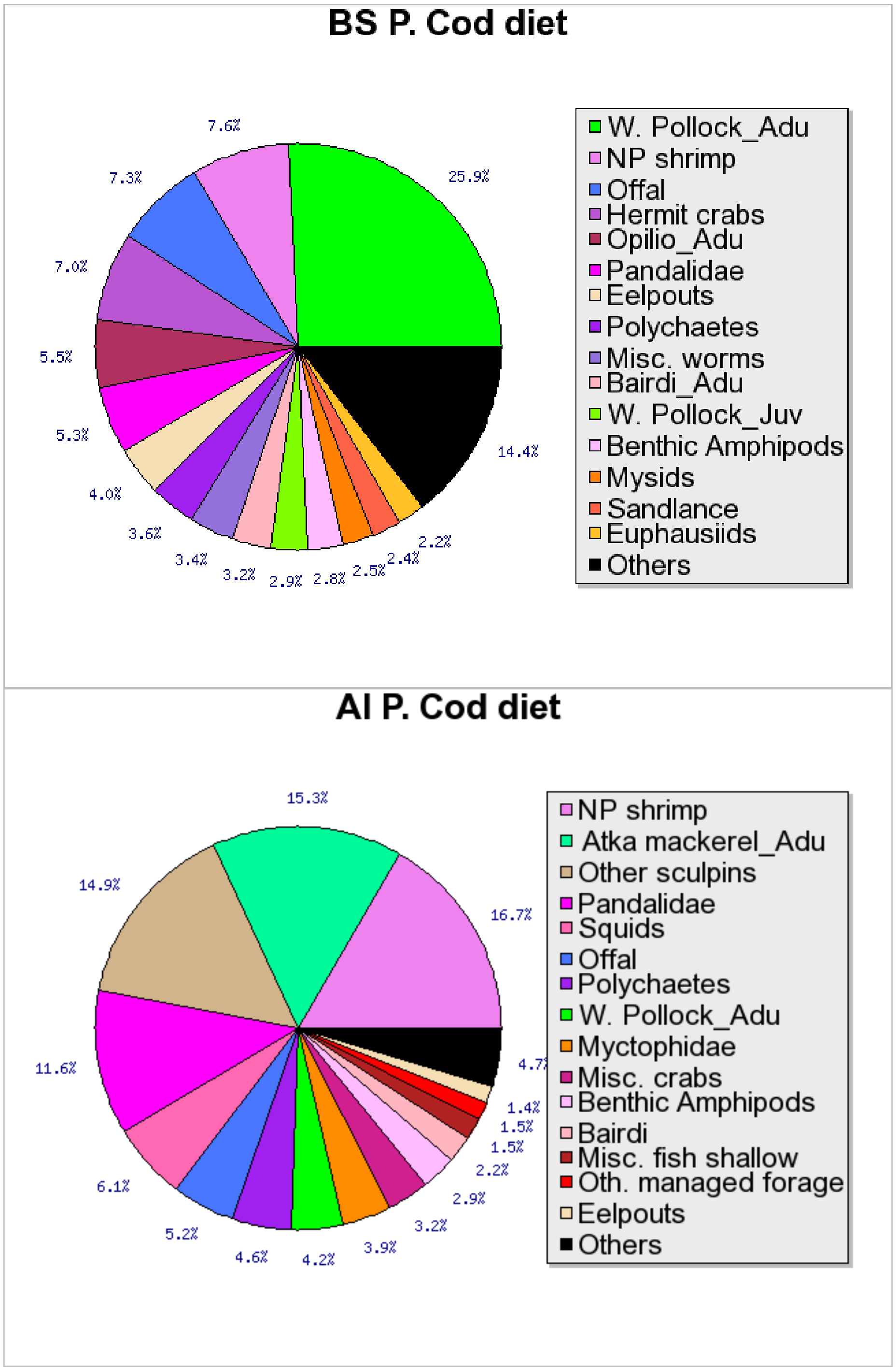


Figure 2. Comparison of Pacific cod diet compositions for the EBS (top) and AI (bottom) ecosystems. Diets are estimated from stomach collections taken aboard NMFS bottom trawl surveys in 1991 (EBS) and in 1991-1994 (AI). See Annex 2.1.A for detailed methods.

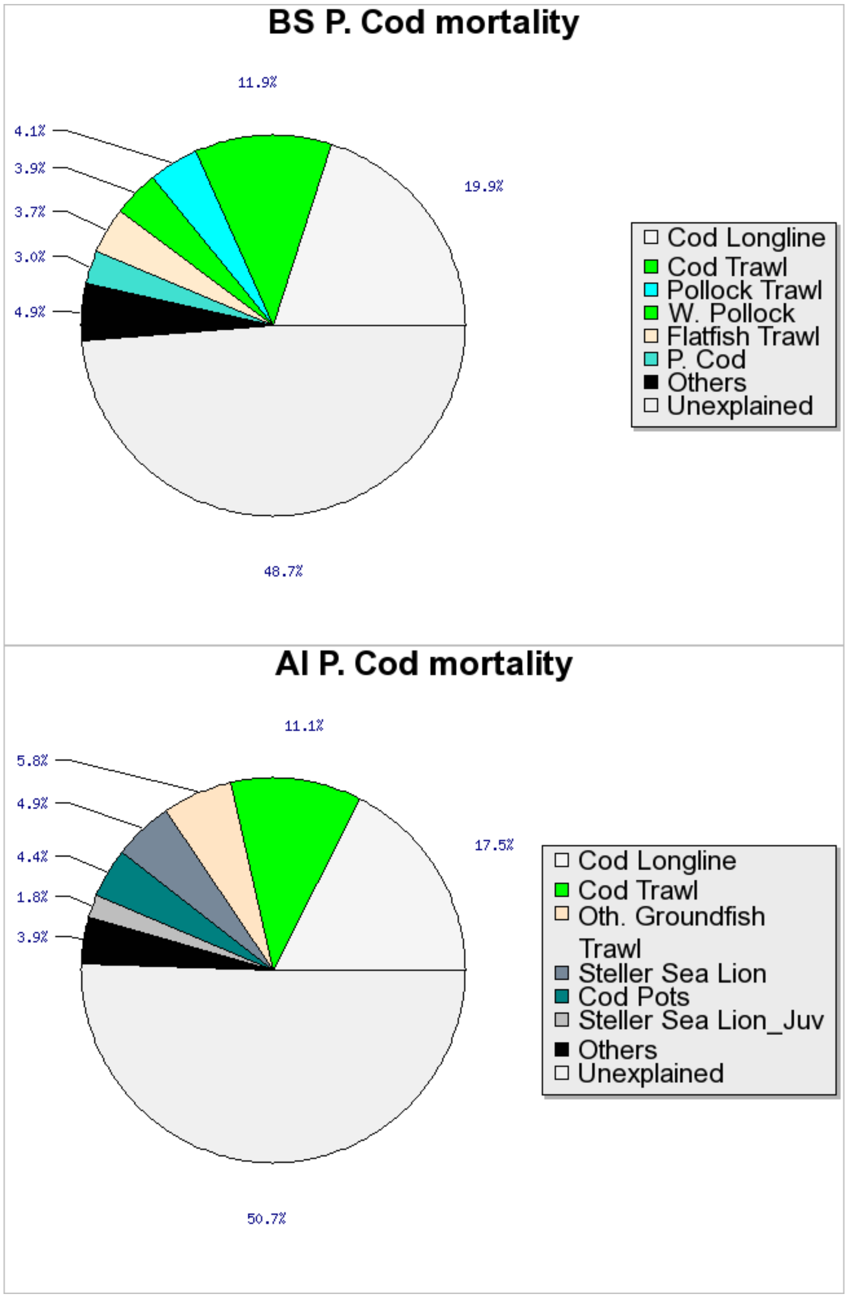


Figure 3. Comparison of Pacific cod mortality sources for the EBS (top) and AI (bottom) ecosystems. Mortality sources reflect cod predator diets estimated from stomach collections taken aboard NMFS bottom trawl surveys in 1991 (EBS) and in 1991-1994 (AI), cod predator consumption rates estimated from stock assessments and other studies, and catch of cod by all fisheries in the same time periods (Aydin et al in review). See Annex 2.1.A for detailed methods.

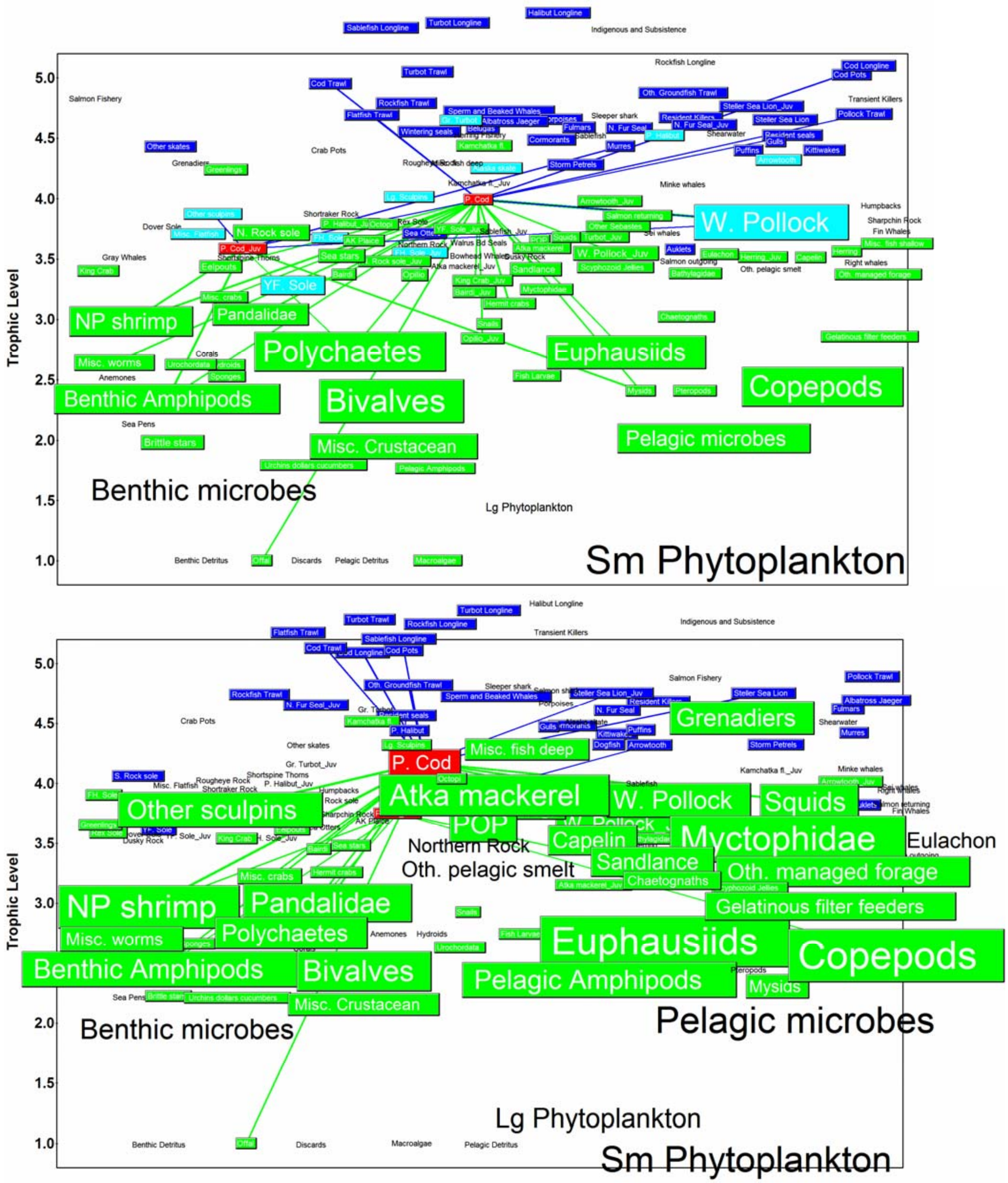


Figure 4. Adult and juvenile cod in the EBS (top) and AI (bottom) food webs. Predators of cod are dark blue, prey of cod are green, and species that are both predators and prey of cod are light blue. Box size is proportional to biomass and lines between boxes represent the most significant energy flows.

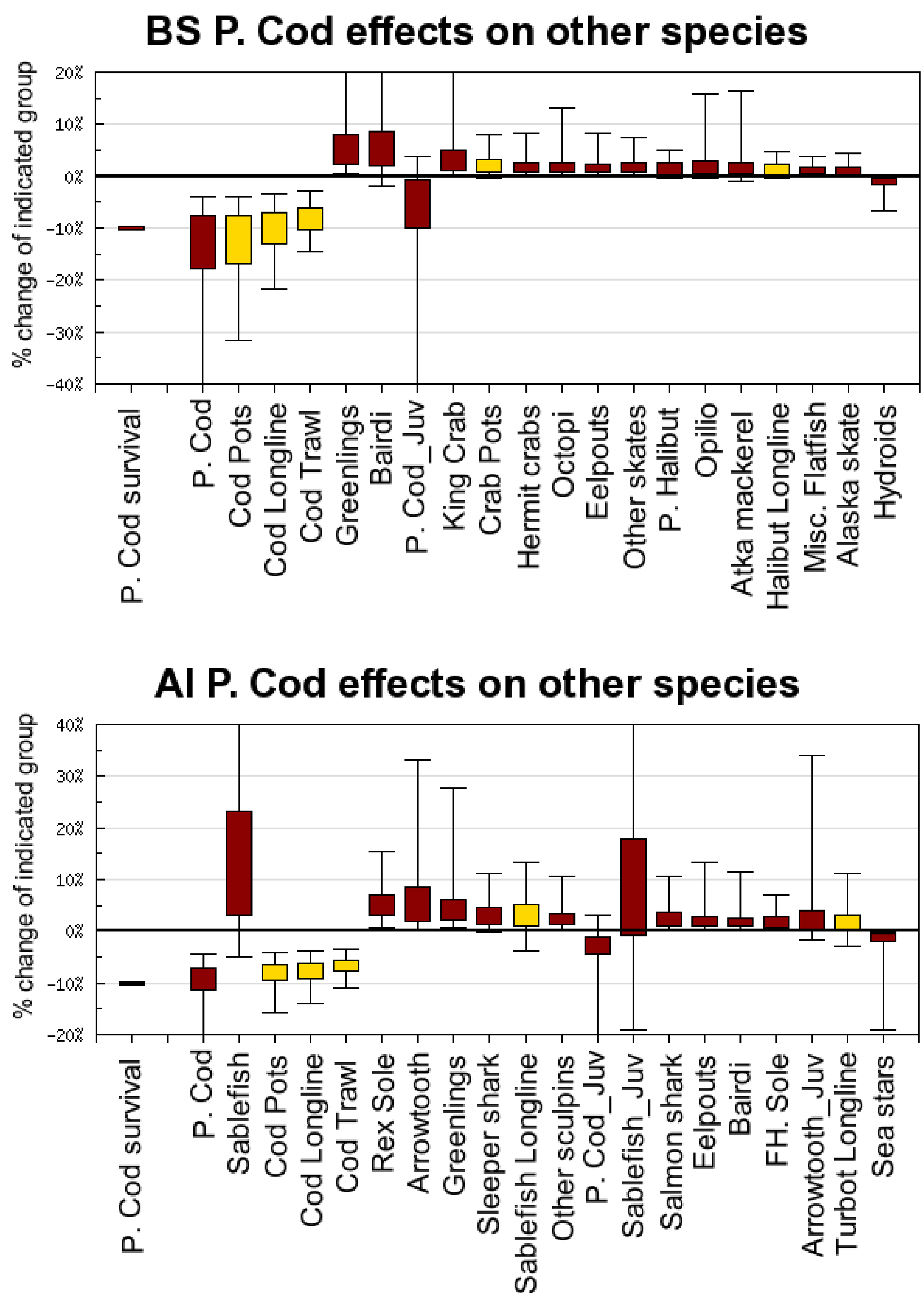
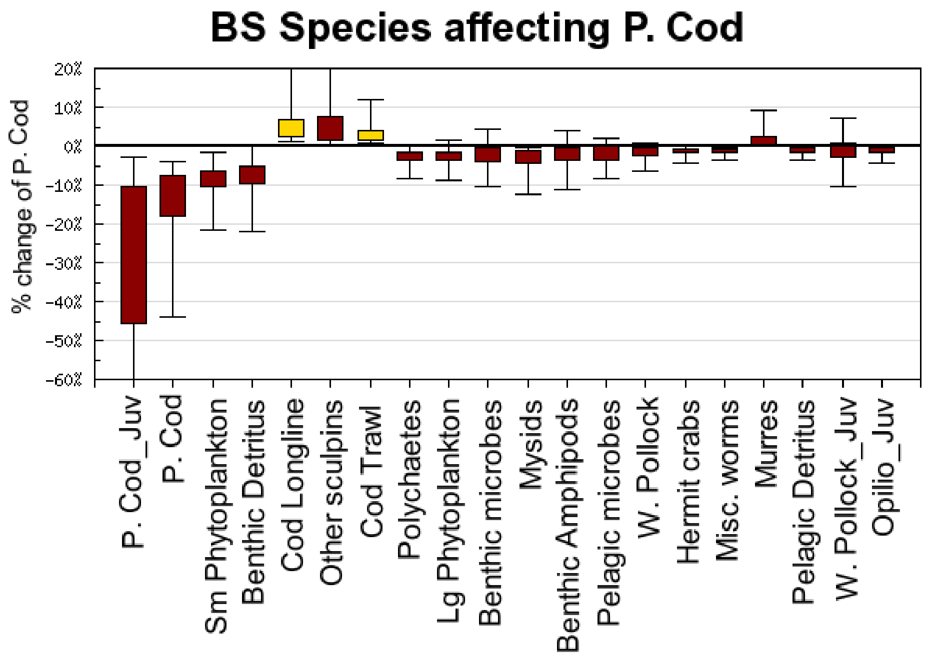


Figure 5. Effect of changing cod survival on fishery catch (yellow) and biomass of other species (dark red): EBS (top) and AI (bottom), from a simulation analysis where cod survival was decreased by 10% and the rest of the ecosystem adjusted to this decrease for 30 years. Boxes show resulting percent change in the biomass of each species on the x axis after 30 years for 50% of feasible ecosystems, error bars show results for 95% of feasible ecosystems (see Aydin et al in review for detailed Sense methods).



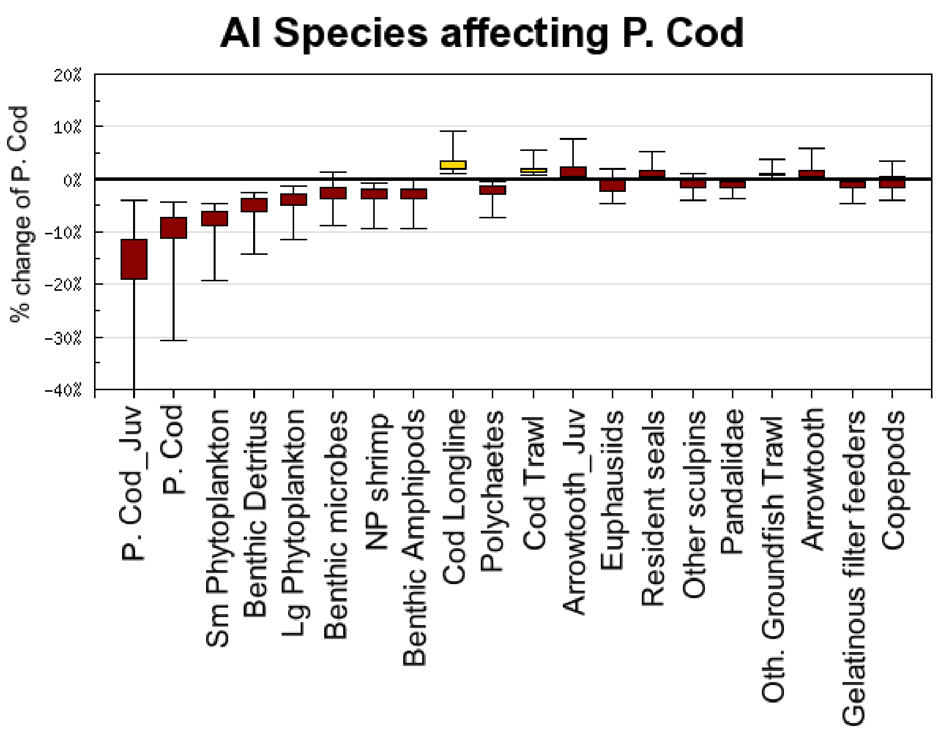


Figure 6. Effect of reducing fisheries catch (yellow) and other species survival (dark red) on cod biomass: EBS (top) and AI (bottom), from a simulation analysis where survival of each X axis species group was decreased by 10% and the rest of the ecosystem adjusted to this decrease for 30 years. Boxes show resulting percent change in the biomass of adult cod after 30 years for 50% of feasible ecosystems, error bars show results for 95% of feasible ecosystems (see Aydin et al in review for detailed Sense methods).

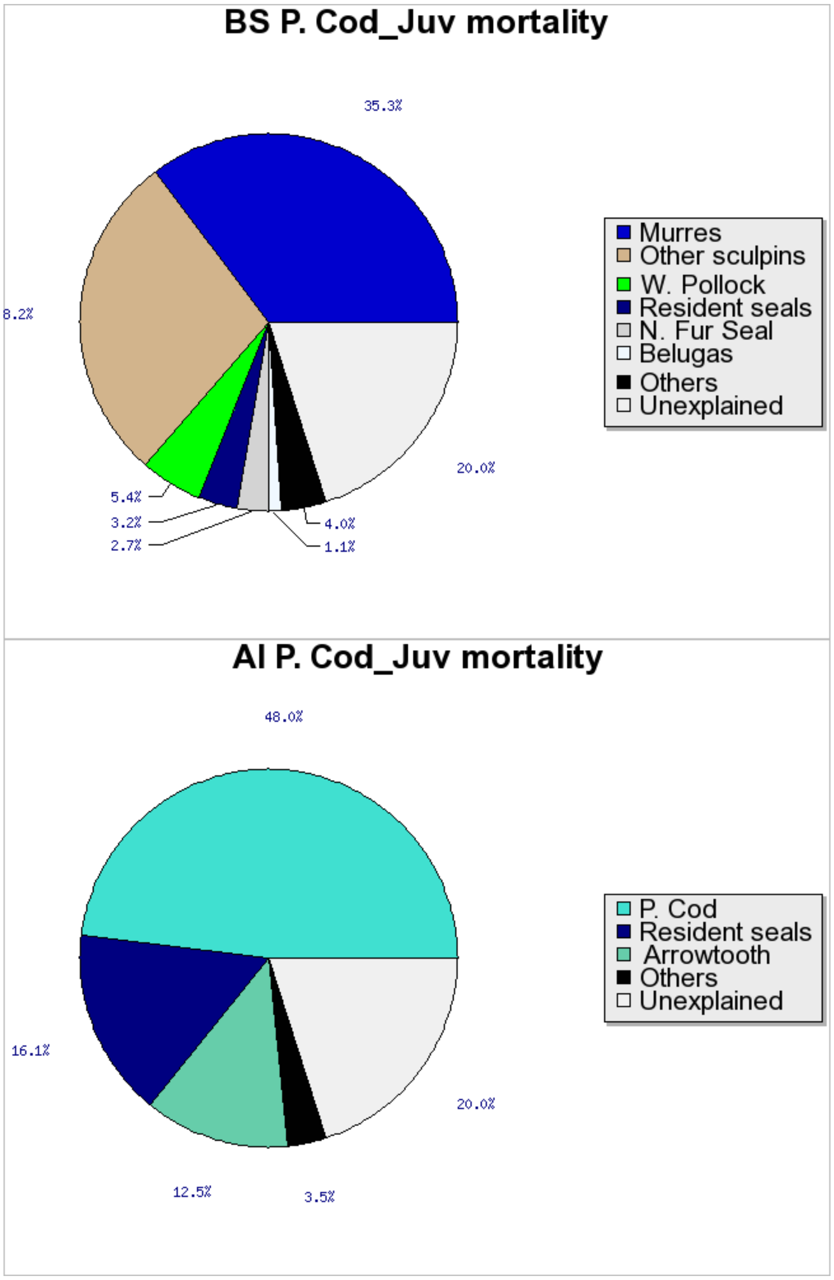


Figure 7. Juvenile cod mortality sources: EBS (top) and AI (bottom). Mortality sources reflect juvenile cod predator diets estimated from stomach collections taken aboard NMFS bottom trawl surveys in 1991 (EBS) and in 1991-1994 (AI), cod predator consumption rates estimated from stock assessments and other studies, and catch of cod by all fisheries in the same time periods (Aydin et al in review). See Annex 2.1.A for detailed methods.

Annex 2.1.A

Diet composition calculations

Notation:

DC = diet composition
W = weight in stomach
n = prey
p = predator
s = predator size class
h = survey haul
r = survey stratum
B = biomass estimate
v = survey
a = assessment
R = ration estimate

The diet composition for a species is calculated from stomach sampling beginning at the level of the individual survey haul (1), combining across hauls within a survey stratum (2), weighting stratum diet compositions by stratum biomass (3), and finally combining across predator size classes by weighting according to size-specific ration estimates and biomass from stock assessment estimated age structure (4). Ration calculations are described in detail below.

Diet composition (DC) of prey n in predator p of size s in haul h is the total weight of prey n in all of the stomachs of predator p of size s in the haul divided by the sum over all prey in all of the stomachs for that predator size class in that haul:

$$DC_{n,p,s,h} = W_{n,p,s,h} \Big/ \sum_{n} W_{n,p,s,h} \qquad (1)$$

Diet composition of prey n in predator p of size s in survey stratum r is the average of the diet compositions across hauls within that stratum:

$$DC_{n,p,s,r} = \sum_{h} DC_{n,p,s,h} \Big/ h \qquad (2)$$

Diet composition of prey n in predator p of size s for the entire area t is the sum over all strata of the diet composition in stratum r weighted by the survey biomass proportion of predator p of size s in stratum r:

$$DC_{n,p,s,t} = \sum_{r} DC_{n,p,s,r} * B^{v}_{p,s,r} \Big/ \sum_{r} B^{v}_{p,s,r} \qquad (3)$$

Diet composition of prey n in predator p for the entire area t is the sum over all predator sizes of the diet composition for predator p of size s as weighted by the relative stock assessment biomass of predator size s times the ration of predator p of size s:

$$DC_{n,p,t} = \sum_{s} DC_{n,p,s,t} * B^{a}_{p,s} * R_{p,s} \Big/ \sum_{s} B^{a}_{p,s} * R_{p,s} \qquad (4)$$

Ration Calculations

Size specific ration (consumption rate) for each predator was determined by the method of fitting the generalized Von Bertalanffy growth equations (Essington et al. 2001) to weight-at-age data collected aboard NMFS bottom trawl surveys.

The generalized Von Bertalanffy growth equation assumes that both consumption and respiration scale allometrically with body weight, and change in body weight over time (dW/dT) is calculated as follows (Paloheimo and Dickie 1965):

$$\frac{dW_t}{dt} = H \cdot W_t^d - k \cdot W_t^n \qquad (5)$$

Here, W_t is body mass, t is the age of the fish (in years), and H, d, k, and n are allometric parameters. The term $H \cdot W_t^d$ is an allometric term for “useable” consumption over a year, in other words, the consumption (in wet weight) by the predator after indigestible portions of the prey have been removed and assuming constant caloric density between predator and prey. Total consumption (Q) is calculated as $(1/A) \cdot H \cdot W_t^d$, where A is a scaling fraction between predator and prey wet weights that accounts for indigestible portions of the prey and differences in caloric density. The term $k \cdot W_t^n$ is an allometric term for the amount of biomass lost yearly as respiration.

Based on an analysis performed across a range of fish species, Essington et al. (2001) suggested that it is reasonable to assume that the respiration exponent n is equal to 1 (respiration linearly proportional to body weight). In this case, the differential equation above can be integrated to give the following solution for weight-at-age:

$$W_t = W_\infty \cdot \left(1 - e^{-k(1-d)(t-t_0)}\right)^{\frac{1}{1-d}} \qquad (6)$$

Where W_∞ (asymptotic body mass) is equal to $(H/k)^{\frac{1}{1-d}}$, and t_0 is the weight of the organism at time=0. If the consumption exponent d is set equal to 2/3, this equation simplifies into the “specialized” von Bertalanffy length-at-age equation most used in fisheries management, with the “traditional” von Bertalanffy K parameter being equal to the k parameter from the above equations divided by 3.

From measurements of body weight and age, equation 2 can be used to fit four parameters (W_∞ , d, k, and t_0) and the relationship between W_∞ and the H, k, and d parameters can then be used to determine the consumption rate $H \cdot W_t^d$ for any given age class of fish. For these calculations, weight-at-age data available and specific to the modeled regions were fit by minimizing the difference between log(observed) and log(predicted) body weights as calculated by minimizing negative log likelihood: observation error was assumed to be in weight but not aging. A process-error model was also examined but did not give significantly different results.

Initial fitting of 4-parameter models showed, in many cases, poor convergence to unique minima and shallow sum-of-squares surfaces: the fits suffered especially from lack of data at the younger age classes that would allow fitting to body weights near t=0 or during juvenile, rapidly growing life stages. To counter this, the following multiple models were tested for goodness-of-fit:

1. All four parameters estimated by minimization;
2. *d* fixed at 2/3 (specialized von Bertalanffy assumption)
3. *d* fixed at 0.8 (median value based on metaanalysis by Essington et al. 2001).
4. t_0 fixed at 0.
5. *d* fixed at 2/3 with t_0 fixed at 0, and *d* fixed at 0.8 with t_0 fixed at 0.

The multiple models were evaluated using Aikeike's Information Criterion, AIC (spreadsheet review). In general, the different methods resulted in a twofold range of consumption rate estimates; consistently, model #3, *d* fixed at 0.8 while the other three parameters were free, gave the most consistently good results using the AIC. In some cases model #1 was marginally better, but in some cases, model #1 failed to converge. The poorest fits were almost always obtained by assuming that d was fixed at 2/3.

To obtain absolute consumption (*Q*) for a given age class, the additional parameter *A* is required to account for indigestible and otherwise unassimilated portions of prey. We noted that the range of indigestible percentage for a wide range of North Pacific zooplankton and fish summarized in Davis (2003) was between 5-30%, with major zooplankton (copepods and euphasiids), as well as many forage fish, having a narrower range of indigestible percentages, generally between 10-20%. Further, bioenergetics models, for example for walleye pollock (Buckley and Livingston), indicate that nitrogenous waste (excretion) and egestion resulted in an additional 20-30% loss of consumed biomass. As specific bioenergetics models were not available for most species, we made a uniform assumption of a total non-respirative loss of 40% (from a range of 25-60%) for all fish species, with a corresponding *A* value of 0.6.

Finally, consumption for a given age class was scaled to population-level consumption using the available numbers-at-age data from stock assessments, or using mortality rates from stock assessments and the assumption of an equilibrium age structure in cases where numbers-at-age reconstructions were not available.

Production rates

Production per unit biomass (P/B) and consumption per unit biomass (Q/B = R, ration above) for a given population depend heavily on the age structure, and thus mortality rate of that population. For a population with an equilibrium age structure, assuming exponential mortality and Von Bertalanffy growth, P/B is in fact equal to total mortality Z (Allen 1971) and Q/B is equal to (Z+3K)/A, where K is Von Bertalanffy's K, and A is a scaling factor for indigestible proportions of prey (Aydin 2004). If a population is not in equilibrium, P/B may differ substantially from Z although it will still be a function of mortality.

For the Bering Sea, Aleutian Islands, and Gulf of Alaska ECOPATH models, P/B and Q/B values depend on available mortality rates, which were taken from estimates or literature values used in single-species models of the region. It is noted that the single-species model assumptions of constant natural mortality are violated by definition in multispecies modeling; therefore, these estimates should be seen as "priors" to be input into the ECOPATH balancing procedures or other parameter-fitting (e.g. Bayesian) techniques.

Several methods were used to calculate P/B, depending on the level of data available. Proceeding from most data to least data, the following methods were used:

1. If a population is not in equilibrium, total production P for a given age class over the course of a year can be approximated as ($N_{at} \cdot \Delta W_{at}$), where N_{at} is the number of fish of a given age class in a given year, exponentially averaged to account for mortality throughout the year, and ΔW_{at} is the change in body weight of that age class over that year. For a particular stock, if weight-at-age data existed for multiple years, and stock-assessment reconstructed numbers-at-age were also available, production was calculated by summing this equation over all assessed age classes. Walleye pollock P/B for both the EBS and GOA were calculated using this method: examining the components of this sum over the years showed that numbers-at-age variation was responsible for considerably more variability in overall P/B than was weight-at-age variation.
2. If stock assessment numbers-at-age were available, but a time series of weight-at-age was not available and some weight-at-age data was available, the equation in (1), above, was used, however, the change in body weight over time was estimated using fits to the generalized Von Bertalanffy equations described in the consumption section, above.
3. If no stock assessment of numbers-at-age was available, the population was assumed to be in equilibrium, so that P/B was taken to equal Z. In cases for many nontarget species, estimates of Z were not available so estimates of M were taken from conspecifics with little assumed fishing mortality for this particular calculation.

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