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

Grant Thompson, James Ianelli, Robert Lauth, Sarah Gaichas, and Kerim Aydin

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 BSAI SAFE report, the following substantive changes have been made in the Pacific cod stock assessment.

Changes in the Input Data

1) Catch data for 2007 were updated, and preliminary catch data for 2008 were incorporated.
2) Commercial fishery size composition data for 2007 were updated, and preliminary size composition data from the 2008 commercial fisheries were incorporated.
3) Size composition data from the 2008 EBS shelf bottom trawl survey were incorporated.
4) The numeric abundance estimate from the 2008 EBS shelf bottom trawl survey was incorporated (the 2008 estimate of 477 million fish was down about 35% from the 2007 estimate).
5) Age composition data from the 2007 EBS shelf bottom trawl survey were incorporated into some of the models.
6) The ageing error matrix was updated (in those models that use age data).
7) 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.
8) The 2000-2007 time series of Pacific cod catch rates from the International Pacific Halibut Commission (IPHC) longline surveys was recompiled.
9) Pacific cod size composition data from the 2008 IPHC longline survey were incorporated. The size composition data from the 2007 IPHC longline survey were removed from the overall data set due to concerns regarding the sampling design used to obtain those data.
10) The time series of weight-at-length data was recompiled.

Changes in the Assessment Methodology

Many changes have been made or considered in the stock assessment model since last year's assessment. Five models were presented in this year's preliminary assessment, which is included as Attachment 2.2 to the present assessment. The relationships between the five models presented in the preliminary assessment are summarized in Table 2.2.1 of Attachment 2.2. Model 1 in the preliminary assessment was identical to the model accepted for use by the BSAI Plan Team and SSC last year. Models 2 and 3 represented modifications of Model 1 requested by the BSAI Plan Team. Model 4 was identical to the model of the same name from last year's assessment, and was requested by members of the public. Model 5 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. The features that distinguished Model 5 in this year's preliminary assessment from last year's Model 1 were as follows:

1) The January-May trawl fishery was the only fishery assumed to exhibit asymptotic selectivity (Model 1 assumed asymptotic selectivity for several other fisheries, but not the January-May trawl fishery).
2) Log recruitment variability was estimated as the standard deviation of the recruitment "devs" from 1977 to 2007 (Model 1 used the entire time series, including the years prior to 1977).
3) Separate recruitment "dev" vectors were specified for the pre-1977 and post-1976 environmental regimes (Model 1 used a single "dev" vector for the entire time series).
4) The first reference age used in computing the parameters of the length-at-age relationship was set equal to 1.5417, corresponding to the mid-point of the trawl survey season (Model 1 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) Data used to estimate the weight-at-length relationship were taken from the fisheries (Model 1 used data from the surveys).
6) Seasonal weight-at-length relationships were specified (Model 1 used a single relationship throughout the year).
7) For a given gear and season, fishery selectivity was allowed to vary between blocks of years (Model 1 assumed constant fishery selectivity across the entire time series).
8) A lower bound of 5 was placed on the descending "width" parameter of all selectivity schedules.

Eight models are included in the present assessment. Three of them include age composition data and five do not. Names of models that include age composition data end in "1," and names of models that do not include age composition data end in "2." The main features of the eight models may be summarized as follows:

Model A1: This is the "reference" model requested by the SSC at this year's October meeting. It is very similar to Model 5 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 differences with respect to Model 5 are: 1) 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; and 2) 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.

Model A2: This is identical to Model A1, except that age composition data are not included. This model was requested by the SSC.

Model B1: This is similar to Model A1, except that more fisheries are assumed to exhibit asymptotic selectivity. *This is the authors' preferred model.*

Model B2: This is identical to Model B1, except that age composition data are not included.

Model C1: This is identical to Model B1, except that the natural mortality rate *M* is estimated internally.

Model D2: This is identical to Model B1, except that age composition data are not included, the maturity schedule is defined as a function of length rather than age, and *M* is estimated iteratively as follows: 1) Given a candidate value for *M*, run the model and estimate the length-at-age relationship; 2) invert the length-at-age relationship to calculate the age corresponding to the length at 50% maturity; 3) use Jensen's (1996) formula to translate this age at maturity into a new value for *M*; 4) repeat the entire process until the value of *M* converges. This model was requested by members of the public.

Model E2: This is identical to Model B1, except that age composition data are not included, the post-1981 trawl survey selectivity schedule is constrained to be asymptotic, and *M* is estimated internally. This model was requested by members of the public.

Model F2: This differs from the other models in several respects. It is identical to Model 4 from last year's assessment and this year's preliminary assessment (see Table 2.2.1 in Attachment 2.2), except that the starting year is set at 1977 (as in the other seven models). This model was requested by members of the public.

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 quantities from last year's assessment are not available ("n/a") because: 1) the SSC accepted the recommended model "in principle" but declined to endorse the model's estimates of reference points based on average recruitment (e.g., *B100%*, *B40%*, *B35%*), and 2) the SSC's specifications of ABC and OFL were simply rolled over from the previous year and not accompanied by estimates of the associated fishing mortality rates.

	Assessment	
Quantity/Status	Last year	This year
M	0.34	0.34
Specified/recommended Tier	n/a	3b
Projected biomass (ages 0+) for 2009	1,513,000	1,703,000
Projected female spawning biomass for 2009	395,000	373,000
B100%	n/a	1,066,000
B40%	n/a	426,000
B35%	n/a	373,000
B0	n/a	n/a
FOFL for 2009	n/a	0.29
maxFABC for 2009	n/a	0.24
maxFABC for 2010	n/a	0.24
Specified/recommended *FABC* for 2009	n/a	0.24
Specified/recommended *FABC* for 2010	n/a	0.23
OFL for 2009	207,000	212,000
OFL for 2010 (given recommended ABC for 2009)	n/a	235,000
maxABC for 2009	n/a	182,000
maxABC for 2010	n/a	199,000
Specified/recommended ABC for 2009	176,000	176,000
Specified/recommended ABC for 2010	n/a	176,000
Is the stock being subjected to overfishing?	no	no
Is the stock currently overfished?	no	no
Is the stock approaching a condition of being overfished?	no	no

Responses to Comments from the Plan Teams and SSC

BSAI Plan Team Comments

The following are all from the November, 2007 minutes.

BPT1. *"Rather than estimating all three parameters, it would be worth exploring a model with fixed L_{inf} at an externally estimated value and let the model estimate L1 and K because that selectivity has more impacts on the observed sizes of young fish than those of older fish, especially when an asymptotic selectivity curve is used."* This suggestion was incorporated into Model 2 from the preliminary assessment. Results obtained by external estimation of the maximum size (or the size at maximum age) were virtually identical to those obtained by internal estimation. See also Comment JPT4 below.

BPT2. *"Estimated selectivity curves appear reasonable, except that IPHC longline survey selectivity curve is peaked and thus not differentiable (increasing the number of parameters from 4 to 6 parameters still doesn't overcome stated problems with estimating selectivity in stock synthesis)."* This comment was addressed in the "Estimates of Parameters, Length at Age, and Selectivity at Length or Age" section in the preliminary assessment. The length sample from the 2007 IPHC longline survey was almost entirely confined to a very narrow range of lengths, which meant that only a sharply peaked selectivity curve could fit the data adequately. However, the length sample from the 2008 IPHC longline survey is much more broadly distributed. It is likely that the 2007 IPHC length sample was not representative of the entire survey due to the nature of the sampling design used. The 2007 IPHC length sample is not used in the present assessment.

BPT3. *"Recommendation for future assessments: Use 3-parameter exponential-logistic (Thompson 1994) to represent selectivity."* The exponential-logistic selectivity curve is not currently available as an option in Stock Synthesis. Model 3 from the preliminary assessment attempted to address this concern by retaining the six-parameter double normal selectivity curve but fixing certain parameters at constant values. However, the reduction in number of parameters was more than offset by the reduction in goodness of fit. See also Comments JPT2 and JPT5 below.

BPT4. *"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. All of the models in the present assessment also attempt to address this recommendation in one way or another.

GOA Plan Team Comments of Potential Relevance for the BSAI Assessment

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. Except for Model F2, all of the models in the present assessment use seasonal weight-at-length parameters.

GPT3. *"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 5 from the preliminary assessment addressed this suggestion, defining selectivity schedules in terms of fishery-specific blocks of years. Except for Model F2, all of the models in the present assessment use a similar approach.

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 all 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 JPT7 and SSC4 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 (except Model F2) 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 5 from the preliminary assessment. See also Comment BPT3 above and Comment JPT5 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."* Except for Model F2, all models described in the present assessment are based largely on Model 5 from the preliminary assessment.

JPT4. *"Does Fixing L2 outside the model help? No."* Length at age 20 (*L2*) is estimated internally in all models described in the present assessment. See also Comment BPT1 above.

JPT5. *"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 BPT3 and JPT2 above.

JPT6. *"Should unique features of Model 4 be used? The general impression that while some features of this model may be useful for comparison with other models and for contrast in the assessment, none are recommended to be brought forward for specification purposes."* Model 4 from last year's assessment and the preliminary assessment is included again in the present assessment (as Model F2) in response to a request from the public. However, none of its distinguishing features are included in any of the other models, including the authors' preferred model.

JPT7. *"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."* See Comment JPT1 above and Comment SSC4 below.

JPT8. *"Is the method used to define blocks appropriate? Yes."* Except for Model F2, the method used to define selectivity blocks in Model 5 from the preliminary assessment is used for all models described in the present assessment.

JPT9. *"Do the new ... models fix average recruitment problem used for the projections? Yes."* The method used to estimate recruitment parameters in Model 5 from the preliminary assessment is retained in the present assessment for Models A1 and B1. Model A2 uses the same value for log recruitment variability, σ_R, as estimated iteratively in Model A1; and Models B2, C1, D2, and E2 use the same value of σ_R as estimated iteratively in Model B1. Model F2 uses an assumed value of σ_R.

JPT10. *"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.

JPT11. *"Should size at age data be included? No for BS, yes for GOA."* Size at age data are not included in any of the models described in the present assessment.

JPT12. *"Are appropriate values of M being used? Generally yes and well justified now, current data being used and clean understanding of how calculated...."* The value of 0.34 justified in the "Parameters Estimated Independently" section of the preliminary assessment is retained in several of the models described in the present assessment, including the authors' preferred model. However, a slightly different fixed value is used in Model D2, and *M* is estimated internally in Models C1, E2, and F2. See also Comment SSC3 below.

JPT13. *"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 Comment SSC6 below).

SSC Comments Specific to the Pacific Cod Assessments

SSC1. From the December, 2007 minutes: *"Age data are usually much more informative than size data and therefore should not be set aside absent clear evidence of bias. Some questions have been raised about the cod age data, but the readings have been reconsidered and rechecked by the AFSC age readers, and they stand by them. We rely on ages read the same way in other assessments. We should continue to rely on the cod ages until we find something more than circumstantial evidence of a bias."* Age data are used in Models A1, B1, and C1. Age data are not used in Models A2, B2, D2, E2, and F2. See also Comment SSC5 below.

SSC2. From the December, 2007 minutes: *"While endorsing Model 1 in principle, we accept the point made in public testimony that Model 1 overestimates historical recruitment because the recruitment time series effectively includes the estimates of recruitment used to construct initial conditions, and therefore are outside the intended range of recruitments (1977-present). In addition, estimates are complicated by other features of the way that the SS2 software initializes the 1977 stock."* This concern was addressed in detail in the "Discussion" section of the preliminary assessment. Briefly, the estimate of average recruitment from Model 1 in last year's assessment *did not* include estimates of recruitment from outside the current (1977-present) environmental regime. If it did, average recruitment would have been *under*estimated rather than *over*estimated, because recruitments from the previous regime tended to be much smaller than those from the current regime. However, the SSC was correct in noting that last year's assessment *did* include features that made the parametric estimate of average recruitment for the current regime inconsistent with the arithmetic mean of the individual recruitment estimates from the current regime. Those features have been modified appropriately in the preliminary assessment as well as the present assessment, through changes in both the assessment software and the way in which the scale of log recruitment variability is estimated.

SSC3. From the December, 2007 minutes: *"The SSC continues to support the idea of estimating a fixed natural mortality rate external to the assessment on the basis of life history theory. In the next assessment we would like to see some discussion of the alternatives considered for estimating M outside the model and the rationale for the author's choice."* This request was addressed in the "Parameters Estimated Independently" section of the preliminary assessment. See also Comment JPT12 above.

SSC4. 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. In particular, we agree that estimating parameter L2 (length at age 20) externally is not worthwhile (Model 2), and that setting a lower bound of 5 on parameter P4 of trawl survey selectivity (which determines the width of the descending limb) is not advisable (Models 3 and 5). Except for this last feature, we also agree that Model 5 is an improvement on Model 1, because commercial fishery selectivity really does appear to vary over time. As a reference model for this year's BS/AI specifications, the SSC would therefore like to see a fit of Model 5 in which the constraint on parameter P4 is removed or relaxed.* The SSC's "reference" model is included in the present assessment as Model A1.

SSC5. From the October, 2008 minutes: "*Because of continuing questions about the age data (including poor model fits to the age data), we would also like to see a fit of this modified Model 5 that does not include the age data.* The SSC's reference model, with age data removed, is included in the present assessment as Model A2.

SSC6. From the October, 2008 minutes: "*We do not need to see updated fits of Models 1, 2, or 3.*" Models 1, 2, and 3 from the preliminary assessment are not included in the present assessment.

SSC Comments on Assessments in General

SSC7. 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 2.18.

SSC8. 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 1977-2007.

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 34E N latitude, with a northern limit of about 63E N latitude. Pacific cod is distributed widely over the eastern Bering Sea (EBS) as well as in the Aleutian Islands (AI) area. The resource in these two areas (BSAI) is managed as a single unit. Tagging studies (e.g., Shimada and Kimura 1994) have demonstrated significant migration both within and between the EBS, AI, and Gulf of Alaska (GOA). Although at least one previous genetic study (Grant et al. 1987) failed to show significant evidence of stock structure within these areas, current genetic research underway at the Alaska Fisheries Science Center 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 EBS or AI areas.

FISHERY

Catches of Pacific cod taken in the EBS, AI, and BSAI for the periods 1964-1980 and 1981-2008 are shown in Tables 2.1a and 2.1b, 2.2a and 2.2b, and 2.3a and 2.3b, respectively. The catches in Tables

2.1a, 2.2a, and 2.3a are broken down by year and fleet sector (foreign, joint venture, domestic annual processing), while the catches in Tables 2.1b, 2.2b, and 2.3b are broken down by gear type as well. During the early 1960s, a Japanese longline fishery harvested BSAI Pacific cod for the frozen fish market. Beginning in 1964, the Japanese trawl fishery for walleye pollock (*Theragra chalcogramma*) expanded and cod became an important bycatch species and an occasional target species when high concentrations were detected during pollock operations. By the time that the Magnuson Fishery Conservation and Management Act went into effect in 1977, foreign catches of Pacific cod had consistently been in the 30,000-70,000 t range for a full decade. In 1981, a U.S. domestic trawl fishery and several joint venture fisheries began operations in the BSAI. The foreign and joint venture sectors dominated catches through 1988, but by 1989 the domestic sector was dominant and by 1991 the foreign and joint venture sectors had been displaced entirely. Presently, the Pacific cod stock is exploited by a multiple-gear fishery, including trawl, longline, pot, and jig components. 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 (i.e., all-gear, combined area) commercial catches in Table 2.4. From 1980 through 2008, TAC averaged about 82% of ABC, and aggregate commercial catch averaged about 89% of TAC. In 10 of these 29 years (34%), TAC equaled ABC exactly, and in 6 of these 28 years (21%), catch exceeded TAC (by an average of 4%). However, one of those overages occurred in 2007, when TAC was reduced by 3% to account for a small, State-managed fishery inside State of Alaska waters (a similar reduction was made in 2008); thus, while TAC was exceeded in 2007 by about 2%, the actual target catch was not exceeded.

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. All assessments from 1993 through 2004 used the Stock Synthesis 1 modeling software with primarily length-based data, albeit with some changes in model structure from time to time. The assessment was migrated to Stock Synthesis 2 in 2005, and several changes have been made to the model within the SS2 framework (renamed “Stock Synthesis,” without a numeric modifier, in 2008) each year since then. Historically, the great majority of the BSAI catch has come from the EBS area. During the most recent complete five-year period (2003-2007), the EBS accounted for an average of about 86% of the BSAI catch.

The catches shown in Tables 2.1b, 2.2b, 2.3b, and 2.4 include estimated discards. Discard rates of Pacific cod in the various EBS and AI target fisheries are shown for each year 1991-2002 in Table 2.5a and for each year 2003-2004 in Table 2.5b. Values for 2005-2008 have not yet been tabulated.

Seasons for the Pacific cod fisheries are defined in 50 CFR §679.23(5) as follows:

> (i) Hook-and-line gear. Subject to other provisions of this part, directed fishing for CDQ and non-CDQ Pacific cod with vessels equal to or greater than 60 ft (18.3 m) LOA using hook-and-line gear is authorized only during the following two seasons:
>
> > (A) A season. From 0001 hours, A.l.t., Jan. 1 through 1200 hours, A.l.t., June 10; and
> >
> > (B) B season. From 1200 hours, A.l.t., June 10 through 2400 hours, A.l.t., Dec. 31.

(ii) Trawl gear. Subject to other provisions of this part, directed fishing for CDQ and non-CDQ Pacific cod with trawl gear in the BSAI is authorized only during the following three seasons:

(A) A season. From 1200 hours, A.l.t., Jan. 20 through 1200 hours, A.l.t., Apr. 1;

(B) B season. From 1200 hours, A.l.t., Apr. 1 through 1200 hours, A.l.t., June 10; and

(C) C season. From 1200 hours, A.l.t., June 10 through 1200 hours, A.l.t., Nov. 1.

(iii) Pot gear. Subject to other provisions of this part, non-CDQ directed fishing for Pacific cod with vessels equal to or greater than 60 ft (18.3 m) LOA using pot gear in the BSAI is authorized only during the following two seasons:

(A) A season. From 0001 hours, A.l.t., January 1 through 1200 hours, A.l.t., June 10; and

(B) B season. From 1200 hours, A.l.t., September 1 through 2400 hours, A.l.t., Dec. 31.

(iv) Jig gear. Subject to other provisions of this part, directed fishing for CDQ and non-CDQ Pacific cod with jig gear is authorized only during the following three seasons:

(A) A season. From 0001 hours, A.l.t., Jan. 1 through 1200 hours, A.l.t., Apr. 30;

(B) B season. From 1200 hours, A.l.t., Apr. 30 through 1200 hours, A.l.t., Aug. 31; and

(C) C season. From 1200 hours, A.l.t., Aug. 31 through 2400 hours, A.l.t., Dec. 31.

Under Amendment 85, 10.7% of the TAC is allocated to the CDQ fisheries. The remaining 89.3% is allocated as follows:

	Percentage	
Sector	non-CDQ TAC	overall TAC
Jig vessels	1.4	1.250
Hook-and-line/pot catcher vessels < 60 ft. LOA	2.0	1.786
Hook-and-line/pot catcher vessels ≥ 60 ft. LOA	0.2	0.179
Hook-and-line catcher-processors	48.7	43.489
Pot catcher vessels > 60 ft. LOA	8.4	7.501
Pot catcher-processors	1.5	1.340
AFA trawl catcher-processors	2.3	2.054
Non-AFA trawl cathcer-processors	13.4	11.966
Trawl catcher vessels	22.1	19.735
Total	100.0	89.300

Amendment 85 further apportions the above allocations (in percent) by season as follows:

Gear Type	A Season	B Season	C Season
CDQ trawl	60	20	20
CDQ trawl catcher vessels	70	10	20
CDQ trawl catcher-processors	50	30	20
Non-CDQ trawl catcher vessels	74	11	15
Non-CDQ trawl catcher-processors	75	25	0
CDQ hook-and-line catcher-processors, and hook-and-line catcher vessels ≥ 60 ft. LOA	60	40	n/a
Non-CDQ hook-and-line catcher-processors, hook-and-line catcher vessels ≥ 60 ft. LOA, pot catcher-processors, and pot catcher vessels ≥ 60 ft. LOA	51	49	n/a
CDQ jig vessels	40	20	40
Non-CDQ jig vessels	60	20	20
All other nontrawl vessels	---------- no seasonal allowance ----------		

DATA

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

Commercial Catch Data

Catch Biomass

Catches taken in the EBS for the period 1977-2008 are shown in Table 2.6. Catches for the years 1977-1980 may not include discards. Catches in these tables are broken down by the three main gear types and intra-annual periods consisting of the months January-May, June-August, and September-December. This particular division, which was suggested by participants in the EBS fishery, is intended to reflect actual intra-annual differences in fleet operation (e.g., fishing operations during the spawning period may be different than at other times of year). In years for which estimates of the distribution by gear or period were not available, proxies based on other years' distributions were used.

Catch Size Composition

Fishery size compositions are presently available, by gear, for at least one gear type in every year from 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:

BinNumber:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
LowerBound:	9	12	15	18	21	24	27	30	33	36	39	42	45	50	55	60	65	70	75	80	85	90	95	100	105
UpperBound:	11	14	17	20	23	26	29	32	35	38	41	44	49	54	59	64	69	74	79	84	89	94	99	104	110

The collections of relative length frequencies are shown by year and size bin for the trawl fishery in Tables 2.7a, 2.7b, and 2.7c; the longline fishery in Tables 2.8a, 2.8b, and 2.8c; and the pot fishery in Tables 2.9a, 2.9b, and 2.9c.

Catch Per Unit Effort

Fishery catch per unit effort data are available by gear and season for the years 1991-2008 and are shown below (units are kg/hr for trawl gear, kg/hook for longline gear, and kg/pot for pot gear; 2008 data for trawl gear and 2008 season 3 data for longline and pot gear are not yet available):

Year	Trawl			Longline			Pot		
	Sea. 1	Sea. 2	Sea. 3	Sea. 1	Sea. 2	Sea. 3	Sea. 1	Sea. 2	Sea. 3
1991	58.85	49.23	24.40	1.02	0.71	0.55		68.53	103.16
1992	49.11	104.89	30.40	0.80	0.50	0.49	76.14	49.20	26.94
1993	51.00	50.84	106.54	0.66	0.35		85.53		
1994	51.41	45.97	51.01	0.73		0.58	86.03		97.17
1995	62.04	57.44	62.76	0.86		0.60	85.19	69.59	52.18
1996	35.70	36.59	32.98	0.81		0.54	67.67	53.19	49.54
1997	51.20	32.77	75.73	0.87		0.58	76.71	47.20	46.56
1998	36.26	27.95	43.34	0.74		0.44	63.17	46.65	32.70
1999	37.54	16.67	20.80	0.68	0.46	0.50	53.98	40.13	37.50
2000	32.73	14.17	22.40	0.68	0.49	0.40	51.31		
2001	22.42	45.65	14.42	0.56	0.44	0.41	70.30		46.11
2002	29.70	31.72	16.28	0.68	0.39	0.37	67.55		44.93
2003	26.91	33.46	21.86	0.52	0.35	0.35	73.86		58.16
2004	50.06	29.76	16.12	0.56	0.34	0.36	76.48		51.93
2005	45.06	21.12		0.64	0.36	0.35	86.93		46.12
2006	41.58	25.74		0.76	0.43	0.37	87.16		52.40
2007	37.90	42.90	15.94	0.73	0.46	0.37	64.67		65.36
2008				0.77	0.43		81.64		

Survey Data

EBS Shelf Bottom Trawl Survey

The relative size compositions from bottom trawl surveys of the EBS shelf conducted by the Alaska Fisheries Science Center since 1979 are shown in Tables 2.10a for the years 1979-1981 and 2.10b for the years 1982-2007, using the same length bins defined above for the commercial catch size compositions. The survey is shown as two separate time series because of a gear change that was instituted in 1982.

Following a decade-long hiatus in production ageing of Pacific cod, the Age and Growth Unit of the Alaska Fisheries Science Center began ageing samples of Pacific cod from the EBS shelf bottom trawl surveys a few years ago (Roberson 2001, Roberson et al. 2005). To date, the otolith collections from the 1994-2006 surveys and part of the 2007 survey collection have been read. The relative age compositions from these surveys are shown in Table 2.11. The number of fish aged for each of these years is shown below:

Year:	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
N:	715	599	252	719	635	860	864	950	947	1360	1040	609	1301	866

Estimates of total abundance (both in biomass and numbers of fish) obtained from the trawl surveys are shown in Table 2.12a (1979-1981) and 2.12b (1982-2008), together with their respective standard errors. Upper and lower 95% confidence intervals are also shown for the biomass estimates. Survey results indicate that biomass increased steadily from 1978 through 1983, and then remained relatively constant from 1983 through 1988. The highest biomass ever observed by the survey was the 1994 estimate of 1,368,120 t. Following the high observation in 1994, the survey biomass estimate declined steadily through 1998. The survey biomass estimates remained in the 596,000-619,000 t range from 2002 through 2005. However, the survey biomass estimates have dropped consistently since 2005, producing all-time lows in 2007 and again in 2008. The 2008 biomass estimate was 403,125 t.

Numerical abundance has shown more variability than biomass. The 2007 estimate was the eighth highest in the time series, but the 2008 estimate was the sixth lowest, roughly in the same range as all but two of the estimates from 1997 onward.

One concern that has arisen in public comment is that the CPUE trend from the longline fishery overall (across seasons) does not correlate very well with the CPUE trend from the bottom trawl survey (measured in units of biomass), particularly for the years since 2001. The correlation between these two time series is -0.49 (Figure 2.2a). However, these two time trends may be measuring different things: The longline fishery is concentrated in particular areas (which may change between seasons and years), and the catches are filtered through a selectivity schedule; whereas the trawl survey takes place only during the summer months, occurs over the entire shelf (at a fixed set of locations in every year), and is filtered through its own selectivity schedule.

One way to look at this problem is to use the existing survey strata to define areas of greatest fishery concentration. Both in terms of catch and observed sets, the survey stratum with the largest longline fishery concentration in June-August of every year from 2001-2007 is stratum 61, which lies along the outer shelf north of the Pribilof Islands. If the correlation is computed between just the longline fishery CPUE from June-August (when the survey takes place), and the trawl survey CPUE form stratum 61 (where the June-August longline fishery is concentrated), the correlation goes up to 0.36 (Figure 2.2b).

Although a correlation of 0.36 is not perfect, the remaining lack of fit may be due largely to differences between gear-specific selectivity schedules and the fact that the spatial distribution of the June-August longline fishery changes from year to year. For example, while stratum 61 is the dominant stratum in the June-August longline fishery in every year from 2001-2007 (averaging 48% across years), the proportion of the catch taken in that stratum varies from 0.24 (in 2001) to 0.68 (in 2007). The proportions of the catch taken in the other strata show variability also, but confidentiality restrictions prohibit a full description due to the small number of vessels fishing in some strata.

Aleutian Bottom Trawl Survey

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

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

For many years, the assessments of Pacific cod in the BSAI have used a weighted average formed from EBS and Aleutian survey biomass estimates to provide a conversion factor which was used to translate model projections of EBS catch and biomass into BSAI equivalents. Prior to the 2004 assessment, the weighted average was based on the sums of the biomass estimates from the EBS shelf and AI survey biomass time series. However, in December of 2003 the SSC requested that alternative methods of estimating relative biomass between the EBS and AI be explored. Following a presentation of some possible alternatives, the SSC recommended that an approach based on a simple Kalman filter be used

(SSC Minutes, October, 2004). In the 2006 assessment, the Kalman filter approach was applied to the updated (through 2006) time series, indicating that the best estimate of the current biomass distribution is 84% EBS and 16% AI (the previous proportions were 85% and 15%, respectively).

IPHC Longline Survey

The International Pacific Halibut Commission (IPHC) conducts an annual longline survey designed to estimate the relative abundance of Pacific halibut (*Hippoglossus stenolepis*). The survey also takes Pacific cod incidentally. The CPUE time series (number of Pacific cod per hook) from stations in the BS since 2000 is as follows (note that this time series is different from the one reported in last year's SAFE report, due to corrections involving stations from the AI and Western GOA previously mis-identified as Bering Sea stations):

2000	2001	2002	2003	2004	2005	2006	2007
0.077	0.083	0.083	0.098	0.069	0.109	0.154	0.119

Pacific cod length composition data have not been taken historically in the IPHC survey. Just prior to the initiation of the 2007 survey, the IPHC staff was requested to sample Pacific cod size composition to the extent possible given such short notice, and the IPHC staff made a special effort to do so. However, the usefulness of the 2007 size composition data appears to have been compromised by the necessity of collecting those data at the ports. Port sampling is problematic in this context, because Pacific cod retention during the IPHC survey is allowed only at the end of each trip and is not mandated. In contrast, for 2008, the request for collection of size composition data was made with sufficient lead time to allow the IPHC staff to collect these data at sea. The size compositions from the 2007 and 2008 samples were very different from one another. Because of the problems associated with the 2007 sampling protocol, only the 2008 size composition data are used in the present assessment. A total of 5093 lengths were collected in 2008, distributed among length bins as follows (no fish smaller than 42 cm were collected):

Length:	42	45	50	55	60	65	70	75	80	85	90	95	100	105
Number:	2	19	71	284	673	835	807	550	467	438	449	318	139	41

ANALYTIC APPROACH

Model Structure

History of Previous Model Structures Developed Under Stock Synthesis

Beginning with the 1993 SAFE report (Thompson and Methot 1993) and continuing through the 2004 SAFE report (Thompson and Dorn 2004), a model using the Stock Synthesis 1 (SS1) assessment program (Methot 1986, 1990, 1998, 2000) and based largely on length-structured data formed the primary analytical tool used to assess the EBS Pacific cod stock. It should be emphasized that the model has always been intended to assess only the EBS portion of the BSAI stock. Conversion of model estimates of EBS biomass and catch to BSAI equivalents has traditionally been accomplished by application of an expansion factor based on the relative survey biomasses between the EBS and AI.

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

SS1 permits each data time series to be divided into multiple segments, resulting in a separate set of parameter estimates for each segment. The EBS Pacific cod assessments, for example, have usually divided the shelf bottom trawl survey size composition time series into pre-1982 and post-1981 segments to account for the effects of a change in the trawl survey gear instituted in 1982. Also, to account for possible differences in selectivity between the mostly foreign (also joint venture) and mostly domestic fisheries, the fishery size composition time series was split into pre-1989 and post-1988 segments during the era of SS1-based assessments.

In the EBS Pacific cod model, each year has traditionally been partitioned into three seasons: January-May, June-August, and September-December (these seasonal boundaries were suggested by industry participants). Four fisheries were been 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 EBS Pacific cod remained completely unchanged from 1997 through 2001. During the late 1990s, a number of attempts were made to estimate the natural mortality rate *M* and the shelf bottom trawl survey catchability coefficient *Q*, but these were not particularly successful and the Plan Team and SSC always opted to retain the base model in which *M* and *Q* were fixed at their traditional values of 0.37 and 1.0, respectively.

A minor modification of the base model was suggested by the SSC in 2001, namely, that consideration be given to dividing the domestic era into pre-2000 and post-1999 segments. This modification was tested in the 2002 assessment (Thompson and Dorn 2002), where it was found to result in a statistically significant improvement in the model's ability to fit the data. In the 2004 assessment (Thompson and Dorn 2004), further modifications were made to the base model. The 2004 model included a set of selectivity parameters for the EBS slope bottom trawl survey and added new likelihood components for the age compositions and length-at-age data from the 1998-2003 EBS shelf bottom trawl surveys and the size composition and biomass data from the 2002 and 2004 EBS slope bottom trawl surveys. Incorporation of age data and slope survey data had been suggested by the SSC (SSC minutes, December 2003).

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

The 2006 assessment (Thompson et al. 2006) explored alternative functional forms for selectivity, use of Pacific cod incidental catch data from the NMFS sablefish longline survey, and the influence of prior distributions.

A technical workshop was held in April of 2007 to address possible improvements to the assessment model (Thompson and Conners 2007). Based on suggestions received at the workshop, several alternative models were considered in a preliminary 2007 assessment (Thompson et al. 2007a), and four models were advanced during the final 2007 assessment (Thompson et al. 2007b). The recommended model from the final 2007 assessment (Model 1) included the following features that distinguished it from the model used in the 2006 assessment:

1) The natural mortality rate was set externally, based on life history theory.
2) The maturity schedule was modeled as a function of age.

3) The trawl survey selectivity schedule was modeled as a function of age (fishery selectivity schedules were modeled as functions of length).
4) The June-August trawl, September-December trawl, June-August longline, and September-December pot fishery selectivity schedules were assumed to be asymptotic.
5) All fishery selectivity schedules were assumed to be constant across all years.
6) The ascending "width" parameter of the survey selectivity schedule was assumed to vary annually, with a standard deviation of 0.2.
7) The standard deviation of length at age was modeled as a linear function of length at age.
8) Survey abundance was measured in numbers of fish (not biomass).
9) Input multinomial sample sizes were based on a scaled bootstrap harmonic mean.

Model Structures Considered in This Year's Assessment

As described in the Executive Summary, eight models are presented in this assessment, all based on SS version 3.01f. Three of these (Models A1, B1, and C1) use age composition data, while the rest do not. Three models estimate the natural mortality rate internally (Models C1, E2, and F2), while the rest estimate the natural mortality rate based on life history theory (although Model D2 does so iteratively by involving other model-derived quantities in the estimation). Two models were requested by the SSC (Models A1 and A2) and three models were requested by members of the public (Models D2, E2, and F2). Except for Model F2, all of the models are based largely on Model 5 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 Model 1 from last year's assessment are listed in Table 2.2.1 of Attachment 2.2). Model A2 can be thought of as a modification of Model A1, and Models B2, C1, D2, and E2 can be thought of as modifications of Model B1; hence, the remainder of this subsection focuses on development of Models A1 and B1.

The key difference between Models A1 and B1 is 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. Model A1 falls into the former category, assuming that the January-May trawl fishery is the only fishery whose selectivity schedule is necessarily asymptotic, while Model B1 falls into the latter category, assuming asymptotic selectivity for multiple fisheries. The method used to choose the set of fisheries exhibiting asymptotic selectivity in Model B1 was as follows:

1) Determine the set of "major" fisheries in the BS 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 longline fishery, and the September-December longline fishery. These are the only fisheries accounting for more than a 10% 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 74% 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 Model B1 assuming that all fisheries exhibited asymptotic selectivity except for the January-May longline fishery, the September-December longline fishery, and the January-May pot fishery.

A major task in developing Models A1 and B1 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. The following algorithm was used to address these competing concerns in both Models A1 and B1, 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:

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 five possible values for the number of freely estimated age groups (beyond age 0) in the initial numbers-at-age vector (0, 1, 2, 3, and 4). This 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.

Parameters Estimated Independently

Natural Mortality

In the 1993 BSAI Pacific cod assessment (Thompson and Methot 1993), the natural mortality rate *M* was estimated using SS1 at a value of 0.37. Although attempts have been made to obtain internal estimates of *M* in some years, all models of the BSAI Pacific cod stock accepted by the Plan Team and SSC from 1993 through 2006 ultimately retained a value of 0.37 for *M*. The 2007 assessment marked the first time since 1993 that a different value of *M*, 0.34, was accepted by the SSC. This value was based on Equation 7 of Jensen (1996) and an age at maturity of 4.9 years (Stark 2007). In response to a request from the SSC, this year's preliminary assessment included a justification for this value. However, it should be emphasized that, even if Jensen's Equation 7 is exactly right, variability in the estimate of the age at maturity implies that the point of estimate of 0.34 is accompanied by a level of uncertainty. Using the variance for the age at 50% maturity published by Stark (0.0663), the 95% confidence interval for *M* extends from about 0.30 to 0.38.

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

As noted above, three of the models in the present assessment (C1, E2, and F2) estimate *M* conditionally, and a fourth (Model D2) estimates *M* quasi-conditionally. The remaining models estimate *M* independently at the SSC-approved value of 0.34.

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 three assessments to estimate a proportional relationship between standard deviation and age. The regression was recomputed this year, yielding an estimated coefficient of 0.088 (i.e, the standard deviation of estimated age was modeled as 0.088 × 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 all models except Model F2. This was done by computing the long-term survey size composition of fish 5 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 = 0.98), and estimated the mean and standard deviation of length at age 1.5417 at values of 16.135 and 3.692, respectively.

Weight at Length

In recent assessments, bottom trawl survey data were used to estimate the multiplicative constant α and exponent β at values of 3.86×10^{-6} and 3.266, respectively. Model F2 in the present assessment continues to use this pair of values.

For the other seven models, 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:	5.705×10^{-6}	9.055×10^{-6}	5.774×10^{-6}	6.161×10^{-6}
β:	3.184	3.065	3.183	3.165
Samples:	54,798	13,370	22,710	90,878

The seasonal model gives a statistically significant improvement (AIC = 84,762 for the annual model; AIC = 83,989 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. The same parameter values are used for Model 4 in the present assessment. However, in 2007, changes in SS2 allowed for use of either a length-based or an age-based maturity schedule. The accepted model in the 2007 assessment used an age-based schedule with intercept = 4.9 years and slope = -0.965 (Stark 2007). The use of an age-based rather than a length-based schedule follows a recommendation from the author of the maturity study from which the parameter values were taken (James Stark, Alaska Fisheries Science Center, personal communication). In the present assessment, Models D2 and F2 use a length-based maturity schedule, while all of the other models use an age-based maturity schedule.

Parameters Estimated Conditionally

Parameters estimated conditionally (i.e., within individual SS runs, based on the data and the parameters estimated independently) include the natural mortality rate (Models C1, E2, and F2), length-at-age parameters (except for the mean length at reference age 1.5417 years in all models except F2), parameters governing variability in length at age (except for the standard deviation at reference age 1.5417 in all models except F2), log mean recruitment, initial fishing mortality, survey catchability, selectivity parameters, annual recruitment deviations, and annual deviations in the ascending limb of the trawl survey selectivity schedule.

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.

Likelihood Components

All eight models included likelihood components for trawl survey relative abundance, fishery and survey size composition, recruitment, and parameter deviations. In addition, Models A1, B1, and C1 included likelihood components for age composition, and all models except F2 included a likelihood component for 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 each model 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 EBS 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 assessment 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 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 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 pre-1982 trawl survey, length compositions were tentatively set at 16% of an assumed sample size of 10,000. For the post-1981 trawl survey and IPHC survey length compositions, 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. The resulted in the set of multinomial sample sizes shown in Table 2.14.

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 were computed by scaling the actual number of otoliths read in each year proportionally such that the average of the input sample sizes was equal to 300.

To avoid double counting of the same data, Models A1, B1, and C1 ignore length composition data from the EBS shelf bottom trawl surveys in years where age data are available. Models A2, B2, D2, E2, and F2 use the length composition data from the EBS trawl surveys in all years.

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. The same is true for the relative abundance data from the IPHC longline survey.

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.

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, eight models are evaluated in the present assessment. All models appeared to converge successfully and the Hessian matrices from all models were positive definite. Once convergence appeared to be achieved, 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 a few cases (especially Models A1 and A2), 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

Tables 2.15-2.18 present summaries of some key results from the eight models. Table 2.15 pertains to statistical goodness of fit, Table 2.16 pertains to estimates of parameters other than selectivity parameters, Table 2.17 pertains to estimates of selectivity parameters, and Table 2.18 pertains to estimates of management-related quantities. In each row of these tables (except Table 2.17), 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 2.15a is structured as follows:

> Section 1: Parameter counts. This section enumerates the number of internally estimated parameters. The number of parameters ranges from 130-232.
>
> 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, models whose labels end in "1" use a different data set (age compositions included, and trawl survey size compositions ignored in years where age composition data exist) than models whose labels end in "2" (age compositions not included, and all trawl survey size compositions used). Also, the value of σ_R differs between Models A1/A2, B1/B2/C1/D2/E2, and F2, which also affects the likelihood. Finally, Model F2 does not attempt to fit the initial equilibrium catch, which would allow it to do a better job of fitting the other components, if all else were equal.
>
> Section 3: Relative abundance likelihoods. The only likelihoods that are actually used in this section are the trawl survey likelihoods (pre-1982 and post-1981 in all models except F2, post-1981 only in Model F2). 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 2.15b and 2.15c provide alternative measures of how well the models are fitting the fishery CPUE and survey relative abundance data. Table 2.15b shows root mean squared errors (lower values are better) and Table 2.15c shows correlations between observed and estimated values. Note that none of the models actually attempts to fit the fishery CPUE or the IPHC longline survey; these results are shown for information only. Of all the models, F2 gives the worst fit to the post-1981 trawl survey, but tends to do better than the other models in fitting the fishery and IPHC data.

Tables 2.15d and 2.15e provide alternative measures of how well the models are fitting the size composition data (higher values are better). Table 2.18a shows the average of the ratios between output “effective” sample size McAllister and Ianelli 1997) and input sample size, while Table 2.18b shows the ratio of the averages. Model F2 consistently performs the worst by either measure, but it is also the only model that does not use time-varying fishery selectivity (and therefore has far fewer parameters).

For age composition data, the following table summarizes relationships between effective sample size and input sample size (note that Models A1, B1, and C1 are the only ones that use age composition data):

Quantity	Model A1	Model B1	Model C1
Average of ratios (effective/input)	0.375	0.365	0.370
Ratio of averages (effective/input)	0.377	0.375	0.382

None of the models fits the age composition data very well by these measures.

Table 2.16a lists parameters common to all (or almost) all of the eight models, except for recruitment deviations, which are shown in Table 2.16b. Because the set of selectivity parameters differs between models A1/A2, B1/B2/C1/D2/E2, and F2, these are shown in separate tables (see description of Table 2.17 below). Common parameters include the natural mortality rate M, mean lengths at reference ages 1 (=1.5417 years in all models except F2, =1 year in Model F2) and 2 (=20 years in all models), the Brody growth coefficient K, parameters governing the spread of the age-specific length-at-age distributions (SD_1 and SD_2), log mean recruitments for the post-1976 and pre-1977 environmental regimes (R_0 and R_1), the scale of log recruitment variability σ_R, the fishing mortality rate in the initial year, and the log catchability coefficients for the pre-1982 trawl survey ($\ln Q_1$, used in all models except F2), and the post-1981 trawl survey ($\ln Q_2$). Note that two of these parameters, SD_2 and R_1, are expressed as log offsets of their respective counterparts. The standard deviation of length at reference age 2 is thus computed as $SD_1 \times \exp(SD_2)$, and 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).

Table 2.16b lists estimates and standard deviations of annual log recruitment deviations given by the eight 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 all models, the pre-1977 mean is much lower than the post-1976 mean (model estimates of R_1 range from –0.61 to –1.00). All eight models indicate a substantial degree of agreement regarding strong and weak year classes. For example, considering just the year classes spawned during the post-1976 regime, all eight models agree on the sign of the deviation in 25 out of the 31 year classes; for the remaining 6 year classes, at least six (usually seven) of the eight models agree on the sign of the deviation. In particular, all eight models estimate negative values for all recruitment deviations from 2001 through 2005, and all eight models estimate a fairly large positive value (0.41 to 0.72) for the 2006 recruitment deviation.

Table 2.17 pertains to model estimates of selectivity parameters. Table 2.17a contains the legend for the remaining portions of the table. Tables 2.17b-d show the estimates and standard deviations for every selectivity parameter estimated by any of the models. Different sub-tables are required because different sets of selectivity parameters are used by different groups of models. Table 2.17b shows the estimates for Models A1 and A2; Table 2.17c shows the estimates for Models B1, B2, C1, D2, and E2; and Table 2.17d shows the estimates for Model F2.

Table 2.18 contains selected output from the standard projection model, based on SS parameter estimates from the eight models. Recruitments, numbers at age, and biomasses have been divided by the conversion factor of 0.84 described in the "Aleutian Bottom Trawl Survey" subsection, so as to represent quantities relevant to the entire BSAI management region, rather than the BS area on the basis of which the models are configured.

> 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 first assumes that catch in 2009 equals the maximum permissible ABC, and the second assumes that catch in 2009 equals 176,000 t (the ABC for 2007 and 2008).
>
> Section 9: Probability that spawning biomass will fall below 20% of B100% by 2020 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%.

Other derived quantities, not necessarily directly related to management, also deserve some attention. For example, the long-term size composition from the trawl survey indicates fairly distinct modes at about 16 cm, 33 cm, and 46 cm, which may be assumed to represent the mean lengths of ages 1, 2, and 3 observed at the time of the survey (with a mid-point occurring in about July). The means and standard deviations of lengths at ages 1, 2, and 3 during July were estimated by the eight models as shown below (note that the mean and standard deviation for age 1 were fixed in all models except F2):

	Model A1		Model A2		Model B1		Model B2		Model C1		Model D2		Model E2		Model F2	
Quantity	Ave.	SD	Ave.	SD	Ave.	SD	Ave.	SD	Ave.	SD	Ave.	SD	Ave.	SD	Ave.	SD
July L@1	16.1	3.7	16.1	3.7	16.1	3.7	16.1	3.7	16.1	3.7	16.1	3.7	16.1	3.7	16.3	4.4
July L@2	32.7	5.0	33.0	5.1	32.5	5.0	32.9	5.0	32.5	5.0	32.9	5.0	32.5	4.9	32.7	4.9
July L@3	45.6	6.0	46.1	6.1	45.3	6.0	45.9	6.1	45.3	6.0	45.9	6.1	45.6	5.9	46.1	5.5

Another derived quantity of interest is the product of trawl survey catchability and selectivity within the 60-81 cm size range, as Nichol et al. (2007) indicated that this quantity has an expected value of about 0.47 given the configuration of the net used in the BS trawl survey. To estimate this quantity from SS results, estimates of the catchability coefficient and selectivity-at-age schedule were combined with age-specific distributions of length at age and long-term average distributions of numbers at age (the analysis for Model F2 differed slightly because F2 treats survey selectivity as a function of length rather than age). The results were as shown below:

Model:	A1	A2	B1	B2	C1	D2	E2	F2
Ave. Q×Sel. (60-81 cm):	0.39	0.27	0.59	0.44	0.64	0.41	0.00	0.65

Evaluation Criteria

All of the models seem to perform reasonably well in terms of fitting the data, given the assumptions associated with each model.

The following criteria are therefore proposed for this year's assessment:

1) The model should estimate mean lengths for ages 1-3 that are close to the first three modes from the long-term average trawl survey size composition.
2) The model should assume or estimate a reasonable value for *M*.
3) The model should estimate a reasonable average for the product of trawl survey catchability and trawl survey selectivity for the 60-81 cm size range.
4) For models that satisfy the first three criteria above, the following "tie-breaker" criterion will be used: Choose the model that implies the least drastic changes with respect to recent understanding regarding appropriate model structure and the size and productivity of the stock (in other words, do not make big changes in the model unless there is a compelling reason to do so).

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, some or all of the criteria listed above would not be necessary, or perhaps even useful.

Selection of Final Model

Criterion #1 does not eliminate any of the models.

Criterion #2 eliminates Models E2 and F2, because the estimates of *M* obtained by these models (0.58 and 0.47, respectively) fall outside the 95% confidence interval of 0.30-0.38 described in the "Parameters Estimated Independently" section.

Criterion #3 eliminates Models A2 and E2, because the estimates of the product of trawl survey catchability and selectivity within the 60-81 cm size range obtained by these models (0.27 and 0.00, respectively) fall outside of the 95% confidence interval of 0.39-0.68 obtained by a parametric bootstrap based on the data of Nichol et al. (2007).

Thus, Models A1, B1, B2, C1, and D2 all satisfy the first three criteria. Criterion #4 therefore comes into play. Models A1, B1, and C1 all continue to use age composition data, as has been advised by the Plan Team and SSC. Models A1, B1, and B2 continue to use a value of 0.34 for *M*, as has been advised by the Plan Team and SSC. Models B1, B2, and D2 all imply less than a 10% change in the value of 2009 spawning biomass projected in last year's assessment. Model B1 is the only model for which the maximum permissible ABC for 2009 is within 10% of the 2009 ABC specified last year by the SSC. Model B1 is therefore chosen as the preferred model.

Final Parameter Estimates and Associated Schedules

As noted previously, estimates of all statistically estimated parameters in Model B1 are shown in Tables 2.16a, 2.16b, and 2.17c.

Estimates of year-, gear-, and season-specific fishing mortality rates from Model B1 are shown in Table 2.19.

Schedules of selectivity at length for the commercial fisheries and the IPHC longline survey from Model B1 are shown in Table 2.20a, and schedules of selectivity at age for the trawl surveys from Model B1 are shown in Table 2.20b. Trawl fishery, longline fishery, pot fishery, and survey selectivity schedules are plotted in Figures 2.3a-d, respectively. The time series of post-1981 trawl survey selectivities at age 1 is plotted in Figure 2.4, showing a general upward trend.

Model B1's fit to the time series of trawl survey abundance estimates is shown in Figure 2.5.

Schedules of length at age and weight at age for the population, each gear-and-season-specific fishery, and each survey from Model B1 are shown in Tables 2.21 and 2.22, respectively.

TIME SERIES RESULTS

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

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 2.23a shows the time series of EBS (not expanded to BSAI) Pacific cod age 0+ and female spawning biomass for the years 1977-2009 as estimated last year and this year under Model B1. The estimated spawning biomass time series are accompanied by their respective standard deviations.

The estimated time series of EBS age 0+ biomass and female spawning biomass from Model B1 are shown, together with the observed time series of trawl survey biomass (assuming a catchability of 1.0), in Figure 2.6. 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 2.23b shows the time series of EBS (not expanded to BSAI) Pacific cod age 0 recruitment (1000s of fish) for the years 1977-2007 as estimated last year and this year under Model B1. Both estimated time series are accompanied by their respective standard deviations.

Model B1's recruitment estimates for the entire time series (1977-2007) are shown in Figure 2.7, along with their respective 95% confidence intervals. For the time series as a whole, the largest year class clearly appears to have been the 1977 cohort. Other large cohorts include the 1982, 1984, 1992, and 1996 year classes. The 2006 year class, which appeared exceptionally strong in the 2007 survey, still appears to be well above average, and is currently ranked as the fifth strongest cohort in the time series. However, the 2006 year class follows a string of five consecutive sub-par year classes spawned from 2001-2005, none of which is ranked higher than 23rd out of the 31 year classes spawned during the current (post-1976) environmental regime. The confidence interval surround the most recent observed year class (2007) is very broad, reflecting the fact that it has been observed in only one survey and that survey selectivity of age 1 fish appears to be fairly variable.

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 B1 is shown in Table 2.24.

Exploitation

Figure 2.9 plots the trajectory of relative fishing mortality and relative female spawning biomass from 1977 through 2008 based on Model B1, overlaid with the current harvest control rules (fishing mortality rates in the figure are standardized relative to $F_{35\%}$ and biomasses are standardized relative to $B_{35\%}$, per SSC request). The entire trajectory lies underneath the $maxF_{ABC}$ control rule. Figure 2.9 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 BSAI Groundfish Fishery Management Plan (FMP) defines the "overfishing level" (OFL), the fishing mortality rate used to set OFL (F_{OFL}), the maximum permissible ABC, and the fishing mortality rate used to set the maximum permissible ABC. The fishing mortality rate used to set ABC (F_{ABC}) may be less than this maximum permissible level, but not greater. Because reliable estimates of reference points related to maximum sustainable yield (MSY) are currently not available but reliable estimates of reference points related to spawning per recruit are available, Pacific cod in the BSAI have generally been managed under Tier 3 of Amendment 56. Tier 3 uses the following reference points: $B_{40\%}$, equal to 40% of the equilibrium spawning biomass that would be obtained in the absence of fishing; $F_{35\%}$, equal to the fishing mortality rate that reduces the equilibrium level of spawning per recruit to 35% of the level that would be obtained in the absence of fishing; and $F_{40\%}$, equal to the fishing mortality rate that reduces the equilibrium level of spawning per recruit to 40% of the level that would be obtained in the absence of fishing. The following formulae apply under Tier 3:

3a)Stock status: $B/B_{40\%} > 1$

$F_{OFL} = F_{35\%}$

$F_{ABC} \leq F_{40\%}$

3b)Stock status: $0.05 < B/B_{40\%} \leq 1$

$F_{OFL} = F_{35\%} \times (B/B_{40\%} - 0.05) \times 1/0.95$

$F_{ABC} \leq F_{40\%} \times (B/B_{40\%} - 0.05) \times 1/0.95$

3c)Stock status: $B/B_{40\%} \leq 0.05$

$F_{OFL} = 0$

$F_{ABC} = 0$

Other useful biomass reference points which can be calculated using this assumption are $B_{100\%}$ and $B_{35\%}$, defined analogously to $B_{40\%}$. These reference points are estimated as follows, based on Model B1:

Reference point:	$B_{35\%}$	$B_{40\%}$	$B_{100\%}$
BSAI:	373,000 t	426,000 t	1,066,000 t
EBS:	313,000 t	358,000 t	895,000 t

For a stock exploited by multiple gear types, estimation of $F_{35\%}$ and $F_{40\%}$ requires an assumption regarding the apportionment of fishing mortality among those gear types. For this assessment, the apportionment was based on Model 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 31%, longline 58%, and pot 0.11%. This apportionment results in estimates of $F_{35\%}$ and $F_{40\%}$ equal to 0.34 and 0.28, respectively.

Specification of OFL and Maximum Permissible ABC

BSAI spawning biomass for 2009 is estimated by Model B1 at a value of 373,000 t. This is about 12% below the BSAI $B_{40\%}$ value of 426,000 t, thereby placing Pacific cod in sub-tier "b" of Tier 3. Given this, Model B1 estimates OFL, maximum permissible ABC, and the associated fishing mortality rates for 2009 and 2010 as follows (2010 values are predicated on the assumption that 2009 catch will equal 2009 maximum permissible ABC; catches in t, and are for the entire BSAI):

Year	Overfishing Level	Maximum Permissible ABC
2009	212,000 t	182,000 t
2010	233,000 t	199,000 t
2009	0.29	0.24
2010	n/a	0.24

The age 0+ biomass BSAI projections for 2009 and 2010 from Model B1 are 1,703,000 t and 1,808,000 t.

ABC Recommendation

Review of Past Approaches

In the 2005 assessment, the Plan Team and SSC selected a model that resulted in a maximum permissible ABC of 194,000 t, which was adopted as the 2006 ABC. Similarly, the maximum permissible ABC was selected in the 2006 assessment, giving a 2007 ABC of 176,000 t.

In 2007, the SSC adopted the following rationale in recommending the 2008-2009 ABCs and OFLs:

"While the recent trawl survey trend has been downward and present biomass is low relative to the mid 1980s, the model indicates that the spawning biomass will be on an upward trend from 2008. This suggests keeping ABC where it is for the time being and the SSC therefore recommends that ABC remain at 176,000 t in 2008/09 and OFLs for 2008/09 also rollover the 2007 OFL value of 207,000 t."

Recommendation for 2009-2010

Based on Model B1, the maximum permissible ABC (Tier 3b) for 2009 is 182,000 t. This would constitute a 3% increase from the 2008 value of 176,000. However, the survey biomass estimate dropped by 5% since last year, and the 2008 estimate is now the all-time low in the time series. As Figure 2.6 shows, all measures of biomass (survey biomass, model age 0+ biomass, and model spawning biomass) have trended consistently downward for the last few years. Such a downward trend is expected, given the string of five consecutive below-average year classes spawned from 2001 to 2005. The downward trend is expected to reverse in the relatively near future, however, as the strong 2006 year class works its way through the age structure.

Thus, the conditions that led the SSC to recommend a "constant ABC" policy last year (i.e., downward biomass trend and all-time low survey biomass, but upward trend likely in the near future) continue to hold this year. Therefore, the recommended ABCs for 2009 and 2010 are 176,000 t, equal to the ABCs for 2007 and 2008, and below the maximum permissible levels.

Another reason to set the ABC below the maximum permissible level of 182,000 t computed under Model B1 is that, if the natural mortality rate is estimated internally while keeping Model B1's other assumptions the same (as in Model C1), the maximum permissible ABC would be only 158,000 t.

If the 2009 catch equals the recommended ABC of 176,000 t rather than the maximum permissible level of 182,000 t, the 2010 OFL would be 235,000 t.

Area Allocation of Harvests

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

Standard Harvest and Recruitment Scenarios and Projection Methodology

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

For each scenario, the projections begin with 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 B1 in Tables 2.25-2.31.

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 2.18 contains the appropriate one- and two-year ahead projections for both ABC and OFL under any of the eight 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 173,603 t. This is less than the 2007 OFL of 207,000 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 (Table 2.31):

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 2.30 and 2.31, the stock is not overfished and is not approaching an overfished condition.

ECOSYSTEM CONSIDERATIONS

Attachment 2.1 contains a summary of new results from ecosystem models on the role of Pacific Cod in the Eastern Bering Sea and Aleutian Islands ecosystems. The material in the present section is unchanged from last year's assessment.

Ecosystem Effects on the Stock

A primary ecosystem phenomenon affecting the Pacific cod stock seems to be the occurrence of periodic "regime shifts," in which central tendencies of key variables in the physical environment change on a scale spanning several years to a few decades (Boldt (ed.), 2005). One well-documented example of such a regime shift occurred in 1977, and shifts occurring in 1989 and 1999 have also been suggested (e.g., Hare and Mantua 2000). In the present assessment, an attempt was made to estimate the change in median recruitment of EBS Pacific cod associated with the 1977 regime shift. According to Model 1, pre-1977 median recruitment was only about 20% of post-1976 median recruitment. Establishing a link between environment and recruitment within a particular regime is more difficult. In the 2004 assessment (Thompson and Dorn 2004), for example, the correlations between age 1 recruits spawned since 1977 and monthly values of the Pacific Decadal Oscillation (Mantua et al. 1997) were computed and found to be very weak.

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

Fishery Effects on the Ecosystem

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

Bycatch of Nontarget and "Other" Species

Bycatch of nontarget species and members of the "other species" group are shown in the following set of tables (for the 2003-2005 tables, the "hook and line" gear type includes both longline and jig gear): Tables 2.32a and 2.32b show bycatch for the EBS Pacific cod trawl fishery in 1997-2002 and 2003-2005, respectively. Tables 2.33a and 2.33b show bycatch for the EBS Pacific cod longline fishery in 1997-2002 and the EBS Pacific cod hook and line fishery in 2003-2005, respectively. Tables 2.34a and 2.34b show bycatch for the EBS Pacific cod pot fishery in 1997-2002 and 2003-2005, respectively. Tables 2.35a and 2.35b show bycatch for the AI Pacific cod trawl fishery in 1997-2002 and 2003-2005, respectively. Tables 2.36a and 2.36b show bycatch for the AI Pacific cod longline fishery in 1997-2002 and the AI Pacific cod hook and line fishery in 2003-2005, respectively. Tables 2.37 shows bycatch for the AI Pacific cod pot fishery in 1997-2002 (no data exist for this fishery in 2003-2005).

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

Area	Species group	Trawl	Hook and Line
EBS	Grenadier		X
EBS	Large sculpins	X	X
EBS	Misc. fish	X	
EBS	Other sculpins		X
EBS	Shark		X
EBS	Skate		X
AI	Skate		X

Steller Sea Lions

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

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

Seabirds

The following is a summary of information provided by Livingston (ed., 2002): In both the BSAI and GOA, the northern fulmar (*Fulmarus glacialis*) comprises the majority of seabird bycatch, which occurs primarily in the longline fisheries, including the hook and line fishery for Pacific cod (Tables 2.33b and 2.36b). Shearwater (*Puffinus* spp.) distribution overlaps with the Pacific cod longline fishery in the Bering Sea, and with trawl fisheries in general in both the Bering Sea and GOA. Black-footed albatross (*Phoebastria nigripes*) is taken in much greater numbers in the GOA longline fisheries than the Bering Sea longline fisheries, but is not taken in the trawl fisheries. The distribution of Laysan albatross (*Phoebastria immutabilis*) appears to overlap with the longline fisheries in the central and western Aleutians. The distribution of short-tailed albatross (*Phoebastria albatrus*) also overlaps with the Pacific cod longline fishery along the Aleutian chain, although the majority of the bycatch has taken place along the northern portion of the Bering Sea shelf edge (in contrast, only two takes have been recorded in the GOA). Some success has been obtained in devising measures to mitigate fishery-seabird interactions. For example, on vessels larger than 60 ft. LOA, paired streamer lines of specified performance and material standards have been found to reduce seabird incidental take significantly.

Fishery Usage of Habitat

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

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

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

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

Data Gaps and Research Priorities

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

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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.

Burnham, K. P., and D. R. Anderson. 1998. Model Selection and Inference: A Practical Information-Theoretic Approach. Springer-Verlag, New York. 353 p.

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

Conners, M. E., P. Munro, and S. Neidetcher. 2004. Pacific cod pot studies 2002-2003. Alaska Fisheries Science Center Proc. Rep. 2004-04. 64 p. plus appendices.

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.

Francis, R. I. C. C., R. J. Hurst, and J. A. Renwick. 2003. Quantifying annual variation in catchability for commercial and research fishing. Fish. Bull. 101:293-304.

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.

Handegard, N.O., Michalsen, K., and Tjøstheim, D. 2003. Avoidance behavior in cod (*Gadus morhua*) to a bottom-trawling vessel. Aquatic Living Resources 16:265-270.

Handegard, N.O., and Tjøstheim, D. 2005. When fish meet a trawling vessel: examining the behavior of gadoids using free-floating buoy and acoustic split-beam tracking. Canadian Journal of Fisheries and Aquatic Sciences 62: 2409-2422.

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.

Jensen, A. L. 1996. Beverton and Holt life history invariants result from optimal trade-off of reproduction and survival. Can. J. Fish. Aquat. Sci. 53:820-822.

Ketchen, K. S. 1961. Observations on the ecology of the Pacific cod (Gadus macrocephalus) in Hecate Strait, British Columbia. J. Fish. Res. Bd. Canada 21:1051-1067.

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). 2002. 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.

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. 2005. 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. 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.

Munro, P.T., and Somerton, D.A. 2002. Estimating net efficiency of a survey trawl for flatfishes. Fisheries Research 55: 267-279.

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.

Prentice, R. L. 1976. A generalization of the probit and logit methods for dose response curves. Biometrics 32:761-768.

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. 2007. Geographic and seasonal variations in maturation and growth of female Pacific cod (*Gadus macrocephalus*) in the Gulf of Alaska and Bering Sea. Fish. Bull. 105:396-407.

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. K. Dorn. 2001. Assessment of the Pacific cod stock in the eastern Bering Sea and Aleutian Islands area. *In* Plan Team for the Groundfish Fisheries of the Bering Sea and Aleutian Islands (compiler), Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the Bering Sea/Aleutian Islands Regions, p. 2.1-2.74. North Pacific Fishery Management Council, 605 West 4th Ave., Suite 306, Anchorage, AK 99501.

Thompson, G. G., and M. K. Dorn. 2002. Assessment of the Pacific cod stock in the eastern Bering Sea and Aleutian Islands area. *In* Plan Team for the Groundfish Fisheries of the Bering Sea and Aleutian Islands (compiler), Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the Bering Sea/Aleutian Islands Regions, p. 121-205. North Pacific Fishery Management Council, 605 West 4th Ave., 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. 2004. 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. 185-302. 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 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. 219-330. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.

Thompson, G. G., M. W. Dorn, S. Gaichas, and K. Aydin. 2006. 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. 237-339. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.

Thompson, G. G., J. N. Ianelli, M. W. Dorn, and D. G Nichol. 2007a. An exploration of altnernative models of the Bering Sea Pacific cod stock. Unpubl. manuscr., Alaska Fisheries Science Center, Resource Ecology and Fisheries Management Division, 7600 Sand Point Way NE., Seattle, WA 98115-6349. 29 p.

Thompson, G., J. Ianelli, M. Dorn, D. Nichol, S. Gaichas, and K. Aydin. 2007b. 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., 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 D. G. Nichol. Unpubl. manuscr. Estimating off-bottom distance from depth-only archival tag data: preliminary evaluation of a hierarchical Bayesian methodology. National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Alaska Fisheries Science Center, Resource Ecology and Fisheries Management Division, 7600 Sand Point Way NE., Seattle, WA 98115-6349.

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. 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.

Von Szalay, P.G., and Somerton, D.A. 2005. The effect of net spread on the capture efficiency of a demersal survey trawl used in the eastern Bering Sea. Fisheries Research 74: 86-95.

Walters, C. J., and D. Ludwig. 1981. Effects of measurement errors on the assessment of stock-recruitment relationships. Can. J. Fish. Aquat. Sci. 38:704-710.

Weinberg, K.L., Somerton, D.A., and Munro, P.T. 2002. The effect of trawl speed on the footrope capture efficiency of a survey trawl. Fisheries Research 58: 303-313.

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.

Winger, P.D., He, P., and Walsh, S.J. 2000. Factors affecting the swimming endurance and catchability of Atlantic cod (*Gadus morhua*). Canadian Journal of Fisheries and Aquatic Sciences 57:1200-1207.

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.

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

Eastern Bering Sea only:

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

Table 2.1b—Summary of 1981-2008 catches (t) of Pacific cod in the Eastern Bering Sea by fleet sector and gear type. All catches include discards. LLine = longline, Subt. = sector subtotal. Catches for 2008 are through early October.

Eastern Bering Sea only:

	Foreign			Joint Venture		Domestic Annual Processing					
Year	Trawl	LLine	Subt.	Trawl	Subt.	Trawl	LLine	Pot	Other	Subt.	Total
1981	30347	5851	36198	7410	7410	12884	1	0	14	12899	56507
1982	23037	3142	26179	9312	9312	23893	5	0	1715	25613	61104
1983	32790	6445	39235	9662	9662	45310	4	21	569	45904	94801
1984	30592	26642	57234	24382	24382	43274	8	0	205	43487	125103
1985	19596	36742	56338	35634	35634	51425	50	0	0	51475	143447
1986	13292	26563	39855	57827	57827	37646	48	62	167	37923	135605
1987	7718	47028	54746	47722	47722	46039	1395	1	0	47435	149903
1988	0	0	0	106592	106592	93706	2474	299	0	96479	203071
1989	0	0	0	44612	44612	119631	13935	145	0	133711	178323
1990	0	0	0	8078	8078	115493	47114	1382	0	163989	172067
1991	0	0	0	0	0	129392	76734	3343	0	209469	209469
1992	0	0	0	0	0	77259	80174	7512	33	164978	164978
1993	0	0	0	0	0	81790	49295	2098	2	133185	133185
1994	0	0	0	0	0	84931	78566	8037	730	172264	172264
1995	0	0	0	0	0	110956	97665	19275	599	228496	228496
1996	0	0	0	0	0	91910	88882	28006	267	209064	209064
1997	0	0	0	0	0	93924	117008	21493	173	232598	232598
1998	0	0	0	0	0	60780	84323	13232	192	158526	158526
1999	0	0	0	0	0	51902	81463	12399	100	145865	145865
2000	0	0	0	0	0	53815	81640	15849	68	151372	151372
2001	0	0	0	0	0	35655	90360	16385	52	142452	142452
2002	0	0	0	0	0	51065	100269	15051	166	166552	166552
2003	0	0	0	0	0	47580	106967	21957	155	176659	176659
2004	0	0	0	0	0	57784	109692	17238	231	184945	184945
2005	0	0	0	0	0	52604	112994	17104	104	182807	182807
2006	0	0	0	0	0	53202	95485	18957	81	167725	167725
2007	0	0	0	0	0	45158	77096	17222	82	139558	139558
2008	0	0	0	0	0	31017	70607	16294	19	117939	117939

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

Aleutian Islands region only:

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

Table 2.2b—Summary of 1981-2008 catches (t) of Pacific cod in the Aleutian Islands region by fleet sector and gear type. All catches include discards. LLine = longline, Subt. = sector subtotal. Catches for 2008 are through early October.

Aleutian Islands region only:

	Foreign			Joint Venture		Domestic Annual Processing					
Year	Trawl	LLine	Subt.	Trawl	Subt.	Trawl	LLine	Pot	Other	Subt.	Total
1981	2680	235	2915	1749	1749	2744	26	0	0	2770	7434
1982	1520	476	1996	4280	4280	2121	0	0	0	2121	8397
1983	1869	402	2271	4700	4700	1459	0	0	0	1459	8430
1984	473	804	1277	6390	6390	314	0	0	0	314	7981
1985	10	829	839	5638	5638	460	0	0	0	460	6937
1986	5	0	5	6115	6115	784	1	1	0	786	6906
1987	0	0	0	10435	10435	2662	22	88	0	2772	13207
1988	0	0	0	3300	3300	1698	137	30	0	1865	5165
1989	0	0	0	6	6	4233	284	19	0	4536	4542
1990	0	0	0	0	0	6932	602	7	0	7541	7541
1991	0	0	0	0	0	3414	3203	3180	0	9797	9797
1992	0	0	0	0	0	14558	22108	6317	84	43068	43068
1993	0	0	0	0	0	17312	16860	0	33	34204	34204
1994	0	0	0	0	0	14382	7009	147	0	21539	21539
1995	0	0	0	0	0	10574	4935	1024	0	16534	16534
1996	0	0	0	0	0	21179	5819	4611	0	31609	31609
1997	0	0	0	0	0	17349	7151	575	89	25164	25164
1998	0	0	0	0	0	20531	13771	424	0	34726	34726
1999	0	0	0	0	0	16437	7874	3750	69	28130	28130
2000	0	0	0	0	0	20362	16183	3107	33	39684	39684
2001	0	0	0	0	0	15826	17817	544	19	34207	34207
2002	0	0	0	0	0	27929	2865	7	0	30801	30801
2003	0	0	0	0	0	31478	974	2	0	32455	32455
2004	0	0	0	0	0	25766	3099	0	0	28865	28865
2005	0	0	0	0	0	19613	3001	0	13	22627	22627
2006	0	0	0	0	0	20054	3552	567	8	24181	24181
2007	0	0	0	0	0	28632	4712	695	7	34045	34045
2008	0	0	0	0	0	21675	4072	2942	209	28898	28898

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

Eastern Bering Sea and Aleutian Islands region combined:

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

Table 2.3b—Summary of 1981-2008 catches (t) of Pacific cod in the combined Eastern Bering Sea and Aleutian Islands region by fleet sector and gear type. All catches include discards. LLine = longline, Subt. = sector subtotal. Catches for 2008 are through early October.

Eastern Bering Sea and Aleutian Islands region combined:

	Foreign			Joint Venture		Domestic Annual Processing					
Year	Trawl	LLine	Subt.	Trawl	Subt.	Trawl	LLine	Pot	Other	Subt.	Total
1981	33027	6086	39113	9159	9159	15628	27	0	14	15669	63941
1982	24557	3618	28175	13592	13592	26014	5	0	1715	27734	69501
1983	34659	6847	41506	14362	14362	46769	4	21	569	47363	103231
1984	31065	27446	58511	30772	30772	43588	8	0	205	43801	133084
1985	19606	37571	57177	41272	41272	51885	50	0	0	51935	150384
1986	13297	26563	39860	63942	63942	38430	49	63	167	38709	142511
1987	7718	47028	54746	58157	58157	48701	1417	89	0	50207	163110
1988	0	0	0	109892	109892	95404	2611	329	0	98344	208236
1989	0	0	0	44618	44618	123864	14219	164	0	138247	182865
1990	0	0	0	8078	8078	122425	47716	1389	0	171530	179608
1991	0	0	0	0	0	132806	79937	6523	0	219266	219266
1992	0	0	0	0	0	91818	102282	13829	117	208046	208046
1993	0	0	0	0	0	99102	66155	2098	35	167389	167389
1994	0	0	0	0	0	99313	85575	8184	730	193802	193802
1995	0	0	0	0	0	121530	102600	20299	599	245029	245029
1996	0	0	0	0	0	113089	94701	32617	267	240673	240673
1997	0	0	0	0	0	111273	124159	22068	262	257762	257762
1998	0	0	0	0	0	81310	98094	13657	192	193253	193253
1999	0	0	0	0	0	68339	89337	16150	169	173995	173995
2000	0	0	0	0	0	74177	97823	18956	101	191056	191056
2001	0	0	0	0	0	51482	108177	16929	71	176659	176659
2002	0	0	0	0	0	78994	103134	15058	166	197352	197352
2003	0	0	0	0	0	79059	107941	21959	156	209114	209114
2004	0	0	0	0	0	83550	112790	17239	231	213810	213810
2005	0	0	0	0	0	72217	115995	17104	117	205434	205434
2006	0	0	0	0	0	73256	99037	19524	89	191906	191906
2007	0	0	0	0	0	73790	81807	17917	89	173603	173603
2008	0	0	0	0	0	52692	74679	19237	228	146837	146837

Table 2.4—History of Pacific cod ABC, TAC, total BSAI catch, and type of stock assessment model used to recommend ABC. Catch for 2008 is current through early October. "SS1" refers to Stock Synthesis 1 and "SS2" refers to Stock Synthesis 2; after 2007, the program is referred to simply as "SS." Each cell in the "Stock Assessment Model" column lists the type of model used to recommend the ABC in the corresponding row, meaning that the model was produced in the year previous to the one listed in the corresponding row.

Year	ABC	TAC	Catch	Stock assessment model (from previous year)
1980	148,000	70,700	45,947	projection of 1979 survey numbers at age
1981	160,000	78,700	63,941	projection of 1979 survey numbers at age
1982	168,000	78,700	69,501	projection of 1979 survey numbers at age
1983	298,200	120,000	103,231	projection of 1979 survey numbers at age
1984	291,300	210,000	133,084	projection of 1979 survey numbers at age
1985	347,400	220,000	150,384	projection of 1979-1985 survey numbers at age
1986	249,300	229,000	142,511	separable age-structured model
1987	400,000	280,000	163,110	separable age-structured model
1988	385,300	200,000	208,236	separable age-structured model
1989	370,600	230,681	182,865	separable age-structured model
1990	417,000	227,000	179,608	separable age-structured model
1991	229,000	229,000	219,266	separable age-structured model
1992	182,000	182,000	208,046	SS1 model (age-based data)
1993	164,500	164,500	167,389	SS1 model (length-based data)
1994	191,000	191,000	193,802	SS1 model (length-based data)
1995	328,000	250,000	245,029	SS1 model (length-based data)
1996	305,000	270,000	240,673	SS1 model (length-based data)
1997	306,000	270,000	257,762	SS1 model (length-based data)
1998	210,000	210,000	193,253	SS1 model (length-based data)
1999	177,000	177,000	173,995	SS1 model (length-based data)
2000	193,000	193,000	191,056	SS1 model (length-based data)
2001	188,000	188,000	176,659	SS1 model (length-based data)
2002	223,000	200,000	197,352	SS1 model (length-based data)
2003	223,000	207,500	209,114	SS1 model (length-based data)
2004	223,000	215,500	213,810	SS1 model (length-based data)
2005	206,000	206,000	164,404	SS1 model (length- and age-based data)
2006	194,000	194,000	191,906	SS2 model (length- and age-based data)
2007	176,000	170,720	173,603	SS2 model (length- and age-based data)
2008	176,000	170,720	146,837	SS model (length- and age-based data)

Table 2.5a—Pacific cod discard rates by area, target species/group, and year for the period 1991-2002 (see Table 2.5b for the period 2003-2004). The discard rate is the ratio of discarded Pacific cod catch to total Pacific cod catch for a given area/target/year combination. An empty cell indicates that no Pacific cod were caught in that area/target/year combination. Note that the absolute amount of discards may be small even if the discard rate is large.

Eastern Bering Sea

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

Aleutian Islands

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

Table 2.5b—Pacific cod discard rates by area, target species/group, and year for the period 2003-2004 (see Table 2.5a for the period 1991-2002; note that the IFQ halibut target does not exist in Table 2.5a). The discard rate is the ratio of discarded Pacific cod catch to total Pacific cod catch for a given area/target/year combination. An empty cell indicates that no Pacific cod were caught in that area/target/year combination. Note that the absolute amount of discards may be small even if the discard rate is large.

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

Table 2.6—EBS catch (t) of Pacific cod by year, gear, and period for the years 1977-2008. Season 3 catch values for 2007 are extrapolations based on the previous year's catch. Because direct estimates of gear- and period-specific catches are not available for the years 1977-1980, the figures shown here are estimates derived by distributing each year's total catch according to the average proportion observed for each gear/period combination during the years 1981-1988.

Year	Trawl Fishery			Longline Fishery			Pot Fishery		
	Sea. 1	Sea. 2	Sea. 3	Sea. 1	Sea. 2	Sea. 3	Sea. 1	Sea. 2	Sea. 3
1977	14935	6139	6858	1851	260	3292	0	0	0
1978	19710	8101	9051	2443	343	4344	0	0	0
1979	16131	6630	7407	1999	281	3555	0	0	0
1980	18387	7558	8444	2279	320	4053	0	0	0
1981	15067	14087	21486	1286	624	3942	0	0	0
1982	21742	18151	16348	363	475	2308	0	0	0
1983	40757	24300	22705	2941	748	2756	0	0	0
1984	48237	24964	25045	5012	2128	19508	0	0	0
1985	55673	28673	22310	13703	1710	21379	0	0	0
1986	59786	26598	22382	8895	438	17278	0	0	0
1987	64413	15604	21462	20947	723	26752	0	0	0
1988	127470	25662	47166	444	646	1385	90	51	160
1989	127459	16986	19798	3810	4968	5157	33	63	49
1990	101645	11402	10524	13171	16643	17299	0	986	395
1991	107979	15549	5863	25470	21472	29792	12	1042	2288
1992	59460	11840	5959	49696	24201	6276	2622	4632	258
1993	67148	5362	9280	49244	27	23	2073	24	0
1994	61009	5806	18115	57968	13	20585	4923	0	3113
1995	90366	8543	12047	68458	26	29180	12484	3469	3322
1996	78194	3126	10590	62011	26	26845	18143	6401	3462
1997	81313	3927	8684	70676	43	46290	14584	3576	3333
1998	45008	5603	10169	54234	18	30071	9022	2779	1432
1999	44904	3312	3686	55180	1923	24360	9346	1001	2052
2000	44508	4578	4730	40180	1375	40086	15742	0	107
2001	22849	7025	5781	38368	6700	45291	11645	442	4298
2002	37008	9554	4503	50024	12132	38113	10852	401	3799
2003	34515	9986	3079	53156	11032	42773	15452	74	6586
2004	42181	12407	3197	56050	10459	43183	12560	521	4388
2005	45014	6664	926	53556	12773	46665	12147	0	4957
2006	46045	6124	1033	51079	14598	29808	14265	0	4692
2007	35411	8170	1577	44867	12465	19763	12283	18	4921
2008	23574	5544	1577	45374	12143	19763	11023	1	4921

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

Year	9	12	15	18	21	24	27	30	33	36	39	42	45	50	55	60	65	70	75	80	85	90	95	100	105
1978	0	0	0	1	1	0	1	0	3	16	19	73	220	103	29	19	13	4	5	4	0	1	2	0	0
1979	0	0	0	0	0	0	1	21	45	94	204	315	329	77	122	147	144	37	5	4	3	1	1	0	0
1980	0	0	0	0	0	0	2	36	75	235	635	1014	1560	1038	971	714	497	632	485	197	86	49	17	5	2
1982	0	0	0	0	0	2	1	6	58	113	64	73	294	386	518	729	731	534	241	104	51	41	21	3	3
1983	0	0	0	0	0	1	1	50	154	93	95	176	492	758	1626	2344	2071	1307	644	211	77	36	21	12	6
1984	0	1	2	1	0	15	194	401	367	220	105	223	709	779	1264	2262	3195	2930	2027	1039	434	144	24	13	2
1985	0	0	2	0	4	0	2	39	116	257	720	1752	2234	1079	1388	2440	4999	5563	4288	2630	1385	594	221	67	23
1986	0	4	16	8	34	60	118	249	635	761	683	783	2228	3560	3287	2095	2631	3469	3357	2442	1346	454	168	58	17
1987	0	0	3	13	15	58	192	440	477	592	1161	2054	3898	2890	3326	5470	5461	4306	3650	3106	1953	1076	440	198	63
1988	1	0	1	1	6	29	92	580	1448	1956	2185	4311	11135	10599	10194	9103	10096	12012	10395	5807	3010	1686	814	346	92
1989	0	0	3	3	1	0	28	217	494	795	720	954	3110	4341	4654	5664	7033	8561	8246	6265	3826	1867	919	388	144
1990	0	0	0	0	0	11	93	214	284	269	232	203	416	853	1482	2458	3274	3396	3059	2109	1365	738	424	161	52
1991	0	0	0	0	0	14	128	335	393	367	389	604	2129	2128	1770	2416	3307	3528	3007	2104	1371	761	403	192	66
1992	0	0	0	0	0	9	52	156	323	382	568	1077	2241	1742	1545	1531	1753	1532	1385	1024	682	409	230	102	44
1993	0	0	0	0	0	10	93	428	617	658	1718	2987	4493	3792	3576	2542	1640	1288	1041	759	505	316	182	78	35
1994	0	0	0	0	0	13	136	457	789	664	398	626	2039	2917	2912	2322	2297	1901	1170	699	424	240	140	69	34
1995	0	0	0	0	0	20	71	127	163	303	1181	2663	4198	2714	3176	3669	3894	3045	1763	1022	624	345	175	92	32
1996	0	0	0	0	0	7	76	224	277	232	232	507	1862	3157	2940	2095	2323	2488	1957	1292	733	441	227	116	59
1997	0	0	0	0	0	8	76	296	564	574	439	503	1842	2099	2798	3872	3840	2762	1613	1010	641	342	169	75	31
1998	0	0	0	0	0	11	106	204	191	144	125	191	697	831	920	1389	1982	2110	1283	646	312	183	102	45	20
1999	1	0	0	0	0	1	36	143	134	119	347	847	1669	1011	1038	1292	1673	1697	1218	781	384	190	77	36	17
2000	0	0	0	0	0	1	21	61	54	83	180	336	950	1383	1491	1376	1361	1405	1104	761	466	259	135	63	28
2001	0	0	0	0	0	1	3	10	29	54	37	59	306	487	646	918	972	783	497	358	215	137	61	30	13
2002	0	0	0	0	0	4	34	148	255	253	221	261	749	860	906	1494	1912	1672	959	440	211	97	45	19	10
2003	0	0	0	0	0	0	3	31	95	128	139	246	670	703	760	989	1290	1466	1049	622	308	130	58	27	10
2004	0	0	0	0	0	2	3	32	122	196	194	186	799	1329	1487	1739	1760	1393	946	590	315	190	111	62	26
2005	0	0	0	0	0	2	7	52	120	162	147	140	461	756	1118	1584	1958	1796	1139	728	404	232	108	44	16
2006	0	0	0	0	0	1	5	28	91	147	161	176	582	882	992	1186	1473	1570	1299	952	578	290	133	39	25
2007	0	1	2	8	13	28	55	149	230	276	380	443	1225	1865	2284	3131	3028	2593	2096	1637	1078	657	352	131	55
2008	0	0	2	4	5	31	63	73	81	75	116	180	640	802	1029	1597	1723	1490	864	551	371	290	144	68	25

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

Year	9	12	15	18	21	24	27	30	33	36	39	42	45	50	55	60	65	70	75	80	85	90	95	100	105
1977	0	0	0	0	0	0	0	0	6	12	22	39	40	273	331	367	355	188	104	38	12	3	2	0	0
1981	0	0	0	1	2	3	10	71	398	675	423	365	1109	1006	448	152	34	13	1	0	0	0	0	0	0
1983	0	0	0	0	0	1	0	1	4	15	42	71	77	81	200	284	248	186	83	28	6	3	4	0	0
1984	0	1	4	51	201	206	313	556	455	357	339	305	679	695	891	1109	959	817	597	453	312	120	41	8	1
1985	0	0	0	0	0	0	0	3	24	74	68	119	404	256	66	35	39	58	46	23	9	5	7	2	1
1986	0	0	0	0	0	0	7	2	2	3	5	7	15	62	92	72	67	95	98	84	46	30	8	4	0
1987	0	0	0	0	0	1	2	5	9	4	8	22	116	204	333	592	974	1093	720	525	385	248	133	68	25
1991	2	0	0	0	0	2	11	15	24	43	37	54	237	258	411	444	435	467	409	362	252	142	30	6	9
1997	0	0	0	0	0	0	2	0	0	2	5	5	45	167	229	219	283	167	67	27	12	2	0	0	0
1998	0	0	0	0	0	0	0	1	36	70	82	54	127	282	351	324	252	165	110	46	15	12	6	12	8
2001	0	0	0	0	0	0	0	2	11	27	53	65	151	337	356	301	313	226	115	58	61	31	33	15	2
2002	0	0	0	0	0	0	2	2	8	40	155	227	306	505	667	480	356	210	171	128	59	37	18	9	2
2003	0	0	0	0	0	0	1	2	4	19	34	51	141	324	345	361	401	336	267	192	110	45	16	8	3
2004	0	0	0	0	0	1	2	5	5	12	9	27	92	193	291	355	333	289	289	283	215	130	69	25	5
2005	0	0	0	0	0	0	1	0	4	12	38	72	97	124	154	167	173	165	175	150	97	66	37	12	4
2006	0	0	0	0	0	0	4	9	20	44	48	64	129	156	128	126	112	90	89	128	133	101	32	12	2
2007	0	0	0	0	1	5	9	25	89	185	172	150	331	363	416	340	227	119	72	43	27	21	14	3	1
2008	0	0	0	0	0	0	0	19	43	35	20	17	33	66	108	94	81	51	37	29	25	21	16	3	1

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

Year	9	12	15	18	21	24	27	30	33	36	39	42	45	50	55	60	65	70	75	80	85	90	95	100	105
1978	0	0	0	0	0	6	35	79	37	21	19	5	62	387	999	882	337	159	81	37	13	2	0	0	0
1979	0	0	0	0	0	0	0	3	5	24	74	150	220	78	38	47	58	31	14	4	0	0	0	1	1
1981	0	0	0	0	0	0	0	2	1	0	2	7	21	111	315	353	284	179	103	27	13	7	2	0	0
1982	0	0	0	0	0	0	1	0	0	1	4	27	70	143	215	196	302	346	215	90	18	9	5	1	0
1983	0	0	0	0	1	15	24	26	15	8	35	205	421	508	1450	1996	2482	2430	2220	1546	742	272	64	21	5
1984	0	0	0	0	0	7	21	15	114	434	372	190	140	126	235	375	502	506	437	363	210	92	29	11	0
1985	0	0	0	0	0	0	0	1	0	5	43	104	389	168	98	63	144	212	187	148	76	39	2	0	0
1986	0	0	0	0	0	0	2	1	13	15	25	24	69	111	153	184	209	156	179	133	92	59	22	4	5
1987	0	0	0	0	0	0	0	0	6	10	56	60	198	929	1639	1957	2591	3113	2678	2055	1930	1548	802	306	53
1988	0	0	0	0	0	0	0	0	5	0	13	52	257	326	284	348	348	373	332	305	166	56	20	6	6
1990	0	0	0	0	0	0	4	8	13	10	32	115	211	102	69	137	228	284	234	199	170	107	50	25	12
1992	0	0	0	0	0	0	0	68	205	2359	4667	479	120	171	17	51	0	0	0	0	0	0	0	0	0
1994	0	0	0	0	0	0	0	0	0	228	330	1650	9415	1700	482	51	25	0	0	0	0	0	0	0	0
1995	0	0	0	0	0	0	0	0	0	0	83	76	206	251	127	54	114	200	213	289	181	162	130	25	6
1996	0	0	0	0	0	0	0	0	1	0	7	27	94	120	150	153	135	132	136	197	197	170	98	43	15
1998	0	0	0	0	0	0	2	4	6	25	74	123	269	366	485	308	300	199	148	127	74	53	55	39	16
1999	0	0	0	0	0	0	1	1	2	3	4	18	49	97	127	100	107	84	65	56	43	26	21	9	3
2001	0	0	0	0	0	0	3	10	15	10	27	43	103	143	263	253	243	203	116	67	34	15	8	5	3
2002	0	0	0	0	0	0	0	1	7	7	30	69	116	121	161	125	107	112	95	85	55	25	12	5	1
2003	0	0	0	0	0	0	0	0	0	0	2	9	29	58	61	67	69	75	72	71	48	28	11	2	0
2004	0	0	0	0	0	0	0	0	0	1	6	5	20	37	71	64	50	49	59	79	60	33	23	5	1

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

Year	9	12	15	18	21	24	27	30	33	36	39	42	45	50	55	60	65	70	75	80	85	90	95	100	105
1978	0	0	0	0	0	0	0	0	1	4	23	124	623	812	435	269	216	160	110	58	36	7	7	0	0
1979	0	0	0	0	0	0	0	8	83	377	683	434	337	1135	2126	2432	1356	465	233	128	56	27	3	6	0
1980	0	0	0	0	0	0	0	0	5	15	66	212	591	604	320	182	199	244	111	36	11	4	0	0	0
1981	0	0	0	0	5	18	7	7	10	0	18	48	285	496	448	335	197	153	89	70	36	9	4	0	0
1982	0	0	0	0	0	0	0	1	0	9	13	18	131	184	266	334	314	211	101	61	44	31	10	1	1
1983	0	0	0	0	0	0	0	0	3	16	48	170	1116	1525	2035	2732	3421	3065	1838	792	334	163	88	36	7
1984	0	0	0	0	0	1	0	6	19	40	41	46	416	800	1323	2414	3163	3015	2012	1015	437	155	70	24	6
1985	0	0	0	0	0	0	0	1	12	34	186	550	1367	958	1828	3877	7018	8009	5977	3362	1591	537	175	44	7
1986	0	0	0	0	0	0	0	8	30	81	121	385	1765	3055	3578	3014	3739	5900	5622	3348	1554	654	237	63	13
1987	0	0	0	0	0	2	0	5	18	88	425	1362	4950	5219	8337	14661	16709	12862	11421	9132	4689	1828	519	180	31
1990	0	0	0	0	0	0	0	0	0	0	1	2	20	100	221	377	480	420	342	230	174	107	67	31	11
1991	0	0	0	0	0	0	0	0	1	3	12	32	109	249	502	912	1150	978	700	406	248	137	84	33	14
1992	0	0	0	0	0	0	0	4	7	24	96	256	869	1282	1329	1601	1886	1639	1158	837	528	307	165	75	25
1993	0	0	0	0	0	0	2	9	21	49	167	369	1080	2056	2763	2413	1688	1280	946	692	425	229	98	49	12
1994	0	0	0	0	0	0	2	3	9	20	54	144	733	1845	3065	3958	3309	1817	850	485	294	186	91	46	15
1995	0	0	0	0	0	0	2	3	8	27	159	456	1231	2085	3529	4520	4244	2616	1121	443	214	111	54	28	13
1996	0	0	0	0	0	0	0	2	6	18	62	181	996	2224	2991	3323	3131	2280	1335	655	297	146	82	36	16
1997	0	0	0	0	0	0	1	2	10	24	62	190	970	2005	3472	4601	4086	2399	1243	658	376	172	71	25	10
1998	0	0	0	0	0	0	0	4	16	34	88	253	843	1395	2048	2946	3141	2307	1196	518	233	125	52	18	8
1999	0	0	0	0	0	0	1	5	12	45	261	775	1824	1807	2111	2533	2483	2089	1308	679	291	139	59	29	18
2000	1	0	0	0	0	0	1	4	12	45	154	364	1510	2476	2555	2115	1736	1219	708	361	176	72	36	14	4
2001	0	0	0	0	0	1	2	6	23	67	98	203	909	1761	2404	2672	2095	1110	545	274	136	73	33	16	7
2002	0	0	0	0	0	2	5	25	57	89	255	641	1465	1704	2443	3386	3031	1836	722	300	133	77	55	12	6
2003	0	0	0	0	0	0	2	8	46	107	290	704	2109	3046	3153	2909	2552	1841	937	414	150	61	24	10	3
2004	0	0	0	0	0	0	7	15	23	45	84	233	1128	2541	3874	4240	2951	1562	801	422	183	76	34	13	4
2005	0	0	0	0	0	0	1	7	21	49	128	274	931	1516	2204	3184	3467	2395	947	380	182	73	28	9	2
2006	0	0	0	0	0	0	0	3	10	31	70	146	750	1880	2391	2453	2317	1988	1335	650	248	101	38	11	4
2007	0	0	0	0	0	1	2	6	16	32	138	369	1824	3707	6392	8815	7310	5432	3714	2456	1322	520	200	81	37
2008	0	0	0	0	0	0	6	12	40	81	257	556	1692	2960	5042	7282	8403	6253	3052	1735	924	520	239	97	32

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

Year	9	12	15	18	21	24	27	30	33	36	39	42	45	50	55	60	65	70	75	80	85	90	95	100	105
1978	0	0	0	0	0	0	0	0	0	0	3	2	78	444	1093	783	436	328	170	64	30	6	1	1	0
1979	0	0	0	0	0	0	0	0	2	14	49	90	155	93	302	604	628	274	74	33	14	3	3	0	0
1980	0	0	0	0	0	0	0	0	0	0	1	29	169	334	293	185	148	140	67	17	4	2	0	0	0
1981	0	0	0	0	0	0	0	0	2	1	8	29	88	160	265	292	228	108	35	32	24	3	1	0	0
1982	0	0	0	0	0	0	0	0	0	9	42	17	98	190	128	161	130	117	74	38	11	5	3	2	0
1983	0	0	0	0	0	0	0	0	1	2	14	13	91	319	383	504	623	675	505	355	150	50	18	10	0
1984	0	0	0	0	0	2	0	0	2	7	14	17	102	376	750	1602	2167	1873	1405	891	567	203	59	16	3
1985	0	0	0	0	0	0	0	0	0	1	3	28	246	368	206	418	775	1000	823	590	429	245	105	23	2
1986	0	0	0	0	0	0	0	0	0	0	0	1	15	94	247	306	175	162	205	104	60	24	13	0	0
1990	0	0	0	0	0	0	0	0	1	3	6	11	35	106	263	439	574	560	462	332	227	149	97	39	14
1991	0	0	0	0	0	0	0	0	0	1	2	8	43	124	266	466	614	690	629	513	357	191	109	49	18
1992	0	0	0	0	0	0	0	1	5	12	32	63	320	643	671	729	793	685	515	411	317	219	136	74	25
1999	0	0	0	0	0	0	0	0	0	0	2	6	44	88	75	74	76	66	45	32	19	10	4	2	1
2000	0	0	0	0	0	0	0	0	0	0	0	1	9	26	54	85	65	45	31	22	11	7	3	1	0
2001	0	0	0	0	0	0	0	1	2	6	13	27	106	260	374	417	410	285	116	50	23	12	7	2	1
2002	0	0	0	0	0	0	0	4	10	24	42	81	328	578	653	664	646	447	260	115	49	26	13	7	1
2003	0	0	0	0	0	0	0	1	3	9	25	60	248	541	674	636	538	403	219	116	51	21	9	3	1
2004	0	0	0	0	0	0	0	0	1	2	4	17	91	247	457	564	531	399	236	156	80	36	13	5	1
2005	0	0	0	0	0	0	0	0	1	2	9	20	100	208	320	415	507	496	390	257	142	78	29	8	2
2006	0	0	0	0	0	0	0	0	0	1	9	27	106	257	403	419	422	363	329	317	243	150	72	27	7
2007	0	0	0	0	0	0	0	1	0	5	19	75	580	1805	2889	3506	3490	2709	1836	1780	1563	1122	600	248	52
2008	0	0	0	0	0	0	0	0	2	3	10	51	276	728	1094	1414	1209	789	509	344	280	237	155	80	14

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

Year	9	12	15	18	21	24	27	30	33	36	39	42	45	50	55	60	65	70	75	80	85	90	95	100	105
1978	0	0	0	0	0	0	0	0	0	0	2	0	54	344	719	770	275	94	49	32	16	7	2	0	0
1979	0	0	0	0	0	0	0	0	0	4	11	51	252	263	195	401	705	605	220	44	11	9	2	0	0
1980	0	0	0	0	0	0	0	0	0	0	1	18	235	558	679	652	350	194	138	76	25	5	0	1	0
1981	0	0	0	0	0	0	0	0	0	0	0	2	8	86	230	318	300	220	89	29	15	2	0	1	0
1982	0	0	0	0	0	0	0	1	0	1	14	33	92	235	460	773	1149	1066	614	235	77	27	6	2	2
1983	0	0	0	0	0	0	1	0	0	0	4	28	129	459	1162	1260	1544	1776	1561	991	476	148	37	9	6
1984	0	0	0	0	0	0	1	3	14	55	293	764	1721	2467	6595	12255	15779	15982	12816	8397	4192	1528	407	91	24
1985	0	0	0	0	0	1	0	0	4	23	116	605	5449	16095	14240	10594	17780	24998	19637	11586	6071	2786	920	215	51
1986	0	0	0	0	0	0	0	0	0	18	158	616	2233	5154	14368	23612	20725	10897	10483	9006	4991	2308	881	326	85
1987	0	0	0	3	0	0	0	3	9	30	147	593	4503	18418	29582	24338	25914	28336	20972	10694	6630	3800	1532	414	134
1990	0	0	0	0	0	0	0	0	0	1	1	3	19	87	270	489	604	569	456	306	182	108	67	31	14
1991	0	0	0	0	0	1	2	2	4	7	11	24	94	231	406	623	759	807	766	615	421	239	138	62	25
1992	0	0	0	0	0	0	0	0	0	1	3	10	49	147	160	152	173	152	120	98	78	55	35	18	6
1994	0	0	0	0	0	0	0	1	1	6	16	27	84	295	603	870	1016	766	446	238	140	87	53	31	15
1995	0	0	0	0	0	0	0	2	2	5	21	51	280	678	784	907	1101	1008	739	443	246	136	79	38	12
1996	0	0	0	0	0	0	0	0	1	7	14	32	123	423	909	1132	871	640	560	453	321	178	82	33	10
1997	0	0	0	0	0	0	1	6	11	20	42	114	329	639	1037	1424	1841	1709	1182	614	415	251	135	58	23
1998	0	0	0	0	0	0	2	2	3	13	69	146	339	539	812	988	1140	1031	767	474	242	127	76	32	13
1999	0	0	0	0	0	0	1	4	8	15	47	87	463	990	859	780	837	761	523	362	208	109	48	24	12
2000	0	0	0	0	0	0	0	1	1	5	44	145	485	1156	1903	2459	1908	1086	665	411	240	131	62	23	9
2001	0	0	0	0	0	0	1	2	6	26	126	268	767	1331	2128	2431	2309	1726	794	352	164	92	54	22	9
2002	0	0	0	0	0	0	2	9	29	67	144	300	982	1601	1807	1785	1676	1314	763	375	163	71	29	13	6
2003	0	0	0	0	0	0	0	0	3	10	31	136	734	1577	2155	2151	1869	1381	889	489	217	85	33	13	4
2004	0	0	0	0	0	0	3	6	10	22	49	119	491	1008	1604	2136	2099	1574	883	500	268	118	45	14	4
2005	0	0	0	0	0	0	1	3	8	19	49	125	556	976	1408	1504	1500	1457	1227	831	447	244	95	31	7
2006	0	0	0	0	0	0	0	0	2	7	28	84	388	783	1259	1326	1171	1095	906	874	639	408	213	91	31
2007	1	0	1	0	0	0	0	1	2	14	71	236	1145	3412	4914	5159	5115	3921	2716	2672	2708	2286	1316	572	166
2008	0	0	0	0	0	0	0	0	0	5	14	11	80	186	235	301	339	204	123	87	62	55	39	17	1

Table 2.9a—Length frequencies for the January-May pot fishery by length bin.

Year	9	12	15	18	21	24	27	30	33	36	39	42	45	50	55	60	65	70	75	80	85	90	95	100	105
1992	0	0	0	0	0	0	0	0	0	0	1	2	12	33	42	75	121	108	69	42	27	16	9	4	1
1993	0	0	0	0	0	0	0	0	0	0	0	2	14	33	59	86	87	76	53	32	20	12	5	2	1
1994	0	0	0	0	0	0	0	0	0	0	1	7	38	136	216	225	223	175	118	60	34	20	12	5	1
1995	0	0	0	0	0	0	0	0	0	0	4	19	96	224	493	713	642	452	261	150	88	50	19	10	4
1996	0	0	0	0	0	0	0	1	1	4	8	20	145	430	717	818	838	679	408	237	132	81	44	19	7
1997	0	0	0	0	0	0	0	0	1	2	5	10	70	204	450	805	882	551	298	159	88	60	32	14	7
1998	0	0	0	0	0	0	0	0	0	0	1	7	60	126	186	391	506	440	261	114	44	25	11	5	4
1999	0	0	0	0	0	0	0	0	0	1	2	15	126	198	294	442	456	385	240	123	59	33	11	7	3
2000	0	0	0	0	0	0	0	0	0	0	3	27	226	526	774	766	654	613	362	209	94	42	21	8	3
2001	0	0	0	0	0	0	0	0	1	1	4	6	69	218	514	896	840	428	171	72	38	22	9	5	2
2002	0	0	0	0	0	0	0	0	0	0	2	5	45	179	421	785	768	458	187	65	31	17	9	3	3
2003	0	0	0	0	0	0	0	1	1	3	4	23	115	292	498	735	880	732	394	189	78	29	9	4	2
2004	0	0	0	0	0	2	2	5	6	4	5	9	113	368	613	745	684	461	250	142	52	31	14	6	2
2005	0	0	0	0	0	0	0	0	1	0	4	8	51	194	473	725	698	488	238	121	63	47	22	7	1
2006	0	0	0	0	0	0	0	0	0	1	1	2	66	274	577	799	794	562	282	173	85	46	24	10	4
2007	0	0	0	0	0	0	0	0	0	0	10	24	255	727	1222	1650	1834	1643	1115	802	581	311	195	100	26
2008	0	0	0	0	0	0	0	0	3	3	7	28	152	468	905	1144	1151	982	606	497	285	242	127	41	22

Table 2.9b—Length frequencies for the June-August pot fishery by length bin.

Year	9	12	15	18	21	24	27	30	33	36	39	42	45	50	55	60	65	70	75	80	85	90	95	100	105
1990	0	0	0	0	0	0	0	0	0	0	0	0	1	5	9	17	28	36	27	28	17	10	5	0	0
1991	0	0	0	0	0	0	0	0	0	0	0	0	1	8	18	32	44	45	34	23	11	7	2	1	0
1992	0	0	0	0	0	0	0	0	0	1	5	20	113	201	194	215	211	147	90	62	38	21	11	8	3
1995	0	0	0	0	0	0	0	0	0	0	0	3	31	55	73	125	140	113	89	59	33	27	20	8	5
1996	0	0	0	0	0	0	0	0	0	0	1	4	28	98	202	283	252	179	126	107	75	53	30	16	11
1997	0	0	0	0	0	0	0	0	0	1	1	2	15	51	110	171	235	152	74	37	23	13	9	7	3
1998	0	0	0	0	0	0	0	0	0	0	0	0	8	23	55	99	136	141	84	42	23	16	5	2	1

Table 2.9c—Length frequencies for the September-December pot fishery by length bin.

Year	9	12	15	18	21	24	27	30	33	36	39	42	45	50	55	60	65	70	75	80	85	90	95	100	105
1990	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	4	13	13	16	8	5	3	1	0	0
1991	0	0	0	0	0	0	0	0	0	0	0	0	1	8	21	39	66	81	77	50	27	14	7	2	1
1992	0	0	0	0	0	0	0	0	0	1	2	3	13	21	17	13	10	5	2	2	1	1	0	0	0
1994	0	0	0	0	0	0	0	0	1	0	1	3	19	63	117	141	118	92	66	39	27	16	8	5	2
1995	0	0	0	0	0	0	0	0	0	0	0	0	10	40	73	128	148	111	73	50	32	19	9	4	0
1996	0	0	0	0	0	0	0	0	0	0	0	1	9	25	54	102	111	88	58	53	49	34	20	10	4
1997	0	0	0	0	0	0	0	0	0	0	1	2	11	30	63	107	154	153	79	32	24	17	11	5	2
1998	0	0	0	0	0	0	0	0	0	0	1	1	7	24	35	51	59	59	38	17	9	4	4	2	1
1999	0	0	0	0	0	0	0	0	0	0	0	2	11	57	83	65	71	70	37	26	18	11	5	4	4
2001	0	0	0	0	0	0	0	0	0	1	0	2	26	104	212	229	237	158	63	37	22	13	5	2	1
2002	0	0	0	0	0	0	0	0	0	0	1	4	27	93	190	201	154	112	72	48	21	17	6	3	2
2003	0	0	0	0	0	0	0	0	0	0	0	3	45	206	324	305	258	197	122	85	54	27	10	6	1
2004	0	0	0	0	0	0	0	0	0	0	1	3	18	85	169	193	155	115	71	56	54	27	17	7	2
2005	0	0	0	0	0	0	0	0	0	1	2	3	23	78	176	225	190	125	73	60	45	31	22	15	7
2006	0	0	0	0	0	0	0	0	0	0	0	3	19	78	156	169	142	106	88	70	58	43	27	16	8
2007	0	0	0	0	0	0	0	0	0	1	0	19	150	395	791	1009	726	505	331	193	136	81	49	19	14

Table 2.10a—Length frequencies for the pre-1982 EBS shelf bottom trawl survey by length bin.

Year	9	12	15	18	21	24	27	30	33	36	39	42	45	50	55	60	65	70	75	80	85	90	95	100	105
1979	0	5	44	186	374	457	694	1764	2393	1884	1171	618	202	70	44	51	29	8	0	3	1	1	0	0	0
1980	0	6	85	241	82	42	224	687	929	1320	1542	2062	1364	893	333	100	33	31	19	6	2	0	0	0	0
1981	0	20	156	330	278	32	100	330	653	724	511	1063	1396	1746	1215	812	398	156	39	27	13	1	0	0	0

Table 2.10b—Length frequencies for the post-1981 EBS shelf bottom trawl survey by length bin.

Year	9	12	15	18	21	24	27	30	33	36	39	42	45	50	55	60	65	70	75	80	85	90	95	100	105
1982	17	97	234	148	37	28	132	403	766	750	416	520	1512	1327	1288	1179	875	474	210	90	29	9	4	0	0
1983	393	1396	1289	622	147	32	135	370	551	380	209	394	1367	1289	1341	1128	921	650	325	151	31	19	4	1	0
1984	70	129	82	142	282	920	1653	1712	1041	485	249	261	536	579	864	961	880	590	381	173	94	38	9	1	0
1985	162	540	964	1537	1761	664	298	595	880	942	1154	1528	1879	678	480	543	687	674	496	253	111	38	17	5	0
1986	154	465	501	154	114	693	1775	1908	1585	1083	553	425	1069	1338	1203	628	416	453	370	264	119	74	21	13	0
1987	18	69	250	398	267	185	440	899	779	606	617	956	1478	827	598	654	632	413	211	166	71	49	16	7	0
1988	8	49	76	88	109	233	279	384	641	625	491	659	1418	1306	1114	849	570	420	293	244	74	32	25	7	4
1989	24	154	298	205	70	34	82	87	139	347	339	366	871	1193	1294	1143	945	858	666	338	247	145	89	62	0
1990	201	488	699	355	133	122	249	292	322	276	175	123	194	223	347	419	283	266	182	128	82	33	26	11	3
1991	131	389	432	369	229	272	620	897	932	630	346	193	301	312	249	215	207	178	110	112	49	20	22	7	2
1992	18	456	517	698	556	435	854	1075	856	542	451	622	915	546	242	222	176	103	97	86	51	37	28	15	4
1993	114	924	1087	981	677	213	247	614	846	666	489	615	1071	665	399	267	230	85	62	48	37	20	23	14	6
1994	19	145	291	364	326	445	956	1922	2081	1121	444	523	1216	961	1059	920	565	288	92	46	34	60	16	22	9
1995	30	73	135	208	77	173	460	691	579	705	1064	1233	1360	616	434	483	326	253	132	84	40	27	19	9	3
1996	14	65	164	198	110	103	357	699	677	526	499	744	1477	1404	908	499	288	237	148	109	71	25	16	7	3
1997	91	473	601	728	508	140	215	481	628	451	407	399	919	809	842	583	436	215	105	60	40	26	10	4	1
1998	30	262	334	74	46	311	1151	1837	1396	655	379	367	659	458	378	391	333	244	132	64	33	29	9	10	1
1999	71	334	286	113	141	415	760	874	667	718	1169	1648	1854	768	493	447	337	252	132	89	62	37	24	7	2
2000	174	917	1308	505	54	141	487	784	604	563	748	957	1717	1417	893	536	266	187	99	79	57	33	19	3	0
2001	95	646	1828	2113	1010	408	903	1990	2543	1614	705	486	1192	1277	1077	818	513	257	123	71	34	22	14	4	5
2002	31	190	374	352	105	209	664	1459	1449	1005	792	1216	1578	878	609	545	367	208	103	49	19	16	15	3	2
2003	19	283	634	775	683	490	183	252	683	838	974	1192	1973	1216	768	515	339	260	142	86	35	14	2	1	0
2004	24	275	483	562	318	218	484	729	931	979	712	578	806	925	844	714	474	283	211	111	82	34	15	5	4
2005	5	153	590	892	1018	1053	484	415	575	726	647	625	855	702	520	527	495	360	292	182	104	46	21	7	0
2006	478	1286	1075	883	317	165	266	604	753	866	706	532	728	855	643	494	395	320	259	238	144	76	35	14	3
2007	618	3990	2589	1239	474	151	327	417	386	262	211	225	381	370	260	270	206	148	83	64	67	43	17	16	5
2008	228	1118	889	266	131	947	2000	1958	1083	512	380	409	645	607	519	453	311	192	98	70	58	47	32	17	2

Table 2.11—Age compositions observed by the EBS shelf bottom trawl survey, 1994-2007.

Year	1	2	3	4	5	6	7	8	9	10	11	12+
1994	0.0536	0.4015	0.1844	0.1259	0.1241	0.0837	0.0195	0.0050	0.0020	0.0001	0.0002	0.0000
1995	0.0276	0.2705	0.4401	0.1074	0.0803	0.0536	0.0106	0.0041	0.0042	0.0003	0.0008	0.0006
1996	0.0032	0.2306	0.2469	0.3568	0.0941	0.0541	0.0144	0.0000	0.0000	0.0000	0.0000	0.0000
1997	0.2355	0.1841	0.1737	0.1610	0.1225	0.0898	0.0227	0.0081	0.0009	0.0010	0.0006	0.0000
1998	0.0664	0.4546	0.2020	0.1137	0.0589	0.0596	0.0284	0.0140	0.0022	0.0000	0.0002	0.0000
1999	0.0715	0.1992	0.3090	0.2409	0.0806	0.0575	0.0266	0.0103	0.0036	0.0000	0.0007	0.0000
2000	0.2241	0.1162	0.1675	0.2476	0.1563	0.0595	0.0108	0.0120	0.0028	0.0026	0.0007	0.0000
2001	0.2598	0.2469	0.2052	0.0941	0.0915	0.0703	0.0236	0.0056	0.0014	0.0009	0.0006	0.0001
2002	0.0799	0.1868	0.3104	0.2443	0.0733	0.0575	0.0390	0.0065	0.0018	0.0005	0.0000	0.0001
2003	0.1487	0.1633	0.2546	0.2212	0.1220	0.0412	0.0291	0.0151	0.0033	0.0003	0.0003	0.0007
2004	0.1421	0.1622	0.2805	0.1301	0.1333	0.0908	0.0346	0.0177	0.0062	0.0011	0.0014	0.0000
2005	0.1836	0.2560	0.1868	0.1383	0.0621	0.0843	0.0485	0.0243	0.0106	0.0016	0.0040	0.0000
2006	0.3198	0.1443	0.1703	0.1180	0.0946	0.0632	0.0473	0.0290	0.0097	0.0029	0.0009	0.0002
2007	0.6906	0.1072	0.0645	0.0496	0.0379	0.0213	0.0150	0.0070	0.0043	0.0013	0.0005	0.0005

Table 2.12a—Abundance measured in units of biomass and numbers, with standard errors, as estimated by EBS shelf bottom trawl surveys, 1979-1981. For biomass, 95% confidence intervals (CI) are also shown. All biomass figures are expressed in metric tons. Population numbers are expressed in terms of individual fish. The actual standard errors for abundance measured in numbers during these years are unknown; the standard errors shown here are estimates obtained by assuming that the coefficient of variation was the same as for the biomass estimate.

	Abundance (biomass)				Abundance (numbers)	
Year	Estimate	Standard Error	Lower 95% CI	Upper 95% CI	Estimate	Standard Error
1979	754,314	97,844	562,539	946,089	1,530,429,650	198,515,948
1980	905,344	87,898	733,063	1,077,624	1,084,147,540	105,257,671
1981	1,034,629	123,849	791,885	1,277,373	794,619,624	95,118,971

Table 2.12b— Abundance measured in units of biomass and numbers, with standard errors, as estimated by EBS shelf bottom trawl surveys, 1982-2008. For biomass, 95% confidence intervals (CI) are also shown. All biomass figures are expressed in metric tons. Population numbers are expressed in terms of individual fish.

	Abundance (biomass)				Abundance (numbers)	
Year	Estimate	Standard Error	Lower 95% CI	Upper 95% CI	Estimate	Standard Error
1982	1,012,856	73,588	867,151	1,158,562	583,715,842	38,040,768
1983	1,185,419	120,868	941,146	1,429,692	751,066,723	80,440,661
1984	1,048,595	63,643	922,583	1,174,608	680,914,697	49,913,926
1985	1,001,108	55,845	890,536	1,111,681	841,108,075	112,271,991
1986	1,117,774	69,604	979,957	1,255,590	838,123,105	83,854,636
1987	1,106,621	68,682	970,630	1,242,612	728,956,963	48,520,099
1988	959,000	76,265	807,996	1,110,004	508,065,276	35,526,047
1989	836,177	62,981	711,475	960,878	292,210,905	19,939,408
1990	691,255	51,455	589,375	793,136	423,835,267	36,466,423
1991	517,209	38,158	441,657	592,761	488,861,768	50,972,542
1992	551,369	45,780	460,725	642,013	601,795,262	70,551,400
1993	690,535	54,380	582,862	798,208	851,863,422	106,911,178
1994	1,368,120	250,044	868,032	1,868,209	1,237,758,281	153,120,867
1995	1,003,096	91,739	821,453	1,184,740	757,657,482	75,485,760
1996	890,793	87,552	717,439	1,064,146	609,304,214	88,330,629
1997	604,881	69,250	466,382	743,380	487,429,700	72,155,388
1998	558,419	45,182	468,960	647,879	537,278,347	48,263,858
1999	583,891	50,621	483,662	684,120	500,915,139	46,536,008
2000	528,466	43,037	443,253	613,679	481,358,109	44,098,753
2001	833,626	76,247	681,133	986,119	985,568,802	94,981,577
2002	618,680	69,082	480,516	756,845	566,471,072	57,675,818
2003	593,876	62,090	469,695	718,056	499,027,126	62,244,678
2004	596,467	35,191	526,789	666,144	424,082,380	36,061,059
2005	603,633	42,871	518,748	688,518	448,744,246	63,294,550
2006	517,698	28,341	461,583	573,813	394,051,399	23,784,449
2007	423,703	34,811	354,080	493,326	733,374,144	195,954,076
2008	403,125	26,822	350,018	456,232	476,696,976	49,413,561

Table 2.14—Multinomial sample sizes for length compositions.

	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	Pre82	Post81	IPHC
1977		13										
1978	4		24	22	26	18						
1979	12		6	74	17	21				158		
1980	61			19	10	22				75		
1981		35	11	17	10	10				75		
1982	30		12	13	8	36					79	
1983	76	10	108	130	28	72					208	
1984	122	71	31	112	75	622					192	
1985	222	9	13	265	39	978					267	
1986	212	5	11	247	10	789					244	
1987	304	41	149	689		1312					168	
1988	715		22								158	
1989	434										158	
1990	496		41	169	474	462		13	16		89	
1991	596	8		374	470	715		71	64		114	
1992	367		1	1019	572	175	86	145	27		152	
1993	407			739			64				165	
1994	726		1	965		361	167		20		221	
1995	409		8	1076		441	235	46	33		146	
1996	791		23	966		494	361	63	51		148	
1997	828	4		1128		979	215	43	70		145	
1998	671	14	16	1043		1357	152	37	25		152	
1999	532		11	1240	122	758	203		38		185	
2000	538			805	101	1311	175				199	
2001	277	28	18	994	260	1390	141		68		313	
2002	379	53	40	1074	505	1381	108		72		194	
2003	385	96	35	1483	569	1526	141		85		196	
2004	333	54	26	1287	540	1423	103		66		171	
2005	370	18		1169	615	1376	84		73		179	
2006	375	12		935	523	858	100		86		192	
2007	344	41		671	353	577	166		70		203	
2008	162	11		621	114	28	106				205	81

Table 2.15a—Comparison of negative log likelihoods across models. In the “abundance” component, only the trawl survey values count toward the total. Green=minimum (by row), pink=maximum (by row).

Model:	A1	A2	B1	B2	C1	D2	E2	F2
Number of parameters:	232	232	190	190	191	190	188	130
Abundance:	50.84	48.07	52.27	47.97	52.01	48.64	52.34	66.73
Size composition:	1260.42	1388.85	1326.10	1455.10	1326.99	1454.57	1497.76	1999.05
Age composition:	171.95		178.81		176.97			
Recruitment:	20.21	20.67	26.41	26.85	27.39	26.08	19.32	14.55
Softbounds:	0.04	0.04	0.02	0.02	0.02	0.02	0.02	0.01
Parameter devs:	13.30	9.82	13.62	10.05	13.71	9.99	9.82	23.95
Total:	1516.76	1467.45	1597.23	1540.00	1597.09	1539.31	1579.26	2104.28
Abundance by fleet								
Jan-May trawl fishery:	141.36	109.56	119.98	91.42	117.17	93.65	147.62	95.42
Jun-Aug trawl fishery:	21.13	19.37	16.43	14.90	16.37	14.99	17.12	13.67
Sep-Dec trawl fishery:	33.11	34.29	28.99	26.00	28.76	26.29	28.42	15.86
Jan-May longline fishery:	219.21	183.60	255.97	226.21	255.67	227.71	296.41	198.55
Jun-Aug longline fishery:	56.96	53.31	119.61	97.72	118.30	99.84	159.48	72.67
Sep-Dec longline fishery:	104.41	112.29	151.97	160.53	152.39	162.86	201.97	232.27
Jan-May pot fishery:	33.66	23.93	29.11	19.95	28.35	20.65	39.73	7.53
Jun-Aug pot fishery:	14.48	12.05	3.33	3.17	3.25	3.18	5.03	1.78
Sep-Dec pot fishery:	35.80	30.80	35.53	30.75	35.13	31.19	41.83	21.32
Pre-1982 trawl survey:	2.68	2.12	3.38	3.08	3.45	3.03	0.93	10.42
Post-1981 trawl survey:	48.15	45.95	48.89	44.88	48.56	45.61	51.40	66.73
IPHC longline survey:	13.04	10.88	13.00	10.71	13.02	10.67	11.47	6.77
Size composition by fleet								
Jan-May trawl fishery:	407.50	391.67	409.17	394.82	409.54	395.08	403.91	520.81
Jun-Aug trawl fishery:	55.50	56.87	61.12	62.82	61.14	62.78	60.10	103.93
Sep-Dec trawl fishery:	52.23	52.08	56.38	56.21	56.38	56.16	56.99	72.63
Jan-May longline fishery:	192.84	163.60	191.70	164.20	191.85	164.07	168.94	335.68
Jun-Aug longline fishery:	79.74	77.76	123.85	116.18	123.47	116.08	110.99	134.08
Sep-Dec longline fishery:	208.10	206.41	212.42	214.29	212.56	214.12	226.23	415.41
Jan-May pot fishery:	39.18	39.29	35.41	34.60	35.39	34.67	37.83	47.77
Jun-Aug pot fishery:	12.61	12.50	21.30	22.59	21.36	22.48	19.49	24.88
Sep-Dec pot fishery:	34.11	35.19	40.25	40.48	40.22	40.41	36.76	48.87
Pre-1982 trawl survey:	30.14	27.14	31.90	28.63	31.84	28.79	38.34	185.45
Post-1981 trawl survey:	144.64	321.73	138.41	315.36	139.07	315.06	334.06	289.46
IPHC longline survey:	3.81	4.62	4.18	4.92	4.19	4.88	4.11	5.53

Table 2.15b—Root mean squared errors for fishery CPUE and survey relative abundance time series. Green = row minimum, pink = row maximum.

Fleet	A1	A2	B1	B2	C1	D2	E2	F2
Jan-May trawl fishery	0.289	0.255	0.269	0.233	0.266	0.236	0.287	0.234
Jun-Aug trawl fishery	0.573	0.560	0.518	0.491	0.515	0.494	0.549	0.443
Sep-Dec trawl fishery	0.830	0.854	0.790	0.763	0.788	0.766	0.784	0.631
Jan-May longline fishery	0.251	0.226	0.266	0.245	0.266	0.246	0.285	0.221
Jun-Aug longline fishery	0.208	0.203	0.300	0.275	0.299	0.276	0.332	0.267
Sep-Dec longline fishery	0.200	0.201	0.233	0.234	0.232	0.237	0.279	0.262
Jan-May pot fishery	0.248	0.207	0.217	0.174	0.215	0.176	0.237	0.108
Jun-Aug pot fishery	0.344	0.307	0.161	0.135	0.157	0.138	0.209	0.097
Sep-Dec pot fishery	0.381	0.352	0.364	0.340	0.362	0.342	0.391	0.289
Pre-1982 trawl survey	0.168	0.149	0.188	0.180	0.190	0.178	0.096	0.331
Post-1981 trawl survey	0.193	0.190	0.197	0.195	0.197	0.196	0.201	0.237
IPHC longline survey	0.375	0.342	0.374	0.339	0.374	0.338	0.351	0.268

Table 2.15c—Correlations between observed data and model estimates for fishery CPUE and survey relative abundance time series. Green = row minimum, pink = row maximum.

Fleet	A1	A2	B1	B2	C1	D2	E2	F2
Jan-May trawl fishery	0.031	0.519	0.337	0.638	0.371	0.626	0.013	0.571
Jun-Aug trawl fishery	-0.383	-0.361	-0.411	-0.180	-0.381	-0.225	-0.691	0.282
Sep-Dec trawl fishery	-0.170	-0.491	0.044	0.116	0.052	0.108	0.117	0.027
Jan-May longline fishery	-0.083	-0.071	-0.206	-0.200	-0.196	-0.218	-0.422	0.087
Jun-Aug longline fishery	0.123	0.162	-0.229	-0.186	-0.221	-0.202	-0.383	0.028
Sep-Dec longline fishery	0.255	0.199	-0.198	-0.260	-0.190	-0.296	-0.463	-0.110
Jan-May pot fishery	-0.287	-0.099	-0.092	0.213	-0.072	0.194	-0.115	0.707
Jun-Aug pot fishery	-0.295	-0.171	0.653	0.733	0.680	0.728	-0.052	0.855
Sep-Dec pot fishery	-0.068	0.104	-0.038	0.114	-0.022	0.095	-0.177	0.515
Pre-1982 trawl survey	0.954	0.921	0.966	0.913	0.959	0.923	0.945	-0.615
Post-1981 trawl survey	0.728	0.724	0.717	0.717	0.721	0.713	0.685	0.617
IPHC longline survey	-0.797	-0.772	-0.758	-0.666	-0.755	-0.668	-0.727	0.125

Table 2.15d—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 in models using data file 1. Green = row minimum, pink = row maximum.

Fleet	A1	A2	B1	B2	C1	D2	E2	F2
Jan-May trawl fishery	1.176	1.194	1.263	1.292	1.260	1.296	1.518	1.211
Jun-Aug trawl fishery	10.262	10.243	8.192	8.088	8.208	8.067	7.381	5.347
Sep-Dec trawl fishery	4.276	4.113	4.076	4.120	4.089	4.121	4.160	4.234
Jan-May longline fishery	2.504	2.537	2.407	2.389	2.412	2.373	2.608	1.233
Jun-Aug longline fishery	3.916	3.828	3.035	3.123	3.028	3.134	3.619	4.595
Sep-Dec longline fishery	1.811	1.708	1.868	1.838	1.865	1.850	2.006	1.212
Jan-May pot fishery	2.865	2.719	3.358	3.369	3.367	3.356	3.081	2.645
Jun-Aug pot fishery	5.245	5.494	4.152	4.466	4.167	4.434	3.906	2.986
Sep-Dec pot fishery	6.547	5.989	5.466	5.195	5.489	5.190	5.100	3.775
Pre-1982 trawl survey	0.691	0.786	0.659	0.717	0.660	0.712	0.951	0.145
Post-1981 trawl survey	2.103	1.694	2.044	1.707	2.015	1.710	1.515	1.376
IPHC longline survey	1.955	1.664	1.774	1.530	1.770	1.539	1.669	1.123

Table 2.15e— 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 in models using data file 1. Green = row minimum, pink = row maximum.

Fleet	A1	A2	B1	B2	C1	D2	E2	F2
Jan-May trawl fishery	0.798	0.841	0.851	0.912	0.850	0.914	1.009	0.794
Jun-Aug trawl fishery	4.136	4.005	3.646	3.412	3.646	3.413	3.518	2.245
Sep-Dec trawl fishery	3.868	3.640	3.727	3.791	3.731	3.796	3.937	3.968
Jan-May longline fishery	1.113	1.302	1.069	1.208	1.071	1.202	1.097	0.742
Jun-Aug longline fishery	1.943	2.114	1.214	1.383	1.225	1.373	1.257	1.142
Sep-Dec longline fishery	1.392	1.284	1.345	1.268	1.345	1.275	1.200	0.549
Jan-May pot fishery	2.802	2.659	3.323	3.257	3.332	3.243	2.964	2.894
Jun-Aug pot fishery	4.843	5.040	3.174	3.419	3.180	3.398	3.065	2.272
Sep-Dec pot fishery	6.266	5.660	5.141	4.946	5.165	4.941	4.936	3.328
Pre-1982 trawl survey	0.601	0.695	0.564	0.630	0.565	0.626	0.775	0.120
Post-1981 trawl survey	1.623	1.419	1.612	1.432	1.589	1.434	1.267	1.244
IPHC longline survey	1.955	1.664	1.774	1.530	1.770	1.539	1.669	1.123

Table 2.16a—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.” If a parameter is not used at all in a particular model, “n/a” appears under both “Value” and “SD.”

	Model A1		Model A2		Model B1		Model B2		Model C1		Model D2		Model E2		Model F2	
Parm.	Value	SD	Value	SD	Value	SD	Value	SD	Value	SD	Value	SD	Value	SD	Value	SD
M	0.34	n/a	0.34	n/a	0.34	n/a	0.34	n/a	0.33	0.02	0.35	n/a	0.58	0.01	0.47	0.02
L1	16.14	n/a	16.14	n/a	16.14	n/a	16.14	n/a	16.14	n/a	16.14	n/a	16.14	n/a	5.83	0.29
L2	90.56	0.66	89.69	0.75	91.82	0.72	91.01	0.83	91.77	0.74	91.18	0.83	96.55	0.76	102.2	1.06
K	0.25	0.00	0.26	0.00	0.24	0.00	0.25	0.00	0.24	0.00	0.25	0.00	0.22	0.00	0.21	0.00
SD1	3.69	n/a	3.69	n/a	3.69	n/a	3.69	n/a	3.69	n/a	3.69	n/a	3.69	n/a	4.10	0.12
SD2	0.95	0.02	0.96	0.02	0.96	0.02	0.97	0.02	0.96	0.02	0.97	0.02	0.98	0.02	1.24	0.08
R0	13.69	0.11	13.70	0.14	13.36	0.06	13.33	0.07	13.24	0.21	13.44	0.08	22.54	31.6	13.94	0.16
R1	-0.72	0.15	-0.61	0.16	-0.96	0.15	-0.94	0.16	-1.00	0.16	-0.91	0.16	-0.82	0.20	-0.77	0.12
σR	0.66	n/a	0.66	n/a	0.64	n/a	0.64	n/a	0.64	n/a	0.64	n/a	0.64	n/a	0.60	n/a
Initial F	0.03	0.01	0.03	0.01	0.06	0.01	0.06	0.02	0.07	0.02	0.06	0.01	0.00	0.00	2.23	0.30
lnQ1	-0.38	0.16	-0.61	0.20	-0.02	0.12	-0.12	0.14	0.08	0.22	-0.22	0.15	-8.24	31.6	n/a	n/a
lnQ2	-0.66	0.11	-0.50	0.14	-0.34	0.07	-0.17	0.08	-0.26	0.16	-0.25	0.08	-8.73	31.6	-0.43	0.11

Legend

M = natural mortality rate
L1 = length at reference age A1 (A1 = 1.5417 years in all models except Model F2, A1 = 1 year in model F2)
L2 = length at reference age A2 (A2 = 20 years in all models)
K = Brody's growth coefficient
SD1 = standard deviation of length at reference age A1
SD2 = standard deviation of length at reference age A2, expressed as log offset of SD1
R0 = log mean recruitment for post-1976 regime
R1 = log mean recruitment for pre-1977 regime, expressed as log offset of R0
σR = scale of log recruitment variability
Initial F = equilibrium fishing mortality rate during initial year (1977)
lnQ1 = log catchability of pre-1982 trawl survey
lnQ2 = log catchability of post-1981 trawl survey

Table 2.16b—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.

	Model A1		Model A2		Model B1		Model B2		Model C1		Model D2		Model E2		Model F2	
Year	Value	SD	Value	SD	Value	SD	Value	SD	Value	SD	Value	SD	Value	SD	Value	SD
1974	0.77	0.26	0.77	0.28	1.14	0.21	1.19	0.23	1.15	0.21	1.18	0.23	0.97	0.25	-0.02	0.18
1975	-0.98	0.38	-0.82	0.41	-1.52	0.38	-1.30	0.41	-1.53	0.38	-1.30	0.41	-1.03	0.40	-0.14	0.22
1976	0.21	0.25	0.05	0.28	0.38	0.28	0.12	0.32	0.39	0.28	0.12	0.32	0.06	0.27	0.16	0.17
1977	1.67	0.09	1.92	0.11	1.61	0.09	1.76	0.10	1.59	0.09	1.78	0.10	1.58	0.10	0.90	0.13
1978	0.28	0.20	0.53	0.20	0.24	0.20	0.45	0.19	0.22	0.20	0.46	0.19	0.46	0.19	0.59	0.15
1979	0.50	0.13	0.59	0.14	0.51	0.13	0.57	0.13	0.49	0.13	0.59	0.13	1.00	0.11	0.85	0.10
1980	-0.27	0.16	-0.22	0.16	-0.26	0.16	-0.18	0.15	-0.26	0.16	-0.18	0.15	-0.18	0.16	0.11	0.11
1981	-1.10	0.20	-1.10	0.19	-1.08	0.19	-1.13	0.19	-1.08	0.20	-1.12	0.19	-1.01	0.18	-0.90	0.15
1982	0.93	0.05	0.93	0.05	0.94	0.05	0.93	0.05	0.93	0.05	0.93	0.05	0.93	0.05	0.87	0.04
1983	-0.54	0.14	-0.44	0.13	-0.55	0.14	-0.46	0.13	-0.56	0.14	-0.45	0.13	-0.36	0.12	-0.50	0.11
1984	0.71	0.06	0.68	0.06	0.73	0.06	0.72	0.06	0.72	0.06	0.72	0.06	0.73	0.06	0.68	0.05
1985	-0.01	0.09	0.08	0.09	-0.01	0.09	0.10	0.08	-0.01	0.09	0.10	0.08	0.02	0.08	0.13	0.07
1986	-0.78	0.12	-0.75	0.12	-0.76	0.12	-0.72	0.12	-0.75	0.12	-0.73	0.12	-0.72	0.11	-0.43	0.08
1987	-1.36	0.17	-1.46	0.18	-1.26	0.16	-1.35	0.17	-1.26	0.16	-1.35	0.17	-1.28	0.13	-0.91	0.09
1988	-0.26	0.08	-0.33	0.08	-0.24	0.07	-0.31	0.08	-0.23	0.08	-0.32	0.08	-0.46	0.08	-0.50	0.07
1989	0.56	0.05	0.51	0.06	0.54	0.05	0.48	0.05	0.55	0.05	0.47	0.05	0.34	0.06	0.25	0.05
1990	0.40	0.06	0.46	0.06	0.38	0.06	0.45	0.06	0.39	0.06	0.44	0.06	0.39	0.06	0.34	0.05
1991	-0.14	0.07	-0.37	0.09	-0.15	0.07	-0.35	0.09	-0.14	0.07	-0.36	0.09	-0.35	0.08	-0.35	0.06
1992	0.72	0.04	0.70	0.05	0.68	0.04	0.67	0.05	0.68	0.04	0.66	0.05	0.59	0.05	0.39	0.04
1993	-0.18	0.07	-0.25	0.09	-0.22	0.07	-0.26	0.08	-0.22	0.07	-0.26	0.08	-0.15	0.07	-0.32	0.06
1994	-0.19	0.06	-0.23	0.07	-0.23	0.06	-0.26	0.07	-0.23	0.06	-0.26	0.07	-0.21	0.07	-0.50	0.05
1995	0.04	0.06	-0.28	0.08	-0.02	0.06	-0.33	0.08	-0.02	0.06	-0.33	0.08	-0.27	0.07	-0.66	0.06
1996	0.79	0.04	0.79	0.05	0.77	0.04	0.76	0.05	0.77	0.04	0.75	0.05	0.74	0.05	0.28	0.04
1997	-0.18	0.07	0.02	0.07	-0.13	0.06	0.09	0.06	-0.13	0.06	0.09	0.06	0.15	0.06	0.04	0.04
1998	-0.03	0.05	-0.27	0.08	0.04	0.05	-0.19	0.07	0.04	0.05	-0.19	0.07	-0.14	0.07	-0.14	0.05
1999	0.49	0.04	0.51	0.05	0.56	0.04	0.58	0.05	0.56	0.04	0.58	0.05	0.53	0.05	0.44	0.04
2000	0.10	0.05	0.34	0.06	0.13	0.05	0.40	0.05	0.14	0.05	0.39	0.05	0.37	0.05	0.45	0.04
2001	-0.52	0.06	-0.92	0.11	-0.50	0.06	-0.89	0.11	-0.50	0.06	-0.88	0.11	-0.83	0.10	-0.56	0.07
2002	-0.36	0.06	-0.13	0.06	-0.35	0.06	-0.12	0.06	-0.35	0.06	-0.12	0.06	-0.17	0.06	-0.09	0.05
2003	-0.44	0.07	-0.41	0.08	-0.46	0.07	-0.43	0.08	-0.46	0.07	-0.43	0.08	-0.47	0.07	-0.36	0.06
2004	-0.95	0.08	-0.74	0.09	-0.96	0.08	-0.75	0.09	-0.96	0.08	-0.75	0.09	-0.78	0.09	-0.53	0.07
2005	-0.56	0.08	-0.64	0.10	-0.58	0.08	-0.65	0.10	-0.57	0.08	-0.65	0.10	-0.73	0.11	-0.62	0.09
2006	0.72	0.09	0.54	0.09	0.69	0.08	0.53	0.09	0.70	0.09	0.53	0.09	0.41	0.09	0.57	0.09
2007	-0.04	0.40	-0.07	0.44	-0.08	0.38	-0.12	0.42	-0.08	0.38	-0.12	0.42	-0.10	0.48	0.47	0.20

Table 2.17a—Legend for Tables 2.17b-2.17d (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	Pre-1982 trawl survey
11	Post-1981 trawl survey
12	IPHC longline 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

3dev:	Annual deviation from the base level of Parm. 3
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 2.17b—Selectivity parameters as estimated by Models A1 and A2 (page 1 of 4).

				Model A1		Model A2	
Fleet	Parm.	Block	Axis	Value	SD	Value	SD
2	2	n/a	Size	-1.50	1.50	-2.03	2.69
2	4	n/a	Size	3.92	3.21	4.59	2.73
3	2	n/a	Size	-8.56	29.73	-8.61	28.97
3	4	n/a	Size	4.38	1.65	-4.85	16.85
4	2	n/a	Size	-9.35	16.05	-9.01	22.20
4	4	n/a	Size	5.03	0.10	5.02	0.10
5	2	n/a	Size	-3.39	2.02	-3.28	1.76
5	4	n/a	Size	5.15	0.50	5.04	0.51
6	2	n/a	Size	-2.45	0.47	-2.25	0.41
6	4	n/a	Size	5.07	0.29	5.00	0.30
7	2	n/a	Size	-8.62	28.84	-8.67	28.10
7	4	n/a	Size	4.29	0.35	4.28	0.34
8	2	n/a	Size	-8.11	36.19	-8.08	36.62
8	4	n/a	Size	4.70	1.03	4.75	0.92
9	2	n/a	Size	-7.59	42.57	-6.77	45.98
9	4	n/a	Size	3.92	0.73	3.81	0.87
12	1	n/a	Size	67.87	4.19	68.86	4.57
12	2	n/a	Size	2.08	7.05	2.05	7.29
12	3	n/a	Size	4.53	0.63	4.66	0.64
12	4	n/a	Size	0.00	223.85	0.00	223.86
12	6	n/a	Size	6.90	51.90	7.05	50.11
10	1	n/a	Age	1.25	0.27	1.24	0.22
10	2	n/a	Age	-2.62	0.78	-2.70	1.04
10	3	n/a	Age	-3.75	2.46	-3.81	2.21
10	4	n/a	Age	-0.24	2.73	-0.14	3.13
10	6	n/a	Age	-2.94	1.36	-2.94	1.42
11	1	n/a	Age	1.11	0.02	1.10	0.02
11	2	n/a	Age	-1.91	0.22	-4.64	2.50
11	3	n/a	Age	-4.51	0.42	-4.78	0.45
11	4	n/a	Age	2.44	0.33	2.06	0.39
11	6	n/a	Age	-3.13	0.82	-1.22	0.20
1	1	1977	Size	41.51	3.47	41.70	3.40
1	1	1980	Size	66.14	3.67	65.11	3.70
1	1	1985	Size	72.89	2.15	67.08	3.67
1	1	1990	Size	57.12	1.20	55.27	1.35
1	1	1995	Size	69.30	1.52	67.40	1.80
1	1	2000	Size	72.49	1.48	73.19	1.41
1	1	2005	Size	66.73	1.72	67.77	1.61
1	3	1977	Size	3.11	1.00	3.10	0.97
1	3	1980	Size	6.02	0.23	6.00	0.24
1	3	1985	Size	6.51	0.11	6.27	0.20
1	3	1990	Size	5.47	0.09	5.36	0.11
1	3	1995	Size	6.15	0.08	6.07	0.09
1	3	2000	Size	6.22	0.08	6.23	0.07
1	3	2005	Size	5.92	0.11	5.98	0.11
2	1	1977	Size	50.27	4.68	49.56	4.88
2	1	1985	Size	76.78	7.64	75.13	7.42
2	1	1990	Size	60.13	6.42	59.26	6.10

Table 2.17b—Selectivity parameters as estimated by Models A1 and A2 (page 2 of 4).

				Model A1		Model A2	
Fleet	Parm.	Block	Axis	Value	SD	Value	SD
2	1	2000	Size	62.14	3.27	63.10	4.04
2	1	2005	Size	47.86	7.29	48.16	8.38
2	3	1977	Size	5.73	0.42	5.74	0.43
2	3	1985	Size	6.27	0.46	6.24	0.47
2	3	1990	Size	5.25	0.65	5.18	0.64
2	3	2000	Size	5.46	0.32	5.53	0.37
2	3	2005	Size	4.71	0.97	4.82	1.06
2	6	1977	Size	0.61	0.92	0.30	0.85
2	6	1985	Size	6.81	52.79	5.24	61.88
2	6	1990	Size	0.34	1.73	0.10	1.59
2	6	2000	Size	8.53	30.21	8.66	28.23
2	6	2005	Size	0.73	0.94	0.83	1.09
3	1	1977	Size	59.30	3.49	64.39	0.75
3	1	1980	Size	83.24	5.82	78.21	7.66
3	1	1985	Size	82.62	6.43	79.24	5.09
3	1	1990	Size	47.99	3.34	49.23	0.99
3	1	2000	Size	70.78	10.15	75.17	15.34
3	3	1977	Size	5.21	0.35	5.51	0.20
3	3	1980	Size	6.72	0.25	6.60	0.35
3	3	1985	Size	6.25	0.35	6.14	0.31
3	3	1990	Size	4.26	0.67	4.23	0.41
3	3	1995	Size	7.32	0.14	7.35	0.14
3	3	2000	Size	6.04	0.66	6.28	0.84
3	6	1977	Size	-2.36	2.08	-1.77	0.79
3	6	1980	Size	-0.30	2.91	8.32	33.32
3	6	1985	Size	8.49	30.83	8.44	31.59
3	6	1990	Size	7.28	47.27	0.19	0.99
3	6	2000	Size	8.88	24.67	8.95	23.44
4	1	1977	Size	55.32	1.90	54.85	1.92
4	1	1980	Size	68.51	2.96	67.12	3.22
4	1	1985	Size	73.01	1.07	71.63	1.11
4	1	1990	Size	64.81	0.57	64.45	0.54
4	1	1995	Size	64.71	0.48	64.23	0.48
4	1	2000	Size	61.52	0.45	61.87	0.47
4	1	2005	Size	63.23	0.51	63.24	0.53
4	3	1977	Size	4.74	0.24	4.67	0.24
4	3	1980	Size	5.73	0.24	5.68	0.27
4	3	1985	Size	5.73	0.09	5.69	0.09
4	3	1990	Size	5.10	0.06	5.09	0.06
4	3	1995	Size	5.23	0.05	5.20	0.05
4	3	2000	Size	5.23	0.05	5.26	0.05
4	3	2005	Size	5.15	0.06	5.16	0.06
4	6	1977	Size	-2.07	0.78	-2.07	0.76
4	6	1980	Size	0.33	1.02	0.56	1.07
4	6	1985	Size	-0.95	0.42	-0.89	0.37
4	6	1990	Size	-0.36	0.15	-0.50	0.14
4	6	1995	Size	-0.90	0.15	-0.98	0.15
4	6	2000	Size	-1.48	0.15	-1.43	0.15

Table 2.17b—Selectivity parameters as estimated by Models A1 and A2 (page 3 of 4).

				Model A1		Model A2	
Fleet	Parm.	Block	Axis	Value	SD	Value	SD
4	6	2005	Size	-1.44	0.16	-1.29	0.16
5	1	1977	Size	59.75	2.65	59.60	2.62
5	1	1980	Size	66.80	4.48	65.47	4.74
5	1	1985	Size	68.56	7.56	67.07	6.84
5	1	1990	Size	65.15	1.08	64.53	1.06
5	1	2000	Size	62.49	0.99	62.86	1.07
5	1	2005	Size	61.35	1.09	61.78	1.09
5	3	1977	Size	4.55	0.42	4.52	0.41
5	3	1980	Size	5.32	0.42	5.24	0.47
5	3	1985	Size	5.27	0.73	5.20	0.72
5	3	1990	Size	5.00	0.11	4.96	0.12
5	3	2000	Size	5.10	0.11	5.13	0.11
5	3	2005	Size	4.78	0.14	4.81	0.14
5	6	1977	Size	-3.22	2.84	-2.95	2.30
5	6	1980	Size	1.61	2.75	1.74	2.69
5	6	1985	Size	3.78	23.97	2.42	6.14
5	6	1990	Size	2.48	1.14	1.66	0.55
5	6	2000	Size	-0.85	0.32	-0.69	0.31
5	6	2005	Size	8.30	33.50	9.33	16.43
6	1	1977	Size	58.60	2.87	58.19	2.83
6	1	1980	Size	67.31	1.70	65.89	1.79
6	1	1985	Size	64.91	0.89	63.38	1.02
6	1	1990	Size	66.28	0.92	65.59	0.92
6	1	1995	Size	67.64	0.85	66.70	0.92
6	1	2000	Size	61.99	0.56	62.14	0.59
6	1	2005	Size	59.19	0.89	59.92	0.92
6	3	1977	Size	4.14	0.51	4.04	0.52
6	3	1980	Size	5.21	0.17	5.13	0.18
6	3	1985	Size	4.92	0.10	4.79	0.12
6	3	1990	Size	4.94	0.10	4.91	0.11
6	3	1995	Size	5.41	0.07	5.35	0.07
6	3	2000	Size	5.09	0.06	5.10	0.06
6	3	2005	Size	4.73	0.12	4.80	0.12
6	6	1977	Size	-3.22	2.73	-3.14	2.55
6	6	1980	Size	0.54	0.69	0.57	0.63
6	6	1985	Size	-0.07	0.25	-0.20	0.23
6	6	1990	Size	1.42	0.49	1.05	0.37
6	6	1995	Size	2.17	0.85	1.72	0.56
6	6	2000	Size	-0.81	0.18	-0.69	0.18
6	6	2005	Size	8.66	28.14	9.54	12.08
7	1	1977	Size	68.02	0.82	67.67	0.81
7	1	2000	Size	65.64	0.87	65.76	0.87
7	3	1977	Size	5.11	0.09	5.10	0.09
7	3	2000	Size	4.95	0.11	4.95	0.11
7	6	1977	Size	0.02	0.24	-0.09	0.23
7	6	2000	Size	-0.47	0.21	-0.38	0.21
8	1	1977	Size	64.26	2.13	63.86	2.11
8	1	1995	Size	68.22	2.56	67.78	2.45

Table 2.17b—Selectivity parameters as estimated by Models A1 and A2 (page 4 of 4).

				Model A1		Model A2	
Fleet	Parm.	Block	Axis	Value	SD	Value	SD
8	3	1977	Size	4.87	0.24	4.86	0.25
8	3	1995	Size	5.06	0.29	5.04	0.29
8	6	1977	Size	-0.48	0.47	-0.62	0.45
8	6	1995	Size	3.59	9.50	2.40	3.03
9	1	1977	Size	69.61	2.08	69.30	1.98
9	1	2000	Size	61.07	1.28	61.12	1.35
9	3	1977	Size	5.25	0.20	5.25	0.19
9	3	2000	Size	4.45	0.21	4.45	0.22
9	6	1977	Size	1.29	0.82	1.05	0.67
9	6	2000	Size	0.35	0.30	0.51	0.34
10	3dev	1979	Age	0.08	0.14	0.09	0.14
10	3dev	1980	Age	0.02	0.14	0.02	0.14
10	3dev	1981	Age	-0.09	0.14	-0.11	0.14
11	3dev	1982	Age	0.08	0.11	0.09	0.10
11	3dev	1983	Age	0.03	0.06	0.04	0.05
11	3dev	1984	Age	0.16	0.09	0.18	0.09
11	3dev	1985	Age	-0.05	0.07	-0.05	0.06
11	3dev	1986	Age	0.08	0.07	0.09	0.06
11	3dev	1987	Age	-0.10	0.11	-0.06	0.10
11	3dev	1988	Age	0.11	0.10	0.09	0.10
11	3dev	1989	Age	0.25	0.08	0.23	0.08
11	3dev	1990	Age	0.05	0.06	0.03	0.06
11	3dev	1991	Age	0.08	0.06	0.09	0.06
11	3dev	1992	Age	-0.16	0.11	-0.22	0.11
11	3dev	1993	Age	-0.14	0.08	-0.11	0.07
11	3dev	1994	Age	0.13	0.07	0.08	0.07
11	3dev	1995	Age	0.26	0.08	0.14	0.08
11	3dev	1996	Age	0.29	0.09	0.20	0.09
11	3dev	1997	Age	0.10	0.05	0.12	0.06
11	3dev	1998	Age	0.15	0.06	0.17	0.08
11	3dev	1999	Age	0.18	0.06	0.13	0.07
11	3dev	2000	Age	0.05	0.05	0.06	0.05
11	3dev	2001	Age	-0.34	0.11	-0.18	0.08
11	3dev	2002	Age	0.05	0.06	-0.04	0.09
11	3dev	2003	Age	-0.04	0.06	-0.03	0.07
11	3dev	2004	Age	0.00	0.06	0.02	0.07
11	3dev	2005	Age	-0.27	0.12	-0.22	0.11
11	3dev	2006	Age	-0.45	0.12	-0.37	0.12
11	3dev	2007	Age	-0.48	0.12	-0.47	0.12
11	3dev	2008	Age	-0.05	0.15	-0.04	0.14

Table 2.17c—Selectivity parameters as estimated by Models B1, B2, C1, D2, and E2 (page 1 of 3).

				Model B1		Model B2		Model C1		Model D2		Model E2	
Fleet	Parm.	Block	Axis	Value	SD	Value	SD	Value	SD	Value	SD	Value	SD
2	3	n/a	Size	5.64	0.21	5.68	0.21	5.64	0.21	5.69	0.20	5.82	0.16
4	2	n/a	Size	-9.26	17.75	-9.04	21.79	-9.25	17.98	-9.09	20.95	-9.67	9.10
4	4	n/a	Size	4.99	0.11	4.98	0.11	4.99	0.11	4.98	0.11	4.93	0.13
5	3	n/a	Size	5.00	0.07	5.00	0.07	5.00	0.07	5.00	0.07	5.11	0.06
6	2	n/a	Size	-2.25	0.43	-2.10	0.39	-2.23	0.43	-2.12	0.40	-2.54	0.68
6	4	n/a	Size	5.06	0.35	5.01	0.37	5.06	0.36	5.02	0.37	5.35	0.44
7	2	n/a	Size	-8.95	23.46	-8.86	25.04	-8.95	23.54	-8.86	24.94	-8.89	24.57
7	3	n/a	Size	5.08	0.07	5.08	0.07	5.09	0.07	5.07	0.07	5.07	0.07
7	4	n/a	Size	4.15	0.42	4.17	0.41	4.15	0.42	4.17	0.41	4.11	0.52
8	3	n/a	Size	4.88	0.19	4.86	0.19	4.88	0.19	4.86	0.19	4.92	0.18
12	1	n/a	Size	69.38	4.32	70.27	4.33	69.41	4.31	70.27	4.32	71.73	3.88
12	3	n/a	Size	4.66	0.59	4.77	0.56	4.66	0.58	4.77	0.56	4.84	0.47
10	1	n/a	Age	1.27	0.28	1.26	0.25	1.26	0.28	1.26	0.25	2.07	0.04
10	2	n/a	Age	-2.62	0.62	-2.72	0.81	-2.64	0.65	-2.69	0.77	-3.62	4.22
10	3	n/a	Age	-3.70	2.48	-3.74	2.33	-3.70	2.49	-3.73	2.33	-5.09	1.47
10	4	n/a	Age	-0.16	2.06	-0.01	2.22	-0.12	2.03	-0.05	2.26	-0.59	7.23
10	6	n/a	Age	-2.61	1.31	-2.62	1.37	-2.63	1.32	-2.60	1.37	-2.01	1.39
11	1	n/a	Age	1.11	0.02	1.10	0.02	1.11	0.02	1.10	0.02	1.13	0.02
11	2	n/a	Age	-1.61	0.21	-4.07	1.62	-1.64	0.23	-3.81	1.29	n/a	n/a
11	3	n/a	Age	-4.52	0.42	-4.76	0.44	-4.54	0.42	-4.76	0.44	-4.53	0.42
11	4	n/a	Age	2.15	0.49	2.02	0.47	2.19	0.49	1.97	0.50	n/a	n/a
11	6	n/a	Age	-2.43	0.69	-0.87	0.22	-2.46	0.70	-0.83	0.22	n/a	n/a
1	1	1977	Size	41.43	3.34	41.57	3.18	41.35	3.27	41.63	3.23	42.92	3.80
1	1	1980	Size	67.91	3.25	67.28	3.65	67.85	3.26	67.41	3.69	74.34	3.13
1	1	1985	Size	75.45	2.25	73.00	2.12	75.16	2.32	73.36	2.13	83.27	1.75
1	1	1990	Size	60.56	1.58	57.96	1.95	60.43	1.63	58.32	1.92	68.24	1.53
1	1	1995	Size	72.78	1.23	71.11	1.50	72.80	1.24	71.19	1.49	74.46	1.10
1	1	2000	Size	76.12	1.45	76.98	1.48	76.21	1.47	76.97	1.48	78.65	1.26
1	1	2005	Size	68.95	1.61	69.88	1.73	68.96	1.62	69.93	1.72	72.83	1.48
1	3	1977	Size	3.08	0.97	3.04	0.93	3.06	0.96	3.05	0.94	3.23	0.95
1	3	1980	Size	6.06	0.20	6.06	0.22	6.07	0.20	6.06	0.22	6.14	0.16
1	3	1985	Size	6.58	0.10	6.51	0.10	6.57	0.10	6.51	0.10	6.62	0.07
1	3	1990	Size	5.69	0.11	5.53	0.14	5.68	0.11	5.55	0.14	5.97	0.08
1	3	1995	Size	6.26	0.06	6.20	0.07	6.27	0.06	6.20	0.07	6.18	0.05
1	3	2000	Size	6.30	0.07	6.32	0.07	6.31	0.08	6.31	0.07	6.23	0.06
1	3	2005	Size	6.00	0.10	6.06	0.11	6.00	0.10	6.05	0.11	6.04	0.09
2	1	1977	Size	48.91	2.73	48.37	2.78	48.78	2.75	48.56	2.78	55.79	2.59
2	1	1985	Size	68.81	3.81	68.95	3.81	68.64	3.83	69.15	3.79	76.02	3.39
2	1	1990	Size	64.11	3.85	64.06	3.91	64.07	3.86	64.13	3.90	68.01	3.70
2	1	2000	Size	65.43	2.74	66.39	2.80	65.41	2.75	66.48	2.79	70.77	2.61
2	1	2005	Size	55.48	3.08	55.38	3.16	55.43	3.09	55.50	3.15	60.23	2.89
3	1	1977	Size	57.90	4.31	57.63	4.07	57.88	4.31	57.66	4.13	59.24	4.36
3	1	1980	Size	82.92	6.75	81.51	7.83	82.88	6.79	81.60	7.78	90.39	7.01
3	1	1985	Size	84.46	6.22	81.84	5.02	84.21	6.26	82.05	4.98	90.99	5.46
3	1	1990	Size	48.24	3.47	48.02	3.42	48.19	3.46	48.07	3.44	50.22	4.17
3	1	2000	Size	87.34	11.26	89.80	10.30	87.65	9.38	89.61	10.15	89.48	8.16
3	3	1977	Size	5.23	0.41	5.22	0.39	5.24	0.41	5.22	0.39	5.18	0.39
3	3	1980	Size	6.66	0.28	6.67	0.33	6.67	0.28	6.66	0.33	6.66	0.24

Table 2.17c—Selectivity parameters as estimated by Models B1, B2, C1, D2, and E2 (page 2 of 3).

				Model B1		Model B2		Model C1		Model D2		Model E2	
Fleet	Parm.	Block	Axis	Value	SD	Value	SD	Value	SD	Value	SD	Value	SD
3	3	1985	Size	6.30	0.32	6.21	0.29	6.29	0.32	6.21	0.28	6.36	0.23
3	3	1990	Size	4.25	0.68	4.28	0.68	4.25	0.68	4.28	0.68	4.35	0.70
3	3	1995	Size	7.23	0.13	7.26	0.13	7.24	0.13	7.25	0.13	7.09	0.11
3	3	2000	Size	6.75	0.43	6.80	0.37	6.76	0.37	6.79	0.37	6.63	0.30
4	1	1977	Size	55.46	2.20	54.40	2.44	55.44	2.20	54.45	2.42	56.22	2.29
4	1	1980	Size	69.32	3.03	68.29	3.17	69.27	3.04	68.36	3.16	74.68	2.89
4	1	1985	Size	73.86	1.06	72.90	1.07	73.80	1.07	73.00	1.06	76.91	1.00
4	1	1990	Size	65.80	0.59	65.41	0.61	65.78	0.60	65.48	0.61	67.72	0.55
4	1	1995	Size	65.61	0.47	65.14	0.48	65.61	0.47	65.17	0.48	66.47	0.44
4	1	2000	Size	62.60	0.45	63.01	0.47	62.60	0.45	63.04	0.47	64.49	0.45
4	1	2005	Size	63.89	0.52	63.84	0.54	63.89	0.52	63.88	0.54	65.28	0.53
4	3	1977	Size	4.76	0.26	4.63	0.29	4.76	0.26	4.64	0.29	4.72	0.25
4	3	1980	Size	5.74	0.23	5.70	0.25	5.74	0.23	5.70	0.25	5.84	0.19
4	3	1985	Size	5.75	0.08	5.73	0.09	5.75	0.08	5.73	0.08	5.75	0.07
4	3	1990	Size	5.15	0.06	5.14	0.06	5.15	0.06	5.14	0.06	5.20	0.05
4	3	1995	Size	5.26	0.04	5.23	0.05	5.27	0.05	5.23	0.05	5.22	0.04
4	3	2000	Size	5.29	0.05	5.31	0.05	5.29	0.05	5.31	0.05	5.31	0.04
4	3	2005	Size	5.19	0.06	5.19	0.06	5.19	0.06	5.19	0.06	5.19	0.06
4	6	1977	Size	-1.55	0.78	-1.50	0.76	-1.56	0.79	-1.48	0.76	-1.05	0.80
4	6	1980	Size	0.60	1.20	0.74	1.21	0.60	1.19	0.75	1.22	1.12	2.13
4	6	1985	Size	-1.01	0.44	-0.97	0.41	-1.01	0.44	-0.98	0.41	-1.20	0.56
4	6	1990	Size	-0.18	0.16	-0.29	0.15	-0.19	0.16	-0.28	0.15	0.08	0.19
4	6	1995	Size	-0.67	0.16	-0.74	0.15	-0.67	0.16	-0.74	0.15	-0.55	0.17
4	6	2000	Size	-1.17	0.15	-1.10	0.16	-1.16	0.15	-1.10	0.16	-1.00	0.17
4	6	2005	Size	-1.22	0.16	-1.07	0.16	-1.22	0.16	-1.07	0.16	-1.00	0.18
5	1	1977	Size	61.90	2.09	61.81	2.06	61.88	2.10	61.88	2.06	64.32	1.90
5	1	1980	Size	64.33	1.73	63.90	1.77	64.30	1.74	63.98	1.77	68.14	1.55
5	1	1985	Size	66.59	2.18	66.02	2.26	66.53	2.19	66.13	2.25	70.17	2.03
5	1	1990	Size	65.78	0.76	65.35	0.78	65.76	0.76	65.43	0.78	68.34	0.69
5	1	2000	Size	61.31	0.67	61.58	0.71	61.31	0.68	61.63	0.70	63.96	0.63
5	1	2005	Size	63.64	0.75	63.81	0.77	63.65	0.75	63.86	0.77	66.27	0.68
6	1	1977	Size	59.13	3.24	58.39	3.27	59.08	3.25	58.46	3.27	60.16	3.13
6	1	1980	Size	68.12	1.91	66.99	1.71	68.07	1.91	67.05	1.70	72.09	1.82
6	1	1985	Size	65.55	0.88	64.55	0.97	65.44	0.92	64.73	0.95	69.70	0.92
6	1	1990	Size	67.34	0.93	66.71	0.95	67.33	0.94	66.78	0.95	69.00	0.94
6	1	1995	Size	69.53	0.92	68.48	0.92	69.56	0.93	68.51	0.92	70.60	0.79
6	1	2000	Size	63.16	0.57	63.49	0.62	63.15	0.57	63.54	0.62	65.58	0.57
6	1	2005	Size	60.67	0.89	61.25	0.90	60.67	0.90	61.30	0.90	63.92	1.02
6	3	1977	Size	4.22	0.53	4.08	0.57	4.22	0.53	4.09	0.56	4.23	0.48
6	3	1980	Size	5.25	0.18	5.19	0.17	5.25	0.18	5.19	0.17	5.40	0.14
6	3	1985	Size	4.96	0.10	4.88	0.11	4.95	0.10	4.90	0.11	5.19	0.08
6	3	1990	Size	5.01	0.10	4.98	0.10	5.01	0.10	4.98	0.10	5.05	0.09
6	3	1995	Size	5.50	0.07	5.43	0.07	5.50	0.07	5.43	0.07	5.46	0.06
6	3	2000	Size	5.15	0.06	5.18	0.06	5.16	0.06	5.18	0.06	5.23	0.05
6	3	2005	Size	4.86	0.11	4.91	0.11	4.86	0.11	4.91	0.11	5.04	0.11
6	6	1977	Size	-2.83	2.78	-2.71	2.55	-2.84	2.78	-2.70	2.56	-2.85	3.86
6	6	1980	Size	0.58	0.80	0.56	0.70	0.57	0.80	0.56	0.71	0.78	1.33
6	6	1985	Size	-0.06	0.28	-0.18	0.27	-0.07	0.28	-0.18	0.27	-0.04	0.42

Table 2.17c—Selectivity parameters as estimated by Models B1, B2, C1, D2, and E2 (page 3 of 3).

				Model B1		Model B2		Model C1		Model D2		Model E2	
Fleet	Parm.	Block	Axis	Value	SD	Value	SD	Value	SD	Value	SD	Value	SD
6	6	1990	Size	1.96	0.79	1.52	0.54	1.91	0.76	1.55	0.56	5.72	29.77
6	6	2000	Size	-0.49	0.21	-0.36	0.22	-0.48	0.21	-0.37	0.22	-0.48	0.31
7	1	1977	Size	69.47	1.00	69.16	0.99	69.47	1.00	69.19	0.99	70.63	0.99
7	1	1995	Size	68.03	0.74	67.76	0.74	68.03	0.74	67.78	0.74	68.76	0.74
7	1	2000	Size	67.72	0.76	67.89	0.77	67.73	0.76	67.90	0.77	68.88	0.77
7	1	2005	Size	66.18	0.88	66.08	0.89	66.19	0.88	66.11	0.89	67.22	0.86
7	6	1977	Size	-0.11	0.44	-0.20	0.41	-0.11	0.43	-0.19	0.42	0.10	0.50
7	6	1995	Size	0.49	0.32	0.35	0.30	0.49	0.32	0.36	0.30	0.68	0.37
7	6	2000	Size	-0.68	0.34	-0.66	0.34	-0.67	0.34	-0.67	0.34	-0.61	0.38
7	6	2005	Size	0.20	0.33	0.35	0.36	0.20	0.33	0.36	0.36	0.57	0.41
8	1	1977	Size	63.20	1.60	62.64	1.54	63.18	1.60	62.69	1.56	64.96	1.66
8	1	1995	Size	67.48	1.74	67.00	1.74	67.48	1.74	67.03	1.74	68.66	1.74
9	1	1977	Size	69.97	2.14	69.29	2.11	69.98	2.15	69.33	2.10	71.28	1.99
9	1	2000	Size	59.48	1.33	59.78	1.36	59.49	1.33	59.81	1.36	61.35	1.28
9	3	1977	Size	5.25	0.21	5.22	0.21	5.26	0.21	5.22	0.21	5.25	0.18
9	3	2000	Size	4.25	0.25	4.29	0.25	4.26	0.25	4.29	0.24	4.39	0.21
10	3dev	1979	Age	0.07	0.14	0.08	0.14	0.07	0.14	0.08	0.14	-0.23	0.15
10	3dev	1980	Age	0.02	0.14	0.02	0.14	0.02	0.14	0.02	0.14	0.00	0.14
10	3dev	1981	Age	-0.09	0.14	-0.10	0.14	-0.09	0.14	-0.10	0.14	0.24	0.14
11	3dev	1982	Age	0.08	0.11	0.08	0.11	0.08	0.11	0.08	0.10	0.09	0.09
11	3dev	1983	Age	0.03	0.06	0.04	0.05	0.03	0.06	0.04	0.05	0.03	0.05
11	3dev	1984	Age	0.16	0.09	0.17	0.09	0.16	0.09	0.18	0.09	0.18	0.09
11	3dev	1985	Age	-0.05	0.06	-0.04	0.06	-0.05	0.07	-0.04	0.06	-0.02	0.05
11	3dev	1986	Age	0.08	0.07	0.10	0.06	0.08	0.07	0.09	0.06	0.07	0.06
11	3dev	1987	Age	-0.09	0.11	-0.05	0.09	-0.09	0.11	-0.05	0.09	-0.05	0.08
11	3dev	1988	Age	0.13	0.10	0.11	0.10	0.13	0.10	0.11	0.10	0.11	0.09
11	3dev	1989	Age	0.26	0.08	0.24	0.08	0.26	0.08	0.24	0.08	0.19	0.08
11	3dev	1990	Age	0.04	0.06	0.03	0.06	0.05	0.06	0.02	0.06	-0.01	0.06
11	3dev	1991	Age	0.08	0.06	0.09	0.06	0.08	0.06	0.09	0.06	0.07	0.06
11	3dev	1992	Age	-0.15	0.10	-0.21	0.11	-0.15	0.11	-0.21	0.11	-0.16	0.09
11	3dev	1993	Age	-0.15	0.09	-0.13	0.07	-0.15	0.09	-0.13	0.07	-0.11	0.06
11	3dev	1994	Age	0.13	0.07	0.09	0.07	0.13	0.07	0.09	0.07	0.10	0.07
11	3dev	1995	Age	0.26	0.09	0.14	0.08	0.26	0.09	0.14	0.08	0.13	0.08
11	3dev	1996	Age	0.29	0.09	0.20	0.09	0.29	0.09	0.19	0.09	0.18	0.09
11	3dev	1997	Age	0.11	0.05	0.12	0.06	0.11	0.05	0.12	0.06	0.09	0.05
11	3dev	1998	Age	0.16	0.06	0.19	0.08	0.16	0.07	0.19	0.08	0.17	0.08
11	3dev	1999	Age	0.19	0.06	0.14	0.07	0.20	0.06	0.14	0.07	0.13	0.07
11	3dev	2000	Age	0.06	0.05	0.07	0.05	0.06	0.05	0.07	0.05	0.05	0.05
11	3dev	2001	Age	-0.34	0.11	-0.17	0.08	-0.34	0.11	-0.17	0.07	-0.14	0.06
11	3dev	2002	Age	0.05	0.06	-0.04	0.09	0.05	0.06	-0.04	0.09	-0.02	0.07
11	3dev	2003	Age	-0.05	0.06	-0.04	0.07	-0.05	0.06	-0.04	0.07	-0.03	0.06
11	3dev	2004	Age	-0.01	0.06	0.02	0.07	-0.02	0.06	0.02	0.07	0.01	0.06
11	3dev	2005	Age	-0.28	0.12	-0.23	0.11	-0.28	0.12	-0.23	0.11	-0.20	0.09
11	3dev	2006	Age	-0.46	0.12	-0.39	0.12	-0.46	0.12	-0.39	0.12	-0.35	0.11
11	3dev	2007	Age	-0.49	0.12	-0.47	0.12	-0.48	0.12	-0.47	0.12	-0.48	0.11
11	3dev	2008	Age	-0.05	0.14	-0.05	0.14	-0.06	0.15	-0.05	0.14	-0.03	0.12

Table 2.17d—Selectivity parameters as estimated by Model F2.

				Model F2	
Fleet	Parm.	Block	Axis	Value	SD
1	1	n/a	Size	80.72	0.85
1	3	n/a	Size	6.48	0.03
1	6	n/a	Size	0.15	0.42
2	1	n/a	Size	85.38	5.66
2	3	n/a	Size	6.78	0.20
3	1	n/a	Size	96.58	4.11
3	3	n/a	Size	6.75	0.13
4	1	n/a	Size	67.53	0.31
4	3	n/a	Size	5.36	0.02
4	4	n/a	Size	5.28	0.23
4	6	n/a	Size	-0.29	0.18
5	1	n/a	Size	69.72	0.72
5	3	n/a	Size	5.36	0.06
6	1	n/a	Size	69.37	0.47
6	3	n/a	Size	5.38	0.03
7	1	n/a	Size	69.62	0.78
7	3	n/a	Size	5.11	0.07
7	4	n/a	Size	3.91	0.88
7	6	n/a	Size	0.77	0.30
8	1	n/a	Size	67.73	1.50
8	3	n/a	Size	5.07	0.16
9	1	n/a	Size	66.96	1.21
9	3	n/a	Size	4.93	0.14
11	1	n/a	Size	30.96	0.69
11	3	n/a	Size	3.89	0.33
11	5	n/a	Size	-1.41	0.15
12	1	n/a	Size	76.82	4.75
12	3	n/a	Size	5.22	0.44
11	3dev	1982	Size	-0.59	0.29
11	3dev	1983	Size	-0.50	0.23
11	3dev	1984	Size	0.12	0.11
11	3dev	1985	Size	0.36	0.10
11	3dev	1986	Size	-0.06	0.11
11	3dev	1987	Size	0.26	0.13
11	3dev	1988	Size	0.01	0.14
11	3dev	1989	Size	-0.64	0.27
11	3dev	1990	Size	-0.21	0.23
11	3dev	1991	Size	-0.05	0.18
11	3dev	1992	Size	0.56	0.19
11	3dev	1993	Size	0.59	0.19
11	3dev	1994	Size	0.20	0.12
11	3dev	1995	Size	0.10	0.15
11	3dev	1996	Size	-0.06	0.28
11	3dev	1997	Size	0.18	0.12
11	3dev	1998	Size	-0.13	0.12
11	3dev	1999	Size	-0.10	0.12
11	3dev	2000	Size	-0.46	0.20
11	3dev	2001	Size	0.57	0.16
11	3dev		Size	-0.35	0.22
11	3dev		Size	0.36	0.12
11	3dev		Size	0.24	0.13
11	3dev		Size	0.56	0.17
11	3dev		Size	0.61	0.19
11	3dev		Size	0.74	0.17
11	5dev		Size	0.14	0.28
11	5dev		Size	-0.41	0.20
11	5dev		Size	0.23	0.28
11	5dev		Size	0.43	0.24
11	5dev		Size	-0.05	0.22
11	5dev		Size	0.25	0.35
11	5dev		Size	0.32	0.29
11	5dev		Size	0.34	0.18
11	5dev		Size	-0.50	0.24
11	5dev		Size	-0.12	0.24
11	5dev		Size	-0.02	0.36
11	5dev		Size	-0.15	0.32
11	5dev		Size	0.28	0.32
11	5dev		Size	0.14	0.33
11	5dev		Size	0.19	0.31
11	5dev		Size	0.15	0.29
11	5dev		Size	0.23	0.20
11	5dev		Size	0.20	0.20
11	5dev		Size	-0.20	0.18
11	5dev		Size	0.41	0.27
11	5dev		Size	-0.23	0.25
11	5dev		Size	0.44	0.31
11	5dev		Size	0.21	0.35
11	5dev		Size	0.38	0.35
11	5dev		Size	-0.71	0.29
11	5dev		Size	-1.07	0.27

Table 2.18—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 A1	Model A2	Model B1	Model B2	Model C1	Model D2	Model E2	Model F2
B100%	1,462,660	1,542,460	1,066,170	1,075,710	1,040,400	1,086,580	1.74E+09	745,413
B40%	585,062	616,982	426,470	430,285	416,158	434,631	6.98E+08	298,165
B35%	511,929	539,859	373,161	376,500	364,138	380,302	6.11E+08	260,895
B2009	632,645	675,121	373,341	387,952	347,447	404,197	1.06E+09	283,270
B2010	566,200	585,667	360,591	361,242	342,970	379,031	7.69E+08	287,338
B2009/B100%	0.43	0.44	0.35	0.36	0.33	0.37	0.61	0.38
B2010/B100%	0.39	0.38	0.34	0.34	0.33	0.35	0.44	0.39
F40%	0.28	0.28	0.28	0.28	0.27	0.30	0.54	0.45
F35%	0.33	0.33	0.34	0.34	0.33	0.36	0.65	0.55
maxFABC2009	0.28	0.28	0.24	0.25	0.23	0.28	0.54	0.43
maxFABC2010	0.27	0.27	0.24	0.23	0.22	0.26	0.54	0.43
maxABC2009	331,932	354,496	181,765	195,080	157,782	228,367	1.03E+09	226,467
maxABC2010	341,704	336,194	199,329	193,486	180,184	223,565	9.09E+08	255,705
FOFL2009	0.33	0.33	0.29	0.30	0.27	0.33	0.65	0.52
OFL2009	388,291	414,517	212,352	227,593	184,513	266,791	1.22E+09	265,529
OFL2010*	397,498	391,126	233,030	226,075	210,750	261,701	1.08E+09	300,863
OFL2010**	443,858	449,456	235,255	233,382	204,030	283,476	1.37E+09	328,398
Pr(B<B20%)	0	0	0	0	0	0	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
OFL2010** = OFL for 2010 under Tier 3 assuming 2009 catch = 176,000 t
Pr(B<B20%) = probability that spawning biomass will fall below 20% of B100% by 2020.

Table 2.19—Estimates of Pacific cod fishing mortality rates, expressed on an annual time scale (Model B1). 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 2.20a—Schedules of Pacific cod selectivities at length in the commercial fisheries and IPHC survey as defined by final parameter estimates under Model B1 (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	1980	1985	1990	1995	2000	2005	1977	1985	1990	2000	2005
10.5	0.000	0.000	0.003	0.000	0.001	0.000	0.000	0.005	0.000	0.000	0.000	0.001
13.5	0.000	0.001	0.005	0.001	0.001	0.001	0.000	0.012	0.000	0.000	0.000	0.002
16.5	0.000	0.002	0.008	0.001	0.002	0.001	0.001	0.024	0.000	0.000	0.000	0.004
19.5	0.000	0.004	0.013	0.003	0.005	0.003	0.002	0.046	0.000	0.001	0.001	0.010
22.5	0.000	0.008	0.020	0.007	0.008	0.005	0.005	0.084	0.000	0.002	0.001	0.021
25.5	0.000	0.015	0.031	0.015	0.014	0.009	0.009	0.142	0.001	0.005	0.003	0.041
28.5	0.000	0.027	0.046	0.031	0.024	0.016	0.017	0.227	0.003	0.011	0.008	0.075
31.5	0.011	0.046	0.068	0.057	0.039	0.026	0.030	0.340	0.007	0.023	0.017	0.129
34.5	0.109	0.075	0.097	0.100	0.062	0.042	0.052	0.478	0.015	0.044	0.033	0.209
37.5	0.491	0.116	0.134	0.164	0.094	0.065	0.085	0.629	0.031	0.080	0.062	0.317
40.5	0.961	0.174	0.182	0.255	0.138	0.098	0.133	0.777	0.058	0.138	0.109	0.450
43.5	1.000	0.250	0.241	0.372	0.196	0.142	0.199	0.901	0.102	0.221	0.181	0.600
47.5	1.000	0.380	0.337	0.560	0.297	0.223	0.318	0.993	0.199	0.375	0.318	0.797
52.5	1.000	0.576	0.480	0.802	0.457	0.360	0.510	1.000	0.388	0.619	0.551	0.969
57.5	1.000	0.777	0.638	0.969	0.642	0.530	0.722	1.000	0.634	0.856	0.799	1.000
62.5	1.000	0.934	0.792	1.000	0.818	0.712	0.902	1.000	0.868	0.991	0.970	1.000
67.5	1.000	1.000	0.916	1.000	0.948	0.873	0.995	1.000	0.994	1.000	1.000	1.000
72.5	1.000	1.000	0.988	1.000	1.000	0.976	1.000	1.000	1.000	1.000	1.000	1.000
77.5	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
82.5	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
87.5	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
92.5	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
97.5	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
102.5	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
107.5	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Table 2.20a—Schedules of Pacific cod selectivities at length in the commercial fisheries and IPHC survey as defined by final parameter estimates under Model B1 (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	1977	1980	1985	1990	1995	2000	2005
10.5	0.000	0.001	0.000	0.000	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000
13.5	0.000	0.002	0.000	0.000	0.001	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000
16.5	0.000	0.004	0.000	0.000	0.002	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000
19.5	0.000	0.006	0.000	0.000	0.003	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000
22.5	0.001	0.009	0.001	0.000	0.004	0.007	0.000	0.001	0.000	0.000	0.000	0.000	0.000
25.5	0.004	0.015	0.002	0.001	0.006	0.011	0.000	0.002	0.001	0.000	0.000	0.001	0.000
28.5	0.010	0.023	0.003	0.004	0.008	0.017	0.002	0.005	0.001	0.000	0.001	0.003	0.001
31.5	0.024	0.034	0.006	0.019	0.012	0.026	0.007	0.010	0.003	0.001	0.002	0.008	0.003
34.5	0.054	0.050	0.010	0.068	0.016	0.038	0.023	0.020	0.007	0.003	0.007	0.019	0.008
37.5	0.109	0.071	0.017	0.194	0.023	0.054	0.063	0.038	0.015	0.010	0.017	0.042	0.020
40.5	0.199	0.100	0.029	0.427	0.031	0.076	0.148	0.069	0.029	0.025	0.038	0.085	0.047
43.5	0.331	0.137	0.046	0.727	0.041	0.104	0.294	0.117	0.053	0.056	0.080	0.159	0.098
47.5	0.562	0.201	0.081	0.992	0.060	0.155	0.582	0.216	0.110	0.144	0.183	0.316	0.222
52.5	0.856	0.306	0.153	1.000	0.092	0.240	0.928	0.402	0.234	0.360	0.411	0.597	0.484
57.5	0.999	0.437	0.263	1.000	0.137	0.351	1.000	0.638	0.427	0.672	0.712	0.877	0.796
62.5	1.000	0.587	0.412	1.000	0.196	0.484	0.914	0.861	0.663	0.939	0.951	1.000	0.989
67.5	1.000	0.738	0.589	1.000	0.272	0.630	0.649	0.989	0.879	1.000	1.000	0.982	0.998
72.5	1.000	0.870	0.769	1.000	0.362	0.772	0.392	1.000	0.994	0.952	0.935	0.789	0.851
77.5	1.000	0.963	0.915	1.000	0.467	0.892	0.246	0.941	0.998	0.781	0.725	0.529	0.587
82.5	1.000	1.000	0.993	1.000	0.579	0.973	0.192	0.821	0.858	0.607	0.517	0.347	0.375
87.5	1.000	1.000	1.000	1.000	0.694	1.000	0.178	0.720	0.606	0.506	0.397	0.267	0.270
92.5	1.000	1.000	1.000	1.000	0.802	1.000	0.176	0.669	0.405	0.467	0.352	0.243	0.236
97.5	1.000	1.000	1.000	1.000	0.893	1.000	0.176	0.651	0.307	0.457	0.341	0.238	0.228
102.5	1.000	1.000	1.000	1.000	0.960	1.000	0.176	0.647	0.275	0.456	0.339	0.238	0.227
107.5	1.000	1.000	1.000	1.000	0.996	1.000	0.176	0.646	0.267	0.455	0.339	0.237	0.227

Table 2.20a—Schedules of Pacific cod selectivities at length in the commercial fisheries and IPHC survey as defined by final parameter estimates under Model B1 (page 3 of 4). Lengths (cm) correspond to mid-points of size bins. Years correspond to beginnings of blocks.

	June-August longline fishery						September-December longline fishery						
Len.	1977	1980	1985	1990	2000	2005	1977	1980	1985	1990	1995	2000	2005
10.5	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	0.000	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	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	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	0.000	0.000
28.5	0.001	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.000
31.5	0.002	0.001	0.000	0.000	0.003	0.001	0.000	0.001	0.000	0.000	0.003	0.003	0.001
34.5	0.006	0.002	0.001	0.001	0.008	0.003	0.000	0.003	0.001	0.001	0.007	0.009	0.005
37.5	0.018	0.008	0.003	0.005	0.022	0.010	0.001	0.007	0.004	0.003	0.015	0.022	0.015
40.5	0.046	0.022	0.010	0.014	0.054	0.027	0.006	0.018	0.012	0.008	0.032	0.052	0.042
43.5	0.102	0.054	0.028	0.035	0.118	0.065	0.028	0.042	0.033	0.023	0.063	0.107	0.101
47.5	0.247	0.148	0.086	0.105	0.277	0.173	0.138	0.108	0.102	0.072	0.138	0.243	0.260
52.5	0.552	0.390	0.263	0.305	0.593	0.433	0.525	0.279	0.303	0.230	0.306	0.519	0.595
57.5	0.878	0.730	0.573	0.630	0.907	0.776	0.962	0.554	0.635	0.524	0.553	0.831	0.925
62.5	1.000	0.978	0.893	0.930	1.000	0.991	1.000	0.848	0.937	0.855	0.817	0.998	1.000
67.5	1.000	1.000	1.000	1.000	1.000	1.000	0.992	0.998	1.000	1.000	0.983	1.000	1.000
72.5	1.000	1.000	1.000	1.000	1.000	1.000	0.800	1.000	1.000	1.000	1.000	0.976	1.000
77.5	1.000	1.000	1.000	1.000	1.000	1.000	0.486	0.980	0.915	0.990	1.000	0.814	1.000
82.5	1.000	1.000	1.000	1.000	1.000	1.000	0.237	0.880	0.747	0.953	1.000	0.610	1.000
87.5	1.000	1.000	1.000	1.000	1.000	1.000	0.111	0.764	0.601	0.914	1.000	0.469	1.000
92.5	1.000	1.000	1.000	1.000	1.000	1.000	0.068	0.687	0.523	0.889	1.000	0.405	1.000
97.5	1.000	1.000	1.000	1.000	1.000	1.000	0.058	0.654	0.494	0.879	1.000	0.385	1.000
102.5	1.000	1.000	1.000	1.000	1.000	1.000	0.056	0.644	0.487	0.877	1.000	0.380	1.000
107.5	1.000	1.000	1.000	1.000	1.000	1.000	0.056	0.641	0.485	0.876	1.000	0.380	1.000

Table 2.20a—Schedules of Pacific cod selectivities at length in the commercial fisheries and IPHC survey as defined by final parameter estimates under Model B1 (page 4 of 4). Lengths (cm) correspond to mid-points of size bins. Years correspond to beginnings of blocks.

	January-May pot fishery				Jun-Aug pot		Sep-Dec pot		IPHC
Len.	1977	1995	2000	2005	1977	1995	1977	2000	1977
10.5	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
16.5	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
22.5	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
28.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
31.5	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000
34.5	0.001	0.001	0.001	0.002	0.002	0.000	0.001	0.000	0.000
37.5	0.002	0.003	0.003	0.006	0.007	0.001	0.004	0.001	0.000
40.5	0.006	0.009	0.010	0.017	0.020	0.004	0.011	0.006	0.000
43.5	0.015	0.024	0.026	0.041	0.052	0.013	0.026	0.026	0.002
47.5	0.050	0.073	0.079	0.115	0.153	0.048	0.072	0.130	0.011
52.5	0.168	0.225	0.238	0.314	0.418	0.181	0.203	0.500	0.068
57.5	0.412	0.503	0.524	0.627	0.781	0.468	0.444	0.946	0.264
62.5	0.740	0.827	0.845	0.919	0.996	0.828	0.747	1.000	0.640
67.5	0.976	0.998	1.000	1.000	1.000	1.000	0.969	1.000	0.967
72.5	1.000	0.987	0.968	0.928	1.000	1.000	1.000	1.000	1.000
77.5	0.827	0.817	0.657	0.700	1.000	1.000	1.000	1.000	1.000
82.5	0.581	0.668	0.410	0.576	1.000	1.000	1.000	1.000	1.000
87.5	0.488	0.626	0.344	0.551	1.000	1.000	1.000	1.000	1.000
92.5	0.474	0.621	0.336	0.549	1.000	1.000	1.000	1.000	1.000
97.5	0.473	0.621	0.336	0.549	1.000	1.000	1.000	1.000	1.000
102.5	0.473	0.621	0.336	0.549	1.000	1.000	1.000	1.000	1.000
107.5	0.473	0.621	0.336	0.549	1.000	1.000	1.000	1.000	1.000

Table 2.20b—Schedules of Pacific cod selectivities at age in the pre-1982 and post-1981 bottom trawl surveys as defined by final parameter estimates under Model B1 (page 1 of 2).

age	1979	1980	1981
0	0.000	0.000	0.000
1	0.037	0.062	0.139
2	1.000	1.000	1.000
3	1.000	1.000	1.000
4	0.725	0.725	0.725
5	0.125	0.125	0.125
6	0.069	0.069	0.069
7	0.069	0.069	0.069
8	0.069	0.069	0.069
9	0.069	0.069	0.069
10	0.069	0.069	0.069
11	0.069	0.069	0.069
12	0.069	0.069	0.069
13	0.069	0.069	0.069
14	0.069	0.069	0.069
15	0.069	0.069	0.069
16	0.069	0.069	0.069
17	0.069	0.069	0.069
18	0.069	0.069	0.069
19	0.069	0.069	0.069
20	0.069	0.069	0.069

Table 2.20b—Schedules of Pacific cod selectivities at age in the pre-1982 and post-1981 bottom trawl surveys as defined by final parameter estimates under Model B1 (page 2 of 2).

age	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
0	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	0.000
1	0.306	0.388	0.207	0.496	0.309	0.545	0.246	0.141	0.364	0.311	0.625	0.621	0.246	0.142
2	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
3	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
4	1.000	1.000	1.000	1.000	1.000	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	1.000	1.000	1.000	1.000
6	0.908	0.908	0.908	0.908	0.908	0.908	0.908	0.908	0.908	0.908	0.908	0.908	0.908	0.908
7	0.672	0.672	0.672	0.672	0.672	0.672	0.672	0.672	0.672	0.672	0.672	0.672	0.672	0.672
8	0.415	0.415	0.415	0.415	0.415	0.415	0.415	0.415	0.415	0.415	0.415	0.415	0.415	0.415
9	0.231	0.231	0.231	0.231	0.231	0.231	0.231	0.231	0.231	0.231	0.231	0.231	0.231	0.231
10	0.134	0.134	0.134	0.134	0.134	0.134	0.134	0.134	0.134	0.134	0.134	0.134	0.134	0.134
11	0.096	0.096	0.096	0.096	0.096	0.096	0.096	0.096	0.096	0.096	0.096	0.096	0.096	0.096
12	0.084	0.084	0.084	0.084	0.084	0.084	0.084	0.084	0.084	0.084	0.084	0.084	0.084	0.084
13	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081
14	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081
15	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081
16	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081
17	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081
18	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081
19	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081
20	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081

age	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
0	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
1	0.133	0.272	0.209	0.178	0.336	0.779	0.361	0.502	0.449	0.738	0.840	0.851	0.505
2	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
3	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
4	1.000	1.000	1.000	1.000	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	1.000	1.000	1.000
6	0.908	0.908	0.908	0.908	0.908	0.908	0.908	0.908	0.908	0.908	0.908	0.908	0.908
7	0.672	0.672	0.672	0.672	0.672	0.672	0.672	0.672	0.672	0.672	0.672	0.672	0.672
8	0.415	0.415	0.415	0.415	0.415	0.415	0.415	0.415	0.415	0.415	0.415	0.415	0.415
9	0.231	0.231	0.231	0.231	0.231	0.231	0.231	0.231	0.231	0.231	0.231	0.231	0.231
10	0.134	0.134	0.134	0.134	0.134	0.134	0.134	0.134	0.134	0.134	0.134	0.134	0.134
11	0.096	0.096	0.096	0.096	0.096	0.096	0.096	0.096	0.096	0.096	0.096	0.096	0.096
12	0.084	0.084	0.084	0.084	0.084	0.084	0.084	0.084	0.084	0.084	0.084	0.084	0.084
13	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081
14	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081
15	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081
16	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081
17	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081
18	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081
19	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081
20	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081

Table 2.21—Schedules of Pacific cod length (cm) by season and age as estimated by Model B1. Sea1 = Jan-May, Sea2 = Jul-Aug, Sea3 = Sep-Dec.

	Population			Trawl fishery			Longline fishery			Pot fishery			Trawl survey		
Age	Sea1	Sea2	Sea3	Sea1	Sea2	Sea3	Sea1	Sea2	Sea3	Sea1	Sea2	Sea3	Pre82	Post81	IPHC
0	9.96	11.51	12.86	13.62	15.35	15.25	17.06	19.78	21.51	17.91	16.94	14.42	12.49	12.49	12.59
1	14.59	16.14	21.31	18.17	19.77	23.93	21.40	23.82	29.75	22.35	24.93	33.96	16.22	16.22	18.27
2	27.46	32.48	36.55	31.52	36.05	39.90	34.61	40.68	44.30	35.72	42.66	47.19	32.48	32.48	45.01
3	41.38	45.33	48.53	45.45	47.57	51.96	47.65	51.52	53.32	48.79	53.43	54.62	45.42	45.42	55.37
4	52.34	55.44	57.96	55.38	56.21	61.11	56.25	58.94	60.10	57.32	60.67	60.52	55.47	55.47	62.20
5	60.95	63.40	65.38	62.80	63.59	68.08	62.47	64.95	66.16	63.38	66.19	66.27	63.40	63.40	67.27
6	67.73	69.65	71.21	68.69	69.71	73.42	67.14	70.28	71.49	68.11	71.01	71.52	69.65	69.65	71.69
7	73.07	74.58	75.80	73.54	74.59	77.55	70.80	74.84	75.91	72.13	75.24	75.92	74.58	74.58	75.64
8	77.26	78.45	79.41	77.50	78.45	80.79	73.83	78.57	79.46	75.71	78.79	79.46	78.45	78.45	79.03
9	80.56	81.50	82.26	80.69	81.49	83.36	76.47	81.56	82.28	78.84	81.69	82.28	81.49	81.49	81.84
10	83.16	83.89	84.49	83.23	83.88	85.38	78.76	83.92	84.49	81.49	84.00	84.49	83.88	83.88	84.10
11	85.20	85.78	86.25	85.23	85.75	86.98	80.72	85.78	86.23	83.65	85.83	86.23	85.75	85.75	85.91
12	86.81	87.26	87.63	86.81	87.22	88.24	82.36	87.23	87.59	85.37	87.27	87.58	87.22	87.22	87.33
13	88.07	88.43	88.72	88.04	88.36	89.23	83.71	88.37	88.65	86.73	88.40	88.65	88.36	88.36	88.45
14	89.06	89.34	89.57	89.00	89.25	90.00	84.80	89.26	89.48	87.80	89.29	89.48	89.25	89.25	89.33
15	89.85	90.07	90.25	89.75	89.95	90.61	85.68	89.96	90.12	88.64	89.98	90.12	89.95	89.95	90.01
16	90.46	90.63	90.78	90.34	90.49	91.09	86.37	90.50	90.63	89.29	90.52	90.63	90.49	90.49	90.55
17	90.94	91.08	91.19	90.80	90.92	91.46	86.93	90.92	91.03	89.80	90.94	91.03	90.92	90.92	90.97
18	91.32	91.43	91.52	91.16	91.25	91.75	87.36	91.26	91.34	90.20	91.28	91.34	91.25	91.25	91.30
19	91.62	91.71	91.78	91.45	91.51	91.98	87.71	91.52	91.58	90.52	91.53	91.58	91.51	91.51	91.56
20	91.86	91.93	91.98	91.67	91.72	92.16	87.98	91.72	91.77	90.76	91.74	91.77	91.72	91.72	91.76

Table 2.22—Schedules of Pacific cod weight (kg) by season and age as estimated by Model 1. Sea1 = Jan-May, Sea2 = Jul-Aug, Sea3 = Sep-Dec.

	Population			Trawl fishery			Longline fishery			Pot fishery			Trawl survey		
Age	Sea1	Sea2	Sea3	Sea1	Sea2	Sea3	Sea1	Sea2	Sea3	Sea1	Sea2	Sea3	Pre82	Post81	IPHC
0	0.02	0.02	0.03	0.03	0.05	0.04	0.06	0.09	0.11	0.06	0.07	0.04	0.02	0.02	0.02
1	0.04	0.05	0.11	0.07	0.09	0.16	0.11	0.16	0.30	0.12	0.19	0.45	0.05	0.05	0.09
2	0.24	0.42	0.59	0.36	0.56	0.76	0.48	0.81	1.04	0.53	0.93	1.26	0.42	0.42	1.09
3	0.86	1.15	1.43	1.14	1.31	1.75	1.30	1.65	1.87	1.40	1.84	2.00	1.15	1.15	2.04
4	1.80	2.11	2.49	2.11	2.18	2.91	2.21	2.49	2.74	2.33	2.71	2.80	2.11	2.11	2.91
5	2.90	3.16	3.63	3.15	3.18	4.09	3.08	3.36	3.74	3.22	3.55	3.76	3.16	3.16	3.71
6	4.04	4.21	4.75	4.19	4.21	5.20	3.87	4.30	4.80	4.05	4.42	4.80	4.21	4.21	4.53
7	5.13	5.18	5.79	5.21	5.18	6.18	4.59	5.22	5.81	4.89	5.29	5.81	5.18	5.18	5.36
8	6.11	6.04	6.71	6.16	6.04	7.04	5.27	6.06	6.72	5.72	6.10	6.72	6.04	6.04	6.15
9	6.98	6.78	7.49	7.01	6.78	7.77	5.91	6.79	7.50	6.53	6.81	7.50	6.78	6.78	6.85
10	7.71	7.40	8.15	7.73	7.40	8.39	6.51	7.41	8.15	7.26	7.42	8.15	7.40	7.40	7.44
11	8.32	7.91	8.69	8.33	7.91	8.90	7.06	7.92	8.69	7.90	7.93	8.69	7.91	7.91	7.94
12	8.82	8.33	9.13	8.83	8.33	9.31	7.54	8.33	9.13	8.42	8.34	9.13	8.33	8.33	8.35
13	9.22	8.66	9.48	9.22	8.66	9.64	7.95	8.66	9.48	8.85	8.67	9.48	8.66	8.66	8.68
14	9.54	8.93	9.76	9.54	8.93	9.91	8.29	8.93	9.76	9.20	8.93	9.76	8.93	8.93	8.94
15	9.79	9.14	9.98	9.80	9.14	10.12	8.57	9.14	9.98	9.47	9.14	9.98	9.14	9.14	9.15
16	10.00	9.30	10.15	10.00	9.30	10.29	8.79	9.30	10.15	9.69	9.31	10.15	9.30	9.30	9.32
17	10.16	9.43	10.29	10.16	9.43	10.42	8.97	9.44	10.29	9.86	9.44	10.29	9.43	9.43	9.45
18	10.28	9.54	10.40	10.28	9.54	10.53	9.11	9.54	10.40	10.00	9.54	10.40	9.54	9.54	9.55
19	10.38	9.62	10.49	10.38	9.62	10.61	9.22	9.62	10.49	10.10	9.62	10.49	9.62	9.62	9.63
20	10.46	9.68	10.55	10.46	9.68	10.67	9.31	9.68	10.55	10.19	9.69	10.55	9.68	9.68	9.69

Table 2.23a—Time series of EBS (not expanded to BSAI) Pacific cod age 0+ biomass, female spawning biomass (t), and standard deviation of spawning biomass as estimated last year under the Plan Team's and SSC's preferred model and this year under Model B1. 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 (even after correcting for the BSAI expansion).

	Last year's assessment			This year's assessment		
Year	Age 0+ bio.	Spawn. bio.	Std. dev.	Age 0+ bio.	Spawn. bio.	Std. dev.
1977	527,766	127,575	40,977	842,241	254,248	62,006
1978	638,883	155,625	44,290	899,016	271,985	62,963
1979	915,953	202,290	51,395	1,052,030	292,994	64,980
1980	1,399,170	283,920	62,145	1,482,030	340,179	68,171
1981	1,913,590	425,240	76,965	1,932,570	447,717	74,062
1982	2,320,270	625,900	95,600	2,276,670	622,090	84,594
1983	2,504,630	819,800	110,365	2,418,520	792,125	93,742
1984	2,544,120	924,700	114,105	2,403,580	872,225	94,261
1985	2,501,310	932,450	108,350	2,363,850	862,640	87,626
1986	2,419,680	888,200	98,655	2,293,060	813,255	78,960
1987	2,357,380	849,750	89,370	2,262,680	782,455	71,900
1988	2,254,070	815,200	81,340	2,188,110	763,180	66,731
1989	2,038,300	760,400	73,960	1,992,030	724,445	62,300
1990	1,796,960	702,300	66,530	1,762,410	675,640	57,352
1991	1,587,630	620,050	58,485	1,563,070	595,695	51,131
1992	1,442,630	512,550	50,780	1,450,780	491,365	44,997
1993	1,400,690	451,425	45,295	1,459,860	440,882	41,164
1994	1,429,870	445,295	42,550	1,528,360	451,689	40,324
1995	1,434,130	448,745	41,478	1,589,790	473,295	41,339
1996	1,354,400	432,445	40,990	1,569,500	475,938	43,007
1997	1,244,070	416,680	40,475	1,515,220	481,913	44,522
1998	1,128,100	375,345	39,378	1,449,180	462,345	45,141
1999	1,136,880	351,455	38,376	1,522,510	459,272	45,424
2000	1,170,540	345,010	38,470	1,595,780	474,130	46,453
2001	1,220,940	358,985	40,009	1,641,550	505,955	48,285
2002	1,311,880	384,300	42,260	1,702,650	535,905	49,744
2003	1,361,980	404,030	44,708	1,707,180	546,815	50,377
2004	1,346,700	424,690	47,319	1,630,540	549,570	50,640
2005	1,273,760	429,370	49,245	1,491,060	530,935	50,182
2006	1,173,690	407,020	49,594	1,331,050	484,612	48,476
2007	1,050,650	369,640	48,539	1,165,190	425,560	45,797
2008	1,063,820	333,096	n/a	1,075,950	372,037	42,886
2009				1,115,780	334,283	40,843

Table 2.23b—Time series of EBS (not expanded to BSAI) Pacific cod age 0 recruitment (1000s of fish), with standard deviations, as estimated last year under the Plan Team's and SSC's preferred model and this year under Model B1.

	Last year's values		This year's values	
Year	Recruits	Std. dev.	Recruits	Std. dev.
1977	2,533,200	338,700	2,577,100	312,291
1978	787,020	153,500	651,724	136,257
1979	1,042,300	125,230	855,987	115,728
1980	411,490	65,406	398,064	65,379
1981	211,920	42,523	175,500	36,606
1982	1,354,400	104,650	1,312,260	101,877
1983	248,630	41,473	296,381	43,943
1984	1,045,200	78,116	1,062,620	82,816
1985	553,370	53,793	509,878	51,303
1986	284,700	33,632	241,701	29,914
1987	158,470	24,824	145,513	22,956
1988	392,570	36,646	406,441	37,804
1989	801,750	60,628	884,194	69,872
1990	731,990	51,157	754,655	55,679
1991	383,500	33,706	444,549	39,206
1992	883,170	57,322	1,014,130	72,658
1993	325,880	27,180	414,229	34,677
1994	323,260	26,432	409,616	34,346
1995	359,010	32,332	506,237	45,551
1996	892,480	73,043	1,110,340	85,107
1997	449,700	36,438	454,069	35,349
1998	497,990	41,585	533,278	40,779
1999	904,670	73,104	901,297	65,843
2000	623,730	48,766	586,787	42,102
2001	325,960	30,490	312,067	26,662
2002	398,510	37,284	361,796	30,906
2003	350,100	37,260	325,788	31,611
2004	203,560	25,248	197,043	21,591
2005	393,800	61,178	288,607	31,737
2006	1,835,100	419,310	1,029,020	116,919
2007			475,798	192,125
Average	656,914		633,441	

Table 2.24—Numbers (1000s) at age as estimated by Model B1.

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1977	2577100	203567	21798	221054	58877	39374	26308	17577	11744	7846	5242	3502	2340	1563	1045	698	466	312	208	139	280
1978	651724	1834300	144855	15434	152529	40049	26729	17889	11976	8013	5359	3583	2395	1601	1070	715	478	319	213	142	287
1979	855987	463877	1305160	102408	10560	102536	26855	17957	12046	8078	5412	3622	2423	1620	1083	724	484	323	216	144	291
1980	398064	609266	330101	924653	70734	7192	69690	18283	12250	8230	5525	3704	2480	1660	1110	742	496	332	222	148	298
1981	175500	283330	433538	234155	649864	49093	4944	47697	12492	8365	5620	3773	2529	1694	1133	758	507	339	226	151	305
1982	1312260	124915	201586	307171	164394	451754	33874	3398	32716	8561	5731	3849	2584	1732	1160	776	519	347	232	155	312
1983	296381	934027	88879	142842	215871	114624	313224	23418	2346	22574	5906	3953	2655	1782	1195	800	535	358	239	160	322
1984	1062620	210955	664491	62881	99883	149150	78513	213605	15940	1596	15348	4015	2687	1805	1211	812	544	364	243	163	328
1985	509878	756342	150073	469802	43792	68328	100721	52697	143049	10668	1068	10273	2687	1799	1208	811	544	364	244	163	329
1986	241701	362916	538223	106583	329348	29949	45747	66656	34709	94093	7017	703	6764	1770	1186	797	535	359	240	161	324
1987	145513	172036	258250	382202	74724	225492	20091	30341	43990	22868	61976	4623	463	4459	1167	782	525	353	237	159	320
1988	406441	103572	122417	183361	267553	50905	149976	13184	19805	28682	14918	40470	3022	303	2919	765	512	344	231	155	314
1989	884194	289293	73679	86745	127464	179953	33213	95976	8351	12481	18027	9363	25380	1894	190	1829	479	321	216	145	294
1990	754655	629343	205797	52222	60370	85941	117928	21395	61313	5315	7931	11448	5944	16112	1202	121	1161	304	204	137	279
1991	444549	537141	447903	145790	35894	39651	54976	74806	13551	38848	3370	5032	7267	3774	10233	764	77	738	193	129	264
1992	1014130	316417	382274	317180	99175	22767	24059	32871	44629	8095	23249	2020	3020	4364	2268	6153	459	46	444	116	237
1993	414229	721830	225198	271056	218004	63841	13945	14489	19791	26988	4917	14173	1235	1849	2676	1392	3779	282	28	273	217
1994	409616	294836	513733	159637	187109	143243	40431	8728	9080	12460	17068	3121	9017	787	1180	1709	890	2416	181	18	314
1995	506237	291552	209839	363638	109464	121256	88912	24732	5342	5584	7701	10589	1941	5621	491	737	1069	557	1513	113	208
1996	1110340	360324	207461	148788	250479	70215	72747	51760	14318	3102	3257	4507	6214	1141	3309	289	435	631	329	893	190
1997	454069	790307	256407	147201	102996	162689	42899	43233	30609	8492	1847	1946	2700	3729	686	1990	174	262	380	198	652
1998	533278	323193	562385	181835	101354	65936	97335	24911	24982	17751	4949	1081	1142	1588	2195	404	1173	103	154	224	502
1999	901297	379572	229997	399207	126327	66732	41328	59741	15244	15334	10936	3058	669	708	986	1364	251	730	64	96	452
2000	586787	641517	270133	163356	278096	83615	42128	25595	36955	9473	9576	6856	1922	422	447	622	862	159	462	40	347
2001	312067	417657	456566	191714	112956	182543	52839	26348	16084	23412	6044	6142	4414	1241	273	289	403	559	103	300	252
2002	361796	222120	297252	324036	132518	74375	116534	33532	16821	10351	15168	3935	4012	2891	814	179	190	265	368	68	363
2003	325788	257516	158085	210960	223445	86385	46709	72594	21014	10633	6590	9708	2528	2584	1865	526	116	123	172	238	279
2004	197043	231887	183279	112190	145278	145058	53928	28927	45279	13236	6752	4210	6227	1626	1666	1204	340	75	80	111	335
2005	288607	140250	165036	130029	77070	93746	89806	33094	17876	28259	8329	4275	2676	3971	1039	1066	771	218	48	51	287
2006	1029020	205422	99817	117054	89204	49533	57591	54532	20184	10985	17476	5175	2664	1672	2484	651	668	484	137	30	212
2007	475798	732423	146200	70808	80367	57125	30144	34582	32916	12291	6739	10779	3204	1654	1039	1546	405	417	302	85	151
2008	631624	338659	521259	103678	48646	51595	34890	18179	20974	20149	7582	4180	6712	2000	1034	651	969	254	261	189	149

Table 2.25—Projections for BSAI Pacific cod catch (t), spawning biomass (t), and fishing mortality under the assumption that $F = \mathit{max}\ F_{ABC}$ in 2009-2021 (Scenario 1), with random variability in future recruitment.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2009	182,000	182,000	182,000	182,000	1
2010	199,000	199,000	199,000	199,000	88
2011	231,000	233,000	233,000	236,000	1,795
2012	236,000	251,000	256,000	293,000	18,844
2013	205,000	255,000	264,000	347,000	49,486
2014	171,000	256,000	266,000	390,000	73,425
2015	158,000	260,000	269,000	410,000	84,281
2016	146,000	263,000	270,000	421,000	86,384
2017	141,000	265,000	270,000	420,000	85,915
2018	136,000	268,000	269,000	419,000	86,392
2019	142,000	269,000	270,000	420,000	86,979
2020	143,000	265,000	271,000	426,000	87,173
2021	145,000	267,000	272,000	427,000	88,767

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2009	373,000	373,000	373,000	373,000	0
2010	360,000	361,000	361,000	361,000	155
2011	382,000	384,000	384,000	387,000	1,815
2012	396,000	405,000	407,000	427,000	11,013
2013	384,000	412,000	419,000	478,000	33,508
2014	358,000	415,000	428,000	540,000	63,654
2015	339,000	415,000	436,000	595,000	86,422
2016	328,000	422,000	442,000	622,000	96,801
2017	319,000	424,000	445,000	631,000	98,975
2018	315,000	425,000	446,000	643,000	98,908
2019	315,000	427,000	445,000	633,000	99,567
2020	319,000	427,000	446,000	633,000	100,681
2021	323,000	425,000	447,000	638,000	102,230

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	0.25	0.25	0.25	0.25	0.00
2012	0.26	0.27	0.27	0.28	0.01
2013	0.25	0.27	0.27	0.28	0.01
2014	0.23	0.27	0.27	0.28	0.02
2015	0.22	0.27	0.26	0.28	0.02
2016	0.21	0.28	0.26	0.28	0.02
2017	0.21	0.28	0.26	0.28	0.03
2018	0.20	0.28	0.26	0.28	0.03
2019	0.20	0.28	0.26	0.28	0.03
2020	0.21	0.28	0.26	0.28	0.03
2021	0.21	0.28	0.26	0.28	0.03

Table 2.26—Projections for BSAI Pacific cod catch (t), spawning biomass (t), and fishing mortality under the assumption that F = 96.6% of *max* F_{ABC} in 2009-2021 (Scenario 2), with random variability in future recruitment.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2009	176,000	176,000	176,000	176,000	1
2010	195,000	195,000	195,000	195,000	86
2011	228,000	229,000	229,000	232,000	1,752
2012	233,000	248,000	252,000	286,000	17,919
2013	203,000	252,000	260,000	340,000	47,214
2014	170,000	254,000	262,000	383,000	70,835
2015	157,000	258,000	265,000	403,000	81,759
2016	145,000	260,000	267,000	414,000	84,019
2017	139,000	262,000	266,000	414,000	83,624
2018	135,000	265,000	266,000	411,000	84,087
2019	140,000	265,000	266,000	412,000	84,653
2020	143,000	261,000	267,000	418,000	84,808
2021	144,000	265,000	269,000	422,000	86,342

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2009	374,000	374,000	374,000	374,000	0
2010	363,000	363,000	363,000	363,000	155
2011	386,000	387,000	388,000	391,000	1,817
2012	401,000	410,000	412,000	432,000	11,060
2013	390,000	418,000	425,000	484,000	33,854
2014	364,000	421,000	435,000	549,000	64,716
2015	344,000	421,000	443,000	605,000	88,319
2016	333,000	429,000	450,000	634,000	99,332
2017	324,000	432,000	454,000	642,000	101,826
2018	320,000	433,000	454,000	657,000	101,840
2019	319,000	435,000	454,000	646,000	102,492
2020	324,000	435,000	455,000	647,000	103,616
2021	329,000	433,000	456,000	651,000	105,202

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2009	0.24	0.24	0.24	0.24	0.00
2010	0.23	0.23	0.23	0.23	0.00
2011	0.24	0.24	0.25	0.25	0.00
2012	0.25	0.26	0.26	0.27	0.01
2013	0.25	0.27	0.26	0.27	0.01
2014	0.23	0.27	0.26	0.27	0.02
2015	0.22	0.27	0.26	0.27	0.02
2016	0.21	0.27	0.25	0.27	0.02
2017	0.20	0.27	0.25	0.27	0.02
2018	0.20	0.27	0.25	0.27	0.02
2019	0.20	0.27	0.25	0.27	0.02
2020	0.20	0.27	0.25	0.27	0.02
2021	0.21	0.27	0.25	0.27	0.02

Table 2.27—Projections for BSAI 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	130,000	130,000	130,000	130,000	0
2010	153,000	153,000	153,000	153,000	3
2011	172,000	173,000	173,000	174,000	498
2012	176,000	183,000	185,000	201,000	8,951
2013	164,000	188,000	194,000	244,000	28,068
2014	150,000	193,000	202,000	279,000	43,981
2015	145,000	198,000	208,000	304,000	52,149
2016	140,000	203,000	212,000	311,000	54,619
2017	136,000	205,000	213,000	314,000	54,905
2018	134,000	206,000	213,000	315,000	55,352
2019	137,000	207,000	214,000	319,000	55,937
2020	140,000	206,000	215,000	319,000	56,334
2021	142,000	206,000	216,000	330,000	57,478

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2009	377,000	377,000	377,000	377,000	0
2010	382,000	382,000	382,000	382,000	160
2011	419,000	420,000	421,000	424,000	1,906
2012	453,000	462,000	465,000	486,000	11,753
2013	460,000	491,000	500,000	565,000	37,017
2014	442,000	512,000	527,000	656,000	74,067
2015	421,000	527,000	548,000	740,000	107,201
2016	405,000	539,000	564,000	792,000	127,204
2017	392,000	552,000	574,000	824,000	135,673
2018	384,000	557,000	578,000	839,000	138,486
2019	382,000	564,000	581,000	838,000	140,103
2020	388,000	566,000	583,000	838,000	141,697
2021	390,000	566,000	585,000	840,000	143,572

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2009	0.17	0.17	0.17	0.17	0.00
2010	0.17	0.17	0.17	0.17	0.00
2011	0.17	0.17	0.17	0.17	0.00
2012	0.17	0.17	0.17	0.17	0.00
2013	0.17	0.17	0.17	0.17	0.00
2014	0.17	0.17	0.17	0.17	0.00
2015	0.17	0.17	0.17	0.17	0.00
2016	0.17	0.17	0.17	0.17	0.00
2017	0.17	0.17	0.17	0.17	0.00
2018	0.17	0.17	0.17	0.17	0.00
2019	0.17	0.17	0.17	0.17	0.00
2020	0.17	0.17	0.17	0.17	0.00
2021	0.17	0.17	0.17	0.17	0.00

Table 2.28—Projections for BSAI 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	108,000	108,000	108,000	108,000	0
2010	129,000	129,000	129,000	129,000	2
2011	147,000	148,000	148,000	149,000	409
2012	153,000	158,000	160,000	173,000	7,381
2013	144,000	164,000	169,000	211,000	23,390
2014	133,000	169,000	177,000	242,000	37,145
2015	130,000	174,000	183,000	264,000	44,559
2016	125,000	179,000	187,000	273,000	47,075
2017	122,000	181,000	188,000	274,000	47,553
2018	120,000	182,000	189,000	279,000	48,014
2019	122,000	184,000	190,000	280,000	48,559
2020	125,000	183,000	191,000	282,000	48,931
2021	126,000	183,000	192,000	292,000	49,915

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2009	378,000	378,000	378,000	378,000	0
2010	391,000	391,000	391,000	391,000	160
2011	436,000	438,000	438,000	441,000	1,906
2012	479,000	488,000	491,000	512,000	11,774
2013	493,000	525,000	533,000	599,000	37,368
2014	481,000	551,000	567,000	698,000	75,898
2015	460,000	570,000	593,000	791,000	111,688
2016	447,000	587,000	613,000	855,000	134,420
2017	434,000	604,000	626,000	889,000	144,857
2018	425,000	609,000	633,000	907,000	148,732
2019	421,000	617,000	636,000	912,000	150,825
2020	428,000	622,000	640,000	919,000	152,695
2021	434,000	622,000	643,000	917,000	154,768

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2009	0.14	0.14	0.14	0.14	0.00
2010	0.14	0.14	0.14	0.14	0.00
2011	0.14	0.14	0.14	0.14	0.00
2012	0.14	0.14	0.14	0.14	0.00
2013	0.14	0.14	0.14	0.14	0.00
2014	0.14	0.14	0.14	0.14	0.00
2015	0.14	0.14	0.14	0.14	0.00
2016	0.14	0.14	0.14	0.14	0.00
2017	0.14	0.14	0.14	0.14	0.00
2018	0.14	0.14	0.14	0.14	0.00
2019	0.14	0.14	0.14	0.14	0.00
2020	0.14	0.14	0.14	0.14	0.00
2021	0.14	0.14	0.14	0.14	0.00

Table 2.29—Projections for BSAI 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	385,000	385,000	385,000	385,000	0
2010	437,000	437,000	437,000	438,000	160
2011	526,000	528,000	528,000	532,000	1,907
2012	622,000	631,000	634,000	655,000	11,871
2013	688,000	721,000	729,000	799,000	39,033
2014	715,000	793,000	810,000	957,000	85,079
2015	718,000	850,000	878,000	1,120,000	135,742
2016	718,000	898,000	932,000	1,250,000	175,584
2017	716,000	941,000	973,000	1,340,000	200,221
2018	709,000	971,000	1,000,000	1,400,000	213,436
2019	704,000	990,000	1,020,000	1,440,000	220,858
2020	718,000	1,010,000	1,040,000	1,450,000	225,957
2021	730,000	1,020,000	1,050,000	1,460,000	230,185

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 2.30—Projections for BSAI 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	212,000	212,000	212,000	212,000	1
2010	221,000	221,000	221,000	222,000	100
2011	250,000	251,000	252,000	255,000	2,014
2012	249,000	265,000	271,000	312,000	22,607
2013	212,000	266,000	280,000	391,000	61,260
2014	175,000	266,000	284,000	435,000	87,467
2015	162,000	270,000	287,000	449,000	97,706
2016	150,000	273,000	288,000	460,000	98,864
2017	146,000	273,000	286,000	458,000	98,051
2018	142,000	277,000	285,000	458,000	98,501
2019	145,000	275,000	285,000	459,000	99,187
2020	147,000	272,000	286,000	466,000	99,620
2021	148,000	275,000	287,000	465,000	101,374

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2009	371,000	371,000	371,000	371,000	0
2010	348,000	348,000	348,000	349,000	155
2011	364,000	365,000	365,000	369,000	1,803
2012	372,000	380,000	383,000	402,000	10,832
2013	357,000	384,000	391,000	447,000	32,060
2014	331,000	386,000	397,000	498,000	58,493
2015	314,000	386,000	402,000	543,000	76,798
2016	304,000	389,000	405,000	559,000	83,893
2017	296,000	389,000	406,000	566,000	84,484
2018	294,000	391,000	405,000	570,000	84,073
2019	293,000	392,000	404,000	564,000	84,838
2020	296,000	389,000	405,000	565,000	85,837
2021	297,000	390,000	406,000	577,000	87,069

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2009	0.29	0.29	0.29	0.29	0.00
2010	0.27	0.27	0.27	0.27	0.00
2011	0.28	0.28	0.28	0.29	0.00
2012	0.29	0.30	0.30	0.32	0.01
2013	0.28	0.30	0.30	0.34	0.02
2014	0.26	0.30	0.30	0.34	0.03
2015	0.24	0.30	0.30	0.34	0.03
2016	0.23	0.30	0.30	0.34	0.04
2017	0.23	0.30	0.30	0.34	0.04
2018	0.23	0.31	0.30	0.34	0.04
2019	0.22	0.31	0.30	0.34	0.04
2020	0.23	0.30	0.30	0.34	0.04
2021	0.23	0.30	0.30	0.34	0.04

Table 2.31—Projections for BSAI Pacific cod catch (t), spawning biomass (t), and fishing mortality under the assumption that $F = max\ F_{ABC}$ in each year 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	182,000	182,000	182,000	182,000	1
2010	199,000	199,000	199,000	199,000	88
2011	270,000	272,000	272,000	276,000	2,087
2012	259,000	276,000	282,000	324,000	22,610
2013	216,000	270,000	284,000	392,000	60,793
2014	176,000	266,000	285,000	435,000	87,264
2015	162,000	270,000	287,000	450,000	97,695
2016	150,000	273,000	288,000	460,000	98,900
2017	146,000	273,000	286,000	457,000	98,083
2018	142,000	277,000	285,000	458,000	98,518
2019	145,000	275,000	285,000	459,000	99,195
2020	147,000	272,000	286,000	466,000	99,622
2021	148,000	275,000	287,000	465,000	101,374

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2009	373,000	373,000	373,000	373,000	0
2010	360,000	361,000	361,000	361,000	155
2011	380,000	381,000	382,000	385,000	1,803
2012	381,000	390,000	392,000	412,000	10,830
2013	361,000	389,000	396,000	451,000	32,122
2014	333,000	387,000	398,000	500,000	58,663
2015	314,000	386,000	402,000	544,000	76,962
2016	304,000	389,000	405,000	560,000	83,996
2017	296,000	389,000	406,000	566,000	84,530
2018	294,000	391,000	405,000	570,000	84,086
2019	293,000	392,000	404,000	564,000	84,838
2020	296,000	389,000	405,000	565,000	85,834
2021	297,000	390,000	406,000	576,000	87,066

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	0.30	0.30	0.30	0.30	0.00
2012	0.30	0.30	0.31	0.32	0.01
2013	0.28	0.30	0.31	0.34	0.02
2014	0.26	0.30	0.30	0.34	0.03
2015	0.24	0.30	0.30	0.34	0.03
2016	0.23	0.30	0.30	0.34	0.04
2017	0.23	0.30	0.30	0.34	0.04
2018	0.23	0.31	0.30	0.34	0.04
2019	0.22	0.31	0.30	0.34	0.04
2020	0.23	0.30	0.30	0.34	0.04
2021	0.23	0.30	0.30	0.34	0.04

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

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

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

	Catch (t)			Proportion of total		
Species group	2003	2004	2005	2003	2004	2005
Benthic urochordata	14	4	9	0.01	0.00	0.01
Birds	0	0	0	0.00	0.01	0.00
Bivalves	1	10	0	0.05	0.52	0.03
Brittle star unidentified	1	1	0	0.02	0.03	0.00
Capelin		0			0.02	
Corals Bryozoans	1	1	0	0.28	0.25	0.06
Deep sea smelts (bathylagidae)						
Eelpouts	62	27	1	0.27	0.30	0.02
Eulachon		0	0		0.00	0.00
Giant Grenadier						
Greenlings	4	2	1	0.43	0.40	0.23
Grenadier	14	9	0	0.01	0.00	0.00
Gunnels						
Hermit crab unidentified	5	3	1	0.04	0.05	0.01
Invertebrate unidentified	5	4	0	0.01	0.01	0.00
Lanternfishes (myctophidae)		0			0.07	
Large Sculpins	547	1422	897	0.39	0.32	0.22
Misc crabs	7	3	2	0.13	0.09	0.07
Misc crustaceans	0	0	0	0.24	0.20	0.07
Misc deep fish						
Misc fish	174	152	149	0.35	0.30	0.31
Misc inverts (worms etc)	0	0	0	0.07	0.02	0.00
Octopus	14	44	12	0.10	0.12	0.05
Other osmerids	0	0		0.01	0.09	
Other Sculpins	854	95	58	0.22	0.18	0.12
Pacific Sand lance	0	0	0	0.45	0.40	0.59
Pandalid shrimp	0	0	0	0.15	0.18	0.01
Polychaete unidentified		0	0		0.01	0.08
Scypho jellies	727	699	391	0.11	0.10	0.06
Sea anemone unidentified	14	16	12	0.10	0.09	0.12
Sea pens whips	0	1	0	0.01	0.05	0.01
Sea star	118	91	81	0.03	0.03	0.03
Shark	10	29	11	0.03	0.08	0.05
Skate	1010	1355	570	0.06	0.07	0.03
Snails	14	13	3	0.07	0.05	0.02
Sponge unidentified	3	7	3	0.01	0.08	0.04
Squid	5	4	1	0.00	0.00	0.00
Stichaeidae	0	0	0	0.12	0.07	0.14
Surf smelt						
Urchins dollars cucumbers	11	10	12	0.36	0.43	0.48

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

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

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

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

Table 2.34a—Bycatch of nontarget and "other" species taken in the EBS Pacific cod pot fishery, 1997-2002. The first part of the table ("Bycatch in...") shows the amount (t) of each species group taken as bycatch in the EBS Pacific cod pot fishery, broken down by year. The second part of the table ("Proportion of...") shows the same quantity expressed relative to the total EBS catch (taken in all target categories with all gears) of that species group in that year. An empty cell in the second part of the table indicates that no catch of that group was observed in the EBS during that year.

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

Table 2.34b—Bycatch of nontarget and "other" species taken in the EBS Pacific cod pot fishery, 2003-2005. The first part of the table ("Bycatch") shows the amount (t) of each species group taken as bycatch in the EBS Pacific cod pot fishery, broken down by year. The second part of the table ("Proportion of total") shows the same quantity expressed relative to the total EBS catch (taken in all target categories with all gears) of that species group in that year. An empty cell in the second part of the table indicates that no catch of that group was observed in the EBS during that year. Note that the list of nontarget species groups used for 2003-2005 differs from that used for 1997-2002.

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

Table 2.35a—Bycatch of nontarget and “other” species taken in the AI Pacific cod trawl fishery, 1997-2002. The first part of the table (“Bycatch in...”) shows the amount (t) of each species group taken as bycatch in the AI Pacific cod trawl fishery, broken down by year. The second part of the table (“Proportion of...”) shows the same quantity expressed relative to the total AI catch (taken in all target categories with all gears) of that species group in that year. An empty cell in the second part of the table indicates that no catch of that group was observed in the AI during that year.

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

Table 2.35b—Bycatch of nontarget and "other" species taken in the AI Pacific cod trawl fishery, 2003-2005. The first part of the table ("Bycatch") shows the amount (t) of each species group taken as bycatch in the AI Pacific cod trawl fishery, broken down by year. The second part of the table ("Proportion of total") shows the same quantity expressed relative to the total AI catch (taken in all target categories with all gears) of that species group in that year. An empty cell in the second part of the table indicates that no catch of that group was observed in the AI during that year. Note that the list of nontarget species groups used for 2003-2005 differs from that used for 1997-2002.

	Catch (t)			Proportion of total		
Species group	2003	2004	2005	2003	2004	2005
Benthic urochordata	0	0	0	0.05	0.16	0.37
Birds	0	0	0	0.21	0.01	0.38
Bivalves	15	1	0	0.99	0.92	0.81
Brittle star unidentified		0	0		0.05	0.01
Capelin						
Corals Bryozoans	24	11	12	0.40	0.35	0.24
Deep sea smelts (bathylagidae)						
Eelpouts	0	1	0	0.08	0.51	0.00
Eulachon			0			0.68
Giant Grenadier						
Greenlings	1	0	0	0.66	0.05	0.01
Grenadier		4	0		0.01	0.00
Gunnels						
Hermit crab unidentified	0	0	0	0.80	0.98	0.09
Invertebrate unidentified	0	0	0	0.09	0.00	0.02
Lanternfishes (myctophidae)						
Large Sculpins	78	159	88	0.37	0.23	0.18
Misc crabs	1	1	0	0.73	0.59	0.52
Misc crustaceans	0	0	0	0.99	0.29	0.98
Misc deep fish						
Misc fish	28	15	19	0.23	0.10	0.12
Misc inverts (worms etc)		0	0		0.29	1.00
Octopus	6	5	3	0.36	0.28	0.40
Other osmerids						
Other Sculpins	122	1	3	0.31	0.01	0.04
Pacific Sand lance	0		0	1.00		1.00
Pandalid shrimp	0	0	0	0.06	0.01	0.03
Polychaete unidentified		0	0		0.13	0.97
Scypho jellies	0	0	1	0.17	0.49	0.44
Sea anemone unidentified	0	0	0	0.61	0.31	0.32
Sea pens whips	0	0	0	0.34	0.91	0.42
Sea star	5	3	2	0.49	0.27	0.17
Shark	0	2	2	0.01	0.43	0.10
Skate	72	76	65	0.13	0.09	0.11
Snails	1	1	0	0.52	0.50	0.21
Sponge unidentified	24	18	22	0.30	0.13	0.28
Squid	3	2	1	0.10	0.11	0.07
Stichaeidae			0			0.00
Surf smelt						
Urchins dollars cucumbers	1	1	0	0.40	0.43	0.15

Table 2.36a—Bycatch of nontarget and "other" species taken in the AI Pacific cod longline fishery, 1997-2002. The first part of the table ("Bycatch in...") shows the amount (t) of each species group taken as bycatch in the AI Pacific cod longline fishery, broken down by year. The second part of the table ("Proportion of...") shows the same quantity expressed relative to the total AI catch (taken in all target categories with all gears) of that species group in that year. An empty cell in the second part of the table indicates that no catch of that group was observed in the AI during that year.

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

Table 2.36b—Bycatch of nontarget and “other” species taken in the AI Pacific cod hook-and-line (including jigs) fishery, 2003-2005. The first part of the table (“Bycatch”) shows the amount (t) of each species group taken as bycatch in the AI Pacific cod hook-and-line fishery, broken down by year. The second part of the table (“Proportion of total”) shows the same quantity expressed relative to the total AI catch (taken in all target categories with all gears) of that species group in that year. An empty cell in the second part of the table indicates that no catch of that group was observed in the AI during that year. Note that the list of nontarget species groups used for 2003-2005 differs from that used for 1997-2002.

	Catch (t)			Proportion of total		
Species group	2003	2004	2005	2003	2004	2005
Benthic urochordata	0	0	0	0.09	0.00	0.01
Birds	0	0	0	0.03	0.21	0.29
Bivalves	0	0	0	0.00	0.02	0.18
Brittle star unidentified	0	0	0	0.00	0.00	0.00
Capelin						
Corals Bryozoans	1	1	0	0.01	0.05	0.01
Deep sea smelts (bathylagidae)						
Eelpouts	0	0	0	0.01	0.00	0.00
Eulachon						
Giant Grenadier	0	0	0	0.30	0.00	0.00
Greenlings	0	0	0	0.08	0.16	0.02
Grenadier	46	8	0	0.01	0.01	0.00
Gunnels			0			0.00
Hermit crab unidentified	0	0	0	0.01	0.00	0.00
Invertebrate unidentified	0	1	0	0.00	0.12	0.03
Lanternfishes (myctophidae)						
Large Sculpins	28	133	91	0.14	0.19	0.18
Misc crabs	0	0	0	0.00	0.01	0.01
Misc crustaceans	0	0	0	0.00	0.00	0.00
Misc deep fish						
Misc fish	1	3	1	0.01	0.02	0.00
Misc inverts (worms etc)		0	0		0.00	0.00
Octopus	8	8	4	0.54	0.49	0.55
Other osmerids			0			0.00
Other Sculpins	31	63	1	0.08	0.41	0.01
Pacific Sand lance						
Pandalid shrimp						
Polychaete unidentified	0	0	0	1.00	0.00	0.03
Scypho jellies	0	0	0	0.01	0.00	0.00
Sea anemone unidentified	0	0	0	0.24	0.23	0.58
Sea pens whips	0	0	0	0.46	0.09	0.15
Sea star	1	6	3	0.10	0.47	0.25
Shark	0	0	0	0.01	0.08	0.02
Skate	105	402	245	0.20	0.48	0.43
Snails	0	0	0	0.01	0.03	0.05
Sponge unidentified	2	5	2	0.02	0.04	0.03
Squid		0			0.00	
Stichaeidae	0			0.00		
Surf smelt						
Urchins dollars cucumbers	0	0	0	0.02	0.11	0.01

Table 2.37—Bycatch of nontarget and “other” species taken in the AI Pacific cod pot fishery, 1997-2002. The first part of the table (“Bycatch in...”) shows the amount (t) of each species group taken as bycatch in the AI Pacific cod pot fishery, broken down by year. The second part of the table (“Proportion of...”) shows the same quantity expressed relative to the total AI catch (taken in all target categories with all gears) of that species group in that year. An empty cell in the second part of the table indicates that no catch of that group was observed in the AI during that year.

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

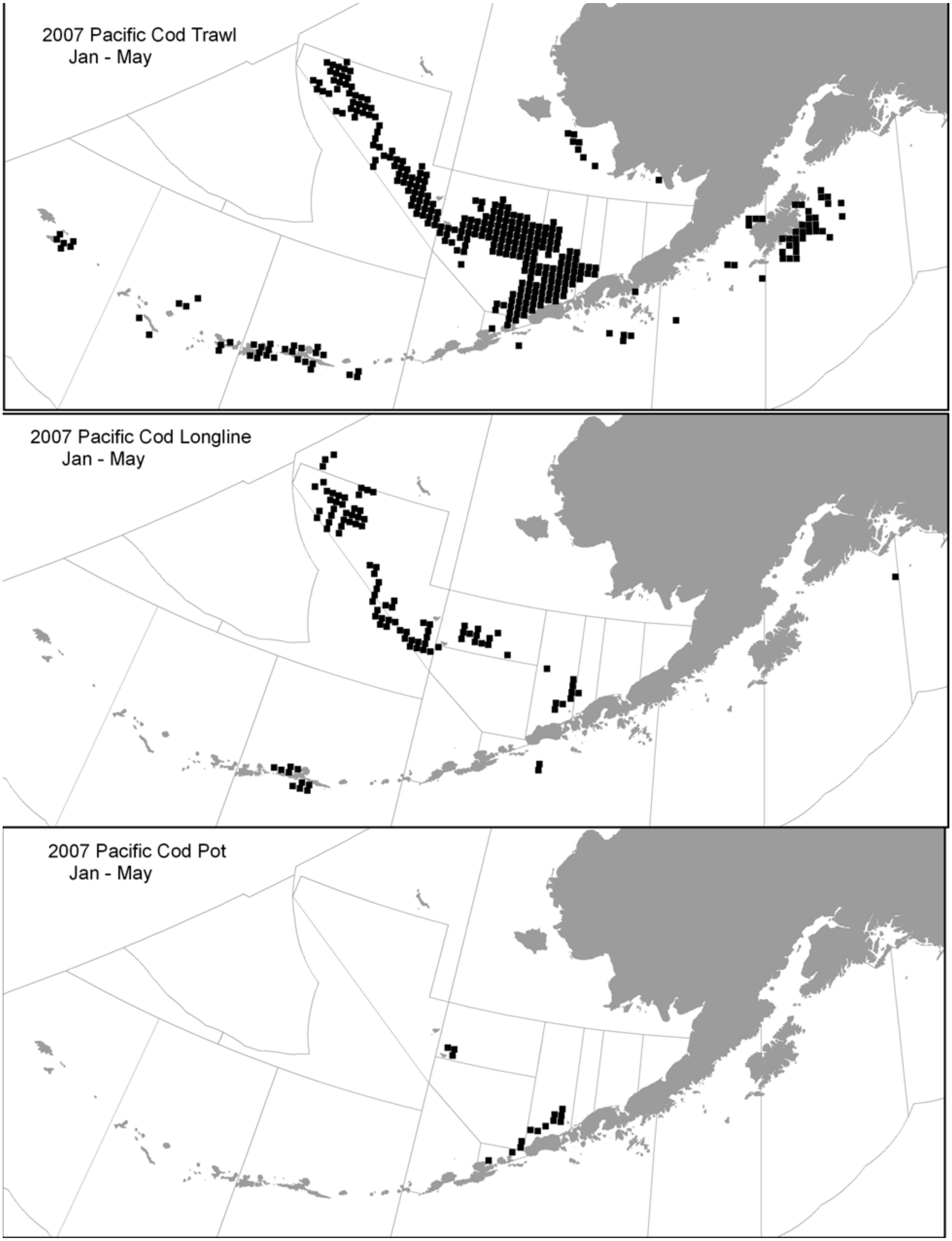


Figure 2.1a—Maps showing each 400 square kilometer cell with hauls/sets containing Pacific cod from at least 3 distinct vessels, January-May 2007, by gear type, overlaid against NMFS 3-digit statistical areas.

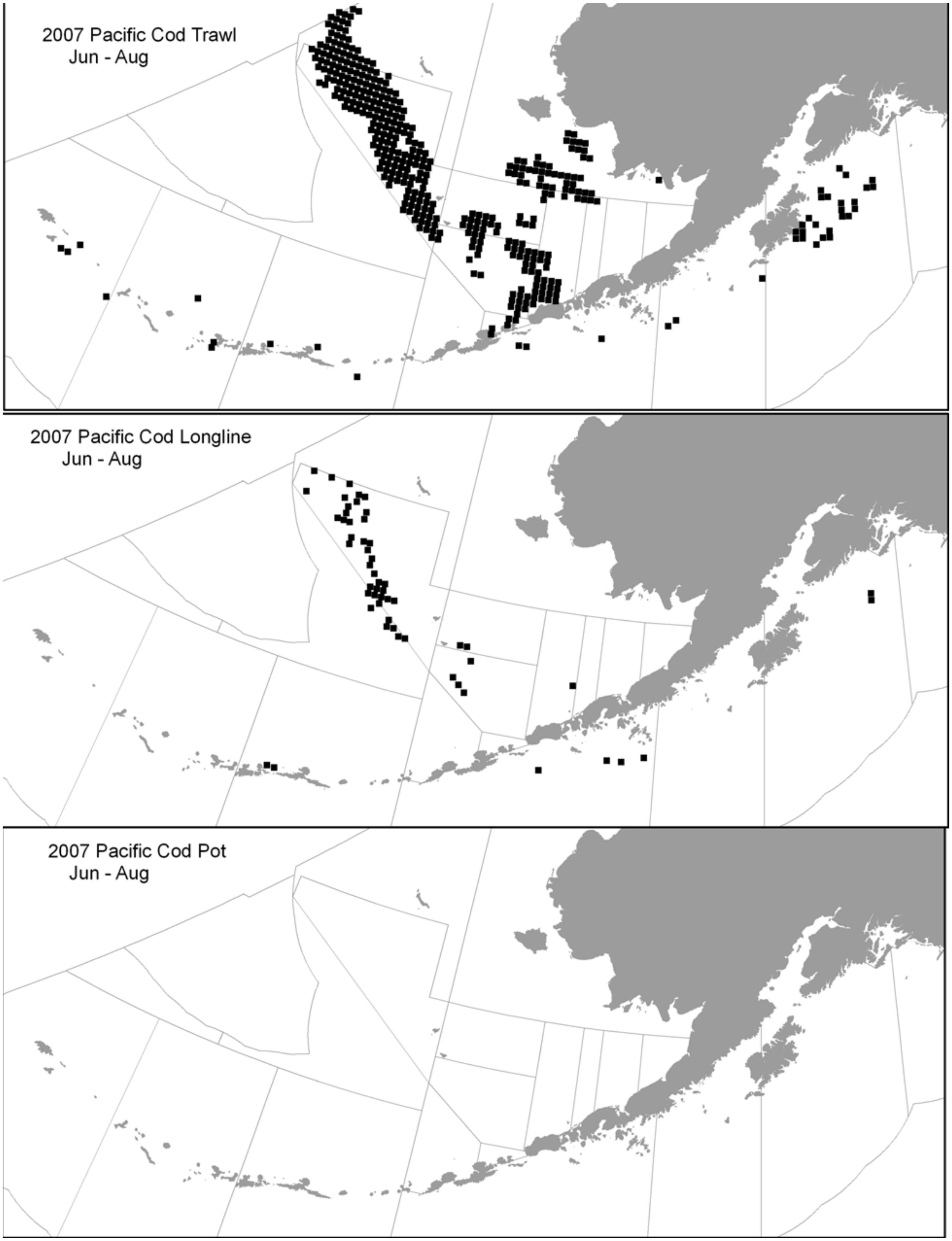


Figure 2.1b—Maps showing each 400 square kilometer cell with hauls/sets containing Pacific cod from at least 3 distinct vessels, June-August 2007, by gear type, overlaid against NMFS 3-digit statistical areas.

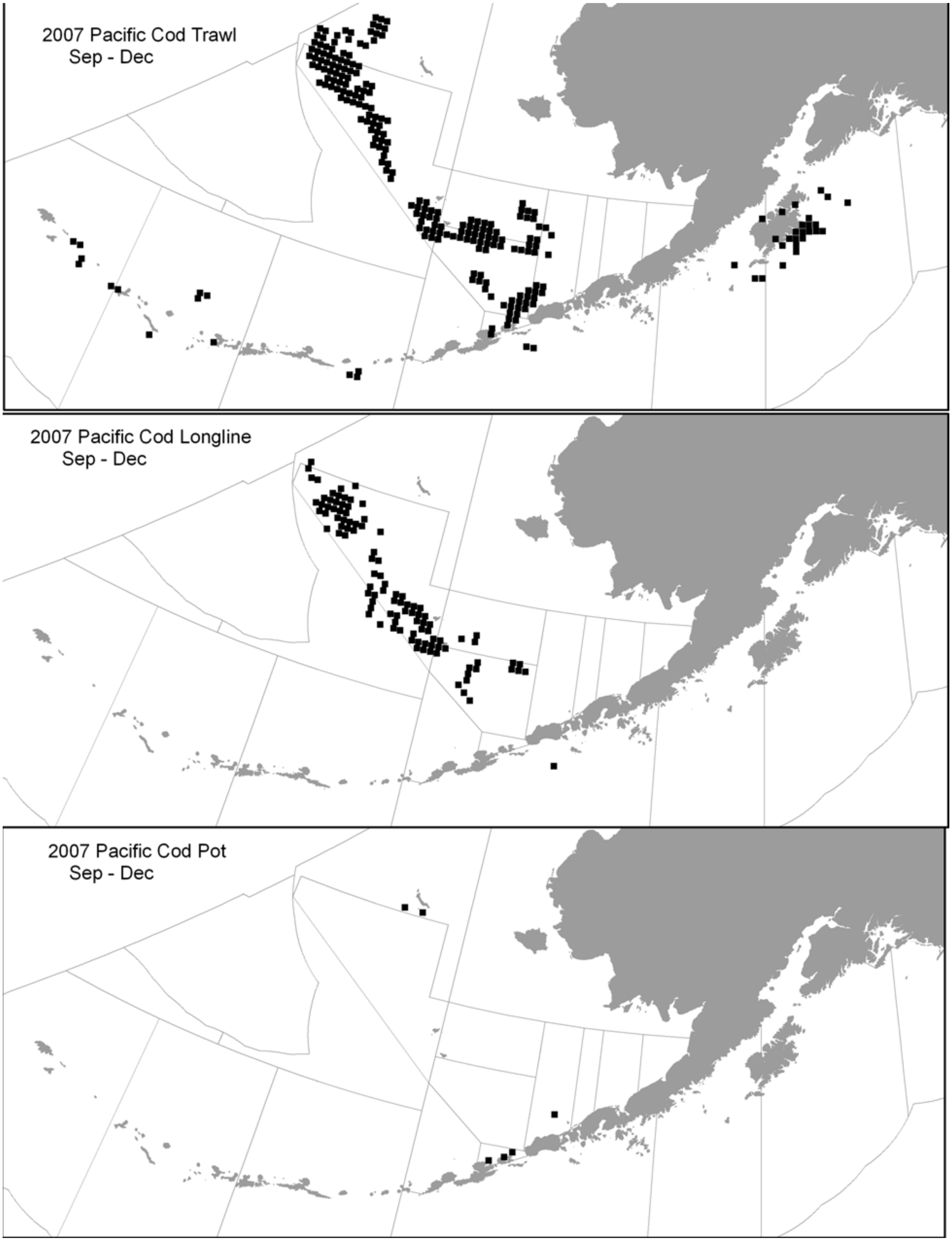


Figure 2.1c—Maps showing each 400 square kilometer cell with hauls/sets containing Pacific cod from at least 3 distinct vessels, Sept.-Dec. 2007, by gear type, overlaid against NMFS 3-digit statistical areas.

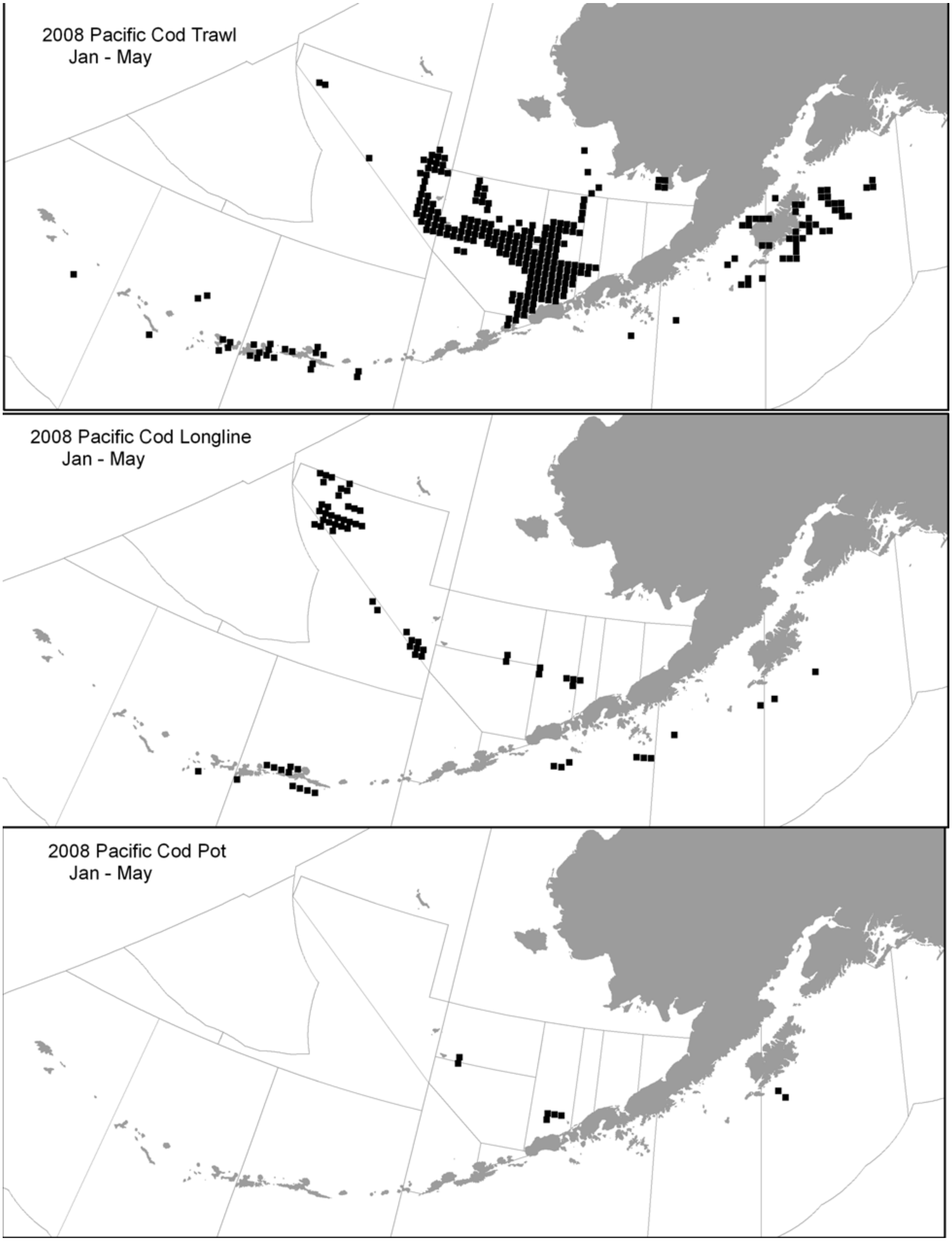


Figure 2.1d—Maps showing each 400 square kilometer cell with hauls/sets containing Pacific cod from at least 3 distinct vessels, January-May 2008, by gear type, overlaid against NMFS 3-digit statistical areas.

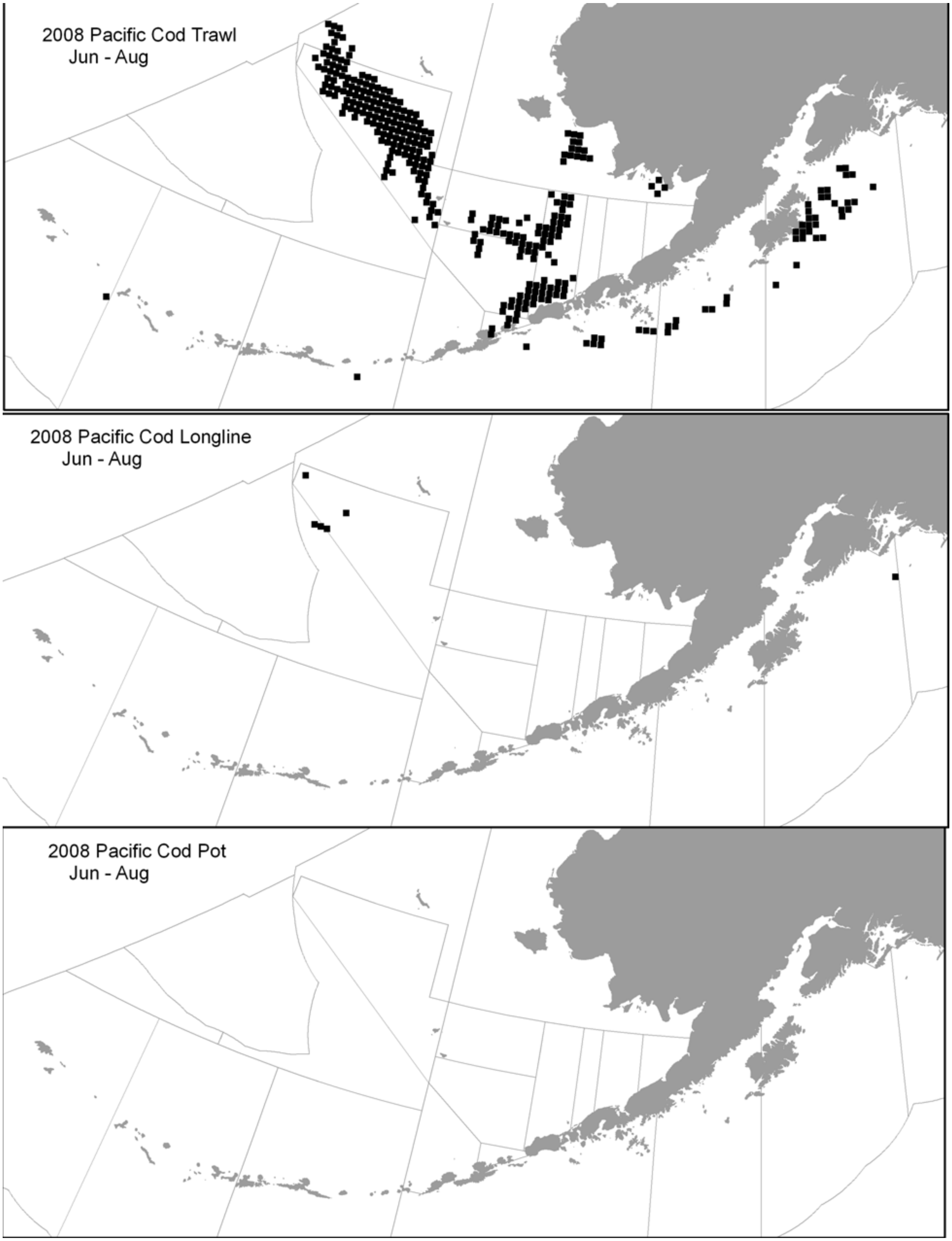


Figure 2.1e—Maps showing each 400 square kilometer cell with hauls/sets containing Pacific cod from at least 3 distinct vessels, June-August 2008, by gear type, overlaid against NMFS 3-digit statistical areas.

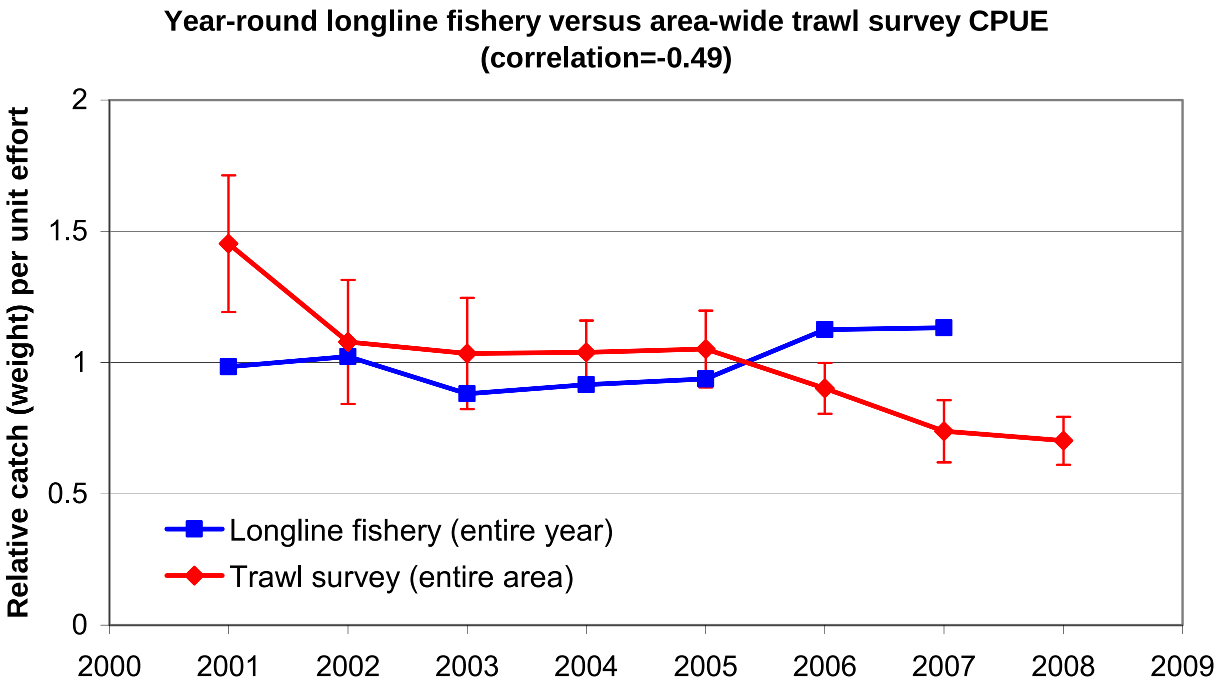


Figure 2.2a—Comparison of year-round longline fishery and area-wide trawl survey CPUE.

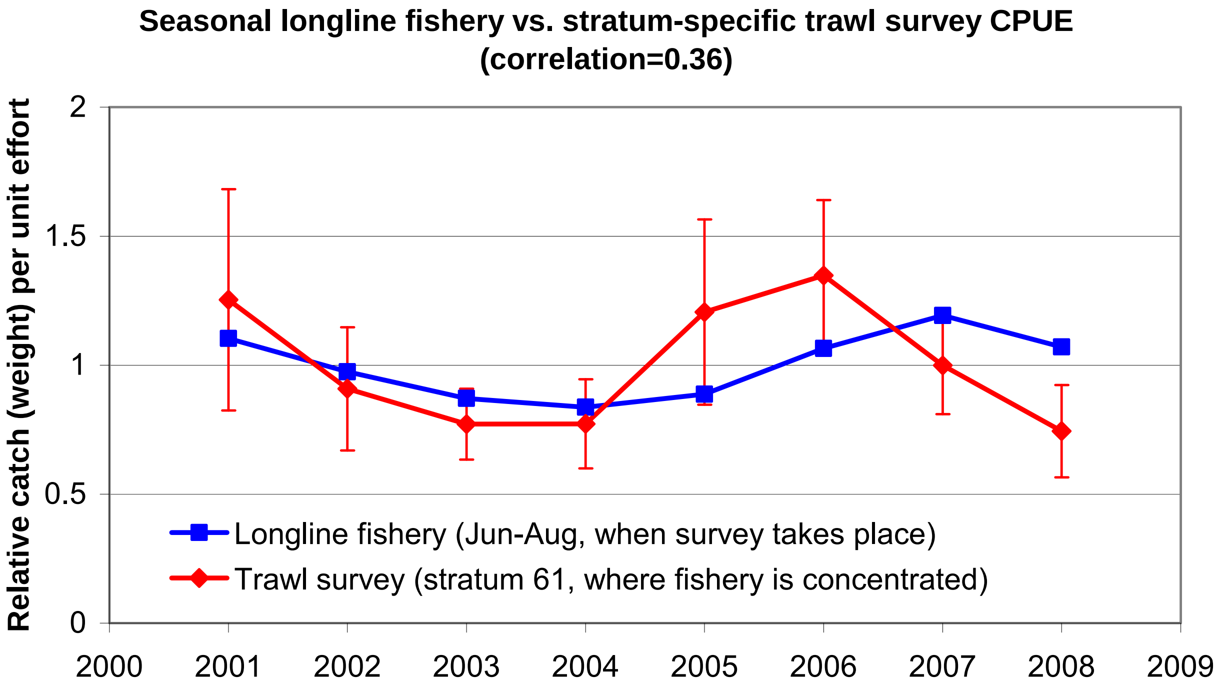
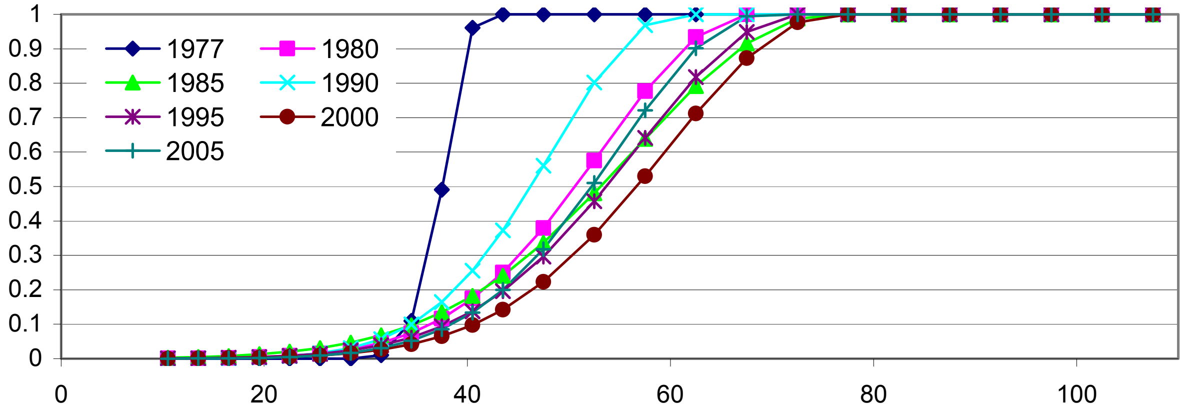
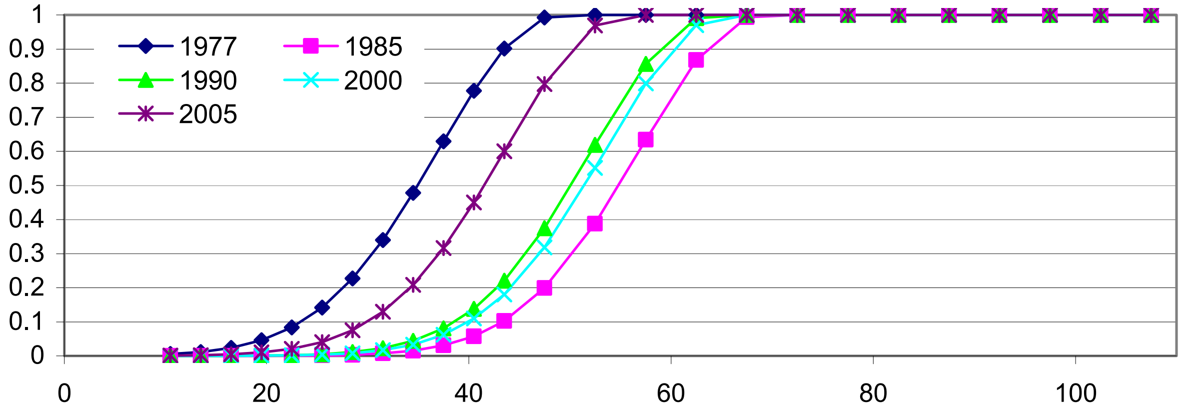


Figure 2.2b—Comparison of seasonal longline fishery and stratum-specific trawl survey CPUE.


Jan-May Trawl Fishery


Jun-Aug Trawl Fishery

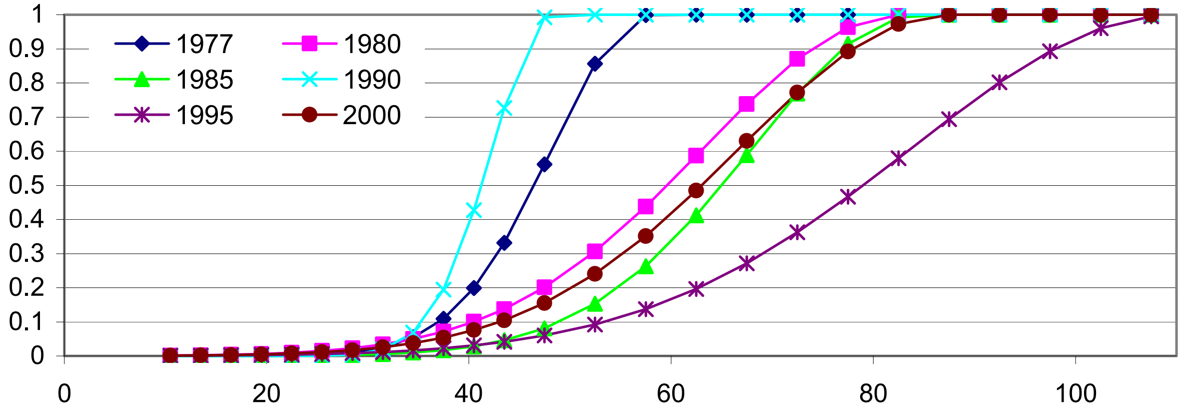

Sep-Dec Trawl Fishery

Figure 2.3a. Trawl fishery selectivity by season and time block (line labels refer to beginning year of time block), as estimated by Model B1.

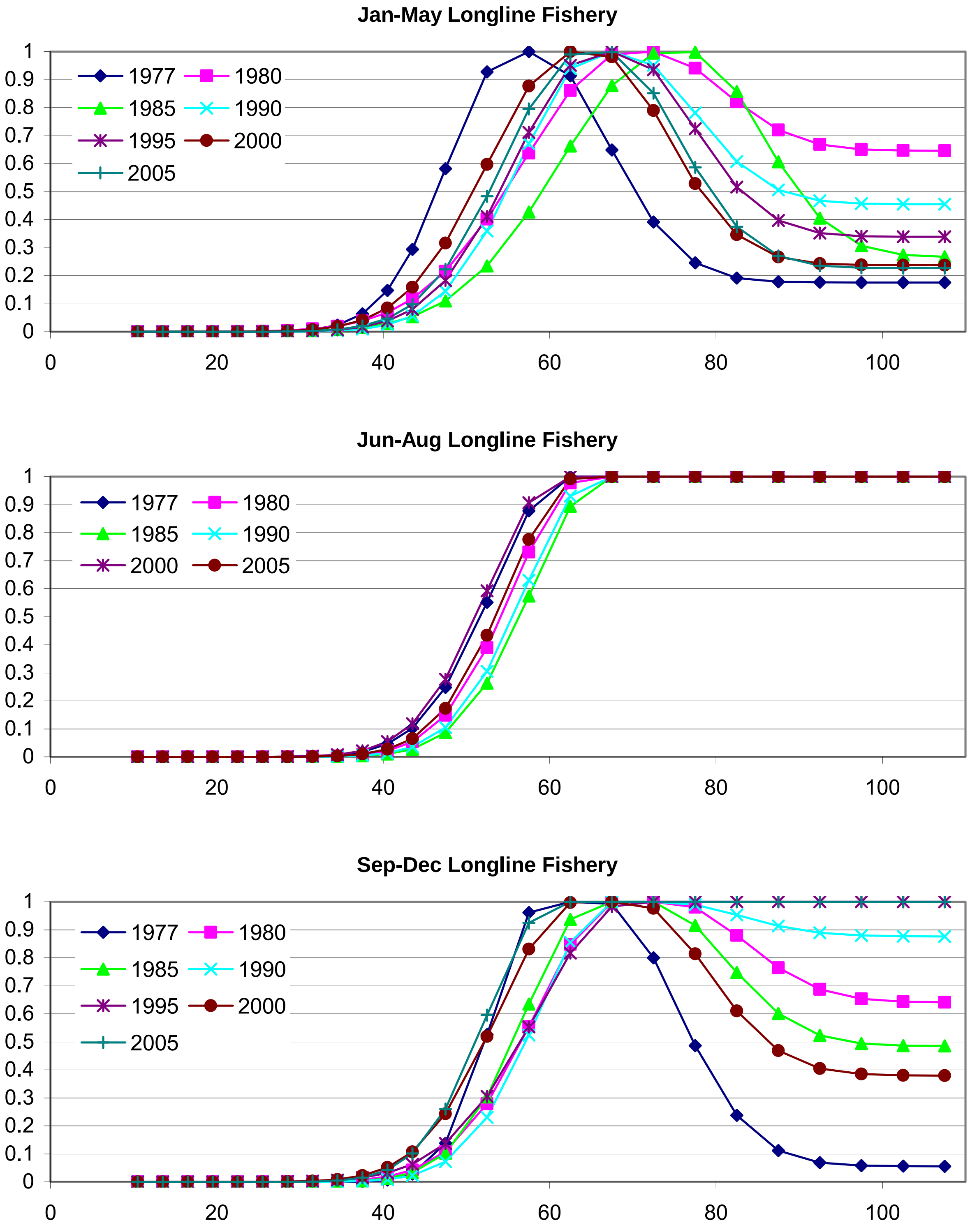


Figure 2.3b. Longline fishery selectivity by season and time block (line labels refer to beginning year of time block), as estimated by Model B1.

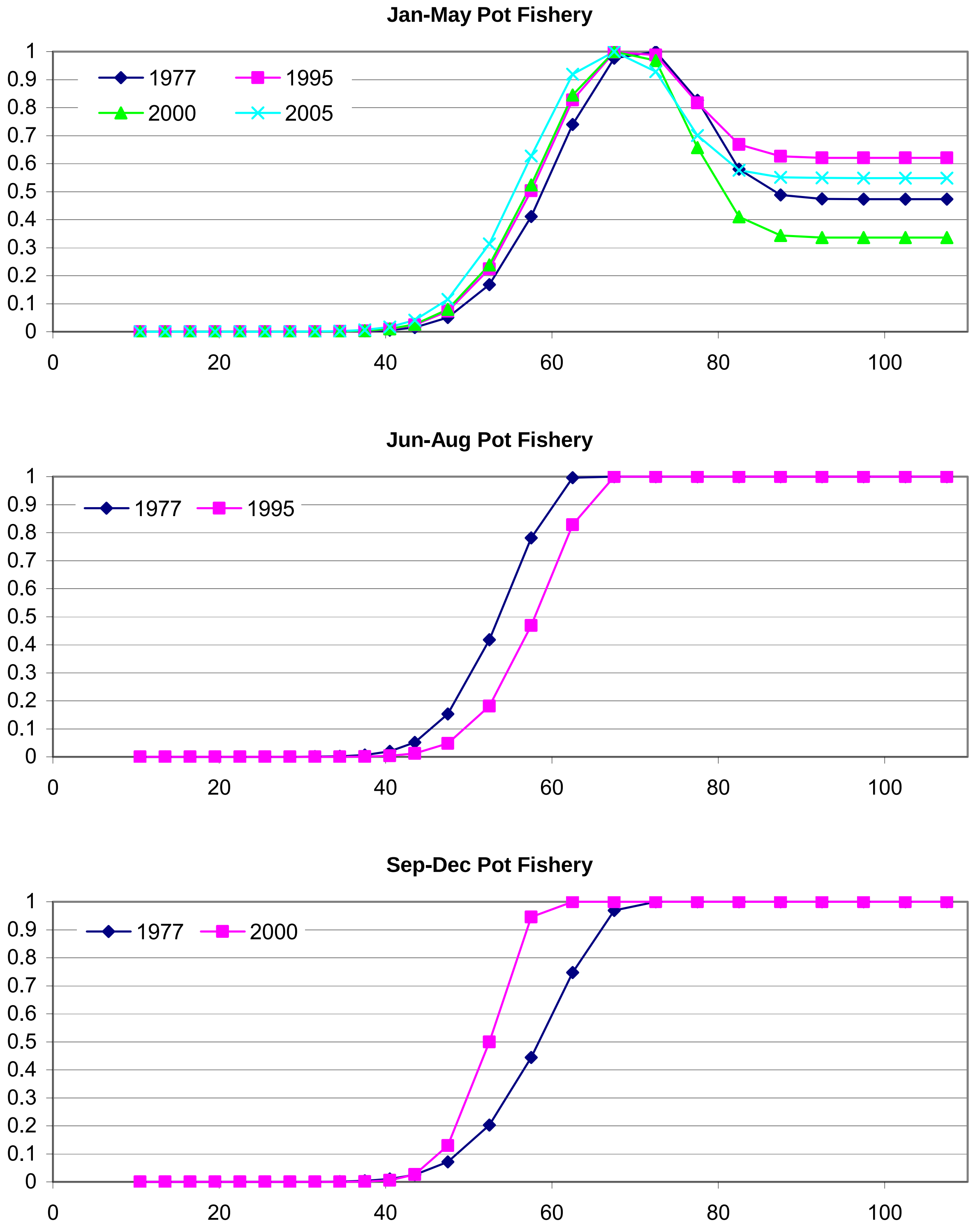


Figure 2.3c. Pot fishery selectivity by season and time block (line labels refer to beginning year of time block), as estimated by Model B1.

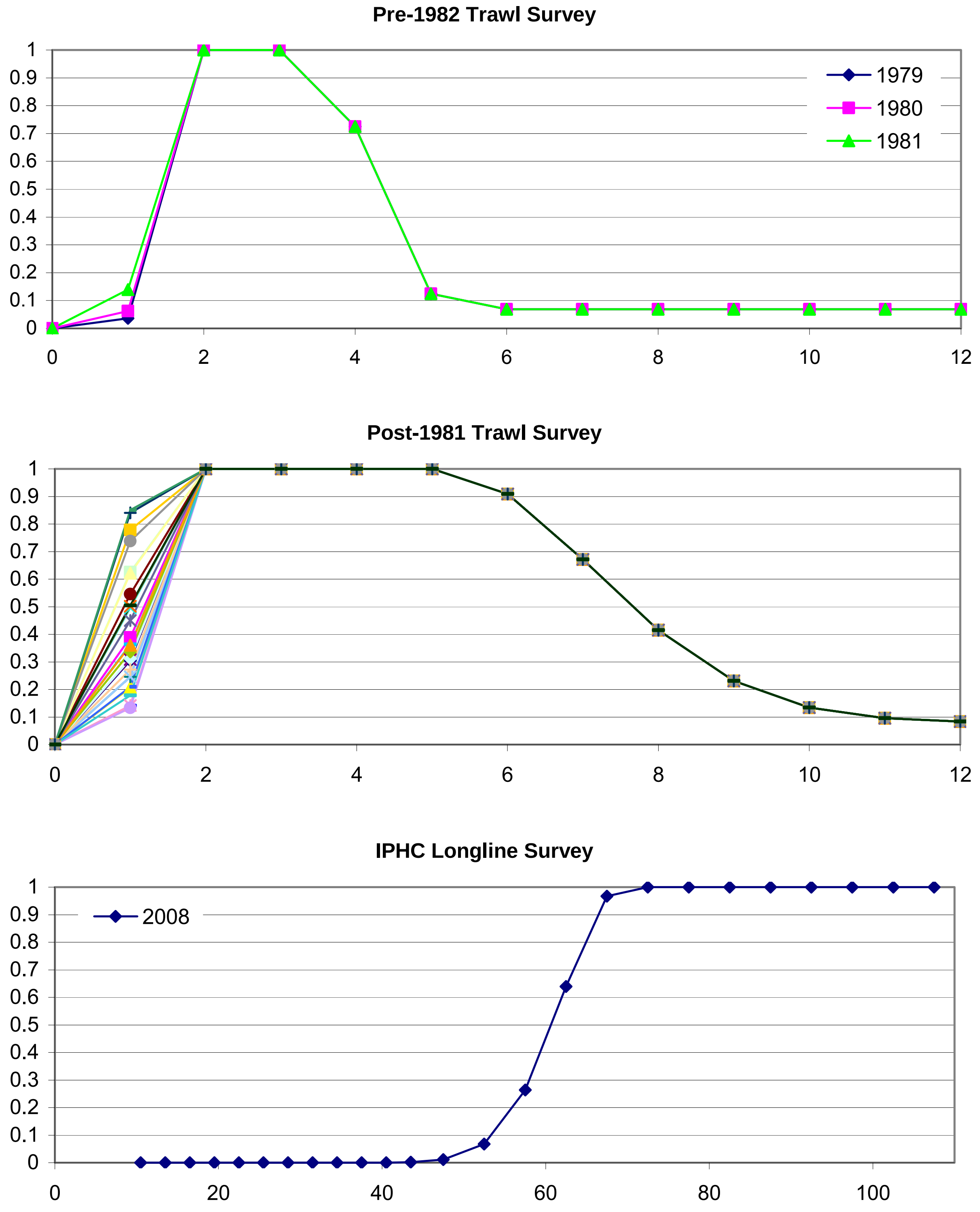


Figure 2.3d. Survey selectivity by season and time block (line labels refer to beginning year of time block), as estimated by Model B1.

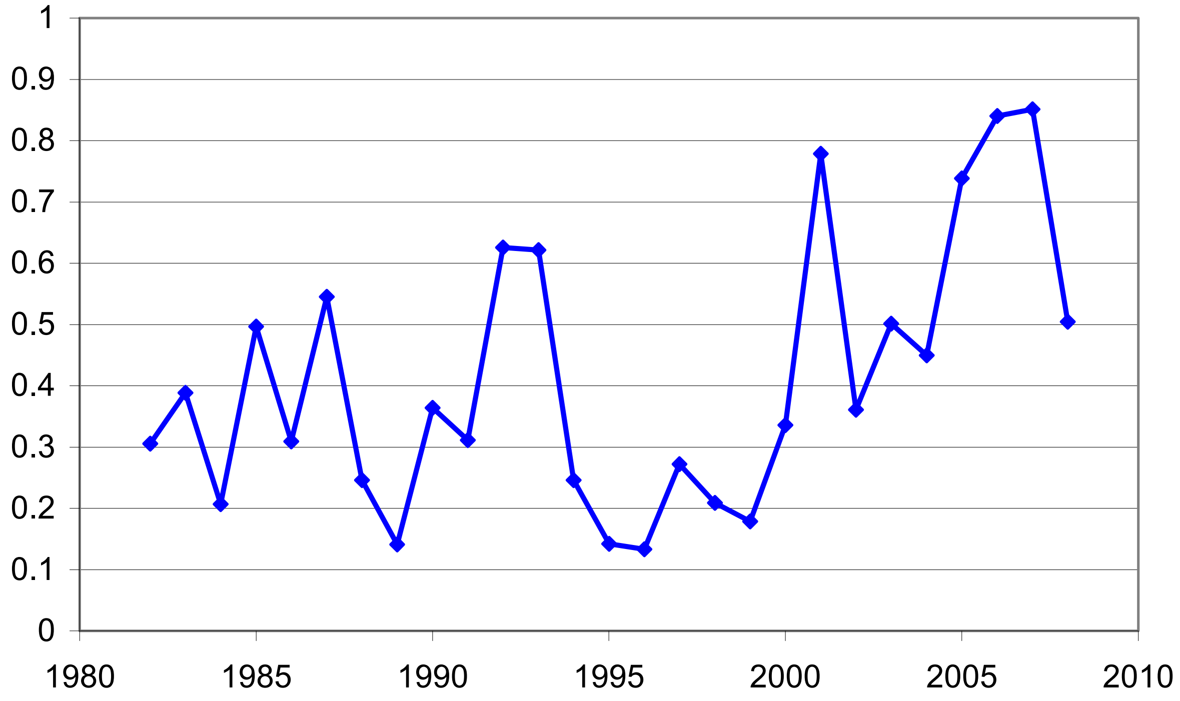


Figure 2.4. Time trend of post-1981 survey selectivity at age 1, as estimated by Model B1 (correlation bewteen year and selectivity = 0.45).

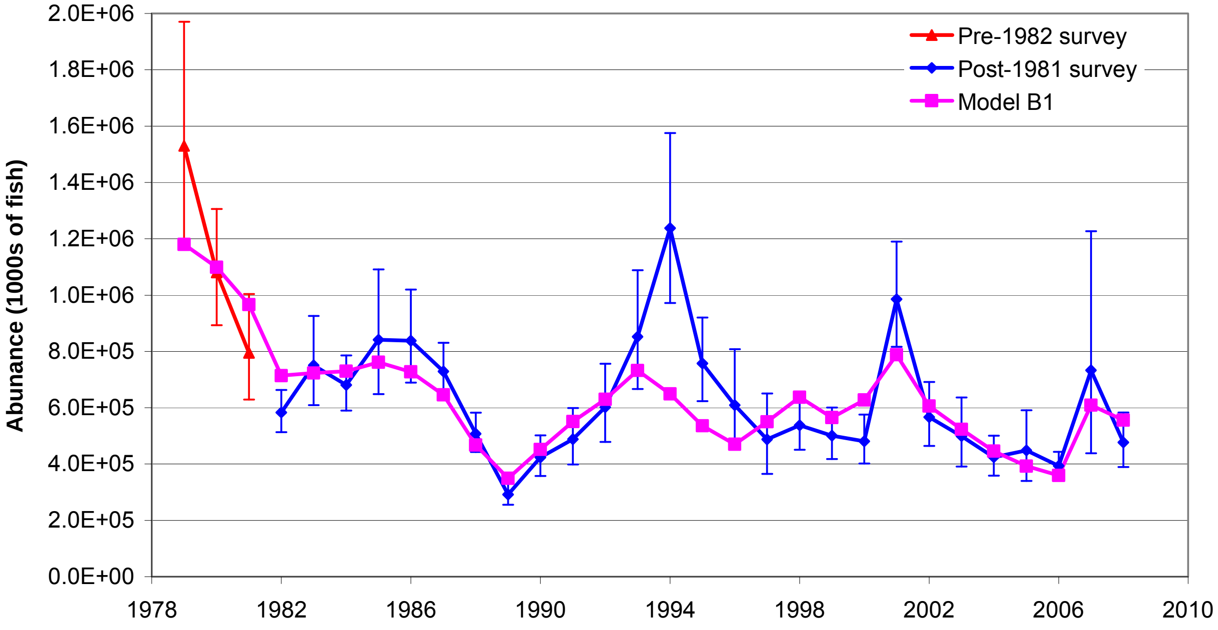


Figure 2.5. Observed and estimated survey abundance (Model B1).

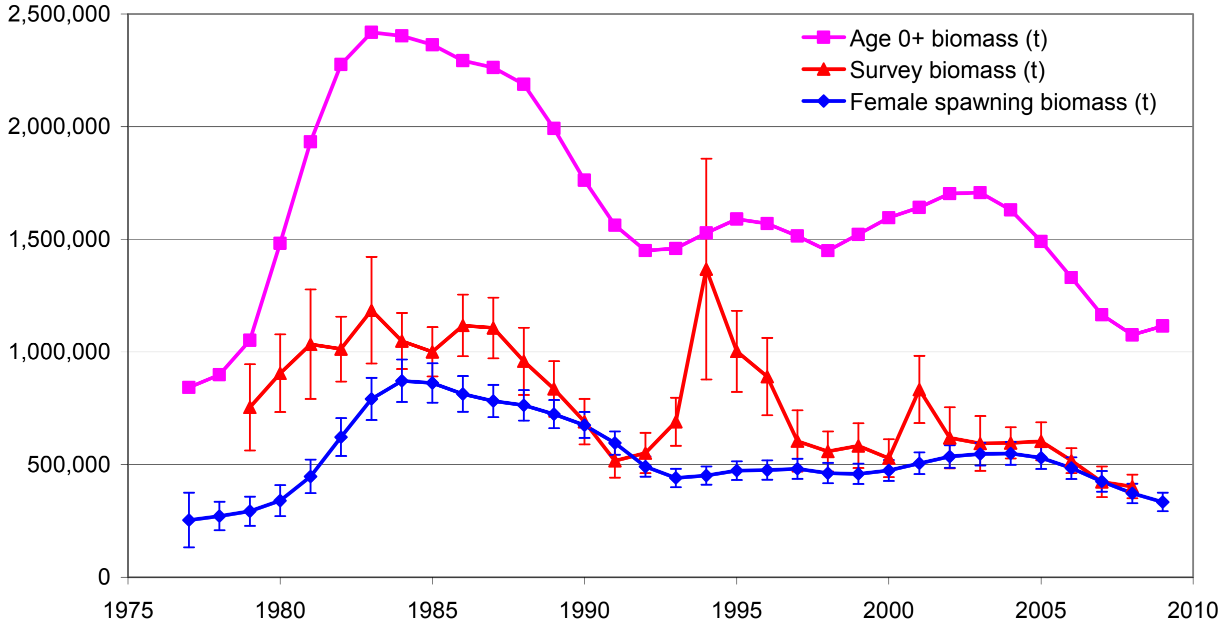


Figure 2.6—Biomass time trends (age 3+ biomass, female spawning biomass, survey biomass) of EBS Pacific cod as estimated by Model B1.

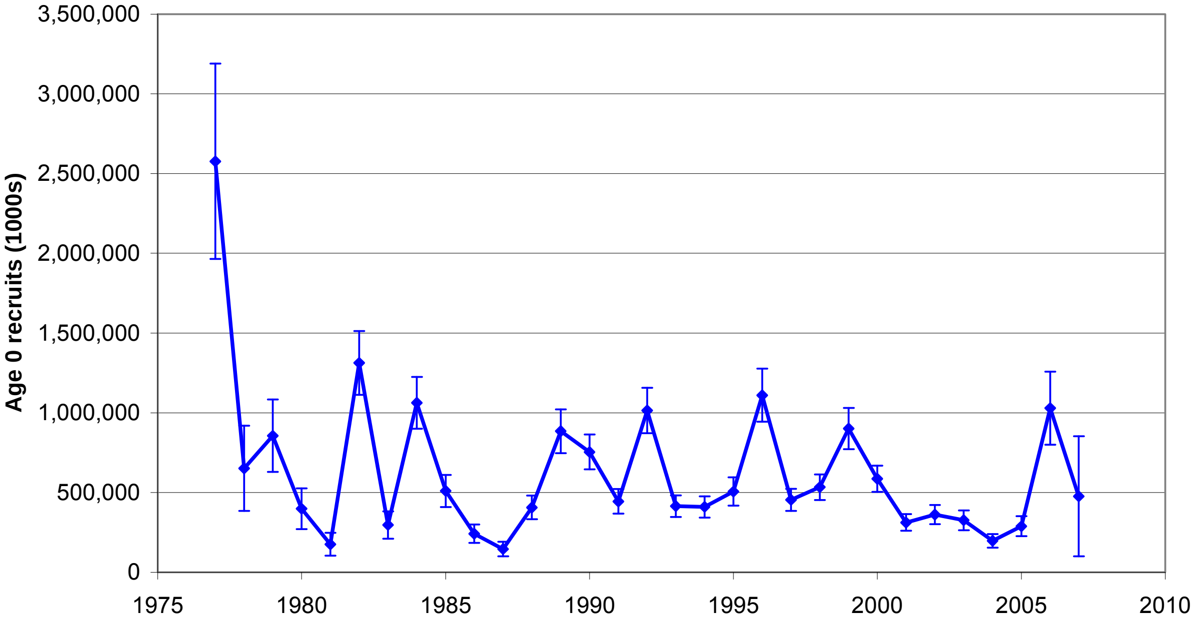


Figure 2.7—Time series of EBS Pacific cod recruitment at age 0, with 95% confidence intervals, as estimated by Model B1.

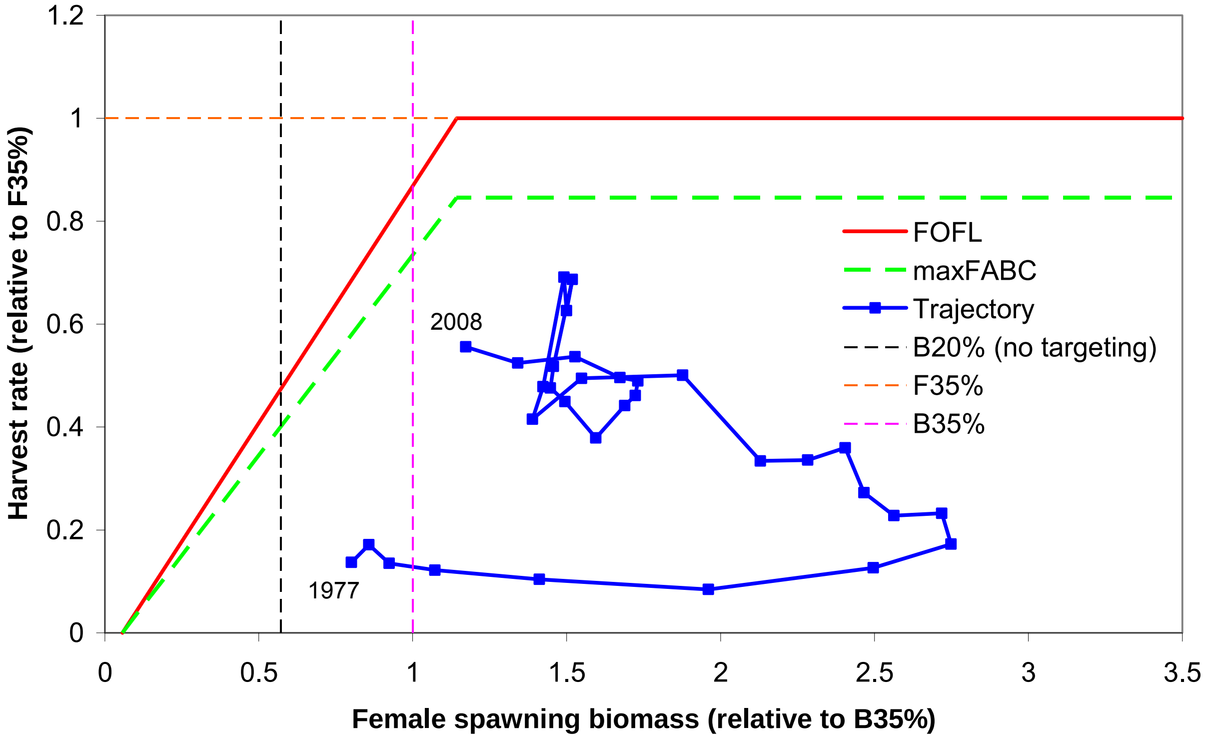


Figure 2.8—Trajectory of Pacific cod fishing mortality and female spawning biomass as estimated by Model B1, 1977-present. Because Pacific cod is a key prey of Steller sea lions, harvests of Pacific cod would be restricted to incidental catch in the event that spawning biomass fell below $B_{20\%}$.

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

(Note: This attachment has not changed since last year's assessment.)

Sarah Gaichas and Kerim Aydin

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

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

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

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

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

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

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

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

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

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

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

Reference

Aydin, K., S. Gaichas, I. Ortiz, D. Kinzey, and N. Friday. In press. A comparison of the Bering Sea, Gulf of Alaska, and Aleutian Islands large marine ecosystems through food web modeling. NOAA NMFS Tech Memo. 294 p.

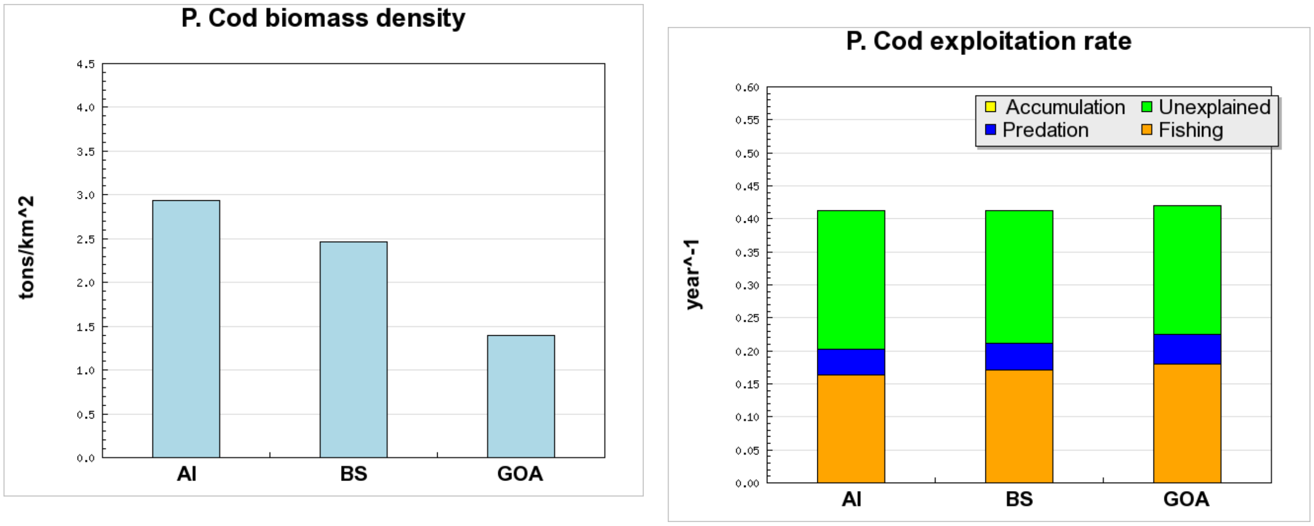


Figure 1. Comparative biomass density (left) and mortality sources (right) for Pacific cod in the AI, EBS, and GOA ecosystems. For the AI and GOA, biomass density (left) is the average biomass from early 1990s NMFS bottom trawl surveys divided by the total area surveyed. For the EBS, biomass density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

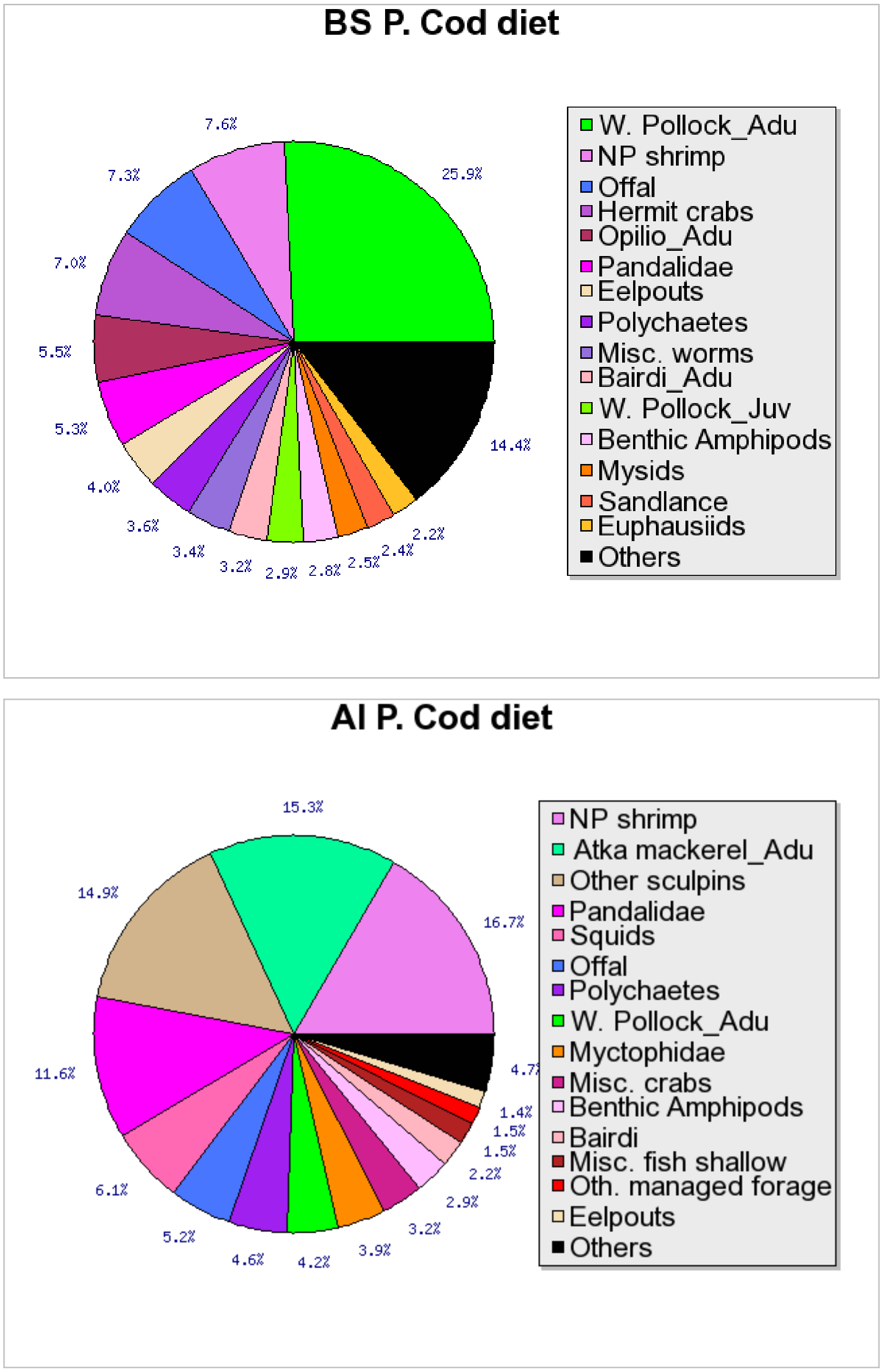
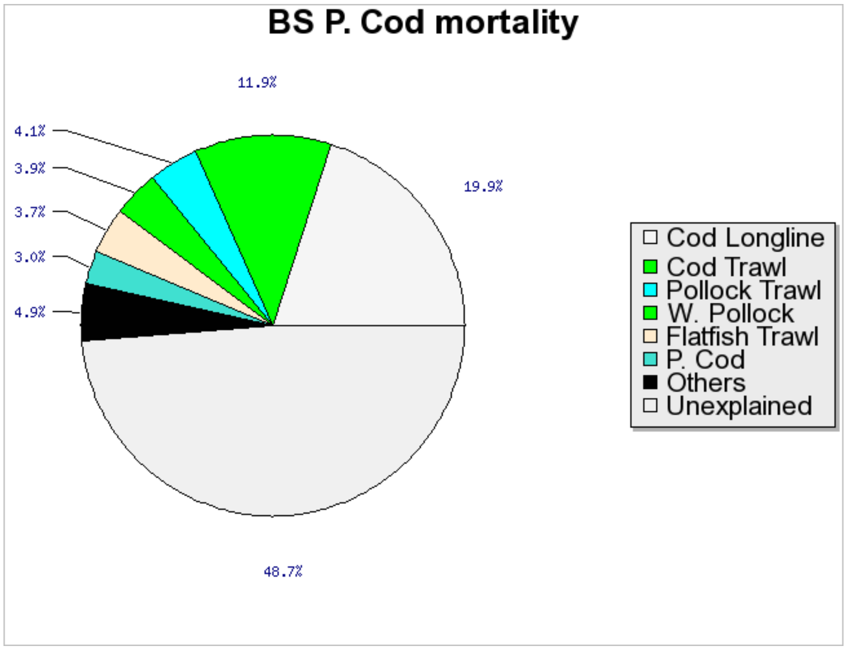


Figure 2. Comparison of Pacific cod diet compositions for the EBS (top) and AI (bottom) ecosystems. Diets are estimated from stomach collections taken aboard NMFS bottom trawl surveys in 1991 (EBS) and in 1991-1994 (AI). See Annex A for detailed methods.



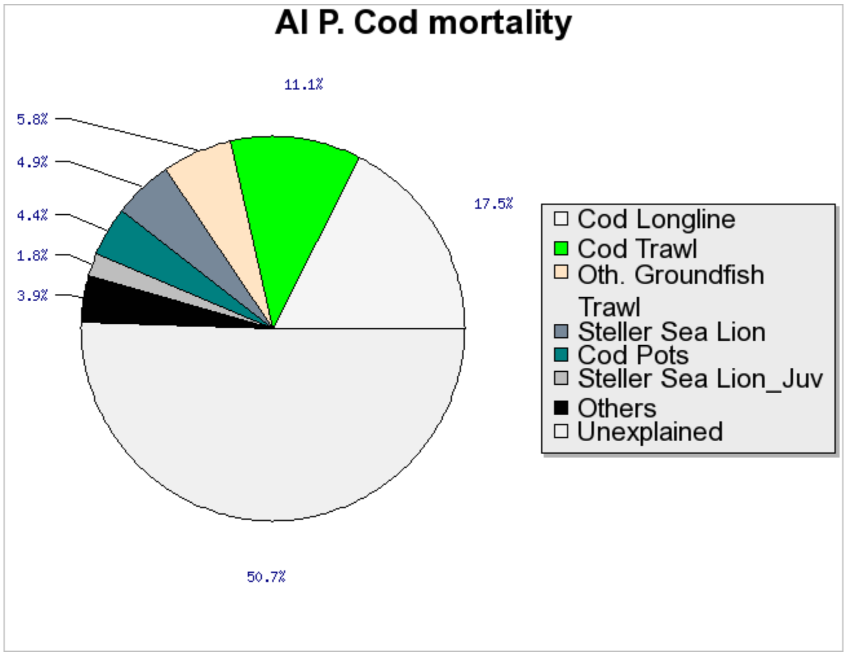
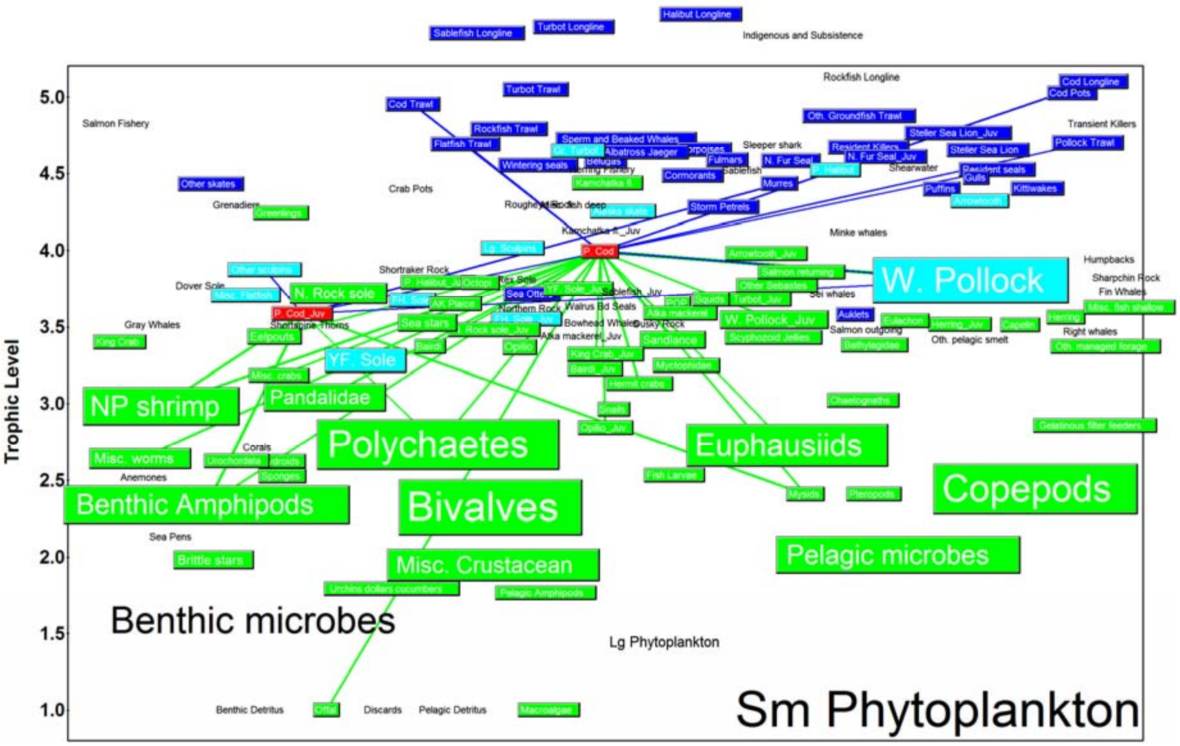


Figure 3. Comparison of Pacific cod mortality sources for the EBS (top) and AI (bottom) ecosystems. Mortality sources reflect cod predator diets estimated from stomach collections taken aboard NMFS bottom trawl surveys in 1991 (EBS) and in 1991-1994 (AI), cod predator consumption rates estimated from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



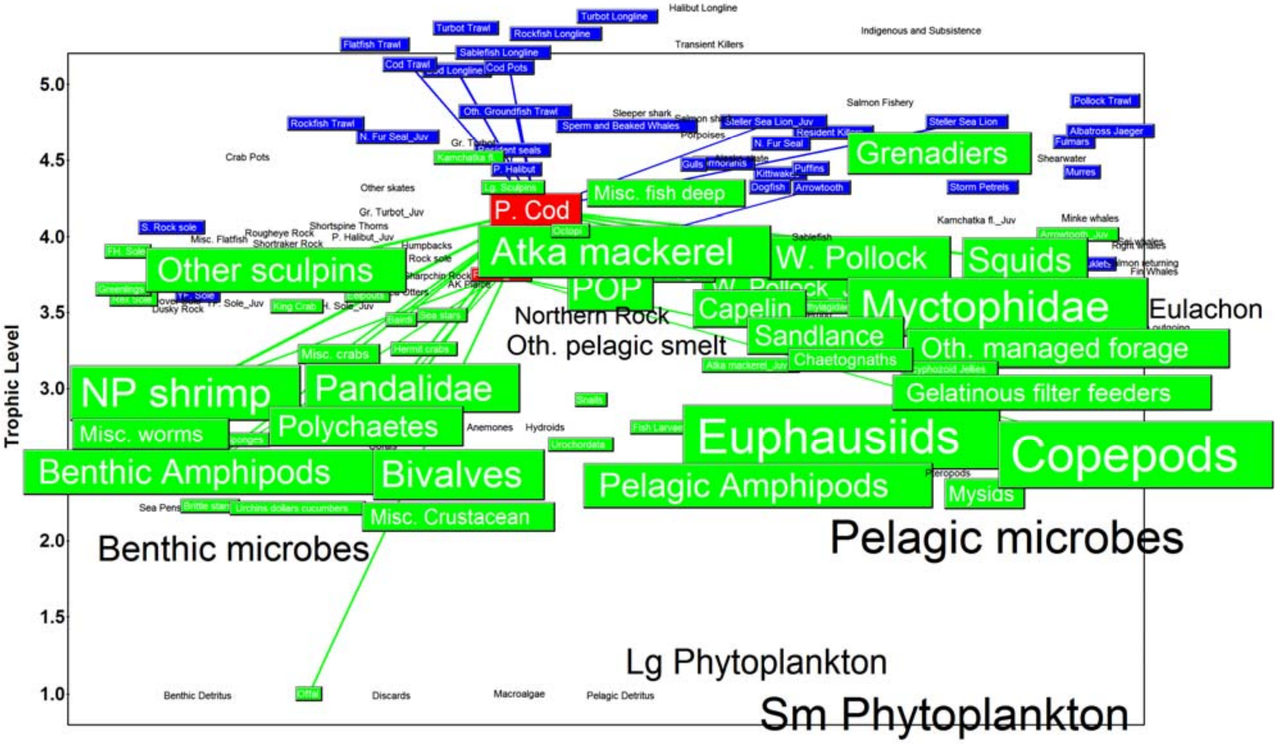
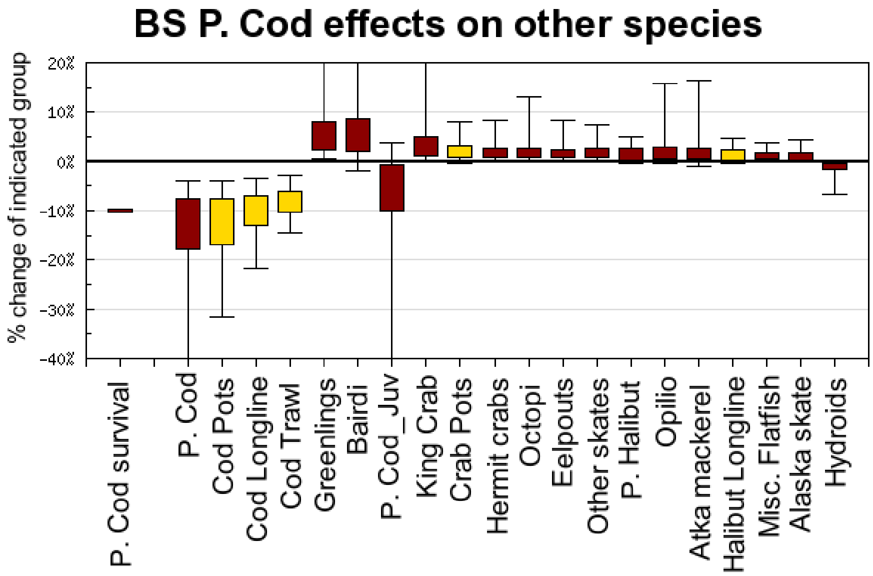


Figure 4. Adult and juvenile cod in the EBS (top) and AI (bottom) food webs. Predators of cod are dark blue, prey of cod are green, and species that are both predators and prey of cod are light blue. Box size is proportional to biomass and lines between boxes represent the most significant energy flows.



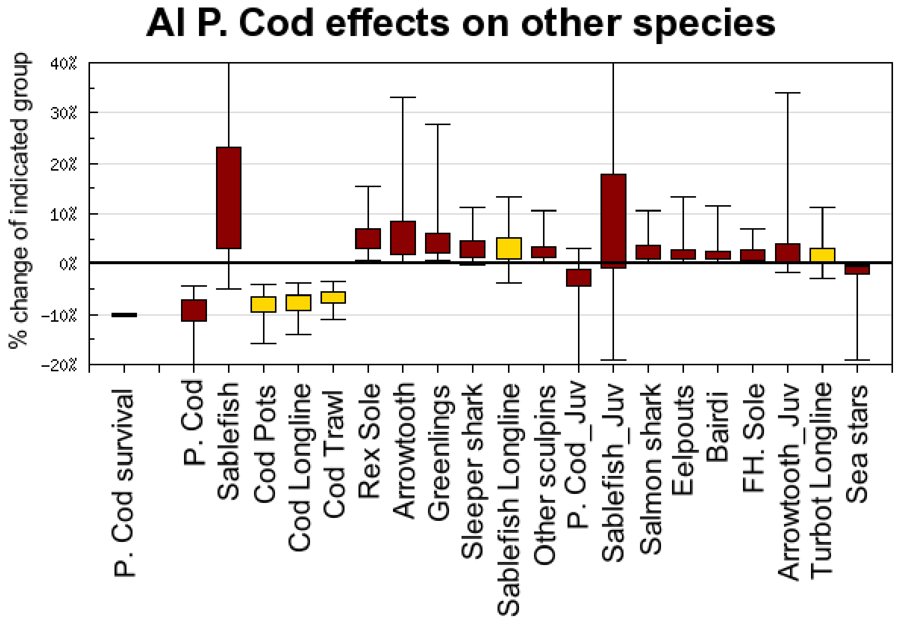
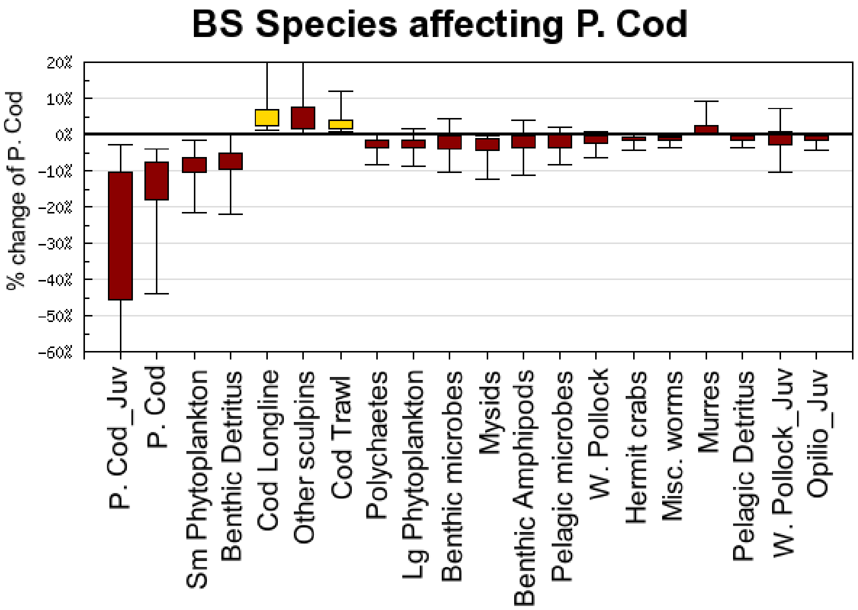


Figure 5. Effect of changing cod survival on fishery catch (yellow) and biomass of other species (dark red): EBS (top) and AI (bottom), from a simulation analysis where cod survival was decreased by 10% and the rest of the ecosystem adjusted to this decrease for 30 years. Boxes show resulting percent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



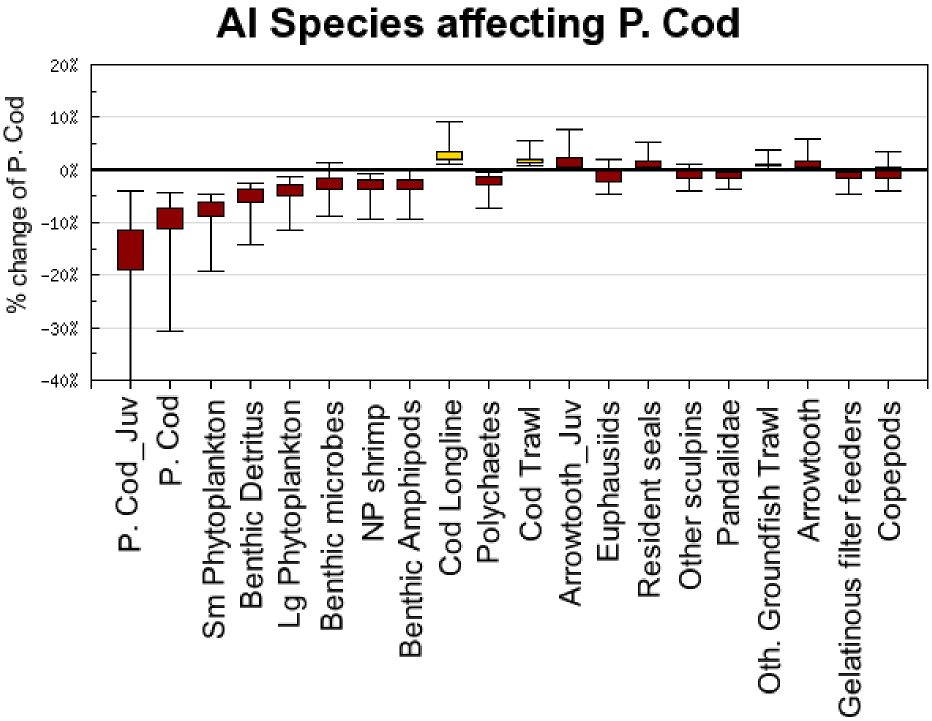
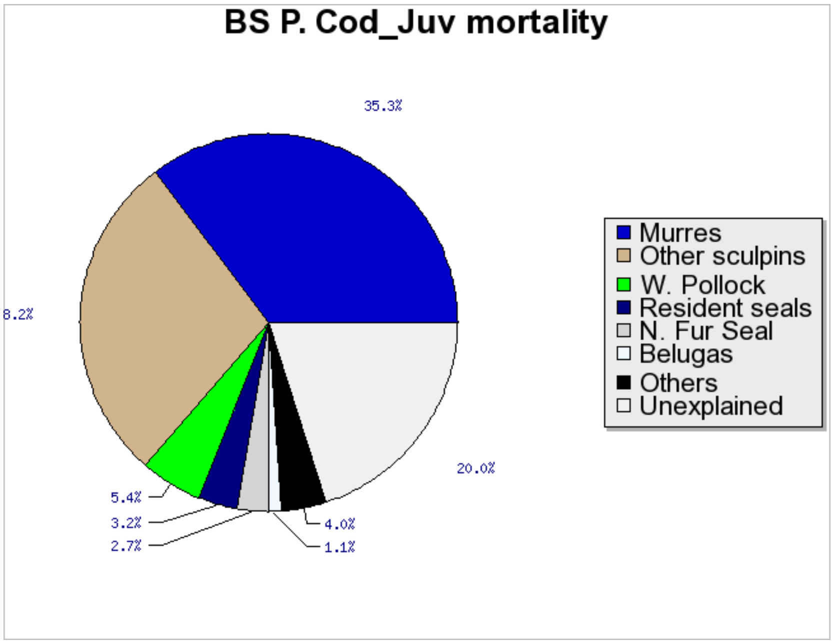


Figure 6. Effect of reducing fisheries catch (yellow) and other species survival (dark red) on cod biomass: EBS (top) and AI (bottom), from a simulation analysis where survival of each X axis species group was decreased by 10% and the rest of the ecosystem adjusted to this decrease for 30 years. Boxes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



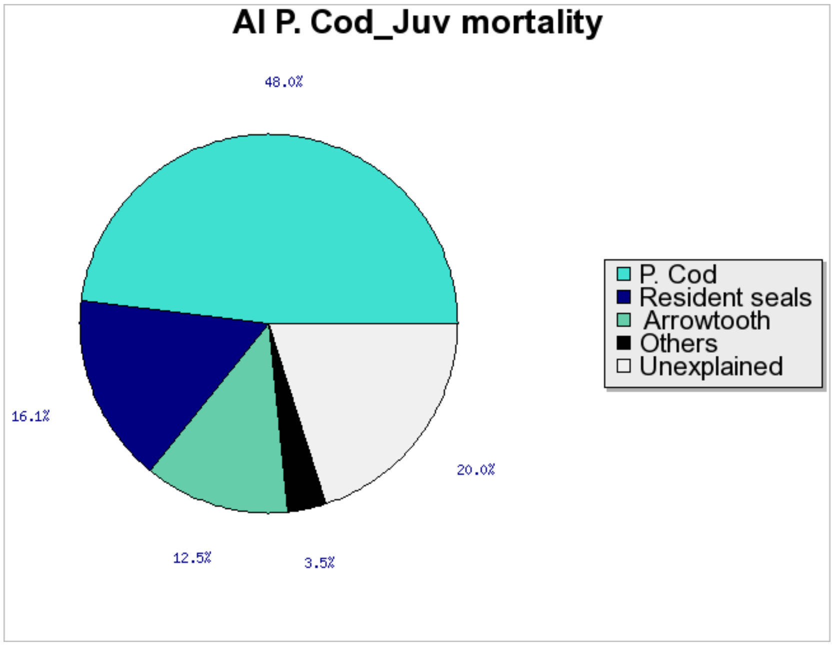


Figure 7. Juvenile cod mortality sources: EBS (top) and AI (bottom). Mortality sources reflect juvenile cod predator diets estimated from stomach collections taken aboard NMFS bottom trawl surveys in 1991 (EBS) and in 1991-1994 (AI), cod predator consumption rates estimated from stock assessments and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

Annex A

Diet composition calculations

Notation:

DC = diet composition

W = weight in stomach

n = prey

p = predator

s = predator size class

h = survey haul

r = survey stratum

B = biomass estimate

v = survey

a = assessment

R = ration estimate

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

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

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

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

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

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

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

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

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

Ration Calculations

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

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

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

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

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

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

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

From measurements of body weight and age, equation 2 can be used to fit four parameters (W_∞ , d, k, and t_0) and the relationship between W_∞ and the H, k, and d parameters can then be used to determine the consumption rate $H \cdot W_t^d$ for any given age class of fish. For these calculations, weight-at-age data available and specific to the modeled regions were fit by minimizing the difference between log(observed) and log(predicted) body weights as calculated by minimizing negative log likelihood:

observation error was assumed to be in weight but not aging. A process-error model was also examined but did not give significantly different results.

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

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

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

To obtain absolute consumption (Q) for a given age class, the additional parameter A is required to account for indigestible and otherwise unassimilated portions of prey. We noted that the range of indigestible percentage for a wide range of North Pacific zooplankton and fish summarized in Davis (2003) was between 5-30%, with major zooplankton (copepods and euphasiids), as well as many forage fish, having a narrower range of indigestible percentages, generally between 10-20%. Further, bioenergetics models, for example for walleye pollock (Buckley and Livingston 1994), indicate that nitrogenous waste (excretion) and egestion resulted in an additional 20-30% loss of consumed biomass. As specific bioenergetics models were not available for most species, we made a uniform assumption of a total non-respirative loss of 40% (from a range of 25-60%) for all fish species, with a corresponding A value of 0.6.

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

Production rates

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

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

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

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

References

Aydin, K.Y. 2004. Age structure or functional response? Reconciling the energetic of surplus production between single species models and ecosim. Ecosystem approaches to fisheries in the Southern Benguela, African Journal of Marine Science 26: 289-301.

Allen, K.R. 1971. Relation between production and biomass. Journal of the Fishery Research Board of Canada 28: 1573-1581.

Buckley, T. W., and Livingston, P. A. 1994. A bioenergetics model of walleye pollock (*Theragra chalcogramma*) in the Eastern Bering Sea: structure and documentation. U.S. Department of Commerce, NOAA Tech. Memo. NMFS-AFSC-37.

Davis, N. D. 2003. Feeding ecology of Pacific salmon (*Oncorhynchus* spp.) in the central North Pacific Ocen and central bering Sea, 1991-2000. Ph.D. Dissertation, Hokkaido University, Hakodate, Japan.

Essington, T.E., J.F. Kitchell, and C.J. Walters, 2001. The von Bertalanffy growth function, bioenergetics, and the consumption rates of fish. Canadian Journal of Fisheries and Aquatic Science 58: 2129-2138.

Paloheimo, J.E., and L.M. Dickie. 1965. Food and growth of fishes. I. A growth curve derived from experimental data. J. Fish. Res. Board Can. 22: 521–542.

Attachment 2.2: An exploration of alternative models of the Bering Sea Pacific cod stock

Grant G. Thompson, James N. Ianelli, and Robert R. Lauth

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

Last year's assessment of the Pacific cod (*Gadus macrocephalus*) stock in the Bering Sea and Aleutian Islands region (Thompson et al. 2007) generated comments from the Plan Team, SSC, and public. In addition, recent versions of Stock Synthesis provide opportunities to explore new possibilities for the assessment. This document represents an effort to respond to the requests of the Plan Team, SSC, and public and to explore new features of Stock Synthesis for possible use in this year's assessment.

Five models are presented here. Model 1 is identical to Model 1 from last year's assessment. Models 2 and 3 respond to requests made by the Plan Team. Model 4 is identical to Model 4 from last year's assessment, and is included here in response to requests from members of the public. Model 5 uses some of the newly available features of Stock Synthesis, and addresses Plan Team comments to some extent.

BSAI Plan Team Comments

"Rather than estimating all three parameters, it would be worth exploring a model with fixed L_{inf} at an externally estimated value and let the model estimate $L1$ and K because that selectivity has more impacts on the observed sizes of young fish than those of older fish, especially when an asymptotic selectivity curve is used." Model 2 uses an externally estimated value of $L2$ (the length of 20-year old fish).

"Estimated selectivity curves appear reasonable, except that IPHC longline survey selectivity curve is peaked and thus not differentiable (increasing the number of parameters from 4 to 6 parameters still doesn't overcome stated problems with estimating selectivity in stock synthesis)." This comment is addressed in the "Estimates of Parameters, Length at Age, and Selectivity at Length or Age" section.

"Recommendation for future assessments: Use 3-parameter exponential-logistic (Thompson 1994) to represent selectivity." While the exponential-logistic selectivity curve is not available as an option in Stock Synthesis, Model 3 assumes a simplified form of the selectivity curve used in last year's assessment.

"The Team recommended reducing the number of parameters in the models." Model 3 is intended to address this recommendation.

GOA Plan Team Comments of Potential Relevance for the BSAI Assessment

"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 5 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 5 vary seasonally.

"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 5 defines selectivity schedules in terms of fishery-specific blocks of years.

SSC Comments

"Age data are usually much more informative than size data and therefore should not be set aside absent clear evidence of bias. Some questions have been raised about the cod age data, but the readings have been reconsidered and rechecked by the AFSC age readers, and they stand by them. We rely on ages read the same way in other assessments. We should continue to rely on the cod ages until we find something more than circumstantial evidence of a bias." Age data are used in Models 1, 2, 3, and 5. Model 4 does not use age data.

"While endorsing Model 1 in principle, we accept the point made in public testimony that Model 1 overestimates historical recruitment because the recruitment time series effectively includes the estimates of recruitment used to construct initial conditions, and therefore are outside the intended range of recruitments (1977-present). In addition, estimates are complicated by other features of the way that the SS2 software initializes the 1977 stock." This concern is addressed in Model 5 and in the Discussion

"The SSC continues to support the idea of estimating a fixed natural mortality rate external to the assessment on the basis of life history theory. In the next assessment we would like to see some discussion of the alternatives considered for estimating *M* outside the model and the rationale for the author's choice." This request is addressed in the "Parameters Estimated Independently" section.

Data

The data used in the models presented here are identical to the data used in last year's final assessment. Relative abundance data are available from the NMFS bottom trawl survey and the IPHC longline survey. Because of a gear change in 1982, the NMFS bottom trawl survey data are split into two portions, one spanning the years 1979-1981 and the other spanning the years 1982-2007. Survey abundance is measured in units of individual fish (not biomass). Fishery data are stratified by gear type (trawl, longline, and pot) and season (Jan-May, Jun-Aug, and Sep-Dec), giving a total of nine fisheries. Catch data from all nine fisheries are included. Catch per unit effort data from all nine fisheries are also included for comparative purposes, but are not used in statistical estimation of parameters. Size composition data from all surveys and fisheries are included. Age data from the bottom trawl survey are included and used in Models 1-3 and Model 5, but not in Model 4.

Analytic Approach

Model Structure

Assessment Software

Last year's assessment was conducted using Stock Synthesis 2, version 2.00i. The nomenclature pertaining to revisions of the Stock Synthesis (SS) program has since been modified, with new versions taking labels of the form "SS-Vm.nnx." The models presented here were run under SS-V3.01f. This version of SS includes two new features that will be explored here:

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

As noted in the Introduction, five models are presented here. Table 2.2.1 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 of Model 1 for which the specification in Model 2, 3, 4, or 5 is different than the specification in Model 1. The column labeled "Model 1" shows how each listed feature is specified in Model 1. The remaining columns show model-specific differences with respect to Model 1 (a blank in one of these columns indicates that the feature associated with that row is unchanged with respect to Model 1).

Model 1 is identical to Model 1 from last year's assessment, which was endorsed by the SSC "in principle."

Model 2 is identical to Model 1, except that it responds to the BSAI Plan Team's request to fix parameter *L2* (length at age 20) outside the model. The maximum likelihood estimate of *L2* based on the bottom trawl survey age data is 93.75 cm.

Model 3 is identical to Model 1, except that it responds to the BSAI Plan Team's requests to use a simpler selectivity curve and to reduce the number of parameters overall. The Plan Team felt that the selectivity function (pattern 24) used in last year's assessment was too complicated, and suggested that a simpler functional form be tried, specifically, the exponential-logistic selectivity curve described by Thompson (1994). However, the exponential-logistic form is not available in Stock Synthesis. Instead, Model 3 uses a special case of selectivity pattern 24, defined by fixing all of the parameters except for the peak location and the selectivity of the largest (oldest) fish. Note that log catchability for the post-1981 bottom trawl survey is fixed at a value of -0.60 in Model 3 (Table 2.2.1), even though the Plan Team request that prompted development of Model 3 did not suggest fixing this parameter. However, if left free, catchability would tend toward unreasonably low values. The fixed value of -0.60 was chosen because, when fixed at this value, Model 3 results in an average value of 0.47 for the product of catchability and selectivity across the 60-81 cm range, which corresponds to the value estimated by Nichol et al. (2007),

Model 4 is identical to Model 4 from last year's assessment, and is included here in response to requests from members of the public. It differs from Model 1 with respect to 14 features (Table 2.2.1). Among these are the specification of a different starting year for the model, disuse of age composition data, and internal estimation of the natural mortality rate.

Model 5 uses the newly available features of SS listed above, addresses BSAI Plan Team concerns regarding complexity of the selectivity function to some extent, and addresses GOA Plan Team comments regarding season-specific weight at length and time-varying fishery selectivity.

To reduce the complexity of the selectivity function, Model 5 sets a lower bound of 5.0 on the descending “width” parameter (Table 2.2.1). 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.

To incorporate time-varying fishery selectivity in Model 5, the following algorithm was used to determine the breakpoints in the time series:

7. 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.
8. Compute the value of Akaike’s Information Criterion (AIC) for the provisional block structure.
9. Find the fishery with the smallest average input sample size, then fit models with the following three block structures:
   a. “10-year” blocks: 1977-1979, 1980-1989, 1990-1999, and 2000-2007.
   b. “20-year” blocks: 1977-1989, 1990-2007
   c. Single block: 1977-2007
10. 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.
11. Find the fishery with the next smallest average input sample size, then repeat steps 3 and 4. Once all fisheries have been explored, the provisional block structure becomes the final block structure.

The above algorithm is only one part of a larger iterative process used to configure Model 5. Other aspects of the model structure determined iteratively were the following:

1. The scale parameter of the log recruitment deviation distribution, σ_R, was set equal to the standard deviation of the estimated log recruitment deviations over the period 1977-2006 (the current environmental regime).
2. The number of freely estimated elements in the initial numbers-at-age vector was determined by minimum AIC.
3. The option used to define variability in length at age (of which SS provides four), was determined by maximum likelihood.
4. The variability in length at the first reference age, *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*).

As with models developed in last year’s assessment, Model 5 forces certain fishery selectivity schedules to be asymptotic. Specifically, Model 5 forces all selectivity schedules for the trawl fishery to be asymptotic (this choice was made by determining which gear type came closest to exhibiting asymptotic selectivity in the unconstrained case). This is a bit different from the assumption used to develop last year’s models, where a gear type could exhibit asymptotic selectivity in 1, 2, or all 3 seasons.

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 5. Therefore, the only parameters discussed in this section are the natural mortality rate (per request of the SSC) and the parameters governing the weight-at-length schedule in Model 5.

Natural Mortality

In the model accepted last year by the Plan Team and SSC, *M* was set at a value of 0.34, based on an age at maturity of 4.9 years (Stark 2007) and Jensen's (1996) formula.

During public comment on last year's assessment, an external reviewer provided a set of alternative estimates for *M*. The alternative estimates were as follow:

Method	Citation	Data used	Estimate of *M*
regression	Hoenig (1983)	maximum age = 19	0.22
regression	Gunderson (1997)	GSI = 0.0848	0.15
regression	Gunderson et al. (2003)	*K* from Model 1, 2007 SAFE	0.34
regression	Gunderson et al. (2003)	*K* from Model 2, 2007 SAFE	0.35
regression	Gunderson et al. (2003)	*K* from Model 3, 2007 SAFE	0.32
regression	Gunderson et al. (2003)	*K* from Model 4, 2007 SAFE	0.37
tagging	Munro (pers. commun.)	2002 FIT study	0.40
tagging	Munro (pers. commun.)	2003 FIT study	0.50

In response, the SSC asked that the 2008 assessment include some discussion of the alternatives considered for estimating *M* outside the model and the rationale for the authors' choice. Absent precise knowledge of the true value of *M*, it is not possible to prove the accuracy of any indirect estimate of *M*, such as the one obtained by Jensen's (1996) formula or any of the estimates in the above table. However, some caveats and possible sources of bias pertaining to the various methods can be described.

To being with, it should be remembered that each of the regression methods is based on a set of *M* values estimated previously by various methods. Many of the *M* estimates in the respective data sets are old and were estimated using methods that would be considered questionable today. For example, Hoenig's data were obviously generated before his study was published in 1983. Gunderson's (1997) data set included estimates of *M* published as far back as 1957, with an average publication date of 1978. Gunderson et al. (2003) used the data set published by Pauly in 1980. With regard to this problem, Gunderson et al. state (p. 181):

> "Nevertheless, many of the original data points on which these relationships are based have become outdated as improved methods of age determination and stock assessment have come into wide usage...."

If the above shortcoming can be overlooked, the overall conclusion from the regression-based estimates is that it appears unlikely for *M* to be much greater than the value obtained last year by Jensen's (1996) method (0.34). Of the six regression-based estimates in the above table, only two (0.35 and 0.37) exceed 0.34, and both of those are within 10% of 0.34. Two factors suggest that this pair of values does not provide strong evidence in favor of a natural mortality rate higher than 0.34: First, they rely on stock assessment models that were rejected by the SSC. Second, they involve application of the formula derived by Gunderson et al. (2003), but the authors of that study suggest that their method probably tends to overestimate *M* (p. 179):

> "Although Pauly's database is the most extensive (in terms of the number of stocks available), age determination and stock assessment methods have improved in the years since it was initially compiled, and estimates of *M* have tended to decline. An updated database would probably reduce the estimates of *M* based on *K*."

Regarding the two tagging-based estimates, the fact that they are very different from each other might call their reliability into question, or at least suggest that they have large variances. The following caveat was provided by P. Munro (AFSC, pers. commun., 8/22/08):

> "The tagging estimates are quite biased due to violation of the assumption that the population of tagged fish had adequately mixed among the general population. Tagged fish were released in a very small area, during a very narrow window of time, rather than throughout the geographic range of the exploited population. Furthermore, the tagged fish were released in very close proximity to heavy trawling and in relatively close proximity to longlining, leading to much higher return rates than would have been had mixing occurred."

In choosing a method for estimating *M*, it should be kept in mind that the use of Jensen's (1996) method in last year's assessment was in direct response to an SSC request from October, 2007, in which the SSC asked that *M* be set at a "fixed value based on life history theory (i.e., the value of *M* for which the observed growth and maturity schedules are optimal)." Jensen's (1996) method is both firmly rooted in life history theory and widely used. According to the *Web of Science*, this paper has been cited 76 times in the peer-reviewed literature since its publication (as of September 2, 2008). Given these considerations and the potential shortcomings of the other methods considered to date, it seems appropriate to use Jensen's method until a better alternative becomes available.

Weight at Length

In recent assessments, bottom trawl survey data were used to estimate the multiplicative constant α and exponent β at values of 3.86×10^{-6} and 3.266, respectively. Models 1-4 continue to use this pair of values.

For Model 5, 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 for the purpose of providing a Bering Sea model that parallels the structure of the new model presented in this year's preliminary GOA Pacific cod assessment, which was developed 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:	6.959×10^{-6}	5.854×10^{-6}	5.406×10^{-6}	6.536×10^{-6}
β:	3.136	3.169	3.199	3.150
Samples:	40,682	8,304	13,293	62,279

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 2.2.1. Although the curves are virtually indistinguishable by eye, the seasonal model gives a statistically significant improvement (AIC = 58,095 for the annual model; AIC = 57,750 for the seasonal model).

For this preliminary investigation of seasonally varying weight at length, data from both the Bering Sea and Aleutian Islands region were used. For the final assessment, consideration will be given to using data from the Bering Sea only.

Parameters Estimated Conditionally

Parameters estimated within SS include the natural mortality rate (Model 4 only), length-at-age parameters (except that *L2* is estimated independently in Model 2), parameters governing variability in length at age, log mean recruitment under one environmental regime (Model 4) or two environmental regimes (Models 1-3 and Model 5), annual fishing mortality rates, bottom trawl survey catchability in the pre-1982 portion of the time series (Models 1-3 and Model 5), bottom trawl survey catchability in the post-1981 portion of the time series, selectivity parameters (see below), annual recruitment deviations, and annual deviations in one (Models 1-3 and Model 5) or two (Model 4) parameters governing the ascending limb of the trawl survey selectivity schedule.

As in last year's assessment, pattern 24 is used to describe the selectivity function. 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 2.2.1). 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 maximum likelihood value. The main exceptions were 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.

For Model 1 and Model 5, one parameter that was fit neither independently nor within SS is the scale parameter of the log recruitment residual distribution, σ_R. In Model 1, σ_R was estimated iteratively as the standard deviation of log recruitment residuals across the entire time series (1974-2006), whereas in Model 5 it was estimated iteratively as the standard deviation of log recruitment residuals under the current environmental regime (1977-2006). In Models 2 and 3, σ_R was set at the value estimated in Model 1. In Model 4, σ_R was fixed independently at an assumed value of 0.60.

Results

Goodness of Fit

Table 2.2.2 compares negative log likelihood values across models, on a component-by-component basis. For each component, the cell for the model with the lowest (best) value is shaded green, and the cell for the model with the highest (worst) value is shaded pink. Overall, Model 5 has much lower total negative log likelihood than any of the other models, and has the lowest value of all the models in 9 out of the 19 components, while Model 3 has the highest negative log likelihood of all the models, and has the highest value of all the models in 10 out of the 19 components. However, it should be emphasized that likelihoods are not strictly comparable across models. For example, Model 4 does not attempt to fit relative abundance from the pre-1982 bottom trawl survey, size composition from the pre-1982 bottom trawl survey, age composition from the post-1981 bottom trawl survey, or initial catch. Also, negative log likelihoods for the recruitment component are not comparable across models because Models 1-3, 4, and 5 use different values for σ_R and because Model 4 estimates a smaller number of year classes than the other models.

Table 2.2.2 also shows the number of parameters in each model. Model 3 has the fewest parameters (103), and Model 5 has the most (215). Model 5 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 2.2.3a compares average input sample sizes and average "effective" sample sizes for the size composition and age composition data. Input sample sizes were the same as in last year's assessment, where the overall average was 300 for both size and age composition data. The upper portion of the table shows the mean of the ratios (effective:input), and the lower portion of the table shows the ratio of the means. For each component, the cell for the model with the highest (best) value is shaded green, and the cell for the model with the lowest (worst) value is shaded pink. By either measure, Model 5 tends to give the highest values, and Model 3 the worst.

None of the models fits the age composition very well (Model 4 does not attempt to fit these data). Table 2.2.3b shows the year-by-year values of the ratio between effective sample size and input sample size for the age composition data, with the same color coding conventions as Table 2.2.3a. None of the ratios exceeds unity for any model in any year except 2006. In 2006, Models 1-3 and Model 5 all succeed in producing a ratio greater than unity.

Figure 2.2.2 shows how the five models fit the various sets of relative abundance data. Figure 2.2.2a shows the fits to the trawl fishery CPUE data by season, Figure 2.2.2b shows the fits to the longline fishery CPUE data by season, Figure 2.2.2c shows the fits to the pot fishery CPUE data by season, and Figure 2.2.2d shows the fits to the pre-1982 bottom trawl survey, post-1981 bottom trawl survey, and IPHC longline survey data. It should be emphasized that the models are not attempting to fit the fishery CPUE data or the IPHC longline survey data; these are shown for comparative purposes only. Although it may be difficult to see much difference between the fits to the post-1981 bottom trawl survey, Model 5's negative log likelihood for this component is more than 15 points lower than its closest competitor (Model 4).

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

Table 2.2.4 shows estimates of some parameters common to most of the models, with accompanying standard deviations. Some of the points to note in Table 2.2.4 are the following:

1. As in last year's assessment, the value of M estimated in Model 4 (0.46) is much higher than the value assumed in the other models (0.34).
2. Fixing the value of $L2$ in Model 2 resulted in little change from Model 1, because the fixed value used in Model 2 (93.75) is almost identical to the value estimated in Model 1 (94.03), and it is easy for the other estimated parameters to compensate for the minor difference in $L2$ values.
3. The spread around the length-at-age curve at young ages is highest under Model 4.
4. Model 5 produces a lower estimate of σ_R than Models 1-3, but it is slightly higher than the value assumed in Model 4.

5. The initial equilibrium fishing mortality rate is much higher under Model 4 than any of the other models, although it pertains to the age composition in 1982, as opposed to 1977 in the other models.
6. The estimates of pre-1982 and post-1981 bottom trawl survey catchability produced by Model 5 are higher than the respective estimates produced by the other models (although it should be noted that the value of the post-1981 catchability in Model 3 was assumed, not estimated).

Figure 2.2.3 describes the length-at-age relationship. The upper panel shows the long-term size composition from the post-1982 bottom trawl survey over the 0-50 cm range, indicating three fairly distinct modes. The lower panel shows the length-at-age schedules estimated by the five models. The model-specific curves show a high degree of overlap through about age 5, then Model 4 tends to produce slightly higher lengths at age than Models 1-2 and 5, while Model 3 tends to produce slightly lower lengths at age than Models 1-2 and 5. The lengths at ages 1, 2, and 3 from all five models pass through the first three modes from the long-term bottom trawl survey size composition (horizontal dashed lines). For comparison, the lower panel also shows the mean lengths at age from the AFSC age reading unit (with 95% confidence intervals). However, these data are not used in any of the models, as it was determined in the process of developing last year’s assessment that it was more important to fit the first three survey size modes than the mean lengths in the age data.

Figure 2.2.4 shows how survey selectivity is estimated by the five models. Figure 2.2.4a shows pre-1982 bottom trawl survey selectivity for 2007 as estimated by Models 1-3 and Model 5 (upper panel), post-1981 bottom trawl survey for 2007 as estimated by all five models (middle panel), and IPHC longline survey selectivity as estimated by all five models (lower panel). Because Models 1-3 and Model 5 view bottom trawl selectivity as a function of age while Model 4 views it as a function of age, the selectivity for Model 4 shown in the middle panel is inferred from Model 4’s estimated selectivity at length schedule for 2007 and Model 4’s estimated age at length distribution for 2007. In addition to showing the estimated selectivities for the IPHC longline survey, the lower panel also shows the size composition (labeled “relative catch”) from the 2007 IPHC survey (the only year available). Note that the shape of the size composition explains the “peaked” nature of the selectivity curve that concerned the BSAI Plan Team.

Figures 4b-4f show annual pre-1982 and post-1981 bottom trawl survey selectivity schedules for Models 1-5, respectively (except that Model 4 does not estimate pre-1982 schedules). These schedules are in terms of age for Models 1-3 and Model 5, and in terms of length for Model 4. Note that Models 1-3 and Model 5 assume that age 0 fish are completely unselected, while Model 4 allows selectivity at minimum size to be a free parameter.

Figure 2.2.5 compares fishery selectivity schedules across models. Figures 5a-5c show season- and model-specific selectivity schedules for the trawl, longline, and pot fisheries, respectively. Because Model 5 allows fishery selectivity to vary between fishery-specific blocks of years, Model 5 typically associates several selectivity schedules with any fishery/season combination. Models 1-4, in contrast, assume that fishery selectivity is time invariant. For the purpose of constructing Figures 5a-5c, the selectivity schedules for 2007 were chosen to represent Model 5.

Figure 2.2.6 completes the set of selectivity schedules for Model 5 by showing the full set of fishery-specific, season-specific, and block-specific selectivity schedules. Figures 6a-6c show the schedules for the trawl, longline, and pot fisheries, respectively.

Estimates of Time Series

Figure 2.2.7 shows how the five 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. Values along the horizontal axes have been staggered slightly to reduce overplotting.

In terms of female spawning biomass (upper panel of Figure 2.2.7), the qualitative shapes of all the trajectories are similar, showing a peak around 1985, a steady decline to about 1993, followed by very gradual fluctuations thereafter. All five models indicate that the trend since 2005 has been downward. Overall, Models 1 and 2 are nearly identical, while Model 3 is consistently higher than Models 1-2 and Model 4 is consistently lower than Models 1-2. Model 5 is very close to Model 4 in the early part of the time series (to about 1990), and very close to Models 1-2 in the late part of the time series (from about 1998 onward).

In terms of log recruitment deviations (middle panel of Figure 2.2.7), the trajectories from all five models are similar from 1977 onward, except that Model 4 is slightly but consistently higher than the others from 2000 onward. To interpret these time series, it is important to remember that they represent log recruitment *deviations* rather than log recruitments per se. In other words, the deviations are expressed relative to their respective regime-specific log median. Depending on the model, the log median for 1974-1976 is between 1.4 and 1.7 units lower than the log median for 1977-2006. This makes no difference for Model 4, which does not estimate individual recruitments from the pre-1977 regime.

For the most part, the models are in agreement that the year classes spawned between 2001 and 2005 are below average, as the point estimates are almost all negative and almost none of the 95% confidence intervals extend into the positive domain. The exceptions are these: The 95% confidence interval for the 2005 year class under Model 3 extends into the positive domain (although the point estimate is negative), and the point estimates for the 2002 and 2005 year classes under Model 4 are positive (although the 95% confidence intervals extend into the negative domain in both cases).

In terms of annual exploitation rates (lower panel of Figure 2.2.7), the qualitative shapes of the trajectories are again similar. All five trajectories are higher, on average, across the 1994-2007 time period than across the 1977-1993 time period. Model 3 estimates lower exploitation rates than the other models in all years, while Model 5 estimates higher exploitation rates than the other models in all years except 1998-2003. Note that the initial equilibrium fishing mortality rate estimated by Model 4 (0.73, Table 2.2.4) is over 5 times as high as the average exploitation rate estimated by that model, and nearly 3 times as high as the highest exploitation rate estimated by that model.

Finally, Figure 2.2.8 shows the trajectories of total (age 0+) biomass estimated by all five models. The relationships between the trajectories are broadly similar to those for female spawning biomass shown in the upper panel of Figure 2.2.7. The time series of survey biomass estimates is also shown for comparison. Because all five models estimate (or assume, in the case of Model 3) that catchability for the post-1981 bottom trawl survey is substantially less than unity, all of the model trajectories tend to lie well above the survey biomass for the period from 1982 onward, the only exception being 1994, when the survey produced a biomass estimate that was more than twice the previous value.

Discussion

Estimation of Average Recruitment

As noted in the Introduction, the SSC has expressed some concerns regarding the estimation of average recruitment: "While endorsing Model 1 in principle, we accept the point made in public testimony that Model 1 overestimates historical recruitment because the recruitment time series effectively includes the estimates of recruitment used to construct initial conditions, and therefore are outside the intended range of recruitments (1977-present). In addition, estimates are complicated by other features of the way that the SS2 software initializes the 1977 stock." The following paragraphs address these concerns.

First, some background and notation: Suppose that log recruitments are drawn randomly from a normal distribution with mean μ_R and standard deviation σ_R. The log of the expected value of recruitment, R_0, is then equal to $\mu_R+\sigma_R^2/2$. However, instead of viewing μ_R and σ_R as the parameters of the distribution, it is also possible to use R_0 and σ_R to parameterize the distribution. This is the convention used by SS. In this alternative parameterization, μ_R is computed as $R_0-\sigma_R^2/2$.

Model 1 in last year's assessment used 1977 as the starting year. In addition to the recruitments spawned in 1977-2006, Model 1 also estimated recruitments for 1974-1976, corresponding to ages 1-3 in the initial (1977) vector of numbers at age. However, the recruitments for 1974-1976 were spawned during the previous environmental regime, and so might be expected to be drawn from a different distribution than the recruitments for 1977-2006. The potential for the 1974-1976 and 1977-2006 recruitments to come from two different distributions was addressed in last year's assessment by use of an SS feature that allowed the value of R_0 to change between environmental regimes. Model 1 in last year's assessment estimated R_0 for the current environmental regime at a value 0f 13.593 and σ_R at a value of 0.78, giving $\mu_R=13.289$. These parameters correspond to an average recruitment (in 1000s of fish) equal to exp(13.593)=800,000. However, the average of the individual estimated recruitments from 1977 to 2006 (in 1000s of fish) was only 657,000, about 18% less than the parametric estimate. The primary reason for the discrepancy lies in the way that last year's version of SS viewed the vector of log recruitment deviations (i.e., the difference between log recruitments and μ_R).

Although last year's version of SS allowed *recruitments* in the two environmental regimes to be drawn from distributions with two different means, it still assumed that the *deviations* all came from a single distribution with mean zero and standard deviation σ_R. While the estimated deviations for the entire time series in Model 1 did indeed have mean zero and standard deviation σ_R, the sample means and standard deviations for the portions of the time series corresponding to the previous and current environmental regimes were somewhat different: The estimated deviations for the 1974-1976 cohorts (spawned under the old regime) had a sample mean $\mu_{old}=1.218$ and a sample standard deviation $\sigma_{old}=0.91$, while the estimated deviations for the 1977-2006 cohorts (spawned under the new regime) had a sample mean $\mu_{new}=-0.122$ and a sample standard deviation $\sigma_{new}=0.66$. Although neither the sample mean nor the sample standard deviation from the 1977-2006 deviations is significantly different (at the 5% level) from the null hypotheses $\mu_{new}=\mu_R=0$ and $\sigma_{new}=\sigma_R=0.78$, if these sample statistics are in fact reflective of regime-specific parameters, they would imply an expected recruitment significantly different from the value of 800,000 estimated by SS. Specifically, if the sample mean and standard deviation from the estimated 1977-2006 deviations were the true values of a set of regime-specific parameters, then the expected value of recruitment (in 1000s of fish) for the new regime would be estimated as $\exp(\mu_R+\mu_{new}+\sigma_{new}^2/2)=\exp(13.289-0.122+0.66^2/2)=650{,}000$. The difference between this value and the average of the estimated recruitments (657,000) is small enough to be attributable to sampling variability.

Model 5 uses a newly available feature of SS that should avoid the ambiguity described above. By making use of the new ability to specify two separate deviation vectors, one for each environmental regime, and by basing the estimate of σ_R on the post-1976 cohorts only, it will necessarily be the case that $\mu_{new}=0$ and $\sigma_{new}=\sigma_R$, meaning that $\exp(R_0)$ will likely be very close to the average of the estimated post-1976 recruitments. In fact, for Model 5, $\exp(R_0)$=565,000 and the average of the estimated post-1976 recruitments is also 565,000.

Outstanding Issues

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. Given that Model 1 was endorsed “in principle” last year, should it be retained without modification, except as necessary to address the issue of average recruitment?
2. Does fixing *L2*, as in Model 2, result in any significant improvement?
3. Given that the exponential-logistic selectivity function is not currently an option in SS, can one or more parameters of selectivity pattern 24 be fixed so as to approximate the exponential-logistic; or, more specifically, are the fixed values used in Model 3 appropriate?
4. Does Model 4 contain features that should be used in one or more other models?
5. Is the lower bound of 5.0 on selectivity parameter #4 specified in Model 5 appropriate for surveys, fisheries, both, or neither?
6. Is the algorithm used in Model 5 to specify selectivity blocks appropriate?
7. Does the method used in Model 5 to estimate σ_R and to specify regime-specific log recruitment deviation vectors satisfactorily address the issue of average recruitment?

References

Gunderson, D.R. 1997. Trade-off between reproductive effort and adult survival in oviparous and viviparous fishes. *Canadian Journal of Fisheries and Aquatic Sciences* 54:990-998.

Gunderson, D.R., M. Zimmermann, D.G. Nichol and K. Pearson. 2003. Indirect estimates of natural mortality rate for arrowthooth folounder (*Atheresthes stomias*) and darkblotched rockfish (*Sebastes crameri*). *Fishery Bulletin* 101: 175-182.

Hoenig, J.M. 1983. Empirical use of longevity data to estimate mortality rates. *Fishery Bulletin* 82(1):898-903.

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.

Pauly, D. 1980. On the interrelationships between natural mortality, growth parameters, and mean environmental temperature in 175 fish stocks. *Journal du Conseil International pour l’Exploration de la Mer* 39:175–192.

Thompson, G. G. 1994. Confounding of gear selectivity and the natural mortality rate in cases where the former is a nonmonotone function of age. *Canadian Journal of Fisheries and Aquatic Sciences* 51:2654-2664.

Thompson, G. G., J. N. Ianelli, M. W. Dorn, S. Gaichas, and K. Aydin. 2007. 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.

Table 2.2.1. Features distinguishing the five models (columns for Models 2-5 list differences with respect to Model 1).

Feature	Model 1	Model 2	Model 3	Model 4	Model 5
Estimation of length at age 20	Internal	External			
Post-1981 trawl survey log catchability	Estimated		Fixed at -0.60		
Fixed fishery selectivity parameters	P5=-10		P2=P5=-10,P3=P4=5		
Fixed survey selectivity parameters	P5=-10		P2=P5=-10,P3=P4=5	P2=P4=0,P6=10	
Starting year	1977			1982	
Age data used?	Yes			No	
Effects of regime shift modeled?	Yes			No	
Initial catch used in estimation of initial F?	Yes			No	
Basis of maturity schedule	Age			Length	
Basis of bottom trawl survey selectivity	Age			Length	
Time-varying survey selectivity parameters	P3			P3, P5	
Std. dev. of selectivity parameter "devs"	0.2			0.4	
Estimation of natural mortality rate	Fixed at 0.34			Estimated	
Spread of length-at-age distribution	SD=f(L@age)			SD=f(age)	
Std. dev. of log-scale recruitment "devs" (σ_R)	Iterative			Fixed at 0.6	
Fisheries with forced asymptotic selectivity	2,3,5,9			2,3,5,6,8,9	1
Recruitment "devs" used to estimate σ_R	1974-2006			Not applicable	1977-2006
Number of recruiment "dev" vectors	1				2 (pre- and post-shift), but 1 σ_R
First length-at-age reference age	1				1.5417 (survey mid-point)
Data source used to estimate weight at length	Surveys				Fisheries
Variation in weight-at-length parameters	None				Seasonal
Variation in fishery selectivity	None				Fishery-specific blocks of years
Lower bound on selectivity parameter P4	-10				5

Fishery	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

Selectity parameter	Definition	Units
P1	First size (age) at which selectivity=1	cm (years)
P2	Last size (age) at which selectivity=1	logit transform over the range P1 to max. length (age)
P3	Scale of ascending limb	ln(normal variance) + ln(2)
P4	Scale of descending limb	ln(normal variance) + ln(2)
P5	Selectivity at minimium size (age)	logit transform over the range 0 to 1
P6	Selectivity at maximum size (age)	logit transform over the range 0 to 1

Table 2.2.2. Comparison of objective function values (green = row minimum, pink = row maximum).

Type	Fleet	Model 1	Model 2	Model 3	Model 4	Model 5
Relative abundance	Pre-82 bottom trawl survey	4.17	4.00	6.37	n/a	7.84
Relative abundance	Post-81 bottom trawl survey	67.52	67.98	87.61	60.50	44.67
Size composition	Jan-May trawl fishery	480.72	480.64	684.15	504.15	397.03
Size composition	Jun-Aug trawl fishery	103.25	103.39	110.47	77.84	53.65
Size composition	Sep-Dec trawl fishery	69.40	69.52	91.51	60.27	74.13
Size composition	Jan-May longline fishery	331.07	331.13	390.90	296.77	175.00
Size composition	Jun-Aug longline fishery	122.72	122.87	125.97	120.86	67.94
Size composition	Sep-Dec longline fishery	377.69	377.84	387.77	364.71	182.91
Size composition	Jan-May pot fishery	37.70	37.59	43.31	43.75	38.94
Size composition	Jun-Aug pot fishery	22.40	22.39	22.57	24.19	12.53
Size composition	Sep-Dec pot fishery	41.57	41.59	44.80	46.25	32.83
Size composition	Pre-82 bottom trawl survey	24.22	24.08	31.79	n/a	25.58
Size composition	Post-81 bottom trawl survey	136.86	137.01	225.34	241.15	136.08
Size composition	IPHC longline survey	0.80	0.81	3.41	1.23	1.32
Age composition	Post-81 bottom trawl survey	206.67	206.23	274.00	n/a	208.43
Recruitment	n/a	29.66	29.41	24.10	17.17	31.05
Parameter "devs"	n/a	9.46	9.45	8.37	18.73	9.52
"Softbounds"	n/a	0.01	0.01	0.02	0.01	0.04
Initial catch	n/a	0.01	0.00	0.00	n/a	0.01
Total	n/a	2065.88	2065.93	2562.43	1877.58	1499.49
Parameters	n/a	120	119	103	124	215

Notes

Model 4 does not attempt to fit :
1) Relative abundance from the pre-82 bottom trawl survey
2) Size composition from the pre-82 bottom trawl survey
3) Age composition from the post-81 bottom trawl survey
4) Initial catch

Recruitment likelihoods are not comparable because:
1) Models 1-3, 4, and 5 use different values of σ_R
2) Model 4 estimates a smaller number of year classes

"Softbounds" is a feature of Stock Synthesis that helps keep selectivity parameters away from bounds.

Table 2.2.3a. Mean effective/input sample sizes (green=row max., pink=row min., Nave=ave. input N).

				Mean(effective N/input N)				
Kind	Fleet	Samples	Nave	Model 1	Model 2	Model 3	Model 4	Model 5
length	Jan-May trawl fishery	29	377	1.30	1.30	0.63	1.08	1.28
length	Jun-Aug trawl fishery	17	30	5.29	5.29	4.02	6.36	10.99
length	Sep-Dec trawl fishery	21	29	4.66	4.66	4.67	4.35	5.49
length	Jan-May longline fishery	28	664	1.21	1.21	1.07	1.13	2.26
length	Jun-Aug longline fishery	21	241	4.16	4.16	4.38	3.08	4.87
length	Sep-Dec longline fishery	26	722	1.17	1.18	0.93	0.70	1.87
length	Jan-May pot fishery	16	151	2.74	2.75	2.29	2.76	2.57
length	Jun-Aug pot fishery	7	59	3.39	3.38	3.48	3.07	4.83
length	Sep-Dec pot fishery	15	53	5.13	5.20	5.41	3.95	6.15
length	Pre-82 bottom trawl survey	3	74	0.82	0.82	0.97		0.88
length	Post-81 bottom trawl survey	26	171	1.63	1.64	0.99	1.43	1.62
length	IPHC longline survey	1	44	21.02	20.83	1.37	4.05	3.61
age	Post-81 bottom trawl survey	13	300	0.38	0.38	0.41		0.45

				Mean(effective N)/Mean(input N)				
Kind	Fleet	Samples	Nave	Model 1	Model 2	Model 3	Model 4	Model 5
length	Jan-May trawl fishery	29	377	0.72	0.72	0.39	0.84	0.87
length	Jun-Aug trawl fishery	17	30	2.23	2.23	1.78	2.55	4.30
length	Sep-Dec trawl fishery	21	29	3.94	3.92	2.72	4.34	4.20
length	Jan-May longline fishery	28	664	0.69	0.69	0.57	0.92	1.06
length	Jun-Aug longline fishery	21	241	1.31	1.31	1.43	1.40	2.10
length	Sep-Dec longline fishery	26	722	0.67	0.67	0.56	0.67	1.41
length	Jan-May pot fishery	16	151	2.94	2.95	2.44	3.06	2.61
length	Jun-Aug pot fishery	7	59	2.87	2.86	2.89	2.35	4.30
length	Sep-Dec pot fishery	15	53	3.92	3.95	3.67	3.24	6.01
length	Pre-82 bottom trawl survey	3	74	0.82	0.82	0.97		0.88
length	Post-81 bottom trawl survey	26	171	1.42	1.42	0.85	1.38	1.41
length	IPHC longline survey	1	44	21.02	20.83	1.37	4.05	3.61
age	Post-81 bottom trawl survey	13	300	0.41	0.41	0.47		0.45

Table 2.2.3b. Effective/input sample sizes for age compositions (green=row max., pink=row min.).

		Effective N/input N				
Year	Input N	Model 1	Model 2	Model 3	Model 4	Model 5
1994	257	0.36	0.36	0.34	n/a	0.24
1995	215	0.37	0.36	0.28	n/a	0.60
1996	91	0.50	0.50	0.34	n/a	0.41
1997	258	0.36	0.35	0.44	n/a	0.26
1998	228	0.29	0.28	0.32	n/a	0.39
1999	309	0.07	0.07	0.07	n/a	0.10
2000	311	0.07	0.07	0.07	n/a	0.09
2001	341	0.11	0.11	0.16	n/a	0.15
2002	340	0.06	0.06	0.05	n/a	0.07
2003	489	0.71	0.73	0.49	n/a	0.63
2004	374	0.07	0.07	0.08	n/a	0.08
2005	219	0.73	0.73	0.70	n/a	0.87
2006	468	1.27	1.27	1.96	n/a	1.53

Table 2.2.4. Estimates of some parameters common to most models, with standard deviations (Sdev).

	Model 1		Model 2		Model 3		Model 4		Model 5	
Parameter	Value	Sdev	Value	Sdev	Value	Sdev	Value	Sdev	Value	Sdev
M	0.34	n/a	0.34	n/a	0.34	n/a	0.46	0.02	0.34	n/a
L1	6.99	0.29	6.96	0.27	4.81	0.29	6.33	0.29	17.15	0.19
L2	94.03	0.85	93.75	n/a	90.35	0.40	102.55	1.08	94.84	0.77
K	0.22	0.0044	0.23	0.0024	0.27	0.0035	0.20	0.0043	0.22	0.0042
SD1	3.11	0.16	3.09	0.15	3.17	0.15	4.12	0.12	3.83	0.12
SD2	1.09	0.071	1.10	0.065	1.00	0.057	1.21	0.086	0.90	0.051
R0	13.59	0.068	13.61	0.053	13.85	0.026	13.84	0.16	13.25	0.045
R1 offset	-1.68	0.15	-1.66	0.14	-1.35	0.14	0.75	0.10	-1.41	0.12
σ_R	0.78	n/a	0.78	n/a	0.78	n/a	0.60	n/a	0.65	n/a
Initial F	0.16	0.051	0.15	0.038	0.05	0.009	0.73	0.078	0.14	0.036
Pre-82 lnQ	-0.11	0.13	-0.14	0.10	-0.68	0.078	n/a	n/a	0.18	0.11
Post-81 lnQ	-0.33	0.071	-0.35	0.053	-0.60	n/a	-0.38	0.11	-0.18	0.054

Notes

Natural mortality rate M is estimated in Model 4 and fixed at 0.34 in all others.
Reference age A1 corresponding to length L1 is 1.5417 years in Model 5 and 1 year in all others.
L2 (length at 20 years) is fixed at 93.75 cm in Model 2 and estimated in all others.
K = Brody growth coefficient
SD1 = standard deviation of length at reference age A1
SD2 = standard deviation of length at reference age A2
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 pertains to 1982 in Model 4 and 1977 in all others.
Pre-82 lnQ = log of catchability coefficient for pre-1982 bottom trawl survey
Pre-82 lnQ is not used in Model 4 but used in all others.
Post-81 lnQ = log of catchability coefficient for post-1981 bottom trawl survey
Post-81 lnQ is fixed at -0.60 in Model 3 but estimated in all others.

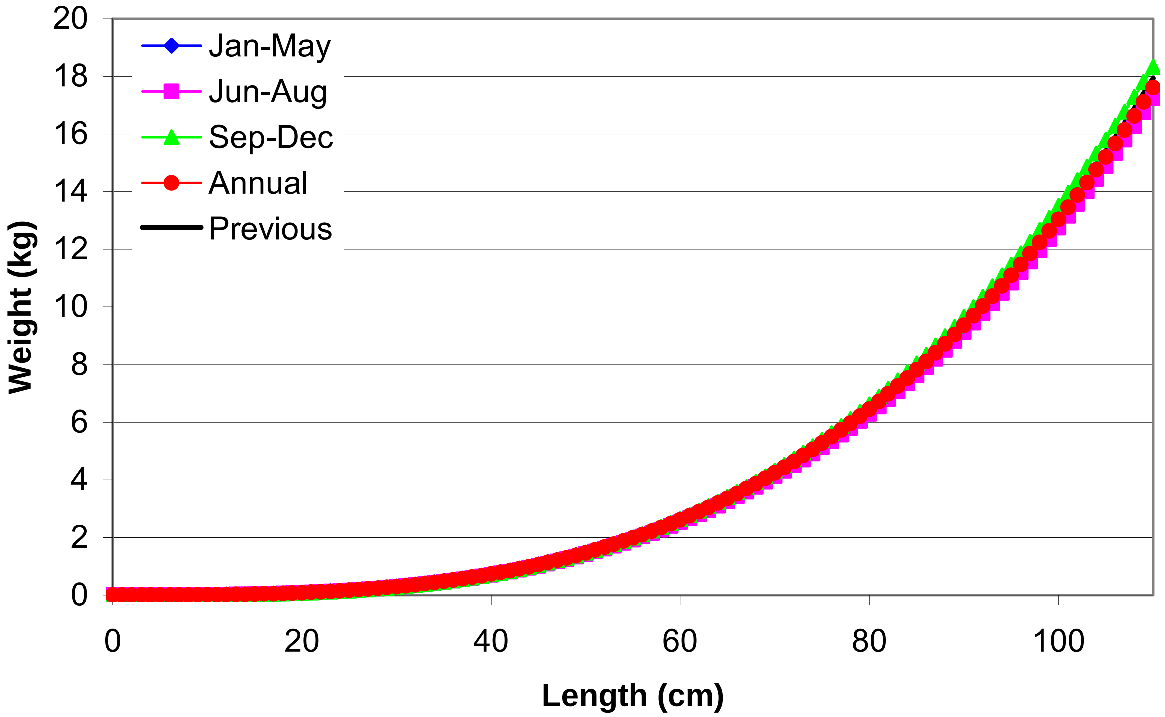


Figure 2.2.1. Weight at length as estimated by three seasonal schedules, the best fitting annual schedule, and the schedule used in previous assessments.

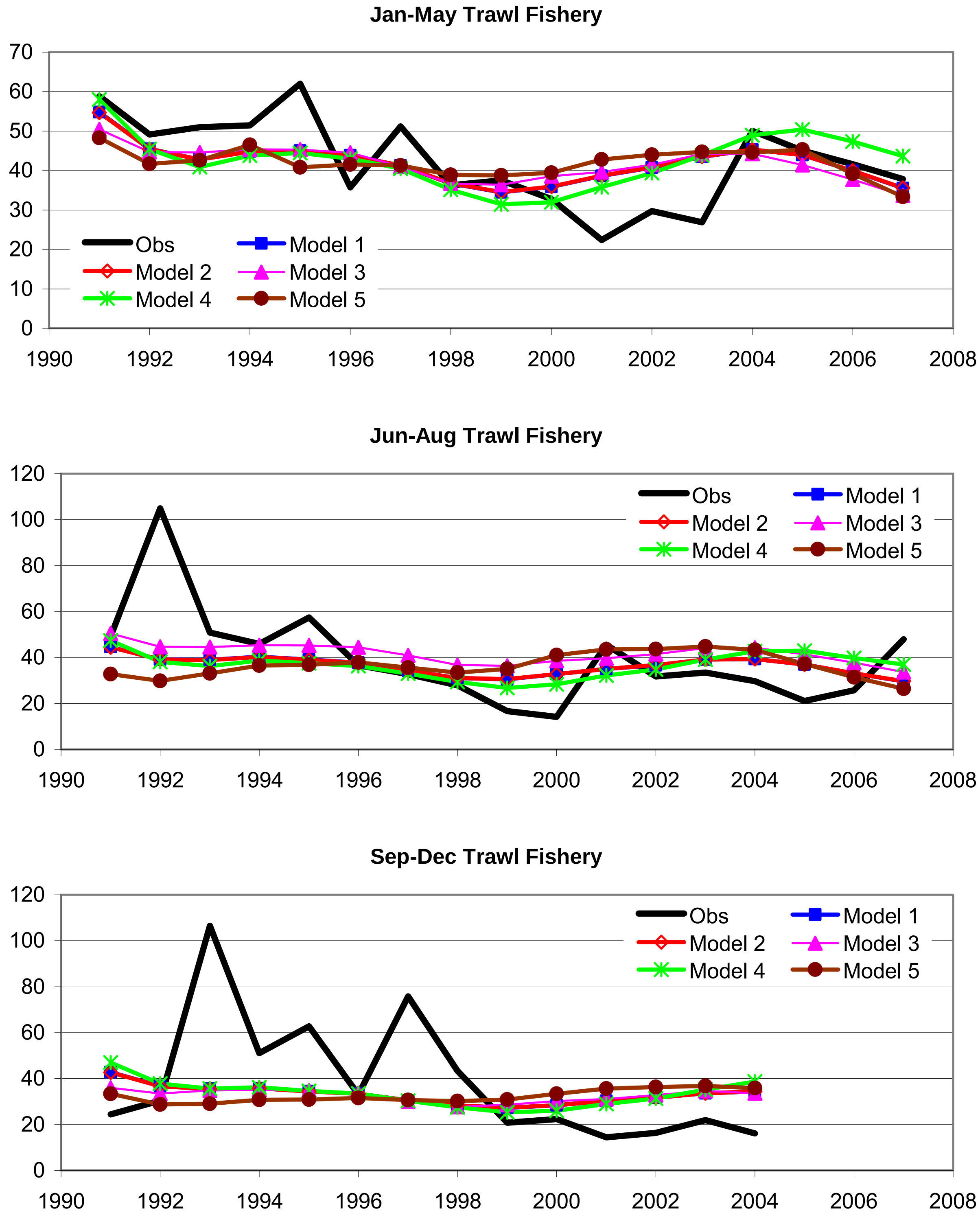


Figure 2.2.2a. Comparison of model estimates to trawl fishery CPUE data.

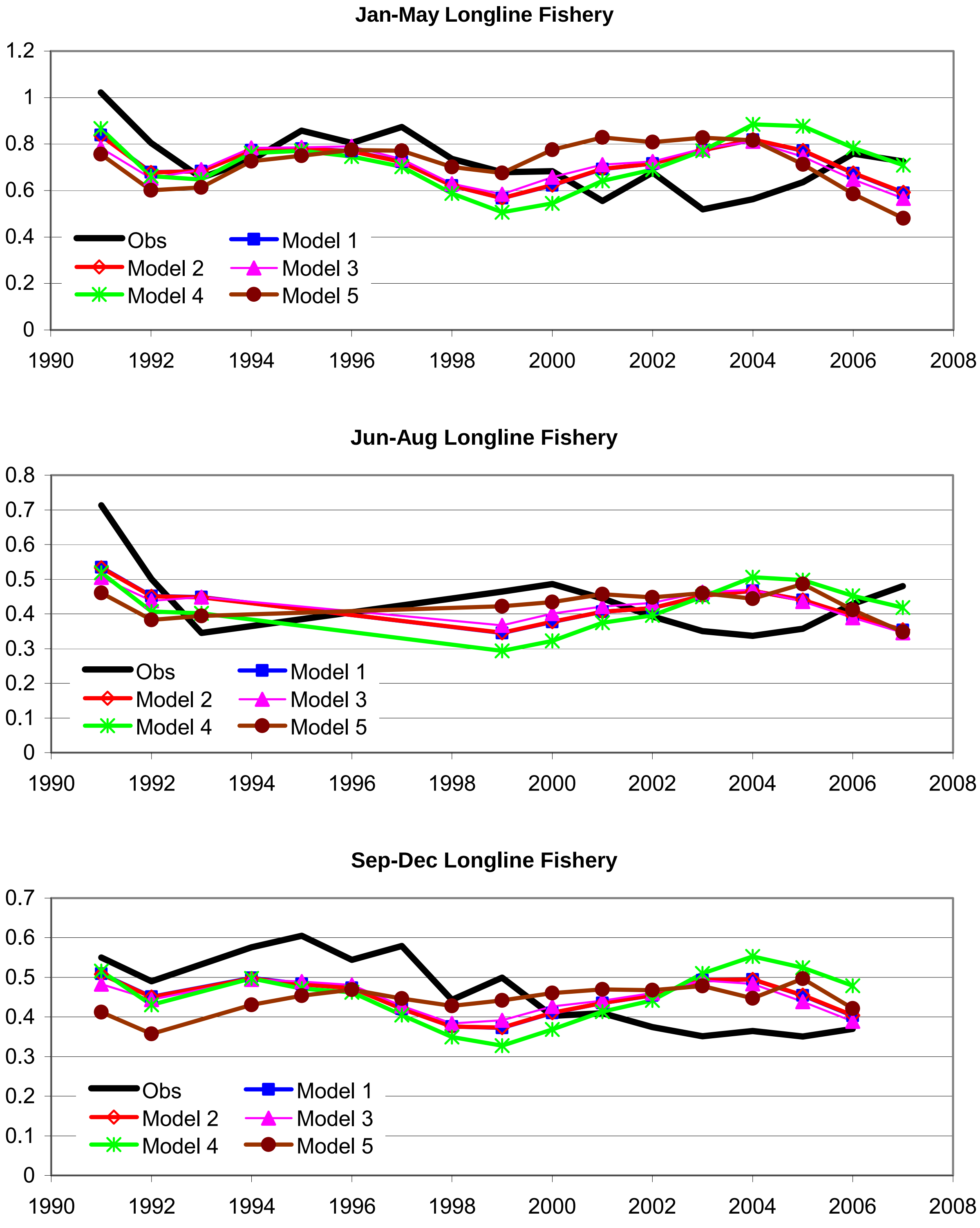


Figure 2.2.2b. Comparison of model estimates to longline fishery CPUE data.

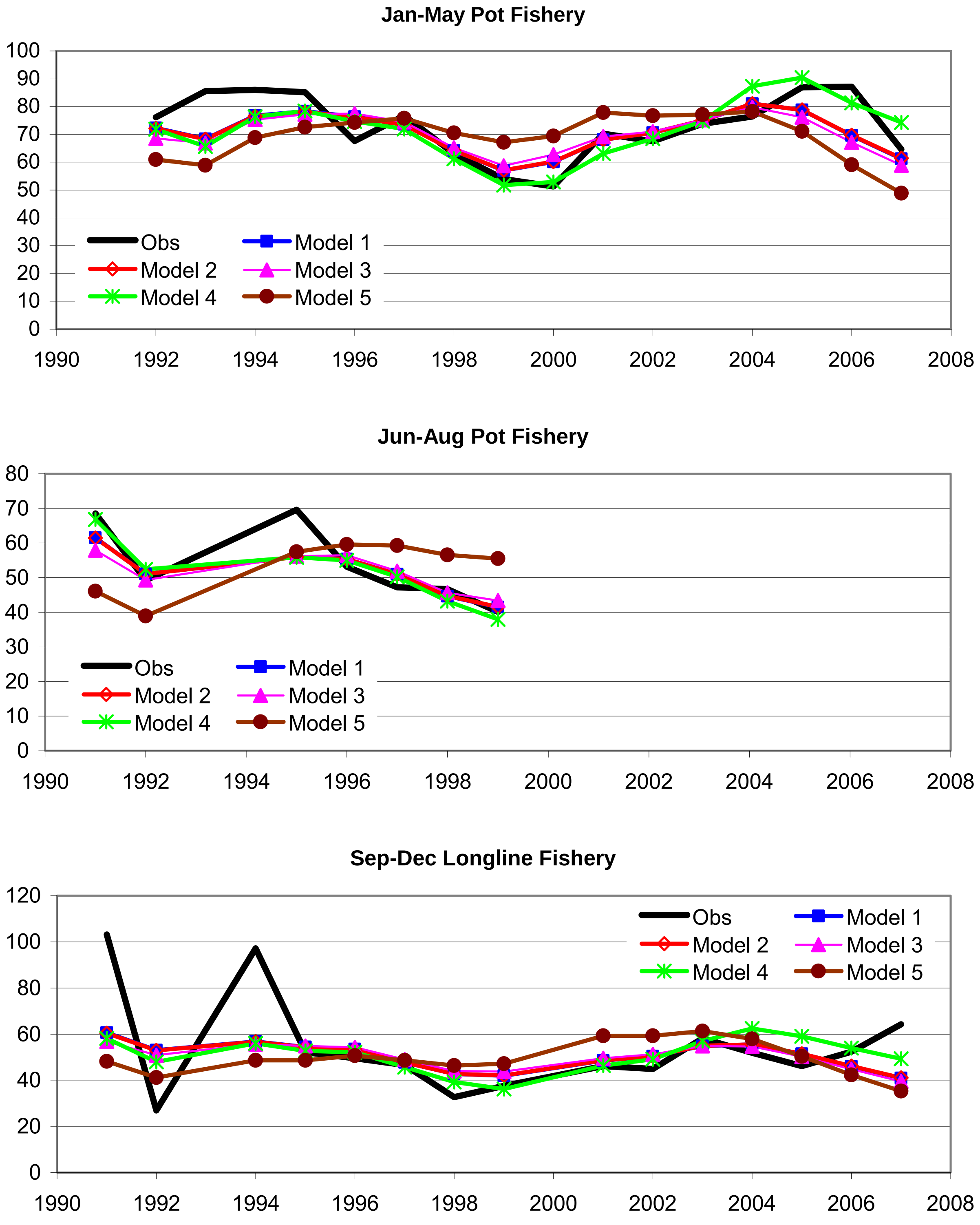
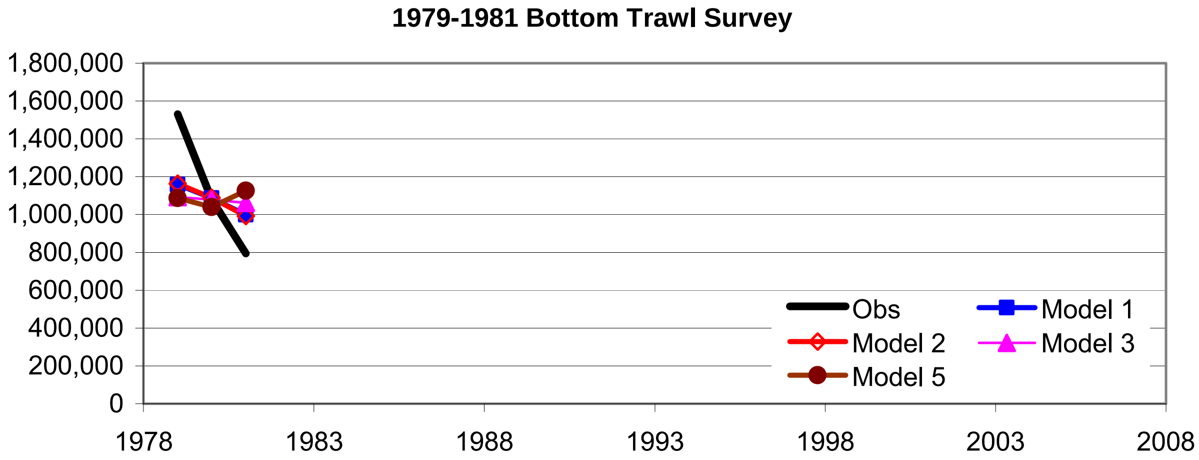
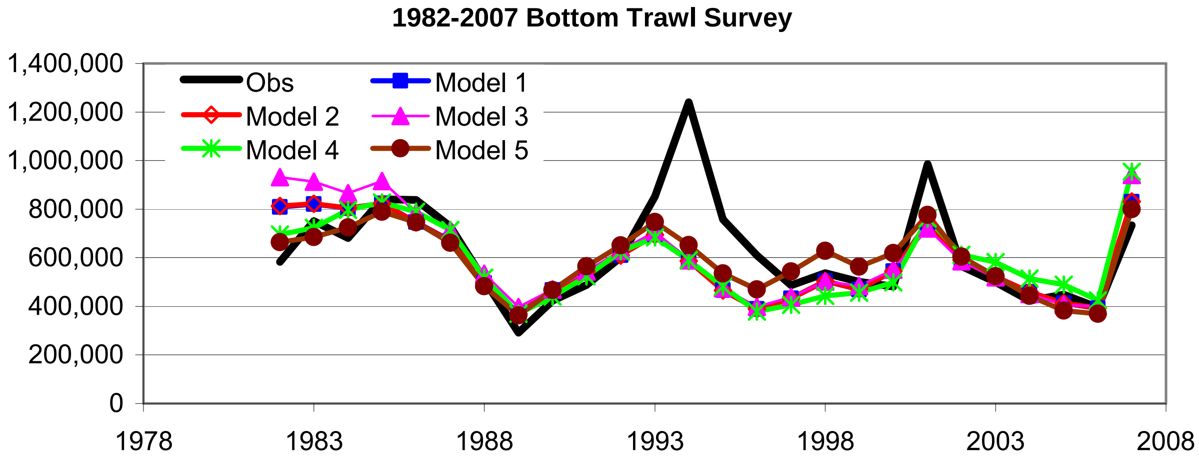


Figure 2.2.2c. Comparison of model estimates to pot fishery CPUE data.





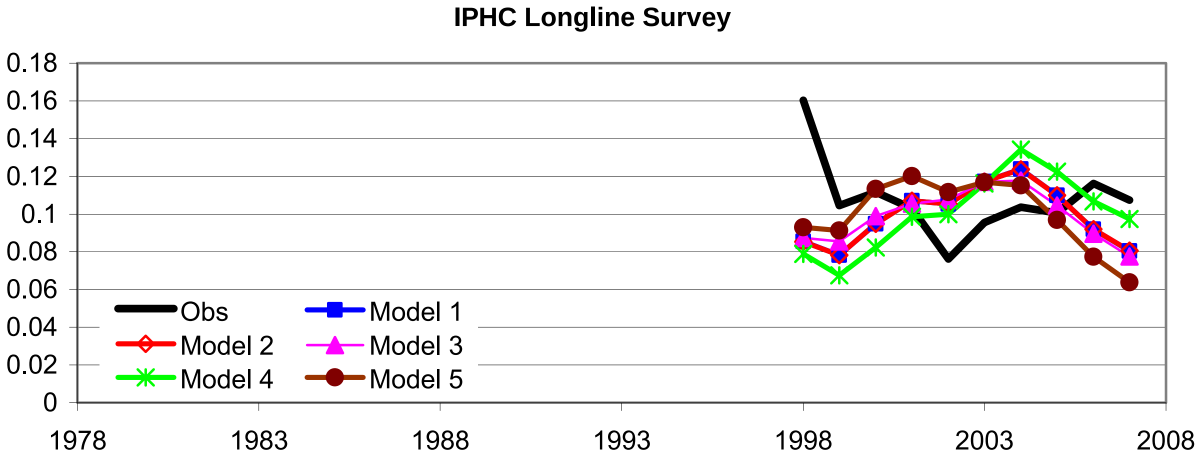


Figure 2.2.2d. Comparison of model estimates to survey relative abundance data.

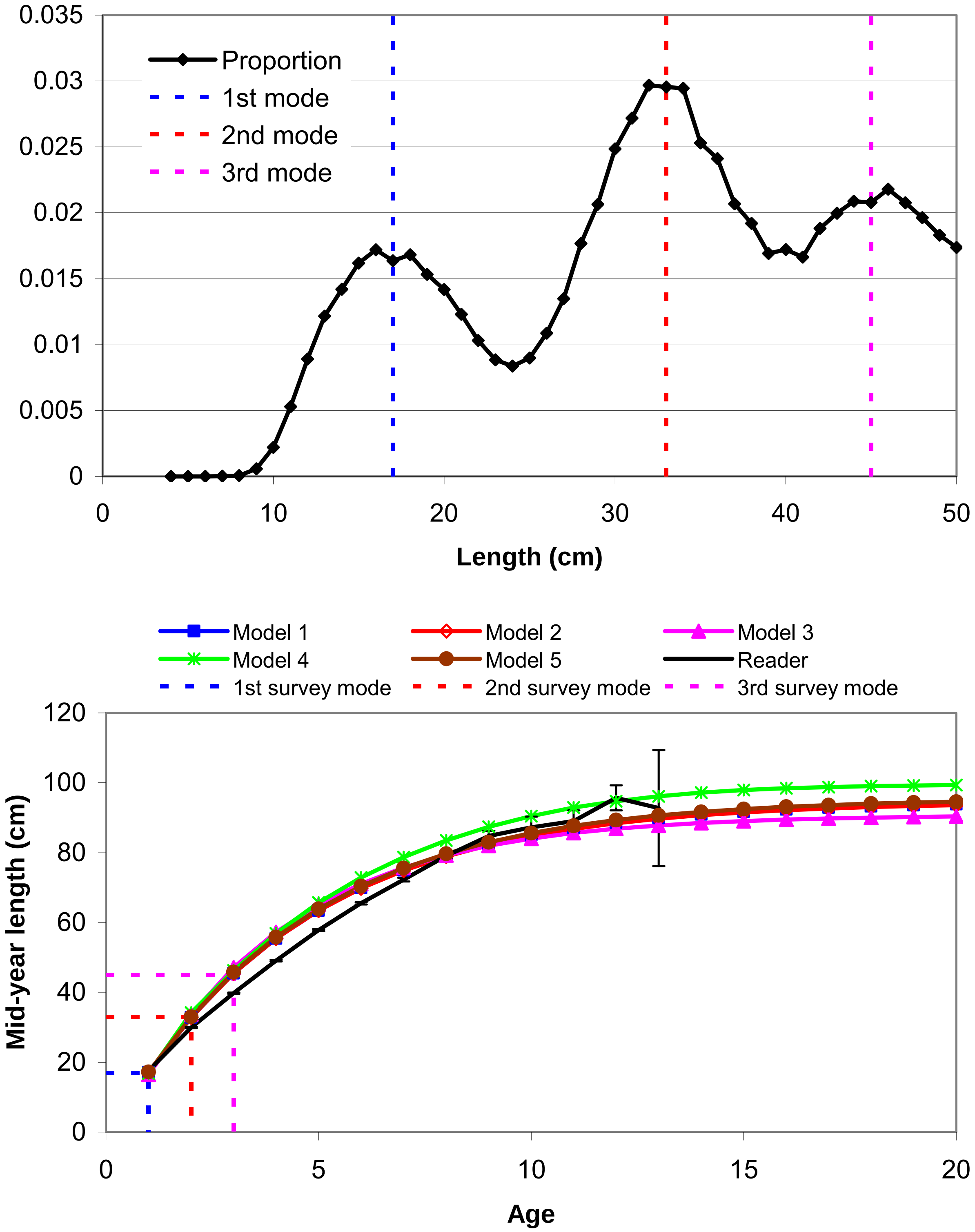
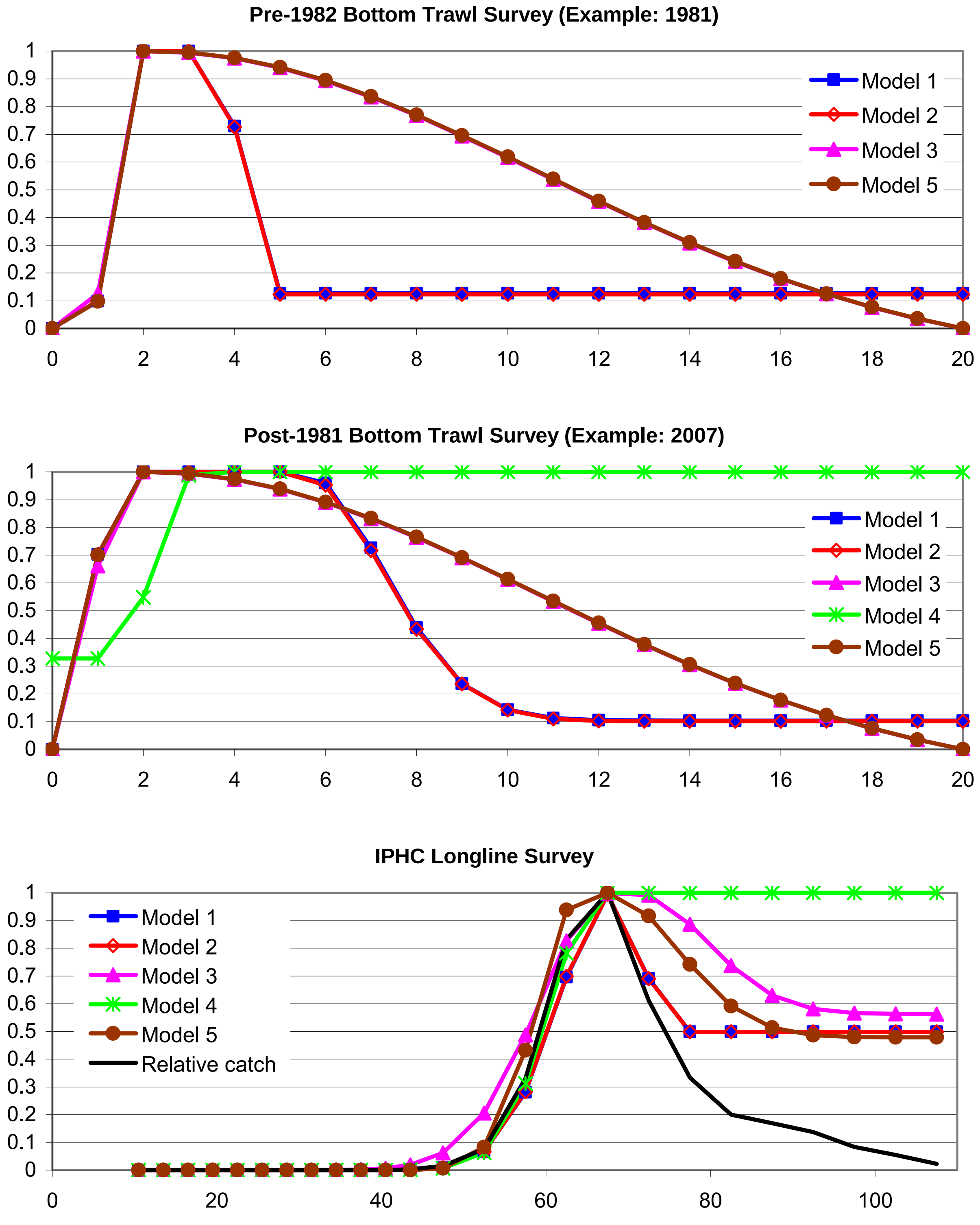


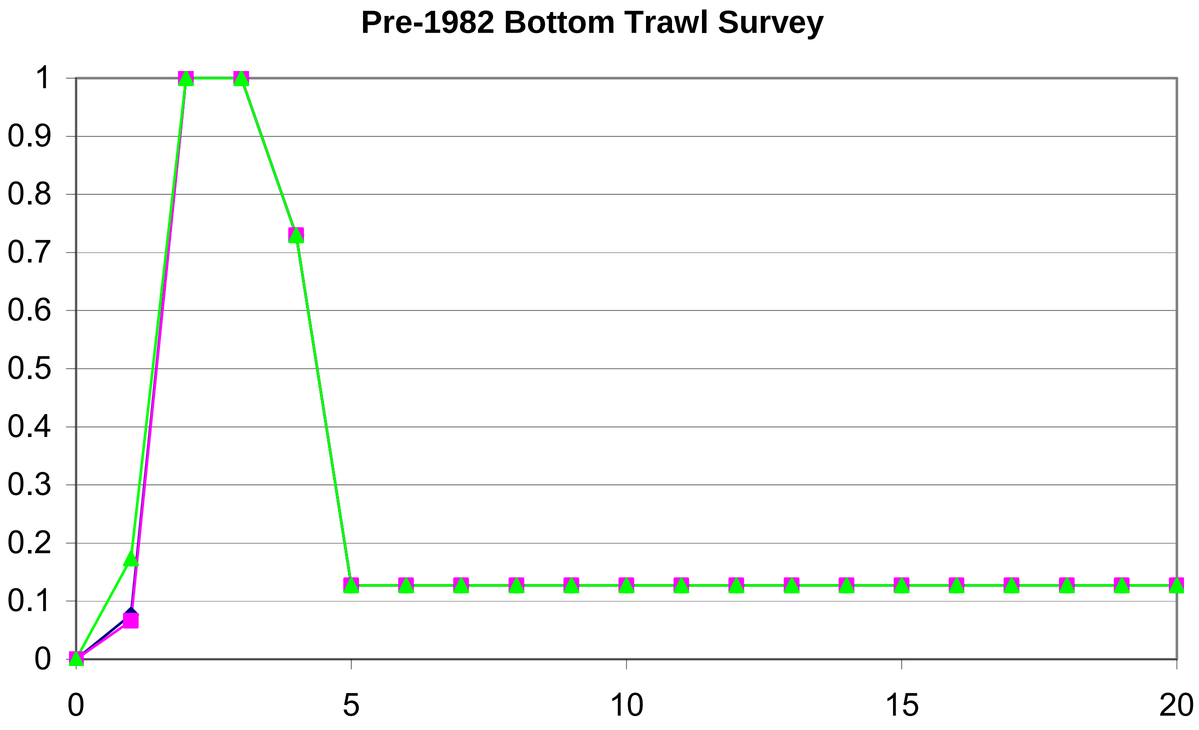
Figure 2.2.3. Length and age. Upper panel: First 3 size modes in long-term bottom trawl survey size distribution. Lower panel: Model and AFSC reader estimates of mean length at age.


Pre-1982 Bottom Trawl Survey (Example: 1981)

Post-1981 Bottom Trawl Survey (Example: 2007)

IPHC Longline Survey

Figure 2.2.4a: Comparison of survey selectivities. For Model 5, 1981 is used as an example year for pre-1982 trawl survey selectivity, and 2007 is used as an example year for post-1981 trawl survey selectivity.



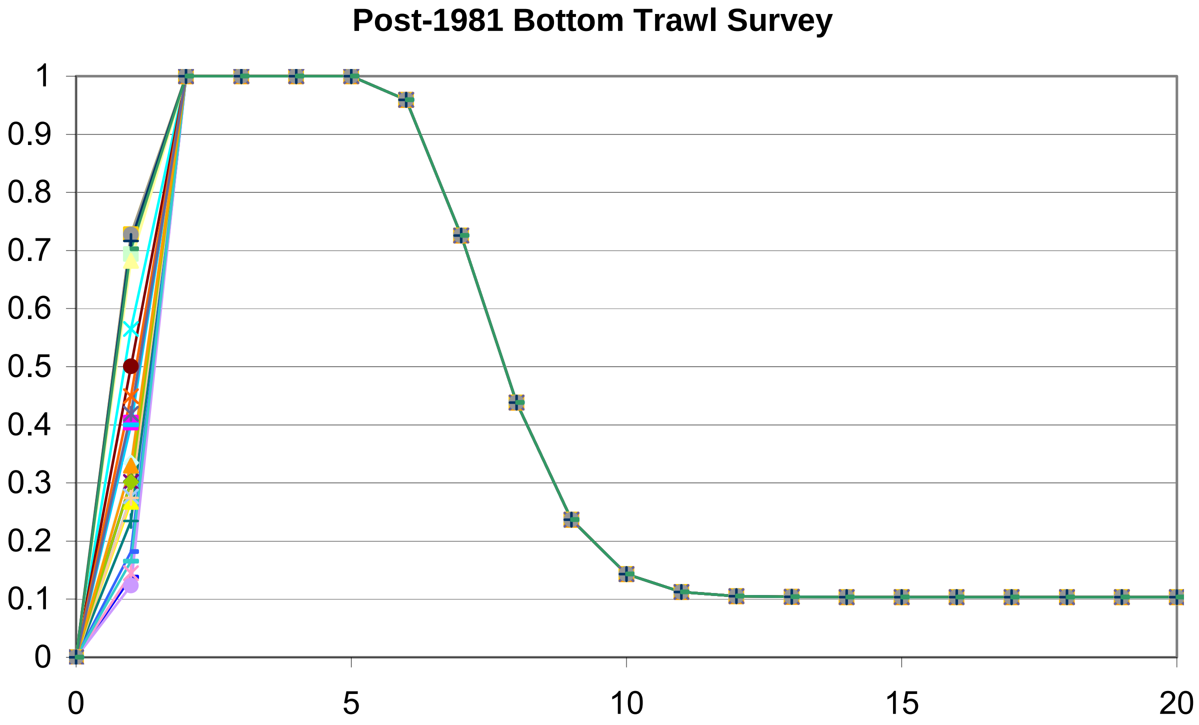
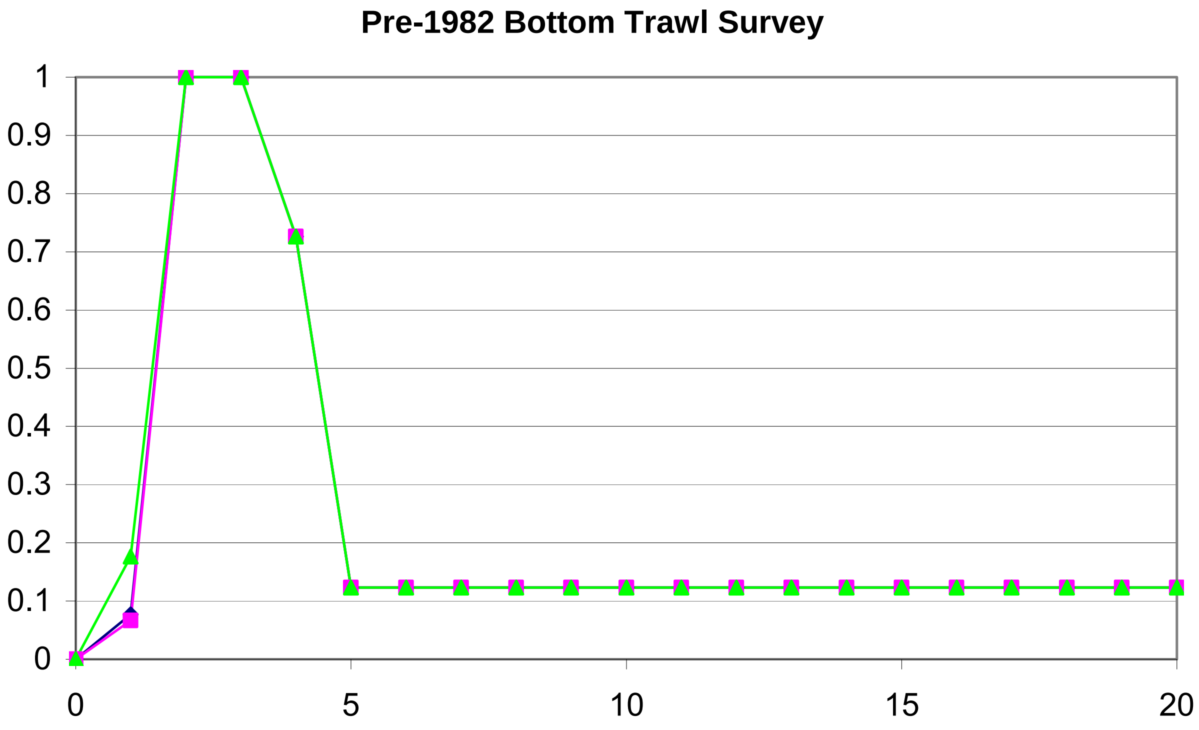


Figure 2.2.4b. Annual bottom trawl survey selectivities as estimated by Model 1.



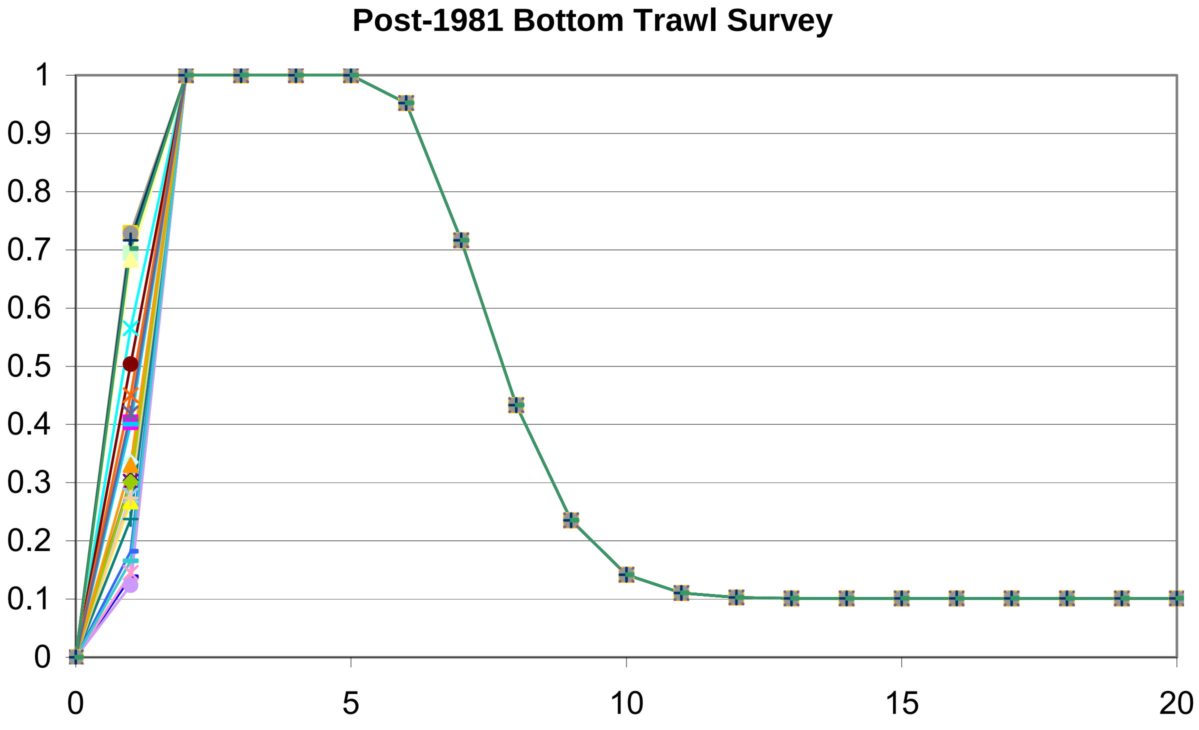
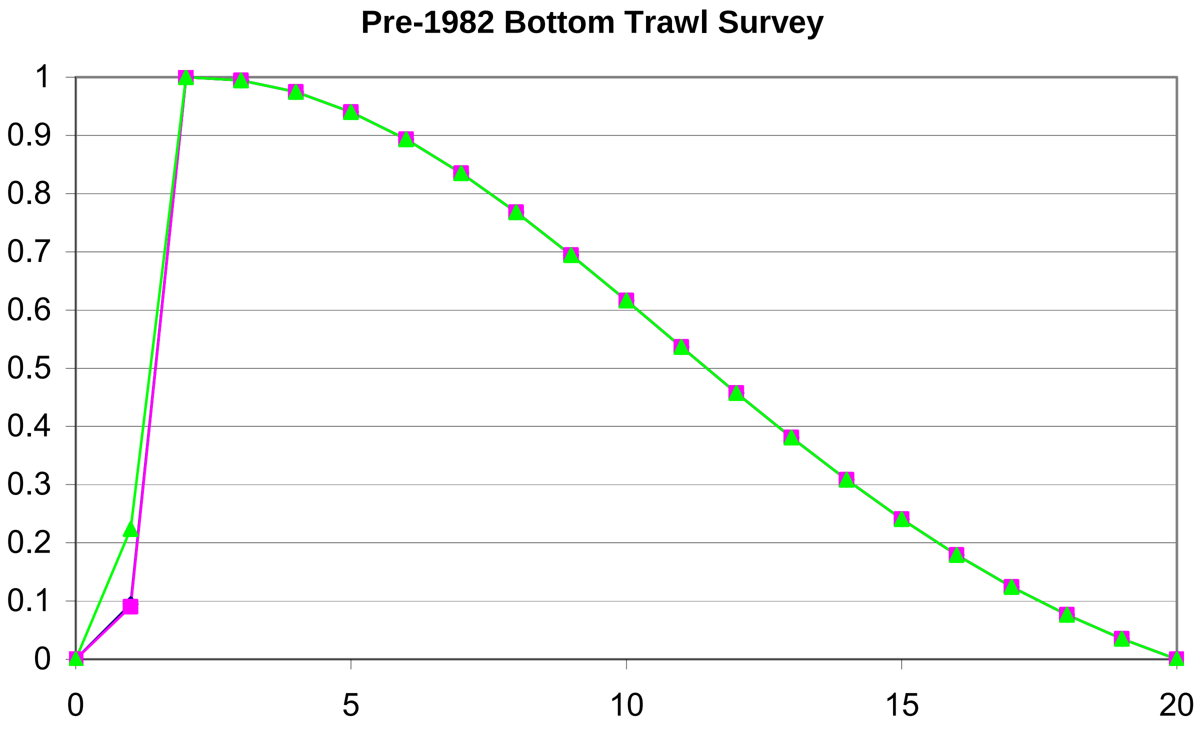


Figure 2.2.4c. Annual bottom trawl survey selectivities as estimated by Model 2.



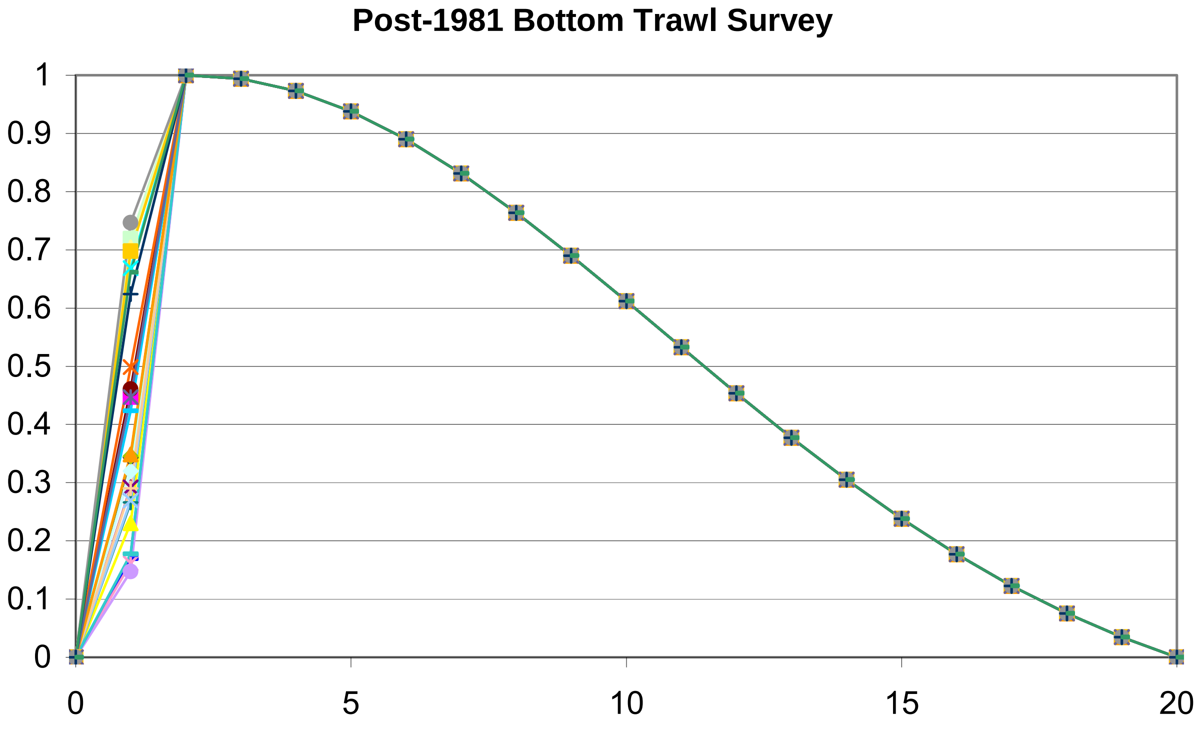


Figure 2.2.4d. Annual bottom trawl survey selectivities as estimated by Model 3.

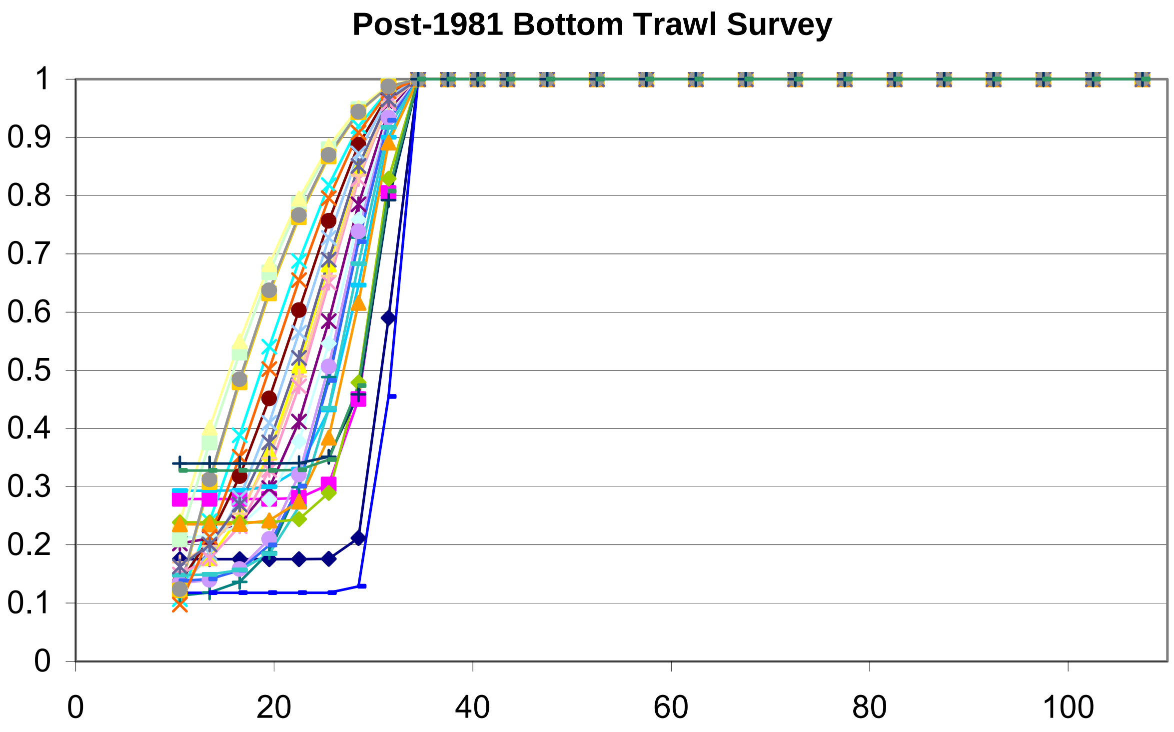
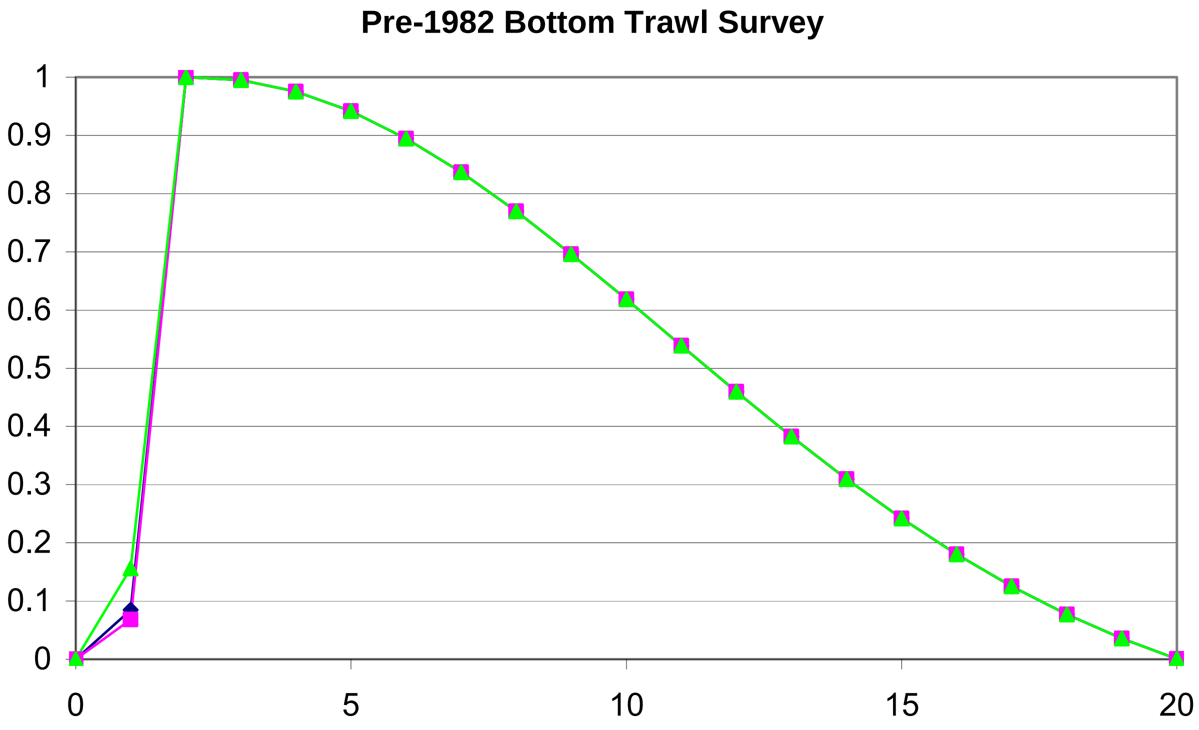


Figure 2.2.4e. Annual bottom trawl survey selectivities as estimated by Model 4.



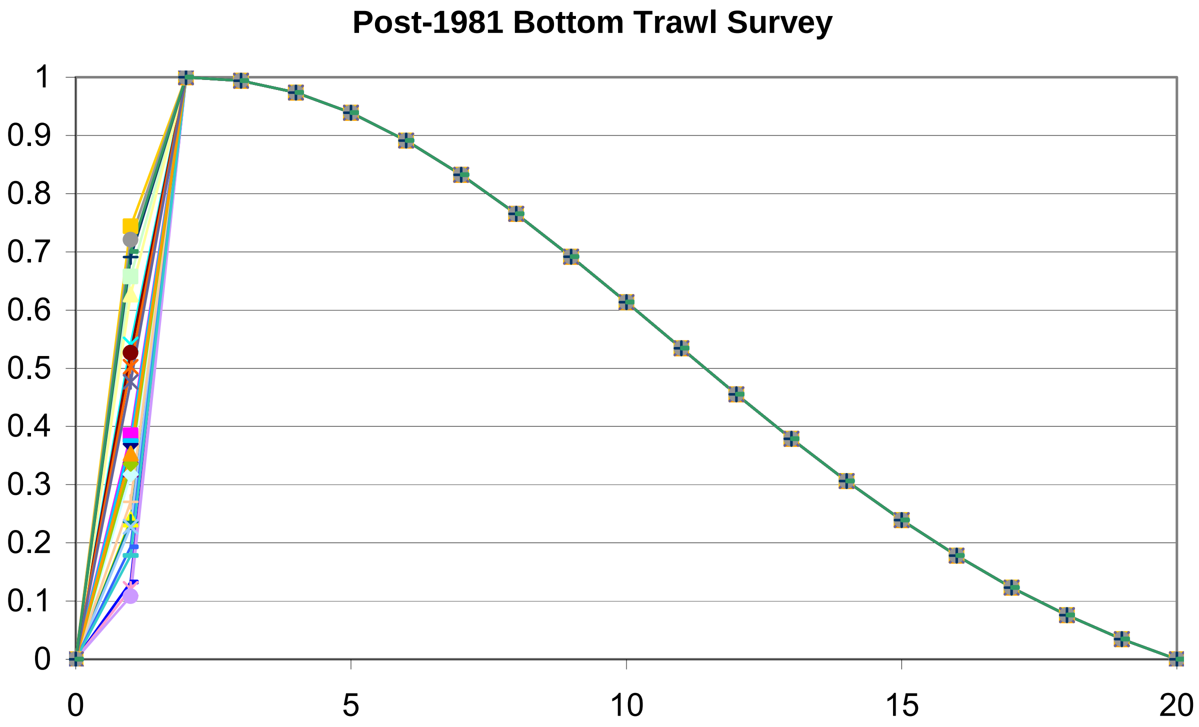


Figure 2.2.4f. Annual bottom trawl survey selectivities as estimated by Model 5.

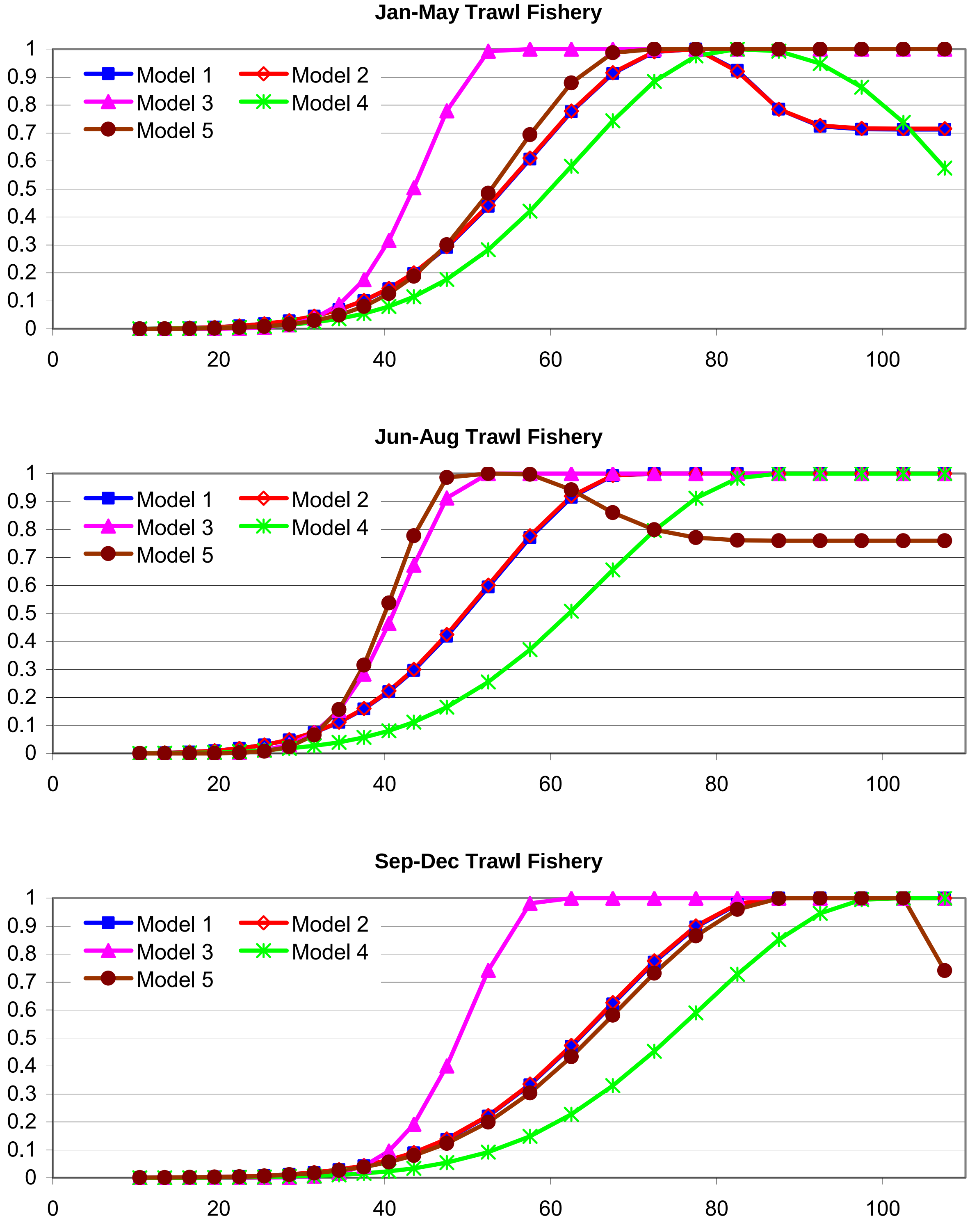
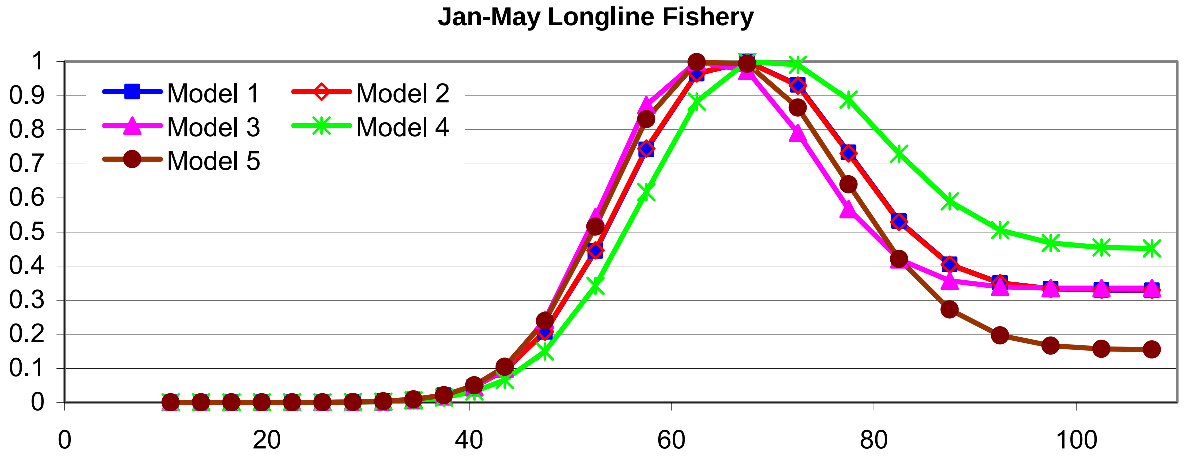
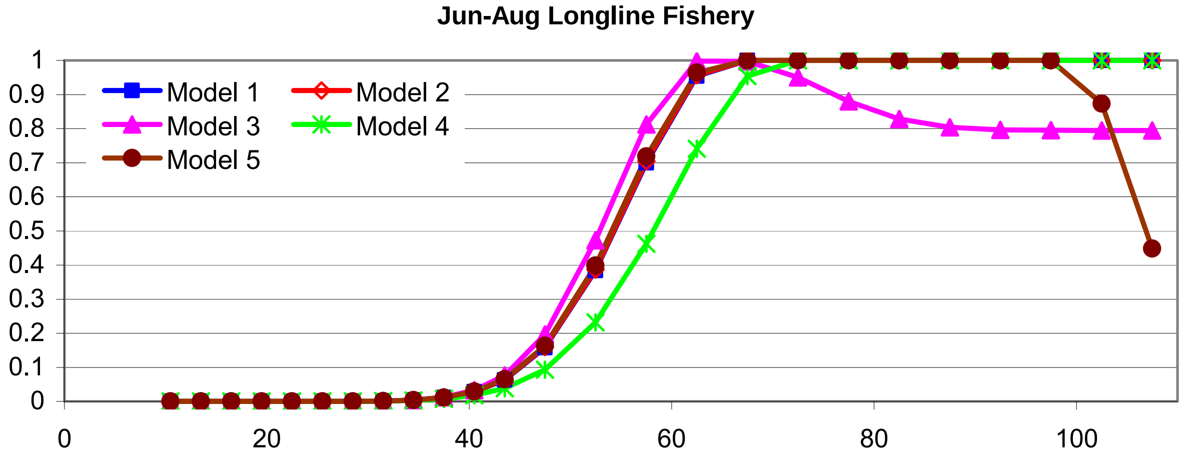


Figure 2.2.5a. Comparison of estimated trawl fishery selectivities (2007 for Model 5).





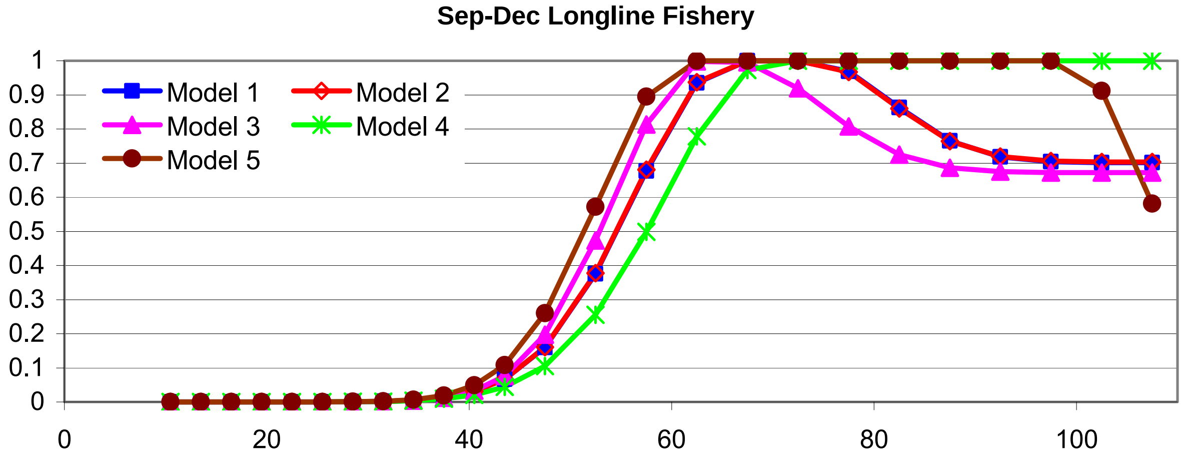
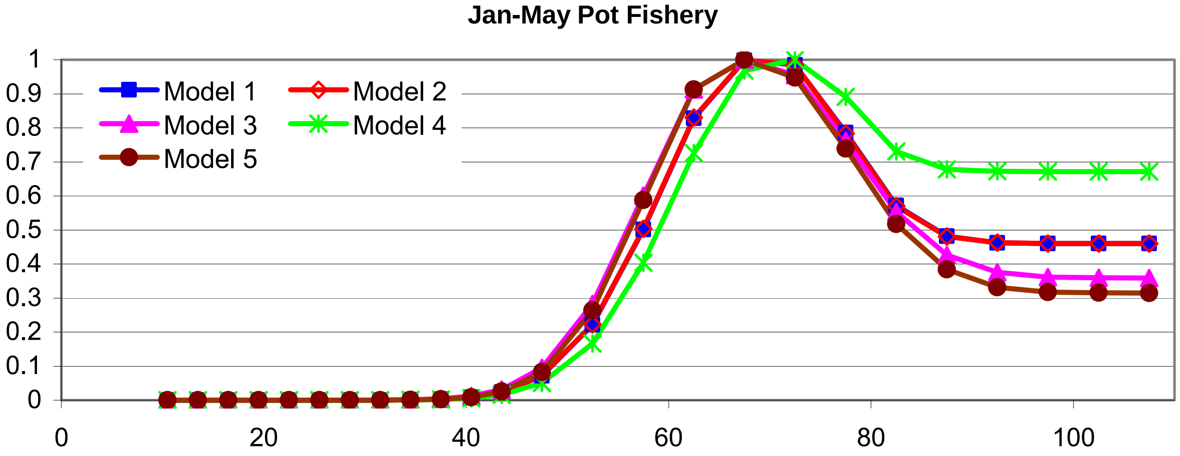
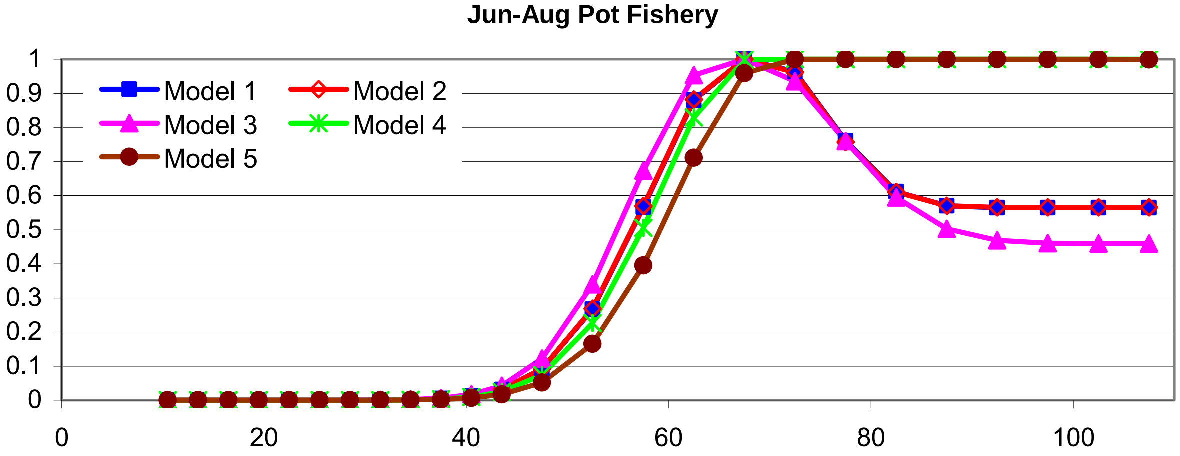


Figure 2.2.5b. Comparison of estimated longline fishery selectivities (2007 for Model 5).





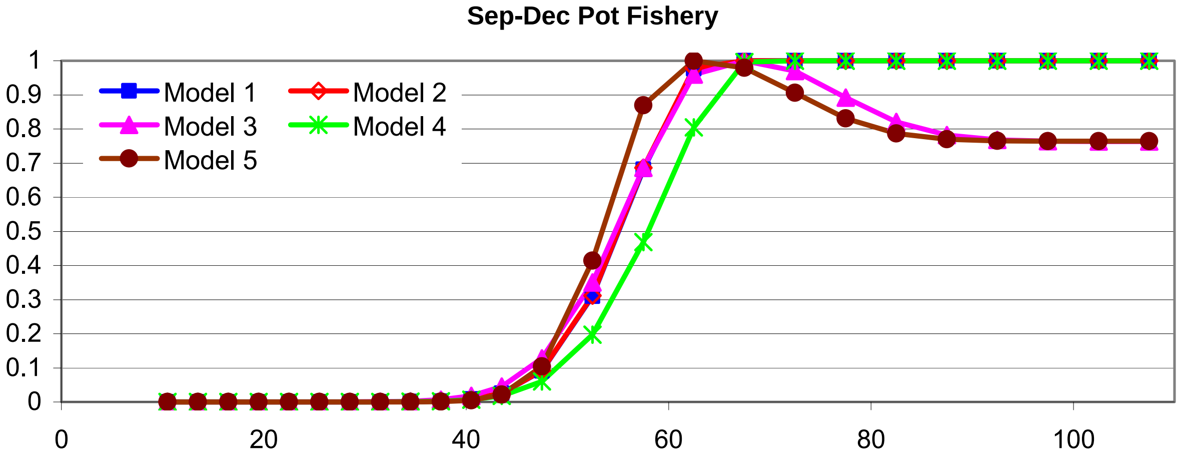


Figure 2.2.5c. Comparison of estimated pot fishery selectvities (2007 for Model 5).

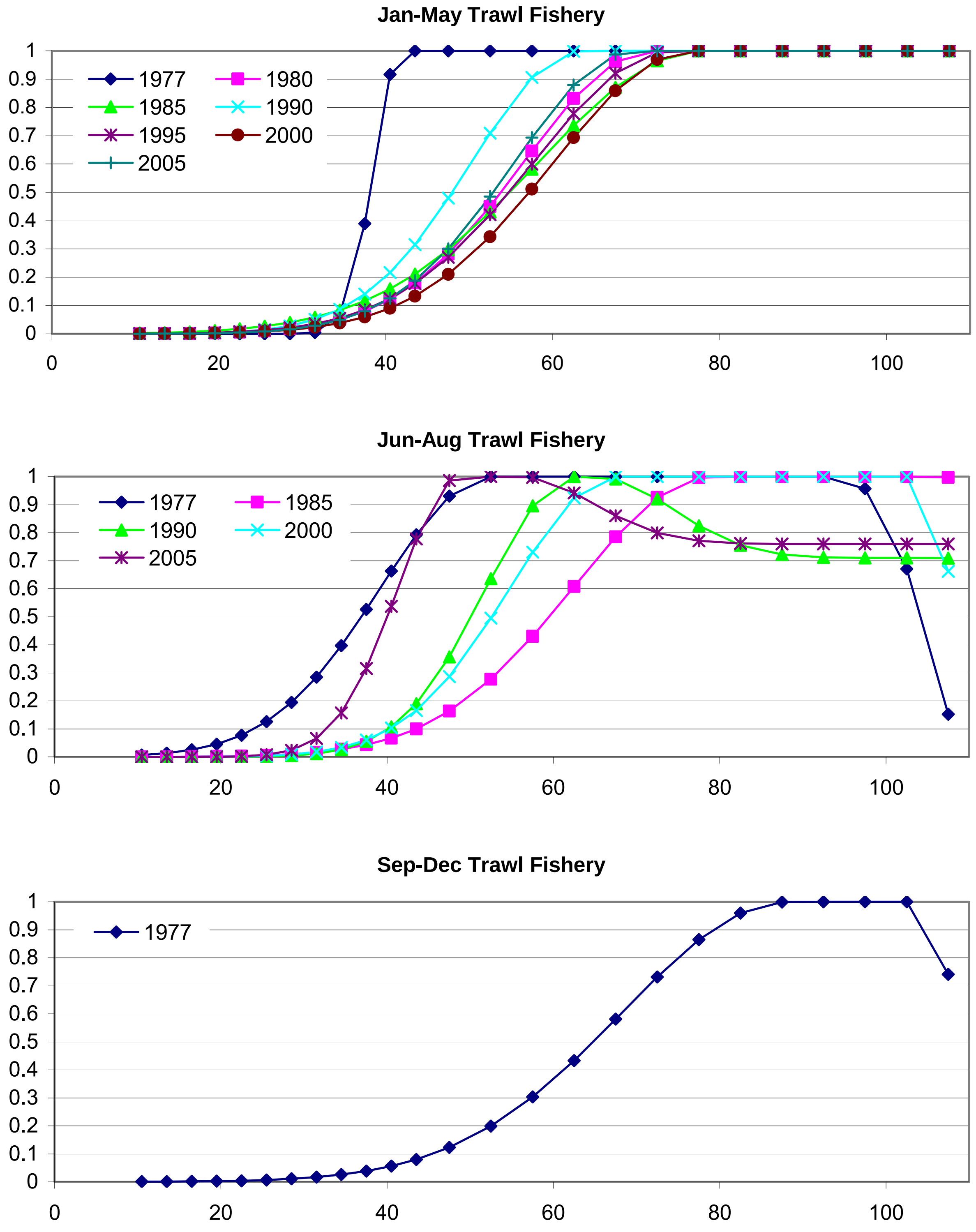


Figure 2.2.6a. Block-specific trawl fishery selectivities as estimated by Model 5.

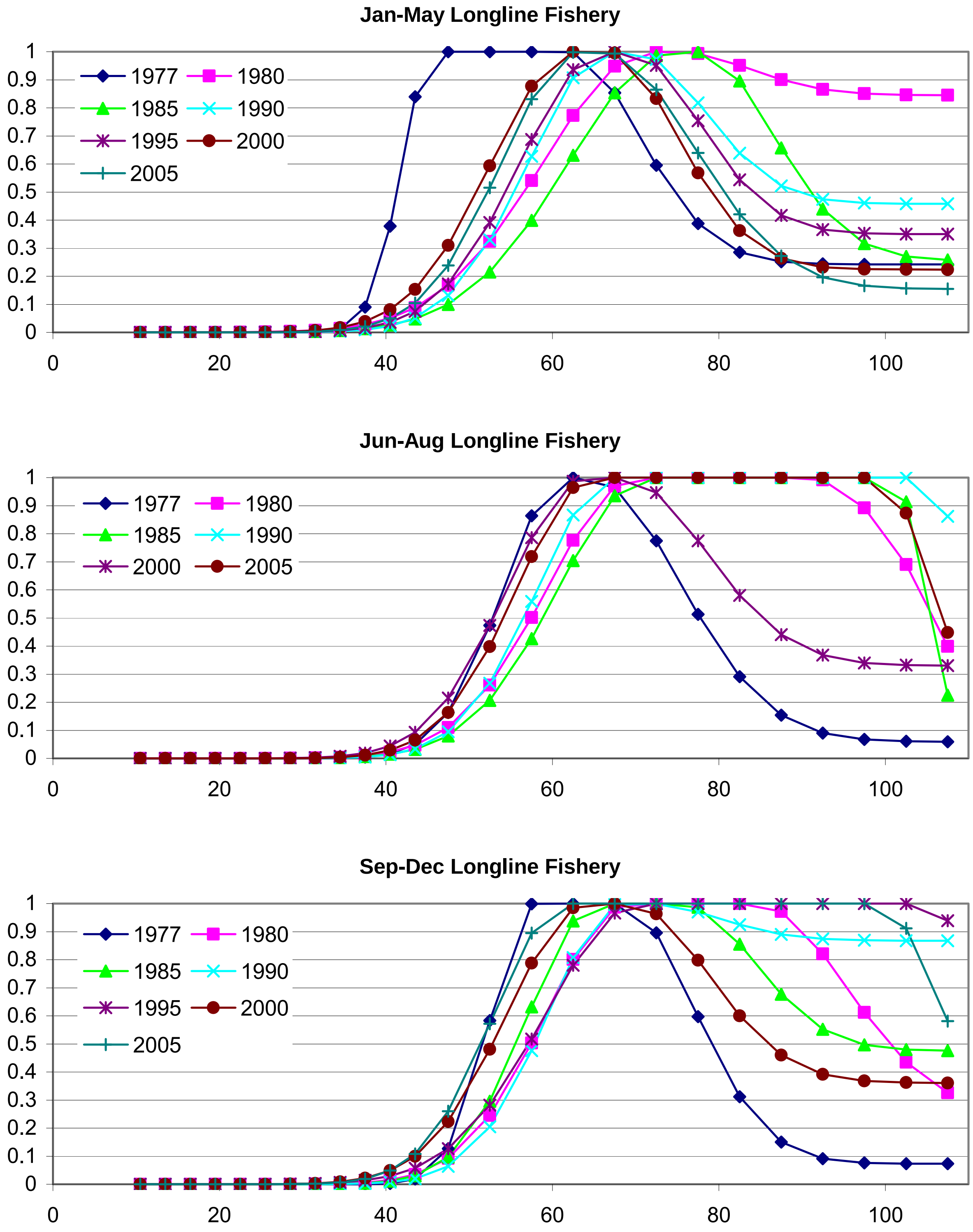
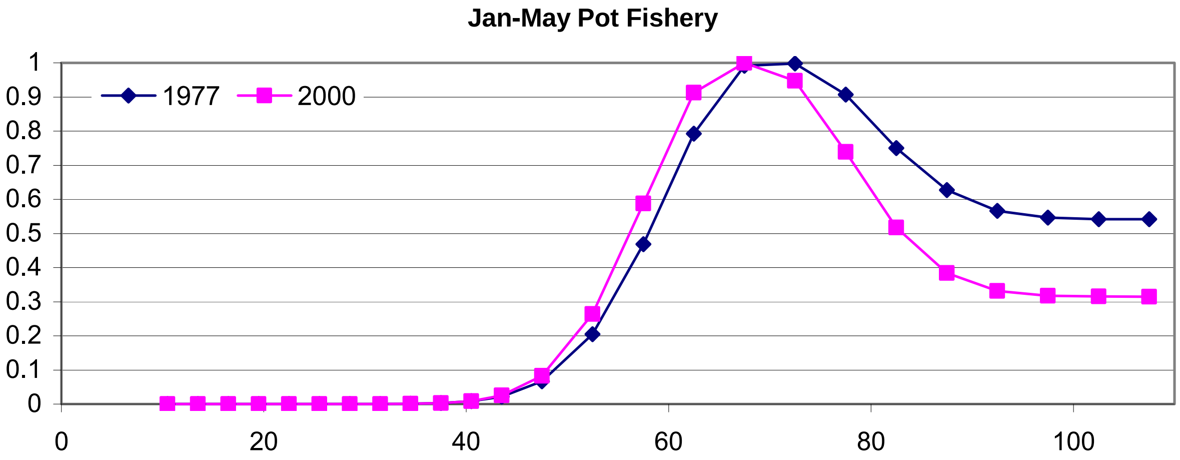
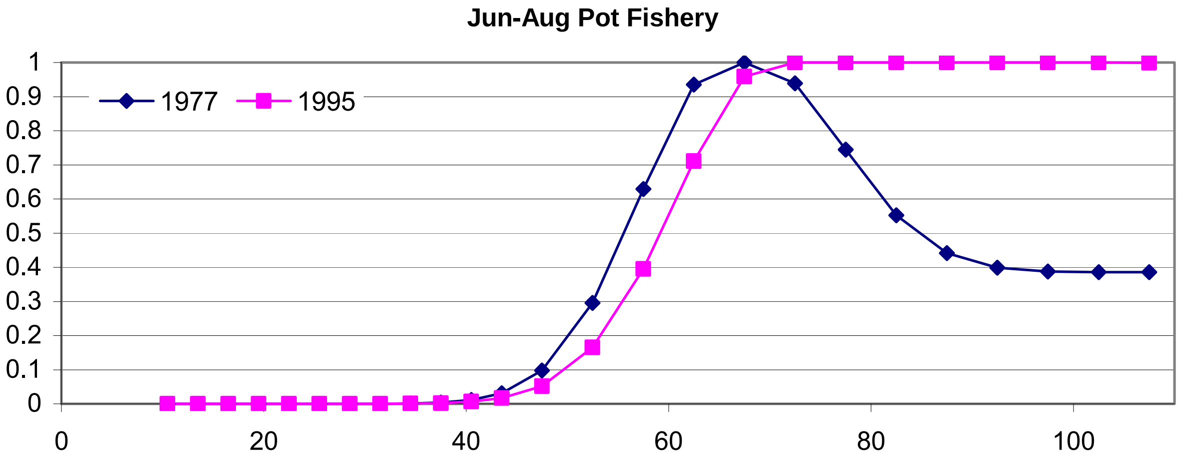


Figure 2.2.6b. Block-specific longline fishery selectivities as estimated by Model 5.





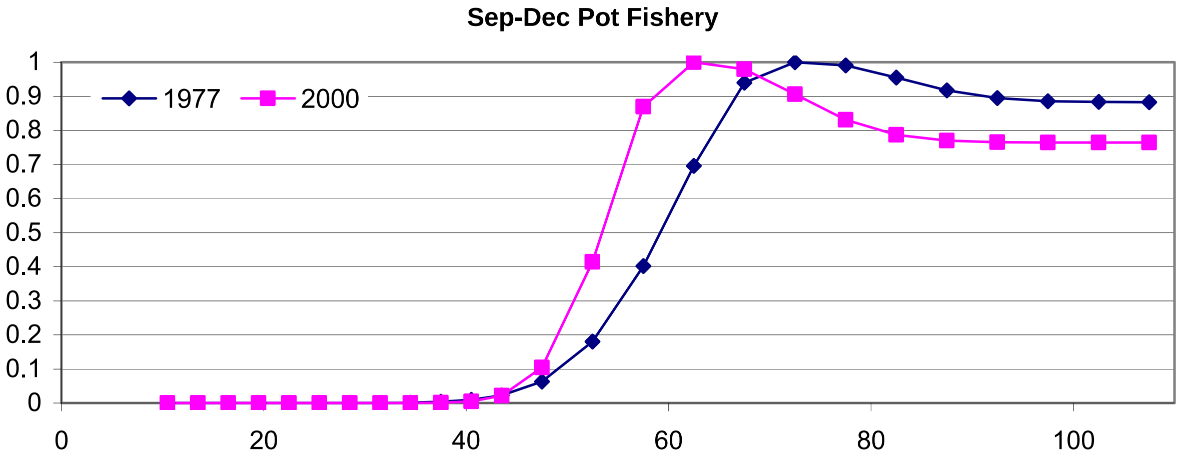


Figure 2.2.6c. Block-specific pot fishery selectivities as estimated by Model 5.

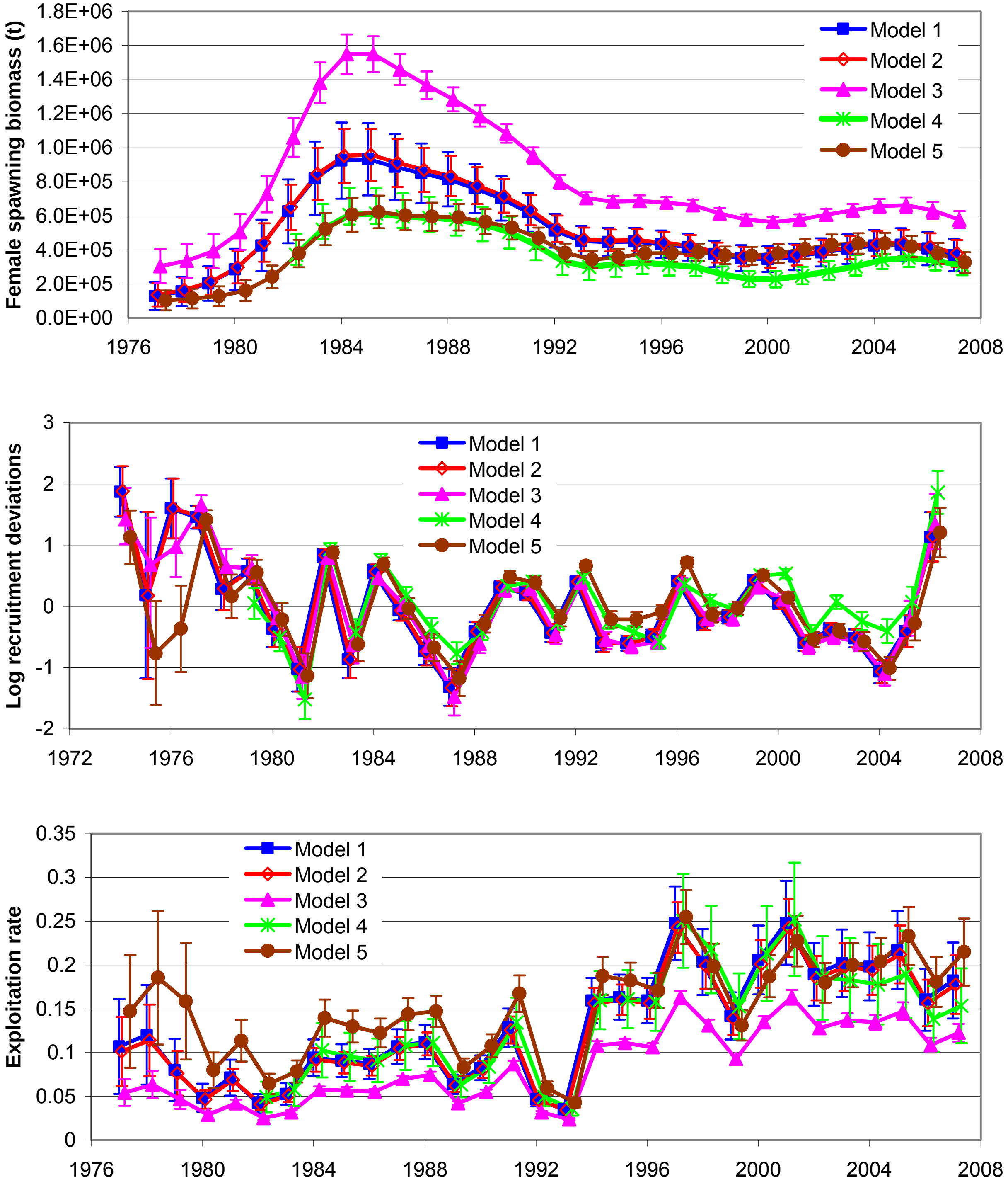


Figure 2.2.7. Upper panel: female spawning biomass. Middle panel: log recruitment deviations *from the respective regime-specific log median*. Note that the log median for 1974-1976 is between 1.4 and 1.7 units lower than the log median for 1977-2006. Lower panel: exploitation rate.

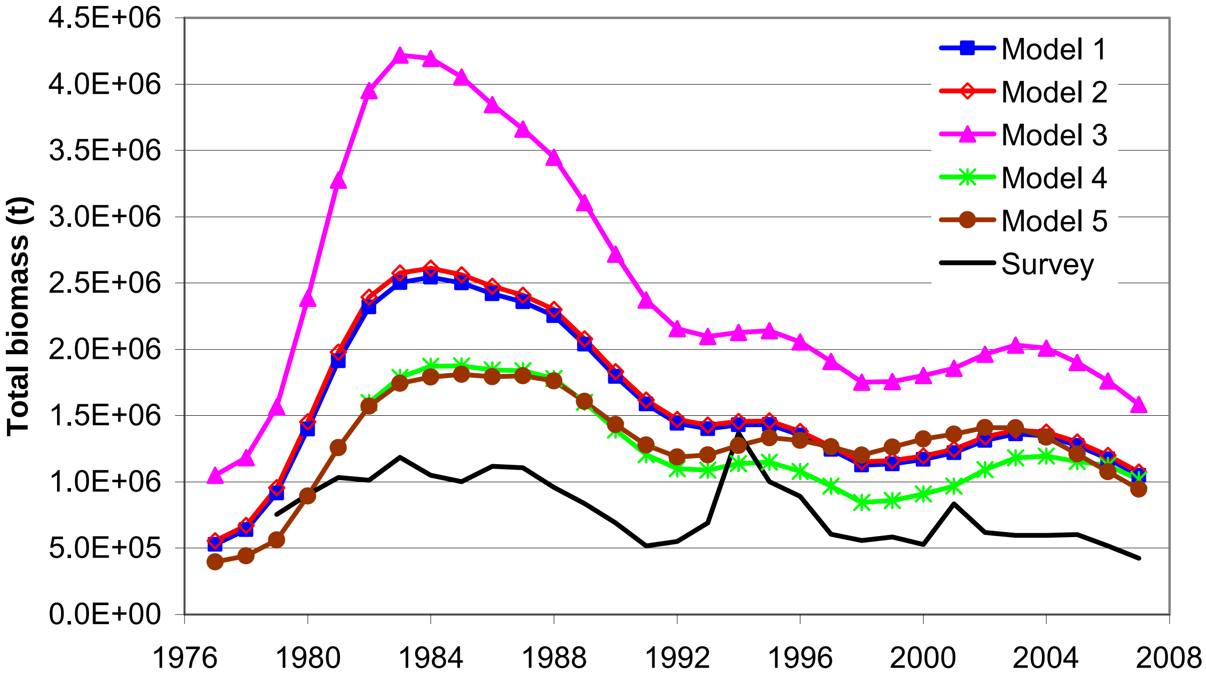


Figure 2.2.8. Comparison of total biomass time series estimates. Bottom trawl survey biomass estimates are also shown.

Attachment 2.3:

Tables and figures for the "Time Series Results" and "Projections and Harvest Alternatives" sections based on the SSC's Reference Model (A1)

The tables and figures contained in the "Time Series Results" and "Projections and Harvest Alternatives" sections in the main text are based on Model B1. This attachment reproduces those tables and figures, but based on the SSC's reference model (A1).

Table 2.3.23a—Time series of EBS (not expanded to BSAI) Pacific cod age 0+ biomass, female spawning biomass (t), and standard deviation of spawning biomass as estimated last year under the Plan Team's and SSC's preferred model and this year under Model A1. 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 (even after correcting for the BSAI expansion).

	Last year's assessment			This year's assessment		
Year	Age 0+ bio.	Spawn. bio.	Std. dev.	Age 0+ bio.	Spawn. bio.	Std. dev.
1977	527,766	127,575	40,977	1,566,800	518,295	124,031
1978	638,883	155,625	44,290	1,601,770	532,025	124,846
1979	915,953	202,290	51,395	1,790,100	545,705	126,373
1980	1,399,170	283,920	62,145	2,393,460	597,005	130,641
1981	1,913,590	425,240	76,965	3,021,500	740,860	143,511
1982	2,320,270	625,900	95,600	3,484,110	985,705	168,728
1983	2,504,630	819,800	110,365	3,647,090	1,222,515	192,453
1984	2,544,120	924,700	114,105	3,594,430	1,330,065	199,050
1985	2,501,310	932,450	108,350	3,519,230	1,311,025	190,341
1986	2,419,680	888,200	98,655	3,408,050	1,237,395	176,331
1987	2,357,380	849,750	89,370	3,349,790	1,186,940	165,127
1988	2,254,070	815,200	81,340	3,236,650	1,155,395	157,587
1989	2,038,300	760,400	73,960	2,973,210	1,105,155	150,968
1990	1,796,960	702,300	66,530	2,652,910	1,037,940	142,085
1991	1,587,630	620,050	58,485	2,377,860	928,000	129,208
1992	1,442,630	512,550	50,780	2,246,140	790,585	115,816
1993	1,400,690	451,425	45,295	2,268,430	720,080	107,879
1994	1,429,870	445,295	42,550	2,364,680	730,810	107,729
1995	1,434,130	448,745	41,478	2,474,300	765,945	112,503
1996	1,354,400	432,445	40,990	2,487,430	786,405	118,292
1997	1,244,070	416,680	40,475	2,440,160	808,680	122,904
1998	1,128,100	375,345	39,378	2,380,950	797,870	124,552
1999	1,136,880	351,455	38,376	2,481,150	797,515	124,279
2000	1,170,540	345,010	38,470	2,560,850	815,725	125,112
2001	1,220,940	358,985	40,009	2,590,210	852,650	127,707
2002	1,311,880	384,300	42,260	2,630,400	882,160	129,426
2003	1,361,980	404,030	44,708	2,604,030	884,575	129,140
2004	1,346,700	424,690	47,319	2,478,810	875,285	127,969
2005	1,273,760	429,370	49,245	2,281,740	841,660	125,213
2006	1,173,690	407,020	49,594	2,066,700	776,090	119,651
2007	1,050,650	369,640	48,539	1,843,270	695,065	111,894
2008	1,063,820	333,096	n/a	1,721,670	619,705	103,595
2009				1,783,020	565,895	97,307

Table 2.3.23b—Time series of EBS (not expanded to BSAI) Pacific cod age 0 recruitment (1000s of fish), with standard deviations, as estimated last year under the Plan Team's and SSC's preferred model and this year under Model A1.

	Last year's values		This year's values	
Year	Recruits	Std. dev.	Recruits	Std. dev.
1977	2,533,200	338,700	3,760,610	601,540
1978	787,020	153,500	933,575	212,882
1979	1,042,300	125,230	1,160,410	190,470
1980	411,490	65,406	539,947	99,518
1981	211,920	42,523	234,896	53,234
1982	1,354,400	104,650	1,790,980	215,303
1983	248,630	41,473	413,291	71,109
1984	1,045,200	78,116	1,433,820	171,302
1985	553,370	53,793	703,426	93,969
1986	284,700	33,632	324,528	48,734
1987	158,470	24,824	181,443	32,932
1988	392,570	36,646	544,654	72,580
1989	801,750	60,628	1,242,890	157,995
1990	731,990	51,157	1,052,600	127,655
1991	383,500	33,706	612,764	78,348
1992	883,170	57,322	1,453,660	172,302
1993	325,880	27,180	590,214	72,299
1994	323,260	26,432	587,364	72,831
1995	359,010	32,332	733,771	95,884
1996	892,480	73,043	1,551,270	186,925
1997	449,700	36,438	592,829	68,708
1998	497,990	41,585	689,513	80,354
1999	904,670	73,104	1,158,620	134,852
2000	623,730	48,766	778,699	89,124
2001	325,960	30,490	421,077	53,490
2002	398,510	37,284	492,178	62,749
2003	350,100	37,260	455,370	62,780
2004	203,560	25,248	274,104	39,921
2005	393,800	61,178	403,989	59,048
2006	1,835,100	419,310	1,453,450	216,297
2007			681,715	293,767
Average	656,914		878,957	

Table 2.3.24—Numbers (1000s) at age as estimated by Model A1.

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1977	3760610	302172	65057	268345	107039	73891	50988	35183	24277	16751	11559	7976	5503	3798	2620	1808	1248	861	594	410	912
1978	933575	2676690	215040	46136	187079	73940	51095	35396	24504	16944	11707	8084	5581	3852	2659	1835	1266	874	603	416	926
1979	1160410	664491	1904740	152299	31935	127921	50633	35174	24473	16990	11769	8140	5625	3885	2682	1852	1278	882	609	420	935
1980	539947	825947	472888	1350920	106081	22024	88307	35097	24466	17061	11861	8223	5690	3933	2717	1876	1296	894	617	426	949
1981	234896	384318	587767	335796	953356	74293	15348	61421	24399	17009	11864	8250	5720	3959	2737	1891	1306	902	623	430	957
1982	1790980	167192	273465	417007	236730	667843	51834	10689	42753	16983	11841	8261	5746	3986	2759	1908	1318	911	629	434	967
1983	413291	1274770	118969	194000	294043	166046	467054	36212	7466	29862	11864	8274	5773	4016	2786	1929	1334	922	637	440	980
1984	1433820	294168	906981	84280	136202	204738	115071	323143	25046	5164	20660	8210	5727	3997	2781	1930	1336	924	639	441	984
1985	703426	1020550	209286	642052	58960	94101	140413	78718	220965	17131	3534	14146	5624	3924	2740	1907	1323	916	634	438	977
1986	324528	500678	726270	148690	451904	40832	64300	95252	53246	149348	11579	2389	9567	3805	2656	1854	1291	896	620	429	959
1987	181443	230990	356300	515941	104657	313167	27933	43678	64510	36027	101033	7834	1617	6476	2576	1798	1256	874	607	420	940
1988	544654	129146	164379	253101	362706	72234	212879	18836	29367	43354	24222	67975	5274	1089	4364	1736	1212	847	590	409	918
1989	1242890	387668	91885	116585	177007	248118	48473	141208	12422	19311	28468	15894	44583	3458	714	2861	1138	795	555	386	870
1990	1052600	884650	275819	65184	81604	121292	167018	32304	93674	8224	12776	18829	10510	29482	2287	472	1892	753	525	367	831
1991	612764	749209	629636	195636	45137	54773	80242	110120	21306	61854	5436	8452	12463	6960	19528	1515	313	1254	499	348	794
1992	1453660	436147	533232	446486	134370	29560	34999	50967	70009	13578	39507	3478	5414	7990	4465	12533	973	201	805	320	734
1993	590214	1034670	310425	378521	309448	89074	19044	22390	32689	45106	8783	25630	2261	3525	5208	2912	8180	635	131	526	689
1994	587364	420097	736419	220322	263390	208489	58817	12515	14746	21605	29904	5836	17059	1507	2351	3475	1944	5462	424	88	812
1995	733771	418069	299000	522117	152617	175763	135798	38070	8117	9601	14116	19590	3831	11212	991	1548	2289	1281	3600	280	593
1996	1551270	522277	297508	212219	362618	101032	111958	85339	23930	5123	6084	8972	12478	2444	7160	633	990	1464	820	2304	559
1997	592829	1104140	371677	211268	148003	242513	65257	71408	54429	15317	3291	3918	5790	8063	1581	4634	410	641	949	531	1856
1998	689513	421958	785768	263845	146809	98098	154778	41106	45000	34442	9731	2097	2503	3704	5164	1013	2972	263	411	609	1533
1999	1158620	490775	300298	558214	184584	99234	64530	100897	26815	29452	22613	6404	1383	1652	2447	3413	670	1966	174	272	1418
2000	778699	824668	349289	213421	391307	125236	65593	42306	66247	17676	19486	15002	4257	920	1101	1632	2277	447	1312	116	1129
2001	421077	554255	586941	248067	148688	263436	82611	43175	27999	44114	11827	13082	10096	2870	621	743	1103	1540	302	888	842
2002	492178	299710	394486	416828	172658	100105	174358	54685	28765	18777	29732	8000	8870	6857	1951	423	506	751	1049	206	1180
2003	455370	350318	213314	280130	289405	115215	65388	113828	35962	19060	12514	19896	5368	5963	4616	1315	285	342	507	708	936
2004	274104	324119	249335	151466	194205	192301	74830	42458	74519	23741	12664	8351	13319	3601	4006	3105	885	192	230	342	1109
2005	403989	195099	230686	176993	104766	128367	124040	48238	27599	48860	15670	8397	5555	8879	2404	2678	2077	592	129	154	972
2006	1453450	287547	138861	163740	122465	69347	82716	79579	31099	17900	31839	10245	5503	3646	5834	1581	1762	1367	390	85	742
2007	681715	1034520	204660	98579	113396	80918	44463	52770	51054	20089	11626	20760	6698	3604	2391	3829	1038	1158	899	256	544
2008	879401	485225	736315	145254	68292	75104	52079	28496	34023	33152	13118	7622	13646	4411	2376	1578	2529	686	765	594	529

Table 2.3.25—Projections for BSAI Pacific cod catch (t), spawning biomass (t), and fishing mortality under the assumption that $F = max\ F_{ABC}$ in 2009-2021 (Scenario 1), with random variability in future recruitment.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2009	332,000	332,000	332,000	332,000	1
2010	342,000	342,000	342,000	342,000	133
2011	351,000	353,000	354,000	359,000	2,894
2012	333,000	356,000	363,000	413,000	28,212
2013	278,000	351,000	364,000	491,000	74,085
2014	228,000	347,000	365,000	551,000	107,124
2015	210,000	353,000	367,000	572,000	120,587
2016	193,000	357,000	368,000	584,000	122,495
2017	187,000	359,000	367,000	579,000	120,794
2018	182,000	362,000	367,000	582,000	120,758
2019	189,000	365,000	368,000	585,000	121,671
2020	192,000	359,000	371,000	594,000	122,864
2021	192,000	365,000	372,000	591,000	125,754

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2009	633,000	633,000	633,000	633,000	0
2010	566,000	566,000	566,000	567,000	223
2011	561,000	563,000	563,000	568,000	2,658
2012	558,000	570,000	574,000	604,000	16,298
2013	531,000	570,000	581,000	669,000	49,379
2014	490,000	568,000	589,000	755,000	92,103
2015	462,000	567,000	599,000	827,000	123,435
2016	447,000	574,000	606,000	862,000	137,141
2017	434,000	580,000	610,000	871,000	139,280
2018	428,000	580,000	610,000	882,000	137,790
2019	431,000	585,000	611,000	878,000	137,726
2020	435,000	585,000	612,000	878,000	139,706
2021	439,000	584,000	615,000	882,000	143,005

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2009	0.28	0.28	0.28	0.28	0.00
2010	0.27	0.27	0.27	0.27	0.00
2011	0.27	0.27	0.27	0.27	0.00
2012	0.27	0.27	0.27	0.28	0.00
2013	0.25	0.27	0.27	0.28	0.01
2014	0.23	0.27	0.26	0.28	0.02
2015	0.22	0.27	0.26	0.28	0.02
2016	0.21	0.27	0.26	0.28	0.03
2017	0.20	0.28	0.26	0.28	0.03
2018	0.20	0.28	0.26	0.28	0.03
2019	0.20	0.28	0.26	0.28	0.03
2020	0.20	0.28	0.26	0.28	0.03
2021	0.21	0.28	0.26	0.28	0.03

Table 2.3.26—Projections for BSAI Pacific cod catch (t), spawning biomass (t), and fishing mortality under the assumption that F = 96.6% of $max\ F_{ABC}$ in 2009-2021 (Scenario 2), with random variability in future recruitment.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2009	176,000	176,000	176,000	176,000	0
2010	201,000	201,000	201,000	201,000	2
2011	221,000	222,000	222,000	223,000	712
2012	222,000	230,000	234,000	256,000	12,442
2013	204,000	234,000	243,000	307,000	36,577
2014	186,000	238,000	250,000	349,000	55,699
2015	178,000	243,000	257,000	374,000	65,122
2016	171,000	247,000	260,000	385,000	68,129
2017	165,000	250,000	260,000	390,000	68,503
2018	160,000	252,000	260,000	387,000	69,013
2019	162,000	253,000	261,000	392,000	69,836
2020	167,000	253,000	263,000	394,000	70,644
2021	169,000	252,000	264,000	405,000	72,373

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2009	644,000	644,000	644,000	644,000	0
2010	631,000	631,000	631,000	631,000	231
2011	669,000	671,000	672,000	677,000	2,796
2012	708,000	722,000	726,000	757,000	17,293
2013	711,000	756,000	769,000	865,000	54,416
2014	681,000	780,000	802,000	995,000	109,363
2015	643,000	797,000	829,000	1,110,000	159,490
2016	616,000	810,000	849,000	1,200,000	190,587
2017	594,000	829,000	862,000	1,230,000	204,074
2018	580,000	833,000	867,000	1,260,000	207,718
2019	574,000	843,000	871,000	1,260,000	208,792
2020	585,000	847,000	875,000	1,270,000	210,903
2021	590,000	849,000	879,000	1,270,000	214,674

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2009	0.14	0.14	0.14	0.14	0.00
2010	0.14	0.14	0.14	0.14	0.00
2011	0.14	0.14	0.14	0.14	0.00
2012	0.14	0.14	0.14	0.14	0.00
2013	0.14	0.14	0.14	0.14	0.00
2014	0.14	0.14	0.14	0.14	0.00
2015	0.14	0.14	0.14	0.14	0.00
2016	0.14	0.14	0.14	0.14	0.00
2017	0.14	0.14	0.14	0.14	0.00
2018	0.14	0.14	0.14	0.14	0.00
2019	0.14	0.14	0.14	0.14	0.00
2020	0.14	0.14	0.14	0.14	0.00
2021	0.14	0.14	0.14	0.14	0.00

Table 2.3.27—Projections for BSAI 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	138,000	138,000	138,000	138,000	0
2010	161,000	161,000	161,000	161,000	2
2011	179,000	179,000	180,000	181,000	553
2012	182,000	189,000	191,000	209,000	9,703
2013	170,000	194,000	201,000	252,000	28,867
2014	156,000	198,000	208,000	287,000	44,592
2015	151,000	203,000	214,000	311,000	52,757
2016	146,000	208,000	218,000	319,000	55,471
2017	141,000	210,000	219,000	323,000	55,714
2018	139,000	212,000	219,000	323,000	55,873
2019	141,000	213,000	221,000	328,000	56,473
2020	145,000	213,000	222,000	331,000	57,311
2021	145,000	213,000	223,000	338,000	58,877

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2009	646,000	646,000	646,000	646,000	0
2010	647,000	647,000	647,000	648,000	231
2011	699,000	701,000	701,000	706,000	2,797
2012	752,000	765,000	769,000	801,000	17,329
2013	768,000	813,000	825,000	923,000	55,023
2014	745,000	846,000	869,000	1,070,000	112,445
2015	711,000	871,000	905,000	1,200,000	166,976
2016	685,000	888,000	931,000	1,300,000	202,642
2017	663,000	912,000	948,000	1,340,000	219,603
2018	645,000	920,000	957,000	1,370,000	225,404
2019	640,000	933,000	962,000	1,390,000	227,641
2020	644,000	939,000	968,000	1,400,000	230,391
2021	657,000	943,000	973,000	1,390,000	234,568

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2009	0.11	0.11	0.11	0.11	0.00
2010	0.11	0.11	0.11	0.11	0.00
2011	0.11	0.11	0.11	0.11	0.00
2012	0.11	0.11	0.11	0.11	0.00
2013	0.11	0.11	0.11	0.11	0.00
2014	0.11	0.11	0.11	0.11	0.00
2015	0.11	0.11	0.11	0.11	0.00
2016	0.11	0.11	0.11	0.11	0.00
2017	0.11	0.11	0.11	0.11	0.00
2018	0.11	0.11	0.11	0.11	0.00
2019	0.11	0.11	0.11	0.11	0.00
2020	0.11	0.11	0.11	0.11	0.00
2021	0.11	0.11	0.11	0.11	0.00

Table 2.3.28—Projections for BSAI 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	174,000	174,000	174,000	174,000	0
2010	199,000	199,000	199,000	199,000	2
2011	219,000	219,000	220,000	221,000	704
2012	220,000	228,000	231,000	253,000	12,296
2013	203,000	232,000	241,000	304,000	36,172
2014	184,000	236,000	248,000	346,000	55,124
2015	177,000	241,000	255,000	371,000	64,465
2016	170,000	245,000	258,000	381,000	67,208
2017	165,000	248,000	258,000	386,000	67,152
2018	163,000	250,000	259,000	384,000	67,230
2019	165,000	251,000	260,000	389,000	67,935
2020	170,000	251,000	261,000	391,000	68,944
2021	171,000	250,000	263,000	402,000	70,836

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2009	644,000	644,000	644,000	644,000	0
2010	632,000	632,000	632,000	632,000	231
2011	671,000	673,000	673,000	678,000	2,796
2012	711,000	724,000	728,000	759,000	17,295
2013	714,000	759,000	772,000	868,000	54,448
2014	684,000	783,000	806,000	998,000	109,525
2015	647,000	800,000	833,000	1,120,000	159,881
2016	619,000	814,000	853,000	1,200,000	191,235
2017	597,000	833,000	866,000	1,240,000	205,019
2018	582,000	837,000	872,000	1,260,000	209,032
2019	575,000	847,000	875,000	1,270,000	210,510
2020	583,000	852,000	879,000	1,280,000	212,920
2021	588,000	854,000	883,000	1,270,000	216,813

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2009	0.14	0.14	0.14	0.14	0.00
2010	0.14	0.14	0.14	0.14	0.00
2011	0.14	0.14	0.14	0.14	0.00
2012	0.14	0.14	0.14	0.14	0.00
2013	0.14	0.14	0.14	0.14	0.00
2014	0.14	0.14	0.14	0.14	0.00
2015	0.14	0.14	0.14	0.14	0.00
2016	0.14	0.14	0.14	0.14	0.00
2017	0.14	0.14	0.14	0.14	0.00
2018	0.14	0.14	0.14	0.14	0.00
2019	0.14	0.14	0.14	0.14	0.00
2020	0.14	0.14	0.14	0.14	0.00
2021	0.14	0.14	0.14	0.14	0.00

Table 2.3.29—Projections for BSAI 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	655,000	655,000	655,000	655,000	0
2010	707,000	707,000	707,000	708,000	231
2011	813,000	815,000	816,000	821,000	2,798
2012	930,000	943,000	947,000	978,000	17,457
2013	1,010,000	1,050,000	1,060,000	1,170,000	57,190
2014	1,030,000	1,140,000	1,160,000	1,380,000	123,997
2015	1,020,000	1,200,000	1,240,000	1,590,000	196,639
2016	1,010,000	1,260,000	1,310,000	1,760,000	252,779
2017	993,000	1,310,000	1,360,000	1,860,000	286,558
2018	975,000	1,340,000	1,390,000	1,960,000	303,389
2019	964,000	1,370,000	1,410,000	2,000,000	311,595
2020	981,000	1,390,000	1,430,000	2,010,000	317,486
2021	1,000,000	1,410,000	1,440,000	2,030,000	323,790

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 2.3.30—Projections for BSAI 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	388,000	388,000	388,000	388,000	1
2010	374,000	374,000	375,000	375,000	150
2011	373,000	375,000	376,000	382,000	3,274
2012	347,000	372,000	382,000	449,000	35,898
2013	285,000	364,000	386,000	549,000	91,319
2014	232,000	359,000	388,000	610,000	126,565
2015	216,000	366,000	391,000	630,000	139,000
2016	200,000	369,000	392,000	641,000	139,701
2017	195,000	371,000	389,000	638,000	137,457
2018	190,000	377,000	388,000	632,000	137,401
2019	194,000	373,000	389,000	637,000	138,602
2020	197,000	369,000	392,000	646,000	140,309
2021	197,000	377,000	394,000	648,000	143,483

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2009	628,000	628,000	628,000	628,000	0
2010	544,000	544,000	544,000	544,000	222
2011	530,000	531,000	532,000	537,000	2,639
2012	521,000	533,000	537,000	566,000	15,912
2013	492,000	530,000	540,000	621,000	46,618
2014	453,000	527,000	545,000	693,000	83,958
2015	428,000	526,000	551,000	753,000	109,179
2016	414,000	533,000	555,000	774,000	118,551
2017	402,000	531,000	556,000	780,000	118,649
2018	399,000	534,000	555,000	788,000	116,788
2019	401,000	537,000	555,000	782,000	117,111
2020	405,000	533,000	556,000	777,000	119,161
2021	405,000	535,000	558,000	795,000	122,021

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2009	0.33	0.33	0.33	0.33	0.00
2010	0.31	0.31	0.31	0.31	0.00
2011	0.30	0.30	0.30	0.30	0.00
2012	0.29	0.30	0.30	0.32	0.01
2013	0.28	0.30	0.30	0.33	0.02
2014	0.25	0.30	0.30	0.33	0.03
2015	0.24	0.30	0.30	0.33	0.03
2016	0.23	0.30	0.29	0.33	0.04
2017	0.22	0.30	0.29	0.33	0.04
2018	0.22	0.30	0.29	0.33	0.04
2019	0.22	0.30	0.29	0.33	0.04
2020	0.22	0.30	0.29	0.33	0.04
2021	0.22	0.30	0.29	0.33	0.04

Table 2.3.31—Projections for BSAI Pacific cod catch (t), spawning biomass (t), and fishing mortality under the assumption that $F = max\ F_{ABC}$ in each year 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	332,000	332,000	332,000	332,000	1
2010	342,000	342,000	342,000	342,000	133
2011	408,000	410,000	411,000	417,000	3,385
2012	363,000	389,000	399,000	467,000	35,479
2013	291,000	371,000	392,000	551,000	90,528
2014	234,000	361,000	390,000	612,000	126,301
2015	216,000	366,000	391,000	630,000	139,009
2016	200,000	369,000	391,000	641,000	139,768
2017	195,000	370,000	389,000	638,000	137,513
2018	190,000	377,000	388,000	632,000	137,431
2019	194,000	373,000	389,000	637,000	138,617
2020	197,000	369,000	392,000	646,000	140,314
2021	197,000	377,000	394,000	648,000	143,484

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2009	633,000	633,000	633,000	633,000	0
2010	566,000	566,000	566,000	567,000	223
2011	557,000	559,000	560,000	564,000	2,640
2012	536,000	548,000	552,000	580,000	15,941
2013	498,000	537,000	547,000	628,000	46,866
2014	455,000	530,000	547,000	696,000	84,368
2015	429,000	527,000	551,000	754,000	109,528
2016	414,000	532,000	555,000	775,000	118,761
2017	402,000	530,000	556,000	781,000	118,745
2018	399,000	533,000	555,000	789,000	116,819
2019	400,000	536,000	555,000	782,000	117,116
2020	405,000	533,000	556,000	777,000	119,158
2021	405,000	535,000	558,000	795,000	122,017

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2009	0.28	0.28	0.28	0.28	0.00
2010	0.27	0.27	0.27	0.27	0.00
2011	0.32	0.32	0.32	0.32	0.00
2012	0.30	0.31	0.31	0.33	0.01
2013	0.28	0.30	0.31	0.33	0.02
2014	0.25	0.30	0.30	0.33	0.03
2015	0.24	0.30	0.30	0.33	0.03
2016	0.23	0.30	0.29	0.33	0.04
2017	0.22	0.30	0.29	0.33	0.04
2018	0.22	0.30	0.29	0.33	0.04
2019	0.22	0.30	0.29	0.33	0.04
2020	0.22	0.30	0.29	0.33	0.04
2021	0.22	0.30	0.29	0.33	0.04

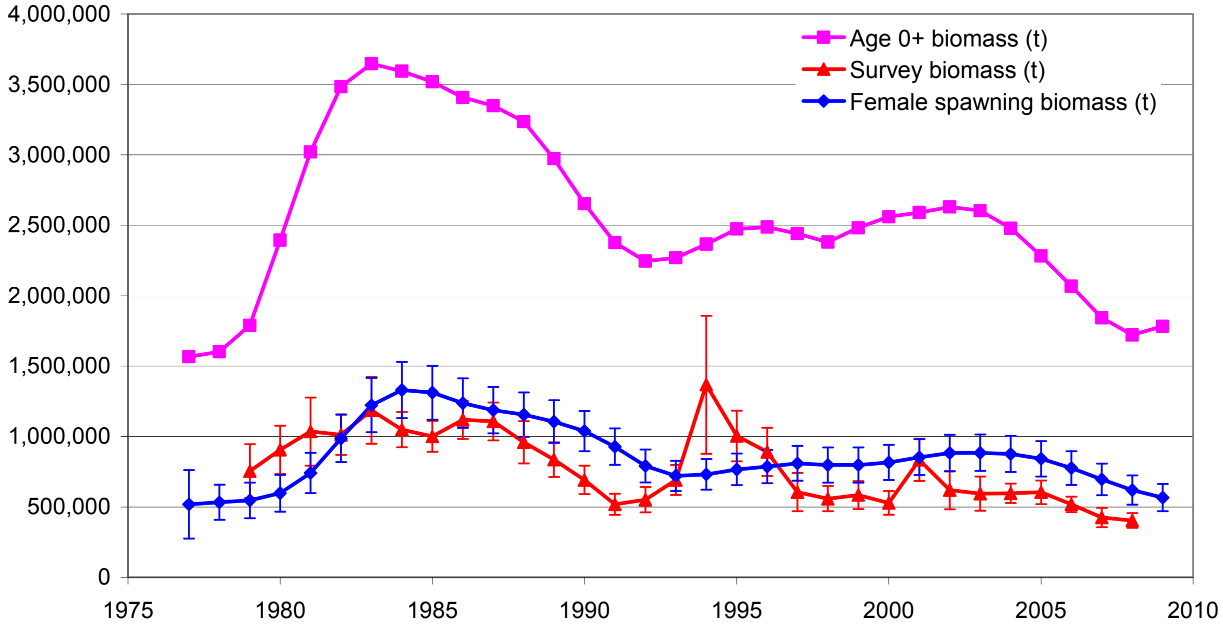


Figure 2.3.6—Biomass time trends (age 3+ biomass, female spawning biomass, survey biomass) of EBS Pacific cod as estimated by Model A1.

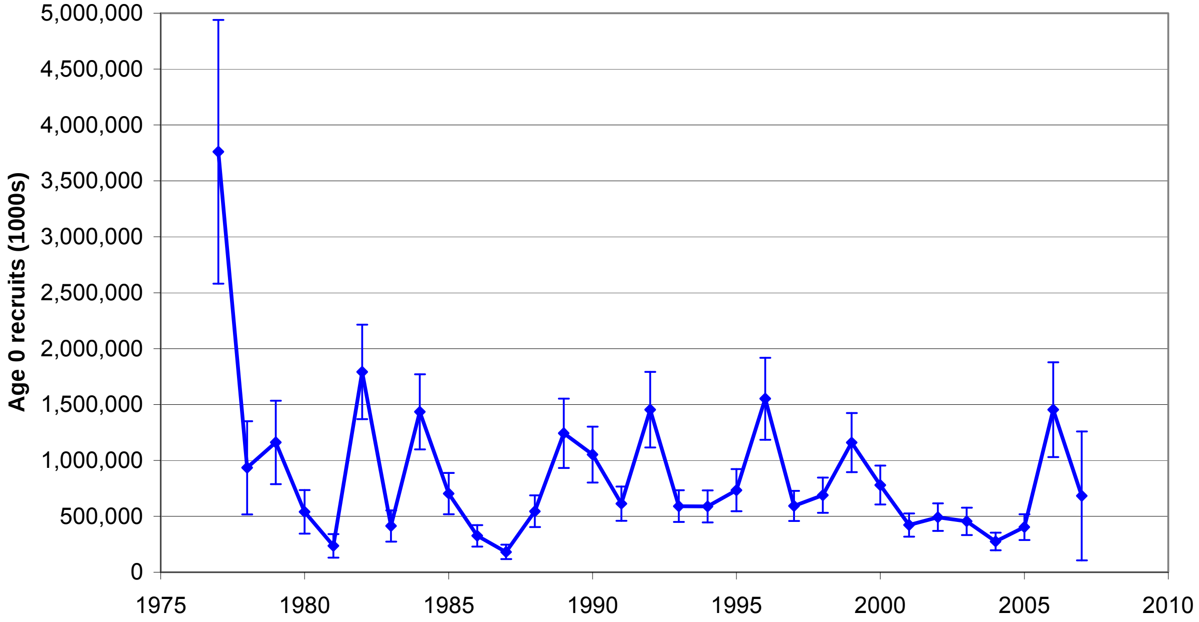


Figure 2.3.7—Time series of EBS Pacific cod recruitment at age 0, with 95% confidence intervals, as estimated by Model A1.

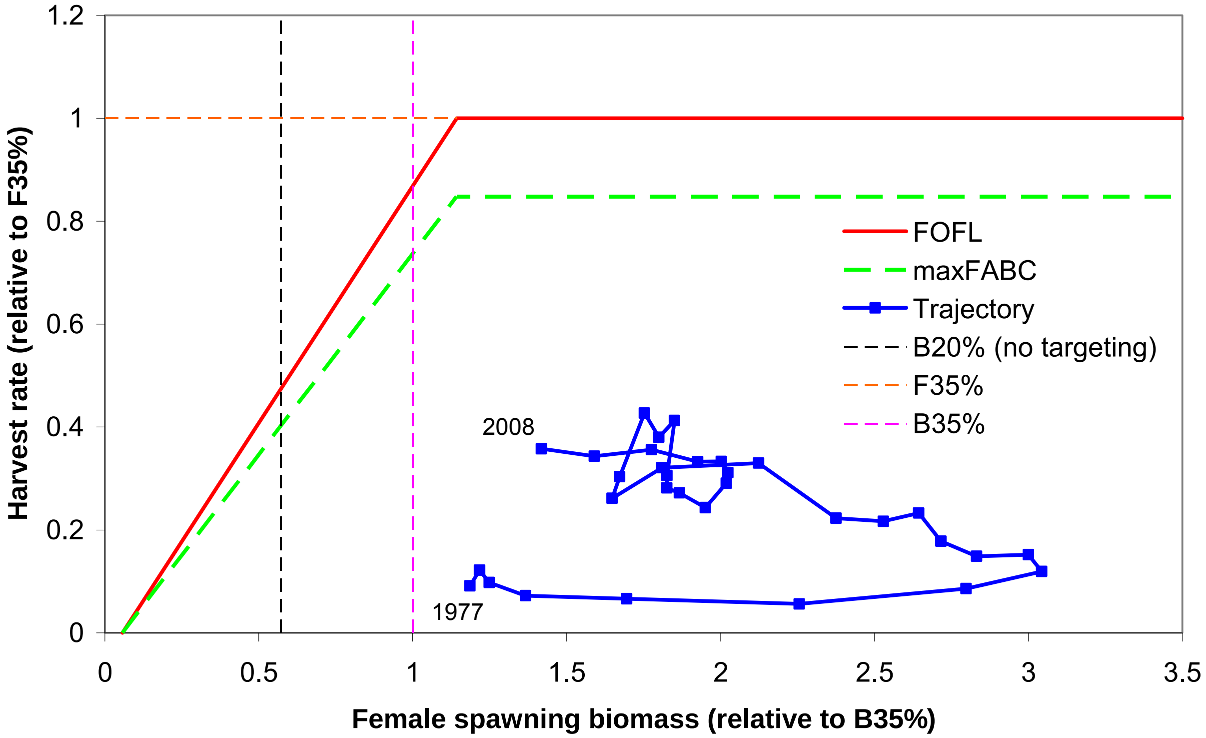


Figure 2.3.8—Trajectory of Pacific cod fishing mortality and female spawning biomass as estimated by Model A1, 1977-present. Because Pacific cod is a key prey of Steller sea lions, harvests of Pacific cod would be restricted to incidental catch in the event that spawning biomass fell below $B_{20\%}$.

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