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

Grant Thompson, James Ianelli, and Mark Wilkins

U.S. Department of Commerce
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Alaska Fisheries Science Center
7600 Sand Point Way NE., Seattle, WA 98115-6349

EXECUTIVE SUMMARY

Summary of Changes in Assessment Inputs

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

Changes in the Input Data

1) Catch data for 2007 were updated, and preliminary catch data for 2008 were incorporated.
2) Commercial fishery size composition data for the years prior to 1990 were recompiled, resulting in several new records.
3) Commercial fishery size composition data for 2007 were updated, and preliminary size composition data from the 2008 commercial fisheries were incorporated.
4) Age composition and mean-length-at-age data from the 1987, 1990, and 1993 GOA shelf bottom trawl surveys were incorporated.
5) The ageing error matrix was updated.
6) Seasonal catch per unit effort (CPUE) data for the trawl, longline, and pot fisheries from 2007 were updated, and preliminary catch rates for the longline and pot fisheries from 2008 were incorporated.
7) The time series of weight-at-length data was recompiled.
8) Each trawl survey abundance estimate and each survey size composition vector was split into two portions: the portion consisting of fish smaller than 27 cm (referred to as the "sub-27" survey), and the portion consisting of fish 27 cm and larger (referred to as the "27-plus" survey).

Changes in the Assessment Methodology

Many changes have been made or considered in the stock assessment model since last year's assessment (Thompson et al. 2007b). Three models were presented in this year's preliminary assessment, which is included as Attachment 2.1 to the present assessment. The relationships between the three models presented in the preliminary assessment are summarized in Table 2.1.1 of Attachment 2.1. Model 1 in the preliminary assessment was identical to the model accepted for use by the GOA Plan Team and SSC in 2006, which was almost identical to the model accepted for use by the GOA Plan Team and SSC in 2005. Model 2 was presented in the 2007 assessment, but not accepted for use by either the GOA Plan Team or SSC. Model 3 was an exploratory model that made use of some new features in Stock Synthesis (SS) and responded to further comments from the Plan Teams and SSC. Briefly, the features that distinguished

Model 3 in this year's preliminary assessment from the model presented in last year's assessment were as follows (see Attachment 2.1 for a more detailed description of differences):

1. Model 3 split each survey abundance estimate and each survey size composition vector into sub-27 (i.e., fish smaller than 27 cm) and 27-plus (i.e., fish 27 cm and larger) portions. Last year's model treated each survey as a single unit.
2. Model 3 used a multi-step algorithm developed in last year's BSAI Pacific cod assessment (Thompson et al. 2007a) to set the input sample size for size composition data. Last year's model set the input size equal to the square root of the actual sample size.
3. Model 3 set the input sample size for age composition data proportional to the number of fish aged, with the proportionality constant chosen so as to result in an average input sample size of 100. Last year's model used an average input sample size of 300.
4. Model 3 set the first reference age used in computing the length-at-age relationship at a value of 1.5417, corresponding to the mid-point of the trawl survey season. Last year's model used a value of 1 for the first reference age. (Note that this change in reference age had no impact on the shape of the estimated length-at-age relationship; the change simply made it easier to compare model outputs with input data from the trawl survey, by making the timing consistent.)
5. Model 3 treated the coefficient of variation of length at age as a linear function of length at age. Last year's model treated the standard deviation, rather than the CV, as the dependent variable.
6. Model 3 used fishery data used to estimate the weight-at-length relationship. Last year's model used data from the surveys rather than the fisheries.
7. Model 3 specified seasonal weight-at-length relationships. Last year's model used a single relationship throughout the year.
8. Model 3 estimated log recruitment variability as the standard deviation of the recruitment "devs" from 1977 to 2007. Last year's model used the entire time series, including the pre-1977 years.
9. Model 3 specified separate recruitment "dev" vectors for the pre-1977 and post-1976 environmental regimes. Last year's model used a single "dev" vector for the entire time series.
10. Model 3 estimated catchability of the 27-plus survey for the years 1984-1995 freely, while catchability of the 27-plus survey for the years 1996-2007 was fixed at 0.91, based on a result using the data of Nichol et al. (2007). Last year's model assumed a constant catchability for the entire time series.
11. Model 3 estimated catchability of the sub-27 survey internally as a random walk, with $\sigma = 0.2$. Last year's model did not use a separate sub-27 survey.
12. Model 3 allowed fishery selectivity to vary between blocks of years for a given gear and season. Last year's model assumed that fishery selectivity for a given gear and season was constant across the entire time series.
13. Model 3 forced the January-May trawl fishery to exhibit asymptotic selectivity during all time blocks (note: Attachment 2.1 states that "all trawl fisheries" were forced to exhibit asymptotic selectivity—this is a typographical error). Last year's model did not force any fisheries to exhibit asymptotic selectivity.
14. Model 3 placed a lower bound of 5 on the descending "width" parameter of all selectivity schedules, which often proved to be constraining. Last year's model used a lower bound of –10 for these parameters, which never proved to be constraining.
15. Model 3 estimated age-specific selectivities for the three ages covered by the sub-27 survey (ages 0, 1, and 2), because this was more efficient than estimating the six parameters used by the usual "double normal" selectivity function. Last year's model did not use a separate sub-27 survey.
16. Model 3 treated selectivity of the 27-plus survey as a function of age, to be consistent with the Bering Sea Pacific cod model. Last year's model treated survey selectivity as a function of length.
17. Model 3 defined a survey selectivity block for each survey year, and estimated the parameters of the ascending limb separately for each block. Last year's model used annual deviations to model

variability in the ascending limb of the survey selectivity schedule, but this resulted in superfluous parameters being estimated, because deviations were estimated for each year regardless of whether a survey took place during that year.

18. Model 3 treated the years 1984-1993 and 1996-2007 as the only two time blocks for the remaining parameters of the 27-plus survey selectivity schedule, to coincide with the switch from 30-minute to 15-minute tows in the survey design. Last year's model assumed that the survey selectivity schedule was asymptotic, and so had no potential for variability except in the ascending limb.

Two models are included in the present assessment. Their main features may be summarized as follows:

Model A: This is the "reference" model requested by the SSC at this year's October meeting. It is very similar to Model 3 from the preliminary assessment, the main difference being that the lower bound on the descending "width" parameter of the selectivity curves is reduced so that it is never constraining. The other difference with respect to Model 3 is that the distribution of mid-year length at age 1 is set equal to the distribution around the first mode of the long-term trawl survey size data (rather than estimated internally).

Model B: This is similar to Model A, except for the following features: 1) for each gear and season, individual selectivity parameters are allowed to vary between blocks of years only if the cost of the additional parameters is outweighed by a sufficient improvement in the model's fit to the data; 2) constant catchability in the 27-plus survey is assumed for the entire time series; and 3) the input sample sizes for the age composition data are decreased substantially. *This is the authors' preferred model.*

Version 3.01f of SS was used to run all the models in this year's preliminary assessment and in the present assessment.

Summary of Results

The principal results of the present assessment, based on the authors' preferred model, are listed in the table below (biomass and catch figures are in units of t) and compared with the corresponding quantities from last year's assessment as specified by the SSC. The values of several biomass quantities from last year's assessment are not available ("n/a") because the GOA Plan Team and SSC rejected the model presented in last year's assessment and defaulted to Tier 5 for making harvest specifications. It should also be noted that relationships between last year's values and this year's values of several other quantities (e.g., projected age 0+ biomass and fishing mortality rates) may be difficult to interpret due to the change from survey-based Tier 5 management to (recommended) model-based Tier 3b management.

	Assessment	
Quantity/Status	Last year	This year
M	0.38	0.38
Specified/recommended Tier	5	3b
Projected biomass (ages 0+) for 2009	233,310	520,000
Projected female spawning biomass for 2009	n/a	88,000
B100%	n/a	255,500
B40%	n/a	102,200
B35%	n/a	89,400
B0	n/a	n/a
FOFL for 2009	0.38	0.54
maxFABC for 2009	0.29	0.44
maxFABC for 2010	0.29	0.52
Specified/recommended *FABC* for 2009	0.29	0.44
Specified/recommended *FABC* for 2010	0.29	0.39
OFL for 2009	88,660	66,600
OFL for 2010 (given recommended ABC for 2009)	n/a	126,000
maxABC for 2009	66,493	55,300
maxABC for 2010	n/a	103,700
Specified/recommended ABC for 2009	66,493	55,300
Specified/recommended ABC for 2010	n/a	79,500
Is the stock being subjected to overfishing?	no	no
Is the stock currently overfished?	n/a	no
Is the stock approaching a condition of being overfished?	n/a	no

Responses to Comments from the Plan Teams and SSC

GOA Plan Team Comments

The following are all from the November, 2007 minutes.

GPT1. *"The Team questioned the re-estimated weight-at-length in last year's assessment which was not included this year, and requested clarification on why the data are restricted to survey length-weight and do not include the observer length-weight data as well.... The Team suggested including a table of sample sizes for the next assessment and that other sources of information on length-weight be included, especially for fisheries data that may apply during seasons other than the summer when survey data are collected."* The preliminary assessment addressed this suggestion, and an updated treatment is included in the present assessment. A table of weight-at-length sample sizes is included in the "Parameters Estimated Independently" section, based on fishery data.

GPT2. *"The Plan Team recommends that the author look at variability in length-weight data, specifically intra-annual variability (previously looked at inter-annual variability) for the subsequent assessment."* The preliminary assessment addressed this suggestion. Season-specific parameters resulted in a statistically significant improvement in fitting the weight-at-length data, although the use of these season-specific parameters had very little effect on assessment model results. Both of the models in the present assessment use seasonal weight-at-length parameters.

GPT3. *"The Team requested that error bars be included in the length at age figure to indicate the low number of samples and the impact on results particularly notable at higher ages."* The requested error bars are included in Figure 2.2.

GPT4. *"The Team notes that previous models have had time-varying changes in fishery selectivity and this has been removed in this model. Previous configurations had a different selectivity from 2000-present to account for the modification to fishery selectivity as a result of SSL RPAs."* Model 3 from the preliminary assessment addressed this suggestion, defining selectivity schedules in terms of fishery-specific blocks of years. Both of the models in the present assessment use a similar approach. See also Comment JPT6 below.

BSAI Plan Team Comments of Potential Relevance for the GOA Assessment

The following is from the November, 2007 minutes.

BPT1. *"The Team recommended reducing the number of parameters in the models."* Model 3 from the preliminary assessment was, in part, an attempt to address this recommendation by including additional selectivity blocks only if the additional parameters were justified by a sufficient improvement in fit to the data. Model A in the present assessment continues this practice, and Model B goes a step further by fixing certain fishery selectivity parameters (for a given gear type and season) across blocks if the reduction in number of parameters is not outweighed by a degraded fit to the data.

Joint Plan Team Comments

The following are all from the September, 2008 minutes.

JPT1. *"The Plan Team recommends that the assessment author examine whether the minimum 'width' bounds are being reached during model estimation and if so, adjust the minimum 'width' bound to examine the effect of this bound on model results."* The minimum bound on selectivity "width" parameters was set initially at −10 in both of the models described in the present assessment. With very few exceptions, no selectivity "width" parameters were pinned against this minimum bound in any of the models presented here. For the very few cases where the minimum bound of −10 proved to be constraining, it was lowered to a value that was no longer constraining. See also Comments JPT5 and SSC3 below.

JPT2. *"The Plan Team commented that the assessment author attempted to reduce number of selectivity parameters to the extent possible but this model is still overly complicated as a result of the software being used. A simpler selectivity parameterization was suggested, e.g. exponential logistic. SS2 notably does not allow for this in the present software. The Plan Teams requested that the selectivity function be further simplified even if it means modifying SS2 accordingly."* Pending possible future inclusion of the exponential-logistic selectivity function in SS, the models in the present assessment attempt to simplify the estimation of selectivity by imposing constant (across time blocks) values of certain selectivity parameters whenever warranted. This resulted in a substantial reduction in the number of selectivity parameters relative to Model 3 from the preliminary assessment. See also Comment BPT1 above and Comment JPT4 below.

JPT3. *"BS Model 1: This model represents a general improvement from previous iterations.... Model 5 seems to be an improvement in model specification over 1."* The analogous model from the preliminary assessment for the GOA was Model 3. Both of the models described in the present assessment are based largely on Model 3 from the preliminary assessment.

JPT4. *"Can fixing parameters simplify selectivity? Yes, but efforts should be made to simplify further, preferably with a different parameterization. Note this is not feasible for November thus in the meantime selectivity as currently configured in model is acceptable...."* The basic configuration of the selectivity function from the preliminary assessment is retained in the present assessment. See also Comments BPT1 and JPT2 above.

JPT5. *"Is setting the lower bound of 5 on width appropriate? The Plan Team recommends that the assessment author examine whether the minimum 'width' bounds are being reached during model estimation and if so, adjust the minimum 'width' bound to examine the effect of this bound on model results."* Time was insufficient to examine the effects of a range of lower bounds for this parameter. Instead, the lower bound was decreased to the point at which it was never constraining. See Comment JPT1 above and Comment SSC3 below.

JPT6. *"Is the method used to define blocks appropriate? Yes."* The method used to define selectivity blocks in Model 3 from the preliminary assessment is used for both models described in the present assessment.

JPT7. *"Do the new ... models fix average recruitment problem used for the projections? Yes."* The method used to estimate recruitment parameters in Model 3 from the preliminary assessment is retained for both models in the present assessment.

JPT8. *"Is age-based selectivity appropriate for survey? Question raised on the consistency of 2 year olds in the GOA survey (lengths absent but ages present)."* The characterization "lengths absent but ages present" is somewhat of an overstatement. The problem is not that the lengths corresponding to age 2 are completely absent from the survey; the problem is that they may be present less frequently than would be expected if survey selectivity were a monotone function of either length or age. Likewise, while it is true that age 2 fish are present in the survey, they may be present less frequently than would be expected if survey selectivity were a monotone function of either length or age. For example, if the relative frequencies of 1-, 2-, and 3-year-old fish from the 1987-2005 surveys are weighted by the number of otoliths read in each year, the weighted average proportions of these three age groups are 0.25, 0.20, and 0.55, respectively. The addition of three new years' worth of age data since the preliminary assessment appears to have decreased the apparent under-representation of age 2 fish somewhat.

JPT9. *"Have input sample sizes been set appropriately? The Teams noted that further investigation on sensitivity of sample sizes is warranted."* Alternative methods for specifying multinomial sample sizes will be investigated in a future assessment.

JPT10. *"Should size at age data be included? No for BS, yes for GOA."* Size at age data are included in both of the models described in the present assessment.

JPT11. *"Should GOA survey be split by size? This seems to be a good idea but need to check on issues related to age 2."* The split survey design is used in both models described in the present assessment. See also Comment JPT8 above.

JPT12. *"The Teams noted that it was difficult to provide feedback on models that should or should not be carried forward for the November meeting given the time available and the complexity of the issues, particularly between the BSAI and GOA. The author sought advice on this specifically and the Teams hope that the SSC could provide more feedback."* The SSC provided feedback on this issue at its October, 2008 meeting (see Comments SSC2-4 below).

SSC Comments Specific to the Pacific Cod Assessments

SSC1. From the October, 2008 minutes: *"At the team meetings the author posed, and the teams answered, a number of questions bearing on model choice. The SSC concurs with almost all of the teams' recommendations."* Both models described in the present assessment conform to Plan Team and SSC guidance to the extent possible.

SSC2. From the October, 2008 minutes: *"We do not need to see updated fits of Models 1, 2, or 3."* Although this comment refers to models from the preliminary assessment for the BSAI stock, the present assessment was prepared under the assumption that it is applicable in principle to the GOA stock also. Therefore, models presented in previous years are not updated here.

SSC3. From the October, 2008 minutes: *"As a reference model for the GOA specifications, the SSC would like to see a fit of a model analogous to the BS/AI reference model, namely GOA Model 3 with the constraint on parameter P4 removed or relaxed."* In its comments on the BSAI Pacific cod preliminary assessment, the SSC concluded further that setting a lower bound of 5 on this parameter "*is not advisable.*" Because any bound that ends up constraining this parameter would be just as subjective as the bound set at a value of 5 in the preliminary assessment, the reference model described here (Model A) sets the bound sufficiently low that it is never constraining. Model B treats this issue in the same way.

SSC4. From the October, 2008 minutes: *"The SSC would also like to see a fit of the reference model without the added length composition data, if time permits."* Time was insufficient to permit inclusion of this additional model.

SSC5. From the October, 2008 minutes: *"The SSC is concerned about the inability of the present Model 3 to estimate a credible value for trawl survey catchability but do not expect that the author will have time to find a solution in the near term if that behavior persists."* Further attempts were made to estimate catchability internally, but these were unsuccessful.

SSC Comments on Assessments in General

SSC6. From the December, 2007 minutes: *"Recommendations to assessment authors of stocks subject to the $B_{20\%}$ threshold: The SSC requests that if stocks drop below Tier 3a and they are subject to the $B_{20\%}$ stopping rule (pollock, cod and Atka mackerel), that the analysts evaluate the probability that the stock will drop below the $B_{20\%}$ threshold.* The probability of dropping below the $B_{20\%}$ threshold is listed in Table 2.16.

SSC7. From the December, 2007 minutes: *"Recommendation to all assessment authors with respect to calculations for biological reference points: The SSC notes that the approach for calculating ABC and other biological reference points is not fully described in the SAFEs. It would be desirable to have a general description in the introduction of the SAFE. In each SAFE chapter, specific details could be provided, if the calculation is done differently. For example, the range of years that is used to calculate average recruitment for converting SPR to $B_{40\%}$ should be given."* Biological reference points in the present assessment are calculated using the standard approach. The range of year classes used to calculate average recruitment is 1977-2006.

INTRODUCTION

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

Fishery

During the two decades prior to passage of the Magnuson Fishery Conservation and Management Act (MFCMA) in 1976, the fishery for Pacific cod in the GOA was small, averaging around 3,000 t per year. Most of the catch during this period was taken by the foreign fleet, whose catches of Pacific cod were usually incidental to directed fisheries for other species. By 1976, catches had increased to 6,800 t. Catches of Pacific cod since 1978 are shown in Tables 2.1a and 2.1b. In Table 2.1a, catches for 1978-1990 are broken down by year, fleet sector, and gear type. In Table 2.1b, catches for 1991-2008 are broken down by year, jurisdiction, and gear type. The foreign fishery peaked in 1981 at a catch of nearly 35,000 t. A small joint venture fishery existed through 1988, averaging a catch of about 1,400 t per year. The domestic fishery increased steadily through 1986, then increased more than three-fold in 1987 to a catch of nearly 31,000 t as the foreign fishery was eliminated. Presently, the Pacific cod stock is exploited by a multiple-gear fishery, including trawl, longline, pot, and jig components. Trawl gear took the largest share of the catch in every year but one from 1991-2002, although pot gear has taken the largest single-gear share of the catch in each year since 2003. Figures 2.1a-2.1c show areas in which sampled hauls or sets for each of the three main gear types (trawl, longline, and pot) were concentrated during January-May, June-August, and September-December, 2007. Figures 2.1d-2.1e show the corresponding information for January-May and June-August, 2008 (preliminary data). 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 hauls/sets containing Pacific cod from more than two distinct vessels were sampled in it during the respective gear/season/year.

The chapters entitled “Profile for Pacific cod Fleet” and “Pacific Cod Market Analysis” in the economic section of the SAFE Report (Hiatt et al., 2007) provide additional information on the Pacific cod fishery.

The history of acceptable biological catch (ABC) and total allowable catch (TAC) levels is summarized and compared with the time series of aggregate commercial catches in Table 2.2. For the first year of management under the MFCMA (1977), the catch limit for GOA Pacific cod was established at slightly less than the 1976 total reported landings. During the period 1978-1981, catch limits varied between 34,800 and 70,000 t, settling at 60,000 t in 1982. Prior to 1981 these limits were assigned for “fishing years” rather than calendar years. In 1981 the catch limit was raised temporarily to 70,000 t and the fishing year was extended until December 31 to allow for a smooth transition to management based on calendar years, after which the catch limit returned to 60,000 t until 1986, when ABC began to be set on an annual basis. Changes in ABC over time are typically attributable to three factors: 1) changes in resource abundance, 2) changes in management strategy, and 3) changes in the stock assessment model. From 1986 (the first year in which an ABC was set) through 1996, TAC averaged about 83% of ABC and catch averaged about 81% of TAC. In 8 of those 11 years, TAC equaled ABC exactly. In 2 of those 11 years (1992 and 1996), catch exceeded TAC. To understand the relationships between ABC, TAC, and catch for the period since 1997, it is important to understand that a substantial fishery for Pacific cod has been conducted during these years inside State of Alaska waters, mostly in the Western and Central Regulatory Areas. To accommodate the State-managed fishery, the Federal TAC was set well below ABC in each of those years (15% in 1997 and 1998; 20% in 1999; 23% in 2000-2003; and 24% in 2004-2008). Thus, although total (Federal plus State) catch has exceeded the Federal TAC in all but three years since 1997, this is basically an artifact of the bi-jurisdictional nature of the fishery and is not evidence of overfishing. At no time since the separate State waters fishery began in 1997 has total catch exceeded ABC.

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

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

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

DATA

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

Commercial Catch Data

Catch Biomass

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

Catch Size Composition

Fishery size compositions are presently available, by gear, for the years 1977 through the first part of 2008. For ease of representation and analysis, length frequency data for Pacific cod can usefully be grouped according to the following set of 25 intervals or "bins," with the upper and lower boundaries shown in cm:

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

The collections of relative length frequencies are shown by year and size bin for the trawl fishery in Tables 2.6a, 2.6b, and 2.6c; the longline fishery in Tables 2.7a, 2.7b, and 2.7c; and the pot fishery in Tables 2.8a, 2.8b, and 2.8c. Pot fishery length frequencies since 1997 include samples from the State-managed fishery.

Survey Data

Survey Size Composition

The relative size compositions from trawl surveys of the GOA conducted by the Alaska Fisheries Science Center since 1984 are shown in Table 2.9, using the same length bins defined above for the commercial catch size compositions. Total sample sizes are shown below:

Year:	1984	1987	1990	1993	1996	1999	2001	2003	2005	2007
Samples:	17413	19591	11440	17149	12190	8645	6771	9126	6842	9099

Survey Age Composition

Following a decade-long hiatus in production ageing of Pacific cod, the Age and Growth Unit of the Alaska Fisheries Science Center began ageing samples of Pacific cod from the EBS shelf bottom trawl surveys a few years ago (Roberson 2001, Roberson et al. 2005). Age composition estimates from each survey except 1984 and 2007 are now available. These are shown, together with sample sizes, in Table 2.10.

Abundance Estimates

Estimates of total abundance (both in biomass and numbers of fish) obtained from the trawl surveys are shown in Table 2.11, together with the standard errors and upper and lower 95% confidence intervals (CI) for the biomass estimates.

The highest biomass ever observed by the survey was the 1984 estimate of 550,971 t, and the low point is the 2007 estimate of 233,310 t. The 2007 estimate represented a 24% decrease from the 2005 estimate. In terms of population numbers, the record high was observed in 1984, when the population was estimated to include over 320 million fish. The 2007 estimate of 192 million fish represented a 37% increase over the 2005 estimate.

ANALYTIC APPROACH

Model Structure

History of Model Structures Developed Under Stock Synthesis 1 and 2

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

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

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

In the both the EBS and GOA Pacific cod models, each year has traditionally been partitioned into three seasons: January-May, June-August, and September-December (these seasonal boundaries were suggested by industry participants in the EBS fishery). Four fisheries were traditionally defined during the era of SS1-based assessments: The January-May trawl fishery, the June-December trawl fishery, the longline fishery, and the pot fishery.

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

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

A major change took place in the 2005 assessment (Thompson and Dorn 2005), as the model was migrated to the newly developed Stock Synthesis 2 (SS2) program, which makes use of the ADMB modeling architecture (Fournier 2005) currently used in most age-structured assessments of BSAI and GOA groundfish. The move to SS2 facilitated improved estimation of model parameters as well as statistical characterization of the uncertainty associated with parameter estimates and derived quantities such as spawning biomass. Technical details of SS2 were described by Methot (2005, 2007).

The 2006 assessment model (Thompson et al. 2006) was structured similarly to the 2005 assessment model; the primary change being external estimation of growth parameters.

A technical workshop was convened in April, 2007 to consider a wide range of issues pertaining to both the BSAI and GOA Pacific cod assessments (Thompson and Conners 2007).

The 2007 assessment model (Thompson et al. 2007b) for Pacific cod in the GOA was patterned after the model used in that year's assessment of the BSAI Pacific cod stock (Thompson et al. 2007a), with several changes as described in the assessment document.

Model Structures Considered in This Year's Assessment

As described in the Executive Summary, two models are presented in this assessment, all based on SS version 3.01f. Model A was requested by the SSC, and Model B represents an alternative model. Both of these models are based largely on Model 3 from this year's preliminary assessment, with the lower bound on the descending selectivity "width" parameter relaxed to a point at which it is no longer constraining (differences between Model 5 from this year's preliminary assessment and the model used in last year's assessment are listed in Table 2.1.1 of Attachment 2.1).

Models A and B use a consistent algorithm for determining the set of fisheries whose selectivity schedules are assumed to be asymptotic. One of the suggestions emerging from the 2007 technical workshop was that it is probably necessary to assume asymptotic selectivity for at least one fishery in order to obtain a reasonably stable model. Since that time (i.e., in the 2007 preliminary and final assessments and this year's preliminary and final assessments), the alternative models have gone back and forth between assuming asymptotic selectivity for a single fishery and assuming asymptotic selectivity for multiple fisheries. For the present assessment, the following algorithm was used:

1) Determine the set of "major" fisheries in the GOA Pacific cod fishery. (The reason for doing this is that the stabilizing benefits of assuming asymptotic selectivity may not be realized if the

fishery(ies) with asymptotic selectivity have such small sample sizes or such small impacts on population dynamics that the asymptotic selectivity assumption has minimal impact on the model.) Both in terms of sample size and catch, three fisheries emerge as being the most significant: the January-May trawl fishery, the January-May pot fishery, and the January-May longline fishery. These are the only fisheries accounting for more than a 14% share of the total sample sizes and total catches, and, between the three of them, they account for more than 81% of the length samples and more than 77% of the catch, both for the entire time series and the more recent years (since 1990).

2) Create a sample-size-weighted, long-term, relative size composition (peaking at a value of unity) for each gear-and-season-specific fishery.

3) For each size bin starting at 70 cm (the smallest size by which all relative size compositions have reached their respective peaks), rank each gear-and-season-specific fishery in terms of relative size composition (i.e., for the 70-74 cm size bin, the fishery with the largest proportion of fish in that bin is ranked first, the fishery with the next largest proportion is ranked second, and so forth).

4) For each size bin starting at 70 cm, average the ranks for each gear-and-season-specific fishery across all larger size bins (i.e., for each gear-and-season-specific fishery, compute the average rank across size bins 70-74, 75-79, 80-84, ..., 105-109 cm; then do the same across size bins 75-79, 80-84, ..., 105-110 cm; then do the same across size bins 80-84, ..., 105-109 cm, and so forth).

5) From the resulting profiles of ranks, pick the highest ranked set of fisheries that consistently includes at least one of the major fisheries.

The above procedure resulted in assuming that only the January-May trawl fishery exhibited asymptotic selectivity.

A major task in developing Models A and B was to reconcile the Plan Teams' desire to be parsimonious in the number of parameters used in the model with the Plan Teams' and SSC's belief that true temporal variability exists in fishery selectivity schedules. Two different, though related, algorithms were used to develop address these competing concerns in both Models A and B, and at the same time estimate the log recruitment variability σ_R, the functional form governing the distribution of length at age, and the number of freely estimated age groups in the initial numbers-at-age vector.

The algorithm for Model B was the more complicated of the two, and proceeded as follows:

1. Through extensive trial and error in exploring alternative initial values for model parameters, estimate parameter values for a model in which all selectivity parameters are free (except that all fishery selectivities are constrained to be zero for fish in the smallest size bin) and in which fisheries for each gear and season are subdivided, to the greatest extent allowed by the data, in terms of the following (approximately) "5-year" blocks: 1977-1979, 1980-1984, 1985-1989, 1990-1994, 1995-1999, 2000-2004, and 2005-2007.
2. Set log recruitment variability, σ_R , equal to the standard deviation of the estimated log recruitment deviations over the period 1977-2006 (the current environmental regime).
3. Profile over all four available options for defining the functional form governing the distribution of length at age (coefficient of variation modeled as a linear function of length at age, coefficient of variation modeled as a linear function of age, standard deviation modeled as a linear function of length at age, and standard deviation modeled as a linear function of age) and various possible values for the number of freely estimated age groups (beyond age 0) in the initial numbers-at-age vector (e.g., 0, 1, 2, 3, and 4). The configuration with the smallest value of the Akaike Information Criterion (AIC) becomes the provisional model.

4. Evaluate whether some sets of block-specific parameters for gear-and-season-specific fisheries can be replaced by "generic" (constant across blocks, but still specific to gear and season) values. This was done as follows:
    a. For each selectivity parameter in each gear-and-season-specific fishery, create a model in which the parameter is constant across all blocks.
    b. Select those models with "generic" selectivity parameters that produced lower AICs than their block-specific counterparts.
    c. Rank this set of models in order of increasing AIC.
    d. Create new models by turning block-specific selectivity parameters into generic selectivity parameters, one at a time in the order described above, until the overall AIC no longer decreases.
5. Evaluate whether 5-year blocks can be replaced by larger blocks. This was done as follows:
    a. Treat the model emerging from Step (4) above as the provisional model; compute AIC.
    b. Find the fishery with the smallest total input sample size, then fit models with the following three block structures:
        i. "10-year" blocks: 1977-1979, 1980-1989, 1990-1999, and 2000-2007.
        ii. "20-year" blocks: 1977-1989, 1990-2007
        iii. Single block (functionally the same as no blocks at all): 1977-2007
    c. Compute the AIC value for each of the above block structures. If the smallest of these AIC values is less than the AIC value for the provisional block structure, the block structure with the smallest AIC value becomes the new provisional block structure.
    d. Find the fishery with the next smallest total input sample size, then repeat steps (b) and (c). Once all fisheries have been explored, the provisional block structure becomes the final block structure.
6. Check to make sure that σ_R is still equal to the standard deviation of the estimated log recruitment deviations over the period 1977-2006; adjust if necessary.

The algorithm for Model A was similar, but it omitted Step 4, which made the algorithm more similar to that used in the preliminary assessment.

Parameters Estimated Independently

Natural Mortality

In the 1993 BSAI Pacific cod assessment (Thompson and Methot 1993), the natural mortality rate *M* was estimated using SS1 at a value of 0.37. All subsequent assessments of the BSAI and GOA Pacific cod stocks (except the 1995 GOA assessment) have used this value for *M*, until the 2007 assessments, at which time the BSAI assessment adopted a value of 0.34 and the GOA assessment adopted a value of 0.38. Both of these were accepted by the respective Plan Teams and the SSC. The new values were based on Equation 7 of Jensen (1996) and ages at 50% maturity reported by (Stark 2007; see "Maturity" subsection below). In response to a request from the SSC, this year's preliminary assessment for the BSAI stock included further discussion and justification for this value (included as attachment 2.3 to this year's BSAI Pacific cod assessment).

For historical completeness, 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

Trawl Survey Catchability

The base model used in previous GOA Pacific cod assessments has fixed the catchability coefficient (Q) for the GOA bottom trawl survey independently of other parameters. Usually, it was fixed at a value of 1.0. Last year, it was fixed at a value of 0.92, conforming to the finding of Nichol et al. (2007) that the product of trawl survey catchability and selectivity for Pacific cod in the GOA was approximately 0.92 for fish in the 60-81 cm size range. Because last year's model assumed asymptotic selectivity for the trawl survey (and because the asymptote was reached well before 60 cm), fixing Q at a value of 0.92 automatically assured that the result of Nichol et al. would be matched.

This year, however, neither model assumes that the trawl survey exhibits asymptotic selectivity, so Q for the 27-plus survey was estimated iteratively such that, when considered together with the survey selectivity schedule, the distributions of length at age, and the long-term average distribution of age in the population, the average value of the product of Q and selectivity for the 60-81 cm size range could be set equal to the value of 0.92 obtained by Nichol et al.

One difference between the models with respect to catchability of the 27-plus survey is that Model A treats Q as a free parameter for the period 1984-1993, while Model B holds Q constant across the entire time series. The reason for allowing Q to take on a different value for 1984-1993 is that the survey used 30-minute tows during that period, but 15-minute tows thereafter.

Catchability for the sub-27 survey is estimated as a free "random walk" parameter in both Models A and B.

Variability in Estimated Age

Variability in estimated age in SS is based on the standard deviation of estimated age. Weighted least squares regression has been used in the past several assessments to estimate a linear relationship between standard deviation and age. The regression was recomputed this year, yielding an estimated intercept of 0.028 and an estimated slope of 0.07 (i.e, the standard deviation of estimated age was modeled as 0.028 + 0.07 × age).

Variability in Length at First Survey Age

To increase model stability and to make comparisons of alternative functional forms for growth variability more consistent, the parameters defining the distribution of length at age 1.5417 (age 1 incremented to reflect the timing of the trawl survey) were estimated independently for use in both models. This was done by computing the long-term survey size composition of fish 12 to 35 cm in length and fitting a mixture of two normal distributions (assuming that fish in this size range are all ages 1 or 2). The mixture model gave an excellent fit (coefficient of determination = 0.96), and estimated the mean and standard deviation of length at age 1.5417 at values of 20.94 cm and 3.806 cm, respectively. These values are extremely close to those obtained simply by computing the mean and standard deviation of lengths corresponding to fish aged as 1-year-olds by the age reading unit (20.24 cm and 3.653 cm, respectively).

Weight at Length

Parameters governing weight at length were re-estimated this year. All weight-length records from the observer database (both shore-based and at-sea samples) were used to estimate seasonally varying values of the weight-at-length parameters. Values of α and β, together with sample sizes, were as follow:

Season:	1	2	3	Annual
α:	8.626×10^{-6}	1.015×10^{-5}	1.434×10^{-5}	8.837×10^{-6}
β:	3.080	3.023	2.948	3.072
Samples:	68,568	4,701	12,309	85,578

The seasonal model gives a statistically significant improvement (AIC = 67,829 for the annual model; AIC = 66,978 for the seasonal model).

Maturity

A detailed history and evaluation of parameter values used to describe the maturity schedule for BSAI Pacific cod was presented in the 2005 assessment (Thompson and Dorn 2005). A length-based maturity schedule has been used for many years. The parameter values used for this schedule in the 2005 and 2006 assessments were set on the basis of a study by Stark (2007) at the following values: length at 50% maturity = 58 cm and slope of linearized logistic equation = -0.132. However, in 2007, changes in SS allowed for use of either a length-based or an age-based maturity schedule. Beginning with the 2007 assessment, an age-based schedule with intercept = 4.3 years and slope = –1.963 (Stark 2007) was used. The use of an age-based rather than a length-based schedule follows a recommendation from James Stark (Alaska Fisheries Science Center, personal communication).

Parameters Estimated Conditionally

Parameters estimated conditionally (i.e., within individual SS runs, based on the data and the parameters estimated independently) include length-at-age parameters (except for the mean length at reference age 1.5417), parameters governing variability in length at age (except for the standard deviation at reference age 1.5417), mean log recruitment for each of two environmental regimes (pre-1977 and post-1976), initial fishing mortality, 27-plus survey catchability for the surveys up through 1993 (Model A only), sub-27 "random walk" survey catchability in all survey years, selectivity parameters, and annual recruitment.

The same functional form (pattern 24 for length-based selectivity, pattern 20 for age-based selectivity) used to define the selectivity schedules in last year's assessments was used again this year. This functional form is constructed from two underlying and rescaled normal distributions, with a horizontal line segment joining the two peaks. This form uses the following six parameters:

1. Beginning of peak region (where the curve first reaches a value of 1.0)
2. Width of peak region (where the curve first departs from a value of 1.0)
3. Ascending "width" (equal to twice the variance of the underlying normal distribution)
4. Descending width
5. Initial selectivity (at minimum length/age)
6. Final selectivity (at maximum length/age)

All but the “beginning of peak region” parameter are transformed: The widths are log-transformed and the other parameters are logit-transformed.

For all parameters estimated within individual SS 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 and the logarithm of the likelihood function.

In addition to the above, the full set of year-, season-, and gear-specific fishing mortality rates are also estimated conditionally, but not in the same sense as the above parameters. The fishing mortality rates are determined exactly rather than estimated statistically because SS 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.

Uniform prior distributions were used for all parameters, except that the “random walk” feature of the sub-27 catchability coefficient (with mean=0 and sigma=0.2) is viewed by SS as a prior distribution.

Likelihood Components

Both models included likelihood components for trawl survey relative abundance, fishery and survey size composition, survey age composition, recruitment, and initial catch.

In SS, emphasis factors are specified to determine which likelihood components receive the greatest attention during the parameter estimation process. As in previous assessments, each likelihood component in both models was given an emphasis of 1.0 in the present assessment.

Use of Size Composition Data in Parameter Estimation

Size composition data are assumed to be drawn from a multinomial distribution specific to a particular year, gear, and season within the year. In the parameter estimation process, SS weights a given size composition observation (i.e., the size frequency distribution observed in a given year, gear, and season) according to the emphasis associated with the respective likelihood component and the sample size specified for the multinomial distribution from which the data are assumed to be drawn. In developing the model upon which SS 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. For many years, the Pacific cod assessments assumed 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 GOA Pacific cod data, this procedure tended to give values somewhat below 400 while still providing SS with usable information regarding the appropriate effort to devote to fitting individual length samples.

Although the “square root rule” for specifying multinomial sample sizes gave reasonable values, the rule itself was largely *ad hoc*. In an attempt to move toward a more statistically based specification, the 2007 BSAI assessment (Thompson et al. 2007a) used the harmonic means from a bootstrap analysis of the available fishery length data from 1990-2006. The harmonic means were smaller than the actual sample sizes, but still ranged well into the thousands. A multinomial sample size in the thousands would likely overemphasize the size composition data. As a compromise, the harmonic means were rescaled proportionally in the 2007 BSAI assessment so that the average value (across all samples) was 300. However, the question then remained of what to do about years not covered by the bootstrap analysis (2007 and pre-1990) and what to do about the survey samples. The solution adopted in the 2007 BSAI assessment was based on the consistency of the ratios between the harmonic means (the raw harmonic means, not the rescaled harmonic means) and the actual sample sizes. For the years prior to 1999, the ratio was very consistently close to 0.16, and for the years after 1998, the ratio was very consistently close to 0.34. This consistency was used to specify the missing values as follows: For fishery data, the sample sizes for length compositions from years prior to 1999 were tentatively set at 16% of the actual sample size, and the sample sizes for length compositions from 2007 were tentatively set at 34% of the actual sample size. For the trawl survey, sample sizes were tentatively set at 34% of the actual sample size. Then, with sample sizes for fishery length compositions from 1990-2006 tentatively set at their bootstrap harmonic means (not rescaled), all sample sizes were adjusted proportionally so that the average was 300.

The same procedure was used in the present assessment, adding in the data for 2008. This resulted in the set of multinomial sample sizes shown in Table 2.12.

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 (in this case, the EBS shelf bottom trawl survey), and time period within the year (in this case, the June-August period).

Input sample sizes for the multinomial distributions associated with age composition data were handled differently in the two models: In Model A, the actual sample number of otoliths read (Table 2.10) was rescaled so that the average value was 100, in keeping with the procedure used in Model 3 from this year's preliminary assessment. In Model B, the average input sample size was adjusted based on the fit to the post-27 survey abundance time series for the period in which age composition data are available (1987-2005). Specifically, the average input sample size was adjusted iteratively so that the average root mean squared error from the model equaled (to two digits) the average input "sigma" from the surveys (see next subsection). This procedure resulted in a considerable down-weighting of the age composition data relative to Model A, with an average input sample size of only 12.

To avoid double counting of the same data, both models ignore length composition data from the trawl surveys in years where age data are available (i.e., all survey years except 1984 and 2007).

Use of Fishery CPUE and Survey Relative Abundance Data in Parameter Estimation

Fishery CPUE data are included in the models for comparative purposes only. Their respective catchabilities are estimated analytically, not statistically.

For the trawl surveys, 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 abundance datum itself serves as the distribution's coefficient of variation, which is then transformed into the "sigma" parameter for the lognormal distribution.

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 (although σ_R is estimated iteratively rather than internally).

MODEL EVALUATION

As described above, two models are evaluated in the present assessment. Both models appeared to converge successfully, to the extent that the Hessian matrices from both models were positive definite. At several points throughout the model development process, 50-100 additional runs were undertaken for each model with initial parameter values displaced randomly from their converged values to provide additional assurance that another (better) solution did not exist. In the case of Model A, it appeared that some very slight additional improvement in goodness of fit could still be obtained, but the models were accepted as converged anyway because the estimates of primary management quantities appeared to have stabilized.

Comparing and Contrasting the Models

Following the algorithms described above for determining the functional form used to describe variability in growth, the number of age groups to estimate freely in the initial (1977) numbers at age vector, the scale of log recruitment variability, and catchability for the 27-plus trawl survey (years 1996-2007 in Model A, all years in Model B), the results were as follow:

- Treating the coefficient of variation as a linear function of age proved to give the best fit for both models. The CV for reference age 1 (CV_1) was specified outside the model at a value of 0.182, based on a mean of 20.94 cm and a standard deviation of 3.806 cm, as described above.
- Model A gave the best performance (in terms of AIC) when 9 age groups beyond age 0 were estimated freely in the initial numbers at age vector, whereas Model B did best when 3 age groups beyond age 0 were estimated.
- Both models estimated the scale of log recruitment variability (σ_R) at a value of 0.80, much higher than in previous assessments.
- Catchability for the 27-plus trawl survey was fixed at a value of 0.94 in Model A (years 1996-2007 only), and a value of 0.92 in Model B. When combined with other features of the respective models, these specifications gave an average value of 0.92 for the product of survey catchability and selectivity across the 60-81 cm size range.

Tables 2.13-2.16 present summaries of some key results from the two models. Table 2.13 pertains to statistical goodness of fit, Table 2.14 pertains to estimates of parameters other than selectivity parameters, Table 2.15 pertains to estimates of selectivity parameters, and Table 2.16 pertains to estimates of management-related quantities. In each row of these tables (except Table 2.15), the cell with the lowest value is shaded green (light gray if the document is viewed in grayscale) and the cell with the highest value is shaded pink (dark gray).

Table 2.13a is structured as follows:

Section 1: Parameter counts. This section enumerates the number of internally estiamted parameters.

Section 2: Aggregate likelihood components. In general, lower values are better than higher values, but this rule must be interpreted in light of other factors, such as the number of parameters used to achieve a given likelihood value. Furthermore, Model B significantly downweights the age composition data relative to Model A, making comparison of likelihoods difficult.

Section 3: Relative abundance likelihoods. The only likelihoods that are actually used in this section are the trawl survey likelihoods. The others are shown for comparative purposes only.

Section 4: Size composition likelihoods. The aggregate size composition likelihood is broken down by gear and season in the case of fisheries, and by individual survey types.

Tables 2.13b and 2.13c provide alternative measures of how well the models are fitting the fishery CPUE and survey relative abundance data. Table 2.13b shows root mean squared errors (lower values are better) and Table 2.13c shows correlations between observed and estimated values (higher values are better). Note that neither of the models actually attempts to fit the fishery CPUE data; these results are shown for information only.

Tables 2.13d and 2.13e provide alternative measures of how well the models are fitting the size composition data (higher values are better). Table 2.13d shows the average of the ratios between output "effective" sample size—McAllister and Ianelli 1997) and input sample size, while Table 2.13e shows the ratio of the averages.

For age composition data, the following table summarizes relationships between effective sample size and input sample size:

Quantity	Model A	Model B
Average of ratios (effective/input)	0.870	1.355
Ratio of averages (effective/input)	0.917	1.275

Although both of the models achieve values close to unity by either measure, both models accomplish this by fitting the age compositions comparatively well in two or three years, but rather poorly in all the others. It is also important to remember that the denominators are different between the two models, with Model A using an average input sample size of 100 and Model B using an average input sample size of 12.

Table 2.14a lists parameters estimated by the models except for recruitment deviations, which are shown in Table 2.14b, and selectivity parameters, which are shown in Table 2.15.

Parameters listed in Table 2.14a include mean length at age 20, the Brody growth coefficient K, the coefficient of variation in length at age 20 (CV_2), log mean recruitment from the post-1976 and pre-1977 environmental regimes (R_0 and R_1), equilibrium fishing mortality rate in 1977, pre-1996 log catchability for the 27-plus survey (Model A only), and log catchabilities for the sub-27 survey. Note that several of the parameters in Table 2.14a are expressed as log offsets of their respective counterparts. For example, the coefficient of variation for length at age 20 is computed as $CV_1 \times \exp(CV_2)$, log mean recruitment for the pre-1976 environmental regime is computed as R_0+R_1 (i.e., added rather than multiplied, because the scale has already been log-transformed), pre-1996 catchability for the 27-plus survey (Model A only) is computed as 0.94×exp(pre-1996 log Q), and sub-27 catchability for each year Y is computed by summing the log catchability for 1984 with all of the log offsets between 1984 and Y, then exponentiating.

Table 2.14b lists estimates and standard deviations of annual log recruitment deviations given by both models. Note that these are deviations, not log recruitments *per se*, and are computed with respect to their regime-specific (pre-1977, post-1976) means. In both models, the pre-1977 mean is much lower than the post-1976 mean. Both models indicate a substantial degree of agreement regarding strong and weak year classes during the current environmental regime (correlation = 0.95). Both models estimate an extremely strong 2006 year class, which likely contributes substantially to the high value of σ_R estimated by both models.

Table 2.15 pertains to model estimates of selectivity parameters. Table 2.15a contains the legend for Table 2.15b. Although different algorithms were used to determine how many selectivity parameters to include in the two models, the overall numbers ended up being close, with Model A estimating four more selectivity parameters than Model B.

Table 2.16 contains selected output from the standard projection model, based on SS parameter estimates from the two models.

Section 1: Spawning biomass reference points. Equilibrium spawning biomass under zero fishing (B100%), and the reference points corresponding to 40% and 30% of that value are shown.

Section 2: Projected spawning biomasses. Values for 2009 and 2010 are shown, with the value for 2010 predicated on the assumption that the 2009 catch will equal the 2009 maximum permissible ABC.

Section 3: The ratio of projected spawning biomass to B100%. Values for 2009 and 2010 are shown.

Section 4: Fishing mortality rates that, in equilibrium, result in spawning biomass equal to B40% and B35% respectively.

Section 5: Maximum permissible values of the fishing mortality rate used to compute ABC under the Tier 3 harvest control rules. Values for 2009 and 2010 are shown.

Section 6: Maximum permissible values for ABC corresponding to the fishing mortality rates shown in Section 5.

Section 7: Fishing mortality rate corresponding to the overfishing limit for 2009 under the Tier 3 harvest control rules.

Section 8: Overfishing limits for 2009 and 2010. Two values for 2010 are shown: The value for 2010 assumes that catch in 2009 equals the maximum permissible ABC.

Section 9: Probability that spawning biomass will fall below 20% of B100% within 5 years under any of the standard harvest scenarios 1-5 described below in the subsection entitled, "Standard Harvest and Recruitment Scenarios and Projection Methodology." Because Pacific cod are a key prey item of endangered Steller sea lions (*Eumetopias jubatus*), current regulations require directed fishing to cease in the event that the spawning biomass falls below 20% of B100%.

Figure 2.2 compares the means lengths at age estimated by the two models against the mean lengths at age estimated by the age reading unit. The model fits are virtually indistinguishable from each other, and distinguishable from the estimates provided by the age readers only at higher ages, where the reader estimates are less precise.

Figure 2.3 compares the relative abundances estimated by the two models for the 27-plus (Figure 2.3a) and sub-27 (Figure 2.3b) trawl surveys. Both models miss the 95% confidence interval for the 1984 survey. Model A tends to exhibit a better residual pattern than Model B, but Model B tends to do a better job of staying within the confidence intervals. By freeing the estimate of catchability for 1984-1993, Model A does a better job of fitting the pre-1996 portion of the 27-plus survey. Model B's estimates for the 27-plus survey fall below the survey point estimates in all years, though sometimes not by much, particularly during the 1999-2005 time period. Both models appear to track the sub-27 survey abundance well.

Evaluation Criteria

Given the comparable fits obtained by both models to most, if not all, data sources, two evaluation criteria are proposed for selecting between Models A and B: 1) regard as suspect any model that relies on unreasonable parameter estimates, and 2) choose the model that implies the least drastic changes with respect to recent understanding regarding the size and productivity of the stock.

It should be understood that the above criteria are not proposed as absolutes, but rather as useful guidelines for the present assessment while model structure is being refined. In particular, if there were clear statistical reasons for preferring one model over the others, either or both of the criteria listed above would not be necessary, or perhaps even useful.

Selection of Final Model

In applying Criterion #1, it may be noted that both models give similar estimates of many parameters. For example, the estimates of parameters governing the length at age schedule are very similar, and the estimates of recruitment deviations tend to be very similar. One parameter that appears to play a strong role in describing the size and productivity of the stock is the catchability of the 27-plus survey for the years 1984-1993. In Model B, this parameter is assumed to have a value of 0.92, which comports well with the findings of Nichol et al. (2007). In Model A, on the other hand, this parameter is estimated to have a value of 3.64, which does not seem reasonable. One parameter that takes a rather unexpected value in both models is the coefficient of variation for length at age 20, which is estimated to be essentially zero. While it would be unrealistic to imagine that age 20 fish all have exactly the same length, it should be remembered that very few Pacific cod survive past about age 12 (no age 20 fish have ever been observed), and that, in estimating the CV of length at age 20, the models are attempting to produce the best distributions of length at age for those ages that contribute meaningfully to the data actually at hand.

Criterion #2 is somewhat difficult to apply, due to the fact that current management is based on Tier 5. However, Model B's estimate of 2007 age 3+ biomass (243,000 t) is much closer to the 2007 survey biomass of 233,000 t than is Model A's estimate (405,000 t), and Model B's estimate of maximum permissible ABC for 2009 (55,300 t) is much closer to the value of 66,493 t specified last year than is Model A's estimate (123,800 t).

By both criteria, then, it seems that Model B is preferable to Model A.

Final Parameter Estimates and Associated Schedules

As noted previously, estimates of all statistically estimated parameters in Model B are shown in Tables 2.14a, 2.14b, and 2.15b.

Estimates of year-, gear-, and season-specific fishing mortality rates from Model B are shown in Table 2.17.

Schedules of selectivity at length for the commercial fisheries from Model B are shown in Table 2.18a, and schedules of selectivity at age for the trawl surveys from Model B are shown in Table 2.18b. Trawl fishery, longline fishery, pot fishery, and survey selectivity schedules are plotted in Figures 2.4a-d, respectively.

Schedules of length at age and weight at age for the population, each gear-and-season-specific fishery, and each survey from Model B are shown in Tables 2.19 and 2.20, respectively.

TIME SERIES RESULTS

Note: Because the preferred model differs substantively from the SSC's reference model (A), the tables and figures referenced in this section are reproduced using Model A in Attachment 2.2.

Definitions

The biomass estimates presented here will be defined in two ways: 1) age 0+ biomass, consisting of the biomass of all fish aged 0 years or greater in January of a given year; and 2) spawning biomass, consisting of the biomass of all spawning females in a given year. The recruitment estimates presented here will be defined as numbers of age 0 fish in a given year.

Biomass

Table 2.21a shows the time series of Pacific cod age 0+ and female spawning biomass for the years 1977-2009 as estimated last year and this year under Model B. The estimated spawning biomass time series are accompanied by their respective standard deviations.

The estimated time series of age 0+ biomass and female spawning biomass from Model B are shown, together with the observed time series of trawl survey biomass (assuming a catchability of 1.0), in Figure 2.5. Confidence intervals are shown for the model estimates of female spawning biomass and for the trawl survey biomass estimates.

Recruitment and Numbers at Age

Table 2.21b shows the time series of Pacific cod age 0 recruitment (1000s of fish) for the years 1977-2006 as estimated last year and this year under Model B. Both estimated time series are accompanied by their respective standard deviations.

Model B's recruitment estimates for the entire time series (1977-2006) are shown in Figure 2.6, along with their respective 95% confidence intervals. For the time series as a whole, the largest year class currently appears to be the 2006 cohort. However, it must be emphasized that this estimate is based entirely on the 2007 survey's observation of the cohort at age 1, and the estimate is accompanied by an extremely large confidence interval. Other large cohorts, much more reliably estimated, innclude the 1977, 1982, and 1984 cohorts, which were also estimated to be large in the Bering Sea.

To date, it has not been possible to estimate a reliable stock-recruitment relationship for this stock.

The time series of numbers at age as estimated by Model B is shown in Table 2.22.

Exploitation

Figure 2.7 plots the trajectory of relative fishing mortality and relative female spawning biomass from 1977 through 2008 based on Model B, 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 since 1982 lies underneath the F_{OFL} control rule, and the entire trajectory since 1983 lies underneath (or very close to, in a couple of years) the $maxF_{ABC}$ control rule. Figure 2.7 is based on SS output, and the estimates of reference points, spawning biomass, and fishing mortality may not match those obtained by the standard projection program exactly.

PROJECTIONS AND HARVEST ALTERNATIVES

Note: Because the preferred model differs substantively from the SSC's reference model (A1), the tables referenced in this section are reproduced using Model A1 in Attachment 2.3.

Amendment 56 Reference Points

Amendment 56 to the GOA Groundfish Fishery Management Plan (FMP) defines the "overfishing level" (OFL), the fishing mortality rate used to set OFL (F_{OFL}), the maximum permissible ABC, and the fishing mortality rate used to set the maximum permissible ABC. The fishing mortality rate used to set ABC (F_{ABC}) may be less than this maximum permissible level, but not greater. Because reliable estimates of reference points related to maximum sustainable yield (MSY) are currently not available but reliable estimates of reference points related to spawning per recruit are available, Pacific cod in the GOA have generally been managed under Tier 3 of Amendment 56 (with the exception of the current year, when the stock is being managed under Tier 5). 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: $B/B_{40\%} \leq 0.05$
$F_{OFL} = 0$
$F_{ABC} = 0$

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 B:

Reference point:	$B_{35\%}$	$B_{40\%}$	$B_{100\%}$
Spawning biomass:	89,400 t	102,200 t	255,500 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 1's estimates of fishing mortality by gear for the three most recent complete years of data (2005-2007). 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 26.7%, longline 20.5%, and pot 52.8%. This apportionment results in estimates of $F_{35\%}$ and $F_{40\%}$ equal to 0.64 and 0.52, respectively.

Specification of OFL and Maximum Permissible ABC

Spawning biomass for 2009 is estimated by Model B at a value of 88,000 t. This is about 14% below the $B_{40\%}$ value of 102,200 t, thereby placing Pacific cod in sub-tier "b" of Tier 3. Given this, Model B estimates OFL, maximum permissible ABC, and the associated fishing mortality rates for 2009 and 2010 as follows (2010 values are predicated on the assumption that 2009 catch will equal 2009 maximum permissible ABC; catches in t):

Year	Overfishing Level	Maximum Permissible ABC
2009	66,600 t	55,300 t
2010	126,000 t	103,700 t
2009	0.54	0.44
2010	n/a	0.52

The age 0+ biomass projections for 2009 and 2010 from Model B are 520,000 t and 608,000 t.

ABC Recommendation

Review of Past Approaches

In 2005, the SSC used a two-year stair-step approach to recommend a 2006 ABC of 68,859 t.

In 2006, the GOA Plan Team and SSC recommended keeping ABC at the 2006 level for 2007 (68,859 t).

In 2007, the GOA Plan Team and SSC adopted a Tier 5 approach, resulting in a recommended 2008 ABC of 66,493 t.

Recommendation for 2009-2010

Based on Model B, the maximum permissible ABC (Tier 3b) for 2009 is 55,300 t. This would constitute a 17% increase from the 2008 value of 66,493 t, roughly commensurate with the 24% reduction in survey biomass between 2005 and 2007. *The recommended ABC for 2009 is 55,300 t.* For 2010, Model B predicts a substantially higher maximum permissible ABC (103,700 t). However, this is based largely on the strength of the 2006 year class, which has been observed only once, at age 1, in the 2007 survey. Although the point estimate of this year class is very large, the level of uncertainty surrounding it is also very large. As an alternative to the point estimate, if the standard projection model is run with the 2006 year class set at average strength (decayed by the natural mortality rate up through the beginning of 2008), the maximum permissible ABC for 2010 drops to 57,300 t. Until the strength of the 2006 year class can be confirmed, a two-year stair-step, giving a 2010 ABC of 79,500 t, would be preferable to setting the 2010 ABC at the maximum permissible level of 103,700 t. *The recommended ABC for 2010 is 79,500 t.*

Area Allocation of Harvests

For the past several years, ABC has been allocated among regulatory areas on the basis of the three most recent surveys. The current proportions are 39% Western, 57% Central, and 4% Eastern.

Standard Harvest and Recruitment Scenarios and Projection Methodology

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

For each scenario, the projections begin with an estimated vector of 2008 numbers at age. This vector is then projected forward to the beginning of 2009 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2008. 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 2009, 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 2009 recommended in the assessment to the *max* F_{ABC} for 2009. (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 the 2003-2007 average F. (Rationale: For some stocks, TAC can be well below ABC, and recent average F may provide a better indicator of F_{TAC} than F_{ABC}.)
>
> *Scenario 4*: In all future years, the upper bound on F_{ABC} is set at $F_{60\%}$. (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 5*: In all future years, F is set equal to zero. (Rationale: In extreme cases, TAC may be set at a level close to zero.)

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

> *Scenario 6*: In all future years, F is set equal to F_{OFL}. (Rationale: This scenario determines whether a stock is overfished. If the stock is expected to be 1) above its MSY level in 2008 or 2) above 1/2 of its MSY level in 2008 and above its MSY level in 2018 under this scenario, then the stock is not overfished.)
>
> *Scenario 7*: In 2009 and 2010, 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 2021 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 B in Tables 2.23-2.28 (Scenarios 1 and 2 are the same in this assessment).

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 2009, it does not provide the best estimate of OFL for 2010, because the mean 2009 catch under Scenario 6 is predicated on the 2009 catch being equal to the 2009 OFL, whereas the actual 2009 catch will likely be less than the 2009 OFL. Table 2.16 contains the appropriate one- and two-year ahead projections for both ABC and OFL under either of the two models considered in the present assessment.

Status Determination
Under the MSFCMA, the Secretary of Commerce is required to report on the status of each U.S. fishery with respect to overfishing. This report involves the answers to three questions: 1) Is the stock being subjected to overfishing? 2) Is the stock currently overfished? 3) Is the stock approaching an overfished condition?

Is the stock being subjected to overfishing? The official catch estimate for the most recent complete year (2007) is 51,489 t. This is less than the 2007 OFL of 97,600 t. Therefore, the stock is not being subjected to overfishing.

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

a. If spawning biomass for 2008 is estimated to be below ½ $B_{35\%}$, the stock is below its MSST.

b. If spawning biomass for 2008 is estimated to be above $B_{35\%}$ the stock is above its MSST.

c. If spawning biomass for 2008 is estimated to be above ½ $B_{35\%}$ but below $B_{35\%}$, the stock's status relative to MSST is determined by referring to harvest Scenario #6 (Table 2.30). If the mean spawning biomass for 2018 is below $B_{35\%}$, the stock is below its MSST. Otherwise, the stock is above its MSST.

Is the stock approaching an overfished condition? This is determined by referring to harvest Scenario #7:

a. If the mean spawning biomass for 2011 is below 1/2 $B_{35\%}$, the stock is approaching an overfished condition.

b. If the mean spawning biomass for 2011 is above $B_{35\%}$, the stock is not approaching an overfished condition.

c. If the mean spawning biomass for 2011 is above 1/2 $B_{35\%}$ but below $B_{35\%}$, the determination depends on the mean spawning biomass for 2021. If the mean spawning biomass for 2021 is below $B_{35\%}$, the stock is approaching an overfished condition. Otherwise, the stock is not approaching an overfished condition.

Based on the above criteria and Tables 2.27 and 2.28, the stock is not overfished and is not approaching an overfished condition.

ECOSYSTEM CONSIDERATIONS

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

Ecosystem Effects on the Stock

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

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

Fishery Effects on the Ecosystem

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

Bycatch of Nontarget and "Other" Species

Bycatch of nontarget species and members of the "other species" group are shown in the following set of tables (for the 2003-2005 tables, the "hook and line" gear type includes both longline and jig gear): Tables 2.29a and 2.29b show bycatch for the GOA Pacific cod trawl fishery in 1997-2002 and 2003-2005, respectively. Tables 2.30a and 2.30b show bycatch for the GOA Pacific cod longline fishery in 1997-2002 and the GOA Pacific cod hook and line fishery in 2003-2005, respectively. Tables 2.31a and 2.31b show bycatch for the GOA Pacific cod pot fishery in 1997-2002 and 2003-2005, respectively.

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

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

Steller Sea Lions

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

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

Seabirds

The following is a summary of information provided by Livingston (ed., 2002): In both the BSAI and GOA, the northern fulmar (*Fulmarus glacialis*) comprises the majority of seabird bycatch, which occurs primarily in the longline fisheries, including the hook and line fishery for Pacific cod (Tables 2.30b and

2.30b). 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) determinants of trawl survey selectivity; 2) ecology of the Pacific cod stock, including spatial dynamics, trophic and other interspecific relationships, and the relationship between climate and recruitment; 3) behavior of the Pacific cod fishery, including spatial dynamics; 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.

ACKNOWLEDGMENTS

Chris Johnston and Delsa Anderl provided age data. Michael Martin provided survey data. Josh Keaton and Kally Spalinger provided fishery data. Angie Greig and Ren Narita provided fishery data and produced Figure 2.1. Dave Ackley, Sarah Gaichas, and Terry Hiatt provided bycatch data. Rick Methot developed the SS software used to conduct this assessment. Anne Hollowed, Teresa A'mar, and the GOA 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.

REFERENCES

Albers, W. D., and P. J. Anderson. 1985. Diet of Pacific cod, *Gadus macrocephalus*, and predation on the northern pink shrimp, *Pandalus borealis*, in Pavlof Bay, Alaska. Fish. Bull., U.S. 83:601-610.

Bakkala, R. G., and V. G. Wespestad. 1985. Pacific cod. *In* R. G. Bakkala and L. L. Low (editors),

Condition of groundfish resources of the eastern Bering Sea and Aleutian Islands region in 1984, p. 37-49. U.S. Dep. Commer., NOAA Tech. Memo. NMFS F/NWC-83.

Boldt, J. (editor). 2005. Ecosystem Considerations for 2006. North Pacific Fishery Management Council, 605 West 4th Ave., Suite 306, Anchorage, AK 99501.

Calkins, D. G. 1998. Prey of Steller sea lions in the Bering Sea. Biosphere Conservation 1:33-44.

Dorn, M. W., S. Barbeaux, S. Gaichas, M. Guttormsen, B. Megrey, K. Spalinger, and M. Wilkins. 2004. Assessment of walleye pollock in the Gulf of Alaska. *In* Plan Team for the Groundfish Fisheries of the Gulf of Alaska (compiler), Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the Gulf of Alaska. p. 35-129. North Pacific Fishery Management Council, 605 West 4^{th} Ave., Suite 306, Anchorage, AK 99501.

Dorn, M. W., A. B. Hollowed, E. Brown, B. Megrey, C. Wilson, and J. Blackburn. 2001. Assessment of the walleye Pollock stock in the Gulf of Alaska. *In* Plan Team for the Groundfish Fisheries of the Gulf of Alaska (compiler), Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the Gulf of Alaska. North Pacific Fishery Management Council, 605 West 4^{th} Ave., Suite 306, Anchorage, AK 99501.

Fournier, D. 1983. An analysis of the Hecate Strait Pacific cod fishery using an age-structured model incorporating density-dependent effects. Can. J. Fish. Aquat. Sci. 40:1233-1243.

Fournier, D. 2005. An introduction to AD Model Builder Version 6.0.2 for use in nonlinear modeling and statistics. Otter Research Ltd. P.O. Box 2040, Sidney BC V8L3S3.

Fournier, D., and C. P. Archibald. 1982. A general theory for analyzing catch at age data. Can. J. Fish. Aquat. Sci. 38:1195-1207.

Fulton, T. W. 1911. The Sovereignty of the Sea; an Historical Account of the Claims of England to the Dominion of the British Seas, and of the Evolution of the Territorial Waters: With Special Reference to the Rights of Fishing and the Naval Salute. William Blackwood and Sons, Edinburgh and London. 799 p.

Grant, W. S., C. I. Zhang, and T. Kobayashi. 1987. Lack of genetic stock discretion in Pacific cod (*Gadus macrocephalus*). Can. J. Fish. Aquat. Sci. 44:490-498.

Hare, S. R., and N. J. Mantua. 2000. Empirical evidence for North Pacific regime shifts in 1977 and 1989. Progress in Oceanography 47:103-146.

Hiatt, T., R. Felthoven, M. Dalton, B. Garber-Yonts, A. Haynie, K. Herrmann, D. Lew, J. Sepez, C. Seung, L. Sievanen, and the staff of Northern Economics. 2007. Stock Assessment and Fishery Evaluation Report for the Groundfish Fisheries of the Gulf of Alaska and Bering Sea/Aleutian Islands Area: Economic Status of the Groundfish Fisheries off Alaska, 2006. Economic and Social Sciences Research Program, Resource Ecology and Fisheries Management Division, Alaska Fisheries Science Center, NMFS, NOAA, 7600 Sand Point Way N.E., Seattle, Washington 98115-6349. 353 p.

Ketchen, K.S. 1964. Preliminary results of studies on a growth and mortality of Pacific cod (*Gadus macrocephalus*) in Hecate Strait, British Columbia. J. Fish. Res. Bd. Canada 21:1051-1067.

Lang, G. M., C. W. Derrah, and P. A. Livingston. 2003. Groundfish food habits and predation on commercially important prey species in the Eastern Bering Sea from 1993 through 1996. Alaska Fisheries Science Center Processed Report 2003-04. Alaska Fisheries Science Center, 7600 Sand Point Way NE., Seattle, WA 98115-6349. 351 p.

Livingston, P. A. 1989. Interannual trends in Pacific cod, Gadus macrocephalus, predation on three commercially important crab species in the eastern Bering Sea. Fish. Bull., U.S. 87:807-827.

Livingston, P. A. 1991. Pacific cod. *In* P. A. Livingston (editor), Groundfish food habits and predation on commercially important prey species in the eastern Bering Sea from 1984 to 1986, p. 31-88. U.S. Dept. Commer., NOAA Tech. Memo. NMFS F/NWC-207.

Livingston, P. A. (editor). 2003. Ecosystem Considerations for 2003. North Pacific Fishery Management Council, 605 West 4th Ave., Suite 306, Anchorage, AK 99501.

Low, L. L. 1974. A study of four major groundfish fisheries of the Bering Sea. Ph.D. Thesis, Univ. Washington, Seattle, WA 240 p.

Mantua, N. J., Hare, S. R., Zhang, Y., Wallace, J. M., & Francis, R. C.. 1997. A Pacific interdecadal climate oscillation with impacts on salmon production. Bulletin of the American Meteorological Society 78, 1069-1079.

McAllister, M. K., and J. N. Ianelli. 1997. Bayesian stock assessment using catch-age data and the sampling-importance resampling algorithm. Can. J. Fish. Aquat. Sci. 54:284-300.

Methot, R. D. 1986. Synthetic estimates of historical abundance and mortality for northern anchovy, *Engraulis mordax*. NMFS, Southwest Fish. Cent., Admin. Rep. LJ 86-29, La Jolla, CA.

Methot, R. D. 1990. Synthesis model: An adaptable framework for analysis of diverse stock assessment data. Int. N. Pac. Fish. Comm. Bull. 50:259-277.

Methot, R. D. 1998. Application of stock synthesis to NRC test data sets. *In* V. R. Restrepo (editor), Analyses of simulated data sets in support of the NRC study on stock assessment methods, p. 59-80. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-F/SPO-30.

Methot, R. D. 2000. Technical description of the stock synthesis assessment program. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-NWFSC-43, 46 p.

Methot, R. D. 2005a. Technical description of the Stock Synthesis II Assessment Program. Unpubl. manuscr. National Marine Fisheries Service, Northwest Fisheries Science Center, 2725 Montlake Blvd. East, Seattle, WA 98112-2097. 54 p.

Methot, R. D. 2005b. User manual for the assessment program Strock Synthesis 2 (SS2), Model Version 1.19. National Marine Fisheries Service, Northwest Fisheries Science Center, 2725 Montlake Blvd. East, Seattle, WA 98112-2097. 47 p.

Methot, R. D. 2007. User manual for the integrated analysis program Stock Synthesis 2 (SS2), Model Version 2.00c. National Marine Fisheries Service, Northwest Fisheries Science Center, 2725 Montlake Blvd. East, Seattle, WA 98112-2097. 47 p.

National Marine Fisheries Service (NMFS). 2004. Alaska Groundfish Fisheries Final Programmatic Supplemental Environmental Impact Statement. National Marine Fisheries Service, Alaska Region. PO Box 21668, Juneau, AK 99802-1668.

National Marine Fisheries Service (NMFS). 2005. Final environmental impact statement for essential fish habitat identification and conservation in Alaska. National Marine Fisheries Service, Alaska Region. P.O. Box 21668, Juneau, AK 99802-1668.

Nichol, D. G., T. Honkalehto, and G. G. Thompson. 2007. Proximity of Pacific cod to the sea floor: Using archival tags to estimate fish availability to research bottom trawls. *Fisheries Research* 86:129-135.

Pitcher, K. W. 1981. Prey of Steller sea lion, *Eumetopias jubatus*, in the Gulf of Alaska. Fishery Bulletin 79:467-472.

Ricker, W. E. 1954. Stock and recruitment. J. Fish. Res. Board Can. 11:559-63.

Ricker. W. E. 1975. Computation and Interpretation of Biological Statistics of Fish Populations. Bulletin 191. Department of the Environment, Canada. 382 p.

Roberson, N. E. 2001. Age determination of Pacific cod (*Gadus macrocephalus*). MS thesis, University of Washington, Seattle, WA. 44 p.

Roberson, N. E., D. K. Kimura, D. R. Gunderson, and A. M. Shimada. 2005. Indirect validation of the age-reading method for Pacific cod (Gadus macrocephalus) using otoliths from marked and recaptured fish. U.S. Natl. Mar. Fish. Serv., Fish. Bull. 103:153-160.

Shimada, A. M., and D. K. Kimura. 1994. Seasonal movements of Pacific cod (*Gadus macrocephalus*) in the eastern Bering Sea and adjacent waters based on tag-recapture data. U.S. Natl. Mar. Fish. Serv., Fish. Bull. 92:800-816.

Sinclair, E.S. and T. K. Zeppelin. 2002. Seasonal and spatial differences in diet in the western stock of Steller sea lions (*Eumetopias jubatus*). Journal of Mammalogy 83(4).

Somerton, D. A. 2004. Do Pacific cod (*Gadus macrocephalus*) and walleye pollock *(Theregra chalcogramma*) lack a herding response to the doors, bridles, and mudclouds of survey trawls? ICES Journal of Marine Science 61:1186-1189.

Stark, J. W. 2005. Length and age at maturity, seasonal maturation and growth of Pacific cod (*Gadus macrocephalus*) in the Gulf of Alaska and southeastern Bering Sea. Unpubl. manuscr. Alaska Fisheries Science Center, 7600 Sand Point Way NE., Seattle, WA 98115-6349. 23 p.

Thompson, G. G., and M. E. Conners. 2007. Report of the Pacific cod technical workshop held at the Alaska Fisheries Science Center, April 24-25, 2007. Unpubl. manuscr., Alaska Fisheries Science Center, Resource Ecology and Fisheries Management Division, 7600 Sand Point Way NE., Seattle, WA 98115-6349. 56 p.

Thompson, G. G., and M. W. Dorn. 1997. Pacific cod. *In* Plan Team for Groundfish Fisheries of the Bering Sea/Aleutian Islands (editor), Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands regions, p. 121-158. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.

Thompson, G. G., and M. W. Dorn. 1998. Pacific cod. *In* Plan Team for Groundfish Fisheries of the Bering Sea/Aleutian Islands (editor), Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands regions, p. 113-181. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.

Thompson, G. G., and M. W. Dorn. 1999. Pacific cod. *In* Plan Team for Groundfish Fisheries of the Bering Sea/Aleutian Islands (editor), Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands regions, p. 151-230. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.

Thompson, G. G., and M. W. Dorn. 2003. Assessment of the Pacific cod stock in the Eastern Bering Sea and Aleutian Islands Area. *In* Plan Team for Groundfish Fisheries of the Bering Sea/Aleutian Islands (compiler), Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands regions, p. 127-222. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.

Thompson, G. G., and M. W. Dorn. 2005. Assessment of the Pacific cod stock in the Gulf of Alaska. *In* Plan Team for Groundfish Fisheries of the Gulf of Alaska (compiler), Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska, p. 155-244. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.

Thompson, G., M. Dorn, and D. Nichol. 2006. Assessment of the Pacific cod stock in the Gulf of Alaska. *In* Plan Team for Groundfish Fisheries of the Gulf of Alaska (compiler), Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska, p. 147-220. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.

Thompson, G., J. Ianelli, M. Dorn, D. Nichol, S. Gaichas, and K. Aydin. 2007a. Assessment of the Pacific cod stock in the Eastern Bering Sea and Aleutian Islands Area. *In* Plan Team for Groundfish Fisheries of the Bering Sea/Aleutian Islands (compiler), Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands regions, p. 209-327. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.

Thompson, G., J. Ianelli, M. Dorn, and M. Wilkins. 2007b. Assessment of the Pacific cod stock in the Gulf of Alaska. *In* Plan Team for Groundfish Fisheries of the Gulf of Alaska (compiler), Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska, p. 169-194. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.

Thompson, G. G., and R. D. Methot. 1993. Pacific cod. *In* Plan Team for Groundfish Fisheries of the Bering Sea/Aleutian Islands (editor), Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands region as projected for 1994, chapter 2. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.

Thompson, G. G., and A. M. Shimada. 1990. Pacific cod. *In* L. L. Low and R. E. Narita (editors), Condition of groundfish resources of the eastern Bering Sea-Aleutian Islands region as assessed in 1988, p. 44-66. U.S. Dep. Commer., NOAA Tech. Memo. NMFS F/NWC-178.

Thompson, G. G, and H. H. Zenger. 1993. Pacific cod. *In* Plan Team for Groundfish Fisheries of the Gulf of Alaska (editor), Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska as projected for 1994, chapter 2. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.

Thompson, G. G, and H. H. Zenger. 1994. Pacific cod. *In* Plan Team for Groundfish Fisheries of the Gulf of Alaska (editor), Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska as projected for 1995, chapter 2. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.

Thompson, G. G., and H. H. Zenger. 1995. Pacific cod. *In* Plan Team for the Groundfish Fisheries of the Gulf of Alaska (editor), Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska as projected for 1996, chapter 2. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.

Thompson, G. G., H. H. Zenger, and M. W. Dorn. 1997. Pacific cod. *In* Plan Team for Groundfish Fisheries of the Gulf of Alaska (editor), Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska, p. 121-163. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.

Thompson, G. G., H. H. Zenger, and M. W. Dorn. 1998. Pacific cod. *In* Plan Team for Groundfish Fisheries of the Gulf of Alaska (editor), Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska, p. 91-155. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.

Thompson, G. G., H. H. Zenger, and M. W. Dorn. 1999. Pacific cod. *In* Plan Team for Groundfish Fisheries of the Gulf of Alaska (editor), Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska, p. 105-184. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.

Thompson, G. G., H. H. Zenger, and M. K. Dorn. 2000. Pacific cod. *In* Plan Team for the Groundfish Fisheries of the Gulf of Alaska (compiler), Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the Gulf of Alaska p. 91-110. North Pacific Fishery Management Council, 605 West 4th Ave., Suite 306, Anchorage, AK 99501.

Thompson, G. G., H. H. Zenger, and M. K. Dorn. 2002. Assessment of the Pacific cod stock in the Gulf of Alaska. *In* Plan Team for the Groundfish Fisheries of the Gulf of Alaska (compiler), Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the Gulf of Alaska p. 89-167. North Pacific Fishery Management Council, 605 West 4th Ave., Suite 306, Anchorage, AK 99501.

Thompson, G. G., H. H. Zenger, and M. K. Dorn. 2003. Assessment of the Pacific cod stock in the Gulf of Alaska. *In* Plan Team for the Groundfish Fisheries of the Gulf of Alaska (compiler), Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the Gulf of Alaska p. 149-241. North Pacific Fishery Management Council, 605 West 4th Ave., Suite 306, Anchorage, AK 99501.

Thompson, G. G., H. H. Zenger, and M. K. Dorn. 2004. Assessment of the Pacific cod stock in the Gulf of Alaska. *In* Plan Team for the Groundfish Fisheries of the Gulf of Alaska (compiler), Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the Gulf of Alaska p. 131-232. North Pacific Fishery Management Council, 605 West 4th Ave., Suite 306, Anchorage, AK 99501.

Wespestad, V., R. Bakkala, and J. June. 1982. Current abundance of Pacific cod (*Gadus macrocephalus*) in the eastern Bering Sea and expected abundance in 1982-1986. NOAA Tech. Memo. NMFS F/NWC-25, 26 p.

Westrheim, S. J. 1996. On the Pacific cod (*Gadus macrocephalus*) in British Columbia waters, and a comparison with Pacific cod elsewhere, and Atlantic cod (*G. morhua*). Can. Tech. Rep. Fish. Aquat. Sci. 2092. 390 p.

Yang, M-S. 2004. Diet changes of Pacific cod (Gadus macrocephalus) in Pavlof Bay associated with climate changes in the Gulf of Alaska between 1980 and 1995. U.S. Natl. Mar. Fish. Serv., Fish. Bull. 102:400-405.

Tables

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

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

Table 2.1b—Summary of catches (t) of Pacific cod since 1991 by management jurisdiction and gear type. Longl. = longline, Subt. = subtotal. All entries include discards. Catches for 2008 are complete through early October.

	Federal					State			
Year	Trawl	Longl.	Pot	Other	Subt.	Pot	Other	Subt.	Total
1991	58,093	7,656	10,464	115	76,328	0	0	0	76,328
1992	54,593	15,675	10,154	325	80,746	0	0	0	80,746
1993	37,806	8,962	9,708	11	56,487	0	0	0	56,487
1994	31,446	6,778	9,160	100	47,484	0	0	0	47,484
1995	41,875	10,978	16,055	77	68,985	0	0	0	68,985
1996	45,991	10,196	12,040	53	68,280	0	0	0	68,280
1997	48,405	10,977	9,065	26	68,474	7,224	1,319	8,542	77,017
1998	41,569	10,011	10,510	29	62,120	9,088	1,316	10,404	72,524
1999	37,167	12,362	19,015	70	68,613	12,075	1,096	13,171	81,784
2000	25,457	11,667	17,351	54	54,528	10,388	1,643	12,031	66,559
2001	24,382	9,913	7,171	155	41,621	7,836	2,084	9,920	51,541
2002	19,809	14,666	7,694	176	42,345	10,423	1,714	12,137	54,483
2003	18,799	9,475	12,675	88	41,037	8,031	3,429	11,461	52,498
2004	17,351	10,337	13,671	310	17,351	10,117	2,804	12,922	54,591
2005	14,513	5,756	14,684	203	35,157	9,712	2,673	12,384	47,541
2006	13,111	10,167	14,411	118	37,807	9,259	690	9,949	47,756
2007	14,780	11,500	13,523	39	39,842	10,886	761	11,647	51,489
2008	18,429	11,634	11,288	74	41,425	11,322	1,720	13,042	54,467

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

Year	ABC	TAC	Catch	Stock Assessment Model (from previous year)
1980	n/a	60,000	35,345	n/a
1981	n/a	70,000	36,131	n/a
1982	n/a	60,000	29,465	n/a
1983	n/a	60,000	36,540	n/a
1984	n/a	60,000	23,898	n/a
1985	n/a	60,000	14,428	n/a
1986	136,000	75,000	25,012	survey biomass
1987	125,000	50,000	32,939	survey biomass
1988	99,000	80,000	33,802	survey biomass
1989	71,200	71,200	43,293	stock reduction analysis
1990	90,000	90,000	72,517	stock reduction analysis
1991	77,900	77,900	76,328	stock reduction analysis
1992	63,500	63,500	80,746	stock reduction analysis
1993	56,700	56,700	56,487	stock reduction analysis
1994	50,400	50,400	47,484	stock reduction analysis
1995	69,200	69,200	68,985	SS1 model (length-based data)
1996	65,000	65,000	68,280	SS1 model (length-based data)
1997	81,500	69,115	77,017	SS1 model (length-based data)
1998	77,900	66,060	72,524	SS1 model (length-based data)
1999	84,400	67,835	81,784	SS1 model (length-based data)
2000	76,400	58,715	66,559	SS1 model (length-based data)
2001	67,800	52,110	51,541	SS1 model (length-based data)
2002	57,600	44,230	54,483	SS1 model (length-based data)
2003	52,800	40,540	52,498	SS1 model (length-based data)
2004	62,810	48,033	54,591	SS1 model (length-based data)
2005	58,100	44,433	47,541	SS1 model (length-based data)
2006	68,859	52,264	47,756	SS2 model (length- and age-based data)
2007	68,859	52,264	51,489	SS2 model (length- and age-based data)
2008	66,493	50,269	54,467	survey biomass

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

	Regulatory Area		
Year(s)	Western	Central	Eastern
1977-1985	28	56	16
1986	40	44	16
1987	27	56	17
1988-1989	19	73	8
1990	33	66	1
1991	33	62	5
1992	37	61	2
1993-1994	33	62	5
1995-1996	29	66	5
1997-1999	35	63	2
2000-2001	36	57	7
2002 (ABC)	39	55	6
2002 (TAC)	38	56	6
2003 (ABC)	39	55	6
2003 (TAC)	38	56	6
2004 (ABC)	36	57	7
2004 (TAC)	35.3	56.5	8.2
2005 (ABC)	36	57	7
2005 (TAC)	35.3	56.5	8.2
2006 (ABC)	39	55	6
2006 (TAC)	38.54	54.35	7.11
2007 (ABC)	39	55	6
2007 (TAC)	38.54	54.35	7.11
2008 (ABC)	39	57	4
2008 (TAC)	38.69	56.55	4.76

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

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

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

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

Table 2.5—Catch of Pacific cod by year, gear, and season as used in the stock assessment model. Jig catches have been merged with other gear types. Catches for season 3 in 2008 are based on 2007.

	Trawl			Longline			Pot		
Year	Sea. 1	Sea. 2	Sea. 3	Sea. 1	Sea. 2	Sea. 3	Sea. 1	Sea. 2	Sea. 3
1977	183	158	311	943	190	482	0	0	0
1978	916	790	1558	4720	950	2413	0	0	0
1979	1063	917	1809	5480	1103	2801	0	0	0
1980	2764	2384	4702	14245	2868	7282	0	0	0
1981	387	3532	6565	10504	5312	9656	0	0	0
1982	1143	2041	3495	9912	2890	9865	0	0	0
1983	2861	2844	3807	10960	4651	11145	0	0	0
1984	3429	2008	3368	11840	425	2579	0	0	0
1985	2427	571	1878	9127	6	280	0	0	0
1986	2999	431	3420	15927	460	1373	0	0	0
1987	5377	7928	9181	5343	983	1935	219	141	282
1988	16021	6569	4555	2979	507	447	1081	23	318
1989	24614	12857	166	2378	356	928	241	103	32
1990	43279	7514	8395	5557	109	253	2577	1008	2076
1991	55977	631	1484	7296	332	142	9591	0	873
1992	51911	1189	1494	12946	802	2251	9672	14	468
1993	33632	2624	1550	8485	307	181	9689	18	0
1994	29152	1421	873	6696	48	133	8742	0	418
1995	38476	802	2597	10662	166	227	15419	43	592
1996	41450	3048	1493	9991	152	106	12014	27	0
1997	40727	1638	6040	10931	967	424	14007	475	1807
1998	34690	3679	3200	10566	510	280	18479	0	1119
1999	30124	1501	5542	12782	555	191	25167	3374	2548
2000	22133	2574	750	12758	436	169	26947	154	638
2001	15234	2035	7113	11199	662	291	13047	37	1923
2002	15829	2705	1276	12963	259	3334	13602	83	4431
2003	10996	2565	5239	8416	407	768	20997	24	3087
2004	9137	2091	6339	8236	109	2027	24250	4	4461
2005	9545	1831	3138	3774	115	1867	22118	4	5150
2006	10148	1634	1328	6137	132	3941	21963	88	2384
2007	10091	1551	3139	7187	241	4258	20404	15	3989
2008	11525	2503	3139	9355	241	4258	20329	0	3989

Table 2.6a—Length frequencies for the January-May trawl fishery by length bin.

Year	5	12	15	18	21	24	27	30	33	36	39	42	45	50	55	60	65	70	75	80	85	90	95	100	105
1984	0	0	0	0	0	0	2	6	5	12	110	291	852	740	567	554	558	439	249	138	60	19	6	0	0
1985	0	0	0	0	1	1	0	2	1	47	149	174	261	87	203	268	257	202	200	108	56	23	1	0	0
1986	0	0	0	0	0	0	0	10	23	17	4	3	14	64	56	55	59	55	42	27	16	4	3	0	0
1988	0	0	0	0	0	0	2	6	11	15	33	76	332	764	615	435	381	355	276	177	116	44	27	22	13
1989	0	0	0	0	0	0	0	0	0	0	0	0	5	52	175	248	141	30	5	3	1	0	0	0	0
1990	2	0	1	1	12	7	15	76	119	163	214	231	607	1346	3197	4899	4678	3355	2563	1572	1312	754	256	66	25
1991	0	1	2	2	2	7	63	142	163	226	235	346	1905	3794	4421	5618	6609	5126	3629	2613	1621	1016	618	273	82
1992	0	0	0	1	4	13	21	78	261	567	921	1084	1796	3160	4966	6796	5825	4257	3355	2548	1734	1143	749	280	124
1993	0	0	1	4	2	5	4	58	234	469	547	544	2077	3445	3613	4744	4817	2832	1430	846	491	345	214	87	35
1994	0	0	0	0	0	0	0	7	31	83	115	138	499	1022	1734	2551	2642	1659	944	490	347	167	82	44	24
1995	0	0	0	0	0	0	1	8	60	91	204	316	1000	2363	3475	4628	5820	4040	1903	993	533	300	164	74	66
1996	0	0	0	1	6	28	39	64	105	187	250	230	290	690	1575	2924	3744	2948	1949	1237	793	437	217	96	48
1997	0	0	3	8	12	12	5	44	123	300	357	276	807	2271	2841	2945	4449	3874	2247	1140	562	288	174	67	17
1998	0	0	0	1	5	7	9	57	293	746	989	832	2009	4345	5676	9100	10443	8205	4970	2379	1278	652	327	98	27
1999	0	0	1	4	4	4	4	21	73	144	184	215	453	1052	1797	2194	2226	1644	851	397	173	61	30	14	4
2000	0	0	0	0	0	0	2	10	29	74	84	99	250	787	1091	1429	1310	806	475	243	163	72	20	6	1
2001	0	1	2	2	1	1	4	7	37	97	158	146	287	694	947	1166	1183	803	336	147	63	22	8	1	2
2002	0	0	0	0	1	3	5	7	36	118	232	298	497	441	756	975	1123	936	508	218	80	36	8	5	2
2003	0	0	0	0	0	1	4	13	34	99	150	130	214	609	963	645	433	358	221	133	85	20	10	6	1
2004	0	0	1	0	2	1	0	6	24	52	65	74	179	433	525	518	413	167	86	35	11	4	2	0	0
2005	0	0	0	0	0	0	0	2	5	7	26	24	58	98	177	318	437	300	143	75	51	21	8	8	2
2006	0	0	0	0	0	1	0	1	3	14	42	27	64	180	228	397	424	342	206	124	63	35	25	11	3
2007	1	0	2	15	37	29	7	4	12	46	165	236	274	378	571	471	435	381	187	99	57	47	19	14	1
2008	0	0	0	1	0	0	1	13	54	125	181	171	183	296	370	376	332	174	75	45	13	4	3	1	0

Table 2.6b—Length frequencies for the June-August trawl fishery by length bin.

Year	5	12	15	18	21	24	27	30	33	36	39	42	45	50	55	60	65	70	75	80	85	90	95	100	105
1980	0	0	0	0	0	0	0	0	0	0	1	6	49	139	86	65	91	133	91	48	16	2	0	0	0
1982	0	0	0	0	0	0	0	0	0	0	12	9	52	146	110	96	56	33	20	4	6	2	2	1	0
1983	0	0	0	0	0	0	1	1	0	3	6	34	155	201	180	208	184	151	121	64	37	11	5	3	0
1984	0	0	0	0	0	0	5	18	29	50	121	305	1148	1706	1157	828	804	527	376	233	113	35	9	2	0
1985	0	0	0	0	0	0	0	1	2	23	61	134	292	399	975	1160	691	312	195	146	95	54	9	0	0
1988	0	0	0	0	0	0	0	1	2	17	56	70	229	571	640	378	113	51	8	6	3	0	1	0	0
1990	62	36	15	0	0	1	0	1	3	31	81	169	419	954	1898	2583	2568	1325	510	181	88	24	3	4	0
1998	0	0	1	3	0	0	1	1	0	2	13	49	196	310	656	854	720	419	148	60	26	1	4	0	1
2000	0	0	0	0	0	0	0	3	1	0	9	21	31	30	56	88	100	48	20	14	4	0	0	0	0
2001	0	0	0	0	0	5	5	5	0	2	6	18	48	45	68	144	147	99	31	20	16	6	0	0	0
2002	0	0	0	0	0	0	0	1	3	1	5	24	145	195	101	114	117	55	24	19	3	1	0	0	0
2003	0	0	0	2	1	2	10	8	7	19	27	59	193	170	162	220	136	101	37	26	5	1	1	0	0
2004	0	0	0	0	0	0	0	2	0	0	1	6	9	24	83	124	106	62	30	16	5	2	1	0	0
2005	0	0	0	0	2	2	2	2	4	8	21	22	8	10	52	144	150	91	40	13	8	2	0	0	0
2007	0	0	0	1	0	17	21	12	6	3	7	23	94	121	61	96	105	77	47	14	3	1	0	0	0
2008	0	0	0	0	0	0	0	0	11	53	125	159	177	54	35	116	167	77	35	10	8	4	0	0	0

Table 2.6c—Length frequencies for the September-December trawl fishery by length bin.

Year	5	12	15	18	21	24	27	30	33	36	39	42	45	50	55	60	65	70	75	80	85	90	95	100	105
1977	0	0	0	0	0	0	0	0	2	15	56	82	95	66	37	32	10	14	6	4	0	0	0	0	0
1978	0	0	0	0	0	1	1	5	13	14	11	28	88	130	163	121	112	66	41	25	5	1	1	0	0
1982	0	0	0	0	0	0	0	0	1	3	14	30	66	109	170	198	118	78	32	10	9	3	0	0	0
1983	0	0	0	0	0	0	0	1	1	8	18	78	184	197	241	234	195	162	131	79	39	12	2	0	0
1984	0	1	1	0	8	2	1	29	50	64	106	264	581	665	590	318	172	127	57	38	17	11	5	3	1
1985	0	0	0	0	0	0	8	42	111	137	107	132	484	506	672	746	352	115	68	42	36	12	4	3	0
1987	0	0	0	0	0	0	0	1	1	4	9	22	67	138	189	112	37	15	1	1	1	0	0	0	0
1990	0	0	0	1	2	0	7	13	39	62	180	427	1447	1239	1240	1740	1717	1253	1082	842	429	131	66	18	19
1992	0	0	0	0	0	1	8	21	18	7	64	214	479	502	415	211	145	77	63	28	2	0	0	0	0
1995	0	0	0	0	0	1	14	14	16	14	12	7	51	140	222	583	642	470	153	50	9	3	1	0	0
1997	0	0	0	1	3	8	29	49	100	62	56	96	318	374	477	823	589	342	262	100	46	10	1	0	0
1998	3	4	0	0	5	35	112	133	209	209	146	225	1027	1139	906	1048	747	438	214	112	45	4	1	1	0
1999	0	0	0	0	0	1	0	2	3	6	2	9	14	31	59	271	281	213	124	54	19	10	2	0	0
2001	0	0	0	0	1	0	10	45	100	154	123	80	303	633	669	783	677	496	301	122	46	14	3	0	0
2003	0	0	0	0	0	1	9	5	9	11	12	43	193	303	291	405	249	139	53	25	8	4	1	0	0
2004	0	0	0	0	0	0	4	9	7	1	4	30	156	284	383	465	532	405	166	70	20	9	0	0	0
2005	0	0	0	0	0	0	3	2	5	4	15	34	34	21	57	275	485	420	229	113	44	14	4	0	0
2007	0	0	0	0	2	3	17	27	30	31	21	21	86	201	213	172	146	54	30	13	4	0	0	0	0

Table 2.7a—Length frequencies for the January-May longline fishery by length bin.

Year	5	12	15	18	21	24	27	30	33	36	39	42	45	50	55	60	65	70	75	80	85	90	95	100	105
1979	0	0	0	0	0	0	0	6	33	93	146	94	191	427	669	973	1025	764	433	245	110	31	6	0	0
1980	0	0	0	0	0	0	0	1	2	37	237	996	2510	1328	971	927	1325	1425	1145	493	195	72	17	2	1
1981	0	0	0	0	0	0	0	0	2	17	53	122	929	2398	1887	840	575	389	318	239	117	44	14	6	0
1982	0	0	0	0	0	0	0	5	37	103	221	237	1243	2105	2639	2468	1777	1001	462	173	89	44	14	3	0
1983	0	0	0	0	0	0	0	2	18	105	230	908	4274	4322	6004	7674	8689	7453	4419	1919	760	237	99	31	1
1984	0	0	0	0	1	7	1	4	21	72	221	858	4324	6783	7637	7503	9547	9996	7612	4602	2351	883	213	45	6
1985	0	0	0	0	0	0	0	3	28	96	438	1118	3608	4677	5341	4955	6271	7723	6625	4556	2659	1364	464	94	13
1986	0	0	0	0	0	0	0	10	138	397	509	724	3093	7348	12279	12702	11312	13262	12110	7969	4127	2268	1033	349	82
1990	0	0	0	0	0	0	2	1	6	26	77	53	180	407	728	1215	1920	1587	1120	823	542	183	70	30	3
1991	0	0	0	0	0	0	0	1	3	8	56	155	670	1351	1839	2473	2486	1740	909	411	229	119	49	23	29
1992	0	0	0	0	0	2	3	8	20	57	137	333	1078	2326	4103	5900	4910	3817	2585	1598	906	580	306	103	45
1993	0	0	0	1	3	6	9	5	8	18	43	67	357	924	1503	2077	1959	1226	1036	947	856	413	163	75	52
1994	0	0	0	0	0	0	0	0	0	1	4	20	166	500	630	1000	1065	788	450	213	167	93	61	26	17
1995	0	0	0	0	1	0	3	2	3	24	96	173	692	1662	2521	4264	5252	4025	2628	1606	874	421	212	117	59
1996	0	0	0	0	0	0	1	4	21	42	54	79	260	516	1268	2763	3858	3178	1627	583	265	109	48	26	4
1997	0	0	0	0	0	0	0	0	3	3	10	12	159	559	925	1267	1575	1431	791	317	118	46	16	6	1
1998	0	0	0	0	0	0	0	0	2	9	18	53	277	748	1015	1458	1548	1197	833	473	243	78	27	2	0
1999	0	0	0	0	0	0	0	0	3	6	20	60	254	707	1385	1802	1679	1243	881	474	268	132	62	22	15
2000	0	0	0	0	0	0	0	1	2	3	2	25	197	797	1697	2548	2714	1747	946	422	179	97	36	10	3
2001	0	0	0	0	0	0	1	1	3	6	33	82	296	915	1969	2850	3074	1919	906	358	126	60	34	6	3
2002	0	0	0	0	1	0	0	5	3	13	32	77	246	542	1250	1849	2208	1712	939	447	161	69	21	7	1
2003	0	0	0	0	0	0	0	0	5	7	30	92	385	800	1337	1415	1523	1097	626	382	149	58	26	9	0
2004	0	0	0	0	0	0	0	0	0	1	4	16	149	654	1188	1563	1367	803	434	257	129	55	19	7	1
2005	0	0	0	0	0	0	0	0	0	1	2	7	75	386	917	1466	1428	796	410	235	152	75	26	2	0
2006	0	0	0	0	0	1	0	0	2	6	17	27	156	569	960	1685	1864	1177	529	248	185	104	69	35	11
2007	0	0	0	0	0	0	0	1	0	6	18	37	112	511	1093	1508	1357	1029	504	203	102	82	66	15	6
2008	0	0	0	0	0	0	1	2	2	22	36	71	180	712	1426	1641	1938	1408	771	395	149	78	42	37	17

Table 2.7b—Length frequencies for the June-August longline fishery by length bin.

Year	5	12	15	18	21	24	27	30	33	36	39	42	45	50	55	60	65	70	75	80	85	90	95	100	105
1978	0	0	0	0	0	0	0	0	1	15	36	102	530	791	1007	1187	681	350	260	122	35	5	0	0	0
1979	1	0	0	0	0	0	1	0	2	9	19	21	59	100	188	248	307	254	131	51	20	5	1	0	0
1980	0	0	0	0	0	0	0	0	0	7	15	148	784	878	448	289	249	316	273	173	57	21	2	0	0
1981	0	0	0	0	0	0	0	0	0	2	12	51	274	1032	1949	1162	343	134	81	51	45	21	5	1	0
1982	0	0	0	0	0	0	0	0	1	0	9	28	131	443	565	547	408	210	88	35	22	10	4	1	0
1983	0	0	0	0	0	0	0	0	1	25	88	153	1258	2344	2531	2217	1376	888	520	230	97	29	22	4	0
1984	0	0	0	0	0	0	0	0	0	4	8	13	197	691	1003	804	430	291	245	184	96	57	28	3	2
1992	0	0	0	0	0	0	0	0	1	2	6	8	13	76	84	119	145	71	28	11	11	2	0	0	0
1998	0	0	0	0	0	0	0	0	0	0	0	0	7	28	34	80	116	79	48	8	6	3	0	1	0
2005	0	0	0	0	0	0	0	0	0	0	0	0	2	14	57	99	92	54	40	33	17	18	12	7	0
2007	0	0	0	0	0	0	0	0	0	0	0	0	8	11	55	142	173	131	84	32	22	16	3	3	1
2008	0	0	0	0	0	0	0	0	0	0	0	0	1	11	65	112	150	156	104	36	23	11	9	9	1

Table 2.7c—Length frequencies for the September-December longline fishery by length bin.

Year	5	12	15	18	21	24	27	30	33	36	39	42	45	50	55	60	65	70	75	80	85	90	95	100	105
1978	0	0	0	0	0	0	0	0	6	22	55	174	626	1435	2050	2847	2670	1773	986	557	188	43	6	1	0
1979	0	0	0	0	0	0	0	0	0	11	120	360	875	802	887	928	1202	1241	837	355	141	39	5	0	0
1980	0	0	0	0	0	0	0	0	0	0	4	46	494	1001	580	345	299	279	233	133	28	6	0	0	0
1981	0	0	0	0	0	0	0	0	7	10	18	90	344	1213	1955	1233	563	320	171	89	37	36	9	1	0
1982	0	0	0	0	0	0	0	0	2	3	50	233	571	1444	1897	1571	930	518	265	143	70	26	8	2	0
1983	0	0	0	0	0	0	0	1	5	33	411	1597	5995	14381	16151	12362	7588	4808	2914	1727	784	324	113	29	7
1984	0	0	0	0	0	1	1	5	33	111	277	644	2940	7080	8092	5473	2209	983	545	426	304	154	68	10	2
1992	0	0	0	0	0	0	0	1	2	0	11	7	68	185	466	986	1130	541	142	43	15	1	2	2	1
2002	0	0	0	0	1	2	9	24	16	16	18	38	103	279	424	618	622	440	263	95	31	8	0	2	0
2003	0	0	0	0	0	0	0	0	0	0	3	16	47	224	378	500	468	276	182	102	59	29	12	4	1
2004	0	0	0	0	0	0	0	0	0	0	4	4	31	203	505	694	633	407	230	96	62	23	10	3	1
2005	0	0	0	0	0	0	0	0	0	2	2	8	39	153	394	719	845	563	236	139	83	65	48	12	4
2006	0	0	0	0	0	0	0	0	4	4	8	39	207	741	1529	2428	2411	1439	525	228	113	94	48	31	4
2007	1	0	0	0	0	0	0	0	0	1	3	14	216	599	831	1632	1674	1225	618	359	99	29	7	3	3

Table 2.8a—Length frequencies for the January-May pot fishery by length bin.

Year	5	12	15	18	21	24	27	30	33	36	39	42	45	50	55	60	65	70	75	80	85	90	95	100	105
1990	0	0	0	0	0	0	0	0	0	0	0	0	9	52	115	247	268	144	57	10	3	1	2	0	0
1991	0	0	0	0	0	0	0	1	2	16	44	87	799	2413	5253	11348	13970	9321	4071	1403	487	180	49	8	1
1992	0	0	0	0	0	0	0	1	10	29	58	148	700	2092	5494	9467	9042	5461	2671	1248	509	190	45	11	1
1993	0	0	0	0	0	0	0	0	0	0	13	51	319	1173	2529	4897	5815	3641	1546	566	201	78	28	7	2
1994	0	0	0	0	0	0	0	0	0	0	3	26	196	943	2218	4052	4217	2759	1228	428	160	71	28	13	0
1995	0	0	0	0	0	0	0	0	1	4	12	33	607	2329	4778	9405	12541	8610	4502	2120	1026	403	170	59	25
1996	0	0	0	0	0	0	0	2	4	6	5	23	174	954	3199	6690	9720	8399	3889	1431	489	184	67	15	5
1997	6	0	1	1	4	9	12	18	43	45	43	53	263	969	2843	6289	7541	5200	2299	750	268	151	50	19	3
1998	0	0	0	0	0	0	0	2	0	1	14	19	281	1081	2513	6362	8088	6459	4003	1699	660	257	97	24	9
1999	0	0	0	0	0	0	0	0	1	1	15	51	392	1769	4157	7042	8712	6480	2980	1313	586	216	102	42	17
2000	0	0	0	0	0	3	2	0	3	1	9	41	464	1839	3998	6894	6987	4694	2237	1055	454	203	73	25	9
2001	1	0	0	0	0	0	0	1	0	4	13	62	310	1339	3324	6205	6366	3540	1202	525	222	106	49	16	5
2002	0	0	0	0	0	0	0	0	0	0	15	39	323	1192	2507	3864	4315	3048	1245	427	159	68	24	8	1
2003	0	0	0	0	0	1	0	2	3	9	46	82	369	1203	2059	2566	2267	1750	945	442	167	63	28	14	3
2004	0	0	0	0	0	0	0	0	0	1	2	26	422	1629	3197	3869	3233	1952	1132	599	344	177	64	29	0
2005	0	0	0	0	0	0	0	0	0	1	3	10	249	1298	2984	4337	3695	2123	1010	662	340	253	113	33	13
2006	0	0	0	0	0	0	0	0	0	0	5	21	216	1156	2725	4676	4931	3368	1583	767	424	312	181	62	18
2007	0	0	0	0	0	0	0	3	2	4	8	30	229	1127	2769	4172	4653	3645	1743	811	413	305	203	81	37
2008	0	0	0	0	0	0	0	0	1	4	9	22	213	970	2150	2931	3142	2266	1227	585	255	150	89	34	19

Table 2.8b—Length frequencies for the June-August pot fishery by length bin.

Year	5	12	15	18	21	24	27	30	33	36	39	42	45	50	55	60	65	70	75	80	85	90	95	100	105
1990	0	0	0	0	0	0	0	0	0	0	0	0	6	38	169	252	253	177	84	42	7	2	0	0	0
1992	0	0	0	0	0	0	0	0	0	0	0	1	10	45	81	118	164	118	71	34	12	5	4	0	1
1996	0	0	0	0	0	0	0	0	0	0	0	0	7	24	105	130	55	36	31	20	12	8	1	2	1
1999	0	0	0	0	0	0	0	0	0	0	0	0	7	56	317	653	720	838	626	306	131	48	11	5	1
2000	0	0	0	0	0	0	0	0	0	0	0	0	1	7	76	374	316	104	17	5	0	2	0	0	0
2003	0	0	0	0	0	0	0	0	0	0	0	9	144	717	1682	2186	2040	1421	689	281	113	39	15	5	2

Table 2.8c—Length frequencies for the September-December pot fishery by length bin.

Year	5	12	15	18	21	24	27	30	33	36	39	42	45	50	55	60	65	70	75	80	85	90	95	100	105
1990	0	0	0	0	0	0	0	0	0	1	7	53	113	215	583	1122	1301	957	549	254	102	56	15	0	0
1992	0	0	0	0	0	0	0	0	0	1	7	24	91	191	489	1073	1337	898	545	222	93	35	7	0	0
1995	0	0	0	0	0	0	0	0	0	0	0	0	8	51	200	394	274	152	74	40	26	8	5	1	0
1997	0	0	0	0	0	0	0	0	0	0	0	4	18	46	90	228	440	390	206	64	29	16	5	1	0
1998	0	0	0	0	0	0	0	3	2	7	7	9	62	126	259	477	623	640	362	184	74	33	15	18	1
1999	0	0	0	1	0	0	0	1	0	1	0	8	65	188	402	824	858	648	339	166	75	48	24	6	2
2001	0	0	0	0	0	0	0	0	0	0	3	10	104	389	730	956	954	553	134	56	26	3	4	1	2
2002	0	0	0	0	0	0	0	1	0	2	2	17	133	312	580	926	982	841	479	217	106	53	16	6	1
2003	0	0	0	0	0	0	0	0	0	0	2	15	204	744	1232	1416	1093	768	392	181	78	35	7	0	1
2004	0	0	0	0	0	0	0	0	0	0	6	11	130	502	1147	1144	812	485	269	157	85	40	18	9	2
2005	0	0	0	0	0	0	0	0	0	0	0	4	67	321	1108	1794	1588	896	479	277	179	94	49	10	1
2006	0	0	0	0	0	0	0	0	0	0	6	21	190	471	749	1245	1191	750	254	111	67	39	16	7	1
2007	0	0	0	0	0	0	0	0	0	0	0	7	59	306	486	821	726	424	244	81	41	17	10	2	1

Table 2.9—Length frequencies for the trawl survey by length bin.

Year	5	12	15	18	21	24	27	30	33	36	39	42	45	50	55	60	65	70	75	80	85	90	95	100	105
1984	718	13	13	39	82	213	417	454	588	549	972	1124	2420	3577	2827	1631	772	329	299	233	96	34	11	1	1
1987	123	22	35	127	130	105	130	536	1128	1652	1823	1254	1721	3310	2947	2196	1300	597	273	96	57	14	10	3	2
1990	374	1	15	90	195	134	75	114	223	276	414	549	1645	1812	1928	1632	934	559	207	137	70	35	13	7	1
1993	46	20	307	372	233	284	191	261	445	513	800	1275	1998	2538	3079	2105	1476	694	294	109	59	22	17	10	1
1996	4	36	239	883	1177	891	240	91	193	314	459	458	732	1037	1378	1656	1388	604	225	86	40	30	15	12	2
1999	1	16	67	151	164	96	74	140	308	349	398	576	1085	1129	1432	1194	783	411	166	58	27	7	9	4	0
2001	6	57	105	192	233	320	229	187	183	310	455	437	749	753	726	764	534	302	133	52	19	15	5	5	0
2003	1	5	28	76	137	87	66	64	160	296	495	753	1280	1319	1624	1308	698	372	190	113	36	15	3	0	0
2005	10	10	106	182	195	113	69	101	188	242	203	216	422	847	1524	1257	485	214	103	72	45	88	98	45	7
2007	2	42	689	1169	549	283	248	207	248	437	643	751	897	592	735	710	464	249	116	33	12	7	6	6	4

Table 2.10—Age composition estimates from the bottom trawl surveys (N = number of otoliths read).

Year	1	2	3	4	5	6	7	8	9	10	11	12+	N
1987	0.0179	0.2024	0.3510	0.2807	0.1298	0.0183	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	140
1990	0.0305	0.0644	0.2366	0.2501	0.2010	0.1309	0.0490	0.0254	0.0096	0.0019	0.0004	0.0001	499
1993	0.0743	0.0753	0.1963	0.2535	0.2102	0.1289	0.0373	0.0196	0.0034	0.0010	0.0001	0.0000	869
1996	0.2429	0.0670	0.1229	0.1354	0.1626	0.1592	0.0887	0.0154	0.0052	0.0005	0.0001	0.0001	776
1999	0.0336	0.0410	0.1557	0.2405	0.2807	0.1592	0.0554	0.0233	0.0080	0.0019	0.0007	0.0000	688
2001	0.1357	0.1091	0.2173	0.1945	0.1458	0.1137	0.0547	0.0203	0.0057	0.0023	0.0001	0.0009	767
2003	0.0335	0.0343	0.1810	0.2677	0.2736	0.1327	0.0487	0.0226	0.0033	0.0009	0.0009	0.0009	737
2005	0.0731	0.0779	0.1121	0.1642	0.2799	0.2038	0.0549	0.0236	0.0049	0.0023	0.0006	0.0027	545

Table 2.11—Pacific cod abundance measured in biomass (t) and numbers of fish, as assessed by the GOA bottom trawl survey. Point estimates are shown along with standard errors and coefficients of variation.

	Biomass (t)			Numbers (fish)		
Year	Estimate	Std. Error	CV	Estimate	Std. Error	CV
1984	550,971	80,385	0.146	320,524,532	49,995,678	0.156
1987	394,987	51,325	0.130	247,020,039	45,739,552	0.185
1990	416,788	63,706	0.153	212,131,668	44,057,687	0.208
1993	409,848	73,431	0.179	231,963,103	44,009,342	0.190
1996	538,154	107,736	0.200	319,068,011	68,610,947	0.215
1999	306,413	38,699	0.126	166,583,892	18,663,808	0.112
2001	257,614	52,457	0.204	158,424,464	28,482,592	0.180
2003	297,402	44,549	0.150	159,749,380	20,632,759	0.129
2005	308,091	80,862	0.262	139,852,429	29,065,580	0.208
2007	233,310	32,349	0.139	192,025,235	33,601,358	0.175

Table 2.12—Input sample sizes associated with size composition data. Sea. 1 = January-May, Sea. 2 = June-August, Sea. 3 = September-December. Trawl survey is divided into fish 27 cm and larger ("27-plus") and fish smaller than 27 cm ("Sub-27").

	Trawl fishery			Longline fishery			Pot fishery			Trawl survey	
Year	Sea. 1	Sea. 2	Sea. 3	Sea. 1	Sea. 2	Sea. 3	Sea. 1	Sea. 2	Sea. 3	27-plus	Sub-27
1977			9								
1978			17		108	284					
1979				111	30	165					
1980		15		247	78	73					
1981				168	109	129					
1982		12	18	267	53	164					
1983		29	33	998	249	1465					
1984	97	158	66	1327	86	621				735	49
1985	43	96	76	1059							
1986	10			1899							
1987			13							857	24
1988	78	45									
1989	14										
1990	539	232	253	190			19	22	113	478	36
1991	815			266			1046				
1992	840		48	610	12	76	787	14	106		
1993	568			249			442			714	57
1994	266			110			346				
1995	551		51	521			987		26		
1996	378			311			746	9		403	145
1997	483		79	153			569		33		
1998	1110	73	143	169	9		668		61		
1999	519		49	405			1523	167	164	367	22
2000	313	19		514			1304	41			
2001	275	30	205	568			1047		177	263	41
2002	283	36		431		135	775		210		
2003	186	53	79	357		103	540	420	277	395	15
2004	117	21	114	299		131	750		217		
2005	79	26	79	269	20	149	770		309	280	28
2006	99			344		443	919		230		
2007	157	32	48	299	31	329	910		145	286	123
2008	109	46		402	31		633				

Table 2.13a— Comparison of negative log likelihoods across models. In the “abundance” component, only the trawl survey values count toward the total. Green = row minimum, pink = row maximum. Note that it is sometimes difficult to compare likelihoods between models. Note that Models A and B weight the age composition data differently.

Model:	A	B
Number of parameters:	235	224
Abundance:	25.05	43.65
Size composition:	1092.94	1070.63
Age composition:	52.03	22.84
Size at age:	84.59	84.80
Recruitment:	27.68	27.87
Forecast recruitment:	0.31	0.38
Priors:	2.31	1.57
Softbounds:	0.05	0.05
Total:	1284.95	1281.14
Abundance by fleet		
Jan-May trawl fishery:	388.69	194.97
Jun-Aug trawl fishery:	109.74	124.93
Sep-Dec trawl fishery:	103.15	145.40
Jan-May longline fishery:	74.38	17.18
Jun-Aug longline fishery:	21.98	13.28
Sep-Dec longline fishery:	11.72	8.30
Jan-May pot fishery:	108.97	41.05
Jun-Aug pot fishery:	0.96	0.42
Sep-Dec pot fishery:	29.63	19.33
27-plus trawl survey:	18.53	38.22
Sub-27 trawl survey:	6.52	5.42
Size composition by fleet		
Jan-May trawl fishery:	233.02	230.07
Jun-Aug trawl fishery:	84.20	78.97
Sep-Dec trawl fishery:	125.42	114.27
Jan-May longline fishery:	240.53	244.50
Jun-Aug longline fishery:	31.71	27.06
Sep-Dec longline fishery:	82.79	88.41
Jan-May pot fishery:	129.29	130.62
Jun-Aug pot fishery:	13.21	13.02
Sep-Dec pot fishery:	44.71	39.37
27-plus trawl survey:	29.09	25.48
Sub-27 trawl survey:	78.96	78.84

Table 2.13b—Root mean squared errors for fishery CPUE and survey relative abundance time series. Green = row minimum, pink = row maximum.

Average RMSE

Fleet	A	B
Jan-May trawl fishery	0.533	0.303
Jun-Aug trawl fishery	0.976	1.091
Sep-Dec trawl fishery	0.735	0.928
Jan-May longline fishery	0.271	0.153
Jun-Aug longline fishery	0.881	0.795
Sep-Dec longline fishery	0.326	0.261
Jan-May pot fishery	0.287	0.201
Jun-Aug pot fishery	0.204	0.048
Sep-Dec pot fishery	0.339	0.243
27-plus trawl survey	0.357	0.494
Sub-27 trawl survey	0.584	0.571

Table 2.13c—Correlations between observed data and model estimates for fishery CPUE and survey relative abundance time series. Green = row minimum, pink = row maximum.

Correlation

Fleet	A	B
Jan-May trawl fishery	-0.482	0.500
Jun-Aug trawl fishery	0.444	-0.115
Sep-Dec trawl fishery	0.162	-0.415
Jan-May longline fishery	-0.511	0.621
Jun-Aug longline fishery	-0.355	-0.248
Sep-Dec longline fishery	-0.459	0.112
Jan-May pot fishery	-0.168	-0.443
Jun-Aug pot fishery	0.978	0.995
Sep-Dec pot fishery	-0.136	0.330
27-plus trawl survey	0.578	0.186
Sub-27 trawl survey	0.636	0.697

Table 2.13d—Average ratio of effective multinomial sample size to input sample size for each fishery and survey size composition time series. Note that trawl survey size composition records from years with age data are turned off. Green = row minimum, pink = row maximum.

Mean(effN/inputN)

Fleet	A	B
Jan-May trawl fishery	1.106	1.190
Jun-Aug trawl fishery	2.346	2.507
Sep-Dec trawl fishery	1.890	1.843
Jan-May longline fishery	2.038	1.949
Jun-Aug longline fishery	4.665	4.149
Sep-Dec longline fishery	2.208	2.126
Jan-May pot fishery	1.728	1.747
Jun-Aug pot fishery	3.839	4.409
Sep-Dec pot fishery	2.221	2.916
27-plus trawl survey	0.439	0.466
Sub-27 trawl survey	0.966	0.989

Table 2.13e— Ratio of average effective multinomial sample size to average input sample size for each fishery and survey size composition time series. Note that trawl survey size composition records from years with age data are turned off. Green = row minimum, pink = row maximum.

MeaneffN/MeaninputN

Fleet	A	B
Jan-May trawl fishery	0.790	0.811
Jun-Aug trawl fishery	2.016	2.304
Sep-Dec trawl fishery	1.279	1.230
Jan-May longline fishery	1.346	1.394
Jun-Aug longline fishery	2.352	2.451
Sep-Dec longline fishery	1.697	1.543
Jan-May pot fishery	1.454	1.412
Jun-Aug pot fishery	3.258	3.725
Sep-Dec pot fishery	2.285	3.113
27-plus trawl survey	0.396	0.384
Sub-27 trawl survey	0.571	0.581

Table 2.14a—Key parameters as specified/estimated by the eight models. "Value" = point estimate, "SD" = standard deviation. Green = row minimum, pink = row maximum. If a parameter is specified rather than estimated, "n/a" appears under "SD."

	Model A		Model B	
Parameter	Value	SD	Value	SD
Length at age 20	109.95	1.52	107.75	1.21
Brody growth coefficient (K)	0.12	0.00	0.12	0.00
CV of length at age 20 (log offset)	-21.75	8252.61	-25.61	71232.30
Mean log recruitment (post-1976)	12.60	0.05	12.48	0.05
Mean log recruitment offset (pre-1977)	-1.67	0.16	-1.64	0.14
Equilibrium fishing mortality in 1977	0.06	0.01	0.07	0.01
Pre-96 log Q (27-plus) offset	1.35	0.16	0.00	n/a
1984 log Q (sub-27)	-1.64	0.35	-1.45	0.35
1987 log Q (sub-27) offset	-0.10	0.19	-0.11	0.19
1990 log Q (sub-27) offset	-0.07	0.19	-0.08	0.19
1993 log Q (sub-27) offset	-0.03	0.19	-0.03	0.19
1996 log Q (sub-27) offset	-0.02	0.18	0.01	0.18
1999 log Q (sub-27) offset	-0.28	0.18	-0.21	0.18
2001 log Q (sub-27) offset	-0.19	0.18	-0.15	0.18
2003 log Q (sub-27) offset	-0.19	0.18	-0.16	0.18
2005 log Q (sub-27) offset	-0.12	0.19	-0.09	0.19
2007 log Q (sub-27) offset	-0.08	0.19	-0.09	0.19

Table 2.14b—Estimates and standard deviations of annual recruitment deviations given by the eight models. “Value” = point estimate, “SD” = standard deviation. Green = row minimum, pink = row maximum. Note that deviations are relative to their regime-specific (pre-1977, post-1976) means. Note also that Model A estimates six more age groups in the inital year (1977) than does Model B.

	Model A		Model B	
Year	Value	SD	Value	SD
1968	-0.75	0.55		
1969	-0.76	0.55		
1970	-0.66	0.58		
1971	-0.34	0.64		
1972	0.62	0.60		
1973	1.28	0.33		
1974	-0.07	0.64	1.30	0.20
1975	0.03	0.48	-1.78	0.43
1976	0.65	0.33	0.47	0.37
1977	0.85	0.10	1.09	0.09
1978	-2.14	0.44	-1.76	0.46
1979	-0.65	0.16	-0.47	0.18
1980	0.03	0.11	0.43	0.10
1981	-0.51	0.18	-0.39	0.19
1982	0.32	0.11	0.60	0.10
1983	-2.28	0.37	-2.56	0.38
1984	0.65	0.12	0.65	0.13
1985	-0.15	0.20	0.30	0.18
1986	-0.66	0.20	-0.91	0.31
1987	0.25	0.10	0.41	0.10
1988	-0.18	0.14	-0.07	0.16
1989	-0.06	0.13	0.15	0.14
1990	0.43	0.10	0.50	0.11
1991	-0.09	0.14	-0.04	0.17
1992	-0.10	0.12	0.07	0.15
1993	0.08	0.10	0.18	0.13
1994	0.13	0.11	0.01	0.14
1995	0.35	0.08	0.50	0.09
1996	-0.10	0.10	-0.19	0.14
1997	-0.25	0.11	-0.14	0.13
1998	-0.15	0.10	-0.47	0.15
1999	0.31	0.09	0.26	0.10
2000	0.50	0.10	0.32	0.10
2001	-0.20	0.16	-0.45	0.21
2002	0.01	0.17	-0.17	0.16
2003	0.21	0.19	-0.18	0.21
2004	0.60	0.20	0.01	0.17
2005	0.65	0.33	0.36	0.32
2006	2.17	0.33	1.95	0.32
2007	-0.63	0.64	-0.70	0.63

Table 2.15a—Legend for Table 2.15b (selectivity parameter estimates).

Fleet	Definition
1	Jan-May trawl fishery
2	Jun-Aug trawl fishery
3	Sep-Dec trawl fishery
4	Jan-May longline fishery
5	Jun-Aug longline fishery
6	Sep-Dec longline fishery
7	Jan-May pot fishery
8	Jun-Aug pot fishery
9	Sep-Dec pot fishery
10	27-plus trawl survey
11	Sub-27 trawl survey

Parm.	Definition	Units
1	First size (age) at which selectivity=1	cm (years)
2	Last size (age) at which selectivity=1	logit transform over the range Parm. 1 to max. length (age)
3	Scale of ascending limb	ln(normal variance) + ln(2)
4	Scale of descending limb	ln(normal variance) + ln(2)
5	Selectivity at minimium size (age)	logit transform over the range 0 to 1
6	Selectivity at maximum size (age)	logit transform over the range 0 to 1

Block: Beginning year of block to which parameter applies ("n/a" means parameter applies to all years)

Axis: Describes whether selectivity is measured as a function of size or age

Value: Point estimate

SD: Standard deviation

Table 2.15b—Selectivity parameters as estimated by Models A and B (page 1 of 4).

Model A						Model B					
Fleet	Parm	Block	Axis	Value	SD	Fleet	Parm	Block	Axis	Value	SD
1	1	1977	Size	63.31	3.06	1	1	1977	Size	68.28	1.24
1	1	1990	Size	76.01	0.99	1	1	1990	Size	74.98	0.67
1	1	1995	Size	78.87	0.97	1	1	1995	Size	77.22	0.68
1	1	2000	Size	71.02	1.26	1	1	2000	Size	71.92	0.78
1	1	2005	Size	72.70	1.91	1	1	2005	Size	71.79	1.06
1	3	1977	Size	5.37	0.26	1	3	n/a	Size	5.81	0.03
1	3	1990	Size	5.83	0.05	2	1	1977	Size	56.02	1.81
1	3	1995	Size	5.88	0.05	2	1	1985	Size	62.85	1.70
1	3	2000	Size	5.72	0.08	2	1	1990	Size	67.54	1.34
1	3	2005	Size	5.88	0.11	2	1	2000	Size	70.30	2.50
2	1	1977	Size	59.99	1.82	2	1	2005	Size	73.47	3.10
2	1	1990	Size	67.31	1.47	2	2	n/a	Size	-9.48	13.44
2	1	2000	Size	74.47	0.37	2	3	1977	Size	4.50	0.26
2	2	1977	Size	-7.82	40.26	2	3	1985	Size	5.00	0.22
2	2	1990	Size	-9.19	19.16	2	3	1990	Size	5.08	0.15
2	2	2000	Size	-8.29	33.74	2	3	2000	Size	5.73	0.18
2	3	1977	Size	4.88	0.20	2	3	2005	Size	5.97	0.18
2	3	1990	Size	5.04	0.16	2	4	n/a	Size	3.79	0.70
2	3	2000	Size	5.99	0.07	2	6	1977	Size	8.83	25.45
2	4	1977	Size	7.77	3.90	2	6	1985	Size	-0.45	0.56
2	4	1990	Size	4.15	0.83	2	6	1990	Size	-1.70	0.63
2	4	2000	Size	-8.38	35.88	2	6	2000	Size	-0.51	1.01
2	6	1977	Size	-2.13	5.70	2	6	2005	Size	-1.41	1.57
2	6	1990	Size	-1.78	0.84	3	1	1977	Size	46.32	4.65
2	6	2000	Size	-0.59	0.54	3	1	1980	Size	56.64	3.06
3	1	1977	Size	46.97	4.58	3	1	1985	Size	65.39	4.30
3	1	1980	Size	63.46	3.60	3	1	1990	Size	65.27	3.30
3	1	1990	Size	74.80	2.37	3	1	1995	Size	79.47	0.25
3	1	2000	Size	73.64	1.82	3	1	2000	Size	71.94	2.39
3	2	1977	Size	0.30	0.91	3	1	2005	Size	80.15	4.31
3	2	1980	Size	-4.13	45.30	3	2	1977	Size	0.33	0.14
3	2	1990	Size	-1.45	1.77	3	2	1980	Size	2.58	25.44
3	2	2000	Size	-8.90	24.31	3	2	1985	Size	-2.15	1.09
3	3	1977	Size	3.96	0.83	3	2	1990	Size	0.55	0.14
3	3	1980	Size	5.53	0.25	3	2	1995	Size	-8.45	31.42
3	3	1990	Size	6.09	0.12	3	2	2000	Size	-1.16	0.32
3	3	2000	Size	5.88	0.11	3	2	2005	Size	-1.49	1.01
3	4	1977	Size	3.20	6.50	3	3	1977	Size	3.89	0.84
3	4	1980	Size	-1.57	139.84	3	3	1980	Size	4.95	0.35
3	4	1990	Size	3.86	2.98	3	3	1985	Size	5.79	0.29
3	4	2000	Size	4.32	1.03	3	3	1990	Size	5.50	0.26
3	6	1977	Size	-2.53	6.34	3	3	1995	Size	6.32	0.06
3	6	1980	Size	-0.08	0.53	3	3	2000	Size	5.85	0.14
3	6	1990	Size	-0.81	1.15	3	3	2005	Size	6.06	0.20
3	6	2000	Size	-1.66	1.35	3	4	n/a	Size	-8.76	29.02
4	1	1977	Size	71.34	1.75	3	6	n/a	Size	-0.95	0.37

Table 2.15b—Selectivity parameters as estimated by Models A and B (page 2 of 4).

Model A						Model B					
Fleet	Parm	Block	Axis	Value	SD	Fleet	Parm	Block	Axis	Value	Stdev
4	1	1985	Size	81.33	1.69	4	1	1977	Size	72.59	1.18
4	1	1990	Size	72.27	1.03	4	1	1985	Size	82.05	1.50
4	1	1995	Size	76.03	1.14	4	1	1990	Size	71.36	1.03
4	1	2000	Size	70.09	0.70	4	1	1995	Size	75.09	0.98
4	1	2005	Size	69.32	0.92	4	1	2000	Size	70.35	0.67
4	2	1977	Size	-0.71	0.49	4	1	2005	Size	68.87	0.76
4	2	1985	Size	-7.84	40.04	4	2	1977	Size	-0.44	0.28
4	2	1990	Size	0.76	16.48	4	2	1985	Size	0.01	0.73
4	2	1995	Size	-2.32	42.06	4	2	1990	Size	-0.50	0.59
4	2	2000	Size	-9.18	19.41	4	2	1995	Size	-8.47	31.17
4	2	2005	Size	-1.94	24.01	4	2	2000	Size	-8.68	27.95
4	3	1977	Size	5.58	0.09	4	2	2005	Size	-9.34	16.26
4	3	1985	Size	5.98	0.07	4	3	1977	Size	5.64	0.07
4	3	1990	Size	5.36	0.08	4	3	1985	Size	6.05	0.07
4	3	1995	Size	5.45	0.08	4	3	1990	Size	5.32	0.08
4	3	2000	Size	5.07	0.06	4	3	1995	Size	5.41	0.07
4	3	2005	Size	4.95	0.09	4	3	2000	Size	5.10	0.06
4	4	1977	Size	5.04	0.74	4	3	2005	Size	4.92	0.08
4	4	1990	Size	0.06	228.99	4	4	n/a	Size	4.18	0.47
4	4	1995	Size	-0.56	183.57	4	6	1977	Size	-2.47	1.26
4	4	2000	Size	4.59	0.59	4	6	1985	Size	-0.96	1.02
4	4	2005	Size	-0.23	205.12	4	6	1990	Size	0.50	0.78
4	6	1977	Size	-4.03	2.45	4	6	1995	Size	1.14	0.69
4	6	1985	Size	-1.44	0.86	4	6	2000	Size	-0.09	0.35
4	6	1990	Size	0.72	1.12	4	6	2005	Size	0.47	0.37
4	6	1995	Size	1.90	1.03	5	1	1977	Size	64.31	3.02
4	6	2000	Size	-0.30	0.43	5	1	1980	Size	58.55	1.00
4	6	2005	Size	0.28	0.28	5	1	1990	Size	70.55	4.76
5	1	1977	Size	58.37	1.02	5	1	2000	Size	70.61	3.02
5	1	1990	Size	72.21	3.13	5	2	n/a	Size	-8.73	27.14
5	2	1977	Size	-8.62	28.88	5	3	1977	Size	5.11	0.28
5	2	1990	Size	-2.74	22.54	5	3	1980	Size	4.34	0.16
5	3	1977	Size	4.38	0.15	5	3	1990	Size	5.11	0.49
5	3	1990	Size	4.89	0.31	5	3	2000	Size	4.60	0.38
5	4	1977	Size	7.62	1.17	5	4	n/a	Size	5.58	0.57
5	4	1990	Size	-0.33	203.02	5	6	1977	Size	-8.47	31.17
5	6	1977	Size	-4.02	4.76	5	6	1980	Size	0.41	0.73
5	6	1990	Size	0.86	1.19	5	6	1990	Size	-3.30	10.43
6	1	1977	Size	64.52	3.02	5	6	2000	Size	6.98	50.83
6	1	1980	Size	58.34	0.53	6	1	1977	Size	67.76	1.91
6	1	1990	Size	69.70	0.90	6	1	1980	Size	58.60	0.58
6	2	1977	Size	-0.60	0.60	6	1	1990	Size	70.04	0.89
6	2	1980	Size	-9.42	14.61	6	2	n/a	Size	-1.90	0.27
6	2	1990	Size	-8.72	27.29	6	3	1977	Size	5.22	0.15
6	3	1977	Size	4.99	0.26	6	3	1980	Size	4.41	0.08
6	3	1980	Size	4.37	0.08	6	3	1990	Size	5.02	0.08

Table 2.15b—Selectivity parameters as estimated by Models A and B (page 3 of 4).

Model A						Model B					
Fleet	Parm	Block	Axis	Value	SD	Fleet	Parm	Block	Axis	Value	Stdev
6	3	1990	Size	4.98	0.09	6	4	1977	Size	4.94	0.38
6	4	1977	Size	4.37	1.00	6	4	1980	Size	-6.54	67.83
6	4	1980	Size	3.67	0.37	6	4	1990	Size	-4.69	27.55
6	4	1990	Size	3.19	0.68	6	6	1977	Size	-7.35	29.48
6	6	1977	Size	-6.09	12.21	6	6	1980	Size	0.05	0.18
6	6	1980	Size	-0.13	0.22	6	6	1990	Size	-0.15	0.24
6	6	1990	Size	-0.32	0.24	7	1	1977	Size	69.07	0.45
7	1	1977	Size	69.40	0.47	7	1	1995	Size	72.04	0.40
7	1	1995	Size	73.43	0.59	7	1	2000	Size	68.89	0.49
7	1	2000	Size	68.83	0.47	7	1	2005	Size	68.24	0.54
7	1	2005	Size	67.88	0.55	7	2	n/a	Size	-14.07	79.72
7	2	1977	Size	-9.76	6.87	7	3	1977	Size	4.74	0.05
7	2	1995	Size	-3.78	45.45	7	3	1995	Size	4.88	0.04
7	2	2000	Size	-9.47	13.67	7	3	2000	Size	4.86	0.05
7	2	2005	Size	-1.66	21.01	7	3	2005	Size	4.73	0.06
7	3	1977	Size	4.75	0.05	7	4	1977	Size	4.39	0.23
7	3	1995	Size	4.98	0.05	7	4	1995	Size	3.85	0.38
7	3	2000	Size	4.85	0.05	7	4	2000	Size	3.94	0.41
7	3	2005	Size	4.69	0.06	7	4	2005	Size	3.44	0.56
7	4	1977	Size	4.35	0.27	7	6	1977	Size	-2.05	0.32
7	4	1995	Size	-1.29	153.13	7	6	1995	Size	-0.44	0.24
7	4	2000	Size	3.97	0.40	7	6	2000	Size	-0.27	0.23
7	4	2005	Size	-0.17	209.59	7	6	2005	Size	0.75	0.28
7	6	1977	Size	-1.84	0.33	8	1	1977	Size	68.36	3.14
7	6	1995	Size	0.00	0.15	8	1	1995	Size	77.80	1.92
7	6	2000	Size	-0.29	0.22	8	1	2000	Size	67.55	0.98
7	6	2005	Size	0.48	0.22	8	2	n/a	Size	-8.61	28.95
8	1	1977	Size	67.74	4.30	8	3	1977	Size	4.67	0.46
8	1	1995	Size	77.66	2.29	8	3	1995	Size	5.11	0.18
8	1	2000	Size	67.63	1.04	8	3	2000	Size	4.55	0.13
8	2	1977	Size	-0.80	10.57	8	4	n/a	Size	4.76	0.54
8	2	1995	Size	-6.26	59.09	8	6	n/a	Size	-1.42	0.72
8	2	2000	Size	-8.41	32.06	9	1	1977	Size	71.57	1.45
8	3	1977	Size	4.59	0.57	9	1	1995	Size	73.39	1.63
8	3	1995	Size	5.09	0.20	9	1	2000	Size	67.06	0.92
8	3	2000	Size	4.56	0.14	9	1	2005	Size	66.40	0.91
8	4	1977	Size	-0.04	221.84	9	2	n/a	Size	-8.98	22.92
8	4	1995	Size	4.97	2.41	9	3	1977	Size	5.01	0.16
8	4	2000	Size	4.69	0.61	9	3	1995	Size	5.09	0.16
8	6	1977	Size	-1.40	1.57	9	3	2000	Size	4.81	0.11
8	6	1995	Size	-0.67	2.75	9	3	2005	Size	4.64	0.12
8	6	2000	Size	-1.44	0.76	9	4	n/a	Size	4.34	0.54
9	1	1977	Size	72.88	1.26	9	6	1977	Size	-1.49	0.85
9	1	2000	Size	66.72	0.71	9	6	1995	Size	0.50	0.97
9	2	1977	Size	-8.65	28.38	9	6	2000	Size	-0.16	0.43
9	2	2000	Size	-8.44	31.61	9	6	2005	Size	0.04	0.40

Table 2.15b—Selectivity parameters as estimated by Models A and B (page 4 of 4).

Model A						Model B					
Fleet	Parm	Block	Axis	Value	SD	Fleet	Parm	Block	Axis	Value	Stdev
9	3	1977	Size	5.07	0.12	10	1	1977	Age	4.03	0.13
9	3	2000	Size	4.72	0.08	10	1	1996	Age	2.37	3.26
9	4	1977	Size	4.08	1.22	10	2	1977	Age	-2.66	0.25
9	4	2000	Size	4.35	0.57	10	2	1996	Age	-0.03	0.60
9	6	1977	Size	-0.29	0.67	10	3	1977	Age	0.24	0.16
9	6	2000	Size	-0.19	0.32	10	3	1987	Age	6.96	51.06
10	1	1977	Age	4.67	0.31	10	3	1990	Age	1.52	0.58
10	1	1996	Age	4.45	0.20	10	3	1993	Age	1.36	0.49
10	2	1977	Age	-6.13	61.90	10	3	1996	Age	-1.78	17.80
10	2	1996	Age	-0.49	0.58	10	3	1999	Age	-1.91	17.87
10	3	1977	Age	0.65	0.27	10	3	2001	Age	-2.19	17.90
10	3	1987	Age	0.59	0.43	10	3	2003	Age	-1.92	17.85
10	3	1990	Age	0.60	0.37	10	3	2005	Age	-1.94	17.85
10	3	1993	Age	0.31	0.34	10	3	2007	Age	-3.43	20.10
10	3	1996	Age	0.86	0.19	10	4	1977	Age	-2.39	43.56
10	3	1999	Age	0.95	0.22	10	4	1996	Age	-3.77	31.66
10	3	2001	Age	1.04	0.18	10	5	1977	Age	-9.43	13.33
10	3	2003	Age	0.71	0.20	10	5	1987	Age	-3.22	4.50
10	3	2005	Age	0.84	0.18	10	5	1990	Age	-8.29	33.72
10	3	2007	Age	0.72	0.17	10	5	1993	Age	-8.06	36.97
10	4	1977	Age	-2.10	13.11	10	5	1996	Age	-7.48	1.07
10	4	1996	Age	-2.41	41.32	10	5	1999	Age	-8.40	0.69
10	5	1977	Age	-9.17	11.31	10	5	2001	Age	-7.77	0.65
10	5	1987	Age	-3.43	0.63	10	5	2003	Age	-8.49	0.78
10	5	1990	Age	-5.16	0.91	10	5	2005	Age	-8.31	0.83
10	5	1993	Age	-4.34	0.40	10	5	2007	Age	-6.17	1.20
10	5	1996	Age	-6.82	0.78	10	6	1977	Age	-0.51	0.37
10	5	1999	Age	-7.64	0.87	10	6	1996	Age	-8.92	23.95
10	5	2001	Age	-8.37	2.97	11	1	n/a	Age	-2.69	0.24
10	5	2005	Age	-6.93	0.94	11	3	n/a	Age	-3.00	0.56
10	6	1977	Age	-1.17	0.35						
10	6	1996	Age	-8.98	23.06						
11	1	n/a	Age	-2.60	0.22						
11	3	n/a	Age	-2.57	0.54						

Table 2.16—Summary of key management reference points from the standard projection algorithm. Green = row minimum, pink = row maximum. All biomass figures are in t.

Quantity	Model A	Model B
B100%	296,600	255,500
B40%	118,600	102,200
B35%	103,800	89,400
B2009	174,600	88,000
B2010	238,000	141,000
B2009/B100%	0.59	0.34
B2010/B100%	0.80	0.55
F40%	0.54	0.52
F35%	0.68	0.64
maxFABC2009	0.54	0.44
maxFABC2010	0.54	0.52
maxABC2009	123,800	55,300
maxABC2010	169,900	103,700
FOFL2009	0.68	0.54
OFL2009	149,500	66,600
OFL2010	206,000	126,000
Pr(B<B20%)	0	0

Legend

B100% = equilibrium unfished spawning biomass
B40% = 40% of B100% (the inflection point of the harvest control rules in Tier 3)
B35% = 35% of B100% (the BMSY proxy for Tier 3)
B2009 = projected spawning biomass for 2009
B2010 = projected spawning biomass for 2009 (assuming 2009 catch = maximum permissible ABC)
B2009/B100% = ratio of 2009 spawning biomass to B100%
B2010/B100% = ratio of 2010 spawning biomass to B100%
F40% = fishing mortality rate that reduces equilibrium spawning per recruit to 40% of unfished level
F35% = fishing mortality rate that reduces equilibrium spawning per recruit to 35% of unfished level
maxFABC2009 = maximum permissible ABC fishing mortality rate for 2009 under Tier 3
maxFABC2010 = maximum permissible ABC fishing mortality rate for 2010 under Tier 3
maxABC2009 = maximum permissible ABC for 2009 under Tier 3
maxABC2010 = maximum permissible ABC for 2010 under Tier 3
FOFL2009 = OFL fishing mortality rate for 2009 under Tier 3
OFL2009 = OFL for 2009 under Tier 3
OFL2010 = OFL for 2010 under Tier 3 assuming 2009 catch = maxABC2009
Pr(B<B20%) = probability that spawning biomass will fall below 20% of B100% by 2013.

Table 2.17—Estimates of Pacific cod fishing mortality rates, expressed on an annual time scale (Model B). Rates are expressed on an annual time scale, relative to F40%.

	Trawl fishery			Longline fishery			Pot fishery		
Year	Sea. 1	Sea. 2	Sea. 3	Sea. 1	Sea. 2	Sea. 3	Sea. 1	Sea. 2	Sea. 3
1977	0.173	0.073	0.084	0.045	0.004	0.070	0.000	0.000	0.000
1978	0.222	0.095	0.108	0.050	0.005	0.084	0.000	0.000	0.000
1979	0.179	0.062	0.078	0.045	0.004	0.072	0.000	0.000	0.000
1980	0.184	0.044	0.088	0.029	0.003	0.043	0.000	0.000	0.000
1981	0.098	0.065	0.157	0.010	0.004	0.026	0.000	0.000	0.000
1982	0.107	0.074	0.094	0.002	0.002	0.012	0.000	0.000	0.000
1983	0.177	0.099	0.118	0.014	0.003	0.013	0.000	0.000	0.000
1984	0.210	0.106	0.131	0.025	0.010	0.101	0.000	0.000	0.000
1985	0.266	0.151	0.137	0.082	0.009	0.130	0.000	0.000	0.000
1986	0.298	0.144	0.144	0.059	0.002	0.107	0.000	0.000	0.000
1987	0.328	0.086	0.142	0.143	0.004	0.168	0.000	0.000	0.000
1988	0.658	0.146	0.326	0.004	0.004	0.010	0.000	0.000	0.000
1989	0.699	0.104	0.146	0.027	0.031	0.036	0.000	0.000	0.000
1990	0.573	0.076	0.066	0.102	0.116	0.124	0.000	0.007	0.003
1991	0.721	0.126	0.042	0.244	0.184	0.268	0.000	0.009	0.020
1992	0.454	0.106	0.043	0.590	0.245	0.065	0.034	0.045	0.003
1993	0.502	0.046	0.063	0.571	0.000	0.000	0.028	0.000	0.000
1994	0.426	0.047	0.117	0.582	0.002	0.184	0.056	0.000	0.028
1995	0.705	0.068	0.230	0.668	0.002	0.247	0.122	0.034	0.030
1996	0.603	0.024	0.200	0.588	0.001	0.220	0.174	0.060	0.030
1997	0.630	0.032	0.167	0.670	0.001	0.394	0.137	0.034	0.030
1998	0.375	0.048	0.197	0.573	0.001	0.269	0.093	0.028	0.013
1999	0.374	0.027	0.070	0.601	0.018	0.212	0.100	0.010	0.019
2000	0.373	0.035	0.046	0.394	0.010	0.334	0.176	0.000	0.000
2001	0.179	0.051	0.053	0.355	0.049	0.369	0.117	0.004	0.029
2002	0.280	0.069	0.041	0.469	0.087	0.310	0.109	0.003	0.026
2003	0.255	0.070	0.027	0.484	0.076	0.339	0.154	0.000	0.043
2004	0.311	0.090	0.029	0.515	0.075	0.365	0.123	0.004	0.030
2005	0.324	0.049	0.009	0.556	0.105	0.355	0.114	0.000	0.038
2006	0.374	0.052	0.012	0.629	0.138	0.262	0.155	0.000	0.042
2007	0.331	0.080	0.020	0.653	0.135	0.202	0.156	0.000	0.051
2008	0.255	0.060	n/a	0.782	0.153	n/a	0.163	0.000	n/a

Table 2.18a—Schedules of Pacific cod selectivities at length in the commercial fisheries as defined by final parameter estimates under Model B (page 1 of 4). Lengths (cm) correspond to mid-points of size bins. Years correspond to beginnings of blocks.

	January-May trawl fishery					June-August trawl fishery				
Len.	1977	1990	1995	2000	2005	1977	1985	1990	2000	2005
8.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
13.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
16.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
19.5	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001
22.5	0.002	0.000	0.000	0.001	0.001	0.000	0.000	0.000	0.001	0.001
25.5	0.004	0.001	0.000	0.002	0.002	0.000	0.000	0.000	0.002	0.003
28.5	0.009	0.002	0.001	0.004	0.004	0.000	0.000	0.000	0.004	0.006
31.5	0.017	0.003	0.002	0.007	0.008	0.001	0.001	0.000	0.008	0.011
34.5	0.033	0.007	0.004	0.015	0.016	0.006	0.005	0.001	0.016	0.021
37.5	0.059	0.015	0.009	0.029	0.030	0.022	0.013	0.004	0.031	0.037
40.5	0.099	0.028	0.018	0.052	0.053	0.070	0.035	0.011	0.057	0.063
43.5	0.159	0.051	0.033	0.089	0.091	0.176	0.081	0.028	0.098	0.101
47.5	0.275	0.104	0.071	0.168	0.171	0.448	0.205	0.083	0.186	0.179
52.5	0.475	0.220	0.160	0.323	0.328	0.872	0.487	0.246	0.359	0.326
57.5	0.706	0.400	0.312	0.536	0.543	1.000	0.825	0.535	0.589	0.522
62.5	0.905	0.627	0.523	0.766	0.772	1.000	0.999	0.854	0.821	0.736
67.5	0.998	0.846	0.754	0.943	0.946	1.000	0.964	1.000	0.975	0.913
72.5	1.000	0.982	0.935	1.000	1.000	1.000	0.613	0.930	1.000	0.998
77.5	1.000	1.000	1.000	1.000	1.000	1.000	0.417	0.436	0.795	0.981
82.5	1.000	1.000	1.000	1.000	1.000	1.000	0.389	0.187	0.468	0.548
87.5	1.000	1.000	1.000	1.000	1.000	1.000	0.388	0.155	0.383	0.247
92.5	1.000	1.000	1.000	1.000	1.000	1.000	0.388	0.154	0.376	0.199
97.5	1.000	1.000	1.000	1.000	1.000	1.000	0.388	0.154	0.376	0.196
102.5	1.000	1.000	1.000	1.000	1.000	1.000	0.388	0.154	0.376	0.196
107.5	1.000	1.000	1.000	1.000	1.000	1.000	0.388	0.154	0.376	0.196

Table 2.18a—Schedules of Pacific cod selectivities at length in the commercial fisheries as defined by final parameter estimates under Model B (page 2 of 4). Lengths (cm) correspond to mid-points of size bins. Years correspond to beginnings of blocks.

	September-December trawl fishery							January-May longline fishery					
Len.	1977	1980	1985	1990	1995	2000	2005	1977	1985	1990	1995	2000	2005
8.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
13.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
16.5	0.000	0.000	0.001	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
19.5	0.000	0.000	0.002	0.000	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
22.5	0.000	0.000	0.004	0.001	0.003	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000
25.5	0.000	0.001	0.008	0.002	0.005	0.002	0.001	0.000	0.001	0.000	0.000	0.000	0.000
28.5	0.001	0.004	0.015	0.004	0.009	0.004	0.002	0.001	0.001	0.000	0.000	0.000	0.000
31.5	0.011	0.011	0.030	0.010	0.016	0.009	0.004	0.003	0.002	0.000	0.000	0.000	0.000
34.5	0.057	0.031	0.054	0.021	0.026	0.018	0.008	0.006	0.005	0.001	0.001	0.000	0.000
37.5	0.203	0.075	0.092	0.043	0.042	0.033	0.015	0.013	0.009	0.004	0.002	0.001	0.001
40.5	0.499	0.158	0.150	0.082	0.065	0.059	0.026	0.026	0.017	0.009	0.005	0.004	0.003
43.5	0.849	0.294	0.230	0.145	0.098	0.098	0.044	0.050	0.030	0.022	0.012	0.013	0.009
47.5	1.000	0.553	0.375	0.277	0.159	0.181	0.084	0.108	0.060	0.061	0.034	0.042	0.035
52.5	1.000	0.886	0.601	0.515	0.270	0.339	0.169	0.240	0.128	0.175	0.103	0.145	0.141
57.5	1.000	1.000	0.826	0.782	0.420	0.550	0.303	0.447	0.241	0.390	0.252	0.367	0.388
62.5	1.000	1.000	0.975	0.969	0.596	0.775	0.484	0.697	0.406	0.681	0.493	0.688	0.743
67.5	1.000	1.000	1.000	1.000	0.773	0.945	0.689	0.912	0.607	0.930	0.773	0.952	0.986
72.5	1.000	1.000	0.347	1.000	0.916	1.000	0.873	1.000	0.806	1.000	0.970	1.000	0.998
77.5	1.000	1.000	0.280	1.000	0.993	1.000	0.984	1.000	0.952	1.000	1.000	0.879	0.852
82.5	0.798	1.000	0.280	1.000	0.573	0.570	1.000	1.000	1.000	1.000	0.938	0.622	0.684
87.5	0.280	1.000	0.280	1.000	0.280	0.280	0.469	1.000	1.000	0.994	0.820	0.501	0.624
92.5	0.280	1.000	0.280	0.498	0.280	0.280	0.280	0.725	1.000	0.838	0.767	0.479	0.615
97.5	0.280	1.000	0.280	0.280	0.280	0.280	0.280	0.288	0.965	0.680	0.758	0.477	0.615
102.5	0.280	1.000	0.280	0.280	0.280	0.280	0.280	0.108	0.591	0.629	0.757	0.477	0.615
107.5	0.280	0.280	0.280	0.280	0.280	0.280	0.280	0.078	0.276	0.622	0.757	0.477	0.615

Table 2.18a—Schedules of Pacific cod selectivities at length in the commercial fisheries as defined by final parameter estimates under Model B (page 3 of 4). Lengths (cm) correspond to mid-points of size bins. Years correspond to beginnings of blocks.

	Jun-Aug longline fishery				Sep-Dec LL fishery			Jan-May pot fishery			
Len.	1977	1980	1990	2000	1977	1980	1990	1977	1995	2000	2005
8.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
13.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
16.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
19.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
22.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
25.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
28.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
31.5	0.002	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000
34.5	0.005	0.001	0.000	0.000	0.003	0.001	0.000	0.000	0.000	0.000	0.000
37.5	0.013	0.003	0.001	0.000	0.007	0.005	0.001	0.000	0.000	0.001	0.000
40.5	0.033	0.014	0.004	0.000	0.018	0.019	0.003	0.001	0.001	0.002	0.001
43.5	0.074	0.052	0.012	0.001	0.042	0.063	0.010	0.003	0.002	0.007	0.004
47.5	0.182	0.202	0.041	0.005	0.110	0.224	0.035	0.017	0.010	0.029	0.022
52.5	0.432	0.619	0.141	0.037	0.285	0.636	0.131	0.090	0.056	0.126	0.112
57.5	0.756	0.986	0.359	0.177	0.567	0.985	0.354	0.309	0.202	0.368	0.360
62.5	0.980	0.999	0.678	0.516	0.861	1.000	0.687	0.685	0.502	0.730	0.747
67.5	1.000	0.950	0.946	0.907	1.000	0.676	0.958	0.979	0.855	0.985	0.995
72.5	0.904	0.855	1.000	1.000	1.000	0.513	1.000	0.998	1.000	0.996	0.984
77.5	0.676	0.754	0.944	1.000	0.969	0.513	0.646	0.729	0.927	0.741	0.770
82.5	0.418	0.677	0.745	1.000	0.698	0.513	0.463	0.344	0.578	0.497	0.684
87.5	0.214	0.632	0.492	1.000	0.351	0.513	0.463	0.160	0.415	0.438	0.678
92.5	0.090	0.611	0.275	0.999	0.124	0.513	0.463	0.119	0.393	0.433	0.678
97.5	0.030	0.604	0.135	0.999	0.030	0.513	0.463	0.114	0.393	0.433	0.678
102.5	0.007	0.601	0.064	0.999	0.005	0.513	0.463	0.114	0.393	0.433	0.678
107.5	0.000	0.601	0.035	0.999	0.001	0.513	0.463	0.114	0.393	0.433	0.678

Table 2.18a—Schedules of Pacific cod selectivities at length in the commercial fisheries as defined by final parameter estimates under Model B (page 4 of 4). Lengths (cm) correspond to mid-points of size bins. Years correspond to beginnings of blocks.

	June-Aug pot fishery			Sep-Dec pot fishery			
Len.	1977	1995	2000	1977	1995	2000	2005
8.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000
13.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000
16.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000
19.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000
22.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000
25.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000
28.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000
31.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000
34.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000
37.5	0.000	0.000	0.000	0.000	0.000	0.001	0.000
40.5	0.001	0.000	0.000	0.002	0.001	0.003	0.002
43.5	0.003	0.001	0.002	0.005	0.004	0.011	0.006
47.5	0.017	0.004	0.014	0.021	0.016	0.045	0.032
52.5	0.095	0.021	0.091	0.089	0.067	0.178	0.154
57.5	0.331	0.083	0.344	0.268	0.210	0.476	0.465
62.5	0.725	0.243	0.764	0.578	0.481	0.845	0.863
67.5	0.993	0.526	1.000	0.896	0.807	1.000	1.000
72.5	0.991	0.844	0.974	1.000	0.995	0.960	0.943
77.5	0.779	0.999	0.728	0.914	0.994	0.724	0.720
82.5	0.474	0.980	0.432	0.545	0.855	0.533	0.564
87.5	0.281	0.743	0.263	0.278	0.698	0.471	0.518
92.5	0.212	0.443	0.207	0.197	0.635	0.461	0.512
97.5	0.196	0.267	0.196	0.185	0.623	0.461	0.511
102.5	0.194	0.207	0.194	0.184	0.622	0.461	0.511
107.5	0.194	0.194	0.194	0.184	0.622	0.461	0.511

Table 2.18b—Schedules of Pacific cod selectivities at age in the 27-plus bottom trawl surveys as defined by final parameter estimates under Model B. The ascending limb of the curve changes with each year's survey. The descending limb changes only at the 1993-1996 breakpoint, corresponding to the change from 30-minute tows to 15-minute tows.

Age	1984	1987	1990	1993	1996	1999	2001	2003	2005	2007
0	0.000	0.039	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.002
1	0.001	0.455	0.108	0.081	0.001	0.000	0.000	0.000	0.000	0.002
2	0.038	0.754	0.387	0.337	0.447	0.398	0.296	0.395	0.389	0.021
3	0.432	0.937	0.786	0.757	1.000	1.000	1.000	1.000	1.000	1.000
4	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
5	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
6	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
7	0.376	0.376	0.376	0.376	1.000	1.000	1.000	1.000	1.000	1.000
8	0.376	0.376	0.376	0.376	1.000	1.000	1.000	1.000	1.000	1.000
9	0.376	0.376	0.376	0.376	1.000	1.000	1.000	1.000	1.000	1.000
10	0.376	0.376	0.376	0.376	1.000	1.000	1.000	1.000	1.000	1.000
11	0.376	0.376	0.376	0.376	0.998	0.998	0.998	0.998	0.998	0.998
12	0.376	0.376	0.376	0.376	0.001	0.001	0.001	0.001	0.001	0.001
13	0.376	0.376	0.376	0.376	0.000	0.000	0.000	0.000	0.000	0.000
14	0.376	0.376	0.376	0.376	0.000	0.000	0.000	0.000	0.000	0.000
15	0.376	0.376	0.376	0.376	0.000	0.000	0.000	0.000	0.000	0.000
16	0.376	0.376	0.376	0.376	0.000	0.000	0.000	0.000	0.000	0.000
17	0.376	0.376	0.376	0.376	0.000	0.000	0.000	0.000	0.000	0.000
18	0.376	0.376	0.376	0.376	0.000	0.000	0.000	0.000	0.000	0.000
19	0.376	0.376	0.376	0.376	0.000	0.000	0.000	0.000	0.000	0.000
20	0.376	0.376	0.376	0.376	0.000	0.000	0.000	0.000	0.000	0.000

Table 2.19—Schedules of Pacific cod length (cm) by season and age as estimated by Model B. Sea1 = Jan-May, Sea2 = Jul-Aug, Sea3 = Sep-Dec.

	Population			Trawl fishery			Longline fishery			Pot fishery			Survey
Age	Sea1	Sea2	Sea3	Sea1	Sea2	Sea3	Sea1	Sea2	Sea3	Sea1	Sea2	Sea3	Sea2
0	7.15	10.60	13.62	8.50	11.79	15.77	8.50	9.73	16.22	8.50	9.73	13.36	9.70
1	17.49	20.94	24.38	20.82	24.73	29.09	24.16	28.12	33.84	22.39	31.03	36.04	20.92
2	28.62	32.23	35.26	34.45	38.04	41.96	39.94	47.57	46.85	41.47	46.78	48.41	32.23
3	39.01	42.19	44.87	45.84	48.45	51.87	50.64	56.28	55.23	51.74	55.06	55.79	42.26
4	48.18	50.99	53.36	54.28	56.41	59.63	57.72	62.00	61.13	58.40	60.53	60.88	51.04
5	56.28	58.77	60.86	60.89	62.67	65.77	62.84	66.29	65.48	63.16	64.59	64.96	58.78
6	63.44	65.63	67.48	66.40	67.58	70.63	67.04	70.16	69.10	67.11	68.02	68.73	65.63
7	69.75	71.69	73.32	71.38	71.46	74.50	70.94	74.06	72.63	70.94	71.16	72.60	71.69
8	75.33	77.04	78.48	76.08	74.75	77.73	74.89	78.08	76.55	75.00	74.31	76.78	77.04
9	80.26	81.77	83.04	80.54	77.88	80.68	79.06	82.13	80.99	79.36	77.72	81.27	81.77
10	84.61	85.95	87.07	84.68	81.27	83.69	83.37	86.03	85.67	83.82	81.60	85.79	85.94
11	88.45	89.63	90.62	88.45	85.28	87.07	87.58	89.63	89.99	88.01	85.98	89.94	89.61
12	91.85	92.89	93.76	91.82	89.90	90.99	91.38	92.85	93.56	91.66	90.51	93.47	92.85
13	94.84	95.76	96.53	94.80	94.40	95.09	94.64	95.71	96.46	94.76	94.59	96.41	95.71
14	97.49	98.30	98.98	97.42	97.89	98.53	97.38	98.23	98.91	97.42	97.84	98.89	98.23
15	99.83	100.54	101.15	99.74	100.41	101.02	99.74	100.46	101.06	99.74	100.36	101.06	100.46
16	101.89	102.52	103.05	101.80	102.44	102.98	101.80	102.44	102.98	101.80	102.42	102.98	102.44
17	103.71	104.27	104.74	103.64	104.20	104.68	103.64	104.20	104.68	103.64	104.20	104.68	104.20
18	105.32	105.81	106.23	105.33	106.02	106.71	105.33	106.02	106.71	105.33	106.02	106.71	106.02
19	106.74	107.18	107.54	107.41	107.50	107.50	107.41	107.50	107.50	107.41	107.50	107.50	107.50
20	108.00	108.38	108.70	107.50	107.50	107.50	107.50	107.50	107.50	107.50	107.50	107.50	107.50

Table 2.20—Schedules of Pacific cod weight (kg) by season and age as estimated by Model B. Sea1 = Jan-May, Sea2 = Jul-Aug, Sea3 = Sep-Dec.

	Population			Trawl fishery			Longline fishery			Pot fishery			Survey
Age	Sea1	Sea2	Sea3	Sea1	Sea2	Sea3	Sea1	Sea2	Sea3	Sea1	Sea2	Sea3	Sea2
0	0.01	0.01	0.03	0.01	0.02	0.05	0.01	0.01	0.06	0.01	0.01	0.03	0.01
1	0.06	0.11	0.19	0.11	0.18	0.31	0.17	0.28	0.48	0.14	0.35	0.58	0.11
2	0.29	0.40	0.57	0.50	0.64	0.92	0.77	1.22	1.25	0.86	1.16	1.36	0.40
3	0.75	0.90	1.15	1.19	1.32	1.70	1.58	2.03	2.02	1.69	1.90	2.07	0.90
4	1.43	1.58	1.89	1.99	2.09	2.56	2.36	2.72	2.72	2.44	2.53	2.68	1.58
5	2.27	2.40	2.76	2.82	2.85	3.40	3.07	3.33	3.32	3.11	3.08	3.25	2.40
6	3.26	3.33	3.71	3.68	3.57	4.17	3.75	3.97	3.89	3.76	3.60	3.84	3.33
7	4.33	4.32	4.71	4.59	4.20	4.86	4.47	4.69	4.52	4.47	4.13	4.53	4.32
8	5.44	5.33	5.72	5.58	4.80	5.49	5.30	5.51	5.30	5.33	4.72	5.35	5.33
9	6.57	6.34	6.72	6.62	5.43	6.12	6.26	6.40	6.26	6.34	5.41	6.32	6.34
10	7.68	7.32	7.68	7.69	6.18	6.81	7.35	7.34	7.36	7.48	6.28	7.38	7.32
11	8.75	8.26	8.59	8.75	7.16	7.66	8.51	8.27	8.45	8.63	7.34	8.43	8.26
12	9.77	9.15	9.46	9.77	8.37	8.71	9.64	9.15	9.42	9.72	8.52	9.39	9.15
13	10.73	9.99	10.26	10.73	9.63	9.87	10.68	9.99	10.25	10.72	9.67	10.24	9.99
14	11.62	10.77	11.01	11.62	10.67	10.90	11.61	10.77	11.00	11.62	10.65	11.00	10.77
15	12.45	11.49	11.70	12.45	11.48	11.69	12.45	11.49	11.70	12.45	11.46	11.70	11.49
16	13.23	12.16	12.34	13.23	12.16	12.34	13.23	12.16	12.34	13.23	12.16	12.34	12.16
17	13.95	12.79	12.94	13.95	12.79	12.94	13.95	12.79	12.94	13.95	12.79	12.94	12.79
18	14.65	13.46	13.68	14.65	13.46	13.68	14.65	13.46	13.68	14.65	13.46	13.68	13.46
19	15.53	14.02	13.96	15.53	14.02	13.96	15.53	14.02	13.96	15.53	14.02	13.96	14.02
20	15.57	14.02	13.96	15.57	14.02	13.96	15.57	14.02	13.96	15.57	14.02	13.96	14.02

Table 2.21a—Time series of GOA Pacific cod age 0+ biomass, female spawning biomass (t), and standard deviation of spawning biomass as estimated by the model presented in last year's assessment and this year under Model B. Values for 2009 listed under this year's assessment represent Stock Synthesis projections, and may not correspond to values generated by the standard projection model.

	Last year's assessment			This year's assessment		
Year	Age 0+ bio.	Spawn. bio.	Std. dev.	Age 0+ bio.	Spawn. bio.	Std. dev.
1977	292,947	119,910	17,876	130,021	42,383	6,941
1978	295,722	121,420	17,492	146,875	46,819	6,636
1979	307,362	117,255	16,557	180,466	49,013	6,156
1980	331,320	110,640	15,512	225,141	48,282	5,842
1981	346,950	106,210	15,144	247,593	58,523	6,530
1982	379,153	122,635	16,177	266,290	84,423	8,325
1983	420,372	138,915	17,083	287,676	90,265	8,656
1984	452,319	156,995	18,251	305,012	91,090	8,523
1985	489,635	185,595	19,726	330,223	103,996	8,888
1986	533,513	205,415	20,229	364,116	120,116	8,830
1987	568,438	214,720	19,886	390,721	131,660	8,481
1988	587,525	220,715	19,120	400,823	132,230	7,560
1989	604,278	232,005	18,379	405,770	142,571	7,081
1990	609,139	237,430	17,526	401,025	143,190	6,361
1991	592,344	221,530	16,443	374,683	124,241	5,645
1992	574,479	208,960	15,673	356,112	111,780	5,329
1993	556,783	199,410	15,111	340,730	100,449	5,226
1994	558,282	208,485	14,780	346,463	104,843	5,366
1995	562,497	218,385	14,313	358,082	116,013	5,540
1996	540,551	213,060	13,534	351,127	112,578	5,249
1997	517,198	200,170	12,569	347,741	107,972	4,950
1998	482,228	182,345	11,606	335,431	101,303	4,872
1999	450,043	169,105	10,832	321,952	99,278	5,181
2000	411,792	154,295	10,334	295,611	96,551	5,613
2001	394,880	143,245	10,000	282,343	91,471	5,481
2002	395,124	138,805	9,969	285,445	86,583	5,260
2003	389,086	138,200	10,519	284,783	81,476	5,456
2004	377,198	143,125	11,731	281,936	86,338	6,529
2005	355,684	141,685	13,111	272,978	89,380	7,881
2006	338,488	133,990	14,034	280,114	87,240	9,024
2007	324,455	121,105	14,641	311,870	83,482	10,492
2008	648,653	109,609	n/a	405,367	81,473	13,201
2009				520,192	90,702	18,532

Table 2.21b—Time series of GOA Pacific cod age 0 recruitment (1000s of fish), with standard deviations, as estimated by the model presented in last year's assessment and this year under Model B.

	Last year's assessment		This year's assessment	
Year	Recruits	Std. dev.	Recruits	Std. dev.
1977	564,300	71,133	567,138	44,304
1978	186,130	54,160	32,837	15,458
1979	302,740	69,707	119,124	21,179
1980	545,710	82,007	293,252	28,322
1981	170,690	48,454	129,061	25,049
1982	290,410	59,557	346,825	32,317
1983	257,370	60,168	14,781	5,739
1984	400,410	79,207	366,314	45,688
1985	440,220	67,344	257,969	42,834
1986	157,350	41,969	76,987	24,534
1987	442,220	54,558	286,070	25,914
1988	278,860	58,815	178,270	28,735
1989	507,820	64,552	222,709	30,118
1990	321,820	55,816	313,815	32,146
1991	375,420	45,068	183,246	31,097
1992	214,820	30,825	204,701	29,483
1993	288,790	29,545	229,405	28,101
1994	272,050	27,457	193,258	26,979
1995	344,260	26,486	313,337	26,919
1996	218,850	23,782	158,432	22,125
1997	217,710	24,182	165,827	21,266
1998	275,990	26,807	118,999	18,474
1999	348,180	34,037	248,282	26,517
2000	283,820	31,182	263,090	29,099
2001	157,190	23,813	121,909	27,668
2002	127,850	20,995	160,355	27,373
2003	196,460	35,483	158,588	36,337
2004	147,460	31,701	192,790	37,478
2005	283,250	87,762	273,494	93,599
2006	451,870	120,670	1,333,990	450,529
Average	302,334		250,828	

Table 2.22—Numbers (1000s) at age as estimated by Model B.

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1977	567138	40782	2942	43606	11084	7399	4846	3130	2006	1281	817	521	332	212	135	86	55	35	22	14	25
1978	32837	387844	27889	2010	29666	7486	4958	3229	2080	1333	853	546	349	224	143	91	58	37	24	15	27
1979	119124	22456	265212	18974	1340	19121	4648	2996	1929	1245	806	524	340	221	143	93	60	39	25	16	28
1980	293252	81465	15356	180491	12645	860	11747	2768	1761	1135	741	488	322	213	141	93	61	39	26	16	29
1981	129061	200544	55704	10438	117209	7508	468	6027	1374	863	558	369	248	169	115	78	53	35	23	15	27
1982	346825	88260	137130	37871	6803	70839	4268	257	3265	742	468	305	205	140	97	67	46	32	21	14	26
1983	14781	237180	60354	93405	25004	4248	42344	2495	149	1890	431	273	180	122	84	59	41	29	20	14	26
1984	366314	10108	162187	41088	61293	15349	2478	24100	1409	84	1071	246	157	105	72	50	35	25	18	12	24
1985	257969	250508	6912	110630	27566	39839	9652	1520	14564	846	51	646	149	97	65	45	32	23	16	11	24
1986	76987	176415	171292	4720	75080	18465	26246	6260	973	9245	534	32	407	94	61	41	29	20	15	11	23
1987	286070	52648	120619	116850	3186	49641	11912	16554	3878	595	5607	323	19	246	57	37	25	18	13	9	22
1988	178270	195632	35986	81997	77555	2028	30562	7256	10123	2389	369	3487	201	12	154	36	23	16	11	8	20
1989	222709	121912	133748	24518	54879	50053	1263	18690	4420	6182	1464	227	2149	124	7	95	22	15	10	7	18
1990	313815	152302	83365	91254	16404	35055	30511	751	11037	2616	3674	873	135	1285	74	4	57	13	9	6	15
1991	183246	214606	104142	56847	61004	10349	20283	16329	384	5556	1322	1879	452	71	679	39	2	31	7	5	11
1992	204701	125315	146754	71118	38281	38914	5957	10416	7721	175	2515	604	871	212	34	323	19	1	15	3	8
1993	229405	139987	85694	100196	47726	24000	21446	2846	4489	3176	72	1045	256	376	93	15	144	8	1	7	5
1994	193258	156881	95728	58527	67535	30525	13903	11174	1381	2120	1505	34	513	128	189	47	8	73	4	0	6
1995	313337	132161	107282	65405	39593	43865	18342	7687	5843	707	1087	781	18	272	68	102	25	4	40	2	3
1996	158432	214279	90369	73269	44215	25599	25707	9481	3577	2567	306	475	347	8	124	31	46	12	2	18	3
1997	165827	108346	146526	61732	49517	28518	14961	13294	4431	1579	1114	133	210	155	4	56	14	21	5	1	9
1998	118999	113403	74072	99939	41466	31387	16059	7286	5754	1801	633	453	55	89	66	2	24	6	9	2	4
1999	248282	81379	77539	50566	67306	26359	17646	7751	3110	2309	717	257	189	24	38	29	1	11	3	4	3
2000	263090	169790	55636	52892	33972	42359	14318	7917	2972	1105	819	264	99	75	10	16	12	0	4	1	3
2001	121909	179917	116106	37986	35548	21318	23195	6801	3471	1292	495	382	127	48	37	5	8	6	0	2	2
2002	160355	83369	123015	79148	25397	22332	12070	11928	3332	1699	648	256	202	68	26	20	3	4	3	0	2
2003	158588	109660	57009	83961	53006	15839	12326	5950	5558	1551	813	320	130	104	35	14	10	1	2	2	1
2004	192790	108452	74981	38879	56169	33068	8725	6033	2750	2579	745	406	165	68	55	19	7	6	1	1	2
2005	273494	131841	74154	51129	25980	34870	18028	4214	2755	1266	1234	372	210	87	36	29	10	4	3	0	1
2006	1333990	187032	90154	50633	34425	16524	20017	9404	2092	1359	634	630	193	110	46	19	15	5	2	2	1
2007	130346	912265	127897	61574	34135	21936	9477	10387	4631	1023	674	321	324	100	57	24	10	8	3	1	1
2008	262673	89139	623814	87316	41366	21469	12250	4736	4901	2170	488	330	160	163	51	29	12	5	4	1	1

Table 2.23—Projections for GOA Pacific cod catch (t), spawning biomass (t), and fishing mortality under the assumption that $F = max\ F_{ABC}$ in 2009-2021 (Scenarios 1-2), with random variability in future recruitment.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2009	55,300	55,300	55,300	55,300	0
2010	104,000	104,000	104,000	104,000	2
2011	139,000	139,000	139,000	140,000	123
2012	133,000	134,000	134,000	138,000	2,126
2013	102,000	108,000	111,000	130,000	10,601
2014	71,300	86,300	92,700	133,000	22,212
2015	41,200	75,000	80,400	136,000	31,955
2016	31,000	70,100	74,300	133,000	34,909
2017	27,300	67,200	71,200	136,000	34,298
2018	26,200	66,300	69,300	130,000	33,201
2019	26,300	65,600	68,700	128,000	33,042
2020	26,500	64,300	69,100	131,000	33,722
2021	25,800	64,200	69,600	138,000	34,861

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2009	88,000	88,000	88,000	88,000	0
2010	141,000	141,000	141,000	141,000	8
2011	206,000	206,000	207,000	207,000	168
2012	194,000	195,000	195,000	199,000	1,986
2013	150,000	157,000	161,000	184,000	12,775
2014	107,000	128,000	137,000	195,000	31,669
2015	79,300	111,000	123,000	200,000	42,667
2016	69,000	104,000	116,000	193,000	45,028
2017	64,800	100,000	112,000	199,000	43,151
2018	62,900	99,200	109,000	191,000	41,193
2019	63,100	98,800	108,000	186,000	40,678
2020	63,200	97,900	109,000	190,000	42,012
2021	62,100	98,000	110,000	199,000	43,330

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2009	0.44	0.44	0.44	0.44	0.00
2010	0.52	0.52	0.52	0.52	0.00
2011	0.52	0.52	0.52	0.52	0.00
2012	0.52	0.52	0.52	0.52	0.00
2013	0.52	0.52	0.52	0.52	0.00
2014	0.52	0.52	0.52	0.52	0.00
2015	0.39	0.52	0.49	0.52	0.04
2016	0.34	0.52	0.47	0.52	0.06
2017	0.32	0.51	0.46	0.52	0.07
2018	0.31	0.50	0.46	0.52	0.08
2019	0.31	0.50	0.46	0.52	0.08
2020	0.31	0.49	0.46	0.52	0.07
2021	0.30	0.49	0.45	0.52	0.08

Table 2.24—Projections for GOA Pacific cod catch (t), spawning biomass (t), and fishing mortality under the assumption that the upper bound on F_{ABC} is set the most recent five-year average fishing mortality rate in 2009-2021 (Scenario 3), with random variability in future recruitment.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2009	55,100	55,100	55,100	55,100	0
2010	89,500	89,500	89,500	89,600	2
2011	123,000	123,000	123,000	124,000	105
2012	122,000	122,000	123,000	126,000	1,813
2013	96,600	102,000	105,000	121,000	9,111
2014	69,900	83,000	88,600	124,000	19,427
2015	51,800	72,300	79,300	128,000	26,412
2016	42,400	66,800	74,200	125,000	28,744
2017	37,600	64,200	71,000	125,000	28,343
2018	34,800	63,000	68,700	122,000	27,391
2019	33,900	62,100	67,600	118,000	27,217
2020	34,200	61,000	67,500	119,000	27,992
2021	33,200	61,000	67,800	125,000	28,953

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2009	88,000	88,000	88,000	88,000	0
2010	142,000	142,000	142,000	142,000	8
2011	213,000	213,000	213,000	213,000	168
2012	206,000	207,000	208,000	211,000	1,987
2013	166,000	173,000	177,000	199,000	12,845
2014	122,000	143,000	152,000	212,000	32,314
2015	90,700	124,000	137,000	220,000	44,505
2016	74,700	115,000	128,000	212,000	48,623
2017	65,600	110,000	122,000	214,000	48,032
2018	60,400	108,000	117,000	207,000	46,574
2019	58,600	106,000	115,000	201,000	46,066
2020	58,400	104,000	115,000	204,000	47,377
2021	56,500	104,000	115,000	213,000	48,865

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2009	0.44	0.44	0.44	0.44	0.00
2010	0.44	0.44	0.44	0.44	0.00
2011	0.44	0.44	0.44	0.44	0.00
2012	0.44	0.44	0.44	0.44	0.00
2013	0.44	0.44	0.44	0.44	0.00
2014	0.44	0.44	0.44	0.44	0.00
2015	0.44	0.44	0.44	0.44	0.00
2016	0.44	0.44	0.44	0.44	0.00
2017	0.44	0.44	0.44	0.44	0.00
2018	0.44	0.44	0.44	0.44	0.00
2019	0.44	0.44	0.44	0.44	0.00
2020	0.44	0.44	0.44	0.44	0.00
2021	0.44	0.44	0.44	0.44	0.00

Table 2.25—Projections for GOA Pacific cod catch (t), spawning biomass (t), and fishing mortality under the assumption that the upper bound on F_{ABC} is set at $F_{60\%}$ in 2009-2021 (Scenario 4), with random variability in future recruitment.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2009	30,300	30,300	30,300	30,300	0
2010	51,600	51,600	51,600	51,600	1
2011	74,700	74,700	74,700	74,800	55
2012	80,300	80,800	81,100	82,800	958
2013	70,600	73,500	74,900	83,800	4,918
2014	56,200	63,600	66,700	86,800	11,015
2015	44,100	56,300	60,600	90,600	15,884
2016	36,600	51,900	56,600	89,100	18,220
2017	32,100	49,400	53,800	88,700	18,628
2018	28,900	48,200	51,800	87,000	18,263
2019	27,800	46,900	50,500	84,100	18,045
2020	26,900	46,000	49,900	84,700	18,388
2021	26,700	45,900	49,800	86,800	19,012

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2009	89,600	89,600	89,600	89,600	0
2010	152,000	152,000	152,000	152,000	8
2011	238,000	238,000	238,000	238,000	168
2012	250,000	251,000	252,000	255,000	1,991
2013	222,000	229,000	233,000	256,000	13,040
2014	180,000	202,000	212,000	275,000	34,148
2015	144,000	182,000	195,000	287,000	49,426
2016	122,000	169,000	183,000	282,000	56,648
2017	106,000	160,000	174,000	282,000	58,048
2018	95,900	155,000	167,000	276,000	57,299
2019	90,800	151,000	162,000	269,000	56,608
2020	87,800	147,000	160,000	270,000	57,690
2021	87,000	146,000	159,000	274,000	59,469

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2009	0.23	0.23	0.23	0.23	0.00
2010	0.23	0.23	0.23	0.23	0.00
2011	0.23	0.23	0.23	0.23	0.00
2012	0.23	0.23	0.23	0.23	0.00
2013	0.23	0.23	0.23	0.23	0.00
2014	0.23	0.23	0.23	0.23	0.00
2015	0.23	0.23	0.23	0.23	0.00
2016	0.23	0.23	0.23	0.23	0.00
2017	0.23	0.23	0.23	0.23	0.00
2018	0.23	0.23	0.23	0.23	0.00
2019	0.23	0.23	0.23	0.23	0.00
2020	0.23	0.23	0.23	0.23	0.00
2021	0.23	0.23	0.23	0.23	0.00

Table 2.26—Projections for GOA Pacific cod catch (t), spawning biomass (t), and fishing mortality under the assumption that *F* = 0 in 2009-2021 (Scenario 5), with random variability in future recruitment.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
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
2020	0	0	0	0	0
2021	0	0	0	0	0

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2009	91,400	91,400	91,400	91,400	0
2010	166,000	166,000	166,000	166,000	8
2011	272,000	272,000	272,000	273,000	168
2012	315,000	316,000	317,000	320,000	1,996
2013	314,000	322,000	326,000	349,000	13,260
2014	290,000	314,000	324,000	390,000	36,331
2015	260,000	302,000	318,000	420,000	55,915
2016	234,000	292,000	309,000	435,000	68,519
2017	213,000	281,000	300,000	434,000	74,748
2018	195,000	275,000	290,000	435,000	77,289
2019	182,000	268,000	282,000	429,000	78,104
2020	173,000	264,000	277,000	434,000	79,553
2021	168,000	257,000	273,000	428,000	81,811

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2009	0.00	0.00	0.00	0.00	0.00
2010	0.00	0.00	0.00	0.00	0.00
2011	0.00	0.00	0.00	0.00	0.00
2012	0.00	0.00	0.00	0.00	0.00
2013	0.00	0.00	0.00	0.00	0.00
2014	0.00	0.00	0.00	0.00	0.00
2015	0.00	0.00	0.00	0.00	0.00
2016	0.00	0.00	0.00	0.00	0.00
2017	0.00	0.00	0.00	0.00	0.00
2018	0.00	0.00	0.00	0.00	0.00
2019	0.00	0.00	0.00	0.00	0.00
2020	0.00	0.00	0.00	0.00	0.00
2021	0.00	0.00	0.00	0.00	0.00

Table 2.27—Projections for GOA Pacific cod catch (t), spawning biomass (t), and fishing mortality under the assumption that $F = F_{OFL}$ in 2009-2021 (Scenario 6), with random variability in future recruitment.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2009	66,600	66,600	66,600	66,600	0
2010	123,000	123,000	123,000	123,000	2
2011	160,000	160,000	160,000	161,000	153
2012	145,000	147,000	147,000	152,000	2,633
2013	105,000	113,000	117,000	140,000	12,962
2014	61,900	88,700	94,200	144,000	28,328
2015	36,200	72,100	80,500	148,000	38,734
2016	29,600	68,700	76,500	147,000	40,070
2017	27,000	65,200	74,400	149,000	38,726
2018	26,600	66,700	73,100	143,000	37,380
2019	27,000	64,500	72,700	144,000	37,445
2020	27,300	64,500	73,400	146,000	38,563
2021	26,600	65,200	74,300	151,000	39,624

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2009	87,300	87,300	87,300	87,300	0
2010	136,000	136,000	136,000	136,000	8
2011	194,000	194,000	195,000	195,000	168
2012	174,000	175,000	176,000	179,000	1,983
2013	128,000	135,000	139,000	162,000	12,660
2014	87,700	107,000	116,000	172,000	30,463
2015	66,900	93,800	105,000	177,000	39,318
2016	60,400	90,700	102,000	174,000	40,139
2017	57,900	89,100	99,600	177,000	37,954
2018	57,200	89,500	97,800	169,000	36,320
2019	57,600	88,200	97,300	165,000	36,275
2020	57,800	88,100	98,100	174,000	37,689
2021	57,400	88,800	99,100	180,000	38,757

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2009	0.54	0.54	0.54	0.54	0.00
2010	0.64	0.64	0.64	0.64	0.00
2011	0.64	0.64	0.64	0.64	0.00
2012	0.64	0.64	0.64	0.64	0.00
2013	0.64	0.64	0.64	0.64	0.00
2014	0.55	0.64	0.62	0.64	0.03
2015	0.41	0.59	0.56	0.64	0.08
2016	0.37	0.57	0.54	0.64	0.10
2017	0.35	0.56	0.54	0.64	0.10
2018	0.34	0.56	0.54	0.64	0.11
2019	0.35	0.55	0.53	0.64	0.11
2020	0.35	0.55	0.53	0.64	0.10
2021	0.35	0.55	0.54	0.64	0.11

Table 2.28—Projections for GOA Pacific cod catch (t), spawning biomass (t), and fishing mortality under the assumption that $F = max\ F_{ABC}$ in each year 2009-2010 and $F = F_{OFL}$ thereafter (Scenario 7), with random variability in future recruitment.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2009	55,300	55,300	55,300	55,300	0
2010	104,000	104,000	104,000	104,000	2
2011	168,000	168,000	168,000	168,000	153
2012	150,000	152,000	153,000	157,000	2,633
2013	108,000	116,000	120,000	143,000	12,963
2014	64,300	90,100	96,000	146,000	27,997
2015	36,800	73,000	81,200	148,000	38,733
2016	29,800	69,000	76,800	148,000	40,103
2017	27,100	65,500	74,500	149,000	38,745
2018	26,600	66,700	73,100	143,000	37,388
2019	27,000	64,500	72,700	144,000	37,448
2020	27,300	64,500	73,400	146,000	38,564
2021	26,500	65,200	74,300	151,000	39,624

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2009	88,000	88,000	88,000	88,000	0
2010	141,000	141,000	141,000	141,000	8
2011	204,000	204,000	204,000	205,000	168
2012	181,000	182,000	182,000	186,000	1,983
2013	132,000	139,000	143,000	165,000	12,660
2014	89,500	109,000	118,000	174,000	30,494
2015	67,400	94,200	106,000	178,000	39,433
2016	60,600	90,900	102,000	174,000	40,217
2017	58,000	89,200	99,700	177,000	37,991
2018	57,200	89,500	97,900	169,000	36,334
2019	57,600	88,200	97,300	165,000	36,279
2020	57,800	88,100	98,100	174,000	37,691
2021	57,300	88,800	99,100	180,000	38,757

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2009	0.44	0.44	0.44	0.44	0.00
2010	0.52	0.52	0.52	0.52	0.00
2011	0.64	0.64	0.64	0.64	0.00
2012	0.64	0.64	0.64	0.64	0.00
2013	0.64	0.64	0.64	0.64	0.00
2014	0.56	0.64	0.62	0.64	0.03
2015	0.41	0.59	0.56	0.64	0.08
2016	0.37	0.57	0.55	0.64	0.10
2017	0.35	0.56	0.54	0.64	0.10
2018	0.34	0.56	0.54	0.64	0.11
2019	0.35	0.55	0.53	0.64	0.11
2020	0.35	0.55	0.53	0.64	0.10
2021	0.35	0.55	0.54	0.64	0.11

Table 2.29a—Bycatch of nontarget and "other" species taken in the GOA Pacific cod trawl fishery, 1997-2002. The first part of the table ("Bycatch in...") shows the amount (t) of each species group taken as bycatch in the GOA Pacific cod trawl fishery, broken down by year. The second part of the table ("Proportion of...") shows the same quantity expressed relative to the total GOA catch (taken in all target categories with all gears) of that species group in that year. An empty cell in the second part of the table indicates that no catch of that group was observed in the GOA during that year.

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

Table 2.29b—Bycatch of nontarget and “other” species taken in the GOA Pacific cod trawl fishery, 2003-2005. The first part of the table (“Bycatch”) shows the amount (t) of each species group taken as bycatch in the GOA Pacific cod trawl fishery, broken down by year. The second part of the table (“Proportion of total”) shows the same quantity expressed relative to the total GOA catch (taken in all target categories with all gears) of that species group in that year. An empty cell in the second part of the table indicates that no catch of that group was observed in the GOA during that year. Note that the list of nontarget species groups used for 2003-2005 differs from that used for 1997-2002.

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

Table 2.30a—Bycatch of nontarget and “other” species taken in the GOA Pacific cod longline fishery, 1997-2002. The first part of the table (“Bycatch in...”) shows the amount (t) of each species group taken as bycatch in the GOA Pacific cod longline fishery, broken down by year. The second part of the table (“Proportion of...”) shows the same quantity expressed relative to the total GOA catch (taken in all target categories with all gears) of that group in that year. An empty cell in the second part of the table indicates that no catch of that group was observed in the GOA during that year.

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

Table 2.30b—Bycatch of nontarget and "other" species taken in the GOA Pacific cod hook-and-line (including jigs) fishery, 2003-2005. The first part of the table ("Bycatch") shows the amount (t) of each species group taken as bycatch in the GOA Pacific cod hook-and-line fishery, broken down by year. The second part of the table ("Proportion of total") shows the same quantity expressed relative to the total GOA catch (taken in all target categories with all gears) of that species group in that year. An empty cell in the second part of the table indicates that no catch of that group was observed in the GOA during that year. Note that the list of nontarget species groups used for 2003-2005 differs from that used for 1997-2002.

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

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

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

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

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

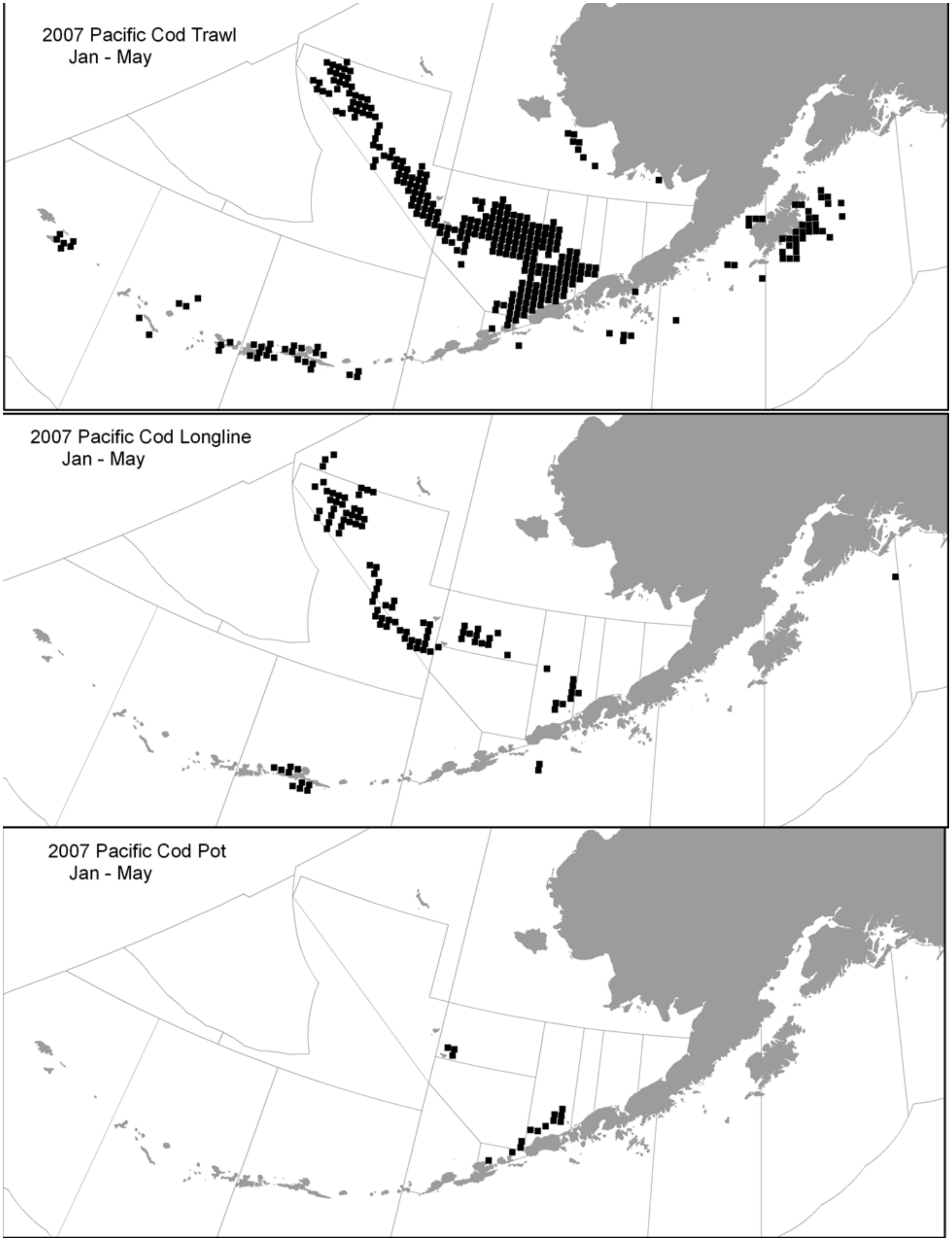


Figure 2.1a—Maps showing each 400 square kilometer cell with hauls/sets containing Pacific cod from at least 3 distinct vessels, January-May 2007, by gear type, overlaid against NMFS 3-digit statistical areas.

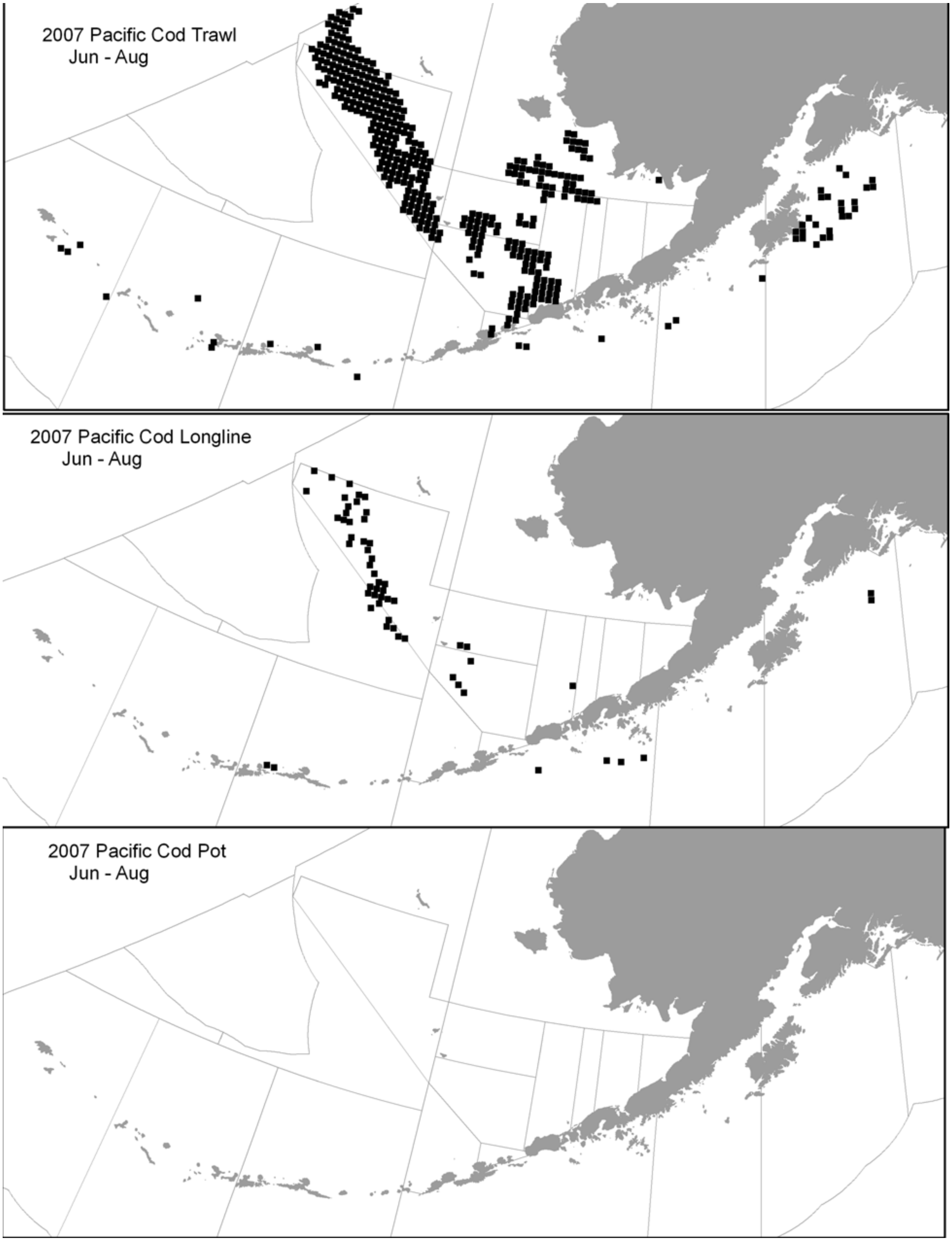


Figure 2.1b—Maps showing each 400 square kilometer cell with hauls/sets containing Pacific cod from at least 3 distinct vessels, June-August 2007, by gear type, overlaid against NMFS 3-digit statistical areas.

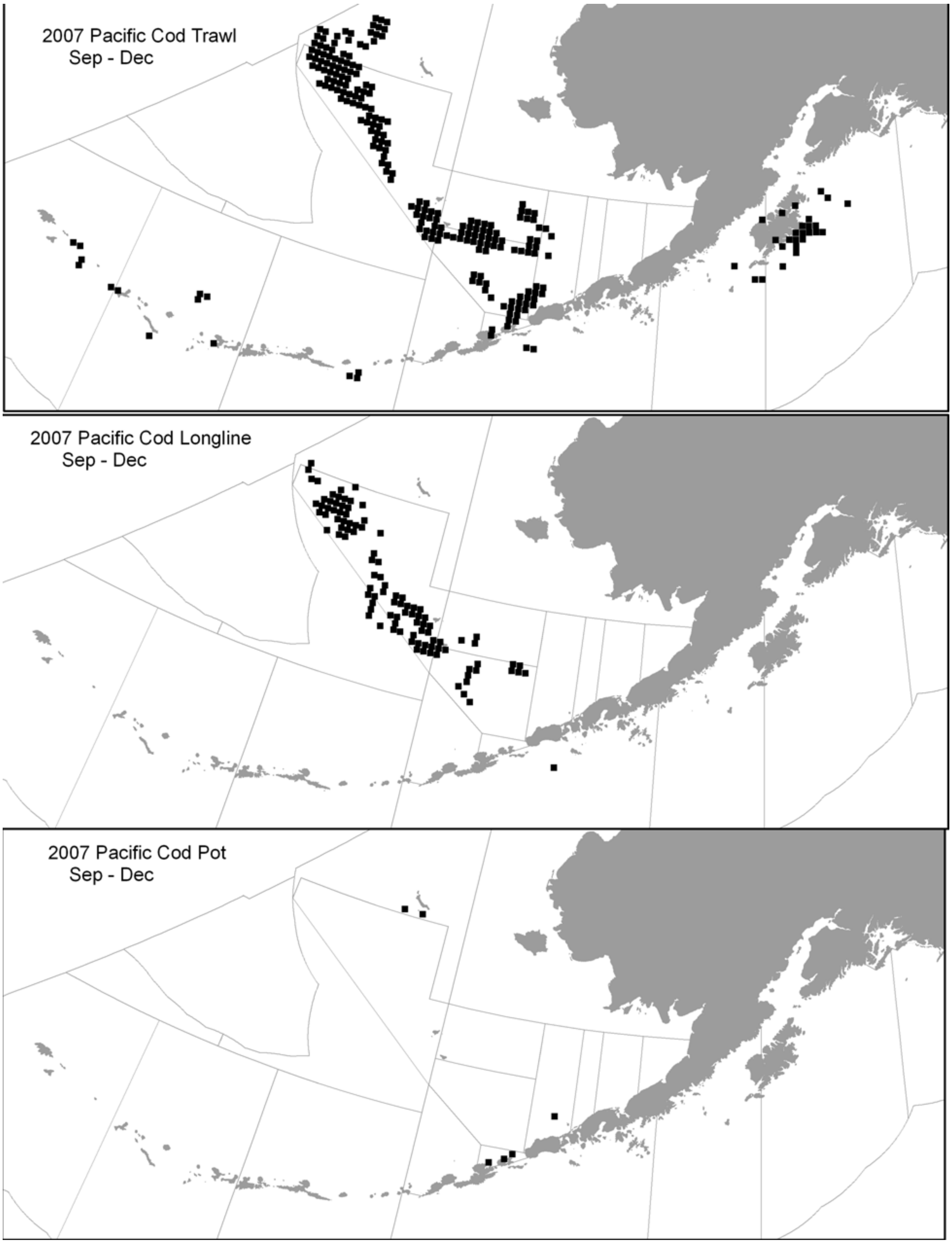


Figure 2.1c—Maps showing each 400 square kilometer cell with hauls/sets containing Pacific cod from at least 3 distinct vessels, Sept.-Dec. 2007, by gear type, overlaid against NMFS 3-digit statistical areas.

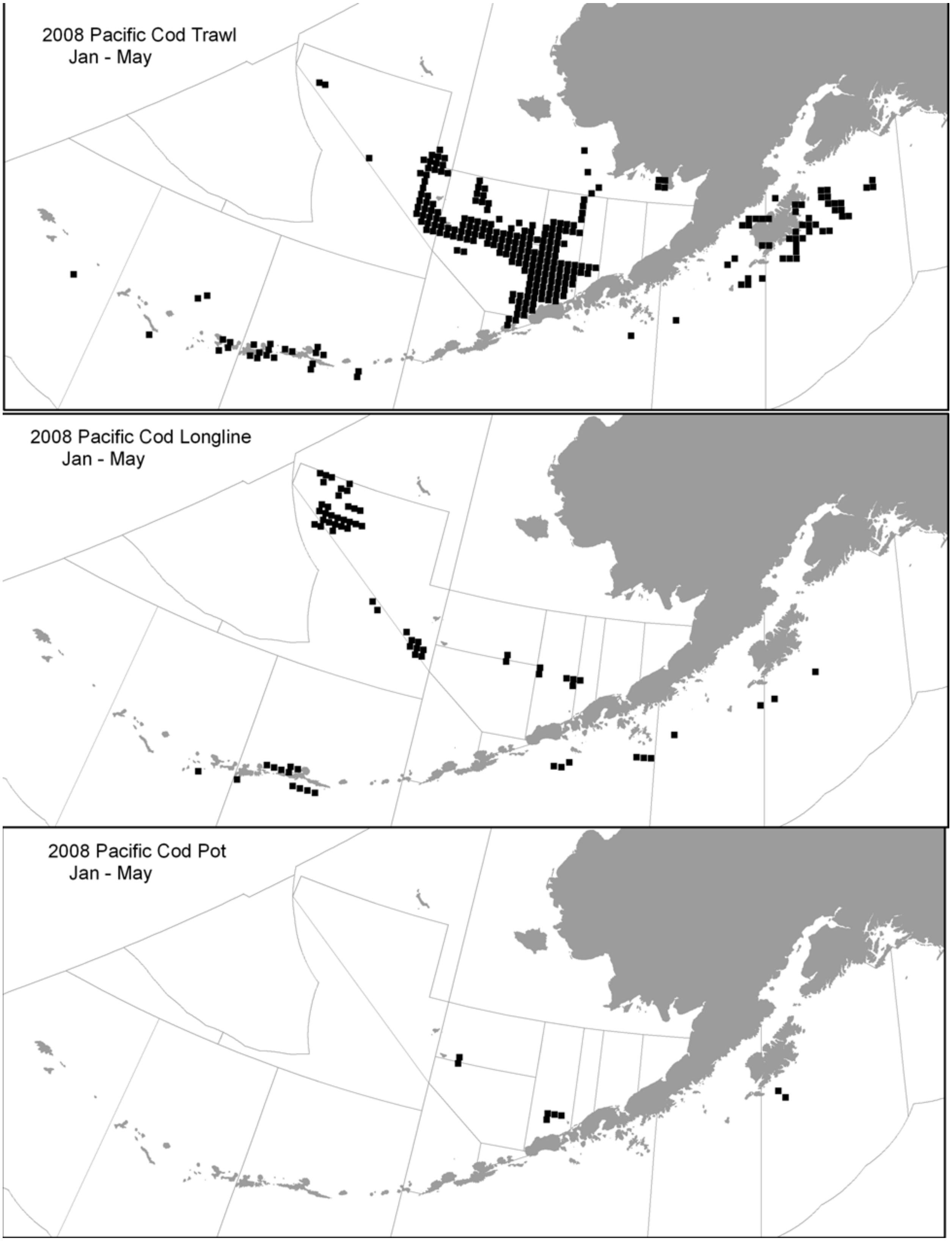


Figure 2.1d—Maps showing each 400 square kilometer cell with hauls/sets containing Pacific cod from at least 3 distinct vessels, January-May 2008, by gear type, overlaid against NMFS 3-digit statistical areas.

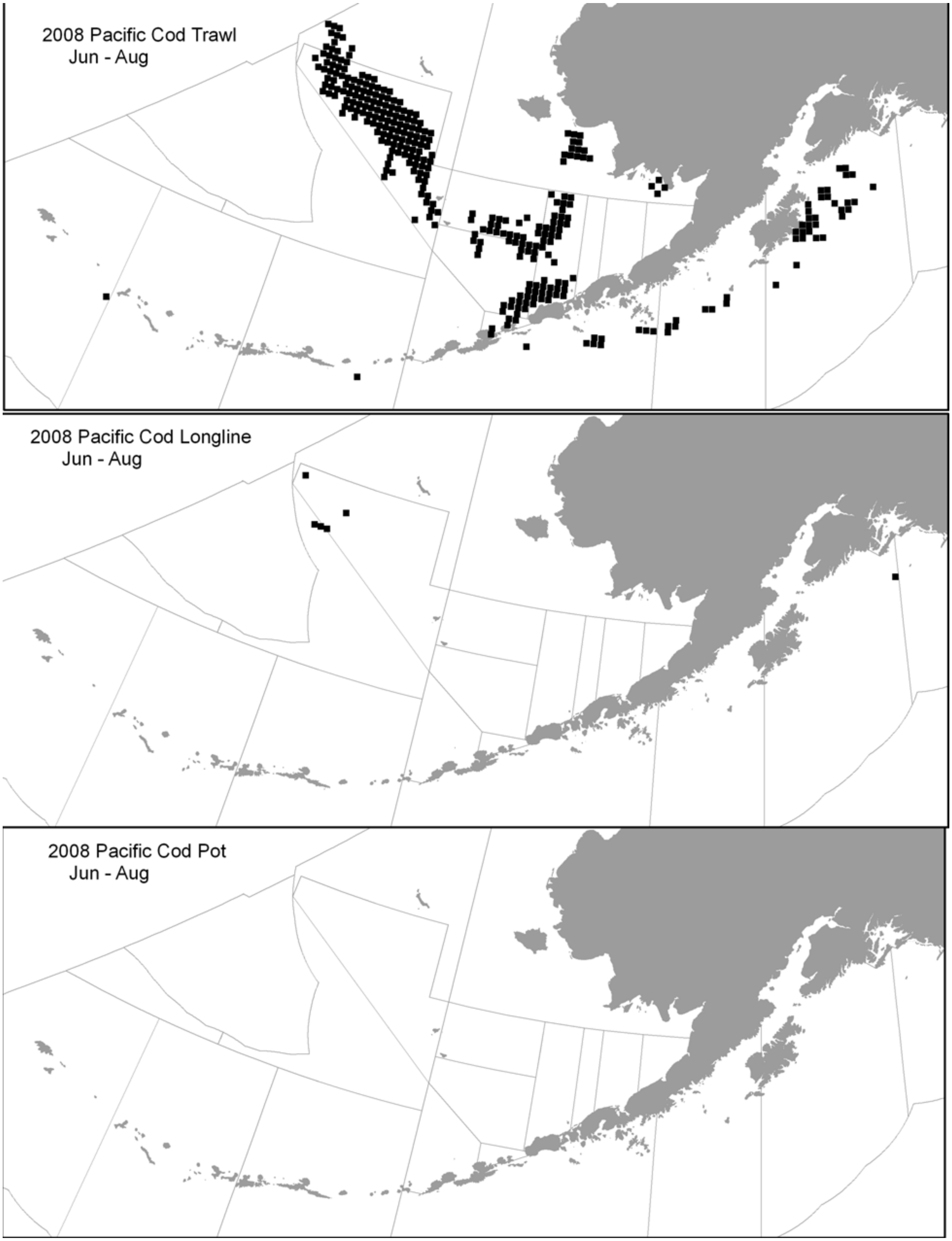


Figure 2.1e—Maps showing each 400 square kilometer cell with hauls/sets containing Pacific cod from at least 3 distinct vessels, June-August 2008, by gear type, overlaid against NMFS 3-digit statistical areas.

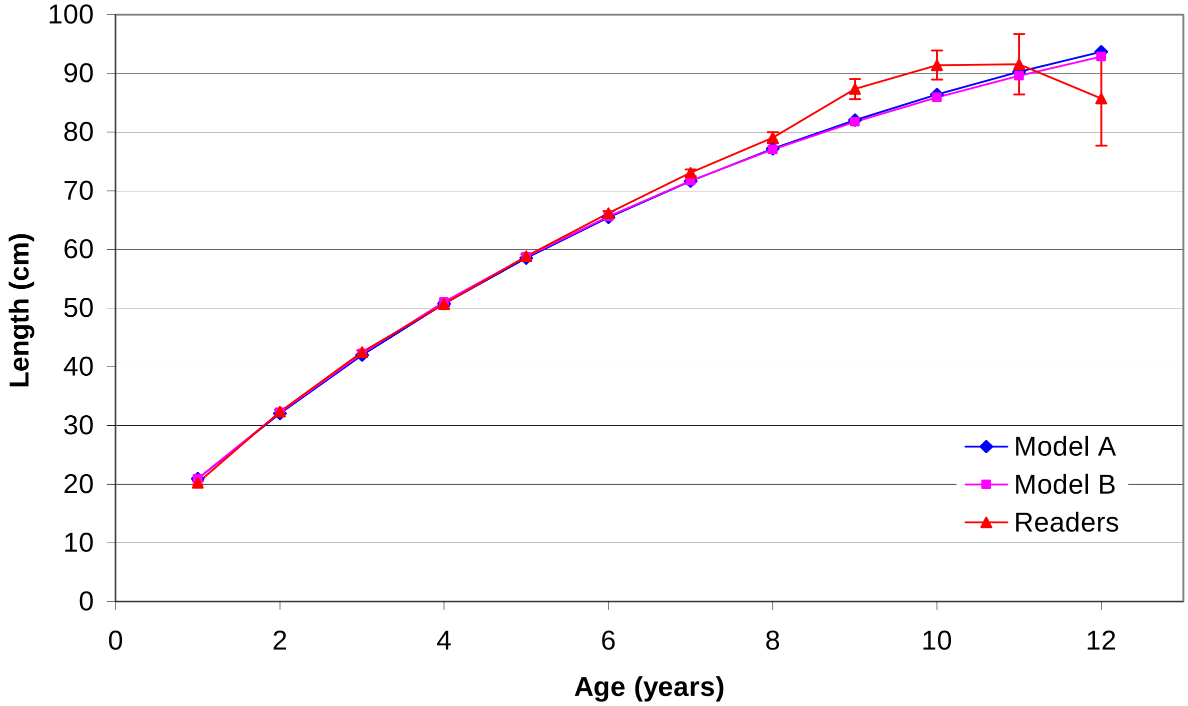


Figure 2.2—Mean length at age as estimated by Models A and B and as determined by age readers, with 95% confidence intervals for mean lengths at age as determined by age readers.

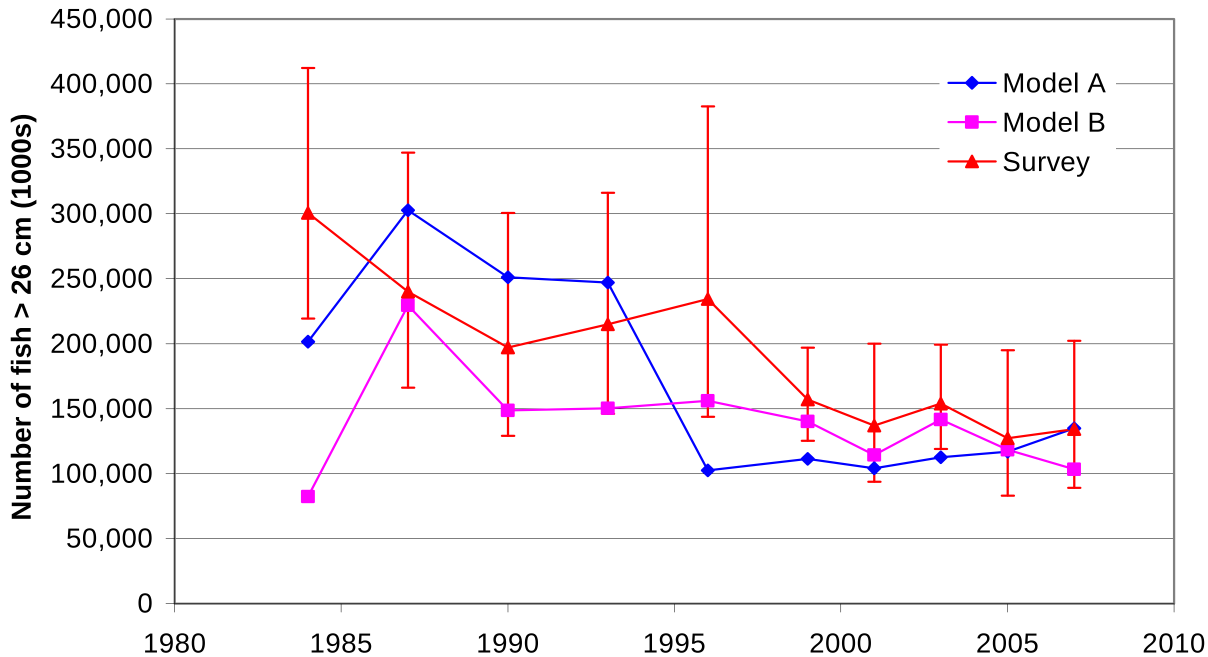


Figure 2.3a—Fits obtained by Models A and B to trawl survey abundance of fish at least 27 cm in length, with 95% confidence intervals shown for survey abundance.

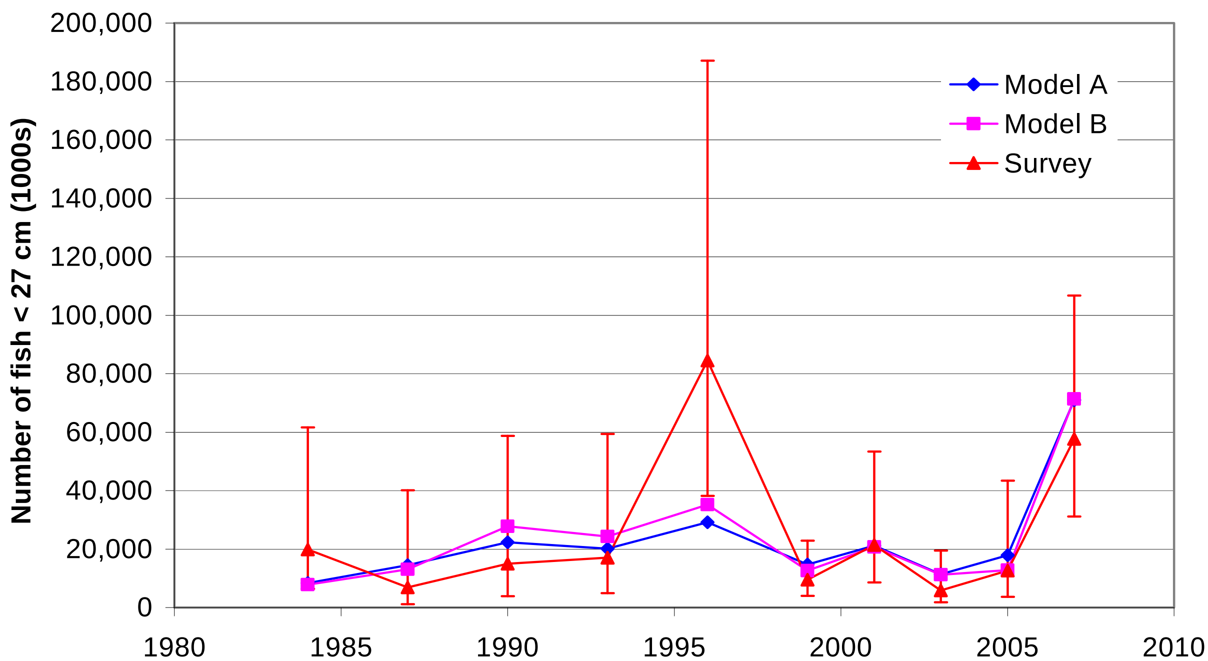


Figure 2.3b— Fits obtained by Models A and B to trawl survey abundance of fish less than 27 cm in length, with 95% confidence intervals shown for survey abundance.

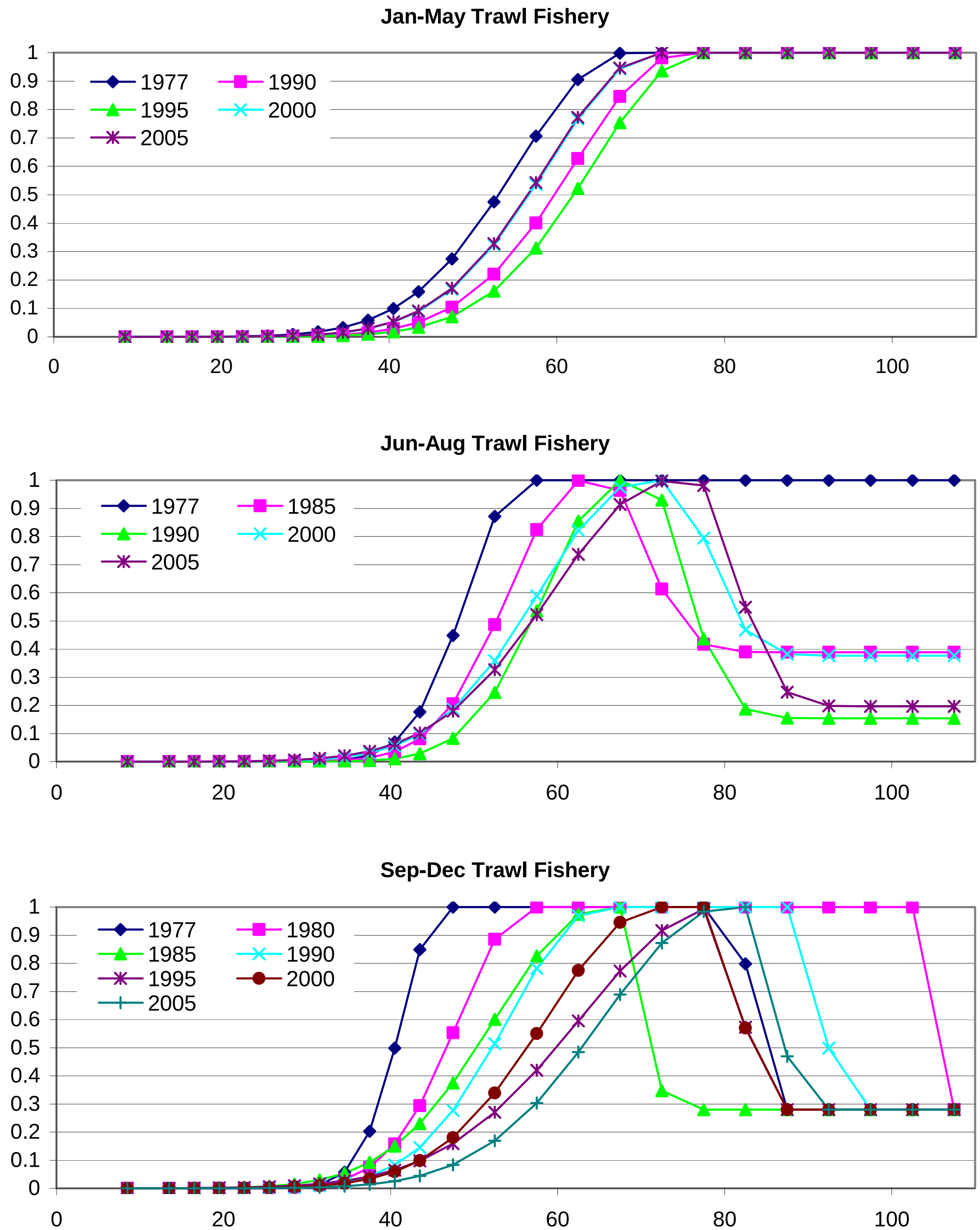


Figure 2.4a. Trawl fishery selectivity by season and time block (line labels refer to beginning year of time block), as estimated by Model B.

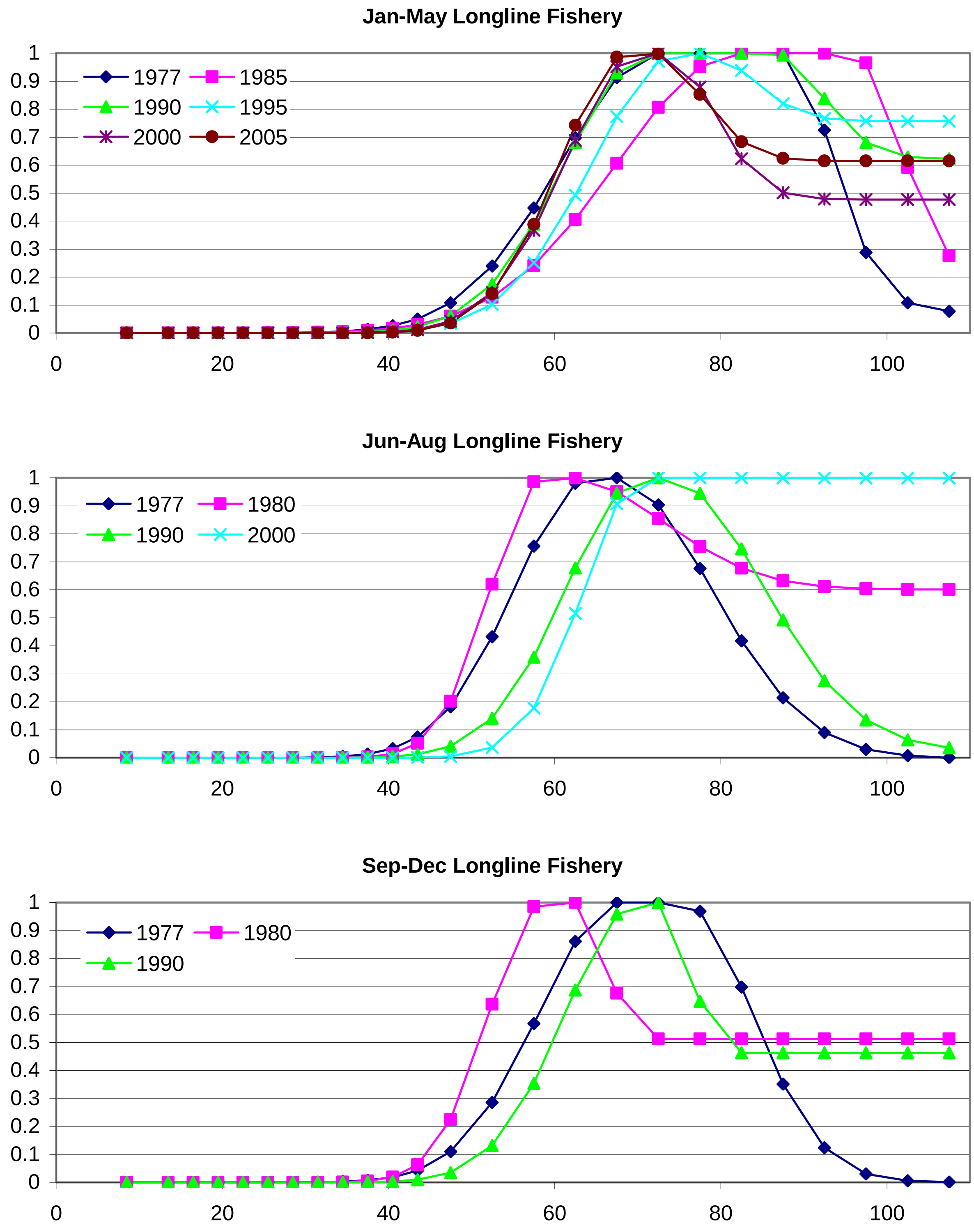


Figure 2.4b. Longline fishery selectivity by season and time block (line labels refer to beginning year of time block), as estimated by Model B.

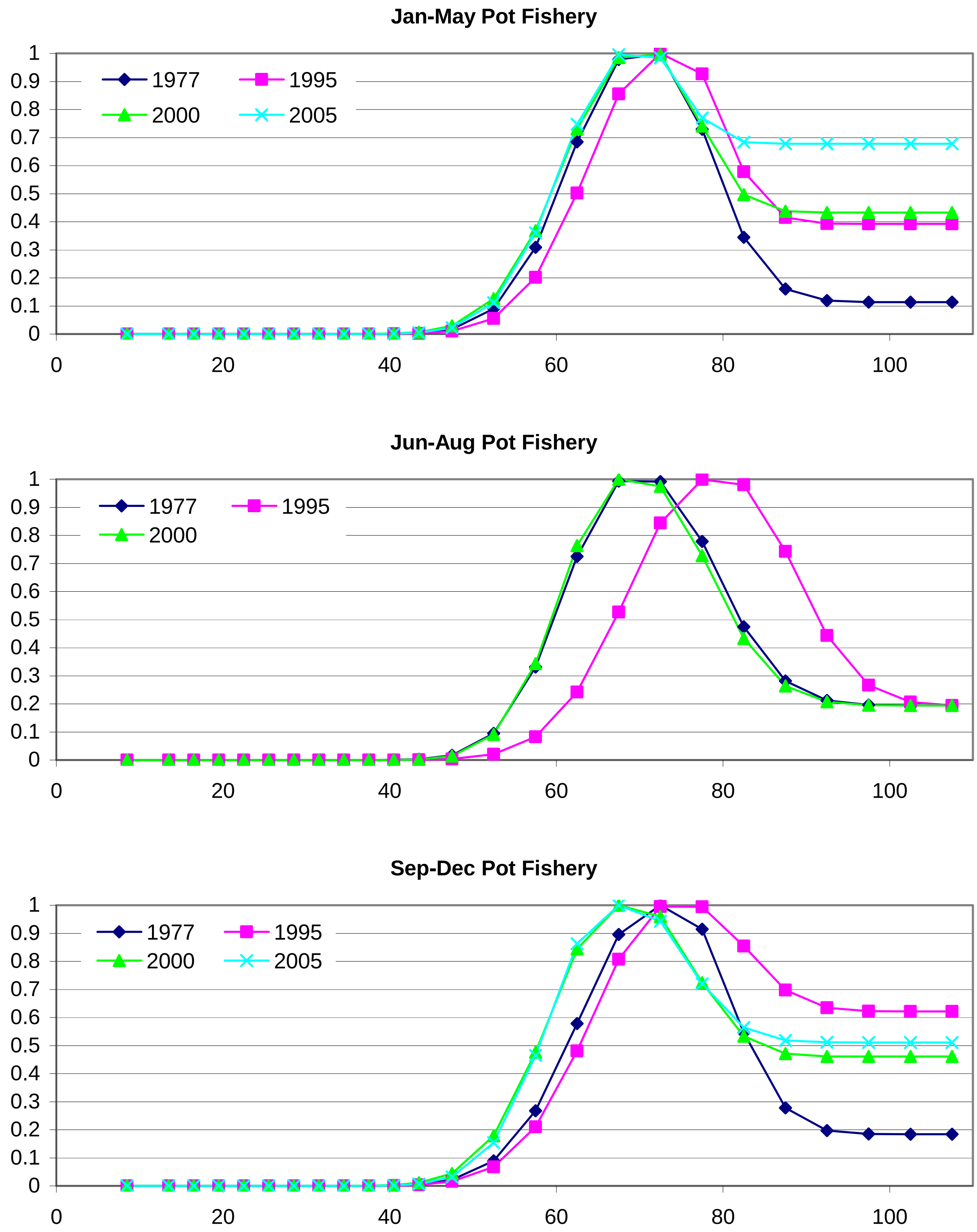
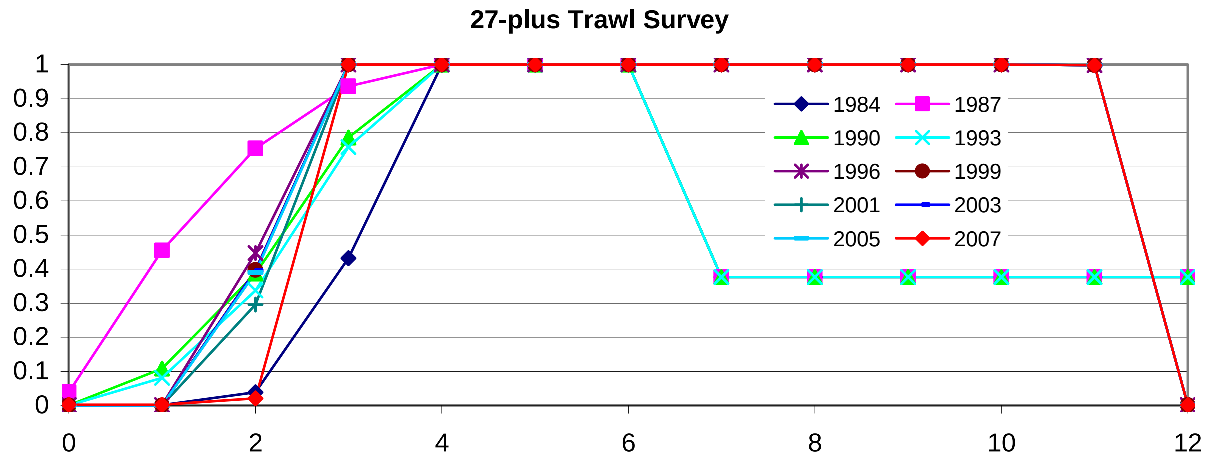
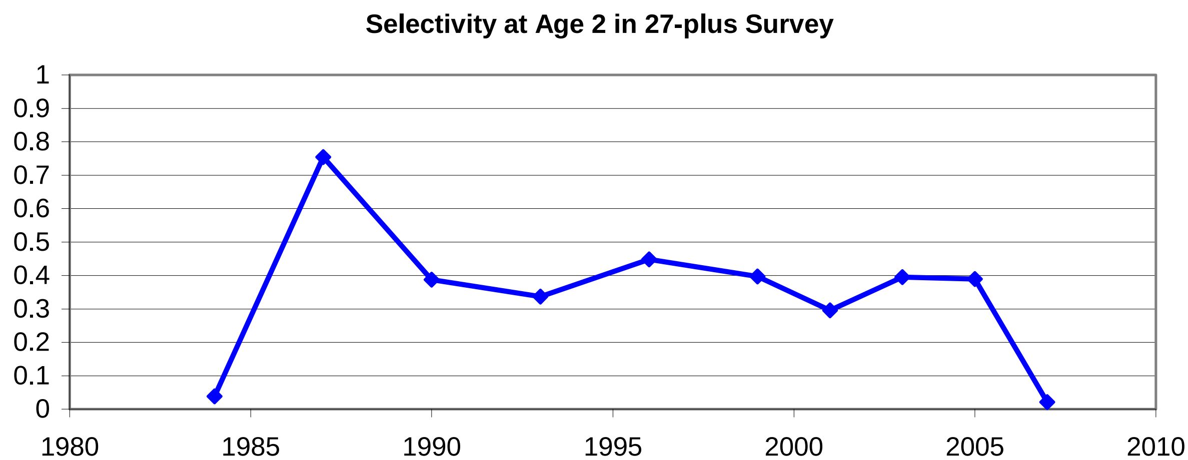


Figure 2.4c. Pot fishery selectivity by season and time block (line labels refer to beginning year of time block), as estimated by Model B.





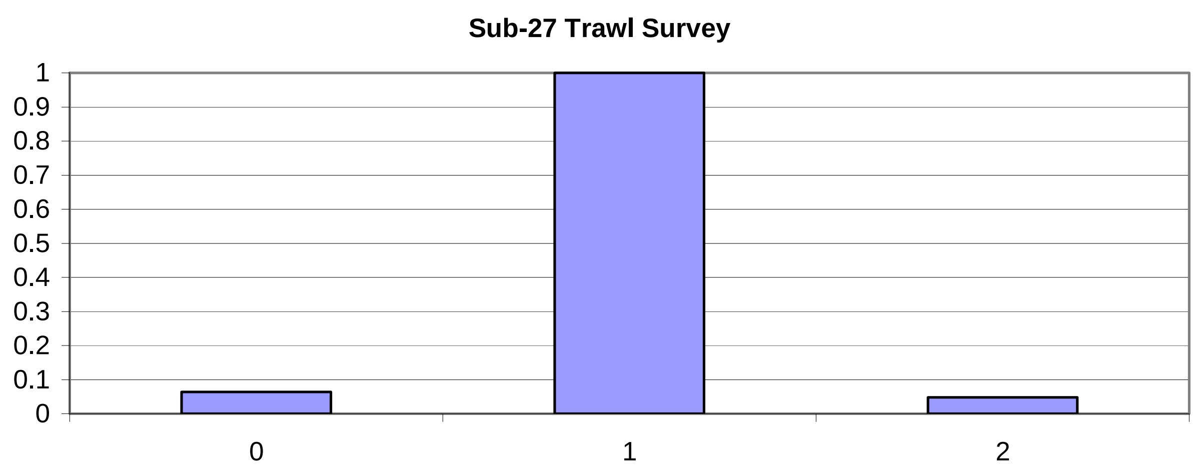


Figure 2.4d. Survey selectivity by season and time block (line labels refer to beginning year of time block), as estimated by Model B.

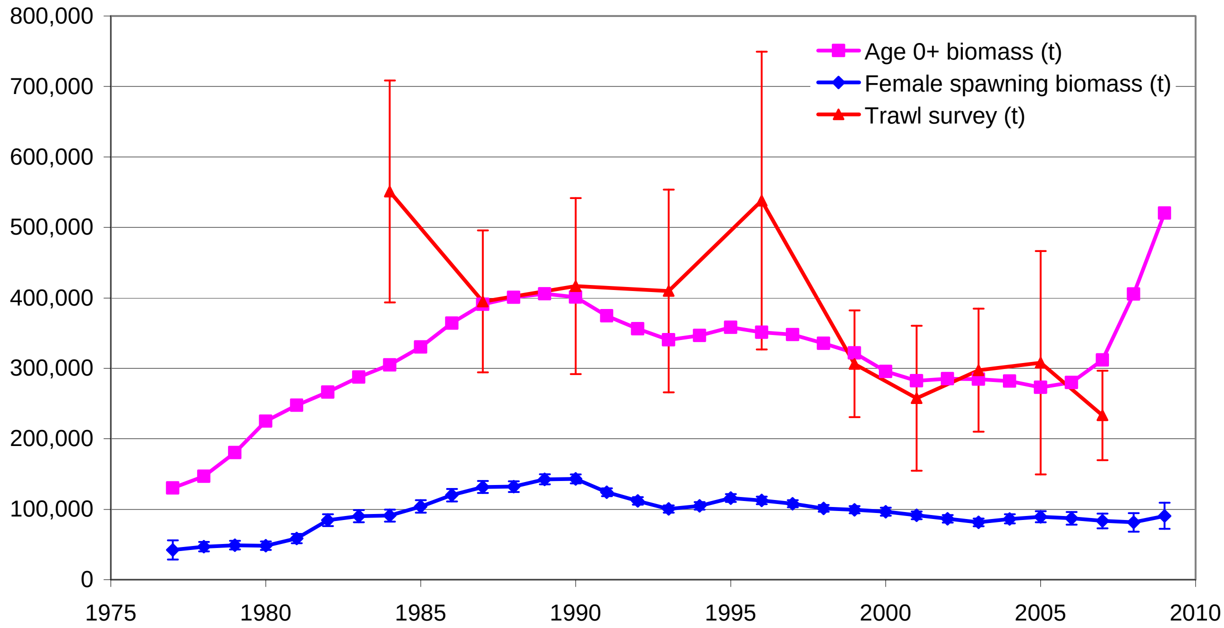


Figure 2.5—Biomass time trends (age 0+ biomass, female spawning biomass, survey biomass) of GOA Pacific cod as determined by final parameter estimates (Model B), with 95% confidence intervals for spawning biomass and survey biomass.

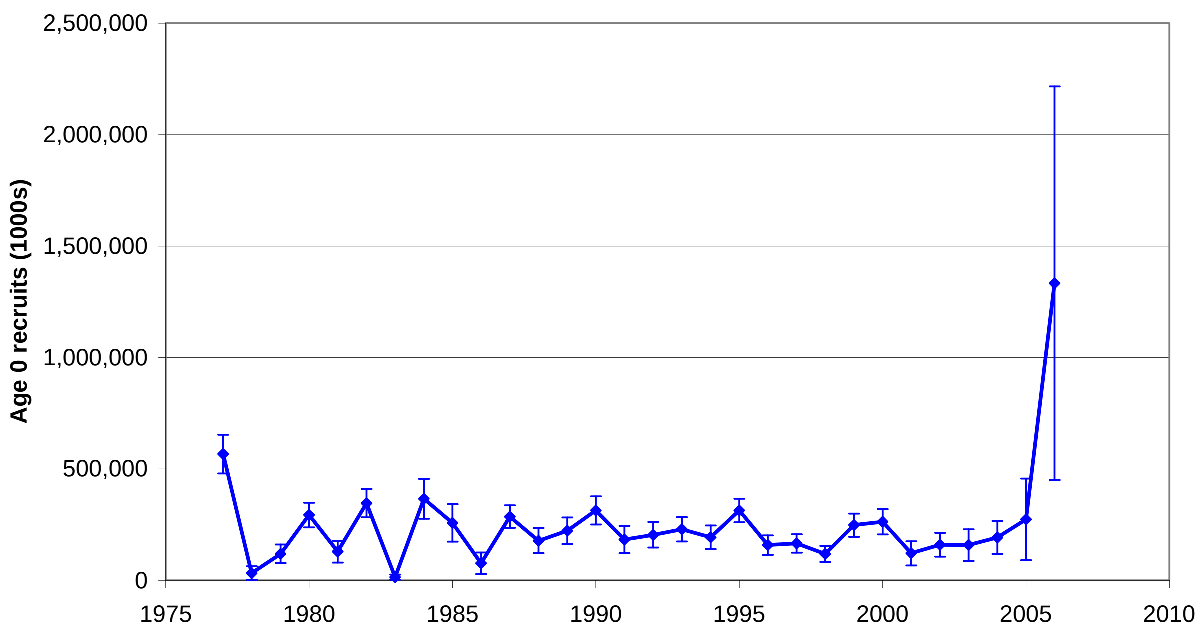


Figure 2.6—Time series of GOA Pacific cod recruitment at age 0, with 95% confidence intervals, as determined by final parameter estimates (Model B).

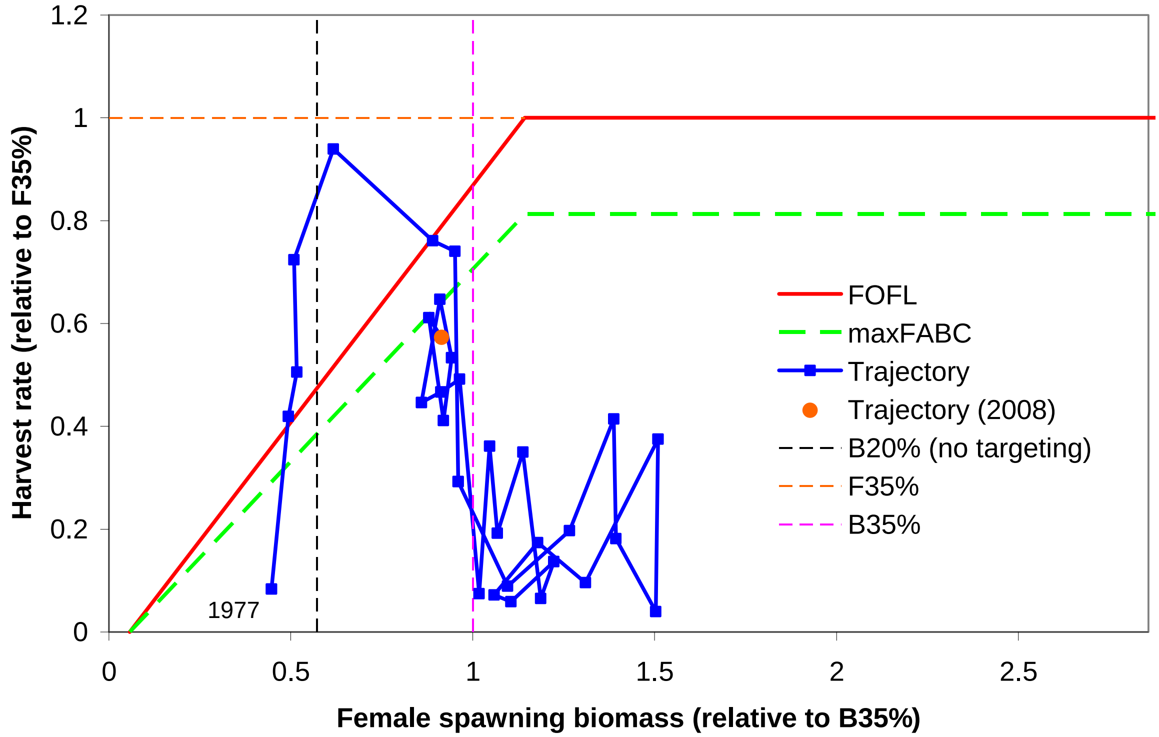


Figure 2.7—Trajectory of GOA Pacific cod fishing mortality and female spawning biomass as estimated by Model B, 1977-2008. Because Pacific cod is a key prey of Steller sea lions, harvests of Pacific cod would be restricted to incidental catch in the event that spawning biomass fell below $B_{20\%}$.

Attachment 2.1: An exploration of alternative models of the Gulf of Alaska Pacific cod stock

Grant G. Thompson, James N. Ianelli, and Mark E. Wilkins

U.S. Department of Commerce

National Oceanic and Atmospheric Administration

National Marine Fisheries Service

Alaska Fisheries Science Center

7600 Sand Point Way NE., Seattle, WA 98115-6349

Introduction

This document represents an effort to respond to comments made by the GOA Plan Team on last year's assessment of the Pacific cod (*Gadus macrocephalus*) stock in the Gulf of Alaska (Thompson et al. 2007b) and to explore new features of Stock Synthesis for possible use in this year's assessment.

Three models are presented here. Model 1 is the model used in the 2006 assessment. Model 2 is the model used in the 2007 assessment. Model 3 uses some of the newly available features of Stock Synthesis and addresses Plan Team comments.

Comments from the GOA Plan Team Minutes

"The Team questioned the re-estimated weight-at-length in last year's assessment which was not included this year, and requested clarification on why the data are restricted to survey length-weight and do not include the observer length-weight data as well.... The Team suggested including a table of sample sizes for the next assessment and that other sources of information on length-weight be included, especially for fisheries data that may apply during seasons other than the summer when survey data are collected." The weight-at-length parameters used in Model 3 were derived from fishery data. Estimation of these parameters, together with a table of sample sizes, is presented in the "Parameters Estimated Independently" section.

"The Plan Team recommends that the author look at variability in length-weight data, specifically intra-annual variability (previously looked at inter-annual variability) for the subsequent assessment." The weight-at-length parameters used in Model 3 vary seasonally.

"The Team requested that error bars be included in the length at age figure to indicate the low number of samples and the impact on results particularly notable at higher ages." Figure 2.1.4 includes the requested error bars.

"The Team notes that previous models have had time-varying changes in fishery selectivity and this has been removed in this model. Previous configurations had a different selectivity from 2000-present to account for the modification to fishery selectivity as a result of SSL RPAs." Model 3 defines selectivity schedules in terms of fishery-specific blocks of years.

Comments from the 2007 GOA SAFE Report Introduction

"The Team recommends that the current model be treated as any new model and be reviewed at next September's Plan Team meeting, alongside previously accepted models for comparison." The model presented in last year's assessment was the "current" model at the time the above comment was written. It is included here as Model 2. The previously accepted model was the one presented in the 2006 assessment (Thompson et al. 2006). It is included here as Model 1.

Data

The basic data sources in all three models are the NMFS bottom trawl survey and the fisheries. In all three models, fisheries are structured by gear (trawl, longline, and pot) and, to some extent at least, season (Jan-May, Jun-Aug, Sep-Dec). Data types include relative abundance from the survey, catch from the fisheries, size composition from the survey and fisheries, age composition from the survey and mean size at age from the survey. Catch per unit effort data from the fisheries are sometimes included for purposes of comparison, but are not used in parameter estimation. The data sets for Models 1 and 2 were described in the 2005 and 2006 assessments, respectively. Generally speaking, the data used in Model 1 are a subset of the data used in Model 2, which in turn are a subset of the data used in Model 3.

For Model 3, two changes were made to the data file used to develop Model 2 in last year's assessment:

1. Each survey abundance estimate and each survey size composition vector was split into two portions: the portion consisting of fish smaller than 27 cm (referred to as the "sub-27" survey), and the portion consisting of fish 27 cm and larger (referred to as the "27-plus" survey).
2. The observer database for the years prior to initiation of the domestic observer was queried to determine if the data file used in recent GOA Pacific cod assessments contains all available size composition data from those years. Several new size composition records for years prior to 1990 were added to the data file as a result.

Analytic Approach

Model Structure

Assessment Software

Model 1, from the 2006 assessment, was developed using Stock Synthesis 2, version 1.23d. Model 2, from the 2007 assessment, was developed using Stock Synthesis 2, version 2.00i. The nomenclature pertaining to revisions of the Stock Synthesis (SS) program has been modified since last year, with new versions taking labels of the form "SS-Vm.nnx." Model 3 was developed under SS-V3.01f. This version of SS includes two new features that will be explored in Model 3:

1. Ability to specify seasonally varying weight-at-length parameters.
2. Ability to specify separate log recruitment deviation vectors (with a common standard deviation), for two recruitment regimes.

Alternative Models

Table 2.1.1 lists all of the features that distinguish the models from one another. The table is structured as follows: The column labeled "Feature" lists every feature for which different specifications are used in at least two of the models. There are 32 such features. These are divided into six groups: data structure, estimation, life history, initial age structure and recruitment, survey catchability, and selectivity. The other three columns list how each feature is specified in (or not applicable to) the respective model. In the columns for Models 2 and 3, cells shaded yellow indicate that the specification of the respective feature (row) is identical to the specification used in Model 1. In the column labeled Model 3, cells shaded blue indicate that the specification of the respective feature (row) is identical to the specification used in Model 2. Of the 32 listed features, Models 1 and 2 differ with respect to 22 (69%), Models 2 and 3 differ with respect to 18 (56%), and Models 1 and 3 differ with respect to 31 (97%).

Model 1, although taken from the 2006 assessment, was for the most part identical to the model used in the 2005 assessment (Thompson and Dorn 2005). Because it has been published previously, just a few of its distinguishing features are listed below:

1. Fishery data structure was only partially seasonal; specifically, the catch data are structured with respect to all three seasons (Jan-May, Jun-Aug, Sep-Dec), but the size composition data for the trawl fishery uses only two seasons (Jan-May and an aggregated Jun-Dec season), and the size composition data for the longline and pot fisheries are not seasonally structured at all.
2. Survey abundance was measured in units of biomass.
3. Nonuniform priors were specified for nearly all parameters.
4. The natural mortality rate *M* was fixed at a value of 0.37.
5. All parameters governing the distribution of length at age were estimated externally.
6. The starting year was set at 1964, with initial numbers at age assumed to be in equilibrium.
7. Survey catchability was fixed at a value of 1.0.
8. Fishery selectivities were estimated independently for each of three “blocks” of years.
9. Survey selectivity was modeled as a function of length.
10. The descending limbs of all selectivity curves were estimated freely.

Model 2 was taken from the 2007 assessment. When it was developed in 2007, Model 2 represented an attempt to use the same assumptions found in the authors’ recommended model from the 2007 assessment of the Pacific cod stock in the Bering Sea, although some of the Bering Sea model assumptions were abandoned for the GOA when it appeared that they did not yield reasonable results. Because Model 2 has been published previously, just a few of its distinguishing features are listed below:

1. Fishery data structure was fully seasonal. Both catch data and size composition data were structured with respect to all three seasons (Jan-May, Jun-Aug, Sep-Dec).
2. Survey abundance was measured in units of individual fish.
3. Uniform priors were specified for all parameters.
4. The natural mortality rate *M* was fixed at a value of 0.38, based on the method of Jensen (1996) and the age at 50% maturity estimated by Stark (2007).
5. All parameters governing the distribution of length at age were estimated internally.
6. The starting year was set at 1977, with initial numbers at ages 1, 2, and 3 estimated freely.
7. Survey catchability was fixed at a value of 0.92, based on Nichol et al. (2007).
8. Fishery selectivities were constant over all years.
9. Survey selectivity was modeled as a function of length.
10. The descending limbs of all selectivity curves were estimated freely, except that survey selectivity was forced to be asymptotic.

Model 3 uses the newly available features of SS listed above, addresses GOA Plan Team comments regarding the data used to estimate weigh-at-length parameters, use of season-specific weight at length, and use of time-varying fishery selectivity. Development of Model 3 involved a lengthy exploration of alternative model structures, during which nearly 400 different models were investigated. Because this is a new model, the 18 features that distinguish Model 3 from Model 2 are described in some detail below:

1. As noted in the Data section, Model 3 splits each survey abundance estimate and each survey size composition vector is split into sub-27 and 27-plus portions (Model 2 did not). The reason for this is illustrated in Figure 2.1.1, which shows the long-term size distributions from the Bering Sea (blue) and GOA (pink) bottom trawl surveys up to 50 cm. The BS survey shows three fairly distinct modes within the 10-50 cm range at about 17 cm (solid red), 33 cm (solid green), and 45 cm (solid brown), which have been interpreted as corresponding to the mean sizes at ages 1, 2, and 3, respectively. In contrast, the GOA survey shows a fairly distinct mode at about 20 cm, and

then what appears to be a mixture of distributions from about 30 cm upward. Two interpretations of the GOA distribution appear to be possible: Either mean length at age 1 is about 20 cm, and mean length at age 2 is somewhere upward of 40 cm; or the GOA survey misses age 2 fish more than it misses age 1 or age 3 fish. The first interpretation seems unlikely, because it would imply that the growth pattern in the GOA is vastly different from the growth pattern in the Bering Sea, yet the AFSC age readers estimate mean GOA sizes at ages 1 (dashed red), 2 (dashed green), and 3 (dashed brown) that are all within about 3 cm of the corresponding Bering Sea size modes. Assuming that the second interpretation is correct, a bimodal survey selectivity pattern is implied. However, the recommended SS selectivity pattern (#24) does not allow bimodal selectivity. This impasse was resolved by splitting the survey time series into a pair of parallel time series, in which fish that are likely of ages 0 or 1 are separated from fish that likely of ages 2 and older. Assuming that the distribution of age 1 fish is approximately symmetrical around 20 cm, it is unlikely that many age 1 fish are larger than about 26 cm at the time of the survey (Figure 2.1.1). Given that the boundaries of the size bins in that general vicinity are 21-23, 24-26, and 27-29 cm, it seemed appropriate to choose 26 cm as the upper bound for the portion of the surveys representing ages 0 and 1, and 27 cm as the lower bound for the portion of the surveys representing ages 2 and older. Once the size boundaries were established, splitting the size composition time series was straightforward. Partitioning the point estimates for the survey abundance time series was also straightforward. However, partitioning the variances for the survey abundance time series involved an additional assumption, viz., that the variance for each portion (sub-27 and 27-plus) was proportional to the point estimate of abundance for that portion.

2. Previous models, including Model 2, set the input sample size for size composition data equal to the square root of the actual sample size. Model 3, on the other hand, used a multi-step procedure to set the input sample size. Based on a result from last year's BSAI Pacific cod assessment (Thompson et al. 2007a), fishery size composition data from years prior to 1999 were weighted initially by a factor of 0.16, and fishery size composition data from years after 1998 were weighted initially by a factor of 0.34. Survey size composition data were weighted initially by a factor of 0.052. These steps resulted in an initial set of input sample sizes with an average value of 1649. All sample sizes were then multiplied by a factor of 300/1649, so that the average input sample size, across all fisheries and surveys, was 300. The average input sample size for the surveys was 100 (the initial survey weighting factor of 0.052 was chosen to achieve this result).
3. For the age composition data, the input sample size was proportional to the number of fish aged, with the proportionality constant chosen so as to result in an average input sample size of 100. Model 2 used in average input sample size of 300.
4. The first reference age for estimation of length-at-age parameters, *A1*, was changed from 1 year to 1.5417 to facilitate comparison of the long-term survey size composition with the estimated length at age distribution corresponding to the mid-point of the Jun-Aug season. Model 2 set the first reference age equal to 1.0.
5. The spread of the length-at-age distribution is estimated by modeling the coefficient of variation as a linear function of length at age. Model 2 used the standard deviation, rather than the coefficient of variation, as the dependent variable. The option used to define variability in length at age (of which SS provides four), was determined by maximum likelihood. The variability in length at *A1* was constrained by the relevant measure of spread (coefficient of variation or standard deviation, depending on the option used to define variability in length at age) associated with a normal distribution fit to the ascending limb of the first mode in the long-term bottom trawl survey size distribution, conditional on the mean being set equal to *L1* (the estimated length at age *A1*).
6. Per GOA Plan Team request, observer data were used to estimate weight-at-length parameters. Model 2 used weight-length data from the same fish used to estimate the age-length keys, all of which came from the bottom trawl survey.

7. Per GOA Plan Team request, seasonal weight-at-length schedules were used. Model 2 assumed a single weight-at-length schedule.
8. As with the last three assessments, the input standard deviation of log recruitment deviations (σ_R) was estimated iteratively. However, instead of basing the estimation on the entire time series of estimated deviations (as in previous assessments), only those deviations corresponding to the current environmental regime (1977-2006) were used. This was done to address a concern expressed by the SSC with respect to last year's BSAI Pacific cod assessment, where the parametric estimate of expected recruitment was significantly different from the average of the estimated recruitments corresponding to the current environmental regime.
9. Separate vectors were specified for the 1974-1976 and 1977-2006 log recruitment deviations. This was done to address the same SSC concern. Previous assessments used a single vector, as was required by SS at the time. The number of freely estimated elements in the initial numbers-at-age vector was determined by minimum AIC.
10. Catchability of the 27-plus survey for the years 1984-1995 was estimated freely, while catchability of the 27-plus survey for the years 1996-2007 was fixed at 0.913 (corresponding to a bootstrap mean derived from the data used by Nichol et al. 2007). The breakpoint coincides with the switch from 30-minute to 15-minute tows in the survey design. Model 2 assumed a constant catchability of 0.92 for the entire time series.
11. Catchability of the sub-27 survey was estimated internally as a random walk, with $\sigma = 0.2$. Model 2 did not use a separate sub-27 survey.
12. Model 2 imposed constant fishery selectivity (which was a departure from previous models). Responding to a comment from the GOA Plan Team, time-varying fishery selectivity was restored in Model 3. However, unlike the fixed block structure used prior to last year's assessment (consisting of pre-1987, 1988-1999, and 2000-2005 blocks), a set of fishery-specific block structures was used in Model 3, based on the following algorithm:
    a. Through extensive trial and error in exploring alternative initial values for model parameters, estimate parameter values for a model in which selectivities for all fisheries are defined, to the greatest extent allowed by the data, in terms of the following (approximately) "5-year" blocks: 1977-1979, 1980-1984, 1985-1989, 1990-1994, 1995-1999, 2000-2004, and 2005-2007. This configuration becomes the provisional block structure.
    b. Compute the value of Akaike's Information Criterion (AIC) for the provisional block structure.
    c. Find the fishery with the smallest average input sample size, then fit models with the following three block structures:

       "10-year" blocks: 1977-1979, 1980-1989, 1990-1999, and 2000-2007.

       "20-year" blocks: 1977-1989, 1990-2007

       Single block: 1977-2007

    d. Compute the AIC value for each of the above block structures. If the smallest of these AIC values is less than the AIC value for the provisional block structure, the block structure with the smallest AIC value becomes the new provisional block structure.
    e. Find the fishery with the next smallest average input sample size, then repeat steps (c) and (d). Once all fisheries have been explored, the provisional block structure becomes the final block structure.
13. In Model 2, the descending limb of all fishery selectivities was free. In Model 3, all trawl fisheries were forced to exhibit asymptotic selectivity. This was done to help stabilize the model and to make the structure more consistent with that of the Bering Sea Pacific cod model. The choice of trawl gear as the set of fishery selectivities to constrain was based on comparing the

selectivities of all gear types in an unconstrained model and selecting the gear whose selectivities came closest to asymptotic form.

14. To reduce the complexity of the selectivity function and avoid a tendency for the model to produce highly "kinked" selectivity curves, Model 3 set a lower bound of 5.0 on the descending "width" parameter of each selectivity schedule based on pattern 24. This implies that the inflection point of the descending limb must be at least 8.6 units (cm or years, depending on whether selectivity is defined in terms of length or age) beyond the largest length (or oldest age) at which selectivity = 1.0. Model 2 set a lower bound of −10 on the descending "width" parameters.
15. For the sub-27 survey, Model 3 did not use selectivity pattern 24, because there are at most 3 ages (0, 1, and 2) included in the sub-27 survey, but selectivity pattern 24 has six parameters. It is more efficient simply to assign a selectivity to each of the three ages (3 parameters), and assume that selectivity at all other ages is zero. Model 2 did not use a separate sub-27 survey.
16. Model 3 treats selectivity of the 27-plus survey as a function of age, to be consistent with the Bering Sea Pacific cod model. Previous GOA Pacific cod models treated survey selectivity as a function of length. It has been suggested that Pacific cod mean length at age varies significantly between year classes. Although SS allows for variability in mean length at age, the variability is with respect to time, not year class. If survey selectivity is modeled as a function of length, there is a danger that variability in length at age will be confounded with variability in survey selectivity. Age-based selectivity is used in an attempt to circumvent these problems.
17. Model 2 used annual deviations to model variability in the ascending limb of the survey selectivity schedule. However, this results in superfluous parameters being estimated, because deviations are estimated for each year regardless of whether a survey takes place. Instead, Model 3 defines a separate selectivity block for each survey year.
18. For the remaining parameters of the 27-plus survey selectivity schedule, Model 3 treats the years 1984-1993 and 1996-2007 as separate blocks, to coincide with the switch from 30-minute to 15-minute tows in the survey design. Model 2 assumed that the survey selectivity schedule, except for the ascending limb, was constant over the entire time series.

Parameters Estimated Independently

All parameters estimated independently are fixed at the values used in last year's assessment, except for the parameters governing the weight-at-length schedule in Model 3.

In recent assessments, bottom trawl survey data were used to estimate the multiplicative constant α and exponent β at values of 6.242×10^{-6} and 3.137, respectively. Models 1-2 use this pair of values.

For Model 3, all weight-length records from the observer database (both shore-based and at-sea samples) were used to estimate seasonally varying values of the weight-at-length parameters. This was done in response to the GOA Plan Team's request for use of seasonal weight at length. Values of α and β, together with sample sizes, were as follow:

Season:	1	2	3	Annual
α:	9.704×10^{-6}	1.621×10^{-5}	1.789×10^{-5}	1.021×10^{-5}
β:	3.052	2.915	2.895	3.038
Samples:	59,589	1,552	7,750	68,891

The seasonal schedules corresponding to the above parameter values are plotted together with the annual schedule and the schedule used in previous assessments in Figure 2.1.1. Generally, the schedule used in previous assessments is bracketed by the seasonal schedules. The seasonal model gives a statistically significant improvement over the new annual model (AIC = 57,684 for the annual model; AIC = 57,211 for the seasonal model).

Parameters Estimated Conditionally

Parameters estimated within SS include the length-at-age parameters (Models 2 and 3), parameters governing variability in length at age (Models 2 and 3), log mean recruitment under one environmental regime (Model 1) or two environmental regimes (Models 2-3), annual recruitment deviations (all models), annual fishing mortality rates (all models), bottom trawl survey catchability (Model 3, except for the 1996-2007 period in the 27-plus survey), selectivity parameters (all models; see below).

As in last year's assessment, pattern 24 is used to describe the selectivity functions (except the selectivity function for the sub-27 survey in Model 3). This pattern uses the following six parameters:

1. Beginning of the peak region (where the curve first reaches a value of 1.0)
2. Width of the peak region (where the curve first departs from a value of 1.0)
3. Ascending "width" (equal to twice the variance of the underlying normal distribution)
4. Descending width
5. Selectivity at minimum length (or age)
6. Selectivity at maximum length (or age)

All but parameter #1 are transformed: The widths are log-transformed and the other parameters are logit-transformed (Table 2.1.1). Selectivity at minimum length (or age) is fixed at 0 for all fisheries and surveys, except that it is a free parameter in the bottom trawl survey under Model 4.

As in last year's assessment, uniform prior distributions were used for all parameters.

Generally, for parameters estimated within SS, the estimator used is the posterior mode. In the case of Models 2 and 3, where all priors are uniform, the posterior mode is equivalent to the maximum likelihood value. In Models 2 and 3, certain parameters were taken out of the internal estimation process, viz., parameters that were pinned against one of the bounds of their respective uniform priors and parameters whose standard deviations exceeded 10.0. Parameters that were bound were fixed at their bound values and removed from the estimation process. Parameters with standard deviations in excess of 10.0 were fixed at their respective (apparent) maximum likelihood values and removed from the estimation process. Because it used nonuniform priors, Model 1 did not have any parameters pinned against bounds. Parameters with large standard deviations were not treated differently from other parameters in Model 1.

Results

Goodness of Fit

Table 2.1.2 compares negative log likelihood values across models, on a component-by-component basis. It should be emphasized that likelihoods are not strictly comparable across models for several reasons, including: 1) Different amounts of data are included in the respective data files, 2) different input sample sizes are specified for some components, and 3) surveys and fisheries are partitioned differently.

Table 2.1.2 also shows the number of parameters in each model. Model 1 has the fewest parameters (121), and Model 3 has the most (205). Model 3 has more parameters than the other models primarily because it allows for time-varying fishery selectivity. Note that annual fishing mortality rates do not count as parameters.

Table 2.1.3a compares average input sample sizes and average "effective" sample sizes for the size composition and age composition data. As with the likelihoods, it is often difficult to compare effective sample sizes across models, and for similar reasons. Models 2 and 3 are difficult to compare with Model 1 because the fisheries are partitioned differently, and Model 3 is difficult to compare with Model 2 because the input sample sizes are very different.

Models 3 fits the age data slightly better on average than does Model 2, even though the average input sample size for Model 2 is three times higher than for Model 3. However, when the fits to the age data are examined on a year-by-year basis (Table 2.1.3b), it can be seen that the distribution of effective sample sizes is highly skewed for both Models 2 and 3, as the effective sample size for the 2001 age composition is about an order of magnitude higher than the effective sample sizes for the other age compositions.

Figure 2.1.3 shows how the three models fit the various sets of relative abundance data. Figure 2.1.3a shows the fits to the trawl fishery CPUE data by season, Figure 2.1.3b shows the fits to the longline fishery CPUE data by season, Figure 2.1.3c shows the fits to the pot fishery CPUE data by season, and Figure 2.1.3d shows the fits to the bottom trawl survey (fits to fishery CPUE data are not available for Model 1). It should be emphasized that the models are not attempting to fit the fishery CPUE data; these are shown for comparative purposes only.

Estimates of Parameters, Length at Age, and Selectivity at Length or Age

Table 2.1.4 shows estimates of some parameters common to most of the models, with accompanying standard deviations. Some of the points to note in Table 2.1.4 are the following:

1. The estimates of L1 are comparable between Models 1 and 2, but not between Model 3 and the other models, because a different value of A1 is used in Model 3.
2. Model 1 estimates the largest effect of the 1977 regime shift (R1 offset), and Model 3 the smallest.
3. Model 2 produces a higher estimate of σ_R than Models 1 or 3, but all three values are small by typical gadid standards, and much smaller than values estimated for Pacific cod in the Bering Sea.
4. Model 3 estimates that the longer tows used in surveys prior to 1996 resulted in a catchability greater than unity.

Figure 2.1.4 describes the length-at-age relationship, showing mean lengths at age for each model along with the mean lengths at age from the AFSC age reading unit (with 95% confidence intervals). All three models fit the reader mean lengths fairly well through about age 8. After age 8, Model 2 tends to give higher mean lengths at age than the other two models, and succeeds in passing through the 95% confidence intervals for all ages through 11, missing the 95% confidence interval for age 12 only. Models 1 and 3, on the other hand, undershoot the 95% confidence interval for age 9, but succeed in passing through all the other 95% confidence intervals.

Figure 2.1.5 shows how selectivity is estimated by Models 1 and 2. Model 1 selectivities are shown in Figure 2.1.5a. Selectivities for the Jan-May and Jun-Dec trawl fisheries are combined in the upper left panel, with the Jun-Dec selectivities distinguished by the use of “open” symbols. The seasonal structure of Model 1 is only partial, and separate selectivities are defined for fixed blocks of years (except for the Jan-May trawl fishery, which uses one fewer block than the other fisheries due to unavailability of data). Model 2 selectivities are shown in Figure 2.1.5b. Model 2 is fully seasonal, but assumes that selectivity for a given gear/season is constant over all years. Note that survey selectivity is expressed as a function of length in both Models 1 and 2.

Figure 2.1.6 shows how selectivity is estimated by Model 3. All fisheries are fully seasonal, and fishery-specific blocks are used to describe variability in fishery selectivity over time. Trawl fishery, longline fishery, and pot fishery selectivities are shown in Figures 2.1.6a, 2.1.6b, and 2.1.6c, respectively. Figure 2.1.6d shows selectivity, modeled as a function of age rather than length, for the 27-plus survey (upper panel) and sub-27 survey (lower panel). The sub-27 survey is assumed to capture only ages 0-2, so individual selectivities are estimated for each of these ages rather than attempting to fit a parametric curve.

Estimates of Time Series

Figure 2.1.7 shows how the three models estimate the time series of female spawning biomass, log recruitment deviations, and annual exploitation rate (catch divided by start-of-year biomass). Each time series is accompanied by 95% confidence intervals (these are not available for exploitation rate in the cases of Models 1 and 2). Values along the horizontal axes have been staggered slightly to reduce overplotting.

In terms of female spawning biomass (upper panel of Figure 2.1.7), the qualitative shapes of the trajectories estimated by Models 1 and 2 have some similarities, tending to increase throughout the 1980s to an initial peak in 1990, followed by gradual up and down fluctuations (mostly down in the case of Model 2). Model 2 shows higher biomasses than Model 1 throughout most of the time series until about 2003, at which point the trajectories cross. Model 3, on the other hand, shows a fairly consistent, gradual decline throughout the time series. Model 3 estimates a higher spawning biomass than the other models in the early part of the time series, but after 1987 it estimates a lower spawning biomass than the other two models.

In terms of log recruitment deviations (middle panel of Figure 2.1.7), the trajectories from all three models are similar during the middle portion of the time series (from about 1983 through about 2001), but there are some discrepancies at either end of the time series. Toward the more recent end of the time series, all three models agree that the 2001 year class was very likely below average. Models 2 and 3 agree that the 2002 year class was also very likely below average, whereas the 95% confidence interval from Model 1 stretches into the positive domain. For the 2003-2005 year classes, the estimates from the three models tend to show considerable variability, and the point estimates are not particularly consistent. Models 2 and 3, however both estimate that the 2006 year class is very unlikely to be below average (Model 1 did not estimate the strength of the 2006 year class).

The versions of SS used to produce Models 1 and 2 did not provide standard deviations for the exploitation rate time series, so only Model 3 is represented in the lower panel of Figure 2.1.7. The overall trend in exploitation rates estimated by Model 3 is generally upward since the mid-1990s, although the short-term trend since 2004 has been downward.

Finally, Figure 2.1.8 shows the trajectories of total (age 0+) biomass estimated by all three models. The relationships between the trajectories are broadly similar to those for female spawning biomass shown in the upper panel of Figure 2.1.7. The time series of survey biomass estimates is also shown for comparison. Because all three models assume a catchability close to unity for at least a portion of the time series, all of the model trajectories overlap the survey biomass trajectory to some extent.

Discussion

This preliminary assessment is intended to illustrate the behavior of alternative model structures. The authors welcome comment on any issue pertaining to model structure, in particular:

1. Is the lower bound of 5.0 on selectivity parameter #4 specified in Model 3 appropriate for surveys, fisheries, both, or neither?
2. Is the algorithm used in Model 3 to specify selectivity blocks appropriate?
3. Is it necessary to split the GOA survey time series in terms of fish size and, if so, is the method used here the best way to accomplish this?
4. Is it appropriate to use mean size at age in the likelihood, given that this component has been removed from the Bering Sea Pacific cod model?
5. Have input sample sizes been specified appropriately?
6. Is age-based survey selectivity preferable to length-based survey selectivity?

References

Jensen, A. L. 1996. Beverton and Holt life history invariants result from optimal trade-off of reproduction and survival. *Canadian Journal of Fisheries and Aquatic Sciences* 53:820-822.

Nichol, D. G., T. Honkalehto, and G. G. Thompson. 2007. Proximity of Pacific cod to the sea floor: Using archival tags to estimate fish availability to research bottom trawls. *Fisheries Research* 86:129-135.

Stark, J. W. 2007. Geographic and seasonal variations in maturation and growth of female Pacific cod (*Gadus macrocephalus*) in the Gulf of Alaska and Bering Sea. *Fishery Bulletin* 105:396-407.

Thompson, G. G., and M. W. Dorn. 2005. Assessment of the Pacific cod stock in the Gulf of Alaska. *In* Plan Team for the Groundfish Fisheries of the Bering Sea/Aleutian Islands (compiler), Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska, p. 155-243. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.

Thompson, G. G., M. W. Dorn, and D. G. Nichol. 2006. Assessment of the Pacific cod stock in the Gulf of Alaska. *In* Plan Team for the Groundfish Fisheries of the Bering Sea/Aleutian Islands (compiler), Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska, p. 147-220. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.

Thompson, G. G., J. N. Ianelli, M. W. Dorn, S. Gaichas, and K. Aydin. 2007a. Assessment of the Pacific cod stock in the Eastern Bering Sea and Aleutian Islands Area. In Plan Team for Groundfish Fisheries of the Bering Sea/Aleutian Islands (compiler), Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands regions, p. 209-327. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.

Thompson, G. G., J. N. Ianelli, M. W. Dorn, and M. Wilkins. 2007b. Assessment of the Pacific cod stock in the Gulf of Alaska. *In* Plan Team for the Groundfish Fisheries of the Bering Sea/Aleutian Islands (compiler), Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska, p. 169-194. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.

Table 2.1.1. Features distinguishing the three models (yellow = same specification as Model 1, blue = same specification as Model 2).

Feature	Model 1 (2006)	Model 2 (2007)	Model 3 (new)
Seasonal fisheries?	Partially	Fully	Fully
Survey abundance units	Biomass	Individual fish	Individual fish
Split survey time series into 27-plus and sub-27?	No	No	Yes
Sizecomp input N	Square root of true N	Square root of true N	Complicated (see text)
Agecomp input N	Harmonic mean of bootstrap	Proportional to true N (ave=300)	Proportional to true N (ave=100)
Priors	Nonuniform	Uniform	Uniform
Treatment of bound parameters	n/a (none were bound)	Fixed at bound	Fixed at bound
Treatment of parameters with large std. dev.	Left free	Fixed if std. dev. > 10	Fixed if std. dev. > 10
Natural mortality rate	Fixed at 0.37	Fixed at 0.38	Fixed at 0.38
First reference age (A1)	1.5	1	1.5417
Second reference age (A2)	12	20	20
Estimation of length at age parameters	External	Internal	Internal
Form of length-at-age spread	CV=f(length at age)	SD=f(length at age)	CV=f(length at age)
Estimation of length-at-age spread	External	Internal	Internal (CV1 bound)
Data source used to estimate weight at length	Survey age-length data	Survey age-length data	Observer data
Variation in weight-at-length parameters	None	None	Seasonal
Basis of maturity schedule	Length	Age	Age
No. initial age groups estimated independently	0	3	3
Starting year	1964	1977	1977
Estimation of pre-1977 log mean recruitment	Iterative	Internal	Internal
Recruitment "devs" used to estimate σ_R	1964-2004	1974-2006	1977-2006
No. recruiment "dev" vectors	1	1	2 (1974-1976, 1977-2006), but 1 σ_R
Trawl survey catchability	Fixed at 1.00	Fixed at 0.92	Internal (pre-'96), fixed at 0.91 (post-'93)
Sub-27 survey catchability	n/a	n/a	Estimated internally as random walk
Blocks used to define fishery selectivity	1964-'86, 1987-'99, 2000-'05	None	Fishery-specific
Form of selectivity functions	8-parameter double logistic	6-parameter double normal	6-parameter double normal (except sub-27)
Fishery selectivities forced to be asymptotic	None	None	All trawl fisheries
Lower bound on descending selectivity "widths"	-10	-10	5
Form of selectivity function for sub-27 survey	n/a	n/a	Age-specific for 0,1,2; zero for other ages
Basis of trawl survey selectivity(ies)	Length	Length	Age
Variation in ascending limb of survey selectivity	None	Annual; sigma=0.2	One block per survey year (27-plus)
Blocks used in remainder of survey selectivity	None	None	1984-1993, 1997-2007 (27-plus)

Table 2.1.2. Comparison of objective function values.

Type	Fleet	Model 1	Model 2	Model 3
Relative abundance	Overall trawl survey	15.76	6.39	
Relative abundance	27-plus trawl survey			10.10
Relative abundance	Sub-27 trawl survey			8.47
Size composition	Jan-May trawl fishery	72.67	95.05	299.13
Size composition	Jun-Dec trawl fishery	173.34		
Size composition	Jun-Aug trawl fishery		57.57	101.79
Size composition	Sep-Dec trawl fishery		126.19	152.42
Size composition	Overall longline fishery	205.45		
Size composition	Jan-May longline fishery		47.93	328.56
Size composition	Jun-Aug longline fishery		22.10	59.61
Size composition	Sep-Dec longline fishery		150.77	133.53
Size composition	Overall pot fishery	124.61		
Size composition	Jan-May pot fishery		63.08	177.18
Size composition	Jun-Aug pot fishery		27.00	21.70
Size composition	Sep-Dec pot fishery		44.94	63.97
Size composition	Overall trawl survey	116.33	118.82	
Size composition	27-plus trawl survey			77.52
Size composition	Sub-27 trawl survey			36.01
Age composition	Overall trawl survey	8.93	125.55	
Age composition	27-plus trawl survey			36.15
Mean size at age	Overall trawl survey	68.56	114.35	
Mean size at age	27-plus trawl survey			143.88
Recruitment	n/a	76.06	25.69	27.37
Forecast recruitment	n/a			0.08
Parameter "devs"	n/a		5.98	
Priors	n/a	70.84	0.00	1.01
"Softbounds"	n/a			0.04
Initial catch	n/a	0.00	0.00	0.00
Total	n/a	932.56	1031.39	1678.52
Parameters	n/a	121	137	205

Notes

Likelihoods are not comparable between models, because:
1) Different amounts of data are included in the respective data files.
2) Different input sample sizes are specified.
3) Surveys and fisheries are partitioned differently.

Blank cells indicate that the respective component (row) is not applicable to that model (column).

"Softbounds" are a feature of SS that helps keep selectivity parameters away from bounds.

Table 2.1.3a. Mean input and effective ("Eff.") sample sizes. "Rec." = number of records.

		Model 1			Model 2			Model 3		
Kind	Fleet	Rec.	Input	Eff.	Rec.	Input	Eff.	Rec.	Input	Eff.
length	Jan-May trawl fishery	18	116	350	19	113	258	27	398	278
length	Jun-Dec trawl fishery	33	37	77						
length	Jun-Aug trawl fishery				14	29	51	22	57	104
length	Sep-Dec trawl fishery				22	39	105	25	76	88
length	Overall longline fishery	51	79	397						
length	Jan-May longline fishery				18	102	684	28	597	585
length	Jun-Aug longline fishery				13	15	65	20	58	124
length	Sep-Dec longline fishery				23	95	138	20	276	264
length	Overall pot fishery	41	92	334						
length	Jan-May pot fishery				18	154	297	18	1081	732
length	Jun-Aug pot fishery				10	34	95	10	95	313
length	Sep-Dec pot fishery				15	56	119	15	179	309
length	Overall trawl survey	9	114	124	10	121	67			
length	27-plus trawl survey							10	100	162
length	Sub-27 trawl survey							10	12	15
age	Overall trawl survey	2	56	51	5	300	103			
age	27-plus trawl survey							5	100	121

Table 2.1.3b. Input and effective sample sizes for age compositions.

	Model 1		Model 2		Model 3	
Year	Input	Effective	Input	Effective	Input	Effective
1996			335	49	112	27
1999			296	31	99	33
2001			326	349	109	495
2003	80	34	309	34	103	25
2005	31	68	233	50	78	27

Table 2.1.4. Estimates of some parameters common to most models, with standard deviations (Sdev).

	Model 1		Model 2		Model 3	
Parameter	Value	Sdev	Value	Sdev	Value	Sdev
L1	13.80	n/a	13.64	0.33	18.62	0.26
L2	93.00	n/a	139.57	5.97	107.01	1.20
K	0.11	n/a	0.06	0.010	0.13	0.004
CV1	0.14	n/a			0.13	n/a
CV2	-0.82	n/a			-0.66	0.087
SD1			3.03	0.30		
SD2			1.84	0.21		
R0	12.52	0.052	12.60	0.047	12.39	0.034
R1 offset	-1.14	n/a	-0.82	0.13	-0.28	0.07
σ_R	0.24	n/a	0.40	n/a	0.27	n/a
Initial F	0.004	0.000	0.043	0.006	0.015	0.001
Overall trawl survey lnQ	0.00	n/a	-0.083	n/a		
27-plus lnQ (1996-2007)					-0.091	n/a
27-plus lnQ offset (1984-1993)					0.78	0.11
Sub-27 lnQ (1984)					-2.26	0.34

Notes

"n/a" means that the parameter was estimated externally and so has no standard deviation
Blank cells indicate that the parameter (row) is not used in the respective model (column)
Reference age A1 corresponding to length L1 is 1.5417 years in Model 3 and 1 year in the others
L2 (length at A2 = 20 years) is fixed at 93 cm in Model 2 and estimated in the others
K = Brody growth coefficient
CV1 = coefficient of variation of length at reference age A1 (bound under Model 3)
CV2 = coefficient of variation of length at reference age A2, as log offset of CV1
SD1 = standard deviation of length at reference age A1
SD2 = standard deviation of length at reference age A2, as log offset of SD1
R0 = log mean recruitment for current (post-1976) environmental regime
R1 offset = log mean pre-1977 recruitment minus log mean post-1978 recruitment
σ_R = standard deviation of log recruitment deviations (not estimated within SS)
Initial F represents the equilibrium F used to initialize numbers at ages 4+ in the start year
Overall trawl survey lnQ represents ln(catchability) for the overall (unitary) trawl survey
27-plus lnQ (1996-2007) represents ln(catchability) for the 27-plus survey during years 1996-2007
27-plus lnQ (1984-1993) is expressed as a log offset of 27-plus lnQ (1996-2007)
Sub-27 lnQ (1984) represents ln(catchability) of the sub-27 survey in the 1st year of random walk

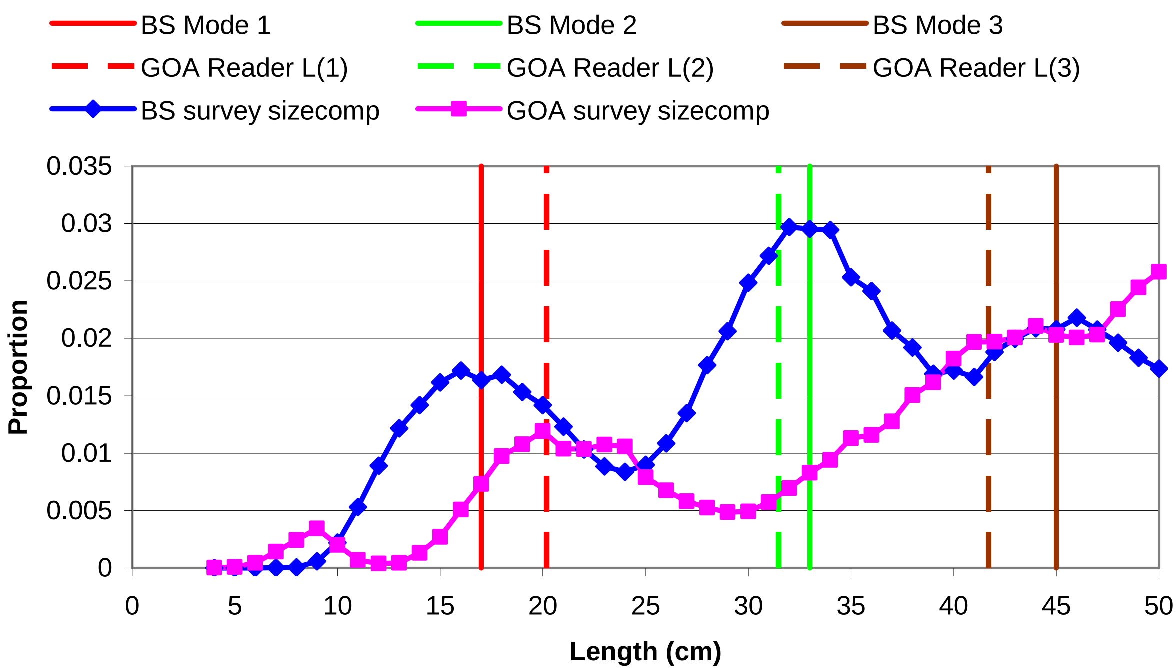


Figure 2.1.1. Long-term survey size distributions (to 50 cm) in the Bering Sea and GOA, with first three modes from the Bering Sea and first three GOA mean sizes at age from AFSC age readers.

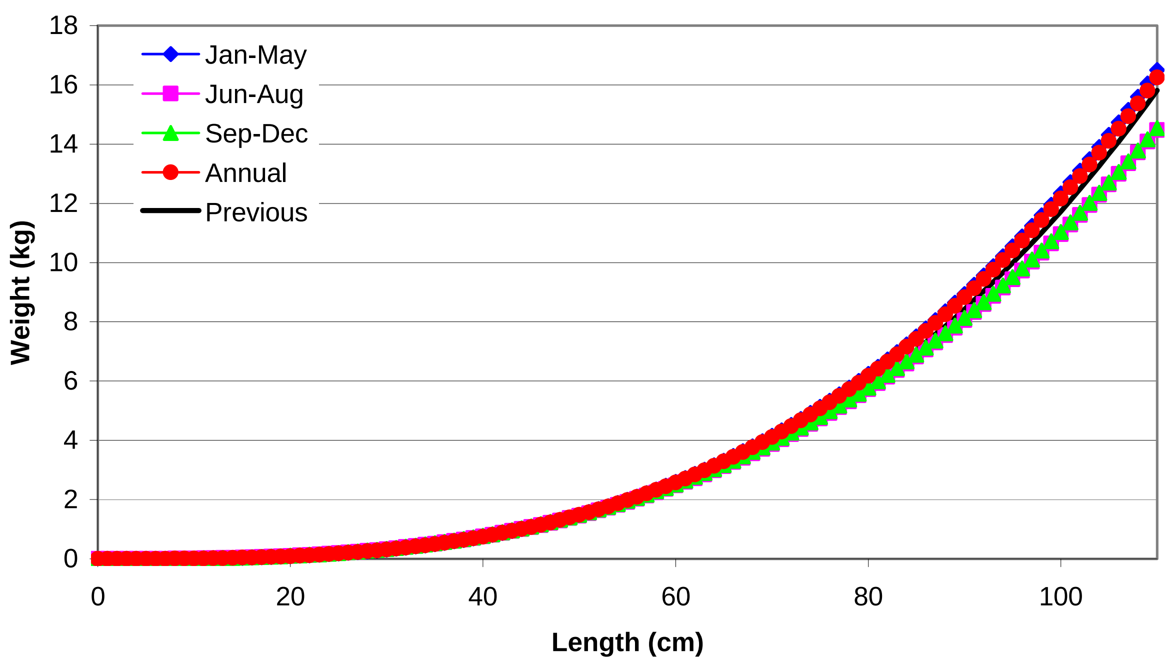


Figure 2.1.2. Weight at length as estimated by three seasonal schedules, the best fitting annual schedule, and the schedule used in previous assessments.

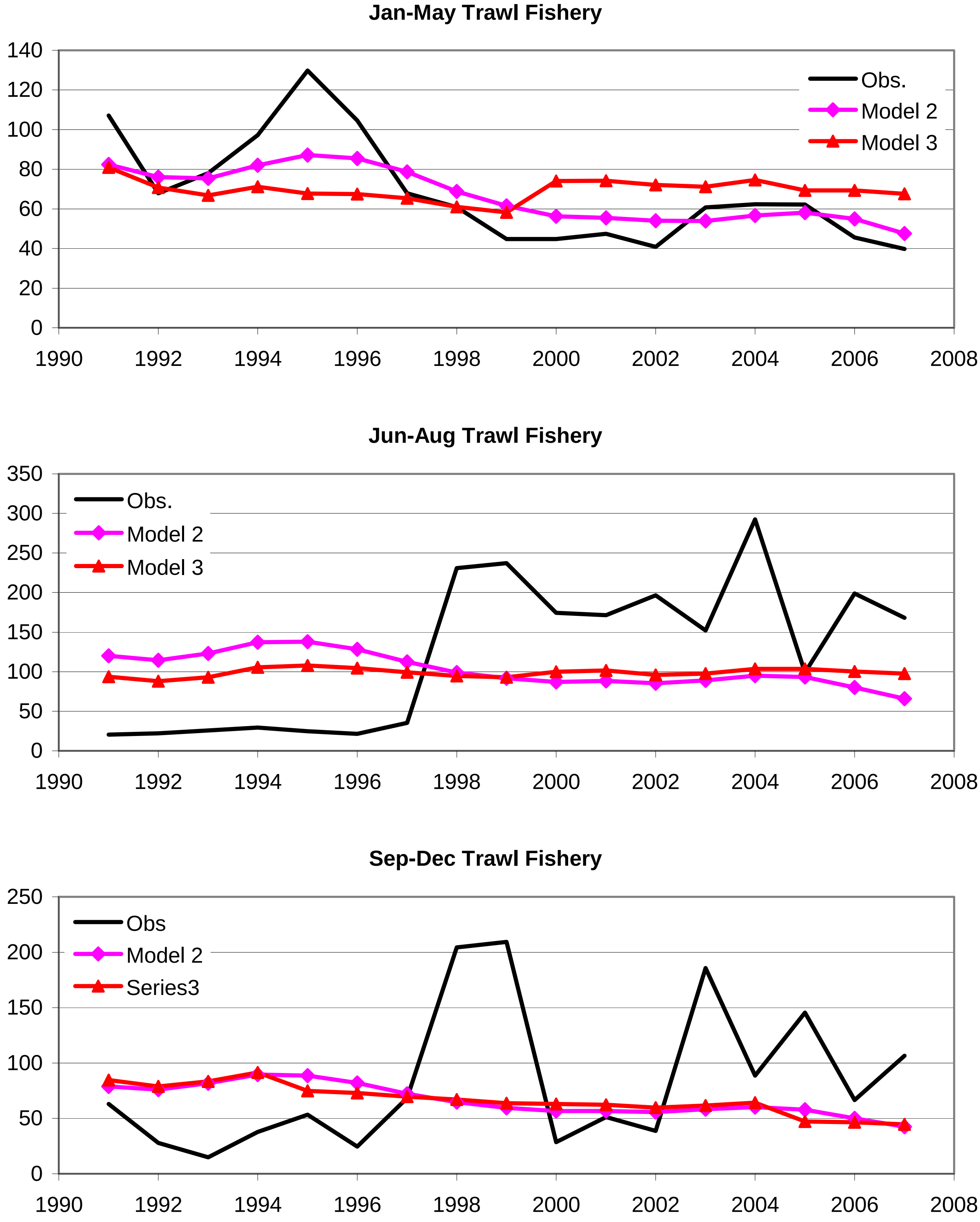


Figure 2.1.3a. Comparison of model estimates to trawl fishery CPUE data.

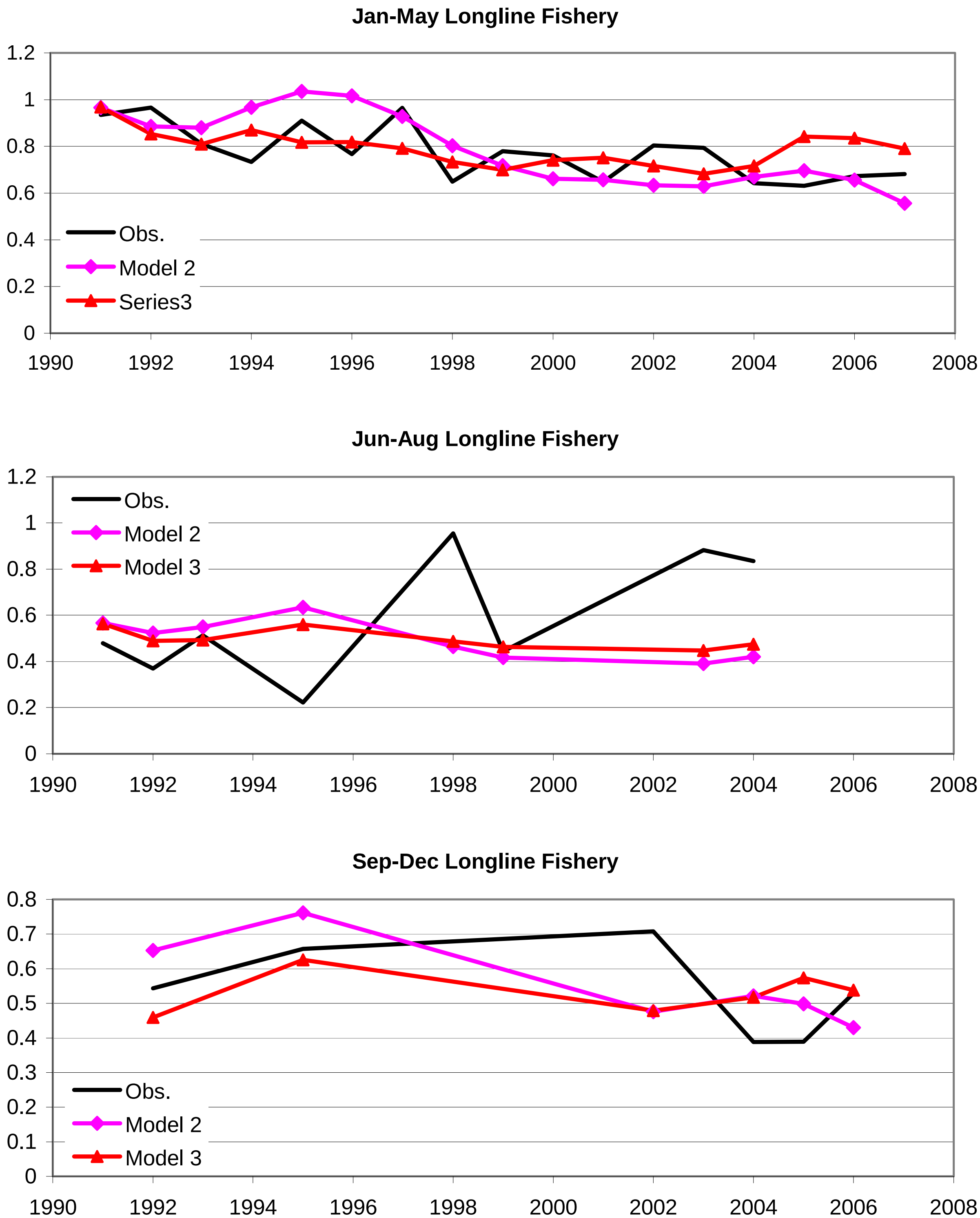


Figure 2.1.3b. Comparison of model estimates to longline fishery CPUE data.

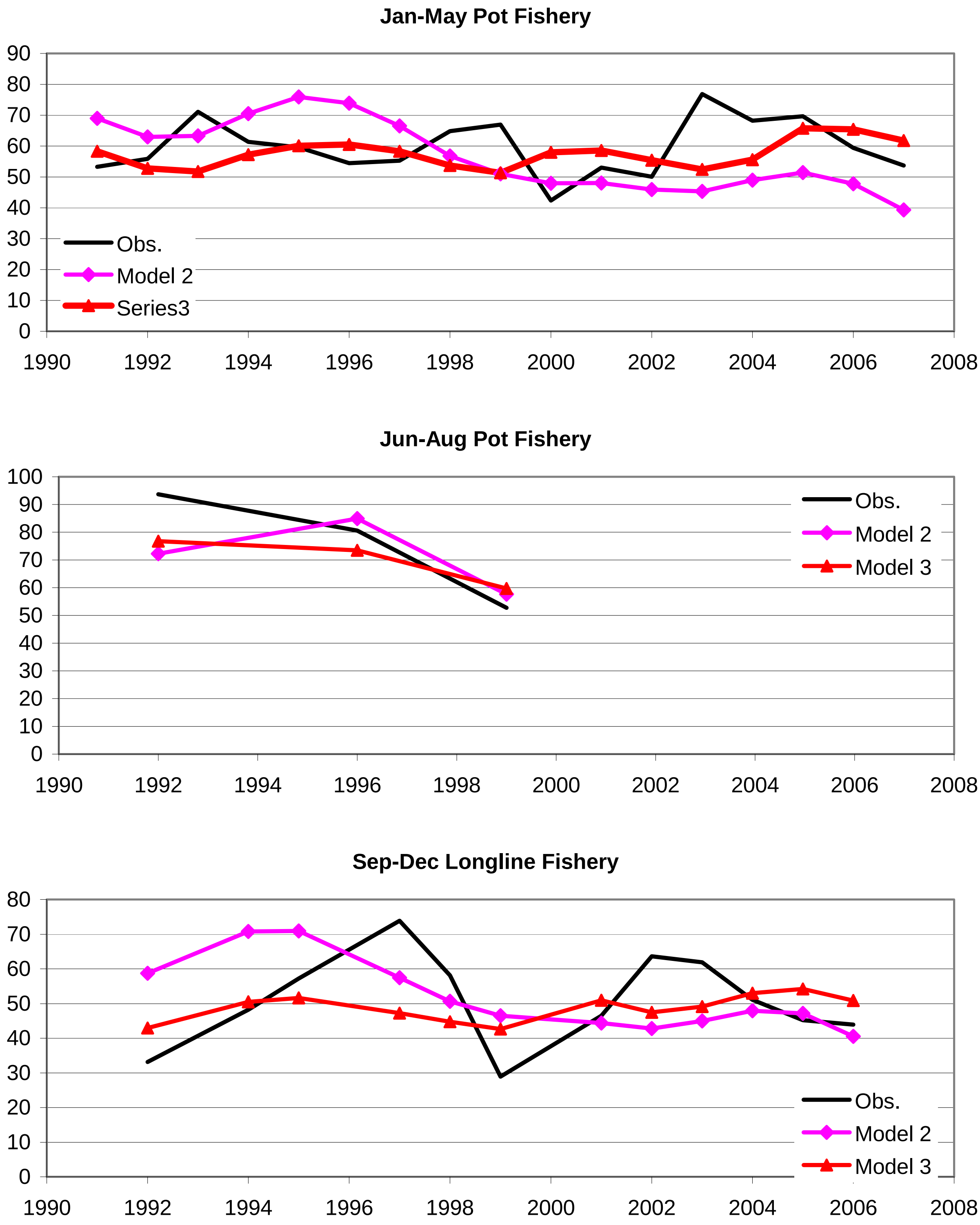


Figure 2.1.3c. Comparison of model estimates to pot fishery CPUE data.

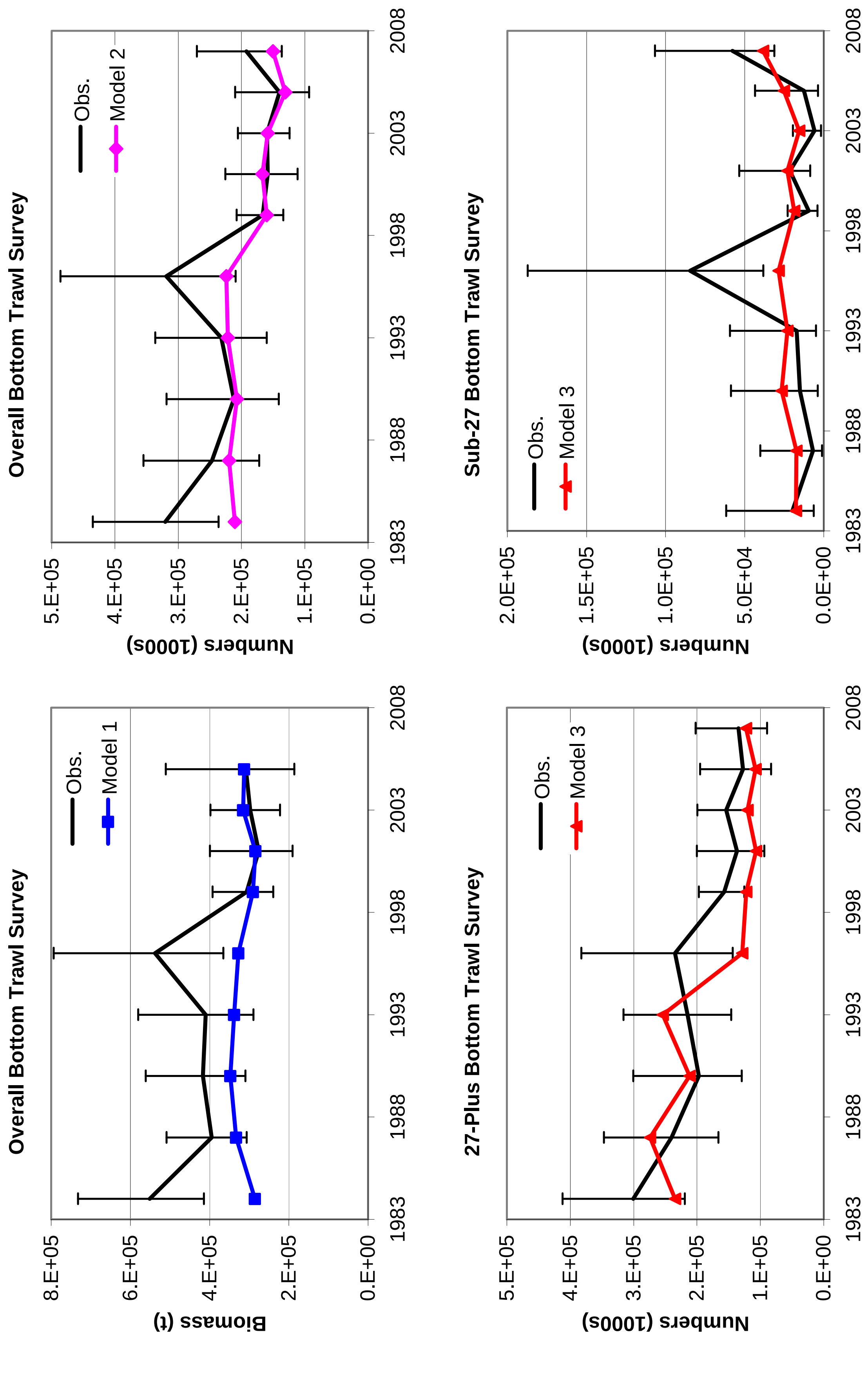


Figure 2.1.3d. Comparison of model estimates to trawl survey relative abundance data.

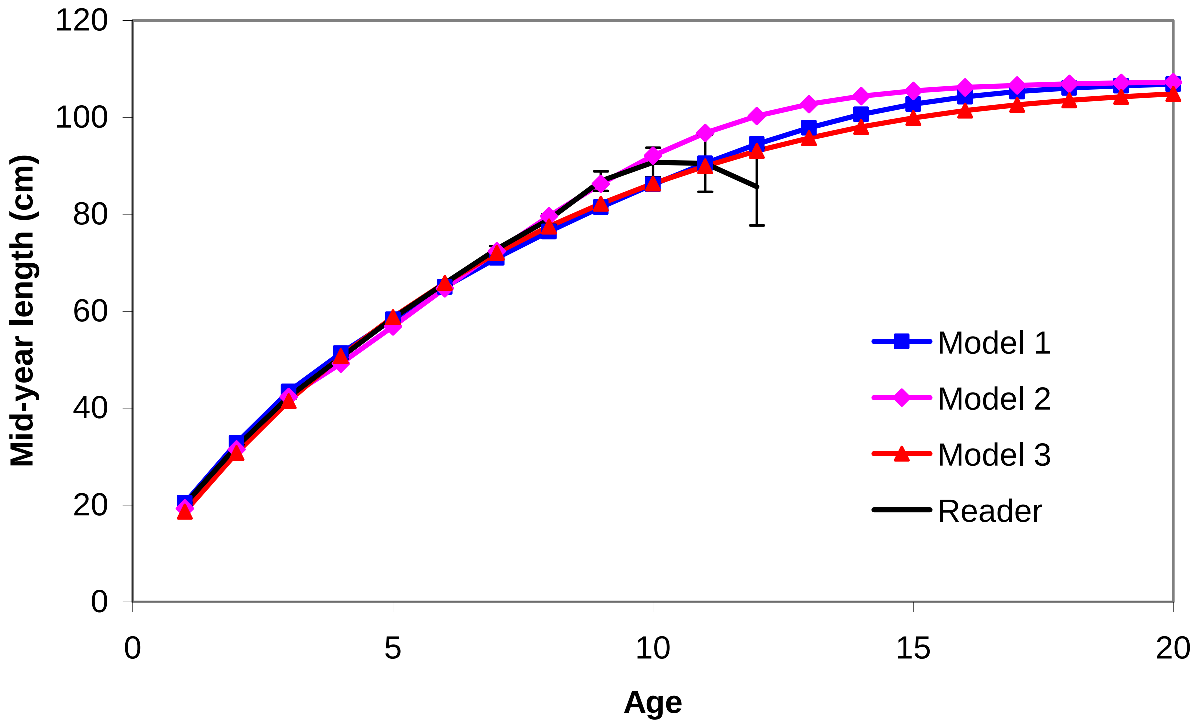


Figure 2.1.4. Model and AFSC reader estimates of mean length at age.

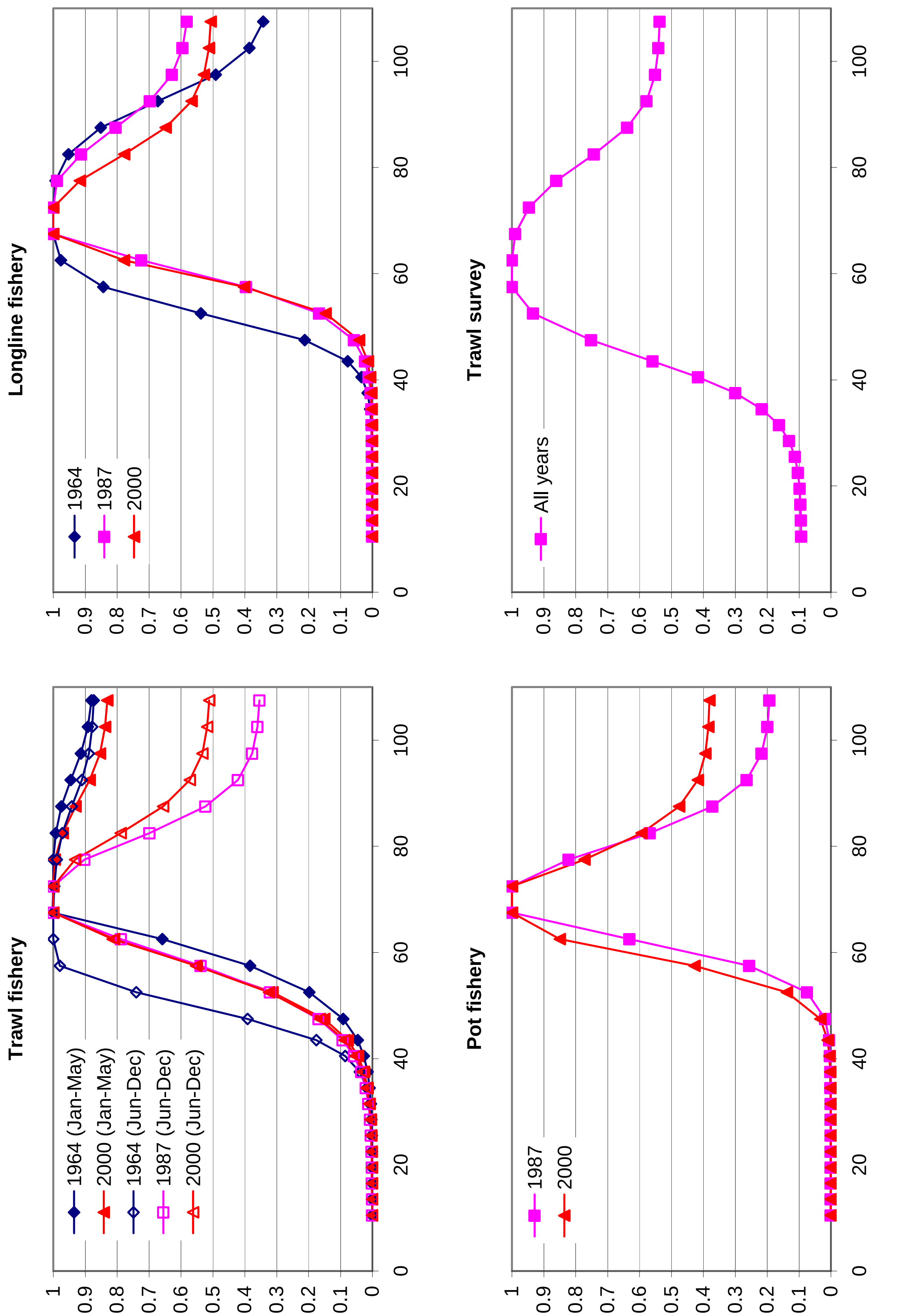


Figure 2.1.5a. Model 1 selectivities.

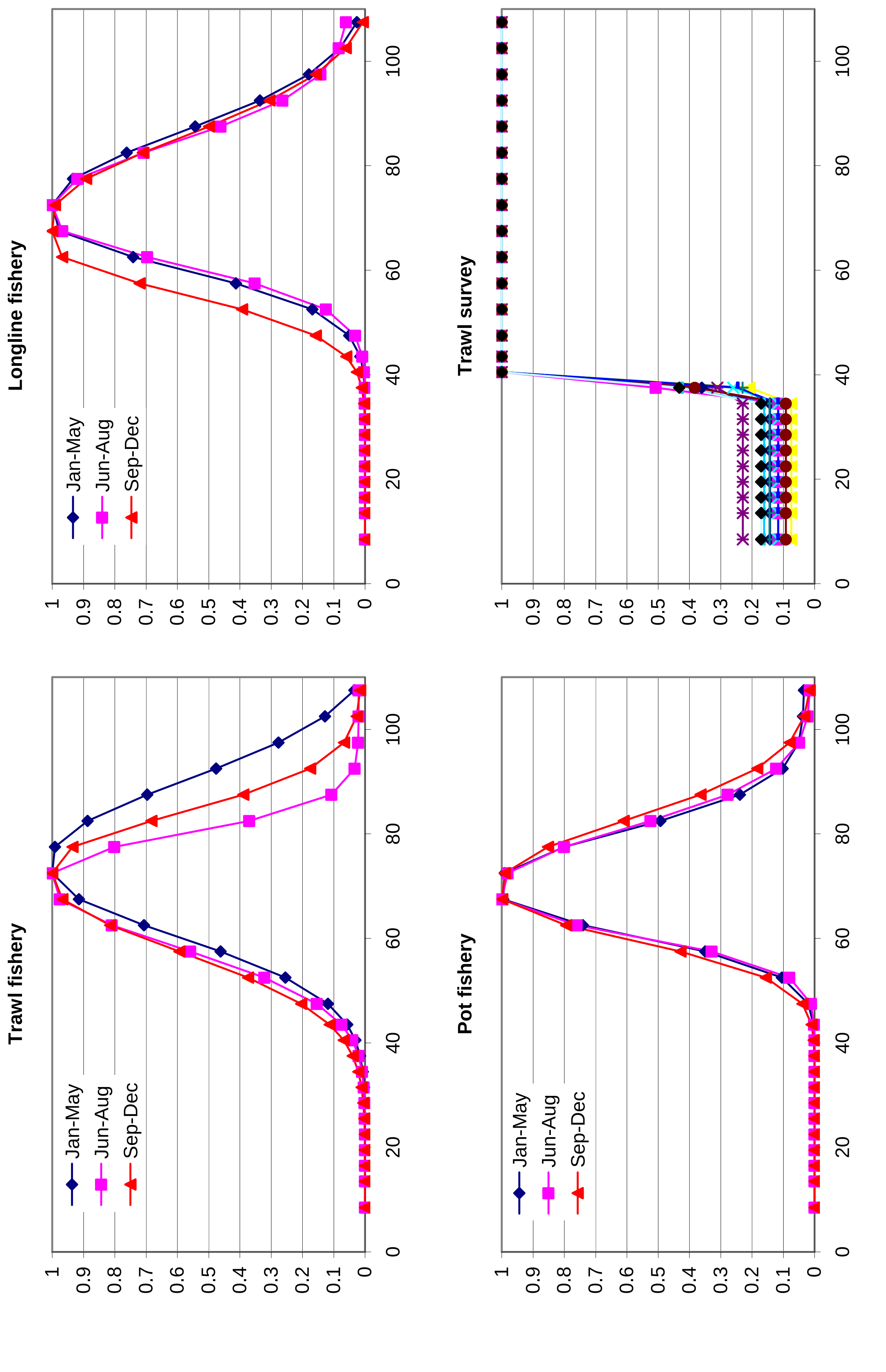
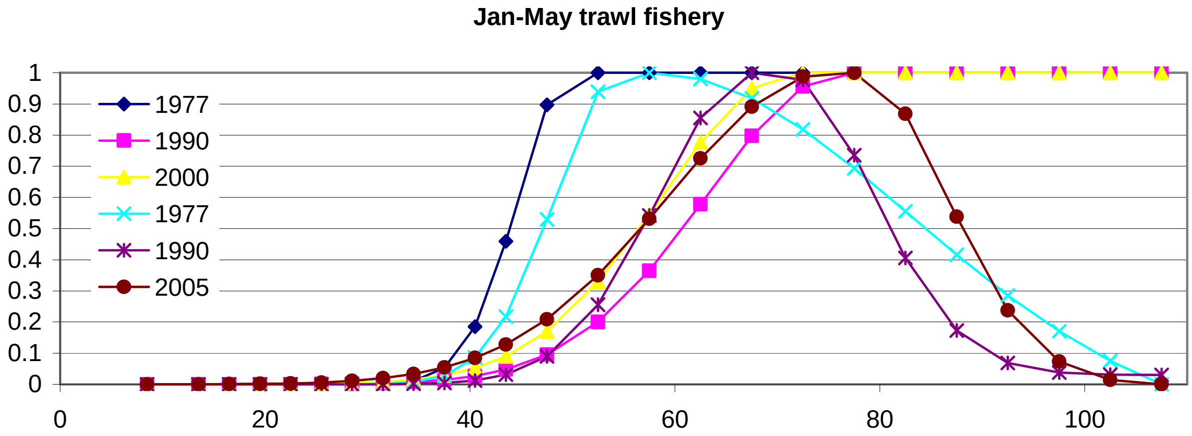
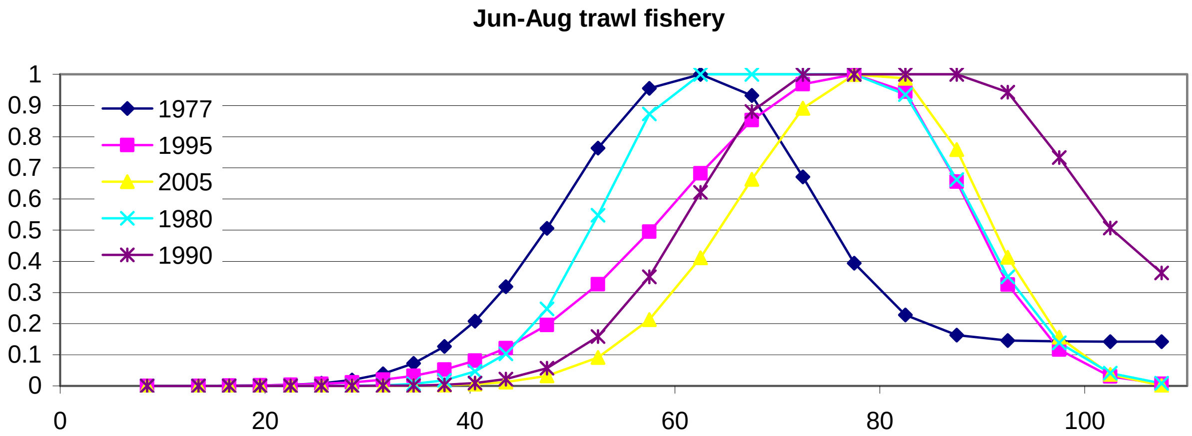


Figure 2.1.5b. Model 2 selectivities.





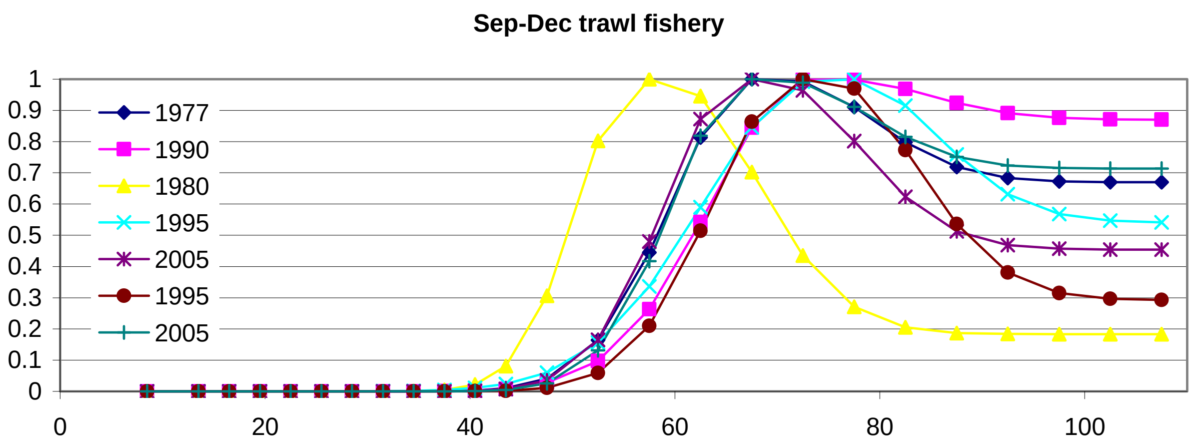


Figure 2.1.6a. Block-specific trawl fishery selectivities as estimated by Model 3.

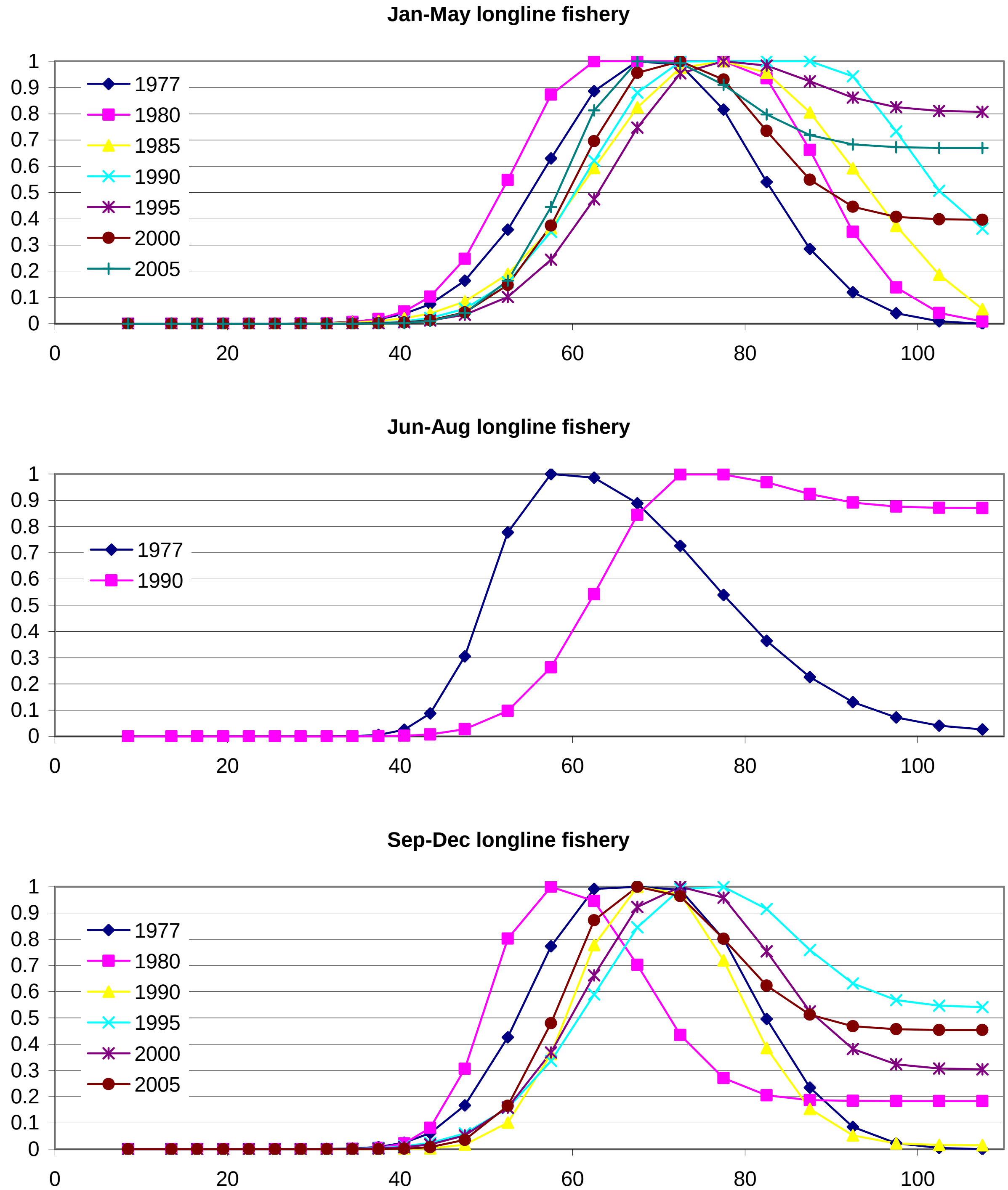


Figure 2.1.6b. Block-specific longline fishery selectivities as estimated by Model 3.

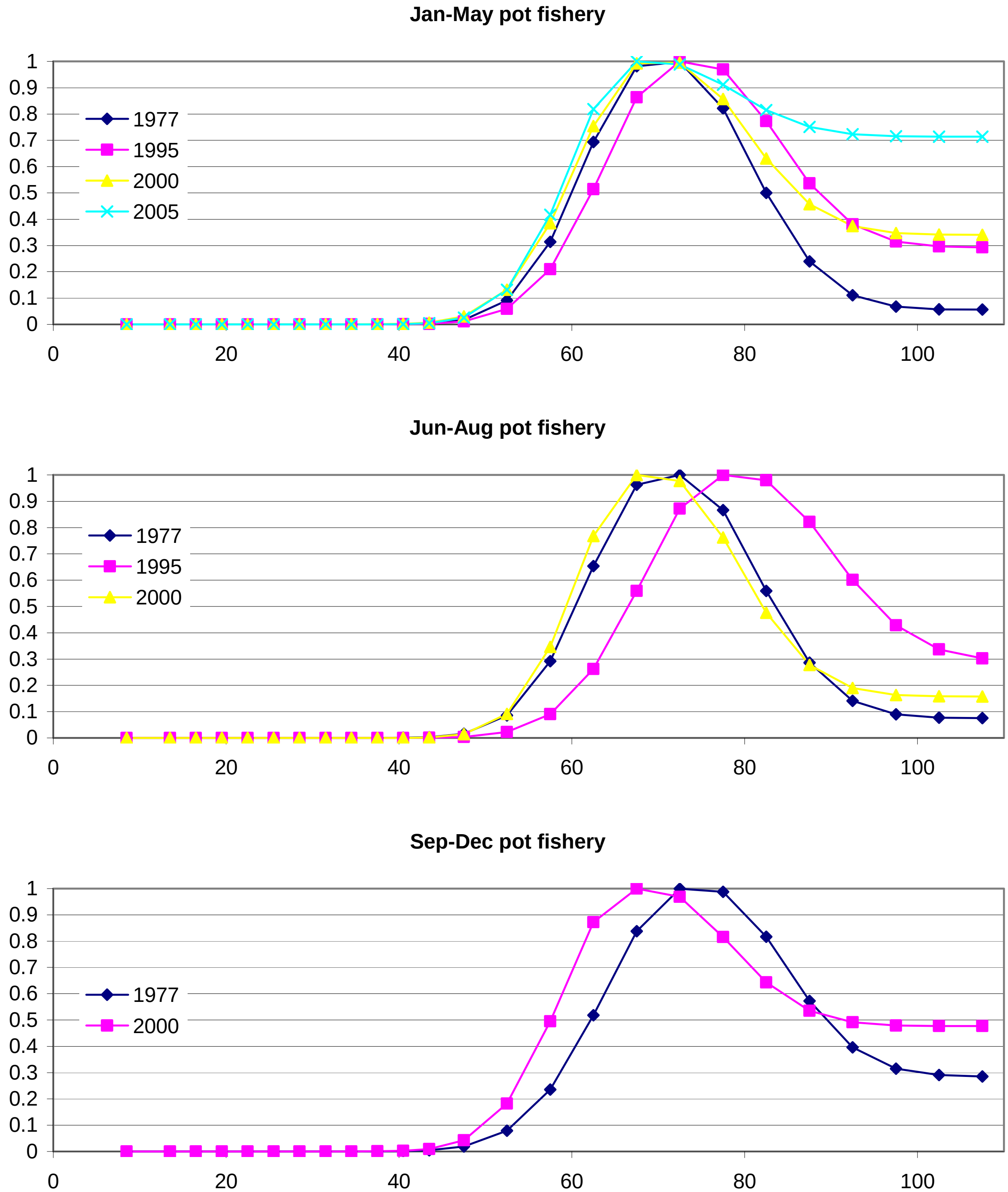


Figure 2.1.6c. Block-specific pot fishery selectivities as estimated by Model 3.

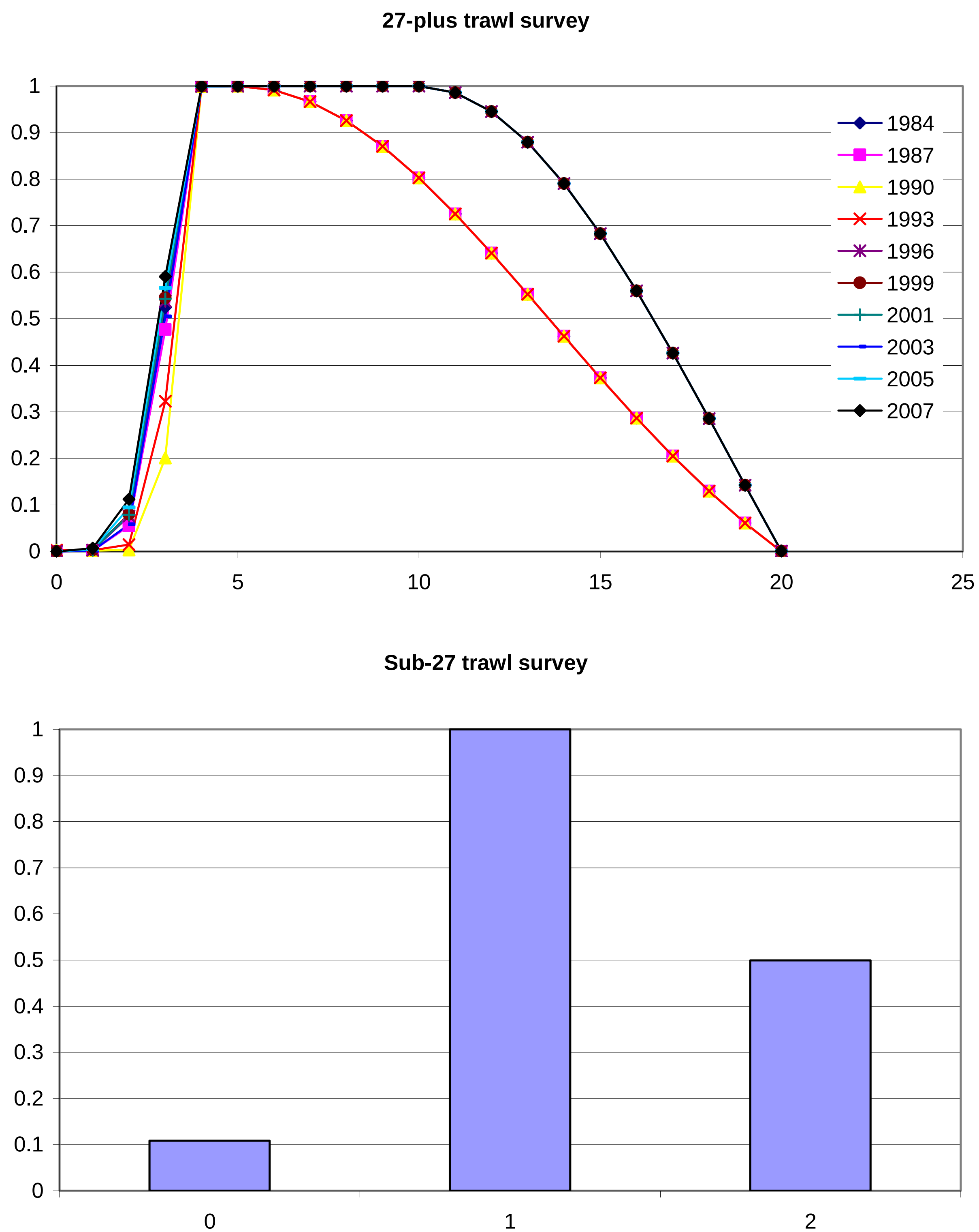


Figure 2.1.6d. Bottom trawl survey selectivities (functions of age) as estimated by Model 3. Top panel: Block-specific 27-plus survey selectivities. Bottom panel: Sub-27 survey selectivities (ages 0-2 only).

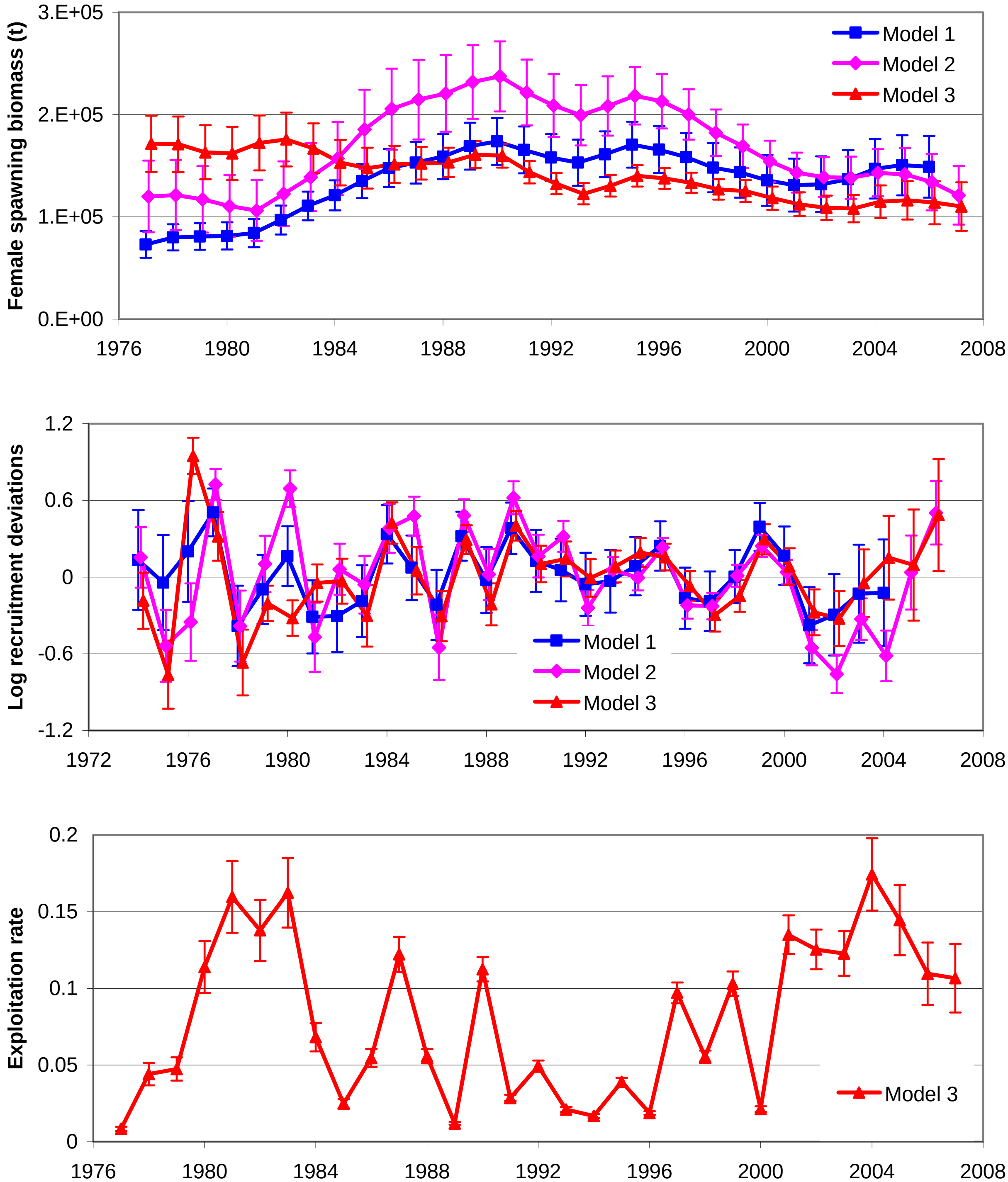


Figure 2.1.7. Comparison of time series estimates. Upper panel: female spawning biomass. Middle panel: log recruitment deviations. Lower panel: exploitation rate (not available for Models 1 and 2).

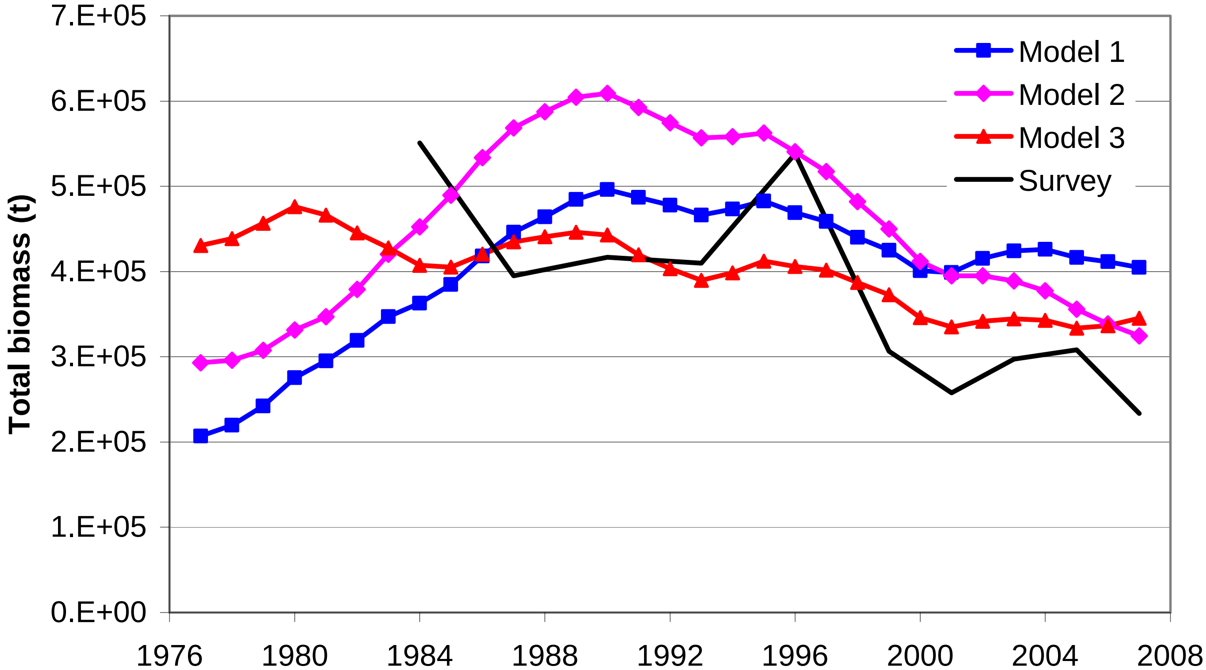


Figure 2.1.8. Comparison of total biomass time series estimates. Bottom trawl survey biomass estimates are also shown.

Attachment 2.2:

Tables and figures for the "Time Series Results" and "Projections and Harvest Alternatives" sections based on the SSC's Reference Model (A)

The tables and figures contained in the "Time Series Results" and "Projections and Harvest Alternatives" sections in the main text are based on Model B. This attachment reproduces those tables and figures, but based on the SSC's reference model (A).

Table 2.2.21a—Time series of GOA Pacific cod age 0+ biomass, female spawning biomass (t), and standard deviation of spawning biomass as estimated by the model presented in last year's assessment and this year under Model A. Values for 2009 listed under this year's assessment represent Stock Synthesis projections, and may not correspond to values generated by the standard projection model.

	Last year's assessment			This year's assessment		
Year	Age 0+ bio.	Spawn. bio.	Std. dev.	Age 0+ bio.	Spawn. bio.	Std. dev.
1977	292,947	119,910	17,876	124,744	38,181	7,485
1978	295,722	121,420	17,492	143,727	47,826	7,952
1979	307,362	117,255	16,557	175,506	48,075	7,650
1980	331,320	110,640	15,512	214,035	48,051	7,281
1981	346,950	106,210	15,144	229,545	57,395	8,147
1982	379,153	122,635	16,177	239,295	78,479	9,858
1983	420,372	138,915	17,083	251,299	81,282	9,810
1984	452,319	156,995	18,251	260,307	78,511	9,047
1985	489,635	185,595	19,726	281,004	86,501	8,797
1986	533,513	205,415	20,229	316,614	99,974	8,351
1987	568,438	214,720	19,886	345,958	110,108	7,748
1988	587,525	220,715	19,120	360,711	114,162	6,696
1989	604,278	232,005	18,379	371,146	128,278	6,097
1990	609,139	237,430	17,526	371,345	129,070	5,282
1991	592,344	221,530	16,443	349,537	113,124	4,638
1992	574,479	208,960	15,673	335,214	103,030	4,452
1993	556,783	199,410	15,111	324,615	92,931	4,432
1994	558,282	208,485	14,780	334,910	98,016	4,663
1995	562,497	218,385	14,313	351,140	111,609	5,004
1996	540,551	213,060	13,534	351,023	110,627	4,917
1997	517,198	200,170	12,569	354,778	107,232	4,733
1998	482,228	182,345	11,606	349,650	103,256	4,916
1999	450,043	169,105	10,832	343,611	105,414	5,636
2000	411,792	154,295	10,334	327,254	105,057	6,457
2001	394,880	143,245	10,000	326,520	102,607	6,866
2002	395,124	138,805	9,969	345,600	101,058	7,288
2003	389,086	138,200	10,519	362,633	102,234	8,426
2004	377,198	143,125	11,731	378,242	114,543	10,853
2005	355,684	141,685	13,111	390,769	126,257	14,063
2006	338,488	133,990	14,034	429,502	130,986	16,792
2007	324,455	121,105	14,641	504,318	134,405	20,212
2008	648,653	109,609	n/a	659,224	145,556	26,010
2009				831,604	174,936	

Table 2.2.21b—Time series of GOA Pacific cod age 0 recruitment (1000s of fish), with standard deviations, as estimated by the model presented in last year's assessment and this year under Model A.

	Last year's assessment		This year's assessment	
Year	Recruits	Std. dev.	Recruits	Std. dev.
1977	564,300	71,133	505,610	44,815
1978	186,130	54,160	25,338	11,438
1979	302,740	69,707	112,560	17,606
1980	545,710	82,007	223,070	23,555
1981	170,690	48,454	130,310	23,761
1982	290,410	59,557	297,140	29,155
1983	257,370	60,168	22,013	8,346
1984	400,410	79,207	414,660	42,741
1985	440,220	67,344	186,590	36,619
1986	157,350	41,969	112,150	21,784
1987	442,220	54,558	278,440	23,590
1988	278,860	58,815	179,820	24,352
1989	507,820	64,552	203,130	24,720
1990	321,820	55,816	332,750	27,580
1991	375,420	45,068	197,260	25,608
1992	214,820	30,825	196,020	23,018
1993	288,790	29,545	234,230	23,521
1994	272,050	27,457	246,240	25,067
1995	344,260	26,486	305,510	25,366
1996	218,850	23,782	194,940	20,767
1997	217,710	24,182	169,050	19,511
1998	275,990	26,807	186,170	21,476
1999	348,180	34,037	294,110	31,181
2000	283,820	31,182	357,760	45,278
2001	157,190	23,813	177,620	32,131
2002	127,850	20,995	217,360	42,431
2003	196,460	35,483	265,620	57,188
2004	147,460	31,701	393,910	93,765
2005	283,250	87,762	412,610	147,300
2006	451,870	120,670	1,899,400	667,970
Average	302,334		292,380	

Table 2.2.22—Numbers (1000s) at age as estimated by Model A.

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1977	505609	53392	19726	12175	31713	10962	2762	1305	760	497	930	599	386	248	160	103	66	43	28	18	32
1978	25338	345766	36512	13477	8282	21400	7334	1836	865	504	330	620	401	259	168	108	70	45	29	19	34
1979	112561	17327	236443	24857	8993	5333	13269	4428	1096	517	304	202	386	255	167	110	72	47	30	20	36
1980	223074	76976	11849	160996	16571	5760	3273	7902	2602	644	307	184	125	243	163	109	73	48	31	20	37
1981	130308	152552	52629	8052	104404	9735	3082	1655	3904	1283	321	156	96	68	136	95	65	44	30	20	36
1982	297143	89113	104298	35768	5239	62385	5431	1667	890	2111	702	179	89	56	40	83	58	41	28	19	35
1983	22013	203205	60932	71019	23549	3233	36619	3121	955	512	1224	411	106	53	34	25	52	37	26	18	35
1984	414660	15054	138941	41453	46322	14153	1826	20182	1717	529	287	694	237	62	32	21	15	32	23	16	33
1985	186591	283570	10293	94728	27717	29724	8711	1094	11934	1012	313	171	419	145	39	20	13	10	21	15	32
1986	112147	127602	193910	7030	64244	18506	19452	5588	690	7442	628	194	106	262	91	25	13	9	6	14	31
1987	278436	76693	87253	132318	4741	42260	11812	12059	3380	410	4381	369	114	63	158	56	15	8	5	4	29
1988	179819	190412	52434	59365	87684	2999	25776	7090	7211	2024	246	2647	224	70	39	98	35	10	5	3	21
1989	203132	122972	130198	35751	39702	56286	1851	15561	4245	4315	1215	149	1604	137	43	24	60	22	6	3	15
1990	332748	138914	84094	88863	23875	25174	33930	1084	9017	2458	2509	711	88	951	81	26	14	37	13	4	11
1991	197263	227553	94974	57340	59525	15099	14478	17758	533	4328	1181	1220	350	44	478	41	13	7	19	7	8
1992	196022	134901	155604	64859	38652	38021	8637	7251	8008	228	1824	501	525	153	19	211	18	6	3	8	6
1993	234227	134052	92246	106243	43579	24272	20799	4003	2948	3044	85	691	194	206	61	8	86	7	2	1	6
1994	246236	160179	91666	63003	71679	27911	13987	10606	1866	1321	1361	39	319	91	98	29	4	41	4	1	4
1995	305510	168391	109536	62632	42655	46628	16727	7625	5398	921	651	678	20	163	47	50	15	2	22	2	2
1996	194944	208926	115146	74815	42363	27639	27361	8568	3456	2268	376	265	279	8	68	19	21	6	1	9	2
1997	169054	133315	142868	78664	50605	27425	16239	14133	3946	1481	944	156	111	117	3	28	8	9	3	0	5
1998	186172	115609	91150	97478	52922	32266	15600	7959	6080	1569	573	366	61	44	47	1	11	3	4	1	2
1999	294113	127316	79052	62241	65764	33894	18406	7639	3417	2424	613	226	146	25	18	19	1	5	1	1	1
2000	357762	201133	87050	53948	41916	41835	18868	8540	3026	1243	866	223	84	56	10	7	7	0	2	1	1
2001	177624	244660	137539	59453	36367	26605	23456	9273	3898	1372	581	420	112	43	29	5	4	4	0	1	1
2002	217361	121470	167291	93842	39951	23179	15454	12472	4714	1980	714	311	230	62	24	16	3	2	2	0	1
2003	265622	148644	83064	114240	63163	25376	13276	8030	6175	2334	1006	373	166	125	34	13	9	2	1	1	1
2004	393910	181649	101642	56700	76930	40338	14685	6985	4034	3113	1212	540	205	93	70	19	7	5	1	1	1
2005	412614	269380	124210	69386	38191	49167	23410	7779	3547	2061	1640	660	301	117	53	40	11	4	3	0	1
2006	1899380	282170	184207	84839	46925	24831	29765	13274	4277	1951	1151	930	378	174	67	31	23	6	2	2	1
2007	158542	1298910	192958	125859	57484	30662	15146	17019	7357	2369	1095	655	534	218	101	39	18	13	4	1	1
2008	297827	108420	888226	131805	85135	37378	18558	8586	9359	4049	1324	622	376	308	126	58	23	10	8	2	2

Table 2.2.23—Projections for GOA Pacific cod catch (t), spawning biomass (t), and fishing mortality under the assumption that $F = max\ F_{ABC}$ in 2009-2021 (Scenarios 1-2), with random variability in future recruitment.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2009	124,000	124,000	124,000	124,000	0
2010	170,000	170,000	170,000	170,000	3
2011	211,000	211,000	211,000	212,000	188
2012	191,000	192,000	193,000	198,000	2,726
2013	138,000	146,000	149,000	173,000	12,910
2014	92,200	110,000	118,000	166,000	26,700
2015	54,100	91,800	99,300	164,000	37,032
2016	37,700	84,100	88,900	158,000	40,851
2017	32,300	78,800	83,900	162,000	40,304
2018	30,800	77,600	81,200	154,000	39,340
2019	30,600	75,900	80,200	150,000	39,088
2020	30,600	73,700	80,500	154,000	39,567
2021	29,800	74,400	81,000	160,000	40,490

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2009	175,000	175,000	175,000	175,000	0
2010	238,000	238,000	238,000	238,000	16
2011	315,000	315,000	315,000	316,000	270
2012	277,000	278,000	279,000	284,000	2,770
2013	201,000	211,000	215,000	245,000	16,468
2014	136,000	162,000	173,000	244,000	38,969
2015	97,400	135,000	149,000	240,000	50,951
2016	81,600	124,000	137,000	231,000	52,985
2017	75,200	117,000	131,000	233,000	50,759
2018	73,000	116,000	127,000	228,000	48,725
2019	72,700	114,000	126,000	216,000	48,326
2020	72,700	113,000	126,000	223,000	49,327
2021	71,800	113,000	127,000	232,000	50,162

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2009	0.54	0.54	0.54	0.54	0.00
2010	0.54	0.54	0.54	0.54	0.00
2011	0.54	0.54	0.54	0.54	0.00
2012	0.54	0.54	0.54	0.54	0.00
2013	0.54	0.54	0.54	0.54	0.00
2014	0.54	0.54	0.54	0.54	0.00
2015	0.44	0.54	0.53	0.54	0.04
2016	0.37	0.54	0.50	0.54	0.06
2017	0.33	0.54	0.49	0.54	0.08
2018	0.32	0.53	0.48	0.54	0.09
2019	0.32	0.52	0.48	0.54	0.08
2020	0.32	0.52	0.48	0.54	0.08
2021	0.32	0.52	0.48	0.54	0.08

Table 2.2.24—Projections for GOA Pacific cod catch (t), spawning biomass (t), and fishing mortality under the assumption that the upper bound on F_{ABC} is set the most recent five-year average fishing mortality rate in 2009-2021 (Scenario 3), with random variability in future recruitment.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2009	76,600	76,600	76,600	76,600	0
2010	111,000	111,000	111,000	111,000	2
2011	146,000	146,000	146,000	146,000	111
2012	145,000	146,000	146,000	149,000	1,613
2013	117,000	122,000	124,000	138,000	7,820
2014	86,000	97,400	102,000	134,000	17,044
2015	63,600	82,000	88,300	133,000	23,746
2016	50,600	73,300	79,900	127,000	26,452
2017	43,200	68,100	74,600	126,000	26,633
2018	39,000	65,400	71,000	121,000	26,065
2019	36,600	63,600	68,900	116,000	25,898
2020	36,200	61,900	68,000	116,000	26,323
2021	34,900	62,000	67,700	121,000	26,912

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2009	178,000	178,000	178,000	178,000	0
2010	259,000	259,000	259,000	259,000	16
2011	358,000	358,000	358,000	359,000	270
2012	343,000	345,000	346,000	351,000	2,777
2013	278,000	287,000	292,000	322,000	16,752
2014	208,000	235,000	247,000	324,000	41,364
2015	157,000	200,000	216,000	322,000	57,041
2016	126,000	180,000	196,000	304,000	62,931
2017	108,000	167,000	182,000	304,000	63,341
2018	96,100	159,000	172,000	291,000	62,265
2019	89,800	154,000	166,000	280,000	61,833
2020	87,500	150,000	164,000	283,000	62,887
2021	84,800	150,000	163,000	289,000	64,124

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2009	0.32	0.32	0.32	0.32	0.00
2010	0.32	0.32	0.32	0.32	0.00
2011	0.32	0.32	0.32	0.32	0.00
2012	0.32	0.32	0.32	0.32	0.00
2013	0.32	0.32	0.32	0.32	0.00
2014	0.32	0.32	0.32	0.32	0.00
2015	0.32	0.32	0.32	0.32	0.00
2016	0.32	0.32	0.32	0.32	0.00
2017	0.32	0.32	0.32	0.32	0.00
2018	0.32	0.32	0.32	0.32	0.00
2019	0.32	0.32	0.32	0.32	0.00
2020	0.32	0.32	0.32	0.32	0.00
2021	0.32	0.32	0.32	0.32	0.00

Table 2.2.25—Projections for GOA Pacific cod catch (t), spawning biomass (t), and fishing mortality under the assumption that the upper bound on F_{ABC} is set at $F_{60\%}$ in 2009-2021 (Scenario 4), with random variability in future recruitment.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2009	59,100	59,100	59,100	59,100	0
2010	87,900	87,900	87,900	87,900	2
2011	117,000	117,000	118,000	118,000	84
2012	120,000	121,000	121,000	124,000	1,226
2013	101,000	105,000	106,000	117,000	5,993
2014	77,400	86,200	90,100	114,000	13,309
2015	58,700	73,300	78,400	114,000	18,969
2016	47,100	65,600	71,000	109,000	21,562
2017	40,100	61,000	66,100	108,000	22,015
2018	35,700	58,200	62,700	105,000	21,678
2019	33,600	56,300	60,500	101,000	21,524
2020	32,300	54,700	59,400	100,000	21,836
2021	31,600	54,500	58,900	102,000	22,326

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2009	179,000	179,000	179,000	179,000	0
2010	267,000	267,000	267,000	267,000	16
2011	375,000	376,000	376,000	376,000	270
2012	371,000	373,000	373,000	378,000	2,780
2013	312,000	321,000	326,000	356,000	16,851
2014	243,000	271,000	283,000	361,000	42,232
2015	189,000	234,000	250,000	360,000	59,328
2016	155,000	210,000	228,000	346,000	66,632
2017	131,000	196,000	211,000	342,000	67,987
2018	116,000	186,000	199,000	331,000	67,311
2019	108,000	178,000	192,000	318,000	66,889
2020	104,000	173,000	188,000	314,000	67,921
2021	101,000	171,000	186,000	322,000	69,277

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2009	0.24	0.24	0.24	0.24	0.00
2010	0.24	0.24	0.24	0.24	0.00
2011	0.24	0.24	0.24	0.24	0.00
2012	0.24	0.24	0.24	0.24	0.00
2013	0.24	0.24	0.24	0.24	0.00
2014	0.24	0.24	0.24	0.24	0.00
2015	0.24	0.24	0.24	0.24	0.00
2016	0.24	0.24	0.24	0.24	0.00
2017	0.24	0.24	0.24	0.24	0.00
2018	0.24	0.24	0.24	0.24	0.00
2019	0.24	0.24	0.24	0.24	0.00
2020	0.24	0.24	0.24	0.24	0.00
2021	0.24	0.24	0.24	0.24	0.00

Table 2.2.26—Projections for GOA Pacific cod catch (t), spawning biomass (t), and fishing mortality under the assumption that F = 0 in 2009-2021 (Scenario 5), with random variability in future recruitment.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
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
2020	0	0	0	0	0
2021	0	0	0	0	0

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2009	183,000	183,000	183,000	183,000	0
2010	294,000	294,000	294,000	294,000	16
2011	439,000	439,000	439,000	440,000	270
2012	481,000	482,000	483,000	488,000	2,788
2013	460,000	470,000	475,000	505,000	17,166
2014	412,000	441,000	454,000	537,000	45,110
2015	360,000	410,000	429,000	551,000	67,509
2016	316,000	385,000	405,000	555,000	81,081
2017	280,000	360,000	382,000	543,000	87,837
2018	250,000	344,000	362,000	536,000	90,756
2019	228,000	330,000	346,000	520,000	91,999
2020	213,000	319,000	335,000	515,000	93,686
2021	204,000	308,000	326,000	503,000	95,750

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2009	0.00	0.00	0.00	0.00	0.00
2010	0.00	0.00	0.00	0.00	0.00
2011	0.00	0.00	0.00	0.00	0.00
2012	0.00	0.00	0.00	0.00	0.00
2013	0.00	0.00	0.00	0.00	0.00
2014	0.00	0.00	0.00	0.00	0.00
2015	0.00	0.00	0.00	0.00	0.00
2016	0.00	0.00	0.00	0.00	0.00
2017	0.00	0.00	0.00	0.00	0.00
2018	0.00	0.00	0.00	0.00	0.00
2019	0.00	0.00	0.00	0.00	0.00
2020	0.00	0.00	0.00	0.00	0.00
2021	0.00	0.00	0.00	0.00	0.00

Table 2.2.27—Projections for GOA Pacific cod catch (t), spawning biomass (t), and fishing mortality under the assumption that $F = F_{OFL}$ in 2009-2021 (Scenario 6), with random variability in future recruitment.

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2009	150,000	150,000	150,000	150,000	0
2010	199,000	199,000	199,000	199,000	4
2011	240,000	240,000	240,000	241,000	233
2012	206,000	207,000	208,000	215,000	3,378
2013	141,000	150,000	154,000	183,000	15,783
2014	82,900	111,000	119,000	178,000	32,695
2015	43,700	88,600	97,100	177,000	45,689
2016	34,700	80,900	90,000	173,000	46,985
2017	30,900	76,000	86,800	175,000	45,431
2018	31,100	77,900	85,100	169,000	44,110
2019	31,100	74,700	84,600	163,000	44,210
2020	31,700	75,000	85,300	172,000	45,024
2021	30,600	76,000	86,400	177,000	45,844
Biomass projections:					
Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2009	173,000	173,000	173,000	173,000	0
2010	227,000	227,000	227,000	227,000	16
2011	293,000	294,000	294,000	294,000	269
2012	245,000	246,000	247,000	252,000	2,766
2013	168,000	178,000	182,000	211,000	16,303
2014	109,000	133,000	144,000	213,000	37,525
2015	78,800	112,000	126,000	211,000	47,205
2016	70,100	107,000	119,000	205,000	47,188
2017	66,600	103,000	116,000	207,000	44,625
2018	65,800	104,000	114,000	198,000	43,019
2019	66,100	102,000	113,000	193,000	43,149
2020	66,600	102,000	114,000	204,000	44,146
2021	65,900	103,000	115,000	207,000	44,771
Fishing mortality projections:					
Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2009	0.68	0.68	0.68	0.68	0.00
2010	0.68	0.68	0.68	0.68	0.00
2011	0.68	0.68	0.68	0.68	0.00
2012	0.68	0.68	0.68	0.68	0.00
2013	0.68	0.68	0.68	0.68	0.00
2014	0.62	0.68	0.67	0.68	0.02
2015	0.44	0.64	0.60	0.68	0.09
2016	0.38	0.60	0.57	0.68	0.11
2017	0.36	0.58	0.56	0.68	0.11
2018	0.36	0.59	0.56	0.68	0.11
2019	0.36	0.58	0.56	0.68	0.11
2020	0.36	0.58	0.56	0.68	0.11
2021	0.36	0.58	0.56	0.68	0.11

Table 2.2.28—Projections for GOA Pacific cod catch (t), spawning biomass (t), and fishing mortality under the assumption that $F = max\ F_{ABC}$ in each year 2009-2010 and $F = F_{OFL}$ thereafter (Scenario 7), with random variability in future recruitment.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2009	124,000	124,000	124,000	124,000	0
2010	170,000	170,000	170,000	170,000	3
2011	255,000	255,000	255,000	255,000	233
2012	215,000	217,000	218,000	224,000	3,378
2013	146,000	155,000	159,000	188,000	15,783
2014	87,000	113,000	122,000	180,000	32,319
2015	44,500	90,600	98,400	179,000	45,631
2016	35,000	81,400	90,500	174,000	47,028
2017	31,000	76,300	86,900	176,000	45,461
2018	31,100	77,900	85,100	169,000	44,123
2019	31,200	74,700	84,600	163,000	44,215
2020	31,700	75,000	85,300	172,000	45,026
2021	30,600	76,000	86,400	177,000	45,844

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2009	175,000	175,000	175,000	175,000	0
2010	238,000	238,000	238,000	238,000	16
2011	312,000	312,000	312,000	312,000	269
2012	256,000	258,000	259,000	264,000	2,766
2013	174,000	184,000	188,000	217,000	16,303
2014	111,000	136,000	147,000	216,000	37,564
2015	79,500	113,000	127,000	212,000	47,349
2016	70,400	107,000	119,000	205,000	47,302
2017	66,700	103,000	116,000	208,000	44,682
2018	65,900	104,000	114,000	198,000	43,042
2019	66,100	102,000	113,000	193,000	43,157
2020	66,500	102,000	114,000	204,000	44,149
2021	66,000	103,000	115,000	207,000	44,772

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2009	0.54	0.54	0.54	0.54	0.00
2010	0.54	0.54	0.54	0.54	0.00
2011	0.68	0.68	0.68	0.68	0.00
2012	0.68	0.68	0.68	0.68	0.00
2013	0.68	0.68	0.68	0.68	0.00
2014	0.63	0.68	0.67	0.68	0.01
2015	0.44	0.64	0.60	0.68	0.08
2016	0.39	0.61	0.58	0.68	0.11
2017	0.36	0.58	0.57	0.68	0.11
2018	0.36	0.59	0.56	0.68	0.11
2019	0.36	0.58	0.56	0.68	0.11
2020	0.36	0.58	0.56	0.68	0.11
2021	0.36	0.58	0.56	0.68	0.11

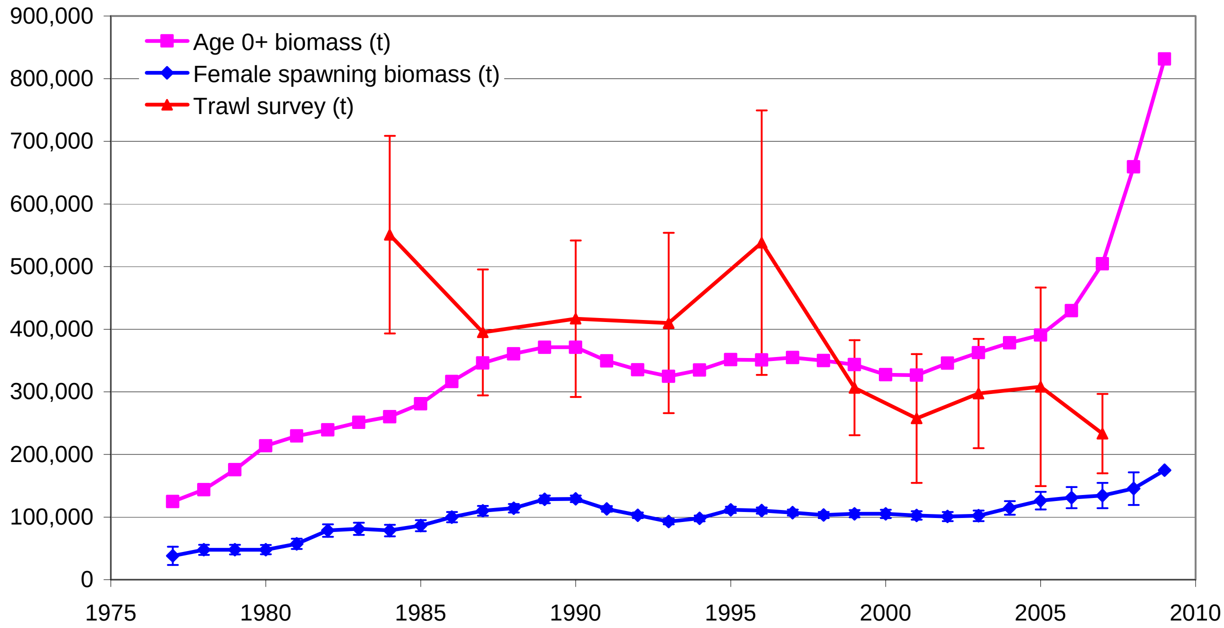


Figure 2.2.5—Biomass time trends (age 0+ biomass, female spawning biomass, survey biomass) of GOA Pacific cod as determined by final parameter estimates (Model A), with 95% confidence intervals for spawning biomass and survey biomass.

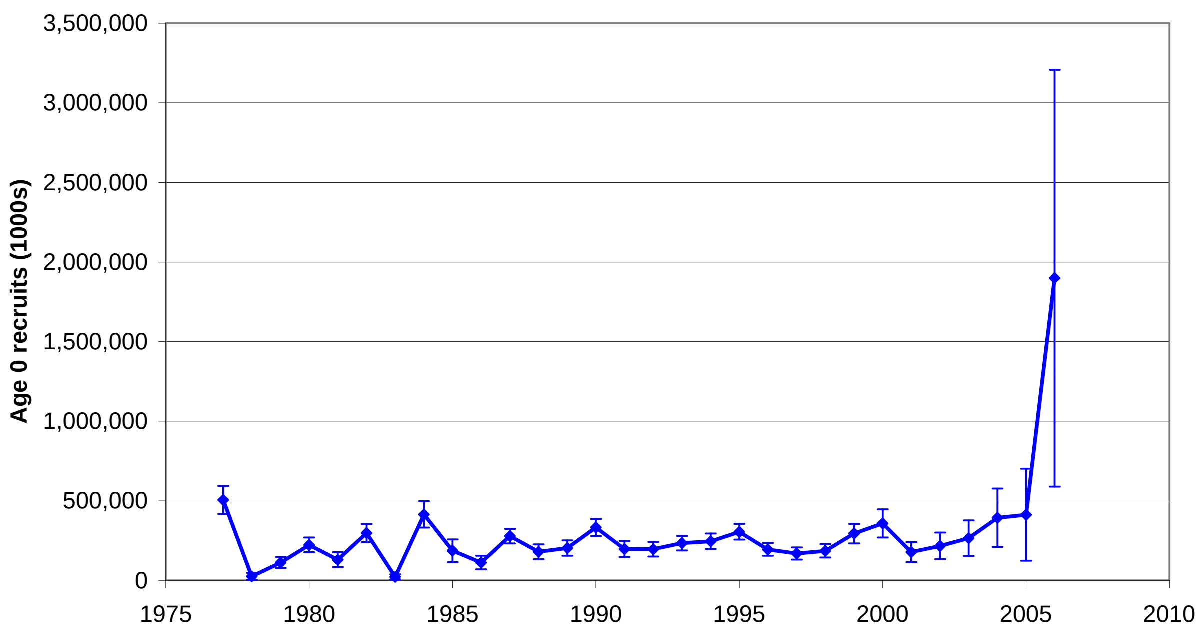


Figure 2.2.6—Time series of GOA Pacific cod recruitment at age 0, with 95% confidence intervals, as determined by final parameter estimates (Model A).

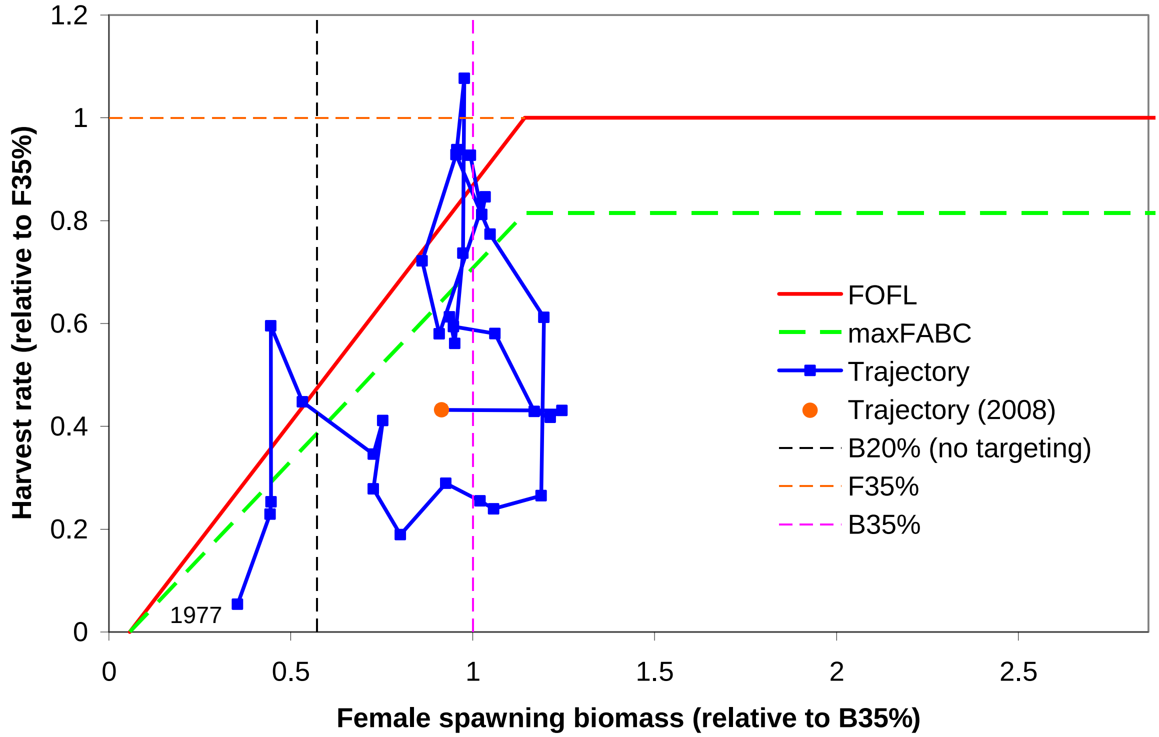


Figure 2.2.7—Trajectory of GOA Pacific cod fishing mortality and female spawning biomass as estimated by Model A, 1977-2008. Because Pacific cod is a key prey of Steller sea lions, harvests of Pacific cod would be restricted to incidental catch in the event that spawning biomass fell below $B_{20\%}$.

(This page intentionally left blank)