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

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EXECUTIVE SUMMARY

Summary of 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 1991-2008 were updated, and preliminary catch data for 2009 were incorporated.
2) Commercial fishery size composition data for 2008 were updated, and preliminary size composition data from the 2009 commercial fisheries were incorporated.
3) Size composition data from the 2009 EBS shelf bottom trawl survey were incorporated.
4) The numeric abundance estimate from the 2009 EBS shelf bottom trawl survey was incorporated (the 2009 estimate of 717 million fish was up about 50% from the 2008 estimate).
5) Age composition data from the 2008 EBS shelf bottom trawl survey were incorporated into some of the models.
6) Age composition data from the 2008 January-May longline fishery were incorporated into some of the models.
7) Mean length at age data from the 1994-2008 EBS shelf bottom trawl surveys were incorporated into some of the models.
8) Mean length at age data from the 2008 January-May longline fishery were incorporated into some of the models.
9) The variances in the ageing error matrix were updated in all of the models that use age data, and possible biases in age data were corrected for in some of the models that use age data.
10) Seasonal catch per unit effort (CPUE) data for the trawl, longline, and pot fisheries from 2008 were updated, and preliminary catch rates for the trawl, longline, and pot fisheries from 2009 were incorporated.
11) The Pacific cod catch rate from the 2008 International Pacific Halibut Commission (IPHC) longline survey was incorporated.

12) Pacific cod size composition data from the 2009 IPHC longline survey were incorporated.

Changes in the Assessment Methodology

Many changes have been made or considered in the stock assessment model since the 2008 assessment. Eight models were presented in this year's preliminary assessment (Attachment 2.1). The relationships between the eight models presented in the preliminary assessment are summarized in Table 2.1.1 of Attachment 2.1. The set of eight models in the preliminary assessment represented a 3-way factorial design, where the three factors were suggested by either the Plan Team(s) or SSC. Model A in the preliminary assessment was identical to the model accepted for use by the BSAI Plan Team and SSC last year, and was the only model from the preliminary assessment recommended by either the Plan Team or SSC to be carried forward for inclusion in this final assessment.

Fourteen models are included in this final assessment. Seven of them include age composition data and seven do not. Models whose names end in "1" include age composition data, and models whose names end in "2" do not include age composition data. The one model whose name ends in "3" (Model A3) includes all available age composition data except the 2008 January-May longline fishery data. The fourteen models are designed to respond to requests made by the Plan Team(s), SSC, and public, as described in Table 2.0.

The 14 models presented in this final assessment may be classified into three groups as follows:

Models without mean size-at-age data. This group includes three versions of the model accepted for use by the Plan Team and SSC last year, differing only with respect to the amount of age composition data included. These are labeled A1 (all available age composition data), A2 (no age composition data), and A3 (all available age composition data except the 2008 January-May longline fishery data). Given the SSC's past endorsement of the survey age composition data and request for inclusion of fishery age composition data (see "Responses to Comments from the Plan Teams and SSC" below), Model A1 is considered the base model.

The group of models without mean size-at-age data also includes Model F2, which is identical to Model F2 from the 2008 assessment (and almost identical to Model 4 from the 2007 assessment). Model F2 was requested by members of the public, and includes the following features not found in any of the other models: weight at length does not vary seasonally, trawl survey selectivity is assumed to be asymptotic, the 1976-1977 regime shift is not modeled, initial catch is not used to estimate the initial fishing mortality rate, the maturity schedule is length-based rather than age-based, trawl survey selectivity is length-based rather than age-based, both the ascending "width" selectivity parameter and the selectivity at minimum length in the trawl survey are allowed to vary annually, the input standard deviation of the survey selectivity "dev" vector is set equal to 0.4, the natural mortality rate is estimated internally, the standard deviation of length at age is assumed to be a linear function of age, and all fisheries are assumed to exhibit asymptotic selectivity except for the January-May trawl fishery, the January-May longline fishery, and the January-May pot fishery.

Models with mean size-at-age data and age composition data. This group includes five models with various new features requested by the Plan Team(s), SSC, and public. All models in this group share the following requested features: Potential bias in age readings is corrected for, survey selectivity is held constant at base values for the two most recent years (i.e., no selectivity "devs" are estimated for those years), and growth rates are cohort-specific. As indicated by the paragraph header above, mean size-at-age data are included in this group of models. Because trawl survey size composition data are not used for any year in which trawl survey age composition data are used (to avoid double counting), and because fishery size composition data give almost no information about ages 1 or 2, inclusion of mean size-at-age data is necessary for meaningful estimation of cohort-specific growth.

Model B1 is the base model for this group. Input standard deviations of all “dev” vectors were set iteratively by matching the standard deviations of the set of estimated “devs,” and the standard deviation of length at age was estimated outside the model as a linear function of mean length at age. Selectivity at maximum size or age was treated as a controllable parameter. Catchability for the post-1981 trawl survey was fixed at the value that sets the average (weighted by numbers at length) of the product of catchability and selectivity for the 60-81 cm size range equal to the point estimate of 0.47 obtained by Nichol et al. (2007). Potential ageing bias was accounted for in the ageing error matrix by examining alternative bias values in increments of 0.1 for ages 2 and above (age-specific bias values were also examined, but did not improve the fit significantly).

For the remaining models in this group, the input standard deviations for all “dev” vectors and the amount of ageing bias were held constant at the values obtained by Model B1. Differences with respect to Model B1 in the remaining models were as follow:

Model C1 is identical to Model B1 except that it sets *catchability itself* (rather than the average product of catchability and selectivity for the 60-81 cm size range) equal to 0.47.

Model D1 is identical to Model B1 except that selectivity at maximum size or age is removed from the set of controllable parameters (instead, selectivity at maximum size or age becomes a function of other selectivity parameters).

Model E1 is identical to Model B1 except that selectivity at maximum size or age for all non-asymptotic fleets is set equal to a single value that is constant across fleets.

Model G1 is identical to Model B1 except that survey selectivity is held constant across all years (i.e., no selectivity “devs” are estimated for any years).

<u>Models with mean size-at-age data and without age composition data.</u> This group includes a no-age-composition-data counterpart for each model in the preceding group. Size composition data are included in place of age composition data. The input standard deviations for all “dev” vectors and the amount of ageing bias were held constant at the values obtained by Model B1. These models are labeled B2, C2, D2, E2, and G2.

Table 2.0 shows how the various requests from the Plan Team(s), SSC, and public map into the 14 models presented here.

Version 3.03c of SS was used to run all the models in the preliminary assessment and in this final assessment.

Model B1 is the authors’ recommended model.

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.

	Assessment	
Quantity/Status	Last year	This year
M	0.34	0.34
Specified/recommended Tier	3b	3b
Projected total biomass (ages 0+) for 2010	1,389,000	1,244,000
Projected summary biomass (ages 3+) for 2010	1,301,000	1,144,000
Projected female spawning biomass for 2010	373,000	345,000
B100%	1,066,000	1,027,000
B40%	426,000	411,000
B35%	373,000	360,000
B0	n/a	n/a
FOFL for 2010	n/a	0.29
maxFABC for 2010	0.24	0.24
maxFABC for 2011	0.25	0.26
Specified/recommended *FABC* for 2010	0.24	0.24
Specified/recommended *FABC* for 2011	n/a	0.26
OFL for 2010	235,000	205,000
OFL for 2011 (given recommended ABC for 2010)	n/a	251,000
maxABC for 2010	199,000	174,000
maxABC for 2011	233,000	214,000
Specified/recommended ABC for 2010	199,000	174,000
Specified/recommended ABC for 2011	n/a	214,000
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

Joint Plan Team Comments

JPT1 (09/08 minutes): *"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."* In response to this request, Stock Synthesis (SS) now includes a version of the exponential-logistic selectivity function as an option. The preliminary assessment considered several new models that used the exponential-logistic selectivity function, as described in the "Analytic Approach" section of Attachment 2.1, under the heading "Model Structure," subheading "Alternative Models." See also comments BPT3 and SSC10.

JPT2 (09/09 minutes): *"Alternatives in modeling Pacific cod growth specifically by cohort may improve the fit to the data, however, other time varying features such as selectivity in the assessment model may be confounded with cohort-specific growth."* Ten of the 14 models presented in this final assessment (B1, B2, C1, C2, D1, D2, E1, E2, G1, and G2) include cohort-specific growth.

JPT3 (09/09 minutes): *"Research priorities include: Stock assessment model incorporating bias into the existing ageing error matrix for ages 2-3 could be employed in the short term to evaluate a process-oriented approach to assessing inconsistency in these data sources."* Five of the 14 models presented in this final assessment (B1, C1, D1, E1, and G1) incorporate bias into the ageing error matrix as a short-term means of addressing possible inconsistencies between size composition and age composition data.

JPT4 (09/09 minutes): *"The Teams requested ... some model fits that do not attempt to fit the age data in both regions."* Seven of the 14 models presented in this final assessment (A2, F2, B2, C2, D2, E2, and G2) do not attempt to fit the age composition data.

BSAI Plan Team Comments

BPT1 (11/08 minutes): *"The Team encouraged the AFSC to document the accuracy of the age data."* The preliminary assessment contained a comparison of mean lengths at age under different methods of estimation, as described in the "Data" section of Attachment 2.1. An AFSC response to the issue of ageing accuracy was provided at the September 2009 Plan Team meeting. Research at the AFSC is continuing on this subject.

BPT2 (2008 BSAI SAFE): *"The authors describe a reasonable method for selecting which fisheries should exhibit asymptotic selectivity.... The Plan Team recommends that the authors apply this method in next year's model(s) and examine whether assuming asymptotic selectivity also is appropriate for the shelf bottom trawl survey."* All eight of the models presented in the preliminary assessment and all but one (Model F2) of the models presented in this final assessment assume the same set of fisheries exhibiting asymptotic selectivity as in the model adopted last year by the BSAI Plan Team and SSC. In addition, four of the models presented in the preliminary assessment assumed that the shelf bottom trawl survey also exhibits asymptotic selectivity, as described in Attachment 2.1.

BPT3 (09/09 minutes): *"The Stock Synthesis package contains an option for removing the user's control over selectivity at the smallest (youngest) or largest (oldest) size (age) in the double normal selectivity function, resulting in fewer parameters to be estimated. The BSAI Team recommended ... use [of] that feature as needed, rather than retaining the exponential-logistic function."* Two of the 14 models presented in this final assessment (Models D1 and D2) make use of the "-999" feature of the double-normal selectivity function, which removes selectivity at maximum age or length from the set of controllable parameters. The exponential-logistic selectivity function is not used in any of the models presented in this final assessment. See also Comments JPT1 and SSC10.

BPT4 (09/09 minutes): *"The Team did not recommend a return to setting [non-uniform] priors on selectivities, or any change in the selectivity deviations."* As in the 2007 and 2008 assessments, uniform priors are used for all parameters (except "dev" vectors) in all models. Four of the 14 models presented in this final assessment (A1, A2, A3, and F2) make no change in any of the specifications used to estimate selectivity deviations. The other 10 models do make some changes, however. See also Comment SSC9.

SSC Comments on Assessments in General

SSC1 (12/08 minutes): *"The BSAI Plan Team recommended that all authors of stocks managed in Tiers 1 through 3 should estimate the probability of the spawning stock biomass falling below $B_{20\%}$. The recommended time frame for this projection was 3-5 years. The SSC agrees with this recommendation and encourages authors to provide estimates of the probability of falling below biologically relevant thresholds such as $B_{20\%}$."* The probability of the spawning biomass falling below $B_{20\%}$ in 2012, 2013, and 2014 under any of the 14 models is virtually zero, as reported in Table 2.20. It should be understood that these estimates of probability are conditional on the data currently available and on the structures of the respective models.

SSC2 (06/09 minutes): *"The SSC recommends to stock assessment authors that if harvest strategies are modified to explicitly incorporate uncertainty in the buffer between OFL and ABC, then authors should strive to select the "best estimate" for parameterizing models and not the most precautionary estimate."* For all 14 models presented in this final assessment, best estimates (based in part on SSC and Plan Team input and conditional on the structure of the respective model) are used.

SSC Comments Specific to the BSAI Pacific Cod Assessment

The SSC suggested “further work along the following lines to attempt to reduce the wide range of variation among alternative models.”

SSC3 (12/08 minutes): *“Perform analytical work to resolve the discrepancy between reader-based and model-estimated mean length at age. In particular, does the discrepancy result from calculating the reader-based mean length at age from length-stratified otolith samples rather than from keyed-out joint age-length distributions?”* A comparison of mean lengths at age under different methods of estimation was contained in the preliminary assessment, as described in the “Data” section of Attachment 2.1. Briefly, the discrepancy does *not* result from the difference between the two estimation methods mentioned in the above minute.

SSC4 (12/08 minutes): *“Age cod otoliths from the fishery. Commercial age data going back ten or fifteen years should help estimate the historical abundance.”* The AFSC Age Reading Program has begun to age otoliths from the fishery. A sample of otoliths from the 2008 January-May longline fishery was used in six of the 14 models presented in this final assessment (A1, B1, C1, D1, E1, and G1).

SSC5 (12/08 minutes): *“Consider a return to models with survey Q fixed, or restrained by an influential prior. This would be a retreat for the cod assessment but we still rely on this device in other assessments (including GOA cod), and in the present circumstances a temporary retreat may be in order.”* All but four of the 14 models presented in this final assessment (A1, A2, A3, and F2) assume a fixed value for survey catchability (*Q*). In the preliminary assessment, a prior distribution based on results of archival tagging was also examined but not carried forward because it had very little impact on model results, as described in the “Analytic Approach” section of Attachment 2.1, under the heading “Model Structure,” subheading “Other Models Evaluated but not Carried Forward.”

SSC6 (12/08 minutes): *“Conduct mark-recapture experiments to make direct estimates of fishery selectivity and length at known age.”* A summary of previous and ongoing mark-recapture experiments was provided in the preliminary assessment (see “Discussion” section of Attachment 2.1).

SSC7 (12/08 minutes): *“Consider the strengths and weaknesses of model averaging as an alternative to model selection and provide a rationale for or against use of this method in future assessments.”* Strengths and weaknesses of model averaging, together with an explanation of why this method is currently not recommended for use, were included in the preliminary assessment (see “Discussion” section of Attachment 2.1).

SSC8 (10/09 minutes): *“Contrary to our previous guidance, we would like to see alternative models that constrain selectivity parameters to preserve a reasonable shape, for example by fixing selectivity at maximum age.”* Two of the 14 models presented in this final assessment (E1 and E2) fix selectivity at maximum size or age.

SSC9 (10/09 minutes): *“The SSC recommends that alternatives [be developed] that keep selectivity deviations in the last several years of the time series at ‘base’ values.”* All but four of the 14 models presented in this final assessment (A1, A2, A3, and F2) set survey selectivity deviations equal to zero for the two most recent years (2008 and 2009). The survey selectivity schedules for those two years correspond to base values. See also Comment BPT4.

SSC10 (10/09 minutes): *“We agree with PT recommendations to abandon the use of exponential logistic selectivities for this assessment.”* Exponential-logistic selectivity is not used in any of the 14 models presented in this final assessment (see also Comments JPT1 and BPT3).

INTRODUCTION

Pacific cod (*Gadus macrocephalus*) is a transoceanic species, occurring at depths from shoreline to 500 m. The southern limit of the species' distribution is about 34° N latitude, with a northern limit of about 63° N latitude. Pacific cod is distributed widely over the eastern Bering Sea (EBS) as well as in the Aleutian Islands (AI) area. The resource in these two areas (BSAI) is managed as a single unit. Tagging studies (e.g., Shimada and Kimura 1994) have demonstrated significant migration both within and between the EBS, AI, and Gulf of Alaska (GOA). Although at least one previous genetic study (Grant et al. 1987) failed to show significant evidence of stock structure within these areas, current genetic research underway at the Alaska Fisheries Science Center 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 for the periods 1964-1980 and 1981-2009 are shown in Tables 2.1a and 2.1b respectively. Catches of Pacific cod in the AI for the periods 1964-1980, 1981-1990, and 1991-2009 are shown in Tables 2.2a, 2.2b, and 2.2c respectively. Catches of Pacific cod in the EBS and AI regions combined for the periods 1964-1980, 1981-1990, and 1991-2009 are shown in Tables 2.3a, 2.3b, and 2.3c 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, 2.1c, 2.2b, 2.2c, 2.3b, and 2.3c 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. A State-managed fishery for Pacific cod in the Aleutian Islands began in 2006.

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, 2008. Figures 2.1d-2.1e show the corresponding information for January-May and June-August, 2009 (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 2009 TAC averaged about 80% of ABC, and from 1980 through 2008 aggregate commercial catch averaged about 90% of TAC (remembering that 2009 catch data are not yet final). In 10 of these 30 years (33%), TAC equaled ABC exactly, and in 5 of these 30 years (17%), catch exceeded TAC (by an average of 5%). 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 (similar reductions were made in 2008-2009); 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 (2004-2008), the EBS accounted for an average of about 85% of the BSAI catch.

The catches shown in Tables 2.1b, 2.2b, 2.2c, 2.3b, 2.3c, 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, for each year 2003-2004 in Table 2.5b, and for each year 2005-2009 in Table 2.5c.

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:

Sector	Percentage 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 ----------		

An incidental catch allowance will be deducted from the aggregate portion of Pacific cod TAC annually allocated to the hook-and-line and pot gear sectors before the allocations above are made to these sectors. Since 2001 this amount has been 500 t and included in the harvest specifications.

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 1977-2009 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 2009. 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 1991-2009 and are shown below (units are kg/hr for trawl gear, kg/hook for longline gear, and kg/pot for pot gear; season 3 data for 2009 data are partial):

	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
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	29.91	55.52	39.38	0.78	0.36	0.33	81.64		57.25
2009	44.64	44.74	44.42	0.93	0.37	0.34	93.05		69.31

Fishery Age Composition Data

This year marks the first time that fishery age composition data have become available since production ageing of Pacific cod resumed several years ago (Roberson 2001, Roberson et al. 2005). An estimate of age composition from the 2008 January-May longline fishery is now available, as shown in Table 2.11a.

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 1982-2009, 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.

Age compositions from the 1994-2008 surveys are available. The age compositions and sample sizes (scaled so that the average across all age compositions, including the 2008 January-May longline fishery age composition, equals 300) are shown in Table 2.11b.

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 (1982-2009), 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 dropped after 2005, producing all-time lows in 2007 and again in 2008. The 2009 biomass estimate was slightly higher than the 2008 estimate.

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. The 2009 estimate was up, nearly as high as the 2007 value.

Mean size-at-age data are available for all of the years in which age compositions are available. These are shown, along with sample sizes, in Table 2.13. This table also includes mean size at age for the single record of fishery age composition data currently available (2008 Jan-May longline fishery).

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). The 84%-16% distribution has been used consistently since the 2006 assessment.

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 (the 2009 value is not available yet):

2000	2001	2002	2003	2004	2005	2006	2007	2008
0.077	0.083	0.083	0.098	0.069	0.109	0.154	0.119	0.115

Pacific cod length composition data have been taken in the IPHC survey since 2007. The sampling protocol was improved substantially after the 2007 season, so only the data since 2008 are used in this assessment. The 2008 and 2009 size compositions are shown in Table 2.10c.

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 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 made 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 a number of features that distinguished it from the model used in the 2006 assessment, including: a fixed value for the natural mortality rate (0.34) based on life history theory, maturity schedule modeled as a function of age rather than length, trawl survey selectivity modeled as a function of age rather than length, constant fishery selectivity across all years, annual variability in the ascending "width" parameter of the trawl survey selectivity schedule (with a standard deviation of 0.2), standard deviation of length at age modeled as a linear function of length at age, survey abundance measured in numbers of fish (rather than biomass), and setting the input sample size for multinomial distributions on the basis of a scaled bootstrap harmonic mean.

Relative to the 2007 assessment, the model accepted by the Plan Team and SSC from the 2008 assessment featured two main changes: 1) an explicit algorithm was used to determine which fleets (including surveys as well as fisheries) would be forced to exhibit asymptotic selectivity; and 2) an explicit algorithm was used to determine which selectivity parameters would be allowed to vary periodically in “blocks” of years, and to determine the appropriate block length for each such time-varying parameter.

Model Structures Considered in This Year’s Assessment

Fourteen models are presented in this final assessment; all based on SS version 3.03c. Seven of them include age composition data and seven do not. Models whose names end in “1” include age composition data, and models whose names end in “2” do not include age composition data. The one model whose name ends in “3” (Model A3) includes all available age composition data except the 2008 January-May longline fishery data. The fourteen models are designed to respond to requests made by the Plan Team(s), SSC, and public, as described in Table 2.1

The 14 models presented in this final assessment may be classified into three groups as follows:

<u>Models without mean size-at-age data</u>. This group includes three versions of the model accepted for use by the Plan Team and SSC last year, differing only with respect to the amount of age composition data included. These are labeled A1 (all available age composition data), A2 (no age composition data), and A3 (all available age composition data except the 2008 January-May longline fishery data). Given the SSC’s past endorsement of the survey age composition data and request for inclusion of fishery age composition data (see “Responses to Comments from the Plan Teams and SSC” below), Model A1 is considered the base model.

This group also includes Model F2, which is identical to Model F2 from the 2008 assessment (and almost identical to Model 4 from the 2007 assessment). Model F2 was requested by members of the public, and includes the following features not found in any of the other models: weight at length does not vary seasonally, trawl survey selectivity is assumed to be asymptotic, the 1976-1977 regime shift is not modeled, initial catch is not used to estimate the initial fishing mortality rate, the maturity schedule is length-based rather than age-based, trawl survey selectivity is length-based rather than age-based, both the ascending “width” selectivity parameter and the selectivity at minimum length in the trawl survey are allowed to vary annually, the input standard deviation of the survey selectivity “dev” vector is set equal to 0.4, the natural mortality rate is estimated internally, the standard deviation of length at age is assumed to be a linear function of age, and all fisheries are assumed to exhibit asymptotic selectivity except for the January-May trawl fishery, the January-May longline fishery, and the January-May pot fishery.

<u>Models with mean size-at-age data and age composition data.</u> This group includes five models with various new features requested by the Plan Team(s), SSC, and public. All models in this group share the following requested features: Potential bias in age readings is corrected for, survey selectivity is held constant at base values for the two most recent years (i.e., no selectivity “devs” are estimated for those years), and growth rates are cohort-specific. As indicated by the paragraph header above, mean size-at-age data are included in this group of models. Because trawl survey size composition data are not used for any year in which trawl survey age composition data are used (to avoid double counting), and because fishery size composition data give almost no information about ages 1 or 2, inclusion of mean size-at-age data is necessary for meaningful estimation of cohort-specific growth.

Model B1 is the base model for this group. Input standard deviations of all "dev" vectors were set iteratively by matching the standard deviations of the set of estimated "devs," and the coefficient of variation of length at age was estimated outside the model as a linear function of mean length at age. Selectivity at maximum size or age was treated as a controllable parameter. Catchability for the post-1981 trawl survey was fixed at the value that sets the average (weighted by numbers at length) of the product of catchability and selectivity for the 60-81 cm size range equal to the point estimate of 0.47 obtained by Nichol et al. (2007). Potential ageing bias was accounted for in the ageing error matrix by examining alternative bias values in increments of 0.1 for ages 2 and above (age-specific bias values were also examined, but did not improve the fit significantly).

For the remaining models in this group, the input standard deviations for all "dev" vectors and the amount of ageing bias were held constant at the values obtained by Model B1. Differences with respect to Model B1 in the remaining models were as follow:

Model C1 is identical to Model B1 except that it sets *catchability itself* (rather than the average product of catchability and selectivity for the 60-81 cm size range) equal to 0.47.

Model D1 is identical to Model B1 except that selectivity at maximum size or age is removed from the set of controllable parameters (instead, selectivity at maximum size or age becomes a function of other selectivity parameters).

Model E1 is identical to Model B1 except that selectivity at maximum size or age for all non-asymptotic fleets is set equal to a single value that is constant across fleets.

Model G1 is identical to Model B1 except that survey selectivity is held constant across all years (i.e., no selectivity "devs" are estimated for any years).

<u>Models with mean size-at-age data and without age composition data.</u> This group includes a no-age-composition-data counterpart for each model in the preceding group. Size composition data are included in place of age composition data. The input standard deviations for all "dev" vectors and the amount of ageing bias were held constant at the values obtained by Model B1. The models in this group are labeled B2, C2, D2, E2, and G2.

Table 2.1 shows how the various requests from the Plan Team(s), SSC, and public map into the 14 models presented here.

Version 3.03c of SS was used to run all the models in this assessment.

Parameters Estimated Independently

Natural Mortality

In the 1993 BSAI Pacific cod assessment (Thompson and Methot 1993), the natural mortality rate *M* was estimated using SS1 at a value of 0.37. 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, the 2008 assessment included a discussion of alternative values and a justification for the value chosen. 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, some other published estimates of *M* for Pacific cod are shown below:

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

All of the models in this assessment estimate *M* independently at the SSC-approved value of 0.34, with the exception of Model F2, which estimates *M* conditionally.

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), virtually identical to last year's estimate.

Variability in Length at Age

In the 2008 assessment, 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. Variability in length at age 20 was estimated conditionally in the 2008 assessment.

For the present assessment, however, it was necessary to relax these assumptions for all models estimating cohort-specific growth. As described in the SS user manual (Methot 2009), problems can arise when estimating cohort-specific growth unless the first reference age in the length-at-age equation is set at true age 0. Because no data are available to describe the standard deviation of length at true age 0 (which is mostly a theoretical extrapolation anyway), a regression approach was used, based on the outside-the-model estimates of standard deviation of length at age from the survey age data. The best fit was obtained by assuming that the standard deviation is a linear function of length at age, with an intercept of 1.15 and a slope of 0.079.

Use of this regression required an iterative, "quasi-conditional" procedure for specifying the standard deviations of length at ages 0 and 20, because the regression is a function of length at age, and length at age is estimated conditionally (i.e., inside the model).

Weight at Length

For several assessments prior to the 2008 assessment, bottom trawl survey data were used to estimate the multiplicative constant α and exponent β of the weight-at-length equation 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 all other models, the seasonal weight-at-length parameters estimated in the 2008 assessment are used. These were determined from all weight-length records present in the observer database (both shore-based and at-sea samples) as of the 2008 assessment, giving the following values:

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

In the 2008 assessment, the seasonal model gave 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 was 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 F2 in the present assessment. However, in 2007, changes in SS allowed for use of either a length-based or an age-based maturity schedule. Since 2007, the accepted model has 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, all models except F2 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) in all models include the Brody growth coefficient *K*, log mean recruitment, initial fishing mortality, selectivity parameters, and annual recruitment deviations.

Parameters estimated conditionally in some but not all models include: the natural mortality rate (Model F2), mean length at age 0 (all models except A1, A2, A3, and F2), mean length at age 1 (Model F2), mean length at age 20 (Models A1, A2, A3, and F2), asymptotic length (all models except A1, A2, A3, and F2), the parameter governing variability in length at age 1 (Model F2), the parameter governing variability in length at age 20 (Models A1, A2, A3, and F2), trawl survey catchability (Models A1, A2, A3, and F2), annual deviations in the ascending limb of the trawl survey selectivity schedule (all models except G1 and G2), and annual deviations in growth (all models except A1, A2, A3, and F2).

The same functional form (pattern 24 for length-based selectivity, pattern 20 for age-based selectivity) used to define the selectivity schedules in the 2007 and 2008 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 (selectivity parameters are referenced by these numbers in several of the tables in this assessment):

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.

Uniform prior distributions are used for all parameters, except that "dev" vectors are constrained by input standard deviations ("sigma"), which imply a type of joint prior distribution. These input standard deviations were determined iteratively by matching the standard deviations of the estimates for all "dev" vectors in Model B1. Models B2, C1, C2, D1, D2, E1, E2, G1, and G2 use the same values for the input standard deviations as Model B1. In Models A1, A2, and A3, the procedure of matching input and output standard deviations was followed for the recruitment "dev" vector, but the input standard deviation for the survey selectivity "dev" vector was set at a value of 0.2 by assumption. In Model F2, the input standard deviations for the recruitment and survey selectivity "dev" vectors were set at respective values of 0.6 and 0.4 by assumption.

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.

Likelihood Components

All 14 models included likelihood components for trawl survey relative abundance, fishery and survey size composition, recruitment, parameter deviations, and "softbounds" (equivalent to an extremely weak prior distribution used to keep parameters from hitting bounds). In addition, Models A1, A3, B1, C1, D1, E1, and G1 included likelihood components for age composition; all models except A1, A2, A3, and F2 included a likelihood component for mean size at age; and all models except F2 included a likelihood component for initial (equilibrium) 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, likelihood components were generally given an emphasis of 1.0 in the present assessment. Exceptions were those cases where one or more types of data were included in the data file but ignored (e.g., the models that ignore age composition data). In such cases, zero emphasis was placed on the ignored data rather than removing the ignored data from the file, thus enabling a measure of how well the model fit the ignored data.

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 1990-2007 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 2008 assessment and the present assessment as well. The resulting set of multinomial sample sizes is 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 gear, year, and season within the year. 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, A3, B1, C1, D1, E1, and G1 ignore size composition data from each gear/year/season combination in which age composition data are available. Models A2, B2, C2, D2, E2, F2, and G2, which ignore the age composition data, use all the available size composition data.

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, which is then transformed into the "sigma" parameter for the lognormal distribution.

Use of Recruitment Deviation "Data" in Parameter Estimation

The recruitment deviations likelihood component is different from traditional likelihoods because it does not involve "data" in the same sense that traditional likelihoods do. Instead, the log-scale recruitment deviation plays the role of the datum and the log-scale recruitment mean and input standard deviation are related to the parameters of a normal distribution, but, of course, all of these are treated as parameters by SS (although the input standard deviation is estimated iteratively rather than internally).

MODEL EVALUATION

As described above, 14 models are evaluated in the present assessment. All models appeared to converge successfully and the Hessian matrices from all models were positive definite. At several points during the model development process, sets of (typically about 50) additional runs were made for most models with initial parameter values displaced randomly from their converged values to provide additional assurance that another (better) solution did not exist.

Comparing and Contrasting the Models

Tables 2.15-2.20 and Figures 2.2-2.9 present summaries of some key results from the 14 models.

Table 2.15 pertains to statistical goodness of fit.

The first page of Table 2.15a is structured as follows:

> Section 1: Total negative log-likelihood, parameter counts (internally estimated parameters only), and Akaike Information Criterion (AIC). The use of AIC in this context may not be strictly correct, as some of the terms in the log-likelihood may be more properly viewed as priors. Nevertheless, it may still provide information useful for model selection.
>
> 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 in different groups use different data sets, different input standard deviations for "dev" vectors, or both. In general, log-likelihoods of models within the first group are difficult to compare, while log-likelihoods of models within the second group can be compared, as can log-likelihoods of models within the third group.

The second page of Table 2.15a is structured as follows:

Section 1: Relative abundance log-likelihoods. The only log-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 2: Size composition log-likelihoods. The aggregate size composition log-likelihood is broken down by gear and season in the case of fisheries, and by individual survey types.

Section 3: Age composition log-likelihoods. The aggregate age composition log-likelihood is broken down into the single (2008) record from the January-May longline fishery and the 15 records from the trawl survey.

Section 4: Mean size at age. Similar to the above.

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.

Table 2.15d shows the average of the ratios between output "effective" sample size (McAllister and Ianelli 1997) and input sample size for size composition data, thus providing an alternative measure of how well the models are these data (higher values are better). Rows in this table correspond to different fisheries or surveys.

Table 2.15e provides a similar analysis for the age composition, except that the rows in the main part of this table correspond to individual records rather than fisheries or surveys. The bottom two rows show weighted averages for the trawl survey and for all records combined (i.e., including the single record from the January-May longline fishery). Although Models A1 and A2 have average ratios only a bit lower than the ratios for Models B1, C1, D1, and E1 (as examples), it should be noted that the average ratios for Models A1 and A2 would be much lower were it not for the good fit obtained to the 2008 survey age composition, which was dominated by a single spike at age 2.

Table 2.16 pertains to estimates of parameters other than selectivity parameters.

Table 2.16a lists key parameters that are estimated internally by at least one of the 14 models. If a parameter in this table is estimated internally by one of the models, the estimated value is shown along with its standard deviation. If a parameter is estimated externally, just the estimated value is shown. The parameters listed in this table are the natural mortality rate M, mean lengths at reference age 1 and 2 (as noted in the legend, these reference ages may be different between 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, where the latter expresses the log of the ratio between the two means), the fishing mortality rate in the initial year, and the log catchability coefficients for the pre-1982 trawl survey ($\ln Q_1$), and the post-1981 trawl survey ($\ln Q_2$).

Tables 2.16b-2.16c list estimates and standard deviations of annual growth deviations for the second and third groups of models (the first group does not make use of annual growth deviations).

Tables 2.16d-2.16f list estimates and standard deviations of annual log recruitment deviations given by the three groups of models. Note that these are deviations, not log recruitments *per se*, and are computed with respect to their regime-specific (pre-1977, post-1976) log medians.

Table 2.17 pertains to model estimates of selectivity parameters.

Tables 2.17a-2.17c list base fishery selectivity parameters for the three groups. Note that these base parameters may be over-written by block-specific parameters. Block-specific selectivity parameters for the first group of models are shown in Tables 2.17d-2.17f, block-specific selectivity parameters for the second group of models are shown in Tables 2.17g-2.17i, and block-specific selectivity parameters for the third group of models are shown in Tables 2.17j-2.17l. Tables 2.17m-2.17o list base survey selectivity parameters for the three groups. Similar to the base fishery selectivity parameters, some of these may be adjusted by annual deviations. The time series of estimated annual survey selectivity "devs" for the three groups of models are shown in Tables 2.17p-2.17r.

Parameters not listed in Tables 2.16-2.17 include those that have already been identified as being estimated independently (i.e., outside of the stock assessment model), and those that are estimated by trial and error. The parameters in the latter category include the input standard deviations for the various "dev" vectors (growth, recruitment, and trawl survey selectivity, depending on the model), and the amount of ageing error bias in all models except A1, A2, A3, and F2. For Models A1, A2, A3, F2, and B1, the values of the input standard deviations were determined as follows ("estimated" means that the value was determined iteratively by matching the standard deviations of the set of "dev" parameters):

	Growth		Recruitment		Survey selectivity	
Model	value	method	value	method	value	method
A1	n/a	n/a	0.61	estimated	0.20	assumed
A2	n/a	n/a	0.66	estimated	0.20	assumed
A3	n/a	n/a	0.62	estimated	0.20	assumed
F2	n/a	n/a	0.60	assumed	0.40	assumed
B1	0.04	estimated	0.57	estimated	0.07	estimated

For all other models, the input standard deviations were set at the values determined for Model B1.

Another parameter that was estimated by trial and error was the amount of bias to include in the ageing error matrix. Model B1 was used for this estimation. Initially, different ranges of ages were examined, with potentially different amounts of bias for each age in the range, but the results of these initial tests indicated that a constant amount of bias for all ages 2 and above performed nearly as well (in terms of log-likelihood), with fewer parameters. The final estimate of the amount of bias was 0.4. Except for Models A1, A2, A3, and F2, all models used this bias value.

The final parameter that was estimated by trial and error was the single fixed value for selectivity at maximum size or age, which was the distinguishing characteristic of Models E1 and E2 (see Comment SSC8). This fixed value was determined by trying different a range of fixed values, in increments of 0.1, and choosing the one that gave the best log-likelihood. For both Models E1 and E2, this fixed value was 0.4. This value was used for all fisheries and surveys that were not constrained to exhibit asymptotic selectivity.

Table 2.18 shows, among other things, the weighted average of the product of trawl survey catchability and selectivity across the 60-81 cm size range. This statistic is relevant because Nichol et al. (2007) concluded that the value should be about 0.47, given the net configuration used in the Bering Sea trawl survey. The value of catchability in Model B1 was chosen to achieve this result, which Table 2.18 shows that it does. The range of values in Table 2.18 extends from 0.22 (Model C2) to 0.64 (Model A1). Table 2.18 also shows the mean and variability associated with trawl survey selectivity at age 1. The mean selectivity at age 1 ranges from 0.31 (Model F2) to 0.44 (Models A3 and G1), the standard deviation ranges from 0 (Models G1 and G2, by definition) to 0.21 (Models A1 and A3), and the coefficient of variation ranges from 0 (Models G1 and G2, by definition) to 0.52 (Model A2).

Table 2.19 shows how estimated size (cm) at age 1 under each of the models compares with the observed values from the trawl survey for the years in which data are available (1994-2008). All the models that estimate cohort-specific growth (i.e., all models except A1, A2, A3, and F2) show a correlation with the observed data of at least 0.50, indicating that estimated growth deviations really are being used largely to fit the mean size-at-age data, rather than being absorbed mostly into fitting other data sets.

Table 2.20 contains selected output from the standard projection model, based on SS parameter estimates from the 14 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 2010 and 2011 are shown, with the value for 2011 predicated on the assumption that the 2010 catch will equal the 2010 maximum permissible ABC.
>
> Section 3: The ratio of projected spawning biomass to B100%. Values for 2010 and 2011 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 2010 and 2011 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 2010 under the Tier 3 harvest control rules.
>
> Section 8: Overfishing limits for 2010 and 2011. The value for 2011 assumes that catch in 2010 equals the maximum permissible ABC.
>
> Section 9: Probability that spawning biomass will fall below 20% of B100% in 2012, 2013, or 2014 if catch equals maximum permissible ABC in each year from now until then. Because Pacific cod are a key prey item of endangered Steller sea lions (*Eumetopias jubatus*), current regulations require directed fishing to cease in the event that the spawning biomass falls below 20% of B100%.

Figure 2.2 shows the models' fits to the time trend of survey abundance, measured in numbers of fish. Although Table 2.15 indicates that some models fit these data better than others, the trends seem very similar, generally speaking.

Figure 2.3 (one page for each model) shows the models' fits to the 15 years of survey age composition data. Again, the overall fits are often similar enough that visual inspection does not reveal which model gives the better fit.

Figure 2.4 shows the models' fits to the one record of fishery age composition data (from the 2008 January-May longline fishery). This record seems to indicate the existence of a large 2002 year class, which does not appear to evident in any of the other data. It may also be noted that the mean size at ages 2-4 are larger in this single record than in any of the survey size-at-age data, despite the fact that the observation was taken earlier in the year. These apparent discrepancies were the reason for development of Model A3, which ignores the 2008 January-May longline fishery age composition and size-at-age data.

Figure 2.5 shows the models' estimated time series of recruitment deviations. As with Figure 2.2, the trends are very similar across models, with Model F2 perhaps being the most noticeably different from the others.

Figure 2.6 shows the models' estimated time series of relative spawning biomass (i.e., relative to B100%). Once more, the trends are similar, in a qualitative sense. For the first group of models, Model F2 seems the most dissimilar, and for the second and third groups, Models C1 and C2 tend to give the highest estimates and Models D1 and D2 the lowest.

Figure 2.7 shows the models' estimated time series of total (age 0+) biomass, and shows the time series of trawl survey biomass for comparison. This figure emphasizes the difference between Models C1 and C2 and their respective within-group counterparts. As in previous assessments of this stock, the models tend to estimate a higher total biomass than the survey.

Figure 2.8 shows the models' estimated trawl survey schedules. All models except G1 and G2 allow for time-varying selectivity in the ascending limb. Note also that Model F2 interprets survey selectivity as a function of length rather than age. All models show a marked decline in selectivity of old fish, except for Model F2, which assumes asymptotic selectivity.

Figure 2.9 (one page for each model) shows fishery selectivity for each of the nine (3 gears × 3 seasons) fisheries. All models except F2 allow for selectivity to vary by time block. The numbers and lengths of these blocks were determined in the 2008 assessment on the basis of AIC.

Evaluation Criteria

The criteria used for selecting the final model were as follow:

1) Does the model respond to current Plan Team and SSC understanding about the usefulness of the age composition data? The Plan Team and SSC have consistently endorsed continued use of the age composition data.
2) Does the model respond appropriately to recent requests? This criterion is a bit more difficult to evaluate, in part because some requests are in conflict with one another. However, the joint Plan Teams have asked that potential ageing bias be corrected for in the ageing error matrix "in the short term" (Comment JPT3), the SSC has asked for refinements in the estimation of "dev" vectors (Comment SSC9), and the joint Plan Teams have asked for inclusion of cohort-specific growth (Comment JPT2, also requested by the Freezer Longline Coalition).
3) Of the models that satisfy criteria #1 and #2, are there any that can be selected on purely statistical grounds? If the models all use the same data and the same standard deviations for the various "dev" vectors, they can be ranked by AIC.

Selection of Final Model

The 14 models can be evaluated by the three criteria as follows:

1) The only models that meet this criterion are Model A1, the second group of models (B1, C1, D1, E1, G1), and perhaps Model A3 (which uses all available age composition data except for the 2008 January-May longline fishery record).
2) All the models in the second and third groups satisfy these requests.
3) The only models that satisfy both criteria #1 and #2 are the models in the second group (B1, C1, D1, E1, and G1). Because these models all use the same data and the same standard deviations

for the various “dev” vectors, they can be ranked by AIC. Of this group of models, the one with the best AIC is Model B1.

Model B1 is therefore selected as the final 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, 2.16e, 2.17b, 2.17g, 2.17h, 2.17i, 2.17n, and 2.17q.

Estimates of year-, gear-, and season-specific fishing mortality rates from Model B1 are shown in Table 2.21.

Schedules of selectivity at length for the commercial fisheries and the IPHC longline survey from Model B1 are shown in Table 2.22a, and schedules of selectivity at age for the trawl surveys from Model B1 are shown in Table 2.22b. Post-1981 trawl survey and fishery selectivity schedules are plotted in Figures 2.8 and 2.9B1, respectively.

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 2.23 and 2.24, respectively. Mean lengths at ages 1-4 are compared to mean lengths from the age composition data and the long-term trawl survey size composition in Figure 2.10. As this figure shows, Model B1 produces mean lengths at ages 1-3 that line up very well with the first three modes in the long-term trawl survey size composition (the fourth mode is difficult to identify).

TIME SERIES RESULTS

Note: Because the preferred model differs substantively from last year’s model (A1), the tables and figures referenced in this section are reproduced using Model A1 in Attachment 2.2.

Definitions

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

Biomass

Table 2.25a 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 2.11. 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 2.25b shows the time series of EBS (not expanded to BSAI) Pacific cod age 0 recruitment (1000s of fish) for the years 1977-2008 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 (1977-2008) are shown in Figure 2.12, along with their respective 95% confidence intervals. For the time series as a whole, the largest year class appears to have been the 1977 cohort. Other large cohorts include the 1982, 1984, 1992, and 1996 year classes. The 2008 year class, which has been observed only once, also appears to be extremely large, although this estimate is accompanied by a large confidence interval. The 2006 year class, which appeared exceptionally strong in the 2007 survey, still appears to be above average (note that the average has gone up with the addition of the 2008 year class to the time series), and is currently ranked as the 11th 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 22nd out of the 32 year classes spawned during the current (post-1976) environmental regime.

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 2.26.

Exploitation

Figure 2.13 plots the trajectory of relative fishing mortality and relative female spawning biomass from 1977 through 2009 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. While the ratio of $F_{40\%}$ to $F_{35\%}$ shown in Figure 2.13 is based on output from the standard projection model, the trajectory itself is based on SS output, which may not match the estimates obtained by the standard projection program exactly.

PROJECTIONS AND HARVEST ALTERNATIVES

Note: Because the preferred model differs substantively from last year's model (A1), the tables referenced in this section are reproduced using Model A1 in Attachment 2.2.

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:	360,000 t	411,000 t	1,027,000 t
EBS:	302,000 t	345,000 t	863,000 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 (2006-2008). The average fishing mortality rates for those years implied that total fishing mortality was divided among the three main gear types according to the following percentages: trawl 26%, longline 62%, and pot 0.12%. This apportionment results in estimates of $F_{35\%}$ and $F_{40\%}$ equal to 0.35 and 0.29, respectively.

Specification of OFL and Maximum Permissible ABC

BSAI spawning biomass for 2010 is estimated by Model B1 at a value of 345,000 t. This is about 16% below the BSAI $B_{40\%}$ value of 411,000 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 2010 and 2011 as follows (2011 values are predicated on the assumption that 2010 catch will equal 2010 maximum permissible ABC; catches in t, and are for the entire BSAI):

Year	Overfishing Level	Maximum Permissible ABC
2010	205,000 t	174,000 t
2011	251,000 t	214,000 t
2010	0.29	0.24
2011	n/a	0.26

The age 0+ biomass BSAI projections for 2010 and 2011 from Model B1 (using SS) are 1,244,000 t and 1,418,000 t.

For comparison, the age 3+ BSAI projections for 2010 and 2011 from Model B1 (using SS) are 1,144,000 t and 1,358,000 t.

ABC Recommendation

Review of Past Approaches

In 2005, 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 2006, 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."

In 2008, the SSC returned to the practice of setting ABC at the maximum permissible level, which resulted in specifications of 182,000 t for 2009 and 199,000 t for 2010.

Recommendation for 2010-2011

Based on Model B1, the maximum permissible ABC (Tier 3b) for 2010 is 174,000 t. This would constitute a 4% decrease from the 2009 value of 182,000. However, it would be almost identical to the ABCs for 2007 and 2008. The maximum permissible ABC for 2011 is 214,000 t, as the 2006 year class begins to contribute more to the spawning biomass. These values are the recommended ABCs for 2010 and 2011.

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 2009 numbers at age. This vector is then projected forward to the beginning of 2010 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2009. 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 2010, 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 2010 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 2004-2008 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 2009 or 2) above 1/2 of its MSY level in 2009 and above its MSY level in 2019 under this scenario, then the stock is not overfished.)
>
> *Scenario 7*: In 2010 and 2011, 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 2022 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 2.27-2.32 (note that Scenarios 1 and 2 are identical in this case, because the recommended ABC is equal to the maximum permissible ABC).

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 2010, it does not provide the best estimate of OFL for 2011, because the mean 2011 catch under Scenario 6 is predicated on the 2010 catch being equal to the 2010

OFL, whereas the actual 2010 catch will likely be less than the 2010 OFL. Table 2.20 contains the appropriate one- and two-year ahead projections for both ABC and OFL under any of the 14 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 (2008) is 170,614 t. This is less than the 2008 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 2009:

a. If spawning biomass for 2009 is estimated to be below ½ $B_{35\%}$, the stock is below its MSST.

b. If spawning biomass for 2009 is estimated to be above $B_{35\%}$ the stock is above its MSST.

c. If spawning biomass for 2009 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 2.31). If the mean spawning biomass for 2019 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 2.32):

a. If the mean spawning biomass for 2012 is below 1/2 $B_{35\%}$, the stock is approaching an overfished condition.

b. If the mean spawning biomass for 2012 is above $B_{35\%}$, the stock is not approaching an overfished condition.

c. If the mean spawning biomass for 2012 is above 1/2 $B_{35\%}$ but below $B_{35\%}$, the determination depends on the mean spawning biomass for 2022. If the mean spawning biomass for 2022 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 2.31 and 2.32, the stock is not overfished and is not approaching an overfished condition.

ECOSYSTEM CONSIDERATIONS

This section is largely unchanged from last year's assessment, except for the subsection on "Bycatch of Target and Nontarget Species."

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 Target and Nontarget Species

Bycatch (discards) of target and nontarget species are shown in Table 2.33.

It is not clear how much bycatch of a particular species constitutes "too much" in the context of ecosystem concerns. Only eight species or species groups accounts for an average of more than 1,000 t of discards on average over the 2005-2009 period: "skate (other)"—14,280 t, "other species"—11,733 t, walleye pollock—6,973 t, arrowtooth flounder—2,586 t, rock sole—2,145 t, "large sculpins"—1,997 t, Pacific cod—1,773 t, and flathead sole—1,458 t. Only the first six of these species or species groups amounts to more than 1% of the average Pacific cod catch over the same period.

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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Table 2.0—List of models, showing how requests made by the Plan Team(s), SSC, and public have been incorporated. Models whose names end in “2” include the same features as the corresponding model whose name ends in “1,” except for omission of age composition data. “FLC” = Freezer Longline Coalition.

Model	Description	Proposal(s) included	Proposer(s)
A1	Base model	Use Model B1 from 2008 assessment as base model	SSC
		Do not set informative priors on selectivity	BSAI Plan Team
		Retain current methodology for selectivity devs	BSAI Plan Team
		Do not use exponential-logistic selectivity	BSAI Plan Team, SSC
A2	Base model without age data	Include a "no agecomps" counterpart to every model	FLC
A3	Base model without Jan-May longline fishery age data from 2008	n/a	n/a
B1	Preferred model	Include bias in ageing error matrix	Joint Plan Teams
		Turn off variable survey selectivity in recent years	SSC
		Include cohort-specific growth	Joint Plan Teams, FLC
		Do not set informative priors on selectivity	BSAI Plan Team
		Do not use exponential-logistic selectivity	BSAI Plan Team, SSC
B2	Preferred model without age data	Include a "no agecomps" counterpart to every model	FLC
C1	Preferred model with Q fixed at 0.47	Set Q equal to estimate from Nichol et al. (2007)	FLC
C2	Preferred model with Q fixed at 0.47 and without age data	Include a "no agecomps" counterpart to every model	FLC
D1	Preferred model with "-999" selectivity option	Use "-999" selectivity option	BSAI Plan Team, FLC
D2	Preferred model with "-999" selectivity option and without age data	Include a "no agecomps" counterpart to every model	FLC
E1	Preferred model with selectivity fixed at max. size/age	Fix selectivity at maximum size/age	SSC
E2	Preferred model with selectivity fixed at max. size/age and without age data	Include a "no agecomps" counterpart to every model	FLC
F2	Model F2 from 2008 BSAI assessment	Use Model F2 from 2008 BSAI assessment	FLC
G1	Preferred model without selectivity devs	Include cohort-specific growth, turn off selectivity devs	FLC
G2	Preferred model without selectivity devs and without age data	Include a "no agecomps" counterpart to every model	FLC

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 1981-2009 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 2009 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	129393	77505	3343	0	210241	210241
1992	0	0	0	0	0	77261	79398	7512	33	164204	164204
1993	0	0	0	0	0	81763	49294	2098	2	133157	133157
1994	0	0	0	0	0	84932	78564	8037	730	172263	172263
1995	0	0	0	0	0	110958	97666	19275	599	228498	228498
1996	0	0	0	0	0	91912	88883	28006	267	209067	209067
1997	0	0	0	0	0	93925	117010	21493	173	232601	232601
1998	0	0	0	0	0	60781	84324	13233	192	158529	158529
1999	0	0	0	0	0	51903	81464	12400	100	145867	145867
2000	0	0	0	0	0	53817	81642	15849	68	151376	151376
2001	0	0	0	0	0	35657	90361	16472	52	142542	142542
2002	0	0	0	0	0	51067	100271	15052	166	166555	166555
2003	0	0	0	0	0	47132	95056	21959	155	164302	164302
2004	0	0	0	0	0	57794	108015	17242	231	183282	183282
2005	0	0	0	0	0	52604	113125	17104	104	182938	182938
2006	0	0	0	0	0	53204	96024	18957	81	168265	168265
2007	0	0	0	0	0	45673	77123	17222	82	140100	140100
2008	0	0	0	0	0	33493	88721	17344	19	139577	139577
2009	0	0	0	0	0	33551	74004	11904	13	119472	119472

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 1981-1990 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.

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

Table 2.2c—Summary of 1991-2009 catches (t) of Pacific cod in the Aleutian Islands by fleet sector and gear type. All catches include discards. LLine = longline, Subt. = sector subtotal. Catches since 2006 include those from a State-managed fishery. Catches for 2009 are through early October.

Aleutian Islands only:											
	Federal					State					
Year	Trawl	LLine	Pot	Other	Subt.	Trawl	LLine	Pot	Other	Subt.	Total
1991	3414	3203	3180	0	9798						9798
1992	14559	22108	6317	84	43068						43068
1993	17312	16860	0	33	34205						34205
1994	14383	7009	147	0	21539						21539
1995	10574	4935	1025	0	16534						16534
1996	21179	5819	4611	0	31609						31609
1997	17349	7151	575	89	25164						25164
1998	20531	13771	424	0	34726						34726
1999	16437	7874	3750	69	28130						28130
2000	20362	16183	3107	33	39685						39685
2001	15827	17817	544	19	34207						34207
2002	27929	2865	7	0	30801						30801
2003	31215	976	2	0	32193						32193
2004	25770	3103	0	0	28873						28873
2005	19613	3067	0	13	22694						22694
2006	16959	3126	402	8	20496	3103	457	154	0	3715	24210
2007	25727	4172	313	1	30213	2904	539	383	6	3832	34045
2008	19291	5449	1679	156	26575	2540	234	1634	53	4462	31037
2009	20131	3194	457	0	23782	537	279	1237	20	2074	25856

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 1981-1990 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.

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

Table 2.3c—Summary of 1991-2009 catches (t) of Pacific cod in the Eastern Bering Sea and Aleutian Islands by fleet sector and gear type. All catches include discards. LLine = longline, Subt. = sector subtotal. Catches since 2006 include those from a State-managed fishery in the Aleutian Islands. Catches for 2009 are through early October.

Bering Sea and Aleutian Islands region combined:

	Federal					State					
Year	Trawl	LLine	Pot	Other	Subt.	Trawl	LLine	Pot	Other	Subt.	Total
1991	132808	80708	6523	0	220038						220038
1992	91820	101507	13829	117	207272						207272
1993	99075	66154	2098	35	167362						167362
1994	99315	85573	8184	730	193802						193802
1995	121532	102601	20300	599	245033						245033
1996	113091	94702	32617	267	240676						240676
1997	111275	124161	22068	262	257765						257765
1998	81312	98095	13657	192	193256						193256
1999	68341	89338	16150	169	173998						173998
2000	74179	97825	18956	101	191060						191060
2001	51484	108178	17016	71	176749						176749
2002	78996	103136	15058	166	197356						197356
2003	78346	96032	21961	156	196495						196495
2004	83564	111118	17242	231	212155						212155
2005	72217	116193	17104	117	205632						205632
2006	70163	99150	19359	89	188760	3103	457	154	0	3715	192475
2007	71400	81295	17535	83	170313	2904	539	383	6	3832	174145
2008	52784	94170	19023	176	166153	2540	234	1634	53	4462	170614
2009	53683	77199	12360	13	143254	537	279	1237	20	2074	145328

Table 2.4—History of Pacific cod ABC, TAC, total BSAI catch, and type of stock assessment model used to recommend ABC. Catch for 2009 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	220,038	separable age-structured model
1992	182,000	182,000	207,272	SS1 model (age-based data)
1993	164,500	164,500	167,362	SS1 model (length-based data)
1994	191,000	191,000	193,802	SS1 model (length-based data)
1995	328,000	250,000	245,033	SS1 model (length-based data)
1996	305,000	270,000	240,676	SS1 model (length-based data)
1997	306,000	270,000	257,765	SS1 model (length-based data)
1998	210,000	210,000	193,256	SS1 model (length-based data)
1999	177,000	177,000	173,998	SS1 model (length-based data)
2000	193,000	193,000	191,060	SS1 model (length-based data)
2001	188,000	188,000	176,749	SS1 model (length-based data)
2002	223,000	200,000	197,356	SS1 model (length-based data)
2003	223,000	207,500	196,495	SS1 model (length-based data)
2004	223,000	215,500	212,155	SS1 model (length-based data)
2005	206,000	206,000	205,632	SS1 model (length- and age-based data)
2006	194,000	194,000	192,475	SS2 model (length- and age-based data)
2007	176,000	170,720	174,145	SS2 model (length- and age-based data)
2008	176,000	170,720	170,614	SS2 model (length- and age-based data)
2009	182,000	176,540	145,328	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 and Table 2.5c for the period 2005-2009). 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 and Table 2.5c for the period 2005-2009). 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 2.5c—Pacific cod discard rates by area, target species/group, and year for the period 2005-2009 (see Table 2.5a for the period 1991-2002 and 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.

EBS target fishery	2005	2006	2007	2008	2009	Ave.
Alaska Plaice		0.405	0.000	0.000	0.004	0.225
Arrowtooth Flounder	0.050	0.006	0.034	0.001	0.025	0.026
Atka Mackerel	0.007	0.054	0.002	0.015	0.025	0.019
Flathead Sole	0.019	0.085	0.004	0.028	0.029	0.033
Greenland Turbot	0.010	0.157	0.026	0.026	0.013	0.059
Halibut	0.700	0.018	0.109	0.517	0.011	0.476
Other Flatfish	0.072	0.015	0.018	0.027	0.000	0.037
Other Species	0.062	0.125	0.002		0.000	0.067
Pacific Cod	0.017	0.012	0.013	0.012	0.013	0.014
Pollock - bottom	0.000	0.008	0.000	0.001	0.002	0.002
Pollock - midwater	0.005	0.008	0.010	0.002	0.008	0.006
Rock Sole	0.019	0.027	0.045	0.015	0.026	0.025
Rockfish	0.000	0.010	0.000	0.000	0.000	0.009
Sablefish	0.696	0.022	0.729	0.587	0.085	0.453
Unknown	1.000	1.000	1.000	1.000		1.000
Yellowfin Sole	0.045	0.096	0.057	0.061	0.026	0.050
Total	0.017	0.014	0.014	0.014	0.014	0.015

AI target fishery	2005	2006	2007	2008	2009	Total
Arrowtooth Flounder		0.078	0.138		1.000	0.100
Atka Mackerel	0.063	0.028	0.028	0.002	0.021	0.032
Flathead sole			0.000			0.000
Greenland Turbot		0.000	0.017			0.017
Halibut	0.905	0.390	0.341	0.627	0.000	0.695
Other Species	0.000	0.414	0.190	0.000		0.287
Pacific Cod	0.007	0.010	0.015	0.005	0.004	0.008
Pollock - bottom		1.000	1.000	0.451		0.769
Pollock - midwater		0.086	0.057	0.000	0.523	0.187
Rockfish	0.000	0.107	0.090	0.002	0.206	0.061
Sablefish	0.029	0.565	0.314	0.076	0.019	0.236
Unknown				1.000		1.000
Total	0.022	0.013	0.016	0.006	0.005	0.012

Table 2.6—EBS catch (t) of Pacific cod by year, gear, and season for the years 1977-2009. 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. The small amounts of catch from "other" gear types have been merged into the gear types listed below proportionally. Sea. 1 = Jan-May, Sea. 2 = Jun-Aug, Sea. 3 = Sep-Dec. Sea. 3 catches for 2009 are extrapolated.

	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	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	534	697	1545	0	0	0
1989	127459	16986	19798	3810	4968	5157	33	63	49
1990	101645	11402	10524	13171	16643	17299	0	986	395
1991	107980	15550	5864	26240	21472	29792	12	1042	2289
1992	59478	11841	5959	48941	24196	6276	2622	4632	258
1993	67122	5362	9281	49244	27	23	2073	24	0
1994	61117	5974	18265	58071	13	20752	4932	0	3139
1995	90472	8707	12094	68539	27	29292	12498	3536	3335
1996	78249	3159	10605	62055	26	26882	18155	6469	3467
1997	81354	3971	8685	70711	43	46296	14591	3616	3333
1998	45048	5656	10174	54283	18	30082	9030	2805	1433
1999	44921	3329	3690	55201	1933	24384	9349	1006	2054
2000	44538	4579	4731	40206	1375	40088	15752	0	107
2001	22850	7052	5782	38369	6725	45292	11732	444	4298
2002	37026	9606	4504	50049	12197	38114	10857	403	3799
2003	34441	9985	2775	46394	7873	40863	15384	1	6587
2004	42232	12470	3198	54900	10488	42737	12464	406	4388
2005	45025	6691	926	53567	12857	46765	12150	0	4957
2006	46068	6132	1033	51254	14684	30129	14272	0	4692
2007	35416	8711	1578	44873	12532	19765	12285	18	4921
2008	23582	5555	4361	45660	12628	30445	11005	1	6340
2009	22807	7563	3186	48417	12266	26780	11217	0	5318

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	32	66	79	82	75	117	179	631	799	1019	1591	1726	1480	869	554	373	291	145	69	25
2009	0	0	1	3	0	4	10	19	30	50	203	412	617	422	566	1073	1098	904	417	298	157	114	69	27	14

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	2	46	137	171	98	64	87	203	272	148	117	68	42	38	28	24	22	8	2
2009	0	0	0	0	0	0	4	11	33	25	44	65	110	75	69	40	40	15	3	1	1	1	0	1	0

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
2008	1	0	0	0	0	2	0	7	28	74	106	43	27	33	33	20	12	11	5	1	1	3	0	0	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	1	6	13	44	91	276	619	1862	3350	5706	8177	9462	7003	3388	1896	1009	554	258	101	33
2009	0	0	0	0	0	0	1	4	8	60	353	769	1487	2217	3736	5994	7560	6909	4134	1760	683	382	181	82	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	1	1	1	3	7	18	75	205	1191	2686	4106	5194	4452	3100	1961	1302	1055	881	573	293	70
2009	0	0	0	0	0	0	0	0	1	0	16	66	478	952	885	985	826	475	208	119	94	84	38	33	10

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	1	2	3	16	24	195	958	1791	4503	8073	11092	10994	9622	6888	4116	2732	2092	1685	1021	425	111
2009	0	0	0	0	0	0	0	0	0	0	0	2	56	145	94	66	50	22	6	3	0	2	2	0	0

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	153	472	906	1146	1155	987	609	500	286	244	129	41	22
2009	0	0	0	0	0	0	0	0	0	4	8	41	167	338	571	1003	1131	1077	702	462	299	164	84	50	20

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
2008	1	0	0	0	0	0	0	1	3	5	12	46	174	435	982	1021	752	523	364	240	215	193	132	97	40

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	1418	894	536	265	187	99	79	56	32	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	587	889	1013	1052	481	415	572	727	650	627	866	705	521	529	495	358	291	182	103	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	473	151	327	417	386	262	211	225	381	370	260	270	206	148	83	64	67	43	17	16	5
2008	228	1118	890	266	131	948	2000	1958	1083	512	380	409	645	607	519	454	311	192	98	70	58	47	32	17	1
2009	1481	3030	1885	1000	177	209	764	1304	867	655	969	1108	1334	605	410	351	239	127	63	35	26	9	14	5	3

Table 2.10c—Length frequencies for the IPHC longline 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
2008	0	0	0	0	0	0	0	0	0	0	0	2	19	71	284	673	835	807	550	467	438	449	318	139	41
2009	0	0	0	0	0	0	0	0	0	0	1	8	90	247	458	856	994	805	603	424	378	310	294	184	72

Table 2.11a—Age compositions observed in the 2008 January-May longline fishery. N = actual sample size rescaled so that average across all age composition records (including those from Table 2.11b) = 300.

Year	N	1	2	3	4	5	6	7	8	9	10	11	12+
2008	233	0.0000	0.0000	0.0643	0.1323	0.2108	0.3339	0.1308	0.0741	0.0439	0.0078	0.0021	0.0000

Table 2.11b—Age compositions observed by the EBS shelf bottom trawl survey, 1994-2008. N = actual sample size rescaled so that average across all age composition records = 300.

Year	N	1	2	3	4	5	6	7	8	9	10	11	12+
1994	237	0.0882	0.3834	0.1713	0.1200	0.1173	0.0828	0.0218	0.0073	0.0044	0.0013	0.0011	0.0011
1995	199	0.0504	0.2652	0.4214	0.0969	0.0762	0.0507	0.0185	0.0108	0.0062	0.0018	0.0014	0.0005
1996	236	0.0536	0.2082	0.2044	0.2936	0.1335	0.0569	0.0286	0.0118	0.0048	0.0021	0.0020	0.0005
1997	239	0.2495	0.1684	0.1801	0.1541	0.1238	0.0817	0.0247	0.0117	0.0037	0.0013	0.0008	0.0003
1998	211	0.0772	0.4408	0.2016	0.1119	0.0576	0.0594	0.0285	0.0168	0.0044	0.0009	0.0008	0.0002
1999	285	0.0792	0.2003	0.3018	0.2311	0.0805	0.0571	0.0279	0.0129	0.0058	0.0015	0.0012	0.0007
2000	287	0.2342	0.1267	0.1516	0.2414	0.1460	0.0607	0.0135	0.0147	0.0065	0.0027	0.0015	0.0004
2001	315	0.2874	0.2359	0.1935	0.0916	0.0833	0.0677	0.0268	0.0088	0.0024	0.0017	0.0008	0.0002
2002	314	0.0809	0.1874	0.3169	0.2331	0.0718	0.0586	0.0342	0.0112	0.0038	0.0009	0.0005	0.0006
2003	451	0.1722	0.1565	0.2519	0.2101	0.1191	0.0410	0.0298	0.0138	0.0039	0.0005	0.0007	0.0005
2004	345	0.1421	0.1659	0.2721	0.1296	0.1283	0.0902	0.0389	0.0199	0.0081	0.0021	0.0025	0.0004
2005	425	0.1830	0.2444	0.2094	0.1212	0.0659	0.0793	0.0544	0.0237	0.0105	0.0036	0.0038	0.0008
2006	431	0.3245	0.1429	0.1651	0.1215	0.0927	0.0633	0.0463	0.0283	0.0103	0.0030	0.0012	0.0009
2007	190	0.6893	0.0942	0.0735	0.0370	0.0541	0.0152	0.0137	0.0101	0.0067	0.0025	0.0020	0.0017
2008	402	0.2140	0.4450	0.1449	0.0829	0.0484	0.0328	0.0099	0.0104	0.0060	0.0025	0.0016	0.0015

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, 1982-2009. 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	528,161	42,996	443,030	613,293	481,419,451	44,096,485
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	606,394	43,047	521,160	691,628	450,917,953	63,357,715
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
2009	421,290	34,969	352,051	490,528	716,590,485	62,700,080

Table 2.13—Mean size (cm) at age from age-length key applied to respective size compositions, and sample sizes. Mean lengths for samples of size zero result from application of area-specific long-term average age-length keys. Green = column minimum, pink = column maximum.

Average length (cm) at age:

Year	Fleet	1	2	3	4	5	6	7	8	9	10	11	12
2008	Jan-May longline fishery			47.06	54.75	62.69	67.33	73.01	78.98	80.43	84.37	89.73	
1994	Post-1981 trawl survey	19.00	31.75	39.91	49.26	58.00	64.04	70.84	79.99	85.05	92.40	92.15	93.15
1995	Post-1981 trawl survey	17.30	32.34	43.21	52.93	61.74	69.36	73.88	81.07	83.93	91.14	93.47	93.17
1996	Post-1981 trawl survey	17.62	31.62	41.42	50.28	57.58	66.93	75.05	81.73	86.53	89.69	91.59	94.76
1997	Post-1981 trawl survey	17.18	31.73	41.62	51.24	59.27	64.57	71.57	78.46	85.40	91.59	93.94	93.64
1998	Post-1981 trawl survey	15.44	30.76	37.80	49.30	58.89	66.28	70.11	77.61	88.62	87.91	91.94	90.85
1999	Post-1981 trawl survey	15.78	29.66	40.32	46.21	56.59	65.21	71.32	79.51	82.11	89.90	89.84	95.03
2000	Post-1981 trawl survey	15.24	30.28	38.99	47.69	53.69	59.72	72.51	74.80	79.74	81.70	84.02	94.65
2001	Post-1981 trawl survey	17.88	31.36	36.70	48.31	55.23	61.85	65.86	77.23	81.35	80.51	87.53	93.97
2002	Post-1981 trawl survey	16.52	30.07	36.95	46.92	55.68	62.55	68.71	72.31	78.38	91.29	89.47	95.00
2003	Post-1981 trawl survey	18.01	29.83	40.86	48.29	56.51	65.30	70.23	75.32	81.88	84.90	85.21	94.06
2004	Post-1981 trawl survey	17.26	30.23	37.98	48.97	56.99	64.00	70.82	75.99	82.17	87.17	85.92	94.75
2005	Post-1981 trawl survey	18.59	26.70	39.16	48.56	57.04	64.08	72.40	78.55	81.76	87.80	87.76	91.68
2006	Post-1981 trawl survey	15.33	30.89	38.55	47.57	55.89	65.00	73.78	82.25	85.59	88.74	93.41	95.17
2007	Post-1981 trawl survey	14.91	29.84	39.52	48.94	58.17	64.98	72.62	78.62	80.42	90.84	88.35	87.91
2008	Post-1981 trawl survey	15.39	29.78	41.31	53.39	60.87	66.06	72.32	79.08	84.24	89.35	95.56	97.66

Number of samples at age (0 indicates mean length inferred from long-term average age-length key):

Year	Fleet	1	2	3	4	5	6	7	8	9	10	11	12
2008	Jan-May longline fishery			39	83	147	253	92	52	27	6	2	
1994	Post-1981 trawl survey	40	213	143	109	89	73	26	12	7	1	2	0
1995	Post-1981 trawl survey	25	153	202	90	57	38	14	9	6	1	1	2
1996	Post-1981 trawl survey	34	143	138	183	101	65	37	5	2	0	1	2
1997	Post-1981 trawl survey	94	92	109	125	120	110	38	21	5	3	2	0
1998	Post-1981 trawl survey	56	145	97	94	73	88	47	28	6	0	1	0
1999	Post-1981 trawl survey	84	167	195	162	105	77	44	17	8	0	1	0
2000	Post-1981 trawl survey	112	102	131	204	177	83	21	20	7	6	1	0
2001	Post-1981 trawl survey	173	161	159	135	127	119	43	15	7	4	5	1
2002	Post-1981 trawl survey	114	165	206	189	85	91	70	16	6	2	0	2
2003	Post-1981 trawl survey	193	222	205	198	206	129	114	68	17	1	4	0
2004	Post-1981 trawl survey	150	134	205	133	160	136	62	35	17	4	4	0
2005	Post-1981 trawl survey	141	218	238	171	112	146	121	73	30	18	10	0
2006	Post-1981 trawl survey	205	176	179	168	155	140	133	93	36	10	4	1
2007	Post-1981 trawl survey	114	87	88	56	105	31	40	21	17	7	3	2
2008	Post-1981 trawl survey	141	262	244	188	134	97	45	45	28	13	8	6

Table 2.14—Multinomial sample sizes for length compositions.

	Trawl fishery			Longline fishery			Pot fishery			Trawl survey		
Year	Sea1	Sea2	Sea3	Sea1	Sea2	Sea3	Sea1	Sea2	Sea3	pre82	post81	IPHC
1977		13										
1978	4		24	22	26	18						
1979	12		6	74	17	21				159		
1980	62			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					209	
1984	122	71	31	112	75	624					193	
1985	223	9	13	266	39	981					268	
1986	213	5	11	248	11	792					244	
1987	306	41	149	692		1317					169	
1988	717		22								159	
1989	436										159	
1990	498		41	170	476	464		13	16		89	
1991	598	8		375	471	718		71	64		115	
1992	368		1	1023	574	176	86	146	27		153	
1993	409			742			64				165	
1994	729		1	968		362	167		20		221	
1995	410		8	1080		443	236	46	33		146	
1996	794		23	969		496	363	64	52		149	
1997	831	4		1132		983	216	43	70		146	
1998	674	14	16	1046		1362	152	37	26		152	
1999	534		11	1245	123	761	203		39		186	
2000	540			808	102	1315	175				200	
2001	278	28	18	997	261	1395	142		68		314	
2002	380	53	40	1078	507	1386	108		73		195	
2003	387	96	35	1489	571	1531	141		86		196	
2004	334	55	26	1292	542	1428	103		66		172	
2005	371	18		1174	618	1381	85		73		180	
2006	376	12		938	524	861	100		86		193	
2007	345	42		674	354	579	167		70		204	
2008	162	25	6	697	432	1055	106		83		206	81
2009	103	9		578	84	7	97				265	91

Table 2.15a (page 1 of 2)—Comparison of negative log-likelihoods across models. Log-likelihoods within the first group (Models A1, A2, A3, F2) are not comparable with each other. Log-likelihoods within the second group (Models B1, C1, D1, E1, G1) are comparable with one another, as are models within the third group (Models B2, C2, D2, E2, G2). Green = within-group minimum (by row), pink = within-group maximum (by row). AIC = Akaike Information Criterion. Blank cells indicate that the log-likelihood for that row is not defined in the model for that column.

	Models without size-at-age data				Models with size-at-age data									
					Models with age composition data					Models without age composition data				
Item	A1	A2	A3	F2	B1	C1	D1	E1	G1	B2	C2	D2	E2	G2
Total -ln(likelihood)	1652.88	1611.49	1633.51	2286.88	2604.15	2676.00	2822.94	2746.24	2728.63	2619.85	2663.77	2895.17	2768.31	2725.09
Number of parameters	186	186	186	129	215	215	195	195	189	215	215	195	195	189
AIC	3677.76	3594.98	3639.02	4831.76	5638.30	5782.00	6035.88	5882.48	5835.26	5669.70	5757.54	6180.34	5926.62	5828.18
Likelihood component														
Equilibrium catch	0.00	0.00	0.00		0.00	0.00	0.02	0.02	0.00	0.00	0.00	0.01	0.01	0.00
Survey CPUE (numbers)	-23.12	-24.77	-23.44	68.28	-21.83	-6.34	-2.70	-9.47	-5.12	-24.10	-13.84	-10.46	-13.80	-8.95
Size composition	1450.35	1613.78	1456.68	2175.91	1526.48	1523.81	1739.78	1662.06	1562.00	1723.78	1720.17	1980.33	1860.05	1827.22
Age composition	201.73		176.73		160.78	170.57	145.76	158.61	251.38					
Mean size at age					897.29	950.02	894.01	889.09	891.41	878.40	919.03	880.42	876.17	876.63
Recruitment	10.95	12.01	10.59	16.19	9.08	7.51	16.18	16.09	10.27	8.40	7.38	13.55	15.14	9.43
"Softbounds"	0.02	0.02	0.02	0.01	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Deviations	12.94	10.44	12.92	26.50	32.33	30.40	29.86	29.81	18.67	33.33	31.01	31.29	30.71	20.73

Table 2.15a (page 2 of 2)—Log likelihoods broken down by individual fleet. For the CPUE component, only the trawl survey values are counted in the total; the other rows are shown for comparison only. Likewise, log-likelihoods are shown for age composition data in models that do not use these data, simply for purposes of comparison. For the second and third groups of models, green = within-group minimum (by row), pink = within-group maximum (by row).

	Models without size-at-age data				Models with size-at-age data									
					Models with age composition data					Models without age composition data				
	A1	A2	A3	F2	B1	C1	D1	E1	G1	B2	C2	D2	E2	G2
CPUE														
Jan-May trawl fishery	63.31	40.99	65.08	97.47	53.28	50.41	26.97	28.43	51.86	53.96	50.54	30.16	29.18	51.78
Jun-Aug trawl fishery	0.32	-1.70	0.33	19.73	-1.22	-4.55	-3.42	-3.14	-2.31	-1.31	-4.40	-3.08	-3.03	-2.36
Sep-Dec trawl fishery	13.02	10.90	13.19	16.80	9.91	10.92	6.45	6.68	9.55	9.82	10.75	7.42	6.91	9.74
Jan-May longline fishery	253.91	219.78	245.60	228.42	205.11	113.58	227.50	232.25	188.83	187.27	105.89	221.56	226.78	171.77
Jun-Aug longline fishery	78.65	60.25	78.18	72.70	59.68	35.11	61.61	56.23	56.87	55.83	33.84	61.94	54.45	53.16
Sep-Dec longline fishery	77.54	88.82	76.05	222.36	43.31	55.74	213.70	199.24	42.72	34.68	46.12	193.77	194.20	39.12
Jan-May pot fishery	-5.55	-14.12	-5.58	11.18	-9.42	-17.17	-18.43	-16.45	-9.52	-9.69	-17.02	-17.03	-16.63	-10.38
Jun-Aug pot fishery	-9.75	-9.72	-9.68	1.77	-9.67	-9.29	-9.37	-9.07	-9.66	-9.75	-9.41	-9.73	-9.22	-9.70
Sep-Dec pot fishery	7.85	3.51	7.96	24.06	6.05	1.31	2.40	2.35	4.93	5.78	1.43	2.66	2.20	4.55
Pre-1982 trawl survey	-2.77	-3.20	-3.10	10.09	-1.44	1.61	5.84	2.82	-0.82	-3.34	-1.80	2.81	-0.29	-3.16
Post-1981 trawl survey	-20.35	-21.57	-20.33	68.28	-20.40	-7.94	-8.54	-12.28	-4.31	-20.75	-12.04	-13.26	-13.51	-5.78
IPHC longline survey	2.80	0.37	2.71	9.23	1.46	-3.23	-1.90	-1.29	0.53	1.04	-3.20	-1.73	-1.67	-0.06
Size composition														
Jan-May trawl fishery	417.02	402.11	414.01	529.26	454.59	449.32	462.09	456.28	454.12	445.77	441.38	459.00	445.30	447.30
Jun-Aug trawl fishery	62.12	64.31	62.31	109.51	71.70	72.50	72.82	72.51	71.48	72.91	73.74	73.37	73.23	72.85
Sep-Dec trawl fishery	63.79	63.36	63.76	80.90	65.78	66.41	66.58	65.93	65.79	66.03	66.76	66.64	66.01	66.13
Jan-May longline fishery	238.46	220.10	246.24	401.66	220.92	210.23	299.50	233.83	228.53	222.23	213.90	317.37	235.13	227.08
Jun-Aug longline fishery	137.39	130.48	138.32	144.54	147.68	169.57	138.62	139.56	146.67	153.66	173.78	142.14	145.92	153.71
Sep-Dec longline fishery	249.96	252.17	249.61	460.74	277.88	273.89	371.38	380.71	280.10	284.77	283.45	379.82	392.75	287.01
Jan-May pot fishery	39.60	38.31	39.46	50.52	36.38	35.04	53.11	47.11	37.27	35.44	34.43	53.58	46.34	35.79
Jun-Aug pot fishery	21.03	22.32	21.06	25.22	21.36	24.53	20.08	20.93	21.36	21.60	24.46	20.36	21.28	21.73
Sep-Dec pot fishery	40.78	41.83	41.27	51.41	42.28	46.58	43.23	43.40	42.10	43.39	47.41	42.95	44.60	43.21
Pre-1982 trawl survey	33.30	29.47	32.29	1.80	24.16	24.54	35.80	33.54	24.66	21.41	21.55	31.81	28.62	21.56
Post-1981 trawl survey	137.80	339.03	139.07	311.98	151.68	138.66	163.10	154.83	177.61	343.58	325.75	379.91	346.56	437.78
IPHC longline survey	9.11	10.28	9.28	10.18	12.06	12.55	13.49	13.43	12.32	12.98	13.56	13.38	14.32	13.08
Age composition														
Jan-May longline fishery	24.31	27.26	26.51	28.60	24.09	30.23	24.31	24.81	22.50	27.46	33.48	27.22	28.58	26.62
Post-1981 trawl survey	177.41	436.67	176.73	420.56	136.70	140.34	121.45	133.81	228.88	191.02	209.95	150.39	182.93	277.98
Mean size at age														
Jan-May longline fishery	0.00	0.00	0.00	0.00	97.66	112.35	92.97	94.30	93.38	94.59	108.47	90.64	92.64	93.00
Post-1981 trawl survey	0.00	0.00	0.00	0.00	799.63	837.67	801.04	794.79	798.03	783.81	810.56	789.78	783.52	783.63

Table 2.15b—Root mean squared errors for fishery CPUE and survey relative abundance time series. For the second and third groups of models, green = within-group row minimum, pink = within-group row maximum.

		Models w/o size-at-age data				Models with size-at-age data									
						Models w/ age composition data					Models w/o age composition data				
Fleet	Records	A1	A2	A3	F2	B1	C1	D1	E1	G1	B2	C2	D2	E2	G2
Jan-May trawl fishery	19	0.26	0.24	0.27	0.23	0.26	0.24	0.21	0.22	0.25	0.25	0.24	0.22	0.22	0.25
Jun-Aug trawl fishery	19	0.51	0.48	0.51	0.45	0.49	0.47	0.47	0.47	0.48	0.49	0.47	0.48	0.47	0.48
Sep-Dec trawl fishery	17	0.71	0.69	0.71	0.61	0.68	0.68	0.66	0.66	0.67	0.68	0.67	0.66	0.66	0.67
Jan-May longline fishery	19	0.30	0.28	0.30	0.24	0.28	0.22	0.27	0.28	0.27	0.27	0.22	0.27	0.28	0.26
Jun-Aug longline fishery	14	0.27	0.25	0.27	0.25	0.25	0.22	0.25	0.25	0.25	0.25	0.22	0.25	0.25	0.24
Sep-Dec longline fishery	18	0.20	0.21	0.20	0.24	0.17	0.19	0.28	0.27	0.17	0.17	0.18	0.27	0.27	0.17
Jan-May pot fishery	18	0.25	0.21	0.24	0.15	0.23	0.18	0.20	0.21	0.22	0.23	0.18	0.21	0.21	0.22
Jun-Aug pot fishery	7	0.15	0.13	0.15	0.10	0.14	0.15	0.13	0.13	0.14	0.14	0.15	0.12	0.13	0.14
Sep-Dec pot fishery	17	0.37	0.35	0.37	0.30	0.37	0.34	0.34	0.35	0.36	0.37	0.34	0.34	0.34	0.36
Pre-1982 trawl survey	3	0.20	0.19	0.19	0.33	0.24	0.29	0.35	0.31	0.25	0.18	0.23	0.31	0.26	0.19
Post-1981 trawl survey	28	0.19	0.19	0.19	0.23	0.19	0.21	0.22	0.21	0.22	0.19	0.20	0.21	0.21	0.22
IPHC longline survey	9	0.39	0.37	0.39	0.29	0.38	0.32	0.34	0.35	0.37	0.38	0.32	0.34	0.34	0.36

Table 2.15c—Correlations between observed data and model estimates for fishery CPUE and survey relative abundance time series. For the second and third groups of models, green = within-group row minimum, pink = within-group row maximum.

		Models w/o size-at-age data				Models with size-at-age data									
						Models w/ age composition data					Models w/o age composition data				
Fleet	Records	A1	A2	A3	F2	B1	C1	D1	E1	G1	B2	C2	D2	E2	G2
Jan-May trawl fishery	19	0.41	0.57	0.39	0.57	0.50	0.54	0.66	0.65	0.51	0.49	0.54	0.65	0.65	0.50
Jun-Aug trawl fishery	19	-0.32	-0.14	-0.34	0.20	-0.15	-0.17	-0.10	-0.05	-0.18	-0.13	-0.13	-0.14	-0.07	-0.18
Sep-Dec trawl fishery	17	0.11	0.17	0.10	0.02	0.19	0.08	0.29	0.28	0.20	0.19	0.08	0.27	0.27	0.19
Jan-May longline fishery	19	-0.27	-0.27	-0.28	-0.02	-0.22	-0.18	-0.43	-0.44	-0.21	-0.20	-0.13	-0.43	-0.45	-0.21
Jun-Aug longline fishery	14	0.05	0.09	0.04	0.14	0.17	0.16	0.05	0.10	0.16	0.17	0.17	0.04	0.09	0.15
Sep-Dec longline fishery	18	0.35	0.27	0.35	0.11	0.59	0.49	-0.20	-0.12	0.58	0.64	0.59	-0.12	-0.14	0.60
Jan-May pot fishery	18	-0.22	0.00	-0.23	0.49	-0.15	0.10	0.03	-0.02	-0.14	-0.14	0.10	-0.02	-0.02	-0.12
Jun-Aug pot fishery	7	0.74	0.75	0.72	0.85	0.75	0.72	0.73	0.71	0.74	0.78	0.75	0.76	0.72	0.76
Sep-Dec pot fishery	17	-0.06	0.06	-0.07	0.39	-0.02	0.02	0.09	0.10	-0.01	-0.03	0.02	0.07	0.09	-0.02
Pre-1982 trawl survey	3	0.98	0.92	0.97	-0.56	0.80	0.88	0.60	0.58	0.78	0.84	0.88	0.77	0.75	0.84
Post-1981 trawl survey	28	0.74	0.73	0.74	0.73	0.72	0.67	0.69	0.67	0.68	0.68	0.68	0.61	0.62	0.63
IPHC longline survey	9	-0.70	-0.65	-0.70	-0.05	-0.70	-0.69	-0.55	-0.58	-0.70	-0.70	-0.69	-0.57	-0.57	-0.70

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 size composition records from gear/year/season combinations are turned off if age composition records are available and used. For the second and third groups of models, green = within-group row minimum, pink = within-group row maximum.

			Models w/o size-at-age data				Models with size-at-age data									
							Models w/ age composition data					Models w/o age composition data				
Fleet	Records	Ave. N	A1	A2	A3	F2	B1	C1	D1	E1	G1	B2	C2	D2	E2	G2
Jan-May trawl fishery	31	365	1.35	1.39	1.35	1.19	1.29	1.22	1.33	1.28	1.29	1.27	1.21	1.30	1.30	1.26
Jun-Aug trawl fishery	19	29	8.27	8.09	8.24	4.90	9.04	9.24	9.06	8.86	9.46	9.10	9.56	8.93	8.70	9.43
Sep-Dec trawl fishery	22	28	3.98	4.01	3.97	4.06	3.76	3.63	3.87	3.85	3.73	3.72	3.59	3.85	3.86	3.70
Jan-May longline fishery	30	668	2.38	2.30	2.35	1.17	1.95	2.11	1.85	2.19	1.94	1.97	2.10	1.82	2.12	1.96
Jun-Aug longline fishery	23	255	2.87	2.95	2.88	4.20	2.79	2.55	2.83	2.89	2.82	2.77	2.55	2.77	2.90	2.79
Sep-Dec longline fishery	29	710	1.80	1.77	1.81	0.95	1.70	1.65	1.55	1.42	1.72	1.69	1.60	1.53	1.39	1.71
Jan-May pot fishery	18	151	2.94	3.06	2.99	2.67	3.45	3.59	2.70	2.65	3.42	3.55	3.73	2.89	2.76	3.56
Jun-Aug pot fishery	7	60	4.07	4.34	4.08	2.96	4.51	4.95	4.35	4.50	4.53	4.46	4.69	4.31	4.51	4.52
Sep-Dec pot fishery	17	56	5.47	5.24	5.39	3.66	5.62	4.80	5.81	5.79	5.62	5.65	4.87	5.95	5.95	5.64
Pre-1982 trawl survey	3	103	0.64	0.70	0.66	11.92	1.05	1.18	0.76	0.83	1.04	1.17	1.38	0.84	0.95	1.17
Post-1981 trawl survey	28	174	2.00	1.64	2.02	1.34	1.43	1.63	1.26	1.33	1.16	1.31	1.40	1.24	1.28	0.99
IPHC longline survey	2	86	2.02	1.79	2.00	1.44	1.60	1.64	1.39	1.44	1.53	1.54	1.54	1.42	1.42	1.51
Weighted average		299	3.11	3.06	3.10	2.56	3.07	3.04	2.98	3.00	3.07	3.06	3.04	2.97	2.99	3.05

Table 2.15e— Average ratio of effective multinomial sample size to input sample size for each survey and fishery age composition record. For the second and third groups of models, green = within-group row minimum, pink = within-group row maximum.

			Models w/o size-at-age data				Models with size-at-age data									
							Models w/ age composition data					Models w/o age composition data				
Fleet	Year	Input N	A1	A2	A3	F2	B1	C1	D1	E1	G1	B2	C2	D2	E2	G2
Jan-May longline fishery	2008	233	0.12	0.11	0.12	0.08	0.20	0.16	0.20	0.20	0.21	0.18	0.15	0.18	0.17	0.18
Post-1981 trawl survey	1994	237	0.36	0.09	0.35	0.21	0.28	0.31	0.27	0.27	0.22	0.23	0.25	0.24	0.24	0.19
Post-1981 trawl survey	1995	199	0.69	4.17	0.70	0.43	0.15	0.15	0.13	0.15	0.10	0.14	0.13	0.11	0.13	0.09
Post-1981 trawl survey	1996	236	0.57	0.17	0.59	0.22	0.63	0.68	0.58	0.62	0.15	0.67	0.76	0.52	0.65	0.17
Post-1981 trawl survey	1997	239	0.24	0.20	0.24	0.29	0.98	1.32	1.16	0.90	0.35	0.63	0.76	1.24	0.63	0.27
Post-1981 trawl survey	1998	211	0.40	0.08	0.38	0.24	0.39	0.45	0.38	0.41	0.19	0.44	0.49	0.45	0.47	0.18
Post-1981 trawl survey	1999	285	0.11	0.04	0.11	0.04	0.96	1.02	1.16	0.84	0.59	0.45	0.46	0.76	0.39	0.55
Post-1981 trawl survey	2000	287	0.12	0.08	0.13	0.05	0.43	0.56	0.45	0.41	0.63	0.29	0.38	0.32	0.27	0.56
Post-1981 trawl survey	2001	315	0.16	0.07	0.16	0.08	1.88	2.05	1.84	1.84	0.19	1.35	1.39	1.19	1.30	0.22
Post-1981 trawl survey	2002	314	0.10	0.03	0.10	0.03	0.36	0.33	0.34	0.38	0.27	0.24	0.23	0.25	0.25	0.24
Post-1981 trawl survey	2003	451	1.00	0.17	1.00	0.15	1.96	1.89	0.88	1.46	2.37	2.83	2.42	1.11	2.46	1.66
Post-1981 trawl survey	2004	345	0.08	0.03	0.08	0.04	0.21	0.19	0.21	0.21	0.20	0.16	0.15	0.19	0.16	0.17
Post-1981 trawl survey	2005	425	0.69	0.20	0.61	0.31	0.38	0.45	0.33	0.35	0.25	0.25	0.27	0.23	0.25	0.17
Post-1981 trawl survey	2006	431	0.28	0.07	0.28	0.07	0.57	0.47	0.73	0.62	0.13	0.30	0.23	0.31	0.31	0.10
Post-1981 trawl survey	2007	190	0.09	0.12	0.09	0.07	0.08	0.08	0.08	0.08	0.03	0.06	0.06	0.06	0.06	0.03
Post-1981 trawl survey	2008	402	3.04	0.27	3.12	0.67	0.08	0.08	0.08	0.08	0.09	0.07	0.06	0.07	0.07	0.07
Post-1981 trawl survey	Ave.	304	0.53	0.39	0.53	0.19	0.62	0.67	0.58	0.57	0.38	0.54	0.54	0.47	0.51	0.31
All	Ave.	300	0.50	0.37	0.50	0.18	0.60	0.64	0.55	0.55	0.37	0.52	0.51	0.45	0.49	0.30

Table 2.16a—Key parameters as specified/estimated by the 14 models. “Value” = point estimate, “SD” = standard deviation. A blank under “SD” indicates that the parameter was fixed. For the second and third groups of models, green = within-group row minimum, pink = within-group row maximum.

Models with no size-at-age data:

	Model A1		Model A2		Model A3		Model F2	
Parm.	Value	SD	Value	SD	Value	SD	Value	SD
M	0.340		0.340		0.340		0.475	0.017
L1	16.135		16.135		16.135		5.490	0.262
L2	92.536	0.706	91.476	0.844	91.850	0.745	102.073	1.041
K	0.235	0.004	0.247	0.004	0.239	0.004	0.209	0.004
SD1	3.692		3.692		3.692		4.096	0.117
SD2	9.750	0.208	9.862	0.207	9.828	0.209	14.263	0.770
R0	13.298	0.049	13.305	0.060	13.338	0.055	14.042	0.159
R1	-1.012	0.146	-1.025	0.159	-0.982	0.151	-0.761	0.123
Init. F	0.071	0.016	0.069	0.017	0.065	0.015	2.223	0.301
lnQ1	0.071	0.114	-0.048	0.135	0.013	0.121	n/a	
lnQ2	-0.285	0.054	-0.105	0.069	-0.321	0.061	-0.471	0.111

Models with size-at-age data and age composition data:

	Model B1		Model C1		Model D1		Model E1		Model G1	
Parm.	Value	SD	Value	SD	Value	SD	Value	SD	Value	SD
M	0.340		0.340		0.340		0.340		0.340	
L1	-14.958	0.254	-15.659	0.257	-14.156	0.256	-14.648	0.259	-14.867	0.251
L2	95.877	0.399	93.406	0.339	97.310	0.444	96.303	0.421	96.091	0.395
K	0.217	0.003	0.226	0.003	0.209	0.003	0.214	0.003	0.216	0.003
SD1	0.010		0.010		0.010		0.010		0.010	
SD2	8.680		8.680		8.680		8.680		8.680	
R0	13.368	0.021	13.831	0.024	13.285	0.018	13.315	0.019	13.360	0.019
R1	-0.924	0.123	-0.724	0.128	-1.251	0.105	-1.188	0.101	-0.949	0.122
Init. F	0.060	0.010	0.028	0.004	0.112	0.020	0.097	0.016	0.062	0.010
lnQ1	0.000		-0.755		0.000		0.000		0.000	
lnQ2	-0.261		-0.755		-0.261		-0.261		-0.261	

Models with size-at-age data but no age composition data:

	Model B2		Model C2		Model D2		Model E2		Model G2	
Parm.	Value	SD	Value	SD	Value	SD	Value	SD	Value	SD
M	0.340		0.340		0.340		0.340		0.340	
L1	-15.177	0.247	-15.756	0.250	-14.019	0.239	-14.947	0.244	-15.040	0.241
L2	94.710	0.363	92.564	0.318	96.842	0.408	94.918	0.372	94.937	0.361
K	0.222	0.003	0.230	0.003	0.210	0.002	0.220	0.003	0.221	0.003
SD1	0.010		0.010		0.010		0.010		0.010	
SD2	8.680		8.680		8.680		8.680		8.680	
R0	13.413	0.021	13.876	0.024	13.309	0.019	13.364	0.019	13.416	0.020
R1	-0.837	0.124	-0.660	0.129	-1.132	0.114	-1.158	0.109	-0.863	0.124
Init. F	0.051	0.008	0.024	0.004	0.089	0.015	0.085	0.014	0.052	0.008
lnQ1	0.000		-0.755		0.000		0.000		0.000	
lnQ2	-0.261		-0.755		-0.261		-0.261		-0.261	

Legend:

M = instantaneous natural mortality rate
L1 = mean Jan. 1 length at age a1 (a1 = 1.5417 in Models A1-A3, 1 in Model F2, 0 in all other models)
L2 = mean Jan. 1 length at age 20 in Models A1-A3 and F2, asymptotic length in all other models
K = Brody's growth coefficient
SD1 = standard deviation of length at age a1
SD2 = standard deviation of length at age 20
R0 = log mean recruitment for post-1976 environmental regime
R1 = log ratio of pre-1977 mean recruitment to post-1976 mean recruitment
Init. F = equilibrium fishing mortality rate in initial year (1977)
lnQ1 = log catchability of pre-1982 trawl survey
lnQ2 = log catchability of post-1981 trawl survey

Table 2.16b—Growth deviations for models including mean size-at-age data and age composition data. "Value" = point estimate, "SD" = standard deviation.

	Model B1		Model C1		Model D1		Model E1		Model G1	
Cohort	Value	SD	Value	SD	Value	SD	Value	SD	Value	SD
1977	0.053	0.011	0.051	0.012	0.046	0.012	0.043	0.011	0.052	0.011
1978	0.057	0.020	0.049	0.021	0.023	0.022	0.030	0.022	0.055	0.020
1979	0.072	0.017	0.064	0.018	0.052	0.016	0.056	0.017	0.069	0.017
1980	0.098	0.016	0.091	0.018	0.090	0.015	0.090	0.016	0.093	0.016
1981	0.037	0.017	0.032	0.018	0.043	0.017	0.042	0.017	0.035	0.017
1982	0.018	0.009	0.015	0.009	0.027	0.009	0.024	0.009	0.019	0.009
1983	-0.044	0.021	-0.060	0.023	-0.046	0.020	-0.041	0.021	-0.030	0.022
1984	0.043	0.010	0.038	0.010	0.042	0.011	0.045	0.010	0.045	0.010
1985	-0.003	0.013	-0.008	0.013	-0.008	0.013	-0.003	0.013	-0.003	0.013
1986	0.019	0.018	0.013	0.019	0.011	0.018	0.016	0.018	0.019	0.017
1987	0.063	0.021	0.051	0.022	0.054	0.020	0.057	0.021	0.055	0.021
1988	0.087	0.013	0.084	0.013	0.082	0.013	0.086	0.013	0.092	0.013
1989	0.055	0.009	0.054	0.010	0.059	0.009	0.059	0.009	0.060	0.009
1990	0.028	0.010	0.028	0.010	0.032	0.010	0.031	0.010	0.031	0.010
1991	0.024	0.011	0.027	0.012	0.027	0.011	0.028	0.011	0.026	0.011
1992	0.024	0.008	0.027	0.009	0.030	0.008	0.028	0.008	0.022	0.008
1993	0.011	0.009	0.013	0.010	0.015	0.009	0.013	0.009	0.007	0.009
1994	-0.014	0.009	-0.013	0.010	-0.009	0.009	-0.011	0.009	-0.017	0.009
1995	-0.027	0.010	-0.022	0.010	-0.023	0.010	-0.023	0.010	-0.026	0.010
1996	-0.004	0.008	0.000	0.008	0.002	0.008	0.001	0.008	-0.004	0.008
1997	-0.057	0.009	-0.056	0.009	-0.048	0.009	-0.050	0.009	-0.059	0.009
1998	-0.024	0.010	-0.022	0.010	-0.014	0.010	-0.016	0.010	-0.025	0.010
1999	-0.007	0.009	-0.005	0.009	0.004	0.009	0.001	0.008	-0.003	0.008
2000	0.001	0.008	0.004	0.009	0.008	0.008	0.006	0.008	0.001	0.008
2001	-0.046	0.009	-0.044	0.009	-0.040	0.009	-0.042	0.009	-0.048	0.009
2002	0.004	0.008	0.009	0.009	0.009	0.008	0.008	0.008	0.002	0.008
2003	-0.048	0.009	-0.045	0.009	-0.043	0.009	-0.044	0.009	-0.049	0.009
2004	0.030	0.009	0.034	0.009	0.036	0.009	0.034	0.009	0.031	0.009
2005	-0.008	0.010	-0.007	0.010	0.001	0.010	-0.002	0.010	-0.001	0.010
2006	-0.046	0.009	-0.045	0.009	-0.040	0.009	-0.042	0.009	-0.046	0.009
2007	-0.021	0.013	-0.023	0.012	-0.014	0.013	-0.016	0.013	-0.018	0.013
2008	-0.071	0.012	-0.068	0.012	-0.069	0.012	-0.068	0.012	-0.072	0.012

Table 2.16c—Growth deviations for models including mean size-at-age data but no age composition data. "Value" = point estimate, "SD" = standard deviation.

	Model B2		Model C2		Model D2		Model E2		Model G2	
Cohort	Value	SD	Value	SD	Value	SD	Value	SD	Value	SD
1977	0.053	0.011	0.052	0.011	0.049	0.012	0.050	0.012	0.053	0.011
1978	0.065	0.020	0.056	0.021	0.033	0.021	0.043	0.020	0.064	0.020
1979	0.078	0.017	0.069	0.018	0.057	0.016	0.062	0.017	0.077	0.017
1980	0.102	0.016	0.094	0.018	0.094	0.016	0.094	0.016	0.099	0.016
1981	0.039	0.018	0.033	0.018	0.043	0.017	0.043	0.018	0.036	0.018
1982	0.015	0.009	0.012	0.009	0.025	0.009	0.020	0.009	0.016	0.009
1983	-0.042	0.022	-0.056	0.023	-0.044	0.020	-0.039	0.022	-0.031	0.023
1984	0.041	0.010	0.037	0.010	0.040	0.010	0.041	0.010	0.042	0.010
1985	-0.005	0.013	-0.008	0.013	-0.009	0.013	-0.006	0.013	-0.007	0.013
1986	0.018	0.018	0.013	0.019	0.010	0.018	0.013	0.018	0.016	0.018
1987	0.064	0.022	0.052	0.023	0.057	0.021	0.057	0.022	0.053	0.022
1988	0.091	0.013	0.087	0.013	0.088	0.013	0.088	0.013	0.095	0.013
1989	0.057	0.009	0.055	0.010	0.062	0.009	0.059	0.009	0.062	0.009
1990	0.031	0.010	0.032	0.011	0.034	0.010	0.033	0.010	0.035	0.010
1991	0.020	0.012	0.022	0.012	0.018	0.012	0.022	0.012	0.022	0.012
1992	0.015	0.008	0.016	0.008	0.021	0.008	0.017	0.008	0.013	0.008
1993	0.013	0.009	0.015	0.010	0.016	0.009	0.014	0.009	0.010	0.009
1994	-0.008	0.009	-0.007	0.010	-0.003	0.009	-0.006	0.009	-0.009	0.009
1995	-0.017	0.010	-0.012	0.010	-0.016	0.010	-0.014	0.010	-0.016	0.010
1996	-0.003	0.008	0.000	0.008	0.003	0.008	0.001	0.008	-0.003	0.008
1997	-0.059	0.009	-0.059	0.009	-0.050	0.009	-0.054	0.009	-0.060	0.009
1998	-0.033	0.010	-0.031	0.010	-0.023	0.010	-0.026	0.010	-0.033	0.010
1999	-0.005	0.009	-0.004	0.009	0.006	0.009	0.001	0.009	-0.002	0.008
2000	0.007	0.008	0.009	0.008	0.012	0.008	0.010	0.008	0.006	0.008
2001	-0.048	0.009	-0.046	0.009	-0.044	0.009	-0.047	0.009	-0.050	0.009
2002	0.003	0.008	0.008	0.009	0.007	0.008	0.005	0.008	0.001	0.008
2003	-0.050	0.009	-0.047	0.009	-0.046	0.009	-0.048	0.009	-0.051	0.009
2004	0.035	0.009	0.039	0.009	0.040	0.009	0.038	0.009	0.035	0.009
2005	-0.019	0.009	-0.019	0.009	-0.010	0.009	-0.016	0.009	-0.013	0.009
2006	-0.053	0.008	-0.052	0.009	-0.048	0.008	-0.051	0.008	-0.053	0.008
2007	-0.037	0.011	-0.038	0.011	-0.031	0.012	-0.035	0.011	-0.036	0.011
2008	-0.076	0.012	-0.074	0.012	-0.076	0.012	-0.075	0.012	-0.077	0.012

Table 2.16d—Recruitment deviations for models without mean size-at-age data. “Value” = point estimate, “SD” = standard deviation. Note that deviations are relative to their regime-specific (pre-1977, post-1976) log medians.

	Model A1		Model A2		Model A3		Model F2	
Year	Value	SD	Value	SD	Value	SD	Value	SD
1974	1.049	0.211	1.209	0.223	1.069	0.215	-0.037	0.180
1975	-1.435	0.364	-1.396	0.414	-1.422	0.373	-0.136	0.224
1976	0.386	0.267	0.187	0.319	0.353	0.274	0.173	0.170
1977	1.552	0.087	1.720	0.102	1.588	0.090	0.911	0.126
1978	0.184	0.196	0.402	0.190	0.199	0.200	0.605	0.153
1979	0.490	0.125	0.564	0.129	0.484	0.129	0.859	0.095
1980	-0.273	0.160	-0.210	0.155	-0.282	0.163	0.105	0.111
1981	-1.082	0.193	-1.148	0.196	-1.099	0.196	-0.898	0.153
1982	0.923	0.049	0.922	0.051	0.930	0.050	0.851	0.043
1983	-0.569	0.136	-0.479	0.130	-0.568	0.138	-0.506	0.107
1984	0.722	0.057	0.713	0.059	0.724	0.058	0.660	0.047
1985	-0.038	0.089	0.078	0.084	-0.035	0.090	0.123	0.065
1986	-0.770	0.120	-0.743	0.121	-0.786	0.123	-0.467	0.084
1987	-1.233	0.152	-1.355	0.168	-1.276	0.159	-0.941	0.095
1988	-0.246	0.073	-0.315	0.074	-0.253	0.074	-0.536	0.066
1989	0.531	0.050	0.471	0.053	0.533	0.051	0.221	0.046
1990	0.361	0.058	0.438	0.058	0.363	0.059	0.310	0.046
1991	-0.162	0.071	-0.362	0.090	-0.169	0.072	-0.374	0.064
1992	0.641	0.039	0.643	0.045	0.645	0.040	0.362	0.040
1993	-0.272	0.066	-0.292	0.083	-0.268	0.067	-0.345	0.058
1994	-0.286	0.059	-0.293	0.069	-0.285	0.060	-0.534	0.051
1995	-0.088	0.058	-0.372	0.076	-0.083	0.059	-0.686	0.055
1996	0.703	0.038	0.708	0.046	0.714	0.039	0.253	0.037
1997	-0.190	0.063	0.026	0.064	-0.191	0.064	-0.004	0.040
1998	-0.030	0.051	-0.242	0.073	-0.031	0.052	-0.184	0.046
1999	0.484	0.039	0.511	0.045	0.488	0.040	0.388	0.035
2000	0.073	0.047	0.321	0.051	0.079	0.047	0.402	0.036
2001	-0.576	0.058	-0.917	0.107	-0.572	0.059	-0.614	0.065
2002	-0.260	0.048	-0.142	0.056	-0.297	0.050	-0.159	0.046
2003	-0.421	0.057	-0.392	0.071	-0.397	0.058	-0.428	0.058
2004	-0.695	0.069	-0.536	0.078	-0.700	0.071	-0.438	0.061
2005	-0.529	0.070	-0.630	0.086	-0.526	0.070	-0.515	0.071
2006	0.358	0.069	0.366	0.073	0.358	0.069	0.351	0.068
2007	-0.052	0.146	-0.155	0.146	-0.044	0.146	-0.062	0.128
2008	0.751	0.221	0.701	0.257	0.758	0.224	1.293	0.209

Table 2.16e—Recruitment deviations for models with mean size-at-age data and age composition data. "Value" = point estimate, "SD" = standard deviation. Note that deviations are relative to their regime-specific (pre-1977, post-1976) log medians.

	Model B1		Model C1		Model D1		Model E1		Model G1	
Year	Value	SD	Value	SD	Value	SD	Value	SD	Value	SD
1974	0.926	0.190	0.937	0.195	0.944	0.164	1.005	0.164	0.926	0.189
1975	-1.514	0.329	-1.492	0.332	-1.783	0.320	-1.850	0.299	-1.519	0.328
1976	0.587	0.240	0.555	0.244	0.839	0.250	0.844	0.229	0.593	0.239
1977	1.296	0.078	1.496	0.078	1.164	0.074	1.200	0.078	1.281	0.078
1978	0.335	0.145	0.402	0.158	0.287	0.148	0.272	0.151	0.323	0.144
1979	0.243	0.140	0.263	0.148	0.209	0.157	0.238	0.151	0.236	0.139
1980	0.096	0.108	-0.005	0.122	0.095	0.114	0.120	0.113	0.081	0.108
1981	-0.538	0.122	-0.576	0.129	-0.501	0.124	-0.504	0.125	-0.611	0.120
1982	0.835	0.045	0.839	0.047	0.844	0.044	0.881	0.044	0.808	0.043
1983	-0.516	0.150	-0.537	0.169	-0.390	0.152	-0.444	0.150	-0.695	0.136
1984	0.534	0.061	0.502	0.066	0.476	0.064	0.532	0.062	0.578	0.053
1985	0.006	0.078	-0.024	0.082	-0.036	0.078	-0.005	0.078	-0.054	0.075
1986	-0.922	0.128	-0.995	0.131	-0.943	0.128	-0.941	0.128	-0.855	0.117
1987	-1.479	0.175	-1.621	0.187	-1.425	0.174	-1.480	0.177	-1.499	0.169
1988	-0.423	0.067	-0.466	0.072	-0.458	0.069	-0.465	0.068	-0.534	0.067
1989	0.456	0.047	0.433	0.050	0.376	0.046	0.384	0.046	0.438	0.045
1990	0.326	0.053	0.237	0.057	0.242	0.052	0.240	0.052	0.306	0.051
1991	-0.096	0.061	-0.194	0.065	-0.173	0.059	-0.172	0.060	-0.074	0.057
1992	0.501	0.039	0.451	0.041	0.407	0.038	0.423	0.038	0.517	0.038
1993	-0.104	0.051	-0.177	0.053	-0.184	0.049	-0.177	0.049	-0.116	0.049
1994	-0.186	0.053	-0.253	0.056	-0.249	0.051	-0.245	0.052	-0.199	0.051
1995	-0.066	0.060	-0.136	0.063	-0.087	0.059	-0.094	0.060	-0.116	0.058
1996	0.640	0.035	0.630	0.037	0.609	0.035	0.641	0.035	0.635	0.033
1997	0.070	0.048	0.017	0.050	0.086	0.047	0.096	0.048	0.050	0.046
1998	-0.258	0.063	-0.309	0.066	-0.212	0.062	-0.214	0.063	-0.305	0.060
1999	0.351	0.039	0.336	0.041	0.415	0.038	0.416	0.038	0.327	0.037
2000	0.069	0.040	0.071	0.042	0.125	0.039	0.126	0.039	0.110	0.038
2001	-0.555	0.054	-0.538	0.057	-0.492	0.053	-0.505	0.054	-0.561	0.052
2002	-0.244	0.043	-0.160	0.045	-0.197	0.043	-0.206	0.043	-0.226	0.041
2003	-0.458	0.053	-0.340	0.054	-0.403	0.053	-0.417	0.053	-0.468	0.050
2004	-0.700	0.060	-0.560	0.060	-0.650	0.060	-0.662	0.060	-0.646	0.055
2005	-0.358	0.062	-0.203	0.063	-0.286	0.063	-0.307	0.063	-0.244	0.055
2006	0.292	0.065	0.425	0.065	0.388	0.065	0.351	0.065	0.467	0.062
2007	-0.126	0.104	-0.045	0.104	-0.052	0.103	-0.083	0.103	-0.018	0.093
2008	0.979	0.134	1.036	0.134	1.014	0.131	1.001	0.132	1.064	0.109

Table 2.16f—Recruitment deviations for models with mean size-at-age data but no age composition data. "Value" = point estimate, "SD" = standard deviation. Note that deviations are relative to their regime-specific (pre-1977, post-1976) log medians.

	Model B2		Model C2		Model D2		Model E2		Model G2	
Year	Value	SD	Value	SD	Value	SD	Value	SD	Value	SD
1974	0.941	0.194	0.957	0.198	0.952	0.167	1.010	0.168	0.935	0.194
1975	-1.455	0.333	-1.436	0.338	-1.691	0.320	-1.654	0.321	-1.464	0.332
1976	0.514	0.246	0.480	0.250	0.739	0.250	0.644	0.255	0.529	0.245
1977	1.357	0.080	1.558	0.080	1.210	0.074	1.259	0.077	1.336	0.080
1978	0.371	0.146	0.445	0.157	0.299	0.147	0.316	0.147	0.345	0.146
1979	0.252	0.140	0.278	0.146	0.235	0.151	0.269	0.144	0.234	0.139
1980	0.134	0.106	0.035	0.119	0.113	0.113	0.170	0.110	0.133	0.104
1981	-0.533	0.122	-0.573	0.130	-0.483	0.123	-0.490	0.125	-0.600	0.121
1982	0.857	0.046	0.855	0.047	0.846	0.045	0.908	0.045	0.833	0.044
1983	-0.562	0.151	-0.598	0.163	-0.427	0.149	-0.505	0.150	-0.717	0.139
1984	0.562	0.061	0.531	0.064	0.490	0.063	0.563	0.061	0.607	0.053
1985	0.014	0.079	-0.011	0.081	-0.040	0.079	0.002	0.078	-0.049	0.076
1986	-0.937	0.130	-0.995	0.132	-0.956	0.130	-0.961	0.130	-0.880	0.120
1987	-1.548	0.180	-1.662	0.190	-1.487	0.180	-1.567	0.183	-1.555	0.175
1988	-0.432	0.068	-0.467	0.072	-0.465	0.069	-0.481	0.069	-0.547	0.069
1989	0.464	0.050	0.448	0.052	0.394	0.047	0.387	0.048	0.441	0.047
1990	0.363	0.056	0.288	0.059	0.298	0.053	0.266	0.055	0.334	0.053
1991	-0.010	0.061	-0.095	0.065	-0.077	0.060	-0.098	0.060	0.000	0.058
1992	0.511	0.042	0.463	0.044	0.411	0.042	0.428	0.041	0.527	0.041
1993	-0.170	0.056	-0.248	0.060	-0.244	0.054	-0.249	0.055	-0.199	0.056
1994	-0.210	0.057	-0.283	0.060	-0.257	0.054	-0.276	0.056	-0.225	0.056
1995	-0.105	0.063	-0.172	0.066	-0.111	0.063	-0.140	0.063	-0.132	0.061
1996	0.683	0.036	0.672	0.037	0.650	0.036	0.696	0.035	0.677	0.035
1997	0.132	0.048	0.084	0.050	0.158	0.047	0.170	0.048	0.116	0.047
1998	-0.317	0.070	-0.365	0.073	-0.264	0.070	-0.262	0.070	-0.353	0.068
1999	0.303	0.042	0.287	0.045	0.369	0.041	0.384	0.041	0.288	0.041
2000	0.142	0.041	0.141	0.044	0.181	0.041	0.209	0.041	0.181	0.039
2001	-0.568	0.061	-0.563	0.065	-0.491	0.059	-0.512	0.061	-0.563	0.059
2002	-0.194	0.046	-0.116	0.047	-0.148	0.045	-0.155	0.046	-0.173	0.044
2003	-0.526	0.062	-0.419	0.063	-0.479	0.061	-0.486	0.062	-0.513	0.060
2004	-0.648	0.062	-0.512	0.062	-0.621	0.063	-0.610	0.063	-0.610	0.061
2005	-0.315	0.064	-0.172	0.064	-0.237	0.065	-0.265	0.064	-0.254	0.059
2006	0.193	0.071	0.309	0.070	0.293	0.072	0.245	0.071	0.415	0.068
2007	-0.254	0.117	-0.192	0.118	-0.166	0.116	-0.218	0.117	-0.154	0.113
2008	0.990	0.139	1.049	0.140	1.008	0.133	1.003	0.137	1.057	0.110

Table 2.17a—Base fishery selectivity parameters for models without mean size-at-age data. A blank under "SD" means the parameter was fixed. Fixed parameters may be over-written by block-specific values (see Tables 2.17d-2.17f). See text for parameter definitions.

		Model A1		Model A2		Model A3		Model F2	
Fishery	Parm.	Value	SD	Value	SD	Value	SD	Value	SD
Jan-May trawl	1	0		0		0		80.48	0.80
Jan-May trawl	2	0		0		0		-10	
Jan-May trawl	3	0		0		0		6.47	0.03
Jan-May trawl	4	0		0		0		10	
Jan-May trawl	5	-999		-999		-999		-10	
Jan-May trawl	6	10		10		10		0.10	0.40
Jun-Aug trawl	1	0		0		0		82.40	5.25
Jun-Aug trawl	2	0		0		0		0	
Jun-Aug trawl	3	5.66	0.20	5.68	0.20	5.64	0.20	6.71	0.20
Jun-Aug trawl	4	0		0		0		0	
Jun-Aug trawl	5	-999		-999		-999		-10	
Jun-Aug trawl	6	10		10		10		10	
Sep-Dec trawl	1	0		0		0		96.55	4.12
Sep-Dec trawl	2	0		0		0		0	
Sep-Dec trawl	3	0		0		0		6.77	0.13
Sep-Dec trawl	4	0		0		0		0	
Sep-Dec trawl	5	-999		-999		-999		-10	
Sep-Dec trawl	6	10		10		10		10	
Jan-May longline	1	0		0		0		67.81	0.30
Jan-May longline	2	-9.54	11.98	-9.52	12.43	-9.57	11.36	-10	
Jan-May longline	3	0		0		0		5.37	0.02
Jan-May longline	4	4.96	0.11	4.92	0.11	4.92	0.11	5.22	0.21
Jan-May longline	5	-999		-999		-999		-10	
Jan-May longline	6	0		0		0		-0.35	0.17
Jun-Aug longline	1	0		0		0		68.94	0.66
Jun-Aug longline	2	0		0		0		0	
Jun-Aug longline	3	5.01	0.06	5.00	0.07	4.99	0.06	5.30	0.06
Jun-Aug longline	4	0		0		0		0	
Jun-Aug longline	5	-999		-999		-999		-10	
Jun-Aug longline	6	10		10		10		10	
Sep-Dec longline	1	0		0		0		68.77	0.44
Sep-Dec longline	2	-2.28	0.44	-2.15	0.41	-2.28	0.44	0	
Sep-Dec longline	3	0		0		0		5.34	0.03
Sep-Dec longline	4	5.14	0.35	5.09	0.37	5.12	0.35	0	
Sep-Dec longline	5	-999		-999		-999		-10	
Sep-Dec longline	6	0		0		0		10	
Jan-May pot	1	0		0		0		69.70	0.76
Jan-May pot	2	-8.90	24.37	-8.81	25.76	-8.90	24.39	-10	
Jan-May pot	3	5.08	0.07	5.08	0.07	5.08	0.07	5.11	0.07
Jan-May pot	4	4.19	0.44	4.20	0.43	4.18	0.43	3.91	0.89
Jan-May pot	5	-999		-999		-999		-10	
Jan-May pot	6	0		0		0		0.79	0.30
Jun-Aug pot	1	0		0		0		67.68	1.47
Jun-Aug pot	2	0		0		0		0	
Jun-Aug pot	3	4.89	0.19	4.87	0.19	4.88	0.19	5.06	0.16
Jun-Aug pot	4	0		0		0		0	
Jun-Aug pot	5	-999		-999		-999		-10	
Jun-Aug pot	6	10		10		10		10	
Sep-Dec pot	1	0		0		0		66.46	1.13
Sep-Dec pot	2	0		0		0		0	
Sep-Dec pot	3	0		0		0		4.89	0.13
Sep-Dec pot	4	0		0		0		0	
Sep-Dec pot	5	-999		-999		-999		-10	
Sep-Dec pot	6	10		10		10		10	

Table 2.17b—Base fishery selectivity parameters for models with mean size-at-age data and age composition data. A blank under "SD" means the parameter was fixed. Fixed parameters may be over-written by block-specific values (see Tables 2.17g-2.17i). See text for parameter definitions.

		Model B1		Model C1		Model D1		Model E1		Model G1	
Fishery	Parm.	Value	SD	Value	SD	Value	SD	Value	SD	Value	SD
Jan-May trawl	1	0		0		0		0		0	
Jan-May trawl	2	0		0		0		0		0	
Jan-May trawl	3	0		0		0		0		0	
Jan-May trawl	4	0		0		0		0		0	
Jan-May trawl	5	-999		-999		-999		-999		-999	
Jan-May trawl	6	10		10		10		10		10	
Jun-Aug trawl	1	0		0		0		0		0	
Jun-Aug trawl	2	0		0		0		0		0	
Jun-Aug trawl	3	5.68	0.20	5.53	0.22	5.86	0.18	5.84	0.18	5.70	0.19
Jun-Aug trawl	4	0		0		0		0		0	
Jun-Aug trawl	5	-999		-999		-999		-999		-999	
Jun-Aug trawl	6	10		10		10		10		10	
Sep-Dec trawl	1	0		0		0		0		0	
Sep-Dec trawl	2	0		0		0		0		0	
Sep-Dec trawl	3	0		0		0		0		0	
Sep-Dec trawl	4	0		0		0		0		0	
Sep-Dec trawl	5	-999		-999		-999		-999		-999	
Sep-Dec trawl	6	10		10		10		10		10	
Jan-May longline	1	0		0		0		0		0	
Jan-May longline	2	-9.49	13.27	-9.43	14.39	-9.92	2.41	-5.35	5.03	-9.50	12.88
Jan-May longline	3	0		0		0		0		0	
Jan-May longline	4	4.95	0.12	4.98	0.10	6.45	0.06	4.69	0.16	4.94	0.12
Jan-May longline	5	-999		-999		-999		-999		-999	
Jan-May longline	6	0		0		-999		-0.4055		0	
Jun-Aug longline	1	0		0		0		0		0	
Jun-Aug longline	2	0		0		0		0		0	
Jun-Aug longline	3	5.04	0.06	4.91	0.07	5.13	0.06	5.09	0.06	5.05	0.06
Jun-Aug longline	4	0		0		0		0		0	
Jun-Aug longline	5	-999		-999		-999		-999		-999	
Jun-Aug longline	6	10		10		10		10		10	
Sep-Dec longline	1	0		0		0		0		0	
Sep-Dec longline	2	-2.13	0.35	-2.11	0.35	2.20	1.30	6.15	73.16	-2.16	0.35
Sep-Dec longline	3	0		0		0		0		0	
Sep-Dec longline	4	4.81	0.32	4.73	0.30	5.92	3.59	-0.02	220.5	4.82	0.32
Sep-Dec longline	5	-999		-999		-999		-999		-999	
Sep-Dec longline	6	0		0		-999		-0.4055		0	
Jan-May pot	1	0		0		0		0		0	
Jan-May pot	2	-8.90	24.35	-9.08	21.14	-9.51	12.73	-9.50	12.90	-8.89	24.56
Jan-May pot	3	5.08	0.07	5.03	0.07	5.01	0.07	5.06	0.07	5.08	0.07
Jan-May pot	4	4.21	0.42	4.33	0.33	7.05	0.22	5.16	0.37	4.21	0.43
Jan-May pot	5	-999		-999		-999		-999		-999	
Jan-May pot	6	0		0		-999		-0.4055		0	
Jun-Aug pot	1	0		0		0		0		0	
Jun-Aug pot	2	0		0		0		0		0	
Jun-Aug pot	3	4.88	0.18	4.77	0.23	4.92	0.19	4.90	0.19	4.88	0.18
Jun-Aug pot	4	0		0		0		0		0	
Jun-Aug pot	5	-999		-999		-999		-999		-999	
Jun-Aug pot	6	10		10		10		10		10	
Sep-Dec pot	1	0		0		0		0		0	
Sep-Dec pot	2	0		0		0		0		0	
Sep-Dec pot	3	0		0		0		0		0	
Sep-Dec pot	4	0		0		0		0		0	
Sep-Dec pot	5	-999		-999		-999		-999		-999	
Sep-Dec pot	6	10		10		10		10		10	

Table 2.17c—Base fishery selectivity parameters for models with mean size-at-age data but no age composition data. A blank under "SD" means the parameter was fixed. Fixed parameters may be over-written by block-specific values (see Tables 2.17j-2.17l). See text for parameter definitions.

		Model B2		Model C2		Model D2		Model E2		Model G2	
Fishery	Parm.	Value	SD	Value	SD	Value	SD	Value	SD	Value	SD
Jan-May trawl	1	0		0		0		0		0	
Jan-May trawl	2	0		0		0		0		0	
Jan-May trawl	3	0		0		0		0		0	
Jan-May trawl	4	0		0		0		0		0	
Jan-May trawl	5	-999		-999		-999		-999		-999	
Jan-May trawl	6	10		10		10		10		10	
Jun-Aug trawl	1	0		0		0		0		0	
Jun-Aug trawl	2	0		0		0		0		0	
Jun-Aug trawl	3	5.65	0.20	5.51	0.23	5.81	0.20	5.80	0.21	5.66	0.20
Jun-Aug trawl	4	0		0		0		0		0	
Jun-Aug trawl	5	-999		-999		-999		-999		-999	
Jun-Aug trawl	6	10		10		10		10		10	
Sep-Dec trawl	1	0		0		0		0		0	
Sep-Dec trawl	2	0		0		0		0		0	
Sep-Dec trawl	3	0		0		0		0		0	
Sep-Dec trawl	4	0		0		0		0		0	
Sep-Dec trawl	5	-999		-999		-999		-999		-999	
Sep-Dec trawl	6	10		10		10		10		10	
Jan-May longline	1	0		0		0		0		0	
Jan-May longline	2	-9.55	11.90	-9.46	13.74	-9.93	2.10	-6.15	10.70	-9.56	11.52
Jan-May longline	3	0		0		0		0		0	
Jan-May longline	4	4.86	0.11	4.91	0.10	6.41	0.06	4.63	0.15	4.86	0.12
Jan-May longline	5	-999		-999		-999		-999		-999	
Jan-May longline	6	0		0		-999		-0.4055		0	
Jun-Aug longline	1	0		0		0		0		0	
Jun-Aug longline	2	0		0		0		0		0	
Jun-Aug longline	3	5.01	0.06	4.90	0.07	5.11	0.06	5.07	0.06	5.02	0.06
Jun-Aug longline	4	0		0		0		0		0	
Jun-Aug longline	5	-999		-999		-999		-999		-999	
Jun-Aug longline	6	10		10		10		10		10	
Sep-Dec longline	1	0		0		0		0		0	
Sep-Dec longline	2	-2.10	0.34	-2.09	0.34	-8.52	30.28	2.95	65.35	-2.13	0.35
Sep-Dec longline	3	0		0		0		0		0	
Sep-Dec longline	4	4.72	0.32	4.67	0.30	8.49	0.38	0.05	242.2	4.73	0.32
Sep-Dec longline	5	-999		-999		-999		-999		-999	
Sep-Dec longline	6	0		0		-999		-0.4055		0	
Jan-May pot	1	0		0		0		0		0	
Jan-May pot	2	-8.89	24.56	-9.06	21.56	-9.55	11.93	-9.52	12.59	-8.88	24.75
Jan-May pot	3	5.07	0.07	5.03	0.07	5.00	0.07	5.05	0.07	5.07	0.07
Jan-May pot	4	4.18	0.40	4.29	0.33	6.99	0.21	5.04	0.37	4.19	0.41
Jan-May pot	5	-999		-999		-999		-999		-999	
Jan-May pot	6	0		0		-999		-0.4055		0	
Jun-Aug pot	1	0		0		0		0		0	
Jun-Aug pot	2	0		0		0		0		0	
Jun-Aug pot	3	4.87	0.19	4.76	0.23	4.91	0.19	4.88	0.18	4.87	0.19
Jun-Aug pot	4	0		0		0		0		0	
Jun-Aug pot	5	-999		-999		-999		-999		-999	
Jun-Aug pot	6	10		10		10		10		10	
Sep-Dec pot	1	0		0		0		0		0	
Sep-Dec pot	2	0		0		0		0		0	
Sep-Dec pot	3	0		0		0		0		0	
Sep-Dec pot	4	0		0		0		0		0	
Sep-Dec pot	5	-999		-999		-999		-999		-999	
Sep-Dec pot	6	10		10		10		10		10	

Table 2.17d—Block-specific values of trawl fishery selectivity parameters in models without mean size-at-age data. See text for parameter definitions. "Block" refers to first year in the time block.

			Model A1		Model A2		Model A3		Model F2	
Fishery	Parm.	Block	Value	SD	Value	SD	Value	SD	Value	SD
Jan-May trawl	1	1977	41.46	3.37	41.60	3.20	41.48	3.36	n/a	
Jan-May trawl	1	1980	68.62	3.30	67.83	3.22	68.29	3.28	n/a	
Jan-May trawl	1	1985	76.60	2.26	73.86	2.16	76.32	2.28	n/a	
Jan-May trawl	1	1990	61.55	1.48	59.06	1.85	61.00	1.53	n/a	
Jan-May trawl	1	1995	73.16	1.23	71.88	1.47	72.89	1.22	n/a	
Jan-May trawl	1	2000	76.62	1.44	77.38	1.48	76.36	1.44	n/a	
Jan-May trawl	1	2005	71.73	1.50	71.69	1.56	71.29	1.51	n/a	
Jan-May trawl	3	1977	3.08	0.98	3.05	0.94	3.08	0.97	n/a	
Jan-May trawl	3	1980	6.07	0.20	6.07	0.20	6.07	0.20	n/a	
Jan-May trawl	3	1985	6.60	0.10	6.53	0.10	6.60	0.10	n/a	
Jan-May trawl	3	1990	5.74	0.10	5.60	0.13	5.71	0.10	n/a	
Jan-May trawl	3	1995	6.28	0.06	6.23	0.07	6.27	0.06	n/a	
Jan-May trawl	3	2000	6.30	0.07	6.32	0.07	6.30	0.07	n/a	
Jan-May trawl	3	2005	6.07	0.09	6.09	0.09	6.06	0.09	n/a	
Jun-Aug trawl	1	1977	49.48	2.70	48.63	2.75	49.15	2.71	n/a	
Jun-Aug trawl	1	1985	69.38	3.77	69.18	3.76	69.10	3.78	n/a	
Jun-Aug trawl	1	1990	64.47	3.85	64.12	3.88	64.18	3.83	n/a	
Jun-Aug trawl	1	2000	66.08	2.70	66.57	2.75	65.74	2.71	n/a	
Jun-Aug trawl	1	2005	55.14	2.90	54.80	2.92	54.80	2.89	n/a	
Sep-Dec trawl	1	1977	58.11	4.30	57.79	4.23	58.03	4.29	n/a	
Sep-Dec trawl	1	1980	83.84	6.89	82.29	7.74	83.38	6.81	n/a	
Sep-Dec trawl	1	1985	85.24	6.07	82.38	4.88	85.31	6.20	n/a	
Sep-Dec trawl	1	1990	48.29	3.51	48.07	3.44	48.24	3.48	n/a	
Sep-Dec trawl	1	1995	102.50		102.50		102.50		n/a	
Sep-Dec trawl	1	2000	88.47	9.68	90.81	10.75	88.11	9.69	n/a	
Sep-Dec trawl	3	1977	5.23	0.41	5.22	0.40	5.23	0.41	n/a	
Sep-Dec trawl	3	1980	6.67	0.28	6.68	0.32	6.67	0.28	n/a	
Sep-Dec trawl	3	1985	6.32	0.31	6.22	0.28	6.33	0.31	n/a	
Sep-Dec trawl	3	1990	4.25	0.69	4.28	0.68	4.25	0.68	n/a	
Sep-Dec trawl	3	1995	7.05	0.13	7.07	0.13	7.06	0.13	n/a	
Sep-Dec trawl	3	2000	6.85	0.35	6.91	0.36	6.85	0.35	n/a	

Table 2.17e—Block-specific values of longline fishery selectivity parameters in models without mean size-at-age data. See text for parameter definitions. "Block" refers to first year in the time block.

			Model A1		Model A2		Model A3		Model F2	
Fishery	Parm.	Block	Value	SD	Value	SD	Value	SD	Value	SD
Jan-May longline	1	1977	55.87	2.13	54.80	2.29	55.83	2.12	n/a	
Jan-May longline	1	1980	69.95	3.24	68.78	3.11	69.71	3.29	n/a	
Jan-May longline	1	1985	74.30	1.04	73.34	1.06	74.27	1.06	n/a	
Jan-May longline	1	1990	66.12	0.59	65.76	0.60	65.98	0.59	n/a	
Jan-May longline	1	1995	65.78	0.47	65.43	0.48	65.75	0.47	n/a	
Jan-May longline	1	2000	62.92	0.45	63.28	0.47	62.88	0.45	n/a	
Jan-May longline	1	2005	65.94	0.50	65.76	0.48	65.84	0.47	n/a	
Jan-May longline	3	1977	4.79	0.25	4.67	0.27	4.79	0.25	n/a	
Jan-May longline	3	1980	5.76	0.24	5.72	0.24	5.75	0.25	n/a	
Jan-May longline	3	1985	5.76	0.08	5.74	0.08	5.77	0.08	n/a	
Jan-May longline	3	1990	5.17	0.06	5.16	0.06	5.16	0.06	n/a	
Jan-May longline	3	1995	5.27	0.04	5.25	0.05	5.28	0.04	n/a	
Jan-May longline	3	2000	5.30	0.05	5.33	0.05	5.30	0.05	n/a	
Jan-May longline	3	2005	5.25	0.05	5.25	0.05	5.24	0.05	n/a	
Jan-May longline	6	1977	-1.57	0.78	-1.43	0.75	-1.54	0.76	n/a	
Jan-May longline	6	1980	0.61	1.25	0.76	1.22	0.63	1.23	n/a	
Jan-May longline	6	1985	-1.06	0.45	-0.99	0.41	-0.98	0.44	n/a	
Jan-May longline	6	1990	-0.14	0.16	-0.26	0.15	-0.13	0.16	n/a	
Jan-May longline	6	1995	-0.64	0.16	-0.68	0.15	-0.63	0.16	n/a	
Jan-May longline	6	2000	-1.13	0.16	-1.05	0.16	-1.11	0.15	n/a	
Jan-May longline	6	2005	-1.36	0.19	-1.11	0.16	-1.22	0.16	n/a	
Jun-Aug longline	1	1977	62.11	2.06	61.94	2.04	61.93	2.06	n/a	
Jun-Aug longline	1	1980	64.71	1.69	64.08	1.74	64.45	1.71	n/a	
Jun-Aug longline	1	1985	66.84	2.12	66.13	2.20	66.66	2.13	n/a	
Jun-Aug longline	1	1990	66.03	0.71	65.49	0.74	65.81	0.72	n/a	
Jun-Aug longline	1	2000	61.62	0.64	61.70	0.67	61.41	0.64	n/a	
Jun-Aug longline	1	2005	64.30	0.67	64.09	0.69	64.04	0.67	n/a	
Sep-Dec longline	1	1977	59.21	3.20	58.53	3.29	59.15	3.20	n/a	
Sep-Dec longline	1	1980	68.72	1.92	67.36	1.67	68.50	1.93	n/a	
Sep-Dec longline	1	1985	65.94	0.86	64.92	0.94	65.82	0.88	n/a	
Sep-Dec longline	1	1990	67.63	0.89	67.00	0.94	67.48	0.92	n/a	
Sep-Dec longline	1	1995	69.78	0.91	68.93	0.93	69.59	0.91	n/a	
Sep-Dec longline	1	2000	63.52	0.57	63.74	0.61	63.36	0.57	n/a	
Sep-Dec longline	1	2005	61.25	0.69	61.03	0.72	60.94	0.70	n/a	
Sep-Dec longline	3	1977	4.22	0.52	4.10	0.56	4.21	0.53	n/a	
Sep-Dec longline	3	1980	5.29	0.17	5.21	0.16	5.27	0.17	n/a	
Sep-Dec longline	3	1985	4.99	0.09	4.91	0.10	4.98	0.09	n/a	
Sep-Dec longline	3	1990	5.03	0.09	5.00	0.10	5.02	0.10	n/a	
Sep-Dec longline	3	1995	5.51	0.07	5.46	0.07	5.50	0.07	n/a	
Sep-Dec longline	3	2000	5.17	0.06	5.19	0.06	5.16	0.06	n/a	
Sep-Dec longline	3	2005	4.88	0.08	4.87	0.08	4.85	0.08	n/a	
Sep-Dec longline	6	1977	-3.03	3.16	-2.80	2.81	-2.98	3.03	n/a	
Sep-Dec longline	6	1980	0.48	0.84	0.48	0.72	0.50	0.82	n/a	
Sep-Dec longline	6	1985	-0.10	0.30	-0.23	0.28	-0.07	0.29	n/a	
Sep-Dec longline	6	1990	2.05	0.88	1.54	0.57	2.08	0.89	n/a	
Sep-Dec longline	6	1995	10.00		10.00		10.00		n/a	
Sep-Dec longline	6	2000	-0.52	0.22	-0.39	0.23	-0.51	0.22	n/a	
Sep-Dec longline	6	2005	10.00		10.00		10.00		n/a	

Table 2.17f—Block-specific values of pot fishery selectivity parameters in models without mean size-at-age data. See text for parameter definitions. "Block" refers to first year in the time block.

			Model A1		Model A2		Model A3		Model F2	
Fishery	Parm.	Block	Value	SD	Value	SD	Value	SD	Value	SD
Jan-May pot	1	1977	69.62	1.01	69.30	0.98	69.49	0.99	n/a	
Jan-May pot	1	1995	68.09	0.74	67.85	0.73	68.01	0.73	n/a	
Jan-May pot	1	2000	67.87	0.76	67.97	0.76	67.76	0.75	n/a	
Jan-May pot	1	2005	67.54	0.81	67.30	0.82	67.41	0.82	n/a	
Jan-May pot	6	1977	-0.10	0.45	-0.19	0.42	-0.08	0.44	n/a	
Jan-May pot	6	1995	0.52	0.33	0.40	0.31	0.51	0.33	n/a	
Jan-May pot	6	2000	-0.69	0.35	-0.65	0.35	-0.69	0.34	n/a	
Jan-May pot	6	2005	0.49	0.36	0.59	0.38	0.46	0.36	n/a	
Jun-Aug pot	1	1977	63.44	1.60	62.86	1.58	63.30	1.60	n/a	
Jun-Aug pot	1	1995	67.64	1.72	67.23	1.74	67.53	1.72	n/a	
Sep-Dec pot	1	1977	70.22	2.13	69.60	2.11	70.08	2.14	n/a	
Sep-Dec pot	1	2000	60.32	1.19	60.35	1.21	60.16	1.20	n/a	
Sep-Dec pot	3	1977	5.26	0.20	5.23	0.21	5.26	0.21	n/a	
Sep-Dec pot	3	2000	4.35	0.20	4.35	0.21	4.33	0.21	n/a	

Table 2.17g—Block-specific values of trawl fishery selectivity parameters in models with mean size-at-age data and age composition data. See text for parm. definitions. "Block" refers to 1st year in the block.

			Model B1		Model C1		Model D1		Model E1		Model G1	
Fishery	Parm.	Block	Value	SD	Value	SD	Value	SD	Value	SD	Value	SD
Jan-May trawl	1	1977	41.47	3.83	41.53	3.85	41.44	4.18	31.76	3.52	41.44	3.82
Jan-May trawl	1	1980	68.99	3.34	66.64	3.66	73.89	3.52	73.09	3.45	69.10	3.35
Jan-May trawl	1	1985	74.80	1.98	70.82	2.51	77.99	1.84	78.11	1.88	74.96	1.99
Jan-May trawl	1	1990	61.88	1.38	57.01	1.13	64.40	1.80	62.02	1.36	62.08	1.36
Jan-May trawl	1	1995	73.09	1.17	68.36	1.20	75.57	1.21	74.69	1.17	73.52	1.17
Jan-May trawl	1	2000	77.39	1.39	74.25	1.26	81.81	1.56	81.13	1.54	77.55	1.36
Jan-May trawl	1	2005	73.26	1.47	71.38	1.53	74.67	1.56	74.06	1.55	73.69	1.47
Jan-May trawl	3	1977	3.09	1.05	3.12	1.06	3.08	1.10	-4.45	63.13	3.08	1.05
Jan-May trawl	3	1980	6.12	0.20	6.07	0.23	6.25	0.19	6.23	0.19	6.13	0.20
Jan-May trawl	3	1985	6.58	0.10	6.46	0.14	6.68	0.09	6.70	0.09	6.58	0.10
Jan-May trawl	3	1990	5.79	0.10	5.50	0.09	5.93	0.11	5.80	0.09	5.79	0.09
Jan-May trawl	3	1995	6.27	0.06	6.11	0.07	6.32	0.06	6.30	0.06	6.29	0.06
Jan-May trawl	3	2000	6.32	0.07	6.24	0.07	6.42	0.07	6.41	0.07	6.32	0.07
Jan-May trawl	3	2005	6.13	0.09	6.09	0.10	6.17	0.09	6.16	0.09	6.13	0.09
Jun-Aug trawl	1	1977	49.51	2.69	47.03	2.77	52.89	2.76	52.45	2.80	49.67	2.67
Jun-Aug trawl	1	1985	69.38	3.70	66.49	3.78	72.67	3.61	72.51	3.68	69.74	3.66
Jun-Aug trawl	1	1990	64.94	3.88	62.17	3.83	67.98	3.94	67.44	3.99	65.28	3.88
Jun-Aug trawl	1	2000	66.77	2.69	64.03	2.72	70.61	2.91	69.90	2.94	67.16	2.66
Jun-Aug trawl	1	2005	55.67	2.95	53.17	2.92	58.38	2.86	57.78	2.86	56.50	2.93
Sep-Dec trawl	1	1977	58.07	4.49	57.73	4.36	59.30	4.93	59.12	4.92	58.09	4.48
Sep-Dec trawl	1	1980	84.18	7.31	80.95	8.22	93.40	9.01	92.04	8.69	84.35	7.38
Sep-Dec trawl	1	1985	81.28	4.50	78.74	4.51	86.02	6.17	86.64	6.26	81.33	4.46
Sep-Dec trawl	1	1990	49.21	3.83	48.64	3.65	49.14	3.76	49.03	3.74	49.06	3.87
Sep-Dec trawl	1	1995	102.50		102.50		102.50		102.50		102.50	
Sep-Dec trawl	1	2000	89.86	9.86	82.53	9.58	99.70	11.96	99.07	12.00	90.14	9.81
Sep-Dec trawl	3	1977	5.21	0.42	5.23	0.42	5.21	0.44	5.22	0.44	5.21	0.42
Sep-Dec trawl	3	1980	6.68	0.29	6.64	0.35	6.85	0.28	6.83	0.28	6.69	0.29
Sep-Dec trawl	3	1985	6.16	0.27	6.08	0.29	6.36	0.30	6.39	0.30	6.15	0.27
Sep-Dec trawl	3	1990	4.41	0.70	4.39	0.69	4.36	0.71	4.38	0.70	4.43	0.70
Sep-Dec trawl	3	1995	7.04	0.13	7.15	0.14	6.98	0.12	6.99	0.12	7.04	0.13
Sep-Dec trawl	3	2000	6.86	0.34	6.67	0.41	7.06	0.33	7.06	0.33	6.86	0.34

Table 2.17h—Block-specific values of longline fishery selectivity parameters in models with mean size-at-age data and age compositions. See text for parm. definitions. "Block" refers to 1st year in the block.

			Model B1		Model C1		Model D1		Model E1		Model G1	
Fishery	Parm.	Block	Value	SD	Value	SD	Value	SD	Value	SD	Value	SD
Jan-May longline	1	1977	56.18	2.10	55.90	2.06	54.64	2.40	56.51	2.20	56.22	2.10
Jan-May longline	1	1980	69.14	3.28	67.33	3.46	74.70	2.96	75.34	2.71	69.22	3.28
Jan-May longline	1	1985	72.77	0.94	71.31	0.97	72.97	1.01	74.53	0.94	72.76	0.93
Jan-May longline	1	1990	65.96	0.55	64.56	0.52	66.47	0.57	66.50	0.54	66.01	0.55
Jan-May longline	1	1995	65.66	0.45	64.46	0.41	65.27	0.46	66.34	0.48	65.77	0.45
Jan-May longline	1	2000	63.50	0.44	62.64	0.40	62.72	0.43	64.02	0.51	63.60	0.44
Jan-May longline	1	2005	66.97	0.50	66.17	0.49	65.31	0.52	66.90	0.54	67.21	0.50
Jan-May longline	3	1977	4.79	0.25	4.79	0.25	4.60	0.29	4.80	0.25	4.79	0.25
Jan-May longline	3	1980	5.71	0.25	5.65	0.29	5.94	0.20	6.00	0.18	5.71	0.25
Jan-May longline	3	1985	5.68	0.08	5.63	0.09	5.68	0.08	5.77	0.08	5.67	0.08
Jan-May longline	3	1990	5.16	0.06	5.09	0.06	5.21	0.06	5.20	0.06	5.16	0.06
Jan-May longline	3	1995	5.25	0.04	5.19	0.04	5.19	0.05	5.28	0.04	5.26	0.04
Jan-May longline	3	2000	5.33	0.04	5.29	0.04	5.24	0.05	5.36	0.05	5.33	0.04
Jan-May longline	3	2005	5.33	0.05	5.30	0.05	5.18	0.06	5.32	0.05	5.33	0.05
Jan-May longline	6	1977	-1.56	0.79	-1.69	0.78					-1.55	0.79
Jan-May longline	6	1980	1.04	1.52	1.04	1.43					1.05	1.53
Jan-May longline	6	1985	-0.91	0.38	-0.77	0.34					-0.92	0.38
Jan-May longline	6	1990	-0.27	0.15	-0.47	0.14					-0.27	0.15
Jan-May longline	6	1995	-0.73	0.16	-1.05	0.14					-0.70	0.16
Jan-May longline	6	2000	-1.14	0.16	-1.42	0.15					-1.13	0.16
Jan-May longline	6	2005	-1.00	0.19	-1.09	0.18					-0.97	0.19
Jun-Aug longline	1	1977	62.54	1.93	61.19	2.04	64.35	2.00	63.88	1.99	62.65	1.93
Jun-Aug longline	1	1980	64.84	1.67	62.82	1.69	67.56	1.58	66.87	1.58	64.96	1.67
Jun-Aug longline	1	1985	66.50	2.13	64.67	2.14	68.33	2.20	67.89	2.18	66.57	2.13
Jun-Aug longline	1	1990	66.14	0.67	64.09	0.65	67.48	0.67	66.76	0.66	66.26	0.66
Jun-Aug longline	1	2000	62.14	0.61	60.48	0.60	63.74	0.63	63.19	0.62	62.34	0.60
Jun-Aug longline	1	2005	64.98	0.65	63.23	0.63	66.29	0.65	65.70	0.65	65.38	0.65
Sep-Dec longline	1	1977	60.04	3.04	59.80	3.01	58.08	4.53	57.88	4.55	60.10	3.03
Sep-Dec longline	1	1980	67.56	1.86	66.01	1.77	71.40	1.89	70.67	1.93	67.61	1.88
Sep-Dec longline	1	1985	65.22	0.78	63.83	0.79	63.10	0.87	63.17	0.87	65.30	0.77
Sep-Dec longline	1	1990	67.74	0.86	66.33	0.87	68.03	0.88	67.47	0.91	67.76	0.85
Sep-Dec longline	1	1995	69.12	0.83	66.90	0.73	71.43	0.83	70.82	0.83	69.30	0.83
Sep-Dec longline	1	2000	64.44	0.57	63.27	0.54	64.47	0.58	63.96	0.56	64.61	0.57
Sep-Dec longline	1	2005	62.51	0.71	61.13	0.67	63.61	0.84	63.00	0.81	63.13	0.78
Sep-Dec longline	3	1977	4.33	0.47	4.33	0.48	4.08	0.72	4.07	0.73	4.34	0.47
Sep-Dec longline	3	1980	5.22	0.18	5.13	0.18	5.45	0.15	5.41	0.16	5.22	0.18
Sep-Dec longline	3	1985	4.91	0.09	4.80	0.10	4.69	0.12	4.70	0.11	4.91	0.09
Sep-Dec longline	3	1990	5.04	0.09	4.96	0.10	5.06	0.09	5.03	0.10	5.04	0.09
Sep-Dec longline	3	1995	5.45	0.07	5.33	0.07	5.55	0.06	5.52	0.06	5.46	0.07
Sep-Dec longline	3	2000	5.23	0.05	5.16	0.05	5.22	0.05	5.19	0.05	5.24	0.05
Sep-Dec longline	3	2005	5.01	0.08	4.92	0.08	5.09	0.08	5.05	0.08	5.04	0.08
Sep-Dec longline	6	1977	-2.69	2.38	-2.65	2.19					-2.70	2.40
Sep-Dec longline	6	1980	1.32	1.03	1.33	0.89					1.31	1.03
Sep-Dec longline	6	1985	-0.20	0.22	-0.20	0.20					-0.22	0.22
Sep-Dec longline	6	1990	1.51	0.52	1.12	0.36					1.48	0.51
Sep-Dec longline	6	1995	4.07	5.09	1.41	0.39					7.73	40.56
Sep-Dec longline	6	2000	-0.37	0.20	-0.60	0.17					-0.36	0.20
Sep-Dec longline	6	2005	9.79	6.15	9.60	10.72					9.81	5.57

Table 2.17i—Block-specific values of pot fishery selectivity parameters in models with mean size-at-age data and age composition data. See text for parm. definitions. "Block" refers to 1st year in the block.

			Model B1		Model C1		Model D1		Model E1		Model G1	
Fishery	Parm.	Block	Value	SD	Value	SD	Value	SD	Value	SD	Value	SD
Jan-May pot	1	1977	69.44	0.96	68.27	0.92	68.20	0.88	68.84	0.91	69.51	0.98
Jan-May pot	1	1995	68.06	0.71	67.07	0.69	67.67	0.66	68.30	0.72	68.14	0.72
Jan-May pot	1	2000	68.14	0.74	67.29	0.71	67.45	0.72	68.01	0.73	68.20	0.74
Jan-May pot	1	2005	67.63	0.81	66.75	0.80	67.32	0.78	67.89	0.81	67.86	0.82
Jan-May pot	6	1977	-0.23	0.42	-0.43	0.38					-0.24	0.42
Jan-May pot	6	1995	0.34	0.31	-0.09	0.25					0.39	0.31
Jan-May pot	6	2000	-0.76	0.35	-1.04	0.32					-0.75	0.35
Jan-May pot	6	2005	0.71	0.42	0.49	0.36					0.80	0.45
Jun-Aug pot	1	1977	63.25	1.55	61.56	1.78	63.91	1.64	63.37	1.57	63.33	1.54
Jun-Aug pot	1	1995	67.53	1.69	65.70	1.92	68.49	1.81	68.07	1.75	67.69	1.70
Sep-Dec pot	1	1977	69.83	2.07	67.84	1.88	71.18	2.09	70.58	2.08	69.97	2.07
Sep-Dec pot	1	2000	60.91	1.19	59.99	1.17	61.71	1.19	61.44	1.20	61.15	1.18
Sep-Dec pot	3	1977	5.23	0.20	5.13	0.21	5.29	0.19	5.26	0.20	5.24	0.20
Sep-Dec pot	3	2000	4.41	0.20	4.33	0.21	4.48	0.19	4.46	0.19	4.43	0.20

Table 2.17j—Block-specific values of trawl fishery selectivity parameters in models with mean size-at-age data but no age compositions. See text for parm. definitions. "Block" refers to 1st year in the block.

			Model B2		Model C2		Model D2		Model E2		Model G2	
Fishery	Parm.	Block	Value	SD	Value	SD	Value	SD	Value	SD	Value	SD
Jan-May trawl	1	1977	41.49	3.71	41.54	3.71	41.47	4.04	41.46	3.61	41.49	3.73
Jan-May trawl	1	1980	68.34	3.31	66.17	3.69	72.59	3.34	72.52	3.42	68.45	3.32
Jan-May trawl	1	1985	74.14	1.97	70.00	2.56	76.82	2.17	77.54	1.87	74.34	1.97
Jan-May trawl	1	1990	61.25	1.41	56.95	1.13	63.97	1.80	61.08	1.40	61.24	1.40
Jan-May trawl	1	1995	72.25	1.36	67.72	1.19	74.69	1.21	73.74	1.15	72.63	1.14
Jan-May trawl	1	2000	76.83	1.38	74.05	1.26	80.76	1.55	80.49	1.53	76.93	1.37
Jan-May trawl	1	2005	73.01	1.48	71.31	1.56	74.36	1.57	73.65	1.57	73.26	1.48
Jan-May trawl	3	1977	3.09	1.03	3.10	1.03	3.09	1.08	3.04	1.01	3.09	1.04
Jan-May trawl	3	1980	6.11	0.21	6.06	0.24	6.22	0.19	6.23	0.19	6.12	0.21
Jan-May trawl	3	1985	6.57	0.10	6.43	0.14	6.65	0.10	6.70	0.09	6.57	0.10
Jan-May trawl	3	1990	5.75	0.10	5.50	0.10	5.90	0.11	5.75	0.10	5.75	0.10
Jan-May trawl	3	1995	6.25	0.07	6.09	0.07	6.30	0.06	6.28	0.06	6.27	0.06
Jan-May trawl	3	2000	6.31	0.07	6.24	0.07	6.39	0.07	6.40	0.07	6.30	0.07
Jan-May trawl	3	2005	6.14	0.09	6.10	0.10	6.17	0.09	6.17	0.09	6.14	0.09
Jun-Aug trawl	1	1977	48.80	2.67	46.50	2.79	51.83	2.91	51.56	2.90	48.90	2.65
Jun-Aug trawl	1	1985	68.75	3.68	66.05	3.82	71.47	3.98	71.67	3.98	68.98	3.64
Jun-Aug trawl	1	1990	64.14	3.83	61.69	3.82	66.86	4.03	66.45	4.06	64.32	3.83
Jun-Aug trawl	1	2000	66.09	2.69	63.65	2.73	69.48	3.10	68.99	3.10	66.36	2.66
Jun-Aug trawl	1	2005	54.74	2.94	52.51	2.92	57.36	3.13	56.59	3.12	55.37	2.92
Sep-Dec trawl	1	1977	57.93	4.45	57.68	4.33	58.79	4.79	58.72	4.75	57.96	4.45
Sep-Dec trawl	1	1980	83.51	7.27	80.60	8.52	90.79	8.31	91.41	8.76	83.65	7.30
Sep-Dec trawl	1	1985	80.90	4.55	78.45	4.56	84.15	6.03	86.28	6.48	80.94	4.50
Sep-Dec trawl	1	1990	49.16	3.86	48.59	3.67	49.17	3.77	48.96	3.76	48.89	3.85
Sep-Dec trawl	1	1995	102.50		102.50		102.50		102.50		102.50	
Sep-Dec trawl	1	2000	88.96	9.82	81.93	12.93	97.37	11.88	98.40	12.06	89.03	9.70
Sep-Dec trawl	3	1977	5.22	0.42	5.23	0.42	5.21	0.44	5.21	0.43	5.22	0.42
Sep-Dec trawl	3	1980	6.68	0.29	6.64	0.36	6.80	0.28	6.83	0.29	6.68	0.30
Sep-Dec trawl	3	1985	6.15	0.27	6.07	0.30	6.29	0.32	6.39	0.32	6.14	0.27
Sep-Dec trawl	3	1990	4.43	0.70	4.41	0.69	4.38	0.70	4.40	0.70	4.43	0.69
Sep-Dec trawl	3	1995	7.07	0.13	7.16	0.14	7.00	0.12	7.01	0.12	7.06	0.13
Sep-Dec trawl	3	2000	6.85	0.35	6.65	0.55	7.02	0.34	7.07	0.34	6.84	0.35

Table 2.17k—Block-specific values of longline fishery selectivity parameters in models with mean size-at-age data but no age compositions. See text for parm. definitions. "Block" refers to 1st year in block.

			Model B2		Model C2		Model D2		Model E2		Model G2	
Fishery	Parm.	Block	Value	SD	Value	SD	Value	SD	Value	SD	Value	SD
Jan-May longline	1	1977	56.16	2.09	55.86	2.07	53.97	2.38	55.87	2.21	56.21	2.09
Jan-May longline	1	1980	68.57	3.38	66.71	3.89	73.59	2.81	74.98	2.66	68.67	3.37
Jan-May longline	1	1985	72.49	0.96	71.04	0.98	72.36	1.06	74.36	0.94	72.48	0.96
Jan-May longline	1	1990	65.78	0.54	64.53	0.51	66.45	0.56	66.24	0.54	65.77	0.54
Jan-May longline	1	1995	65.47	0.45	64.37	0.41	64.98	0.46	66.11	0.47	65.57	0.45
Jan-May longline	1	2000	63.44	0.43	62.67	0.40	62.46	0.45	63.92	0.50	63.53	0.43
Jan-May longline	1	2005	67.05	0.47	66.31	0.45	65.70	0.50	67.05	0.50	67.20	0.46
Jan-May longline	3	1977	4.80	0.25	4.79	0.25	4.56	0.30	4.75	0.26	4.81	0.25
Jan-May longline	3	1980	5.69	0.27	5.63	0.32	5.91	0.20	6.00	0.18	5.70	0.27
Jan-May longline	3	1985	5.67	0.08	5.62	0.09	5.65	0.09	5.78	0.08	5.66	0.08
Jan-May longline	3	1990	5.15	0.06	5.08	0.06	5.20	0.06	5.19	0.06	5.15	0.06
Jan-May longline	3	1995	5.25	0.04	5.20	0.04	5.18	0.05	5.27	0.05	5.26	0.04
Jan-May longline	3	2000	5.34	0.04	5.29	0.04	5.22	0.05	5.36	0.05	5.34	0.04
Jan-May longline	3	2005	5.34	0.05	5.31	0.05	5.20	0.05	5.34	0.05	5.33	0.05
Jan-May longline	6	1977	-1.52	0.75	-1.61	0.75					-1.52	0.75
Jan-May longline	6	1980	1.11	1.51	1.25	1.64					1.10	1.51
Jan-May longline	6	1985	-0.78	0.35	-0.65	0.32					-0.79	0.35
Jan-May longline	6	1990	-0.24	0.15	-0.42	0.13					-0.25	0.15
Jan-May longline	6	1995	-0.71	0.15	-0.99	0.13					-0.69	0.15
Jan-May longline	6	2000	-1.12	0.15	-1.37	0.14					-1.12	0.15
Jan-May longline	6	2005	-0.86	0.16	-0.94	0.15					-0.84	0.16
Jun-Aug longline	1	1977	62.22	2.07	61.08	2.04	63.75	1.99	63.40	1.96	62.29	2.07
Jun-Aug longline	1	1980	64.33	1.69	62.55	1.69	66.86	1.60	66.36	1.60	64.42	1.69
Jun-Aug longline	1	1985	66.11	2.14	64.43	2.15	67.81	2.20	67.44	2.11	66.15	2.14
Jun-Aug longline	1	1990	65.79	0.67	63.95	0.65	67.18	0.67	66.29	0.66	65.82	0.66
Jun-Aug longline	1	2000	61.82	0.61	60.33	0.60	63.37	0.63	62.80	0.61	61.97	0.61
Jun-Aug longline	1	2005	64.56	0.65	63.01	0.63	65.90	0.66	65.12	0.65	64.81	0.65
Sep-Dec longline	1	1977	60.00	3.04	59.82	3.01	57.20	3.62	57.11	3.78	60.07	3.02
Sep-Dec longline	1	1980	67.00	1.73	65.52	1.81	70.58	1.87	70.02	1.96	67.08	1.73
Sep-Dec longline	1	1985	64.92	0.79	63.58	0.79	62.85	0.82	62.80	0.84	65.02	0.78
Sep-Dec longline	1	1990	67.51	0.86	66.23	0.88	68.17	0.88	67.13	0.92	67.47	0.88
Sep-Dec longline	1	1995	68.49	0.82	66.45	0.74	71.14	0.82	70.06	0.83	68.63	0.82
Sep-Dec longline	1	2000	64.19	0.57	63.16	0.54	64.12	0.56	63.63	0.55	64.35	0.57
Sep-Dec longline	1	2005	62.16	0.67	60.94	0.68	64.50	0.96	62.36	0.67	62.39	0.65
Sep-Dec longline	3	1977	4.34	0.48	4.33	0.48	3.96	0.64	3.95	0.66	4.34	0.47
Sep-Dec longline	3	1980	5.18	0.17	5.10	0.18	5.41	0.16	5.37	0.17	5.19	0.17
Sep-Dec longline	3	1985	4.89	0.09	4.77	0.10	4.66	0.11	4.67	0.11	4.89	0.09
Sep-Dec longline	3	1990	5.03	0.09	4.96	0.10	5.06	0.09	5.01	0.10	5.02	0.10
Sep-Dec longline	3	1995	5.42	0.07	5.31	0.07	5.55	0.06	5.49	0.06	5.43	0.07
Sep-Dec longline	3	2000	5.22	0.05	5.15	0.06	5.19	0.05	5.17	0.05	5.23	0.05
Sep-Dec longline	3	2005	5.00	0.08	4.91	0.08	5.18	0.09	5.01	0.07	5.00	0.07
Sep-Dec longline	6	1977	-2.56	2.18	-2.52	2.06					-2.58	2.20
Sep-Dec longline	6	1980	1.42	1.02	1.47	0.93					1.41	1.02
Sep-Dec longline	6	1985	-0.16	0.21	-0.17	0.19					-0.18	0.21
Sep-Dec longline	6	1990	1.58	0.54	1.22	0.38					1.53	0.52
Sep-Dec longline	6	1995	3.72	3.44	1.50	0.41					4.40	6.65
Sep-Dec longline	6	2000	-0.34	0.18	-0.55	0.16					-0.34	0.19
Sep-Dec longline	6	2005	9.78	6.30	9.61	10.39					9.80	5.80

Table 2.17l—Block-specific values of pot fishery selectivity parameters in models with mean size-at-age data but no age composition data. See text for parm. definitions. "Block" refers to 1st year in the block.

			Model B2		Model C2		Model D2		Model E2		Model G2	
Fishery	Parm.	Block	Value	SD	Value	SD	Value	SD	Value	SD	Value	SD
Jan-May pot	1	1977	69.28	0.95	68.22	0.92	68.11	0.88	68.69	0.91	69.30	0.95
Jan-May pot	1	1995	67.83	0.71	66.92	0.69	67.41	0.68	68.09	0.72	67.90	0.70
Jan-May pot	1	2000	67.98	0.73	67.21	0.71	67.17	0.72	67.86	0.73	68.02	0.73
Jan-May pot	1	2005	67.37	0.81	66.58	0.81	67.09	0.79	67.60	0.81	67.51	0.81
Jan-May pot	6	1977	-0.21	0.42	-0.38	0.38					-0.23	0.41
Jan-May pot	6	1995	0.33	0.30	-0.05	0.24					0.35	0.30
Jan-May pot	6	2000	-0.77	0.34	-1.02	0.31					-0.77	0.34
Jan-May pot	6	2005	0.70	0.41	0.53	0.37					0.76	0.43
Jun-Aug pot	1	1977	63.05	1.56	61.47	1.79	63.76	1.62	63.09	1.54	63.07	1.55
Jun-Aug pot	1	1995	67.25	1.74	65.52	1.92	68.19	1.78	67.73	1.70	67.37	1.74
Sep-Dec pot	1	1977	69.47	2.06	67.70	1.87	70.81	2.09	70.14	2.08	69.55	2.07
Sep-Dec pot	1	2000	60.67	1.19	59.85	1.17	61.48	1.20	61.14	1.20	60.83	1.19
Sep-Dec pot	3	1977	5.22	0.21	5.13	0.21	5.28	0.20	5.25	0.20	5.22	0.21
Sep-Dec pot	3	2000	4.39	0.20	4.32	0.21	4.46	0.19	4.44	0.20	4.40	0.20

Table 2.17m—Base survey selectivity parameters for models without mean size-at-age data. A blank under "SD" means the parameter was fixed. Parameters may be adjusted by selectivity "devs" (see Table 2.17p). See text for parameter definitions. Note that Model F2 assumes size-based selectivity rather than age-based.

		Model A1		Model A2		Model A3		Model F2	
Survey	Parm.	Value	SD	Value	SD	Value	SD	Value	SD
Pre-1982 trawl survey	1	1.27	0.29	1.26	0.26	1.27	0.28	60	_
Pre-1982 trawl survey	2	-2.62	0.63	-2.72	0.79	-2.62	0.63	0	_
Pre-1982 trawl survey	3	-3.67	2.48	-3.71	2.31	-3.67	2.43	0	_
Pre-1982 trawl survey	4	-0.11	2.10	0.04	2.15	-0.14	2.12	0	_
Pre-1982 trawl survey	5	-999	_	-999	_	-999	_	0	_
Pre-1982 trawl survey	6	-2.52	1.33	-2.55	1.39	-2.57	1.34	0	_
Post-1981 trawl survey	1	1.09	0.01	1.10	0.02	1.09	0.01	30.99	0.70
Post-1981 trawl survey	2	-1.73	0.27	-4.85	3.55	-1.82	0.29	0	_
Post-1981 trawl survey	3	-4.79	0.41	-4.76	0.44	-4.79	0.41	4.26	0.40
Post-1981 trawl survey	4	2.81	0.51	2.20	0.46	2.87	0.49	0	_
Post-1981 trawl survey	5	-999	_	-999	_	-999	_	-1.49	0.16
Post-1981 trawl survey	6	-2.50	1.21	-0.85	0.23	-2.65	1.29	10	_
IPHC longline survey	1	71.44	2.56	71.61	2.62	71.31	2.58	76.34	3.12
IPHC longline survey	2	0	_	0	_	0	_	0	_
IPHC longline survey	3	4.92	0.29	4.95	0.29	4.92	0.29	5.21	0.27
IPHC longline survey	4	0	_	0	_	0	_	0	_
IPHC longline survey	5	-999	_	-999	_	-999	_	-10	_
IPHC longline survey	6	10	_	10	_	10	_	10	_

Table 2.17n—Base survey selectivity parameters for models with mean size-at-age data and age composition data. A blank under "SD" means the parameter was fixed. Fixed parameters may be adjusted by selectivity "devs" (see Table 2.17q). See text for parameter definitions.

		Model B1		Model C1		Model D1		Model E1		Model G1	
Survey	Parm.	Value	SD	Value	SD	Value	SD	Value	SD	Value	SD
Pre-1982 trawl survey	1	1.18	2.67	1.12	2.05	1.14	2.12	1.15	2.30	1.17	2.56
Pre-1982 trawl survey	2	-2.22	2.90	-2.08	1.43	-2.93	2.58	-2.18	2.10	-2.21	2.57
Pre-1982 trawl survey	3	-4.20	35.10	-5.23	51.91	-5.02	46.13	-4.74	41.54	-4.34	36.78
Pre-1982 trawl survey	4	-4.08	101.5	-5.46	27.81	2.13	0.92	-4.00	104.5	-4.22	99.45
Pre-1982 trawl survey	5	-13.7	83.11	-13.5	85.24	-13.7	83.44	-13.7	83.01	-13.7	83.20
Pre-1982 trawl survey	6	-2.08	0.74	-2.20	0.76	-999		-0.41		-2.04	0.75
Post-1981 trawl survey	1	1.32	0.09	1.31	0.09	1.29	0.07	1.32	0.09	1.75	0.33
Post-1981 trawl survey	2	-4.01	1.18	-4.36	1.59	-13.4	86.83	-3.50	0.57	-10.6	117.5
Post-1981 trawl survey	3	-2.05	0.58	-2.05	0.58	-2.19	0.55	-2.02	0.58	-0.38	0.93
Post-1981 trawl survey	4	2.31	0.37	2.47	0.32	4.00	0.10	2.28	0.25	2.25	0.36
Post-1981 trawl survey	5	-4.98	0.28	-5.30	0.38	-4.65	0.22	-4.81	0.25	-4.70	0.21
Post-1981 trawl survey	6	-0.67	0.20	-1.11	0.22	-999		-0.41		-0.60	0.20
IPHC longline survey	1	73.19	3.50	71.35	2.74	74.82	3.49	73.97	3.56	74.20	3.42
IPHC longline survey	2	0		0		0		0		0	
IPHC longline survey	3	5.10	0.34	5.01	0.30	5.21	0.32	5.156	0.335	5.152	0.32
IPHC longline survey	4	0		0		0		0		0	
IPHC longline survey	5	-999		-999		-999		-999		-999	
IPHC longline survey	6	10		10		10		10		10	

Table 2.17o—Base survey selectivity parameters for models with mean size-at-age data but no age composition data. A blank under "SD" means the parameter was fixed. Fixed parameters may be adjusted by selectivity "devs" (see Table 2.17r). See text for parameter definitions.

		Model B2		Model C2		Model D2		Model E2		Model G2	
Survey	Parm.	Value	SD	Value	SD	Value	SD	Value	SD	Value	SD
Pre-1982 trawl survey	1	1.24	3.10	1.14	2.37	1.15	2.30	1.17	2.50	1.22	2.97
Pre-1982 trawl survey	2	-2.94	3.69	-2.19	2.54	-3.04	2.90	-2.15	1.36	-2.89	3.37
Pre-1982 trawl survey	3	-3.63	28.94	-4.83	46.80	-4.76	42.37	-4.38	36.10	-3.79	30.43
Pre-1982 trawl survey	4	0.35	1.86	-4.20	99.90	1.91	0.58	-9.43	6.96	0.33	2.01
Pre-1982 trawl survey	5	-13.7	83.01	-13.5	85.03	-13.7	83.35	-13.8	82.59	-13.7	83.07
Pre-1982 trawl survey	6	-2.54	1.09	-2.32	0.75	-999	_	-0.41	_	-2.51	1.11
Post-1981 trawl survey	1	1.31	0.09	1.31	0.09	1.27	0.07	1.31	0.09	2.38	0.10
Post-1981 trawl survey	2	-2.96	0.29	-2.94	0.26	-13.9	81.79	-2.85	0.27	-13.7	83.5
Post-1981 trawl survey	3	-2.18	0.61	-2.20	0.61	-2.44	0.55	-2.16	0.60	0.93	0.18
Post-1981 trawl survey	4	1.06	0.29	1.02	0.27	3.96	0.12	1.08	0.29	0.81	0.20
Post-1981 trawl survey	5	-5.52	0.37	-5.96	0.56	-4.92	0.23	-5.33	0.32	-5.16	0.26
Post-1981 trawl survey	6	-0.56	0.11	-0.74	0.10	-999	_	-0.41	_	-0.54	0.11
IPHC longline survey	1	72.49	2.97	71.15	2.80	74.10	3.63	72.89	3.67	72.91	3.54
IPHC longline survey	2	0	_	0	_	0	_	0	_	0	_
IPHC longline survey	3	5.07	0.31	5.01	0.31	5.17	0.34	5.096	0.365	5.078	0.352
IPHC longline survey	4	0	_	0	_	0	_	0	_	0	_
IPHC longline survey	5	-999	_	-999	_	-999	_	-999	_	-999	_
IPHC longline survey	6	10	_	10	_	10	_	10	_	10	_

Table 2.17p—Annual survey selectivity "devs" for models without mean size-at-age data. See text for parm. definitions. Note that Model F2 subjects more parameters to annual "devs" than the other models.

			Model A1		Model A2		Model A3	
Survey	Parm.	Year	Value	SD	Value	SD	Value	SD
Pre82	3	1979	0.07	0.14	0.08	0.14	0.08	0.14
Pre82	3	1980	0.01	0.14	0.02	0.14	0.01	0.14
Pre82	3	1981	-0.09	0.14	-0.10	0.14	-0.09	0.14
Post81	3	1982	0.10	0.11	0.08	0.11	0.09	0.11
Post81	3	1983	0.05	0.05	0.04	0.05	0.05	0.05
Post81	3	1984	0.18	0.09	0.18	0.09	0.18	0.09
Post81	3	1985	-0.03	0.06	-0.03	0.06	-0.03	0.06
Post81	3	1986	0.09	0.07	0.10	0.06	0.10	0.07
Post81	3	1987	-0.06	0.11	-0.05	0.09	-0.07	0.11
Post81	3	1988	0.15	0.10	0.12	0.10	0.15	0.10
Post81	3	1989	0.27	0.08	0.24	0.08	0.27	0.08
Post81	3	1990	0.06	0.06	0.03	0.06	0.06	0.06
Post81	3	1991	0.10	0.06	0.10	0.06	0.10	0.06
Post81	3	1992	-0.13	0.10	-0.20	0.11	-0.14	0.10
Post81	3	1993	-0.14	0.09	-0.12	0.07	-0.13	0.09
Post81	3	1994	0.02	0.07	0.09	0.07	0.02	0.07
Post81	3	1995	0.18	0.08	0.14	0.08	0.18	0.08
Post81	3	1996	0.26	0.08	0.20	0.09	0.26	0.08
Post81	3	1997	0.11	0.05	0.12	0.06	0.11	0.05
Post81	3	1998	0.15	0.07	0.18	0.08	0.15	0.07
Post81	3	1999	0.19	0.06	0.14	0.07	0.19	0.06
Post81	3	2000	0.06	0.05	0.07	0.05	0.06	0.05
Post81	3	2001	-0.38	0.11	-0.18	0.08	-0.38	0.11
Post81	3	2002	0.06	0.06	-0.03	0.09	0.06	0.06
Post81	3	2003	-0.04	0.06	-0.02	0.07	-0.05	0.06
Post81	3	2004	0.02	0.06	0.03	0.06	0.03	0.06
Post81	3	2005	-0.16	0.09	-0.13	0.09	-0.16	0.09
Post81	3	2006	-0.41	0.11	-0.35	0.11	-0.41	0.11
Post81	3	2007	-0.51	0.12	-0.53	0.11	-0.51	0.12
Post81	3	2008	-0.02	0.07	-0.04	0.08	-0.02	0.07
Post81	3	2009	-0.17	0.14	-0.18	0.14	-0.17	0.14

			Model F2	
Survey	Parm.	Year	Value	SD
Post81	3	1982	-0.66	0.28
Post81	3	1983	-0.55	0.22
Post81	3	1984	0.03	0.11
Post81	3	1985	0.28	0.11
Post81	3	1986	-0.13	0.12
Post81	3	1987	0.19	0.13
Post81	3	1988	-0.06	0.14
Post81	3	1989	-0.69	0.27
Post81	3	1990	-0.25	0.24
Post81	3	1991	-0.09	0.18
Post81	3	1992	0.50	0.20
Post81	3	1993	0.53	0.20
Post81	3	1994	0.12	0.12
Post81	3	1995	0.04	0.15
Post81	3	1996	-0.07	0.20
Post81	3	1997	0.12	0.12
Post81	3	1998	-0.21	0.13
Post81	3	1999	-0.18	0.13
Post81	3	2000	-0.52	0.20
Post81	3	2001	0.51	0.18
Post81	3	2002	-0.42	0.22
Post81	3	2003	0.30	0.13
Post81	3	2004	0.19	0.13
Post81	3	2005	0.44	0.17
Post81	3	2006	0.48	0.21
Post81	3	2007	0.68	0.18
Post81	3	2008	-0.09	0.14
Post81	3	2009	-0.51	0.17
Post81	5	1982	0.14	0.27
Post81	5	1983	-0.44	0.20
Post81	5	1984	0.23	0.27
Post81	5	1985	0.44	0.23
Post81	5	1986	-0.07	0.21
Post81	5	1987	0.27	0.34
Post81	5	1988	0.32	0.29
Post81	5	1989	0.29	0.18
Post81	5	1990	-0.52	0.24
Post81	5	1991	-0.11	0.25
Post81	5	1992	0.01	0.35
Post81	5	1993	-0.11	0.31
Post81	5	1994	0.31	0.32
Post81	5	1995	0.16	0.33
Post81	5	1996	0.24	0.31
Post81	5	1997	0.21	0.28
Post81	5	1998	0.20	0.19
Post81	5	1999	0.16	0.20
Post81	5	2000	-0.25	0.18
Post81	5	2001	0.42	0.25
Post81	5	2002	-0.27	0.24
Post81	5	2003	0.46	0.30
Post81	5	2004	0.26	0.34
Post81	5	2005	0.49	0.31
Post81	5	2006	-0.63	0.29
Post81	5	2007	-1.16	0.27
Post81	5	2008	-0.58	0.26
Post81	5	2009	-0.48	0.29

Table 2.17q—Annual survey selectivity "devs" for models with mean size-at-age data and age composition data. See text for parm. definitions. Model G1 does not use survey selectivity devs.

			Model B1		Model C1		Model D1		Model E1		Model G1	
Survey	Parm.	Year	Value	SD	Value	SD	Value	SD	Value	SD	Value	SD
Post-1981	3	1982	-0.08	0.03	-0.08	0.03	-0.07	0.03	-0.08	0.03	n/a	
Post-1981	3	1983	-0.03	0.02	-0.03	0.02	-0.03	0.02	-0.03	0.02	n/a	
Post-1981	3	1984	-0.09	0.03	-0.09	0.03	-0.10	0.03	-0.09	0.03	n/a	
Post-1981	3	1985	0.02	0.02	0.02	0.03	0.03	0.03	0.02	0.03	n/a	
Post-1981	3	1986	-0.06	0.02	-0.06	0.02	-0.06	0.02	-0.06	0.02	n/a	
Post-1981	3	1987	0.04	0.04	0.05	0.05	0.04	0.05	0.04	0.05	n/a	
Post-1981	3	1988	-0.03	0.04	-0.02	0.05	-0.04	0.04	-0.03	0.04	n/a	
Post-1981	3	1989	-0.10	0.02	-0.10	0.02	-0.10	0.02	-0.10	0.02	n/a	
Post-1981	3	1990	-0.03	0.02	-0.02	0.02	-0.02	0.02	-0.02	0.02	n/a	
Post-1981	3	1991	-0.05	0.02	-0.04	0.02	-0.04	0.02	-0.04	0.02	n/a	
Post-1981	3	1992	0.04	0.03	0.05	0.04	0.05	0.04	0.05	0.04	n/a	
Post-1981	3	1993	0.06	0.03	0.07	0.03	0.08	0.04	0.07	0.04	n/a	
Post-1981	3	1994	-0.04	0.02	-0.04	0.02	-0.04	0.02	-0.04	0.02	n/a	
Post-1981	3	1995	-0.08	0.02	-0.08	0.02	-0.08	0.02	-0.08	0.02	n/a	
Post-1981	3	1996	-0.10	0.02	-0.10	0.02	-0.10	0.02	-0.10	0.02	n/a	
Post-1981	3	1997	-0.05	0.02	-0.05	0.02	-0.05	0.02	-0.05	0.02	n/a	
Post-1981	3	1998	-0.08	0.02	-0.08	0.02	-0.09	0.02	-0.09	0.02	n/a	
Post-1981	3	1999	-0.06	0.02	-0.06	0.02	-0.06	0.02	-0.06	0.02	n/a	
Post-1981	3	2000	-0.03	0.02	-0.03	0.02	-0.04	0.02	-0.04	0.02	n/a	
Post-1981	3	2001	0.12	0.04	0.12	0.04	0.12	0.04	0.12	0.04	n/a	
Post-1981	3	2002	-0.03	0.02	-0.04	0.02	-0.03	0.02	-0.03	0.02	n/a	
Post-1981	3	2003	0.00	0.02	-0.01	0.02	0.00	0.02	0.00	0.02	n/a	
Post-1981	3	2004	-0.02	0.02	-0.03	0.02	-0.02	0.02	-0.02	0.02	n/a	
Post-1981	3	2005	0.05	0.03	0.03	0.03	0.05	0.03	0.05	0.03	n/a	
Post-1981	3	2006	0.08	0.03	0.06	0.03	0.07	0.03	0.07	0.03	n/a	
Post-1981	3	2007	0.19	0.04	0.18	0.04	0.18	0.04	0.18	0.04	n/a	

Table 2.17r—Annual survey selectivity "devs" for models with mean size-at-age data and age composition data. See text for parm. definitions. Model G2 does not use survey selectivity devs.

			Model B2		Model C2		Model D2		Model E2		Model G2	
Survey	Parm.	Year	Value	SD	Value	SD	Value	SD	Value	SD	Value	SD
Post-1981	3	1982	-0.07	0.03	-0.07	0.03	-0.08	0.03	-0.07	0.03	n/a	
Post-1981	3	1983	-0.02	0.02	-0.02	0.02	-0.02	0.02	-0.03	0.02	n/a	
Post-1981	3	1984	-0.08	0.03	-0.08	0.03	-0.09	0.03	-0.08	0.03	n/a	
Post-1981	3	1985	0.02	0.02	0.02	0.02	0.03	0.03	0.02	0.02	n/a	
Post-1981	3	1986	-0.05	0.02	-0.05	0.02	-0.05	0.02	-0.05	0.02	n/a	
Post-1981	3	1987	0.04	0.04	0.05	0.04	0.05	0.05	0.05	0.04	n/a	
Post-1981	3	1988	-0.02	0.04	-0.01	0.05	-0.03	0.04	-0.02	0.04	n/a	
Post-1981	3	1989	-0.09	0.02	-0.09	0.02	-0.10	0.02	-0.09	0.02	n/a	
Post-1981	3	1990	-0.02	0.02	-0.02	0.02	-0.02	0.02	-0.01	0.02	n/a	
Post-1981	3	1991	-0.04	0.02	-0.03	0.02	-0.04	0.02	-0.03	0.02	n/a	
Post-1981	3	1992	0.04	0.03	0.05	0.03	0.04	0.03	0.05	0.03	n/a	
Post-1981	3	1993	0.07	0.03	0.08	0.03	0.08	0.04	0.08	0.03	n/a	
Post-1981	3	1994	-0.05	0.03	-0.04	0.03	-0.04	0.03	-0.04	0.03	n/a	
Post-1981	3	1995	-0.07	0.03	-0.06	0.03	-0.06	0.03	-0.06	0.03	n/a	
Post-1981	3	1996	-0.09	0.02	-0.09	0.02	-0.09	0.02	-0.09	0.02	n/a	
Post-1981	3	1997	-0.05	0.02	-0.05	0.02	-0.05	0.02	-0.06	0.02	n/a	
Post-1981	3	1998	-0.08	0.02	-0.08	0.02	-0.09	0.02	-0.09	0.02	n/a	
Post-1981	3	1999	-0.06	0.02	-0.06	0.02	-0.06	0.02	-0.06	0.02	n/a	
Post-1981	3	2000	-0.03	0.02	-0.03	0.02	-0.05	0.02	-0.04	0.02	n/a	
Post-1981	3	2001	0.09	0.03	0.09	0.03	0.10	0.04	0.09	0.03	n/a	
Post-1981	3	2002	-0.03	0.03	-0.03	0.03	-0.03	0.03	-0.03	0.03	n/a	
Post-1981	3	2003	-0.01	0.02	-0.01	0.02	0.00	0.03	-0.01	0.03	n/a	
Post-1981	3	2004	-0.02	0.03	-0.03	0.02	-0.02	0.03	-0.02	0.03	n/a	
Post-1981	3	2005	0.06	0.04	0.05	0.03	0.08	0.04	0.06	0.04	n/a	
Post-1981	3	2006	0.05	0.03	0.03	0.03	0.03	0.03	0.04	0.03	n/a	
Post-1981	3	2007	0.20	0.04	0.20	0.04	0.20	0.04	0.20	0.04	n/a	

Table 2.18—Average product of trawl survey catchability (Q) and trawl survey selectivity (S) across the 60-81 cm range, and some statistics pertaining to trawl survey selectivity at age 1. Because Model F2 uses length-based survey selectivity, the 15-17 cm length bin is used as a proxy for age 1 fish in Model F2. Ave. = average, SD = standard deviation, CV = coefficient of variation (= SD/Ave.). The average product of Q and S across the 60-81 cm size range estimated by Nichol et al. (2007) was 0.47.

Model	AveQxS(60-81)	Ave. S(1)	SD S(1)	CV S(1)
A1	0.640	0.438	0.210	0.479
A2	0.478	0.378	0.196	0.519
A3	0.612	0.440	0.210	0.477
F2	0.624	0.310	0.158	0.510
B1	0.470	0.401	0.202	0.504
C1	0.259	0.409	0.199	0.487
D1	0.601	0.424	0.206	0.486
E1	0.514	0.414	0.204	0.493
G1	0.483	0.440	0.000	0.000
B2	0.393	0.379	0.195	0.515
C2	0.216	0.387	0.192	0.497
D2	0.591	0.408	0.201	0.492
E2	0.427	0.391	0.197	0.504
G2	0.397	0.409	0.000	0.000

Table 2.19—Time series of mean length (cm) at age 1 as estimated by the 14 models. Years 1994-2008 are shown, to correspond with the range for which observations are available. Mean = average, SE = standard error of the mean, correl. = correlation between estimates and data. For the second and third groups of models, green = within-group minimum (by row) and pink = within-group maximum (by row).

		Models with no size-at-age data				Models with size-at-age data									
						Models with age composition data					Models without age composition data				
Year	Data	A1	A2	A3	F2	B1	C1	D1	E1	G1	B2	C2	D2	E2	G2
1994	19.00	16.14	16.14	16.14	16.02	16.87	16.85	16.91	16.86	16.81	17.05	17.03	17.10	17.04	17.00
1995	17.30	16.14	16.14	16.14	16.02	16.20	16.12	16.28	16.21	16.16	16.47	16.43	16.58	16.49	16.48
1996	17.62	16.14	16.14	16.14	16.02	15.86	15.89	15.90	15.89	15.91	16.22	16.28	16.25	16.27	16.28
1997	17.18	16.14	16.14	16.14	16.02	16.48	16.49	16.56	16.52	16.50	16.61	16.63	16.75	16.67	16.63
1998	15.44	16.14	16.14	16.14	16.02	15.07	14.96	15.27	15.18	15.06	15.13	15.04	15.36	15.22	15.12
1999	15.78	16.14	16.14	16.14	16.02	15.92	15.88	16.15	16.06	15.94	15.81	15.77	16.06	15.95	15.84
2000	15.24	16.14	16.14	16.14	16.02	16.40	16.35	16.62	16.53	16.52	16.57	16.52	16.83	16.68	16.66
2001	17.88	16.14	16.14	16.14	16.02	16.61	16.60	16.72	16.67	16.64	16.87	16.86	16.97	16.91	16.89
2002	16.52	16.14	16.14	16.14	16.02	15.35	15.29	15.46	15.38	15.33	15.40	15.38	15.52	15.41	15.38
2003	18.01	16.14	16.14	16.14	16.02	16.68	16.73	16.75	16.70	16.66	16.77	16.83	16.84	16.77	16.75
2004	17.26	16.14	16.14	16.14	16.02	15.30	15.26	15.39	15.33	15.32	15.35	15.34	15.46	15.37	15.34
2005	18.59	16.14	16.14	16.14	16.02	17.40	17.42	17.48	17.43	17.46	17.67	17.70	17.73	17.70	17.68
2006	15.33	16.14	16.14	16.14	16.02	16.37	16.28	16.54	16.45	16.60	16.17	16.10	16.41	16.23	16.36
2007	14.91	16.14	16.14	16.14	16.02	15.34	15.27	15.48	15.40	15.39	15.27	15.21	15.43	15.30	15.30
2008	15.39	16.14	16.14	16.14	16.02	16.01	15.85	16.15	16.06	16.13	15.69	15.58	15.86	15.73	15.76
Mean:	16.76	16.14	16.14	16.14	16.02	16.12	16.08	16.24	16.18	16.16	16.20	16.18	16.34	16.25	16.23
SE:	0.35	0.00	0.00	0.00	0.00	0.17	0.18	0.17	0.17	0.17	0.19	0.20	0.18	0.19	0.19
Correl:	n/a	0.00	0.00	0.00	0.00	0.60	0.63	0.54	0.56	0.53	0.70	0.73	0.65	0.68	0.66

Table 2.20—Summary of key management reference points from the standard projection algorithm. All biomass figures are in t. For the second and third groups of models, green = within-group row minimum, pink = within-group row maximum.

	Models without size-at-age data				Models with size-at-age data									
					Models with age composition data					Models without age composition data				
Quantity	A1	A2	A3	F2	B1	C1	D1	E1	G1	B2	C2	D2	E2	G2
B100%	1,013,220	1,026,490	1,045,530	813,013	1,027,190	1,611,570	936,645	966,170	1,030,110	1,066,750	1,680,620	952,969	1,005,920	1,078,060
B40%	405,290	410,597	418,213	325,205	410,877	644,626	374,658	386,468	412,043	426,701	672,248	381,188	402,369	431,226
B35%	354,628	359,272	365,936	284,555	359,517	564,048	327,826	338,159	360,538	373,363	588,217	333,539	352,073	377,323
B2010	318,617	329,112	340,840	301,651	344,601	794,451	314,000	330,121	359,356	373,033	833,012	327,023	363,711	397,676
B2011	346,357	348,341	364,071	339,301	369,713	754,315	346,258	356,759	394,735	384,704	772,770	349,568	374,012	416,914
B2010/B100%	0.31	0.32	0.33	0.37	0.34	0.49	0.34	0.34	0.35	0.35	0.50	0.34	0.36	0.37
B2011/B100%	0.34	0.34	0.35	0.42	0.36	0.47	0.37	0.37	0.38	0.36	0.46	0.37	0.37	0.39
F40%	0.29	0.29	0.29	0.45	0.29	0.28	0.29	0.29	0.29	0.29	0.28	0.29	0.29	0.29
F35%	0.35	0.34	0.35	0.55	0.35	0.34	0.35	0.35	0.35	0.35	0.34	0.35	0.35	0.35
maxFABC2010	0.23	0.23	0.23	0.42	0.24	0.28	0.24	0.25	0.25	0.25	0.28	0.25	0.26	0.27
maxFABC2011	0.25	0.24	0.25	0.45	0.26	0.28	0.27	0.27	0.28	0.26	0.28	0.26	0.27	0.28
maxABC2010	158,792	168,931	176,765	254,970	174,378	455,931	160,755	171,392	194,666	194,578	474,301	168,883	197,062	224,310
maxABC2011	201,491	202,355	217,355	327,032	213,717	465,166	204,905	211,530	247,998	220,559	472,331	201,970	220,852	261,207
FOFL2010	0.27	0.27	0.28	0.51	0.29	0.34	0.29	0.30	0.30	0.30	0.34	0.29	0.31	0.32
OFL2010	186,256	197,839	207,116	299,655	204,815	536,026	189,191	201,422	228,642	228,294	557,643	198,619	231,171	263,046
OFL2011	235,974	236,760	254,387	387,906	250,790	547,223	240,746	248,299	290,774	258,829	555,816	237,330	259,135	306,162
Pr(B2012<B20%)	~0	~0	~0	~0	~0	~0	~0	~0	~0	~0	~0	~0	~0	~0
Pr(B2013<B20%)	~0	~0	~0	~0	~0	~0	~0	~0	~0	~0	~0	~0	~0	~0
Pr(B2014<B20%)	~0	~0	~0	~0	~0	~0	~0	~0	~0	~0	~0	~0	~0	~0

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)
B2010 = projected spawning biomass for 2010
B2011 = projected spawning biomass for 2011 (assuming 2010 catch = maximum permissible ABC)
B2010/B100% = ratio of 2010 spawning biomass to B100%
B2011/B100% = ratio of 2011 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
maxFABC2010 = maximum permissible ABC fishing mortality rate for 2010 under Tier 3
maxFABC2011 = maximum permissible ABC fishing mortality rate for 2011 under Tier 3
maxABC2010 = maximum permissible ABC for 2010 under Tier 3
maxABC2011 = maximum permissible ABC for 2011 under Tier 3
FOFL2010 = OFL fishing mortality rate for 2010 under Tier 3
OFL2010 = OFL for 2010 under Tier 3
OFL2011 = OFL for 2011 under Tier 3 assuming 2010 catch = maxABC2010
Pr(B2012<B20%) = probability that spawning biomass will fall below 20% of B100% in 2012
Pr(B2013<B20%) = probability that spawning biomass will fall below 20% of B100% in 2013
Pr(B2014<B20%) = probability that spawning biomass will fall below 20% of B100% in 2014

Table 2.21—Estimates of Pacific cod fishing mortality rates, expressed on an annual time scale (Model B1). Rates are expressed as catch (in weight) divided by gear- and season-specific available biomass.

	Trawl fishery			Longline fishery			Pot fishery		
Year	Jan-May	Jun-Aug	Sep-Dec	Jan-May	Jun-Aug	Sep-Dec	Jan-May	Jun-Aug	Sep-Dec
1977	0.019	0.008	0.009	0.005	0.000	0.008	0	0	0
1978	0.025	0.011	0.012	0.006	0.001	0.010	0	0	0
1979	0.020	0.007	0.009	0.005	0.000	0.008	0	0	0
1980	0.021	0.005	0.011	0.003	0.000	0.005	0	0	0
1981	0.012	0.008	0.019	0.001	0.000	0.003	0	0	0
1982	0.013	0.009	0.011	0.000	0.000	0.001	0	0	0
1983	0.020	0.011	0.014	0.002	0.000	0.001	0	0	0
1984	0.023	0.011	0.014	0.003	0.001	0.010	0	0	0
1985	0.028	0.016	0.014	0.009	0.001	0.014	0	0	0
1986	0.032	0.015	0.015	0.006	0.000	0.012	0	0	0
1987	0.035	0.009	0.014	0.016	0.000	0.019	0	0	0
1988	0.071	0.016	0.034	0.000	0.000	0.001	0	0	0
1989	0.076	0.012	0.015	0.003	0.003	0.004	0.000	0.000	0.000
1990	0.064	0.008	0.007	0.012	0.013	0.014	0.000	0.001	0.000
1991	0.080	0.014	0.005	0.028	0.020	0.030	0.000	0.001	0.002
1992	0.050	0.012	0.005	0.065	0.027	0.007	0.004	0.005	0.000
1993	0.055	0.005	0.007	0.063	0.000	0.000	0.003	0.000	0.000
1994	0.047	0.005	0.013	0.065	0.000	0.021	0.006	0.000	0.003
1995	0.078	0.008	0.021	0.075	0.000	0.028	0.014	0.004	0.003
1996	0.068	0.003	0.019	0.067	0.000	0.025	0.020	0.007	0.003
1997	0.072	0.004	0.016	0.077	0.000	0.045	0.016	0.004	0.003
1998	0.043	0.006	0.019	0.066	0.000	0.031	0.011	0.003	0.002
1999	0.044	0.003	0.007	0.072	0.002	0.025	0.012	0.001	0.002
2000	0.046	0.004	0.006	0.048	0.001	0.041	0.022	0.000	0.000
2001	0.023	0.006	0.007	0.043	0.006	0.045	0.015	0.000	0.004
2002	0.036	0.009	0.005	0.057	0.011	0.039	0.013	0.000	0.003
2003	0.033	0.009	0.003	0.053	0.007	0.041	0.020	0.000	0.006
2004	0.041	0.012	0.004	0.062	0.010	0.045	0.016	0.000	0.004
2005	0.044	0.006	0.001	0.066	0.014	0.046	0.014	0.000	0.005
2006	0.050	0.006	0.002	0.072	0.018	0.033	0.018	0.000	0.005
2007	0.043	0.010	0.003	0.073	0.017	0.024	0.018	0.000	0.006
2008	0.032	0.007	0.008	0.082	0.019	0.041	0.018	0.000	0.009
2009	0.033	0.009	0.006	0.095	0.020	0.038	0.020	0.000	0.008

Table 2.22a—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	0.001	0.003	0.000	0.001	0.000	0.000	0.006	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	0.009	0.002	0.002	0.001	0.001	0.024	0.000	0.000	0.000	0.005
19.5	0.000	0.005	0.014	0.004	0.004	0.002	0.002	0.047	0.000	0.001	0.000	0.012
22.5	0.000	0.009	0.022	0.009	0.008	0.004	0.004	0.083	0.001	0.002	0.001	0.024
25.5	0.000	0.016	0.034	0.017	0.014	0.008	0.007	0.141	0.001	0.005	0.003	0.045
28.5	0.000	0.028	0.051	0.033	0.024	0.013	0.013	0.223	0.003	0.011	0.007	0.081
31.5	0.011	0.046	0.074	0.059	0.038	0.022	0.023	0.331	0.008	0.022	0.014	0.137
34.5	0.110	0.074	0.105	0.101	0.061	0.036	0.038	0.464	0.016	0.043	0.029	0.217
37.5	0.489	0.114	0.145	0.162	0.092	0.057	0.062	0.612	0.031	0.077	0.054	0.325
40.5	0.958	0.169	0.195	0.246	0.135	0.086	0.097	0.759	0.058	0.131	0.095	0.457
43.5	1.000	0.241	0.256	0.355	0.192	0.126	0.146	0.884	0.102	0.209	0.158	0.604
47.5	1.000	0.364	0.355	0.531	0.291	0.200	0.237	0.986	0.196	0.355	0.283	0.797
52.5	1.000	0.551	0.501	0.764	0.450	0.327	0.393	1.000	0.379	0.590	0.500	0.966
57.5	1.000	0.749	0.660	0.943	0.633	0.490	0.583	1.000	0.618	0.828	0.747	1.000
62.5	1.000	0.912	0.810	1.000	0.809	0.671	0.778	1.000	0.851	0.980	0.940	1.000
67.5	1.000	0.995	0.929	1.000	0.943	0.838	0.931	1.000	0.988	1.000	1.000	1.000
72.5	1.000	1.000	0.993	1.000	0.999	0.958	0.999	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 2.22a—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	0.003	0.000	0.000	0.002	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000
19.5	0.000	0.005	0.000	0.000	0.002	0.006	0.000	0.000	0.000	0.000	0.000	0.000	0.000
22.5	0.001	0.008	0.001	0.000	0.004	0.009	0.000	0.001	0.000	0.000	0.000	0.000	0.000
25.5	0.003	0.013	0.001	0.001	0.006	0.013	0.000	0.002	0.000	0.000	0.000	0.001	0.000
28.5	0.009	0.020	0.003	0.005	0.008	0.020	0.002	0.004	0.001	0.000	0.001	0.003	0.001
31.5	0.021	0.030	0.005	0.022	0.012	0.028	0.006	0.009	0.003	0.001	0.002	0.007	0.002
34.5	0.049	0.045	0.010	0.071	0.018	0.041	0.020	0.019	0.007	0.003	0.006	0.017	0.006
37.5	0.100	0.065	0.017	0.188	0.025	0.057	0.056	0.036	0.014	0.010	0.016	0.038	0.015
40.5	0.187	0.091	0.029	0.396	0.035	0.078	0.131	0.066	0.028	0.024	0.036	0.078	0.034
43.5	0.315	0.125	0.048	0.672	0.048	0.106	0.264	0.113	0.053	0.055	0.077	0.145	0.069
47.5	0.545	0.184	0.089	0.965	0.071	0.153	0.536	0.211	0.112	0.142	0.178	0.290	0.159
52.5	0.845	0.283	0.172	1.000	0.113	0.233	0.894	0.399	0.245	0.354	0.404	0.558	0.363
57.5	0.998	0.409	0.301	1.000	0.171	0.335	1.000	0.638	0.450	0.663	0.706	0.841	0.648
62.5	1.000	0.554	0.473	1.000	0.248	0.457	0.938	0.864	0.697	0.934	0.949	0.995	0.908
67.5	1.000	0.705	0.668	1.000	0.344	0.593	0.680	0.991	0.909	1.000	1.000	0.995	1.000
72.5	1.000	0.842	0.849	1.000	0.456	0.730	0.408	1.000	1.000	0.952	0.933	0.829	0.968
77.5	1.000	0.945	0.970	1.000	0.580	0.852	0.250	0.952	0.985	0.771	0.712	0.563	0.758
82.5	1.000	0.996	1.000	1.000	0.705	0.945	0.191	0.860	0.804	0.588	0.498	0.365	0.508
87.5	1.000	1.000	1.000	1.000	0.822	0.994	0.177	0.787	0.555	0.483	0.379	0.275	0.351
92.5	1.000	1.000	1.000	1.000	0.916	1.000	0.174	0.752	0.383	0.445	0.337	0.248	0.288
97.5	1.000	1.000	1.000	1.000	0.978	1.000	0.174	0.741	0.311	0.436	0.326	0.243	0.272
102.5	1.000	1.000	1.000	1.000	1.000	1.000	0.174	0.739	0.290	0.434	0.325	0.242	0.269
107.5	1.000	1.000	1.000	1.000	1.000	1.000	0.174	0.738	0.286	0.434	0.325	0.242	0.268

Table 2.22a—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	0.002	0.001	0.000	0.001	0.000	0.000	0.002	0.003	0.002
34.5	0.006	0.003	0.001	0.001	0.007	0.002	0.000	0.003	0.001	0.001	0.006	0.008	0.005
37.5	0.017	0.008	0.004	0.005	0.019	0.007	0.001	0.007	0.003	0.003	0.014	0.021	0.015
40.5	0.043	0.021	0.012	0.014	0.048	0.020	0.007	0.019	0.011	0.008	0.030	0.047	0.040
43.5	0.095	0.052	0.032	0.036	0.105	0.050	0.027	0.043	0.031	0.022	0.060	0.097	0.090
47.5	0.230	0.142	0.096	0.104	0.248	0.137	0.126	0.113	0.099	0.070	0.135	0.217	0.223
52.5	0.519	0.372	0.280	0.298	0.547	0.363	0.473	0.292	0.304	0.222	0.306	0.468	0.513
57.5	0.848	0.704	0.591	0.615	0.869	0.695	0.919	0.578	0.645	0.507	0.561	0.774	0.846
62.5	1.000	0.965	0.901	0.917	1.000	0.961	1.000	0.870	0.947	0.837	0.829	0.980	1.000
67.5	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.989	1.000	1.000
72.5	1.000	1.000	1.000	1.000	1.000	1.000	0.836	1.000	1.000	1.000	1.000	0.996	1.000
77.5	1.000	1.000	1.000	1.000	1.000	1.000	0.488	0.984	0.890	0.987	1.000	0.853	1.000
82.5	1.000	1.000	1.000	1.000	1.000	1.000	0.219	0.912	0.684	0.927	0.995	0.633	1.000
87.5	1.000	1.000	1.000	1.000	1.000	1.000	0.101	0.841	0.532	0.865	0.989	0.484	1.000
92.5	1.000	1.000	1.000	1.000	1.000	1.000	0.069	0.803	0.469	0.832	0.985	0.426	1.000
97.5	1.000	1.000	1.000	1.000	1.000	1.000	0.064	0.792	0.452	0.821	0.984	0.412	1.000
102.5	1.000	1.000	1.000	1.000	1.000	1.000	0.063	0.789	0.449	0.819	0.983	0.409	1.000
107.5	1.000	1.000	1.000	1.000	1.000	1.000	0.063	0.789	0.449	0.819	0.983	0.409	1.000

Table 2.22a—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	0.000	0.000	0.000	0.000	0.000	0.000
34.5	0.001	0.001	0.001	0.001	0.002	0.000	0.001	0.000	0.000
37.5	0.002	0.003	0.003	0.004	0.006	0.001	0.004	0.001	0.000
40.5	0.005	0.009	0.009	0.010	0.019	0.004	0.010	0.006	0.002
43.5	0.015	0.023	0.023	0.027	0.051	0.012	0.025	0.025	0.005
47.5	0.050	0.072	0.070	0.080	0.151	0.047	0.070	0.113	0.018
52.5	0.168	0.222	0.218	0.241	0.415	0.179	0.201	0.424	0.074
57.5	0.412	0.500	0.494	0.528	0.777	0.465	0.444	0.868	0.224
62.5	0.741	0.825	0.820	0.849	0.996	0.825	0.751	1.000	0.499
67.5	0.977	0.998	0.997	1.000	1.000	1.000	0.971	1.000	0.821
72.5	1.000	0.987	0.982	0.983	1.000	1.000	1.000	1.000	0.997
77.5	0.824	0.809	0.694	0.834	1.000	1.000	1.000	1.000	1.000
82.5	0.567	0.644	0.420	0.711	1.000	1.000	1.000	1.000	1.000
87.5	0.461	0.592	0.332	0.675	1.000	1.000	1.000	1.000	1.000
92.5	0.443	0.585	0.320	0.670	1.000	1.000	1.000	1.000	1.000
97.5	0.442	0.584	0.319	0.670	1.000	1.000	1.000	1.000	1.000
102.5	0.442	0.584	0.319	0.670	1.000	1.000	1.000	1.000	1.000
107.5	0.442	0.584	0.319	0.670	1.000	1.000	1.000	1.000	1.000

Table 2.22b—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 (pre-1982 surveys do not vary).

Age	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
0	0.000	0.000	0.000	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007
1	0.141	0.141	0.141	0.204	0.365	0.173	0.517	0.270	0.584	0.346	0.145	0.356	0.306	0.596	0.656	0.317
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	1.000	1.000
3	1.000	1.000	1.000	0.991	0.991	0.991	0.991	0.991	0.991	0.991	0.991	0.991	0.991	0.991	0.991	0.991
4	0.730	0.730	0.730	0.888	0.888	0.888	0.888	0.888	0.888	0.888	0.888	0.888	0.888	0.888	0.888	0.888
5	0.111	0.111	0.111	0.718	0.718	0.718	0.718	0.718	0.718	0.718	0.718	0.718	0.718	0.718	0.718	0.718
6	0.111	0.111	0.111	0.553	0.553	0.553	0.553	0.553	0.553	0.553	0.553	0.553	0.553	0.553	0.553	0.553
7	0.111	0.111	0.111	0.438	0.438	0.438	0.438	0.438	0.438	0.438	0.438	0.438	0.438	0.438	0.438	0.438
8	0.111	0.111	0.111	0.377	0.377	0.377	0.377	0.377	0.377	0.377	0.377	0.377	0.377	0.377	0.377	0.377
9	0.111	0.111	0.111	0.351	0.351	0.351	0.351	0.351	0.351	0.351	0.351	0.351	0.351	0.351	0.351	0.351
10	0.111	0.111	0.111	0.342	0.342	0.342	0.342	0.342	0.342	0.342	0.342	0.342	0.342	0.342	0.342	0.342
11	0.111	0.111	0.111	0.340	0.340	0.340	0.340	0.340	0.340	0.340	0.340	0.340	0.340	0.340	0.340	0.340
12	0.111	0.111	0.111	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339
13	0.111	0.111	0.111	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339
14	0.111	0.111	0.111	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339
15	0.111	0.111	0.111	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339
16	0.111	0.111	0.111	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339
17	0.111	0.111	0.111	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339
18	0.111	0.111	0.111	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339
19	0.111	0.111	0.111	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339
20	0.111	0.111	0.111	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339

Age	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
0	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007
1	0.194	0.151	0.300	0.192	0.265	0.351	0.785	0.358	0.450	0.386	0.609	0.687	0.867	0.461	0.461
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	1.000
3	0.991	0.991	0.991	0.991	0.991	0.991	0.991	0.991	0.991	0.991	0.991	0.991	0.991	0.991	0.991
4	0.888	0.888	0.888	0.888	0.888	0.888	0.888	0.888	0.888	0.888	0.888	0.888	0.888	0.888	0.888
5	0.718	0.718	0.718	0.718	0.718	0.718	0.718	0.718	0.718	0.718	0.718	0.718	0.718	0.718	0.718
6	0.553	0.553	0.553	0.553	0.553	0.553	0.553	0.553	0.553	0.553	0.553	0.553	0.553	0.553	0.553
7	0.438	0.438	0.438	0.438	0.438	0.438	0.438	0.438	0.438	0.438	0.438	0.438	0.438	0.438	0.438
8	0.377	0.377	0.377	0.377	0.377	0.377	0.377	0.377	0.377	0.377	0.377	0.377	0.377	0.377	0.377
9	0.351	0.351	0.351	0.351	0.351	0.351	0.351	0.351	0.351	0.351	0.351	0.351	0.351	0.351	0.351
10	0.342	0.342	0.342	0.342	0.342	0.342	0.342	0.342	0.342	0.342	0.342	0.342	0.342	0.342	0.342
11	0.340	0.340	0.340	0.340	0.340	0.340	0.340	0.340	0.340	0.340	0.340	0.340	0.340	0.340	0.340
12	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339
13	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339
14	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339
15	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339
16	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339
17	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339
18	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339
19	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339
20	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339

Table 2.23—Schedules of Pacific cod length (cm) by season and age as estimated by Model B1. Sea1 = Jan-May, Sea2 = Jul-Aug, Sea3 = Sep-Dec. Survey lengths correspond to Sea2.

	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
1	9.05	14.70	19.35	11.95	18.33	22.69	13.01	20.52	25.80	12.87	20.63	28.28	16.57	16.57	20.22
2	26.56	31.30	35.18	29.49	34.16	37.83	31.31	37.26	41.00	32.40	38.49	43.59	32.06	32.06	38.24
3	38.86	42.66	45.78	43.43	46.14	49.87	45.16	49.33	51.48	46.29	50.59	52.80	44.63	44.63	50.91
4	51.11	54.22	56.75	53.88	55.07	59.25	54.85	57.63	59.00	55.74	58.79	59.36	54.56	54.56	59.73
5	61.35	63.83	65.86	61.92	62.71	66.64	61.99	63.99	65.31	62.58	64.83	65.36	62.61	62.61	66.09
6	65.17	67.22	68.90	65.64	66.35	69.86	65.26	67.11	68.35	65.74	67.73	68.36	66.31	66.31	68.91
7	72.85	74.47	75.79	72.56	73.57	76.37	71.10	73.76	74.97	71.78	73.99	74.97	73.56	73.56	74.69
8	75.65	77.00	78.11	76.00	76.99	79.33	73.89	77.08	78.12	74.96	77.20	78.12	76.99	76.99	77.65
9	80.91	81.96	82.82	80.78	81.69	83.46	77.81	81.72	82.56	79.66	81.76	82.56	81.69	81.69	81.97
10	83.62	84.47	85.17	84.67	85.41	86.73	81.31	85.42	86.08	83.71	85.44	86.08	85.41	85.41	85.54
11	85.56	86.26	86.84	85.02	85.68	86.92	81.64	85.69	86.28	84.07	85.70	86.28	85.68	85.68	85.80
12	86.80	87.40	87.89	88.15	88.65	89.57	84.81	88.66	89.09	87.42	88.66	89.09	88.65	88.65	88.71
13	89.51	89.96	90.32	88.70	89.15	89.98	85.40	89.15	89.54	88.01	89.16	89.54	89.15	89.15	89.20
14	90.38	90.75	91.06	90.79	91.11	91.75	87.72	91.12	91.39	90.24	91.12	91.39	91.11	91.11	91.15
15	91.61	91.90	92.14	91.63	91.90	92.45	88.70	91.90	92.13	91.15	91.91	92.13	91.90	91.90	91.93
16	92.72	92.94	93.13	92.20	92.43	92.91	89.36	92.43	92.62	91.75	92.43	92.62	92.43	92.43	92.45
17	93.47	93.64	93.78	92.51	92.71	93.16	89.72	92.71	92.87	92.08	92.71	92.87	92.71	92.71	92.73
18	93.95	94.09	94.20	93.55	93.68	94.05	90.96	93.69	93.80	93.18	93.69	93.80	93.68	93.68	93.70
19	94.36	94.47	94.56	93.78	93.90	94.24	91.24	93.90	94.00	93.42	93.90	94.00	93.90	93.90	93.91
20	94.81	94.89	94.95	94.18	94.27	94.59	91.66	94.27	94.35	93.83	94.27	94.35	94.27	94.27	94.29

Table 2.24—Schedules of Pacific cod weight (kg) by season and age as estimated by Model 1. Sea1 = Jan-May, Sea2 = Jul-Aug, Sea3 = Sep-Dec. Survey lengths correspond to Sea2.

	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
1	0.01	0.05	0.11	0.02	0.07	0.13	0.02	0.10	0.19	0.02	0.10	0.25	0.05	0.05	0.10
2	0.22	0.39	0.54	0.29	0.47	0.63	0.34	0.61	0.81	0.38	0.67	0.98	0.39	0.39	0.66
3	0.80	1.07	1.32	0.97	1.18	1.51	1.09	1.43	1.66	1.18	1.55	1.79	1.07	1.07	1.58
4	1.67	1.97	2.33	1.92	2.02	2.61	2.02	2.31	2.56	2.12	2.45	2.60	1.97	1.97	2.57
5	2.73	3.00	3.46	2.98	3.01	3.79	2.98	3.19	3.55	3.07	3.31	3.56	3.00	3.00	3.50
6	3.37	3.58	4.06	3.59	3.58	4.40	3.51	3.69	4.11	3.59	3.79	4.11	3.58	3.58	3.98
7	4.82	4.91	5.51	4.94	4.91	5.84	4.61	4.94	5.52	4.76	4.98	5.52	4.91	4.91	5.11
8	5.65	5.64	6.29	5.72	5.64	6.59	5.22	5.66	6.29	5.48	5.68	6.29	5.64	5.64	5.77
9	6.92	6.76	7.50	6.96	6.76	7.74	6.17	6.77	7.50	6.66	6.77	7.50	6.76	6.76	6.82
10	8.06	7.75	8.56	8.08	7.75	8.75	7.12	7.75	8.56	7.81	7.75	8.56	7.75	7.75	7.77
11	8.17	7.82	8.62	8.18	7.82	8.81	7.21	7.82	8.62	7.92	7.83	8.62	7.82	7.82	7.85
12	9.17	8.68	9.55	9.18	8.68	9.69	8.17	8.68	9.55	8.97	8.68	9.55	8.68	8.68	8.69
13	9.35	8.82	9.70	9.36	8.82	9.83	8.35	8.83	9.70	9.16	8.83	9.70	8.82	8.82	8.84
14	10.07	9.43	10.34	10.07	9.43	10.45	9.10	9.43	10.34	9.91	9.43	10.34	9.43	9.43	9.44
15	10.37	9.68	10.61	10.37	9.68	10.71	9.43	9.68	10.61	10.22	9.68	10.61	9.68	9.68	9.68
16	10.57	9.84	10.78	10.57	9.84	10.88	9.65	9.84	10.78	10.43	9.84	10.78	9.84	9.84	9.85
17	10.68	9.93	10.88	10.69	9.93	10.97	9.78	9.93	10.88	10.55	9.93	10.88	9.93	9.93	9.94
18	11.06	10.25	11.22	11.06	10.25	11.30	10.21	10.25	11.22	10.95	10.25	11.22	10.25	10.25	10.26
19	11.15	10.32	11.29	11.15	10.32	11.37	10.31	10.32	11.29	11.04	10.32	11.29	10.32	10.32	10.33
20	11.30	10.45	11.43	11.31	10.45	11.50	10.46	10.45	11.43	11.19	10.45	11.43	10.45	10.45	10.45

Table 2.25a—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 2010 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	842,241	254,248	62,006	795,891	263,530	44,567
1978	899,016	271,985	62,963	826,579	276,465	44,488
1979	1,052,030	292,994	64,980	1,003,650	292,366	44,769
1980	1,482,030	340,179	68,171	1,387,200	332,876	45,113
1981	1,932,570	447,717	74,062	1,806,980	427,033	45,062
1982	2,276,670	622,090	84,594	2,142,350	581,305	45,242
1983	2,418,520	792,125	93,742	2,328,540	739,845	44,871
1984	2,403,580	872,225	94,261	2,390,860	830,570	42,362
1985	2,363,850	862,640	87,626	2,376,230	848,075	38,382
1986	2,293,060	813,255	78,960	2,325,540	824,990	34,315
1987	2,262,680	782,455	71,900	2,283,750	805,020	30,928
1988	2,188,110	763,180	66,731	2,182,830	782,115	28,228
1989	1,992,030	724,445	62,300	1,958,450	732,800	25,890
1990	1,762,410	675,640	57,352	1,719,200	675,220	23,712
1991	1,563,070	595,695	51,131	1,538,620	592,160	21,326
1992	1,450,780	491,365	44,997	1,431,110	487,744	18,863
1993	1,459,860	440,882	41,164	1,437,960	438,239	17,092
1994	1,528,360	451,689	40,324	1,513,920	449,454	16,596
1995	1,589,790	473,295	41,339	1,559,310	470,584	17,056
1996	1,569,500	475,938	43,007	1,518,370	470,617	17,698
1997	1,515,220	481,913	44,522	1,453,940	472,657	17,946
1998	1,449,180	462,345	45,141	1,383,630	451,367	17,772
1999	1,522,510	459,272	45,424	1,422,590	446,887	17,428
2000	1,595,780	474,130	46,453	1,466,010	455,622	17,196
2001	1,641,550	505,955	48,285	1,489,450	478,210	17,227
2002	1,702,650	535,905	49,744	1,519,000	499,153	17,285
2003	1,707,180	546,815	50,377	1,497,830	497,816	17,193
2004	1,630,540	549,570	50,640	1,436,530	492,587	17,187
2005	1,491,060	530,935	50,182	1,320,810	469,524	17,327
2006	1,331,050	484,612	48,476	1,186,120	428,010	17,363
2007	1,165,190	425,560	45,797	1,063,630	381,627	17,154
2008	1,075,950	372,037	42,886	998,912	344,463	16,904
2009	1,115,780	334,283	40,843	981,017	313,218	16,895
2010				1,044,580	300,485	17,587

Table 2.25b—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	2,577,100	312,291	1,985,750	156,335
1978	651,724	136,257	760,057	112,013
1979	855,987	115,728	692,919	97,612
1980	398,064	65,379	598,415	65,526
1981	175,500	36,606	317,281	39,612
1982	1,312,260	101,877	1,252,250	57,638
1983	296,381	43,943	324,619	49,762
1984	1,062,620	82,816	927,481	55,460
1985	509,878	51,303	546,818	42,182
1986	241,701	29,914	216,123	27,882
1987	145,513	22,956	123,829	22,007
1988	406,441	37,804	356,052	24,312
1989	884,194	69,872	857,757	41,640
1990	754,655	55,679	753,031	40,586
1991	444,549	39,206	493,823	30,713
1992	1,014,130	72,658	897,198	36,060
1993	414,229	34,677	489,914	25,413
1994	409,616	34,346	451,380	24,431
1995	506,237	45,551	508,799	31,241
1996	1,110,340	85,107	1,031,330	38,805
1997	454,069	35,349	582,869	28,516
1998	533,278	40,779	420,094	27,064
1999	901,297	65,843	772,362	31,955
2000	586,787	42,102	582,584	24,702
2001	312,067	26,662	311,973	17,820
2002	361,796	30,906	425,951	20,512
2003	325,788	31,611	343,915	19,790
2004	197,043	21,591	269,951	17,660
2005	288,607	31,737	380,035	25,899
2006	1,029,020	116,919	727,875	50,440
2007	475,798	192,125	479,143	52,453
2008			1,446,850	202,881
Average	633,441		635,263	

Table 2.26—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	1985750	276290	24061	196407	62196	41639	27866	18649	12480	8352	5589	3740	2503	1675	1121	750	502	336	225	150	304
1978	760057	1413400	196607	17055	135652	42260	28206	18911	12689	8509	5702	3819	2557	1712	1146	767	513	344	230	154	311
1979	692919	540986	1005560	139180	11677	91011	28249	18895	12707	8546	5739	3850	2580	1728	1157	775	519	347	232	155	315
1980	598415	493199	384941	712065	96211	7943	61726	19194	12871	8673	5841	3926	2634	1766	1183	792	531	355	238	159	322
1981	317281	425934	350916	272870	499688	66807	5455	42150	13078	8764	5905	3976	2673	1794	1202	806	540	361	242	162	328
1982	1252250	225831	302973	248337	191224	346459	46032	3739	28821	8933	5983	4030	2714	1824	1224	821	550	368	247	165	334
1983	324619	891311	160672	214321	174187	133067	239662	31771	2577	19844	6148	4117	2773	1867	1255	842	565	378	253	170	343
1984	927481	231055	634103	113637	149360	120020	90924	163064	21590	1749	13466	4171	2793	1881	1267	851	571	383	257	172	348
1985	546818	660153	164399	448492	79137	101685	80866	60966	109144	14446	1170	9009	2791	1869	1259	848	570	382	256	172	348
1986	216123	389209	469816	116844	314732	54020	67577	53370	40158	71922	9525	772	5953	1846	1237	833	561	377	253	170	344
1987	123829	153830	276996	333550	82310	215564	36149	44661	35214	26499	47494	6292	511	3938	1221	819	552	372	250	168	341
1988	356052	88138	109476	196744	233210	56529	143084	23650	29128	22996	17337	31131	4127	335	2589	804	539	363	245	165	335
1989	857757	253427	62712	77571	137091	156182	37162	91355	14947	18329	14459	10896	19560	2593	211	1626	505	339	228	154	314
1990	753031	610526	180309	44393	53983	92636	101734	23987	58211	9498	11639	9183	6921	12426	1647	134	1033	321	215	145	297
1991	493823	535985	434532	127427	30372	35478	59199	64283	15150	36813	6015	7382	5826	4392	7889	1046	85	656	204	137	281
1992	897198	351489	381479	307396	85626	19032	21420	35226	38216	9015	22012	3607	4437	3504	2643	4750	630	51	395	123	252
1993	489914	638599	250171	270532	210644	54127	11538	12849	21152	23159	5472	13467	2215	2733	2160	1630	2931	389	32	244	231
1994	451380	348706	454521	177376	186957	137513	33906	7190	8032	13296	14681	3471	8590	1416	1751	1385	1046	1881	249	20	305
1995	508799	321279	248191	321851	121823	121029	84457	20608	4393	4933	8213	9136	2160	5371	887	1099	869	657	1182	157	205
1996	1031330	362148	228648	176087	222162	78108	71911	48538	11878	2549	2875	4807	5375	1271	3170	524	650	514	389	700	214
1997	582869	734070	257740	162373	122314	144014	47208	42153	28444	7027	1516	1714	2874	3225	763	1906	316	392	310	234	550
1998	420094	414869	522432	183016	112697	78446	84993	26967	24048	16392	4089	885	1003	1685	1896	448	1122	186	231	183	463
1999	772362	299011	295269	371079	128058	74784	48757	51468	16325	14653	10062	2522	547	620	1043	1176	278	697	115	143	401
2000	582584	549744	212816	209920	259453	85541	46916	29681	31365	10032	9077	6275	1580	343	389	655	740	175	438	73	343
2001	311973	414666	391265	151212	146913	170557	53661	28734	18265	19553	6317	5757	4003	1011	220	250	421	475	112	282	268
2002	425951	222053	295126	277951	105397	98101	107623	33433	17989	11586	12532	4075	3730	2603	659	143	163	275	310	73	359
2003	343915	303179	158043	209609	192805	69119	61378	65487	20424	11129	7259	7915	2585	2374	1661	421	92	104	176	199	277
2004	269951	244789	215784	112341	145284	125953	43006	37473	40147	12649	6979	4597	5041	1652	1520	1066	271	59	67	113	306
2005	380035	192143	174226	153216	78206	93561	76689	25694	22429	24461	7781	4337	2878	3169	1041	960	674	171	37	42	265
2006	727875	270498	136751	123787	105827	51352	56880	45393	15158	13287	14659	4687	2626	1750	1931	635	586	412	105	23	188
2007	479143	518080	192520	97019	86337	68410	31487	33340	26536	8919	7869	8782	2819	1587	1061	1173	386	357	251	64	129
2008	1446850	341040	368727	136644	66874	57034	41713	18750	19721	15820	5359	4753	5351	1722	972	651	721	238	220	155	119
2009	639464	1029820	242717	261908	94463	42469	34655	24221	10861	11552	9354	3190	2841	3221	1039	588	394	437	144	133	166

Table 2.27—Projections for BSAI Pacific cod catch (t), spawning biomass (t), and fishing mortality under the assumption that $F = max\ F_{ABC}$ in 2010-2022 (Scenarios 1 and 2), with random variability in future recruitment.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2010	174,000	174,000	174,000	174,000	0
2011	214,000	214,000	214,000	214,000	26
2012	286,000	287,000	287,000	288,000	376
2013	312,000	319,000	321,000	336,000	8,196
2014	271,000	299,000	306,000	360,000	31,134
2015	236,000	289,000	299,000	389,000	52,747
2016	193,000	275,000	283,000	395,000	63,686
2017	168,000	267,000	271,000	389,000	68,553
2018	153,000	262,000	264,000	382,000	70,068
2019	143,000	257,000	258,000	385,000	71,098
2020	145,000	257,000	256,000	379,000	71,656
2021	146,000	254,000	256,000	380,000	71,911
2022	150,000	254,000	256,000	390,000	72,861

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2010	345,000	345,000	345,000	345,000	0
2011	370,000	370,000	370,000	370,000	44
2012	415,000	416,000	416,000	419,000	1,562
2013	462,000	470,000	472,000	489,000	9,580
2014	445,000	473,000	480,000	533,000	30,153
2015	416,000	475,000	486,000	589,000	58,900
2016	374,000	453,000	467,000	605,000	76,299
2017	348,000	440,000	454,000	610,000	85,165
2018	332,000	428,000	444,000	604,000	86,056
2019	318,000	419,000	435,000	600,000	84,916
2020	316,000	419,000	432,000	589,000	84,555
2021	320,000	415,000	430,000	586,000	84,617
2022	323,000	410,000	430,000	588,000	85,638

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2010	0.24	0.24	0.24	0.24	0.00
2011	0.26	0.26	0.26	0.26	0.00
2012	0.29	0.29	0.29	0.29	0.00
2013	0.29	0.29	0.29	0.29	0.00
2014	0.29	0.29	0.29	0.29	0.00
2015	0.29	0.29	0.29	0.29	0.00
2016	0.26	0.29	0.28	0.29	0.01
2017	0.24	0.29	0.28	0.29	0.02
2018	0.23	0.29	0.28	0.29	0.02
2019	0.22	0.29	0.27	0.29	0.02
2020	0.22	0.29	0.27	0.29	0.02
2021	0.22	0.29	0.27	0.29	0.02
2022	0.22	0.29	0.27	0.29	0.02

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 the most recent five-year average fishing mortality rate in 2010-2022 (Scenario 3), with random variability in future recruitment.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2010	105,000	105,000	105,000	105,000	0
2011	127,000	127,000	127,000	127,000	1
2012	160,000	160,000	160,000	160,000	185
2013	186,000	189,000	190,000	197,000	4,029
2014	174,000	189,000	192,000	220,000	15,958
2015	162,000	191,000	197,000	246,000	28,730
2016	150,000	187,000	193,000	254,000	34,460
2017	140,000	184,000	190,000	255,000	37,138
2018	134,000	182,000	187,000	257,000	38,111
2019	127,000	179,000	184,000	255,000	38,545
2020	125,000	178,000	183,000	252,000	39,055
2021	127,000	177,000	182,000	253,000	39,422
2022	128,000	175,000	181,000	257,000	40,173

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2010	349,000	349,000	349,000	349,000	0
2011	399,000	399,000	399,000	399,000	45
2012	475,000	476,000	476,000	479,000	1,571
2013	565,000	574,000	576,000	593,000	9,644
2014	589,000	618,000	624,000	679,000	31,196
2015	592,000	657,000	669,000	784,000	64,836
2016	559,000	653,000	670,000	831,000	90,043
2017	528,000	651,000	668,000	866,000	109,785
2018	500,000	644,000	662,000	875,000	118,609
2019	476,000	630,000	648,000	866,000	122,518
2020	458,000	627,000	643,000	866,000	125,214
2021	454,000	621,000	637,000	860,000	126,801
2022	453,000	619,000	634,000	858,000	128,793

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
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
2022	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 the upper bound on F_{ABC} is set at $F_{60\%}$ in 2010-2022 (Scenario 4), with random variability in future recruitment.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2010	106,000	106,000	106,000	106,000	0
2011	128,000	128,000	128,000	128,000	1
2012	161,000	162,000	162,000	162,000	187
2013	187,000	191,000	192,000	199,000	4,072
2014	176,000	190,000	194,000	222,000	16,122
2015	164,000	192,000	198,000	248,000	29,005
2016	150,000	188,000	194,000	256,000	34,771
2017	141,000	185,000	191,000	257,000	37,452
2018	135,000	183,000	188,000	258,000	38,423
2019	128,000	180,000	185,000	257,000	38,855
2020	126,000	179,000	184,000	254,000	39,367
2021	127,000	178,000	183,000	255,000	39,735
2022	129,000	176,000	183,000	259,000	40,492

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2010	349,000	349,000	349,000	349,000	0
2011	399,000	399,000	399,000	399,000	45
2012	474,000	475,000	476,000	478,000	1,571
2013	564,000	572,000	574,000	592,000	9,644
2014	587,000	616,000	623,000	677,000	31,185
2015	590,000	655,000	667,000	782,000	64,772
2016	556,000	650,000	667,000	828,000	89,890
2017	525,000	648,000	665,000	863,000	109,510
2018	497,000	641,000	659,000	871,000	118,249
2019	473,000	627,000	645,000	863,000	122,104
2020	455,000	624,000	640,000	862,000	124,769
2021	452,000	618,000	634,000	857,000	126,343
2022	451,000	616,000	631,000	854,000	128,326

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
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
2022	0.14	0.14	0.14	0.14	0.00

Table 2.30—Projections for BSAI Pacific cod catch (t), spawning biomass (t), and fishing mortality under the assumption that $F = 0$ in 2010-2022 (Scenario 5), with random variability in future recruitment.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
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
2022	0	0	0	0	0

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2010	355,000	355,000	355,000	355,000	0
2011	444,000	444,000	444,000	444,000	45
2012	565,000	566,000	567,000	570,000	1,572
2013	714,000	722,000	724,000	742,000	9,699
2014	799,000	829,000	835,000	891,000	32,212
2015	864,000	934,000	948,000	1,070,000	71,115
2016	867,000	977,000	996,000	1,190,000	105,810
2017	855,000	1,010,000	1,030,000	1,280,000	139,802
2018	839,000	1,030,000	1,050,000	1,340,000	160,007
2019	800,000	1,020,000	1,050,000	1,350,000	172,526
2020	790,000	1,020,000	1,050,000	1,380,000	180,842
2021	780,000	1,030,000	1,050,000	1,370,000	185,160
2022	777,000	1,020,000	1,050,000	1,380,000	188,990

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
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
2022	0.00	0.00	0.00	0.00	0.00

Table 2.31—Projections for BSAI Pacific cod catch (t), spawning biomass (t), and fishing mortality under the assumption that $F = F_{OFL}$ in 2010-2022 (Scenario 6), with random variability in future recruitment.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2010	205,000	205,000	205,000	205,000	0
2011	238,000	238,000	238,000	238,000	29
2012	314,000	315,000	315,000	318,000	1,565
2013	350,000	358,000	360,000	378,000	9,525
2014	291,000	328,000	336,000	400,000	36,948
2015	228,000	312,000	318,000	428,000	65,779
2016	188,000	288,000	294,000	430,000	78,905
2017	165,000	274,000	282,000	425,000	81,233
2018	155,000	265,000	274,000	417,000	81,657
2019	146,000	262,000	270,000	414,000	82,057
2020	148,000	262,000	269,000	412,000	82,564
2021	149,000	259,000	269,000	415,000	82,806
2022	153,000	261,000	270,000	429,000	83,879

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2010	343,000	343,000	343,000	343,000	0
2011	357,000	358,000	358,000	358,000	43
2012	394,000	396,000	396,000	399,000	1,497
2013	432,000	440,000	442,000	459,000	9,203
2014	405,000	432,000	438,000	490,000	29,453
2015	370,000	424,000	435,000	534,000	56,008
2016	335,000	400,000	415,000	542,000	69,186
2017	314,000	390,000	404,000	541,000	73,490
2018	302,000	382,000	397,000	537,000	72,431
2019	294,000	378,000	391,000	527,000	70,978
2020	294,000	378,000	389,000	522,000	70,906
2021	294,000	378,000	389,000	524,000	71,185
2022	298,000	377,000	390,000	529,000	72,171

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2010	0.29	0.29	0.29	0.29	0.00
2011	0.30	0.30	0.30	0.30	0.00
2012	0.33	0.33	0.33	0.34	0.00
2013	0.35	0.35	0.35	0.35	0.00
2014	0.34	0.35	0.35	0.35	0.00
2015	0.31	0.35	0.34	0.35	0.01
2016	0.28	0.34	0.33	0.35	0.02
2017	0.26	0.33	0.32	0.35	0.03
2018	0.25	0.32	0.31	0.35	0.03
2019	0.24	0.32	0.31	0.35	0.04
2020	0.24	0.32	0.31	0.35	0.04
2021	0.24	0.32	0.31	0.35	0.04
2022	0.25	0.32	0.31	0.35	0.04

Table 2.32—Projections for BSAI Pacific cod catch (t), spawning biomass (t), and fishing mortality under the assumption that $F = max\ F_{ABC}$ in each year 2010-2011 and $F = F_{OFL}$ thereafter (Scenario 7), with random variability in future recruitment.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2010	174,000	174,000	174,000	174,000	0
2011	214,000	214,000	214,000	214,000	26
2012	338,000	338,000	338,000	339,000	451
2013	355,000	363,000	366,000	384,000	9,784
2014	298,000	331,000	339,000	403,000	36,692
2015	231,000	313,000	321,000	429,000	65,339
2016	189,000	290,000	295,000	431,000	78,851
2017	166,000	274,000	282,000	426,000	81,306
2018	155,000	265,000	275,000	417,000	81,714
2019	146,000	263,000	270,000	414,000	82,090
2020	148,000	262,000	269,000	413,000	82,581
2021	149,000	259,000	269,000	415,000	82,813
2022	153,000	261,000	270,000	429,000	83,883

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2010	345,000	345,000	345,000	345,000	0
2011	370,000	370,000	370,000	370,000	44
2012	412,000	413,000	413,000	416,000	1,562
2013	442,000	450,000	452,000	469,000	9,559
2014	411,000	438,000	445,000	497,000	29,752
2015	373,000	428,000	439,000	538,000	56,386
2016	336,000	402,000	417,000	544,000	69,602
2017	314,000	391,000	405,000	542,000	73,823
2018	302,000	383,000	397,000	537,000	72,634
2019	293,000	378,000	391,000	527,000	71,082
2020	294,000	378,000	389,000	522,000	70,952
2021	293,000	378,000	389,000	524,000	71,204
2022	298,000	377,000	390,000	529,000	72,178

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2010	0.24	0.24	0.24	0.24	0.00
2011	0.26	0.26	0.26	0.26	0.00
2012	0.35	0.35	0.35	0.35	0.00
2013	0.35	0.35	0.35	0.35	0.00
2014	0.35	0.35	0.35	0.35	0.00
2015	0.31	0.35	0.34	0.35	0.01
2016	0.28	0.34	0.33	0.35	0.02
2017	0.26	0.33	0.32	0.35	0.03
2018	0.25	0.32	0.31	0.35	0.03
2019	0.24	0.32	0.31	0.35	0.04
2020	0.24	0.32	0.31	0.35	0.04
2021	0.24	0.32	0.31	0.35	0.04
2022	0.25	0.32	0.31	0.35	0.04

Table 2.33—Discarded catch (t) of species groups by BSAI Pacific cod fisheries, 2005-2009.

Species group	2005	2006	2007	2008	2009
Alaska plaice flounder	387	329	390	41	8
Arrowtooth flounder	3679	3900	2491	1694	1165
Atka mackerel	722	615	128	77	20
Benthic urochordata	11	5	1	2	0
Birds	9	6	6	6	3
Bivalves	6	7	4	11	9
Brittle star unidentified	0	1	1	0	0
Capelin			0	0	
Corals Bryozoans	14	13	18	13	10
Dark Rockfish				3	1
Eelpouts	42	17	18	7	1
Eulachon	0	0	0	0	
Flathead sole	1434	2269	2685	575	329
General flounder	1204	512	449	97	57
Giant Grenadier	144	195	127	158	63
Greenland turbot	24	31	84	66	13
Greenlings	2	6	1	2	0
Grenadier	192	50	94	15	0
Gunnels	0		0		
Hermit crab unidentified	2	2	2	1	1
Invertebrate unidentified	3	31	22	5	11
Large Sculpins	2455	2223	2484	1759	1066
Majestic squid	1	0	1	0	
Misc crabs	5	17	29	6	1
Misc crustaceans	1	1	1	0	0
Misc fish	225	109	114	54	56
Misc inverts (worms etc)	0	0	0	0	0
Northern rockfish	27	45	10	7	3
Octopus	311	331	166	194	51
Other osmerids	0	0	0		0
Other rockfish	23	21	24	21	5
Other Sculpins	346	450	367	299	186
Other species	15225	12678	11796	10893	8074
Pacific cod	2750	1784	1639	1448	1245
Pacific ocean perch	56	23	15	2	1
Pacific sand lance	0	0	0	0	
Pandalid shrimp	0	0	0	0	0
Polychaete unidentified	0	0	0	0	0
Rock sole	4676	2598	2368	725	361
Rougheye rockfish	4	1	2	4	1
Sablefish	16	13	4	2	0
Scypho jellies	401	67	113	42	71
Sea anemone unidentified	114	78	38	49	86
Sea pens whips	30	16	7	9	32
Sea star	446	322	244	188	118
Shark, Other	10	4	2	1	0
Shark, Pacific sleeper	191	123	44	12	12
Shark, salmon	2	1			0
Shark, spiny dogfish	11	7	3	10	5
Shortraker rockfish	5	2	16	2	12
Skate, Big	174	248	74	49	65
Skate, Longnose	21	20	1	1	1
Skate, Other	19254	14634	13383	14241	9887
Snails	13	17	16	20	20
Sponge unidentified	32	39	21	6	18
Squid	3	1	0	0	0
Stichaeidae	0	0	0	0	0
urchins dollars cucumbers	13	5	14	3	1
Walleye pollock	6913	8691	12650	4109	2503
Yellowfin sole	1685	1153	782	695	366
Total	63309	53712	52951	37623	25936

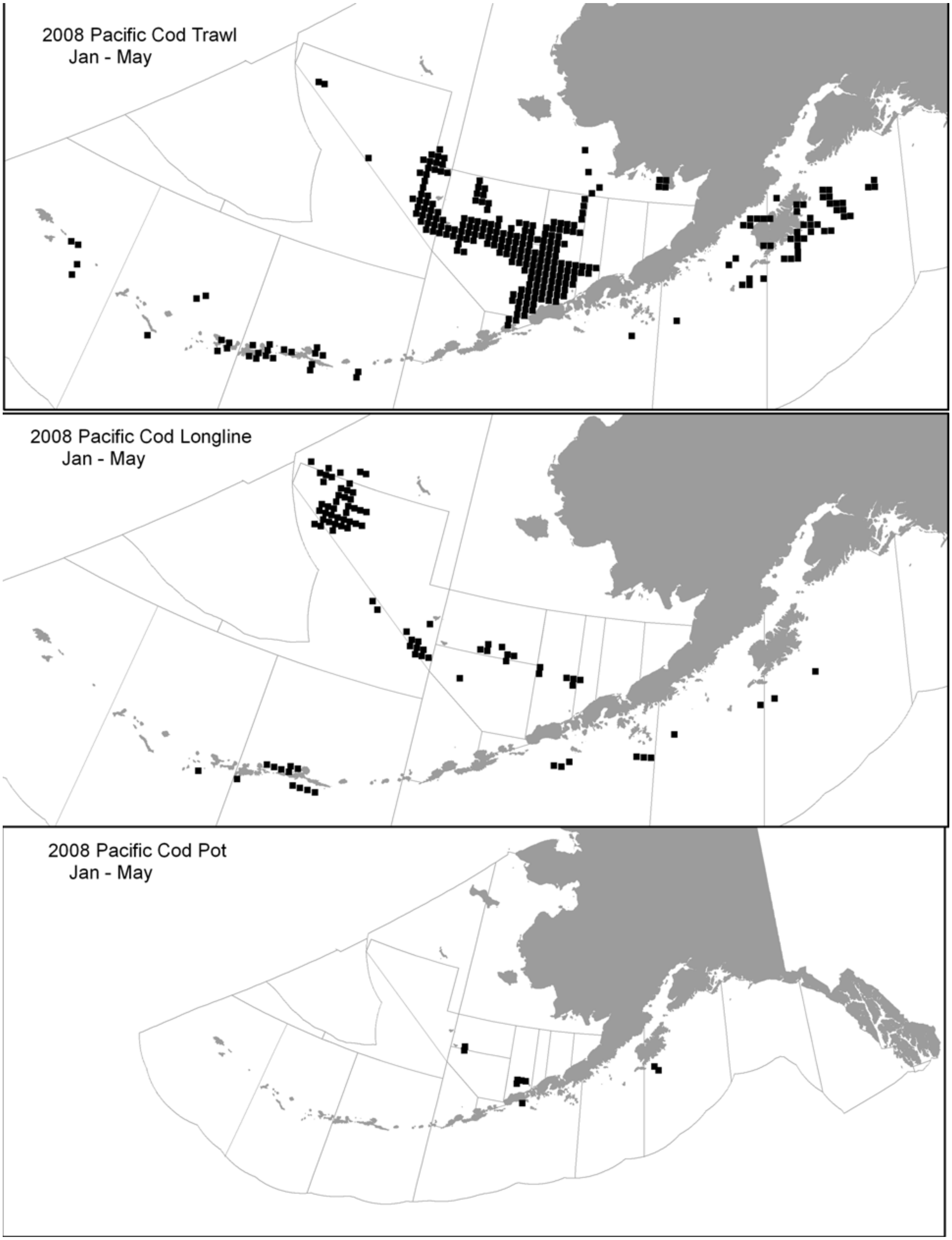

Figure 2.1a—Maps showing each 400 square kilometer cell with hauls/sets containing Pacific cod from at least 3 distinct vessels, January-May 2008, by gear type, overlaid against NMFS 3-digit statistical areas.

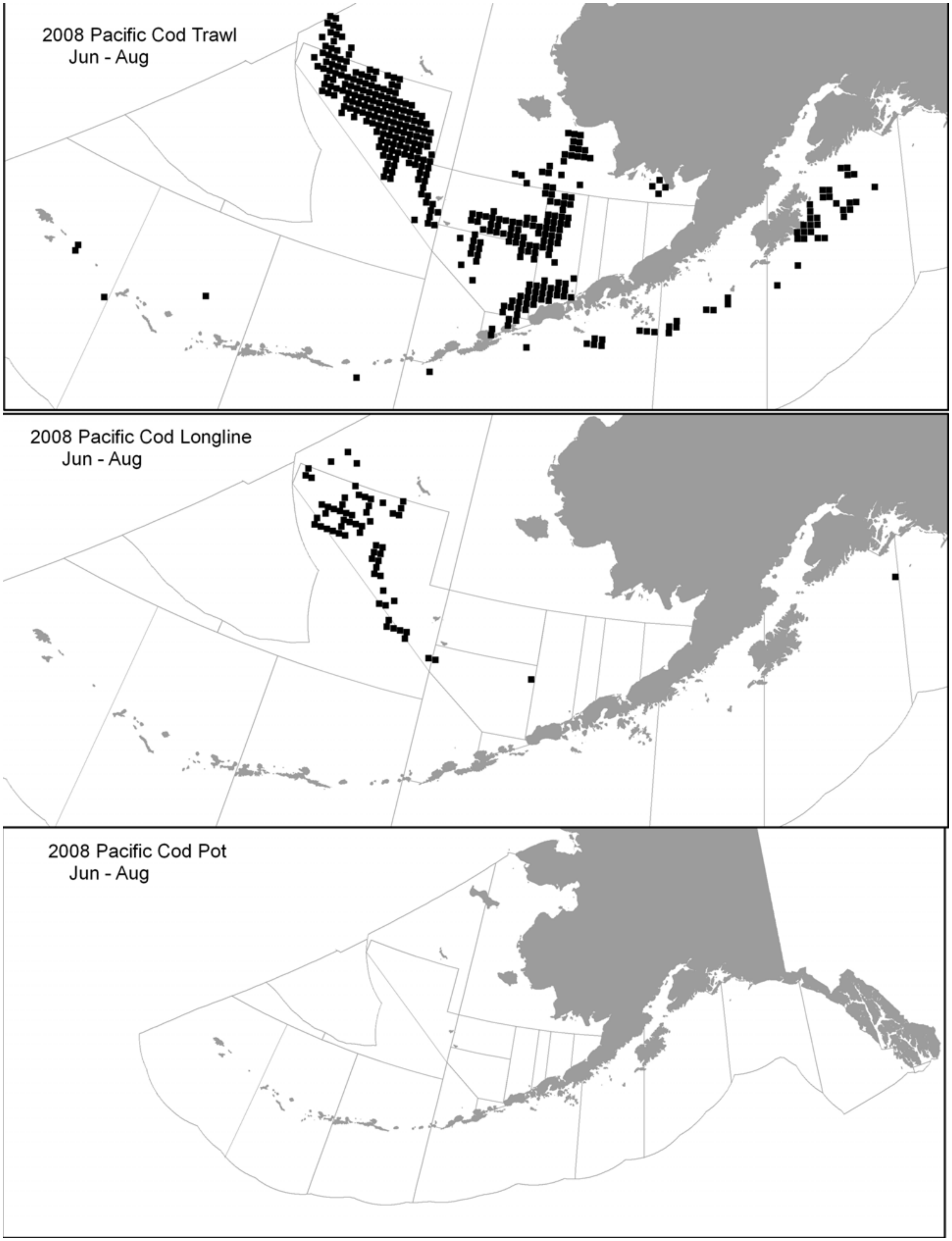

Figure 2.1b—Maps showing each 400 square kilometer cell with hauls/sets containing Pacific cod from at least 3 distinct vessels, June-August 2008, by gear type, overlaid against NMFS 3-digit statistical areas.

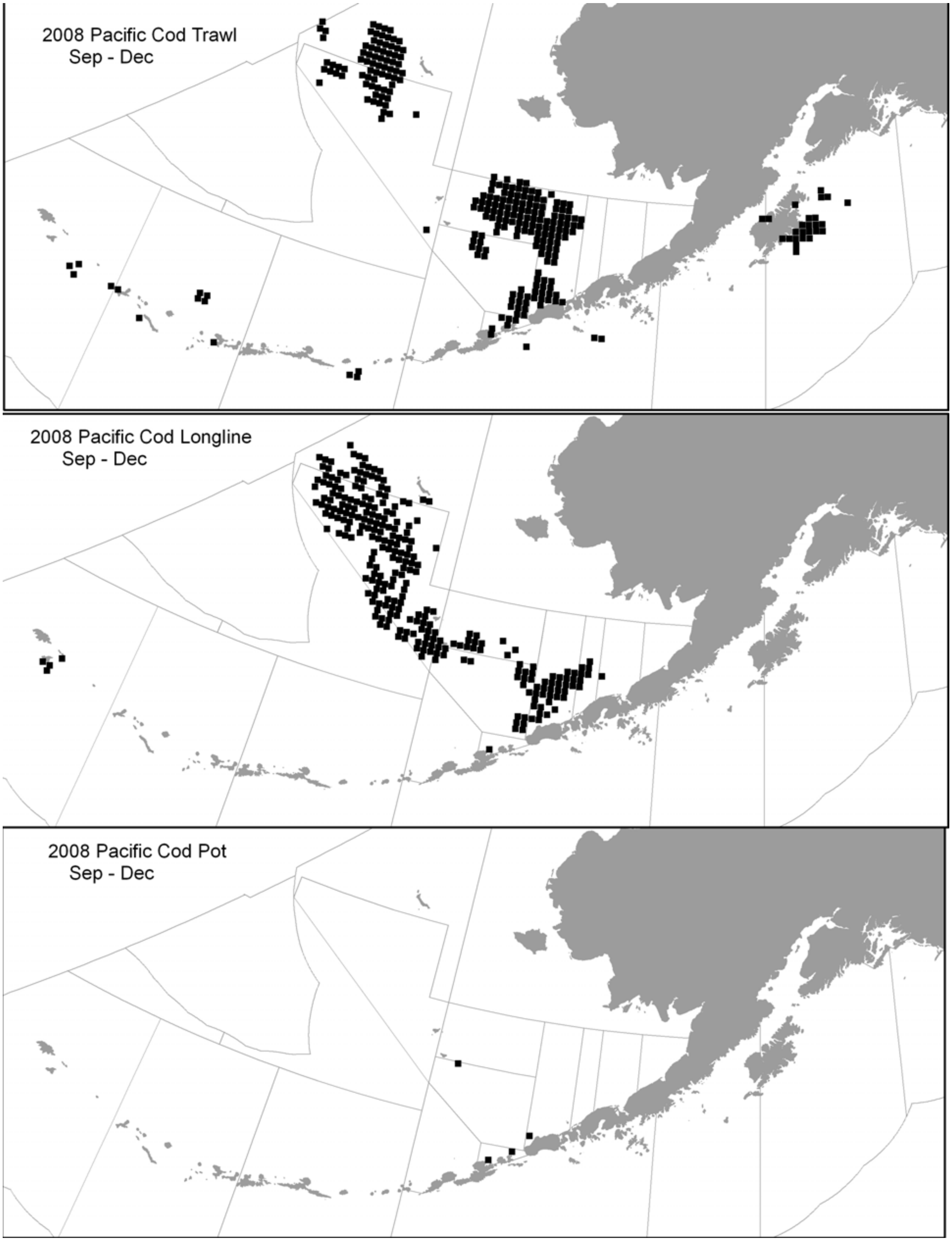

Figure 2.1c—Maps showing each 400 square kilometer cell with hauls/sets containing Pacific cod from at least 3 distinct vessels, Sept.-Dec. 2008, by gear type, overlaid against NMFS 3-digit statistical areas.

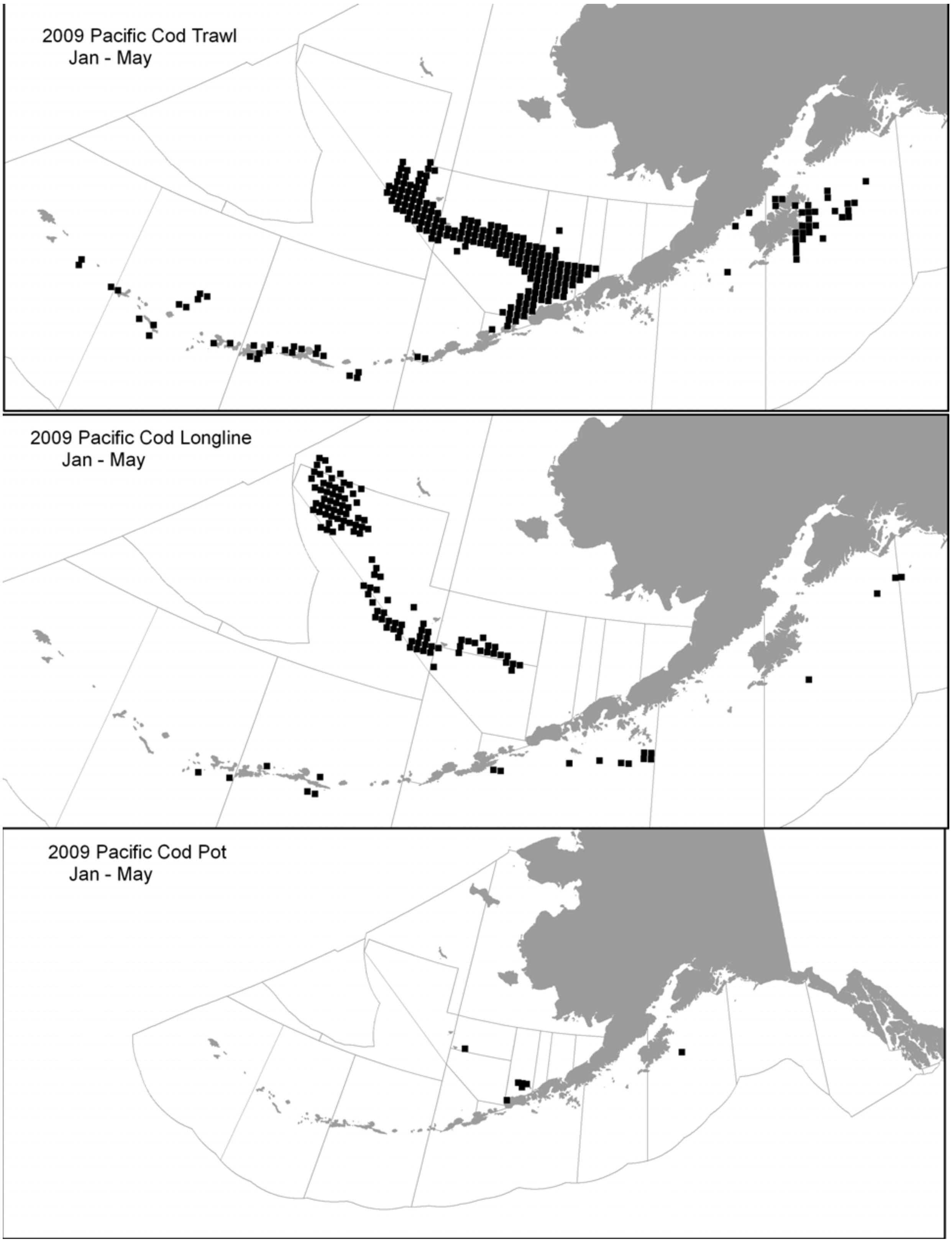

Figure 2.1d—Maps showing each 400 square kilometer cell with hauls/sets containing Pacific cod from at least 3 distinct vessels, January-May 2009, by gear type, overlaid against NMFS 3-digit statistical areas.

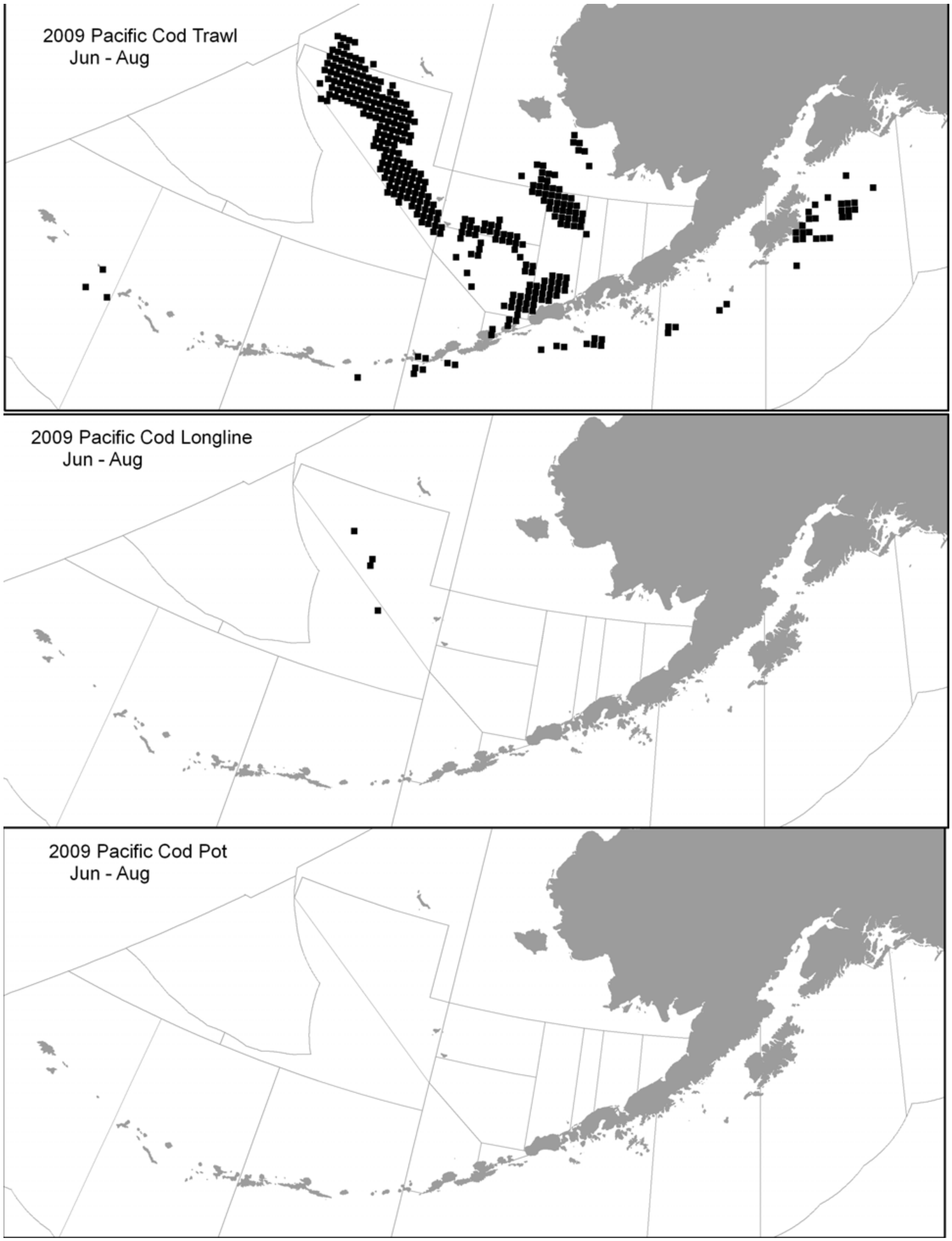

Figure 2.1e—Maps showing each 400 square kilometer cell with hauls/sets containing Pacific cod from at least 3 distinct vessels, June-August 2009, by gear type, overlaid against NMFS 3-digit statistical areas.

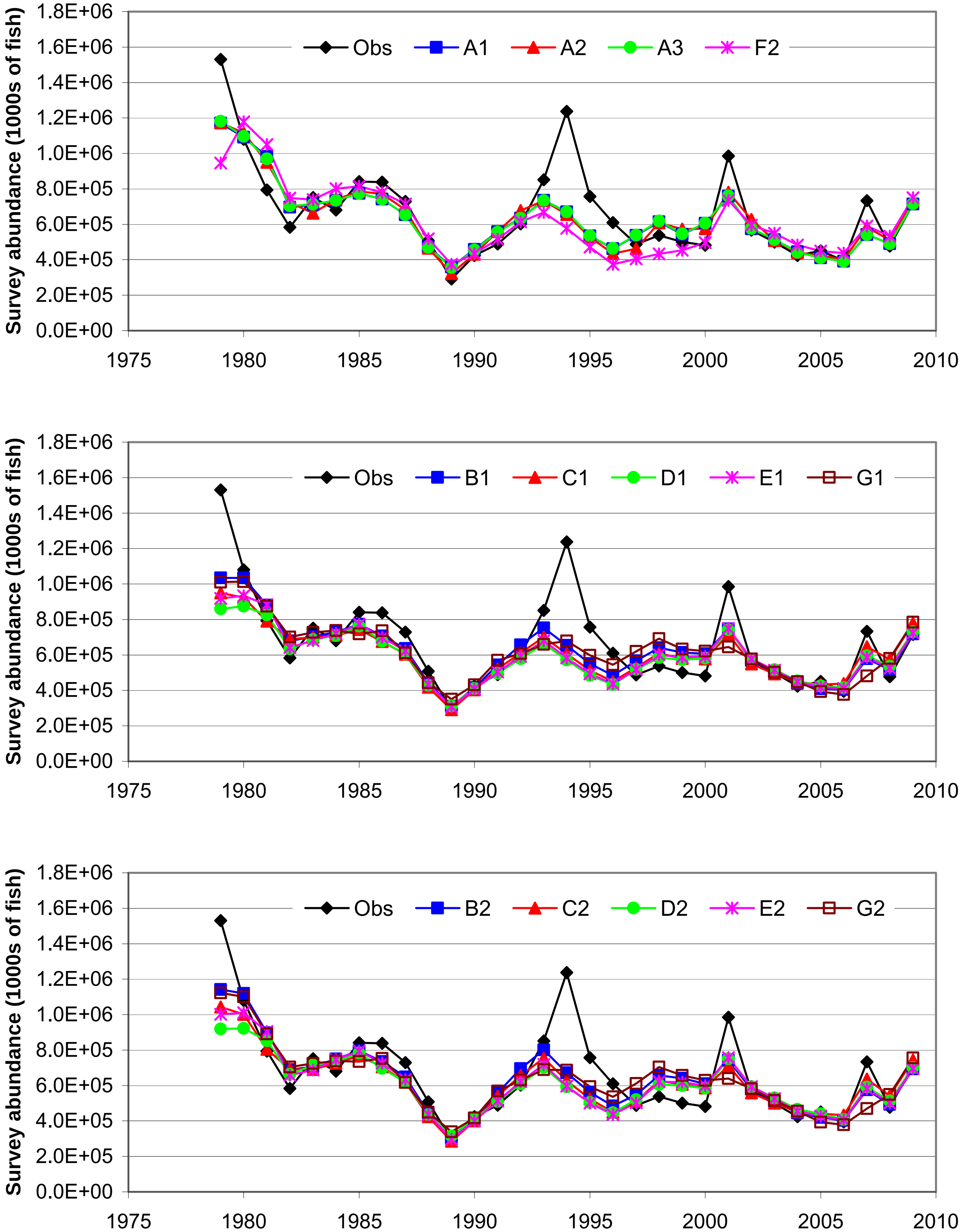

Figure 2.2—Fits of the 14 models to the trawl survey abundance time series.

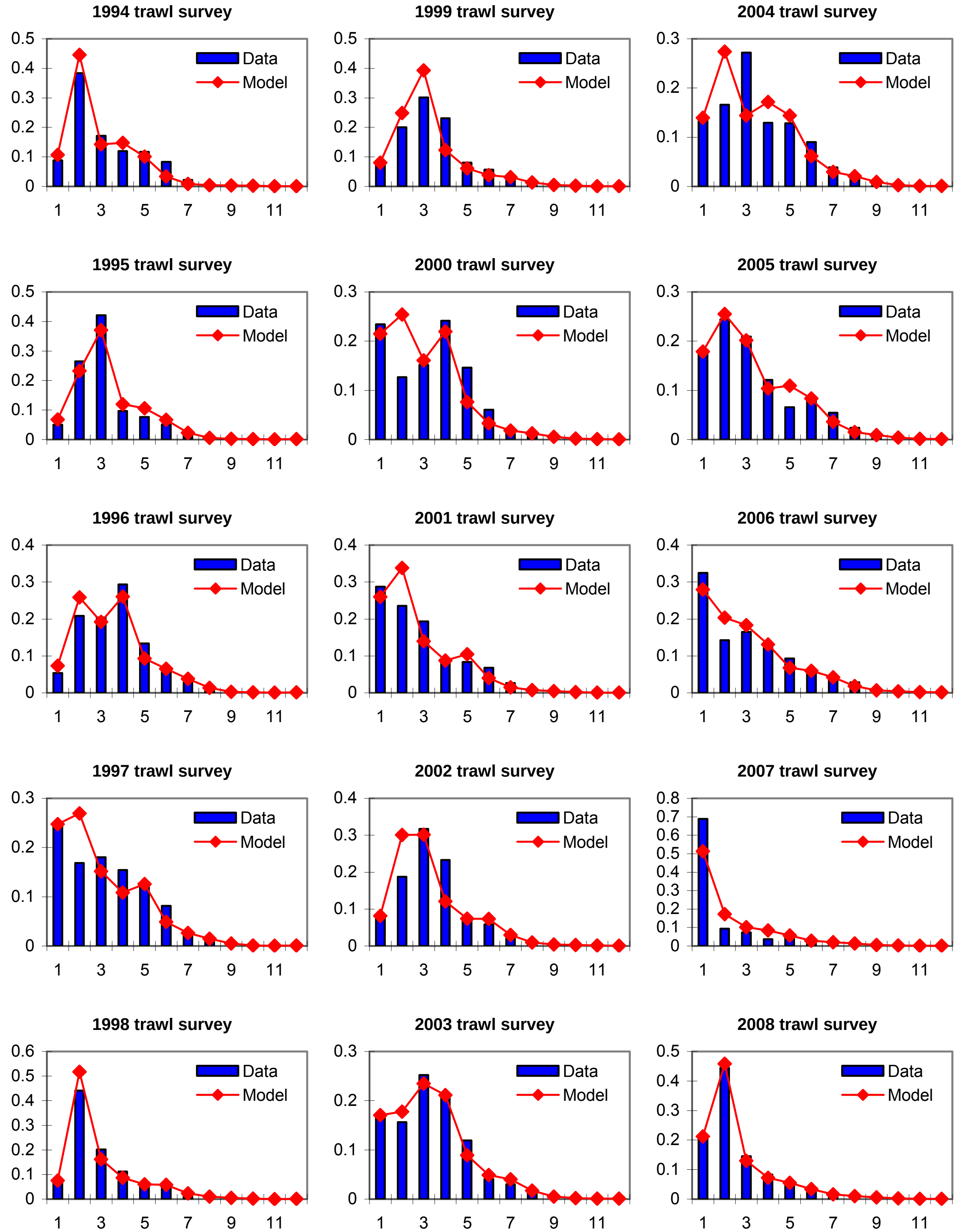

Figure 2.3A1—Fit to trawl survey age composition data obtained by Model A1.

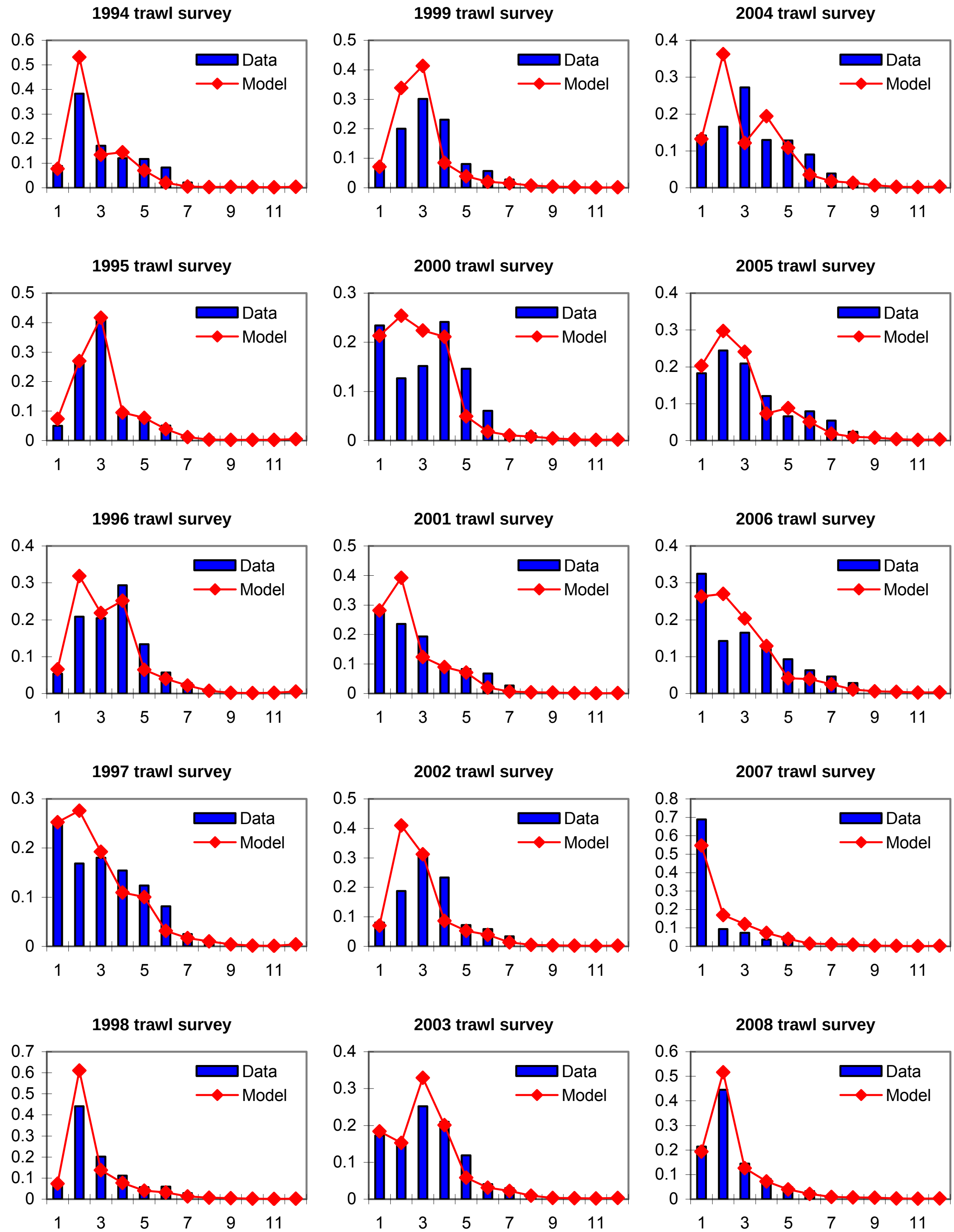

Figure 2.3A2—Fit to trawl survey age composition data obtained by Model A2.

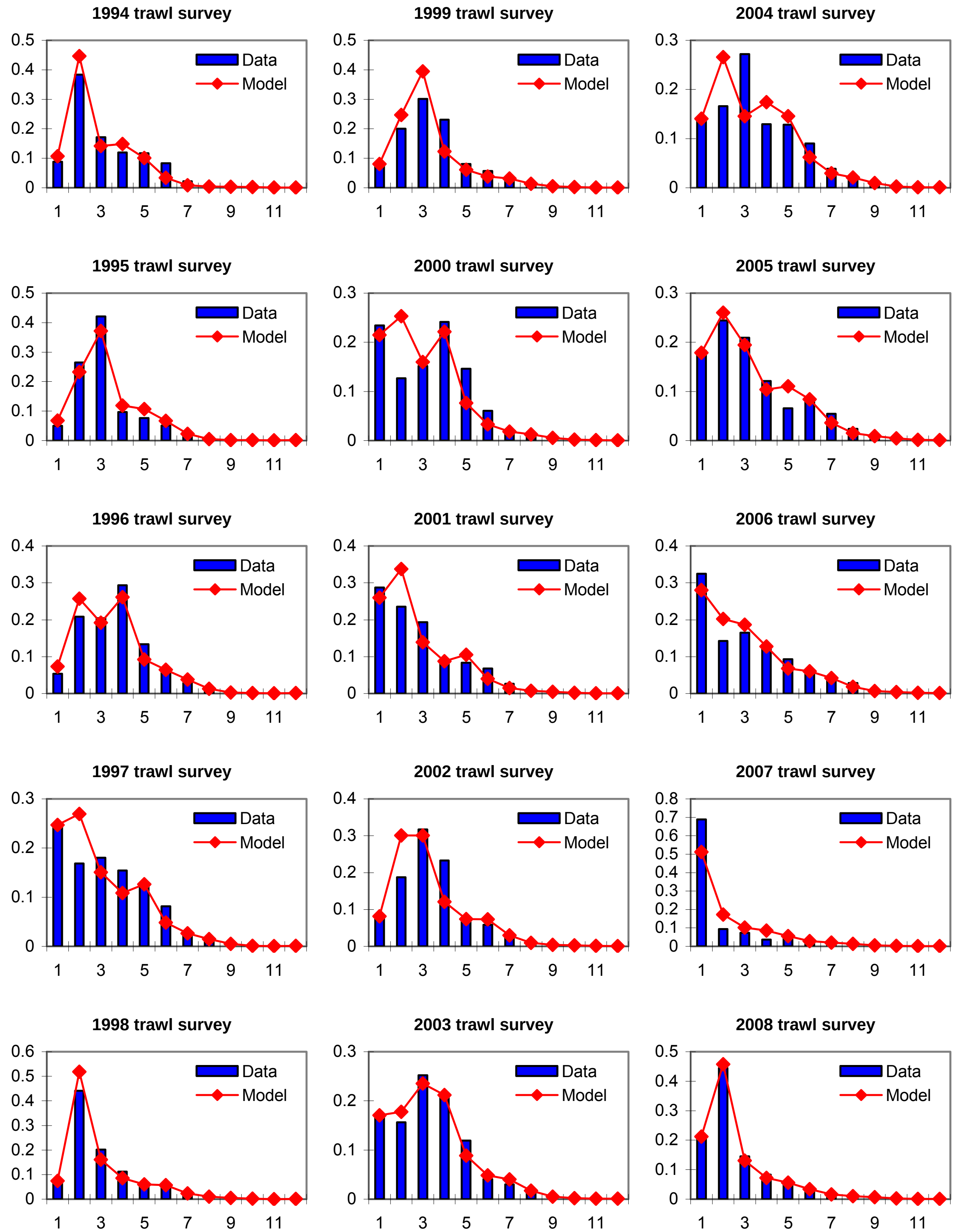

Figure 2.3A3—Fit to trawl survey age composition data obtained by Model A3.

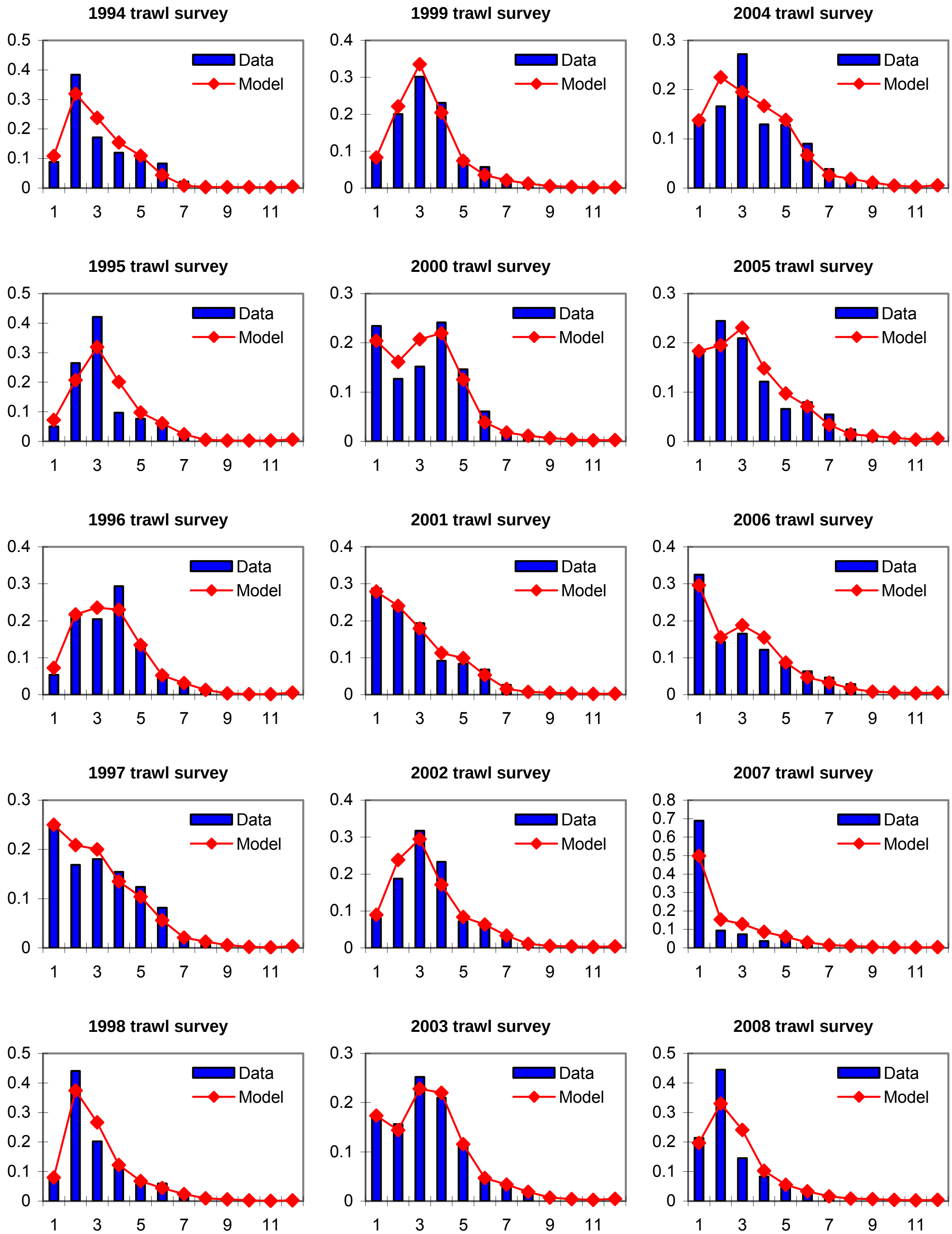

Figure 2.3B1—Fit to trawl survey age composition data obtained by Model B1.

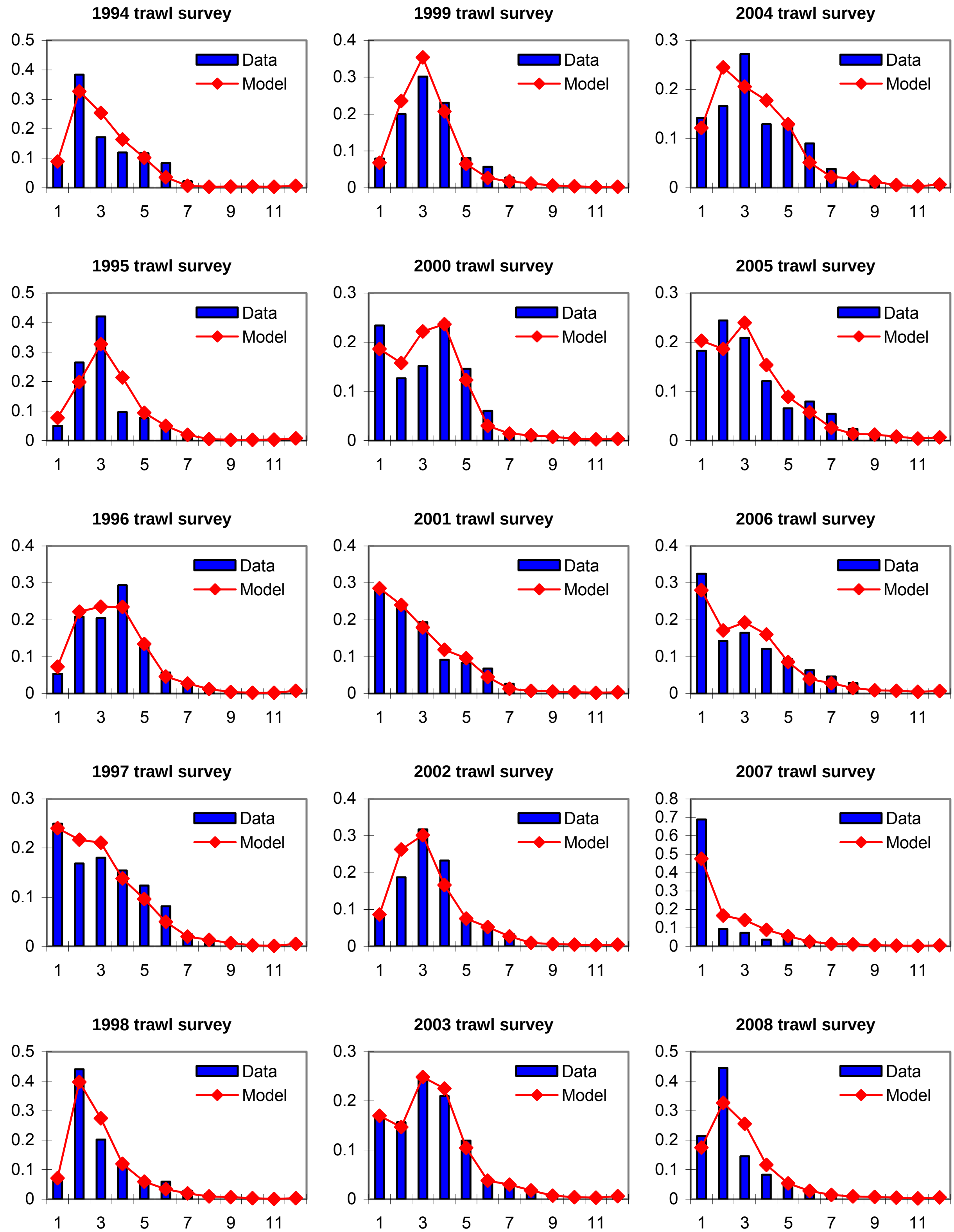

Figure 2.3B2—Fit to trawl survey age composition data obtained by Model B2.

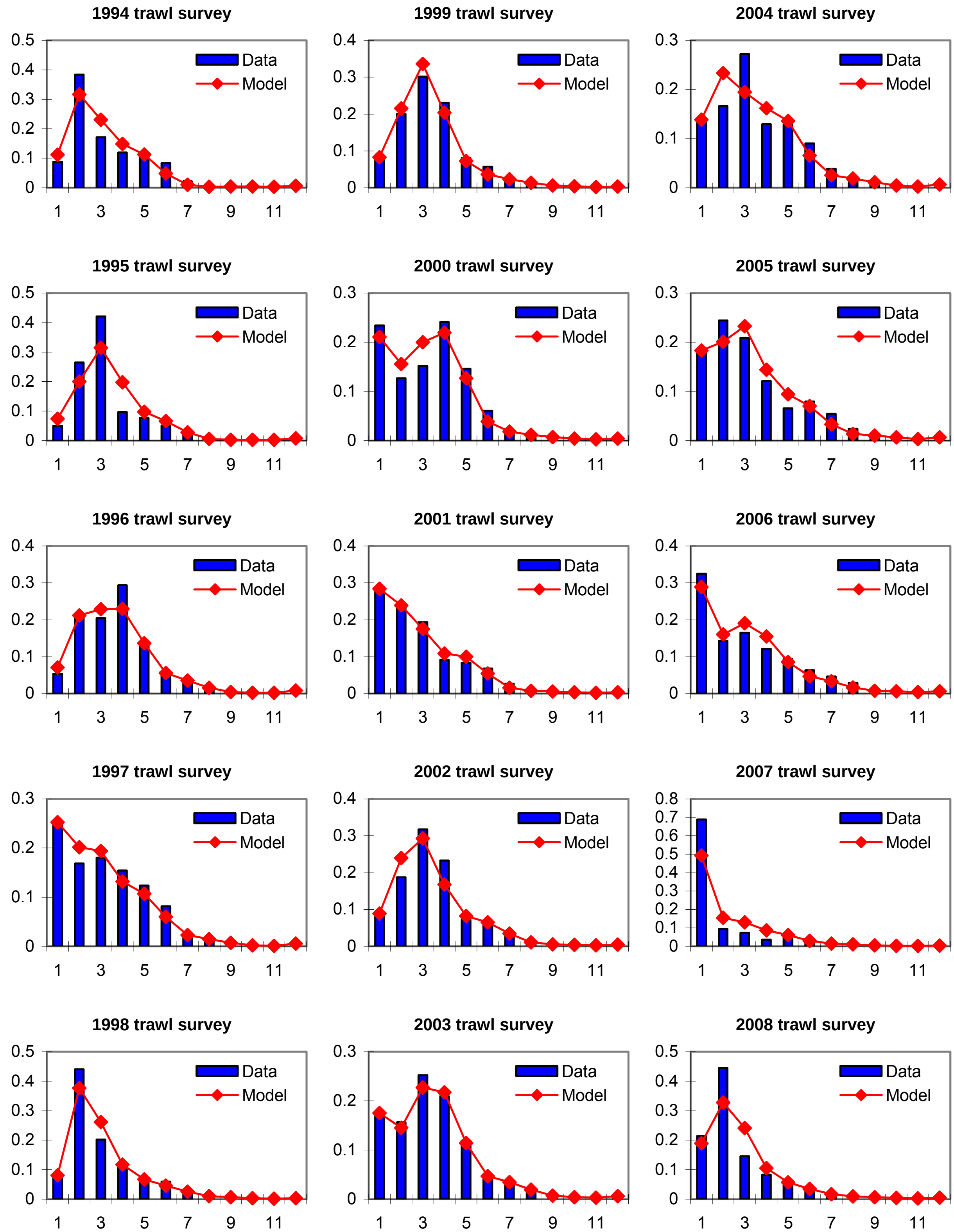

Figure 2.3C1—Fit to trawl survey age composition data obtained by Model C1.

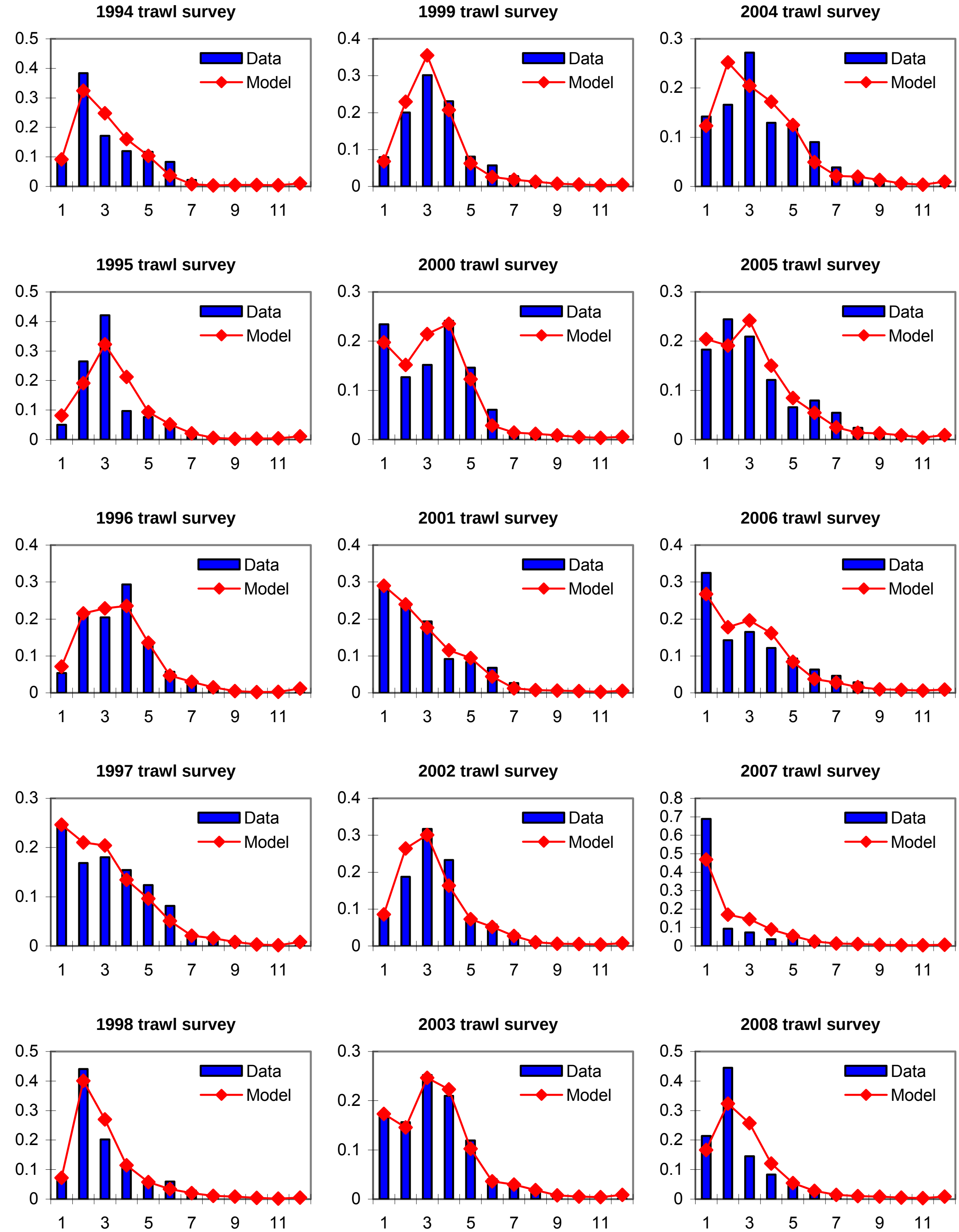

Figure 2.3C2—Fit to trawl survey age composition data obtained by Model C2.

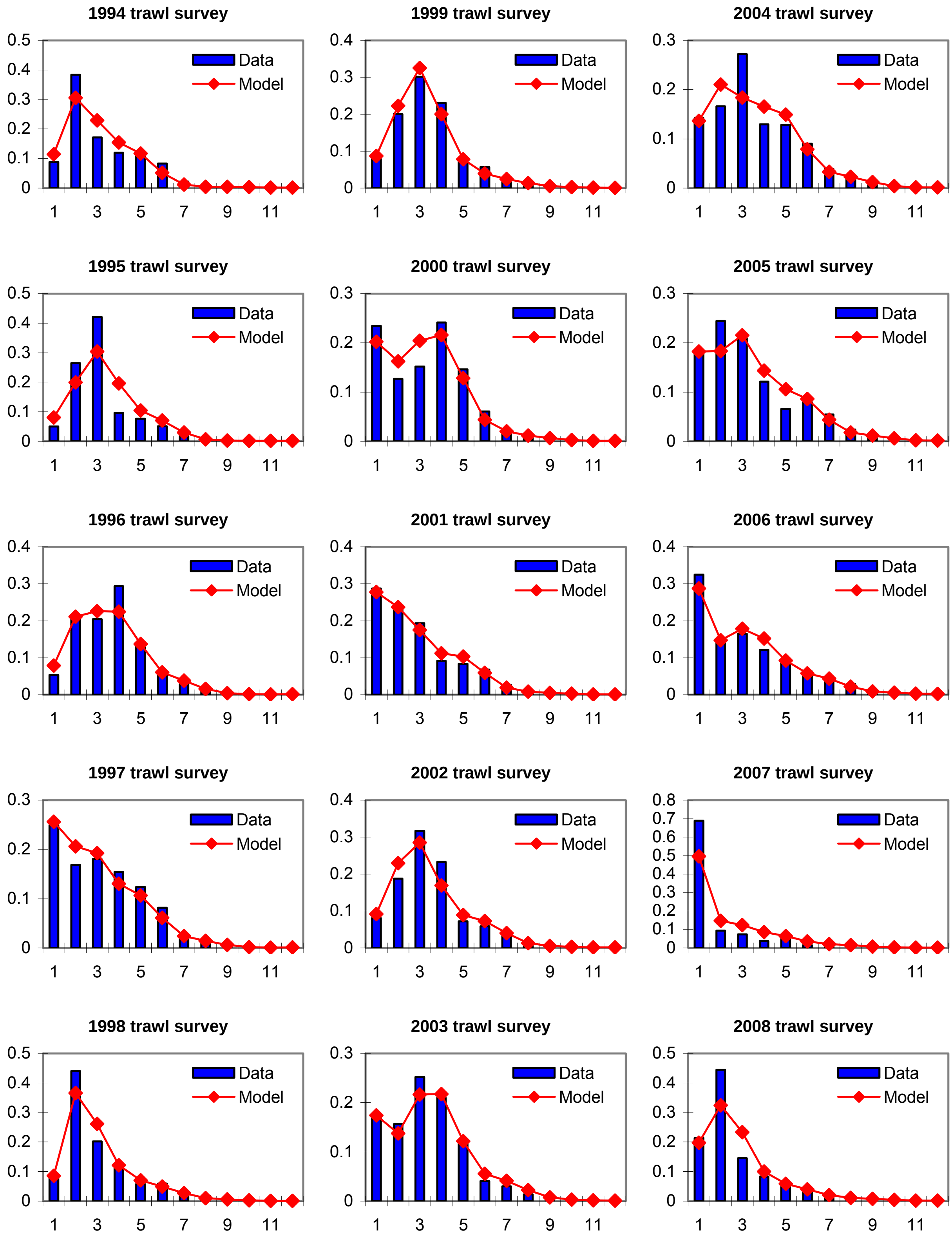

Figure 2.3D1—Fit to trawl survey age composition data obtained by Model D1.

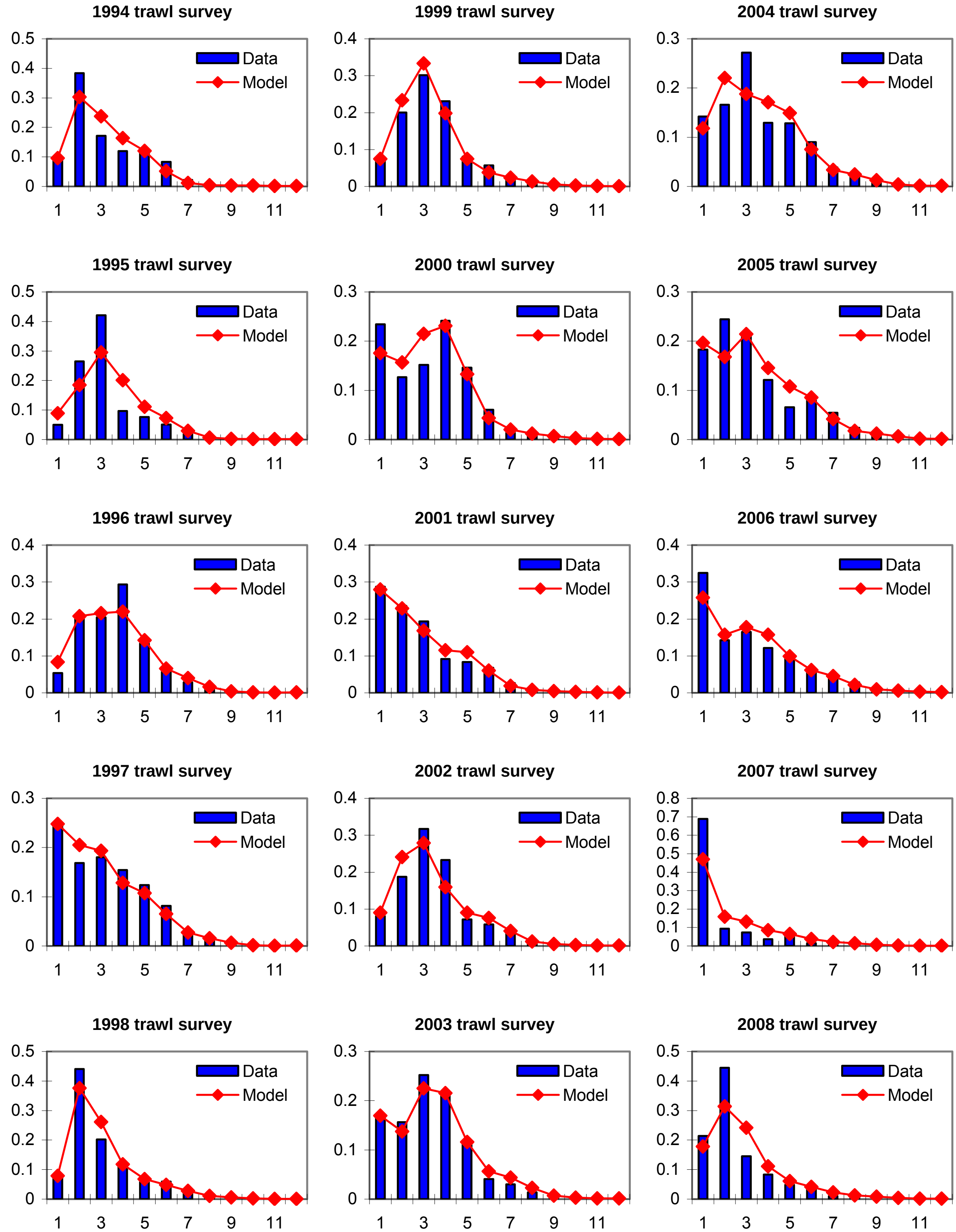

Figure 2.3D2—Fit to trawl survey age composition data obtained by Model D2.

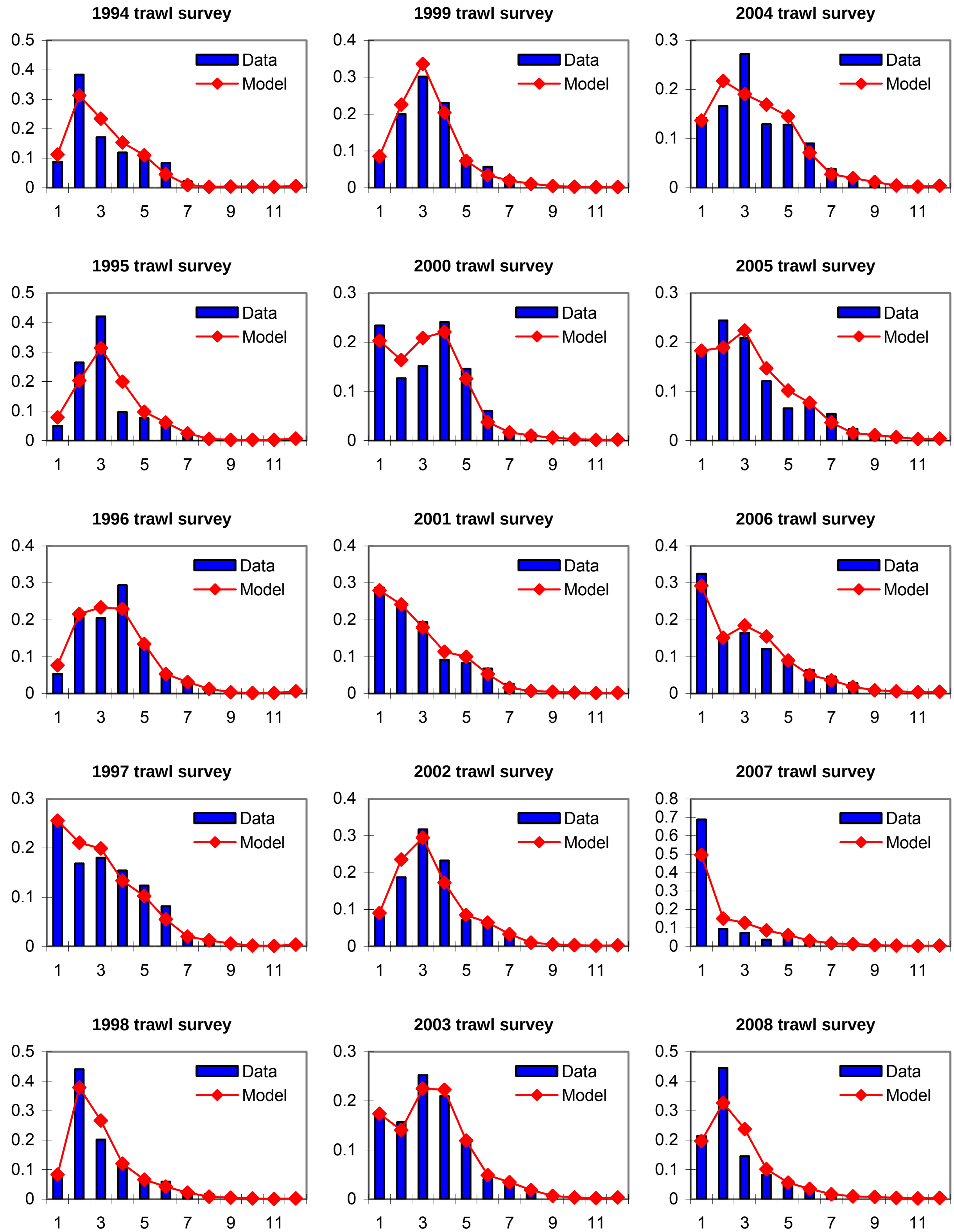

Figure 2.3E1—Fit to trawl survey age composition data obtained by Model E1.

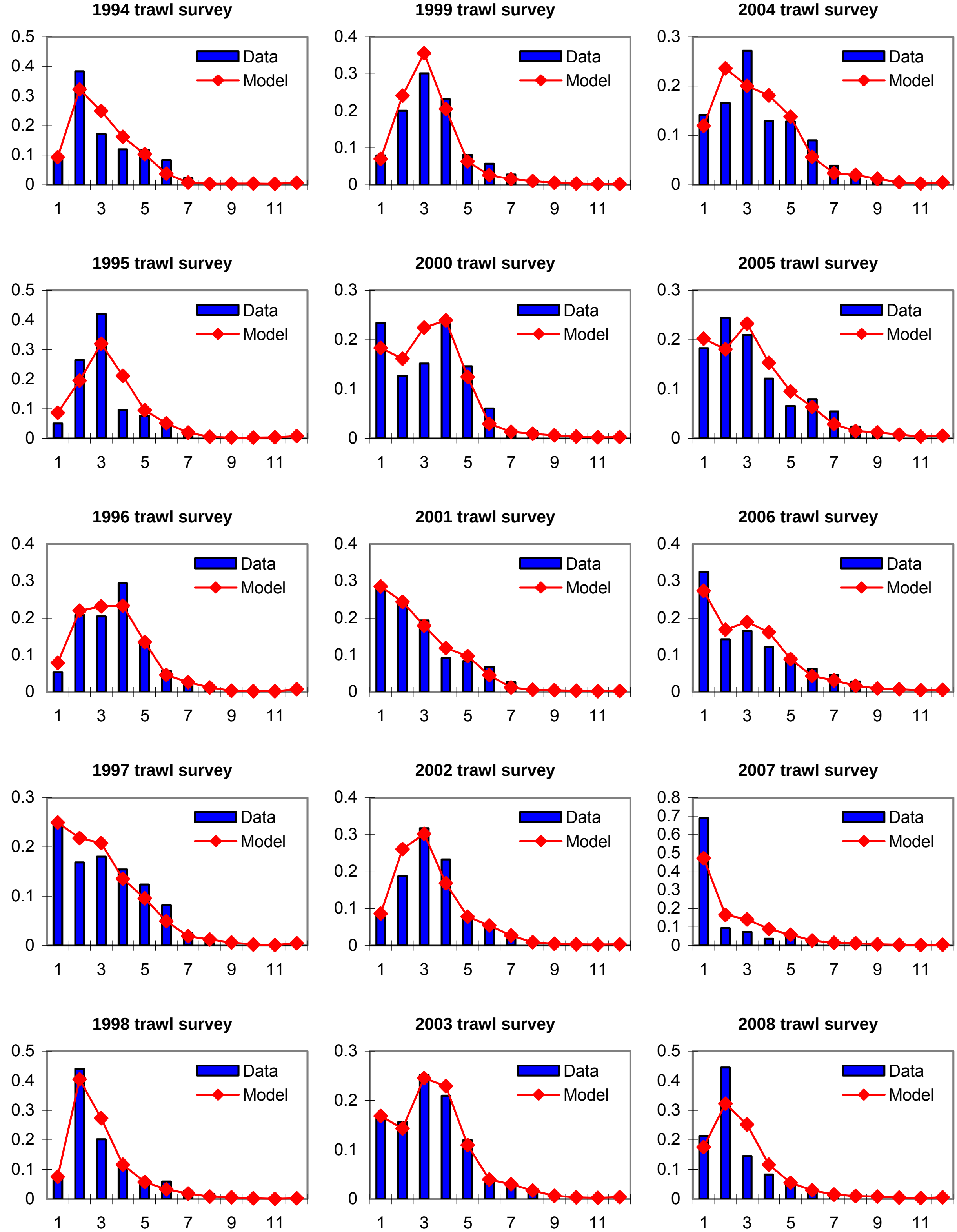

Figure 2.3E2—Fit to trawl survey age composition data obtained by Model E2.

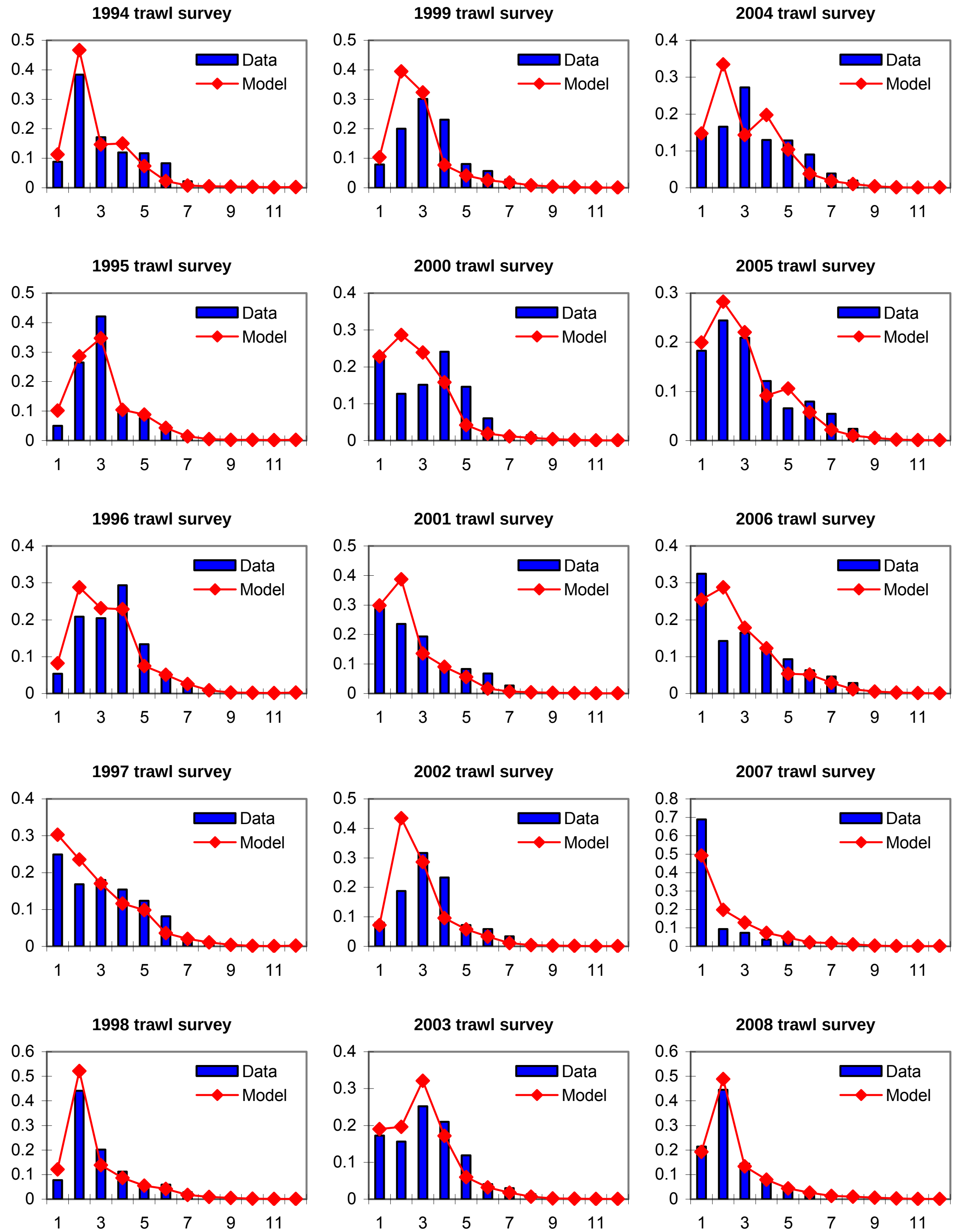

Figure 2.3F2—Fit to trawl survey age composition data obtained by Model F2.

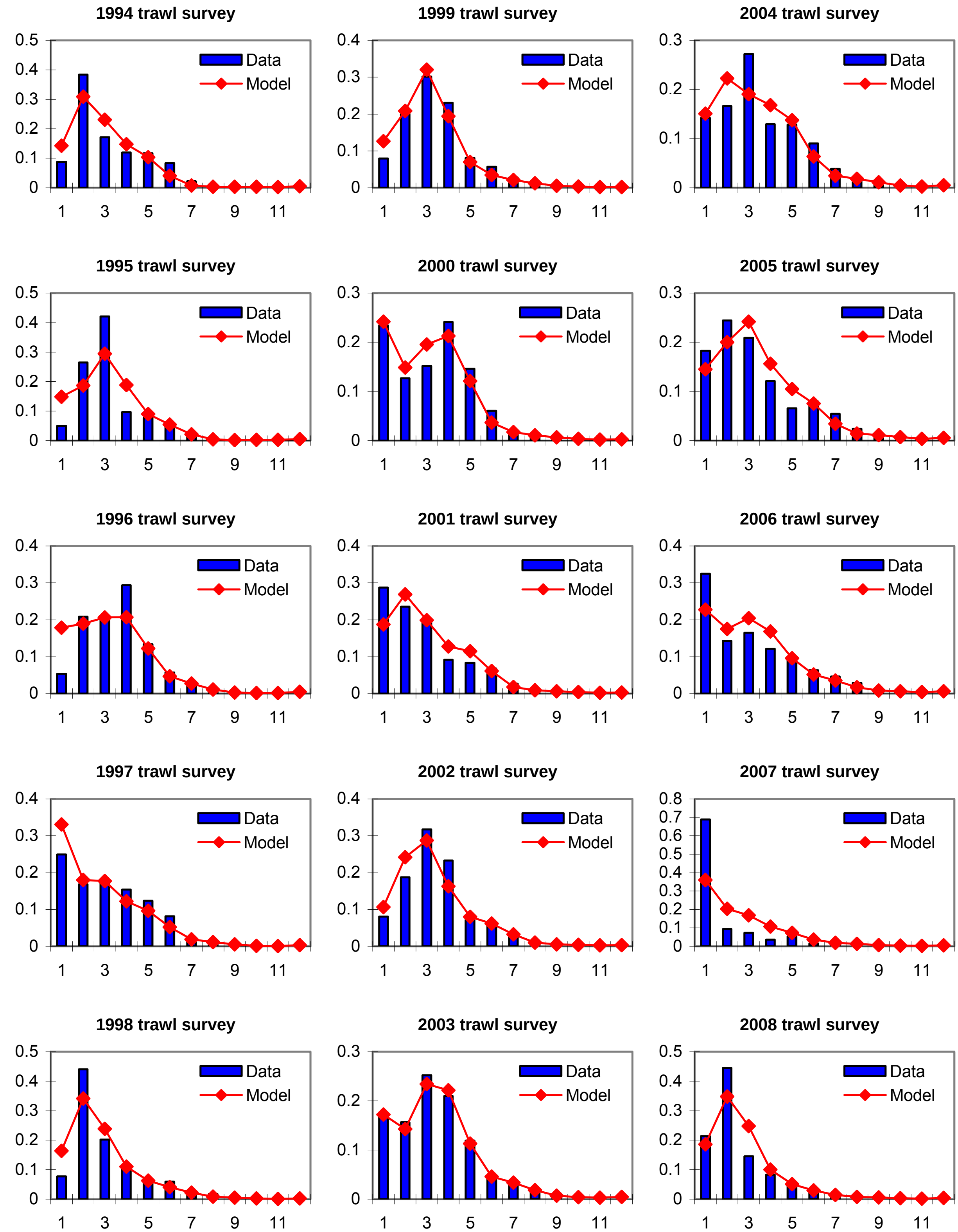

Figure 2.3G1—Fit to trawl survey age composition data obtained by Model G1.

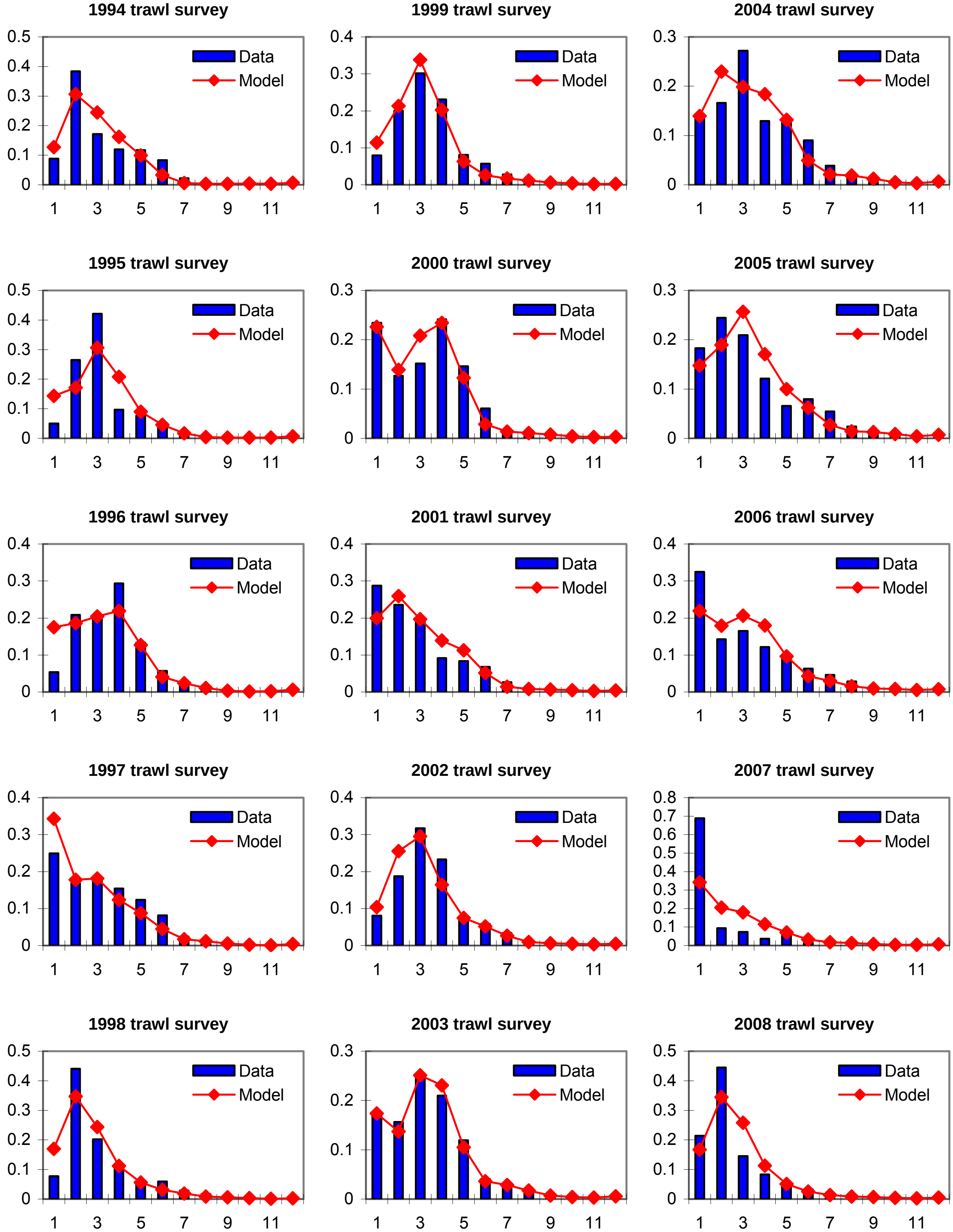

Figure 2.3G2—Fit to trawl survey age composition data obtained by Model G2.

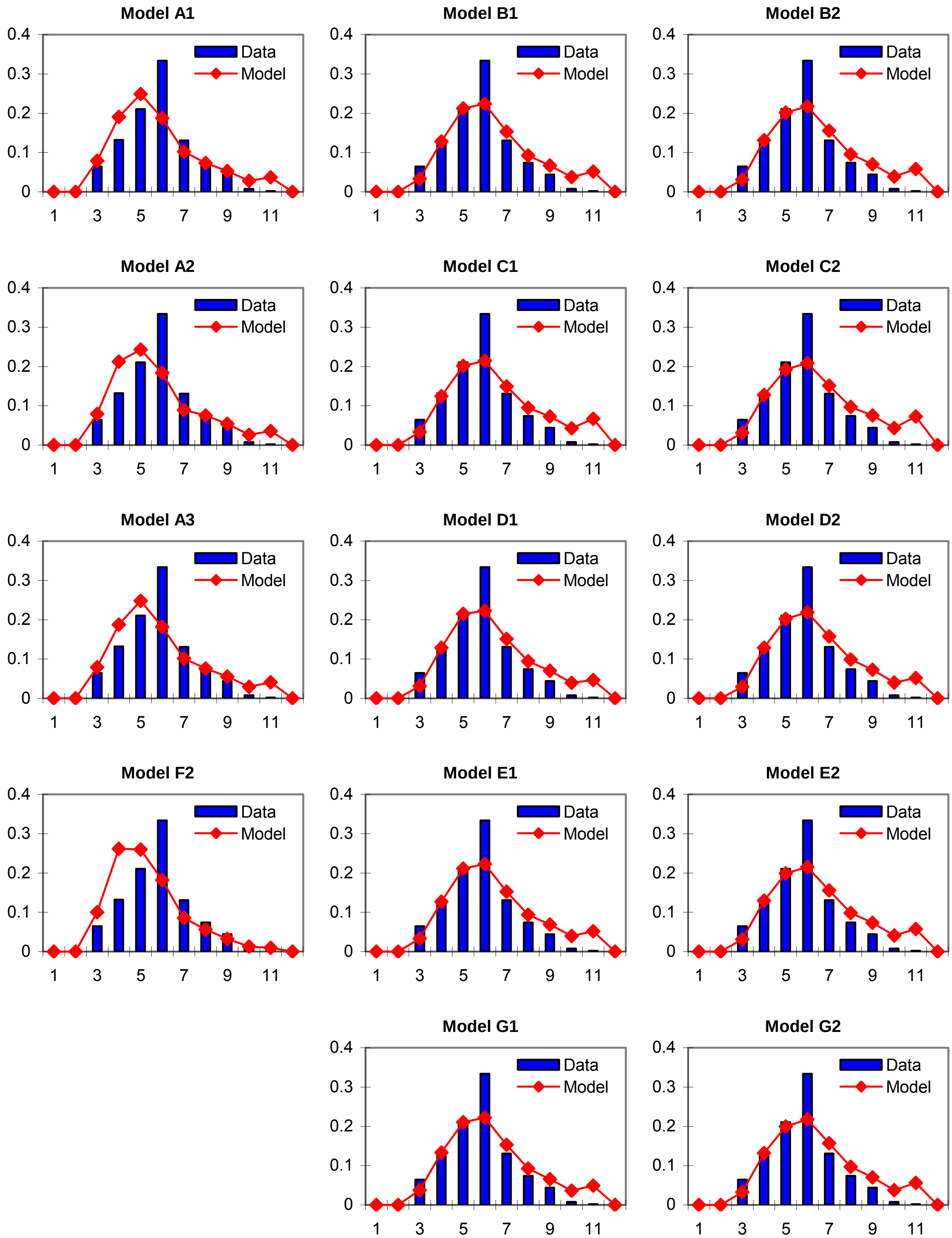

Figure 2.4—Fits to the 2008 Jan-May longline fishery age composition data obtained by the 14 models.

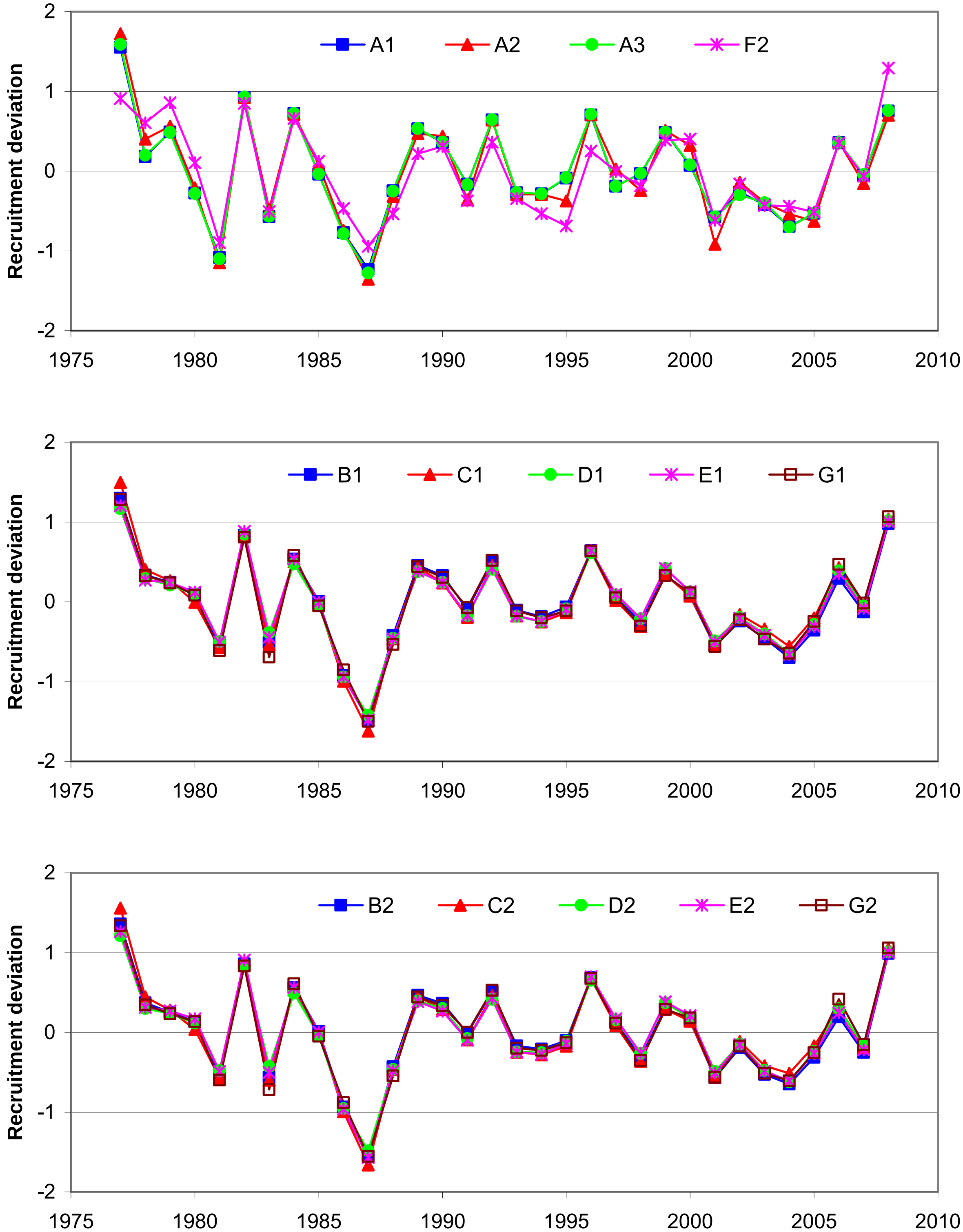

Figure 2.5—Time series of estimated recruitment deviations from the 14 models. Note that the pre-1977 deviations are with respect to the pre-1977 log median.

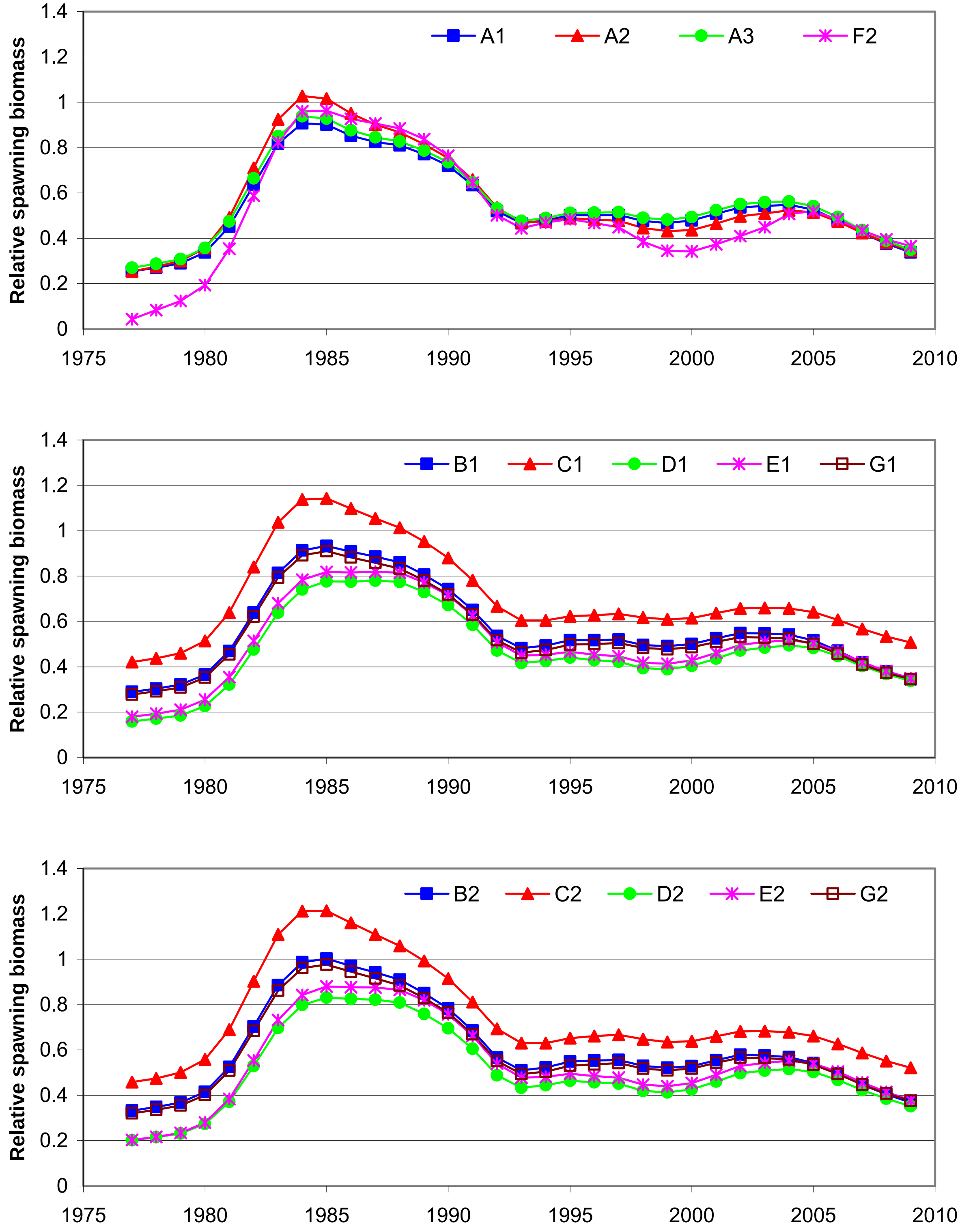

Figure 2.6—Time series of relative spawning biomass as estimated by the 14 models.

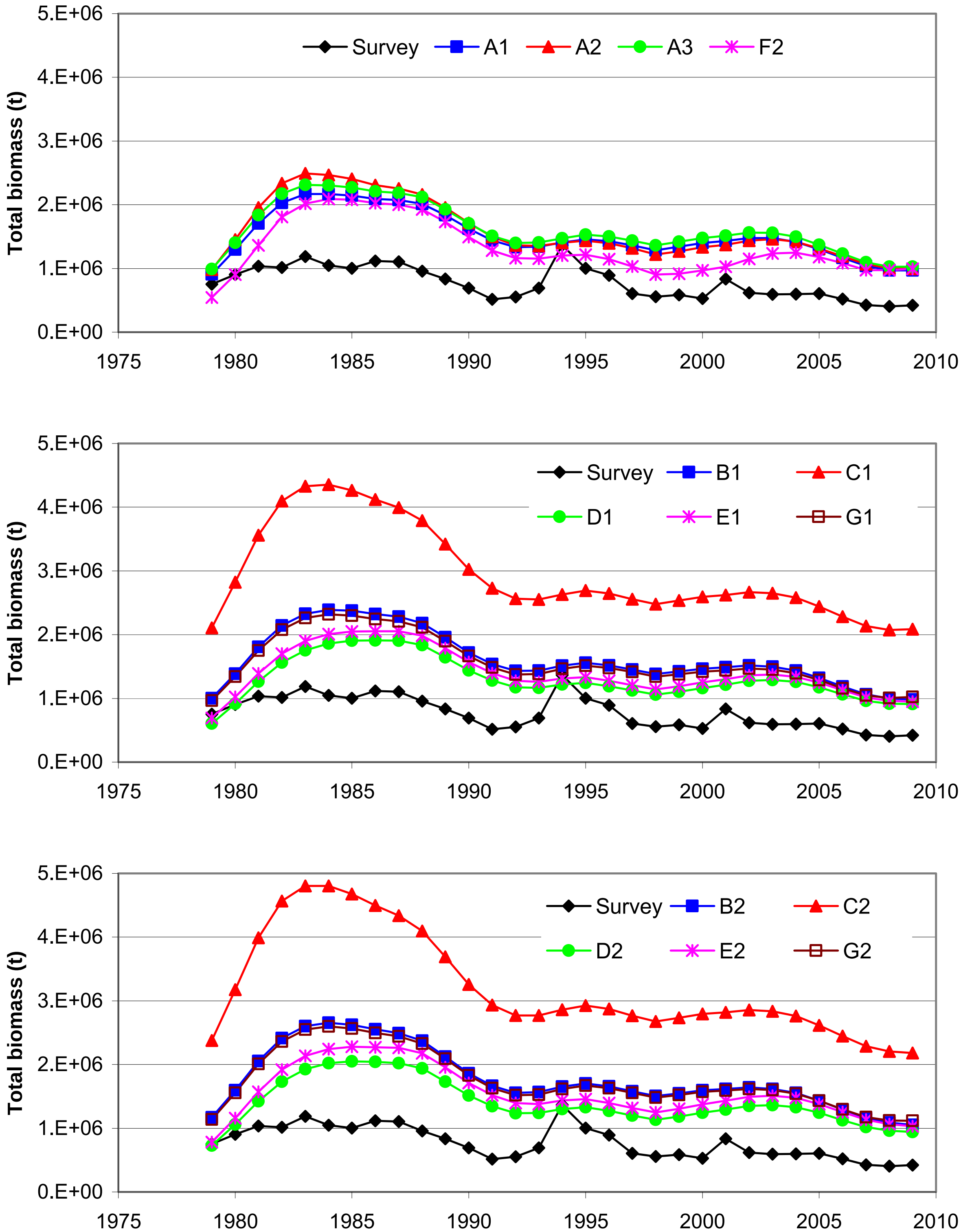

Figure 2.7—Time series of total (age 0+) biomass as estimated by the 14 models. Survey biomass is shown for comparison.

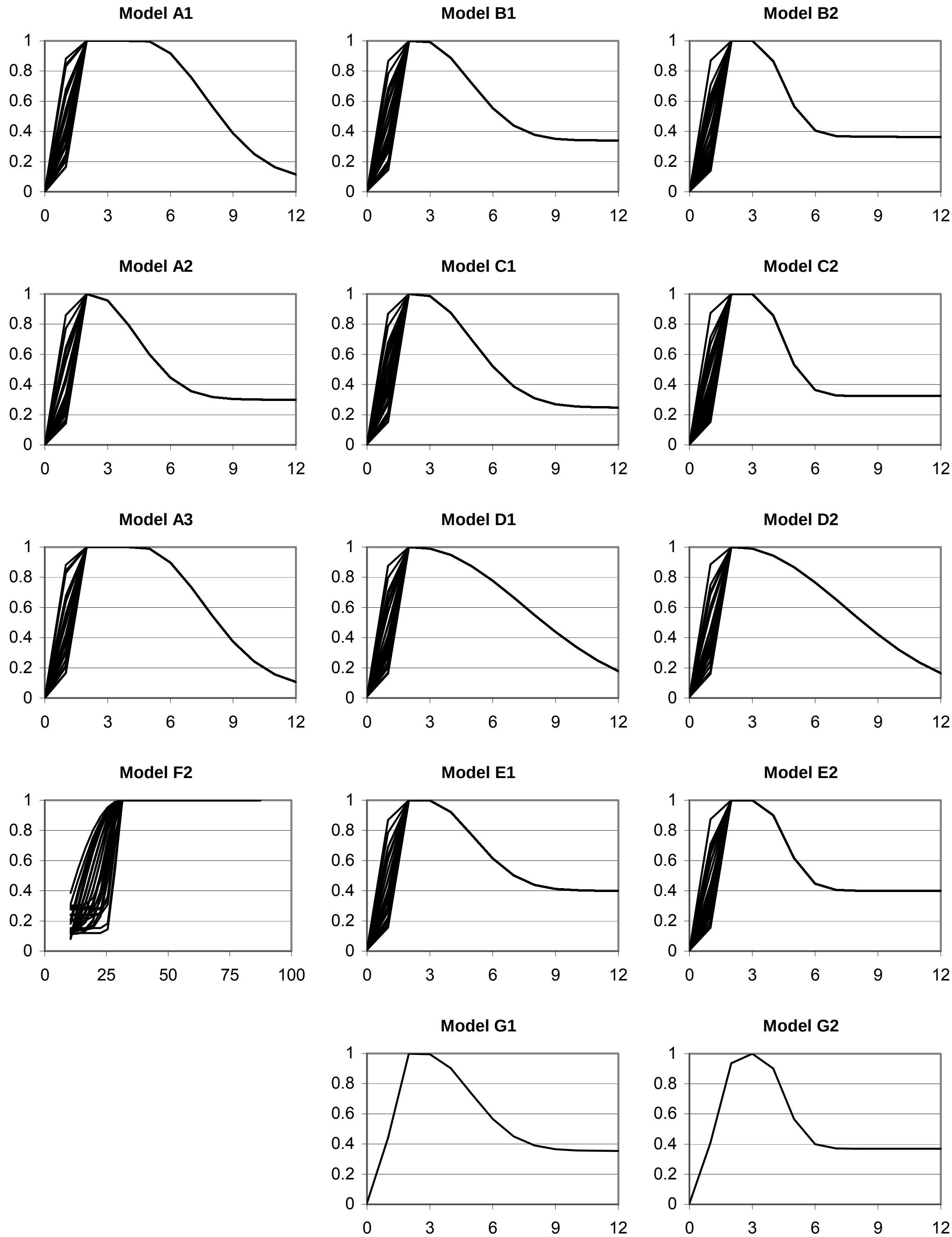

Figure 2.8—Post-1981 trawl survey selectivity as estimated by the 14 models. “Dev” parameters affect the ascending limb annually in all models except G1 and G2. F2 selectivity is size-based, not age-based.

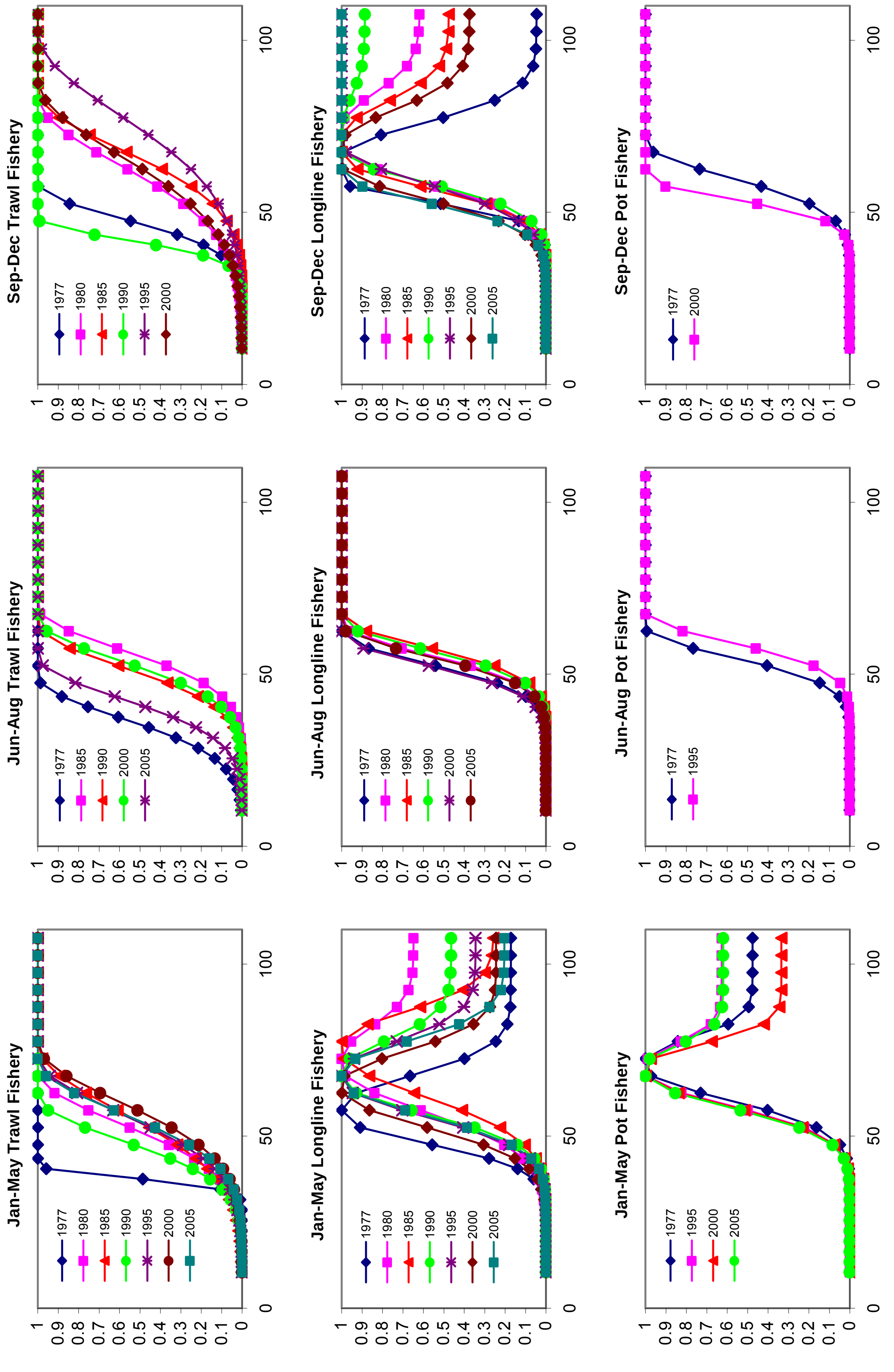

Figure 2.9A1—Fishery selectivities as estimated by Model A1.

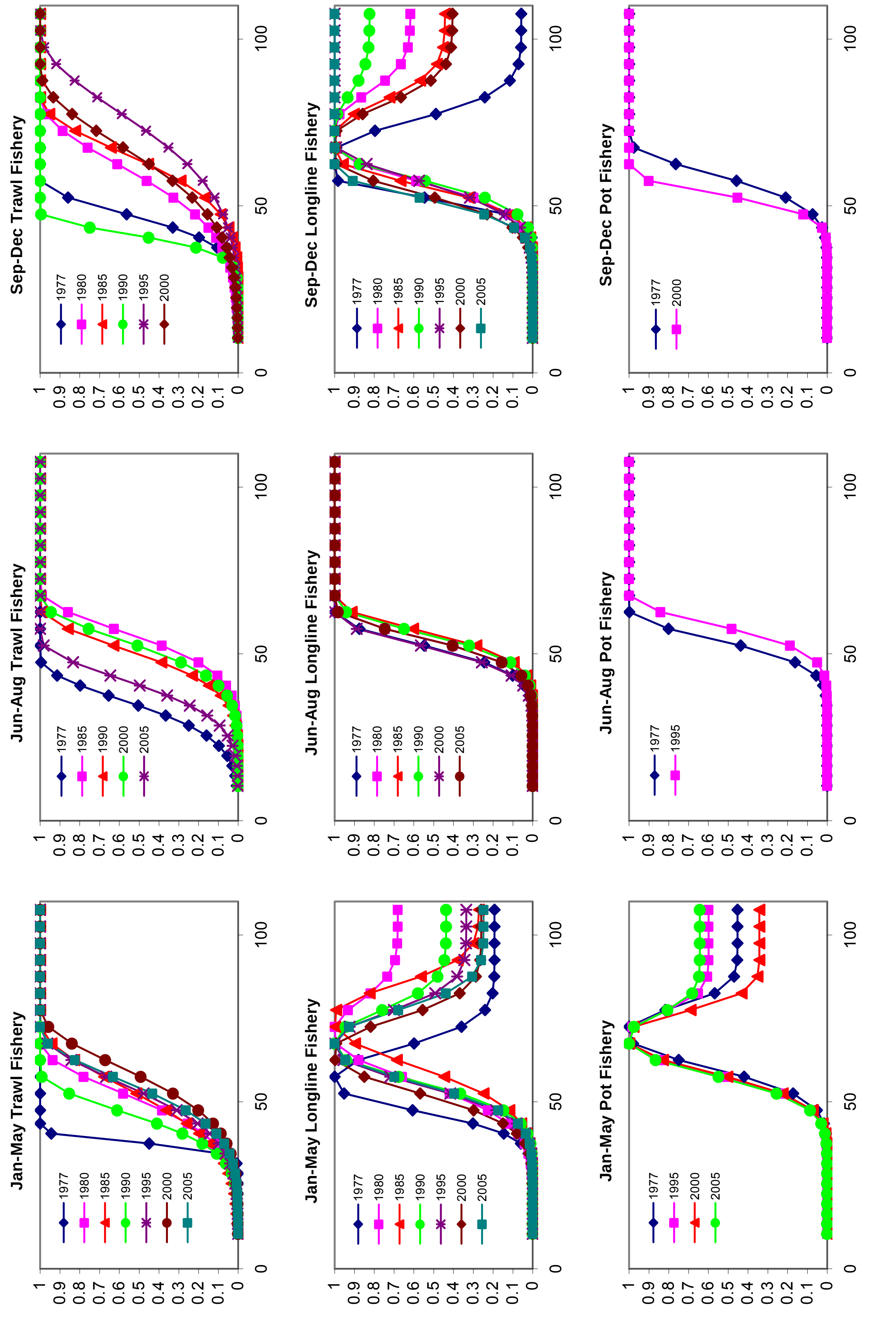

Figure 2.9A2—Fishery selectivities as estimated by Model A2.

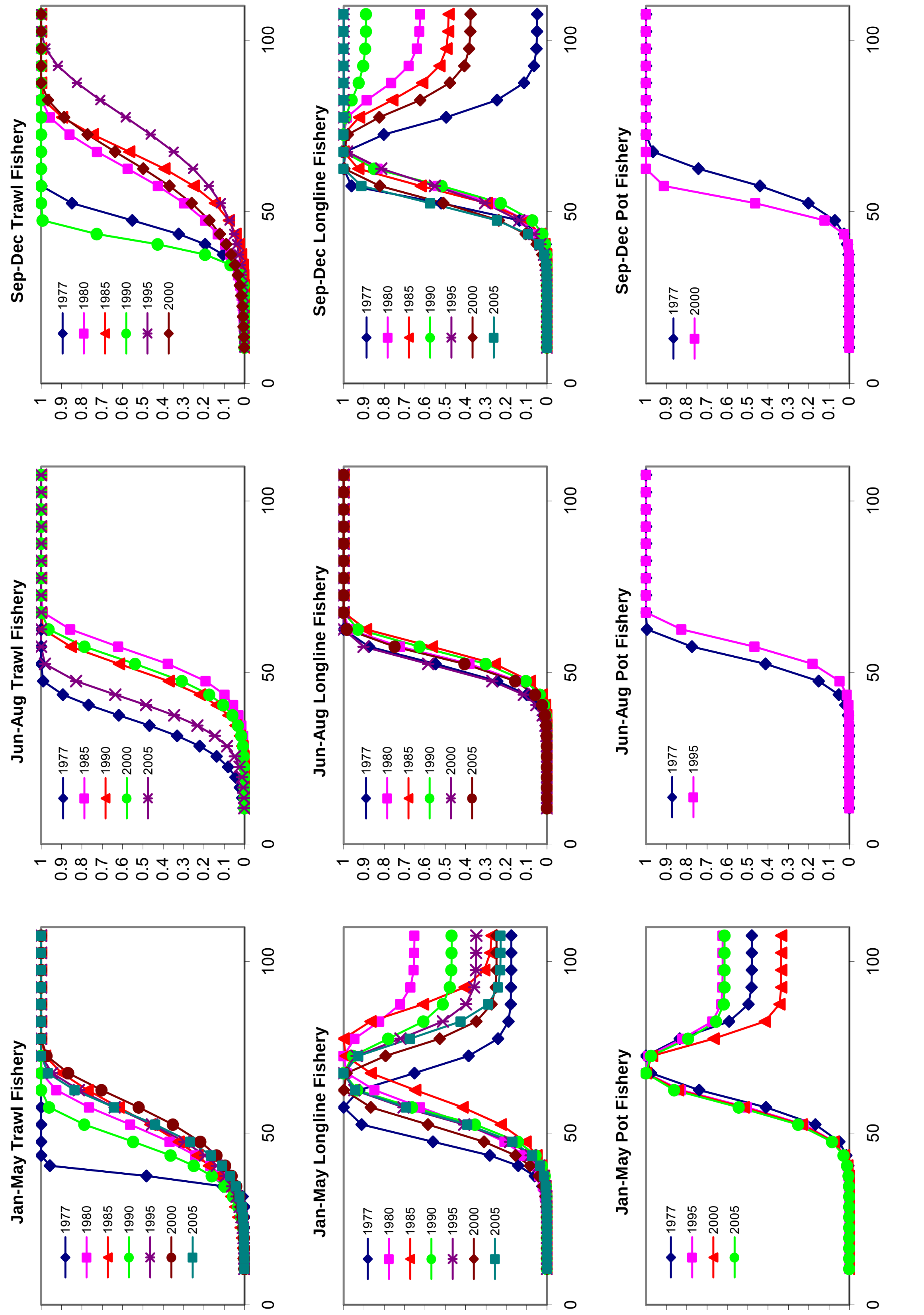

Figure 2.9A3—Fishery selectivities as estimated by Model A3.

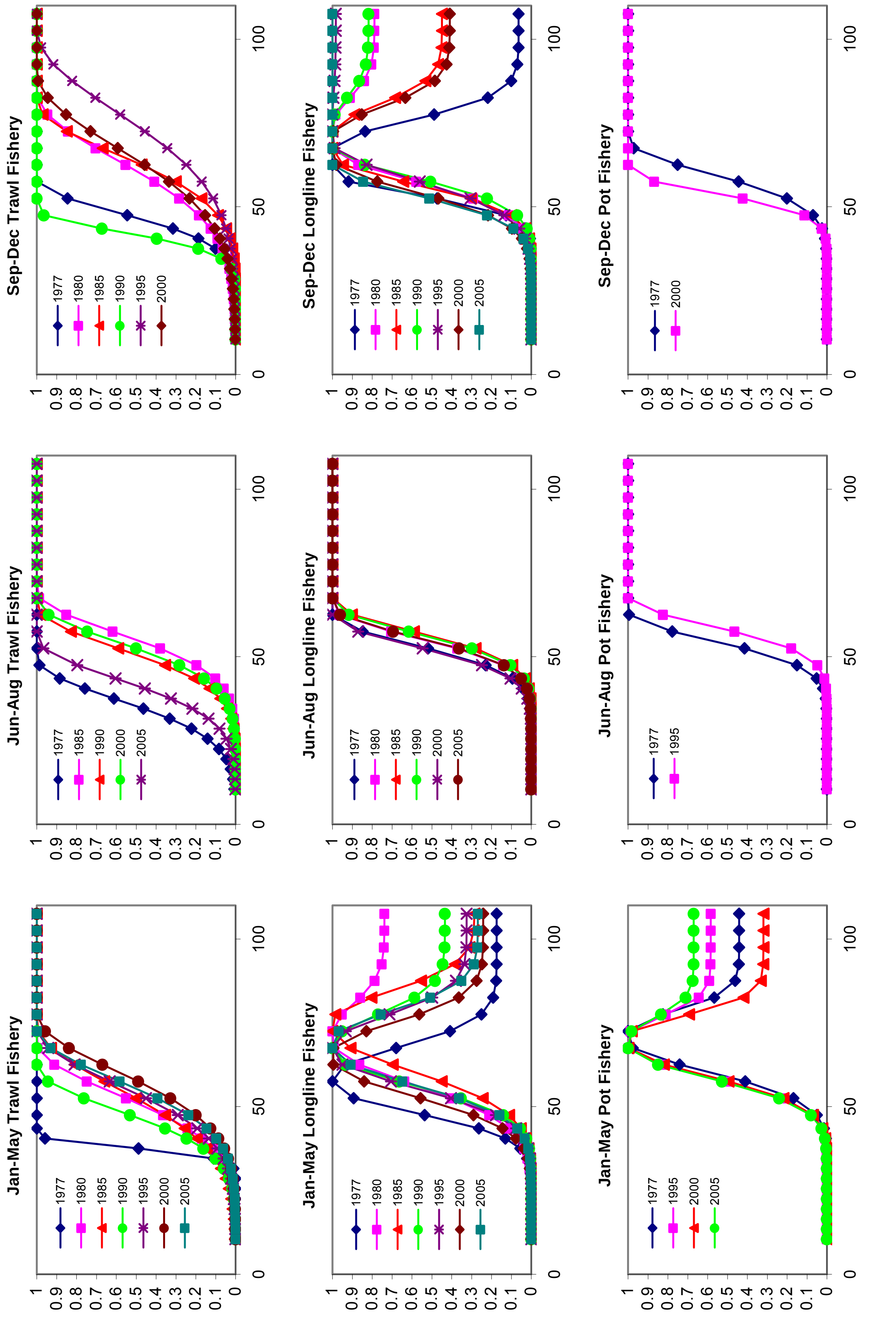

Figure 2.9B1—Fishery selectivity as estimated by Model B1.

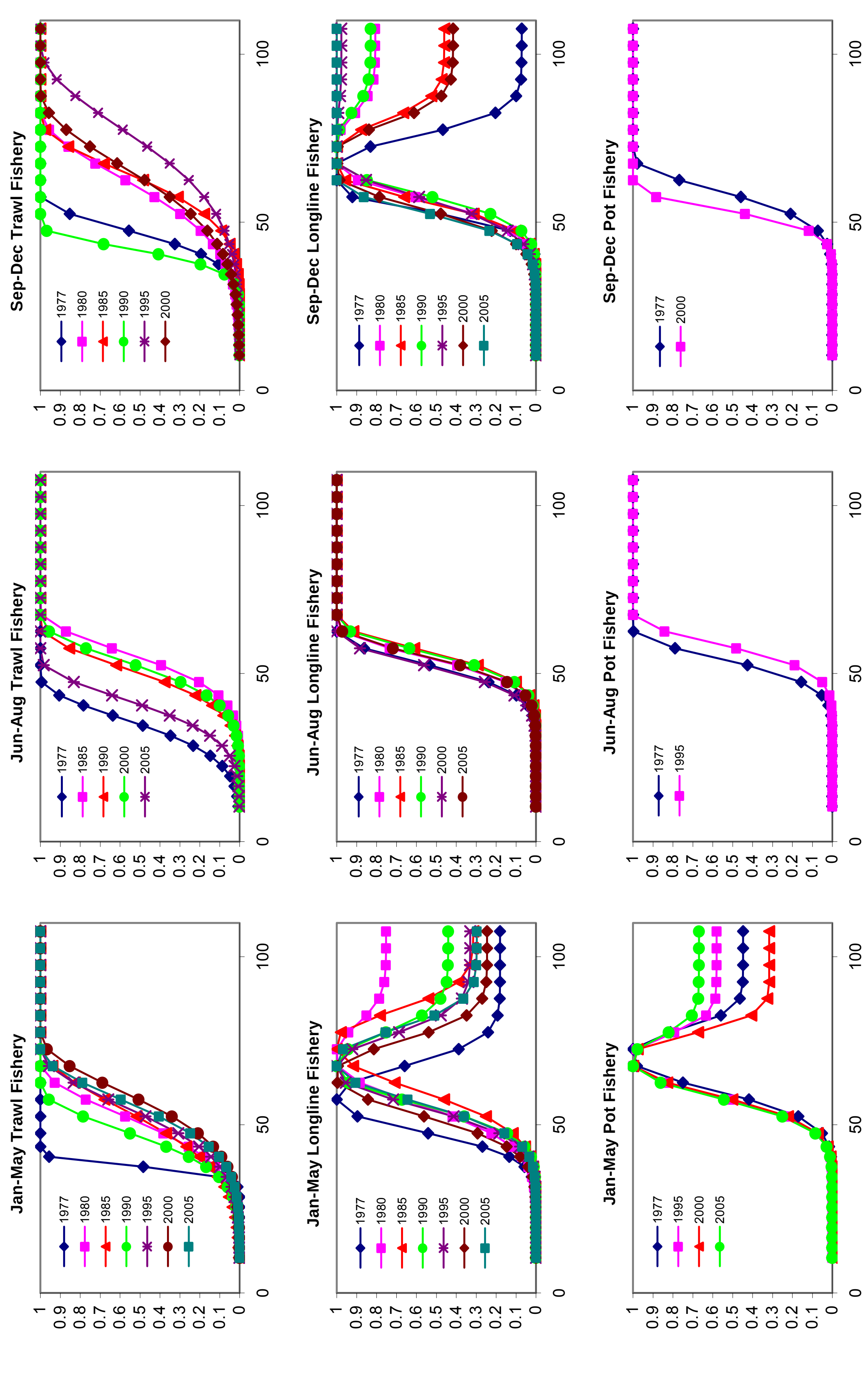

Figure 2.9B2—Fishery selectivity as estimated by Model B2.

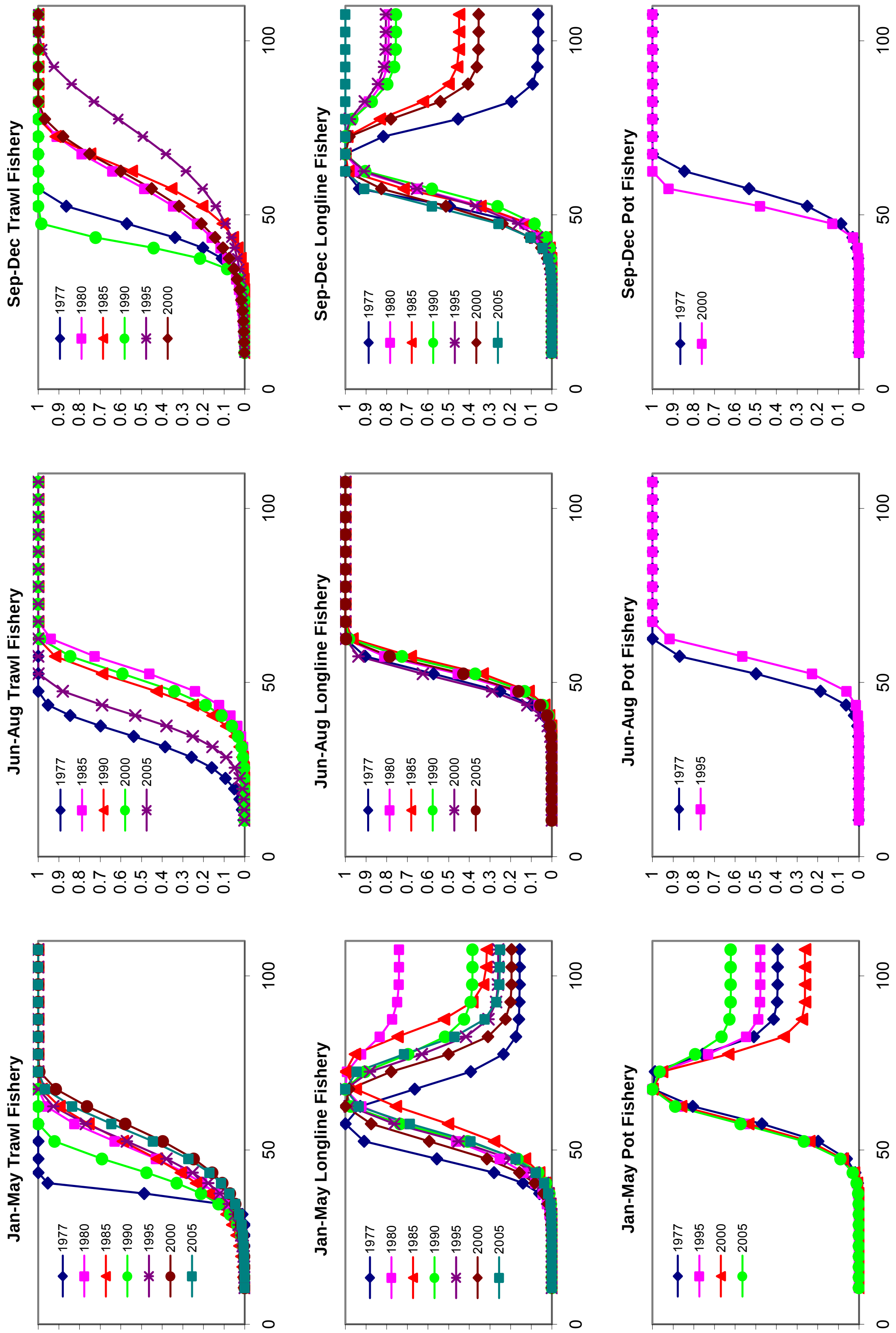

Figure 2.9C1—Fishery selectivity as estimated by Model C1.

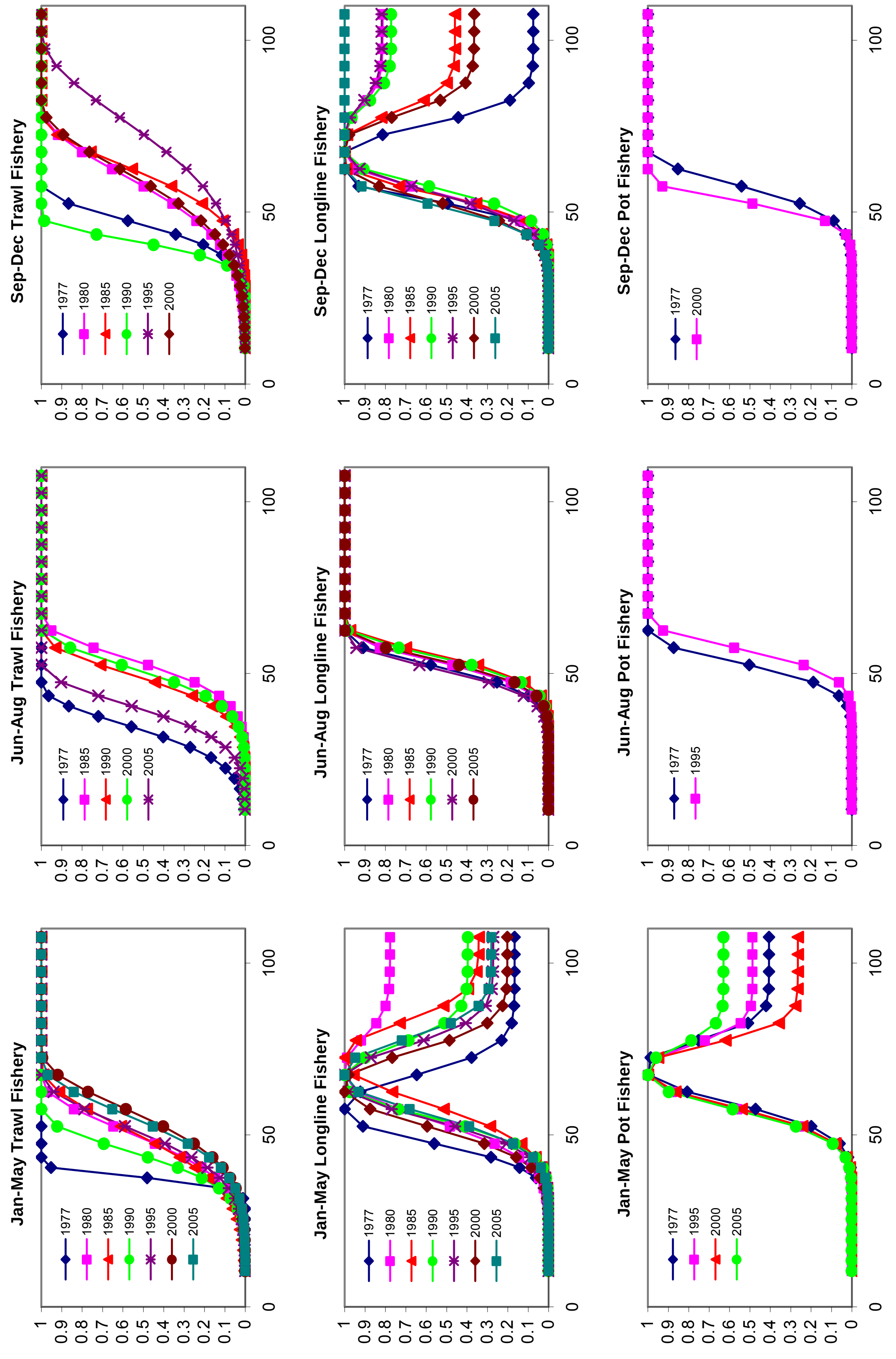

Figure 2.9C2—Fishery selectivities as estimated by Model C2.

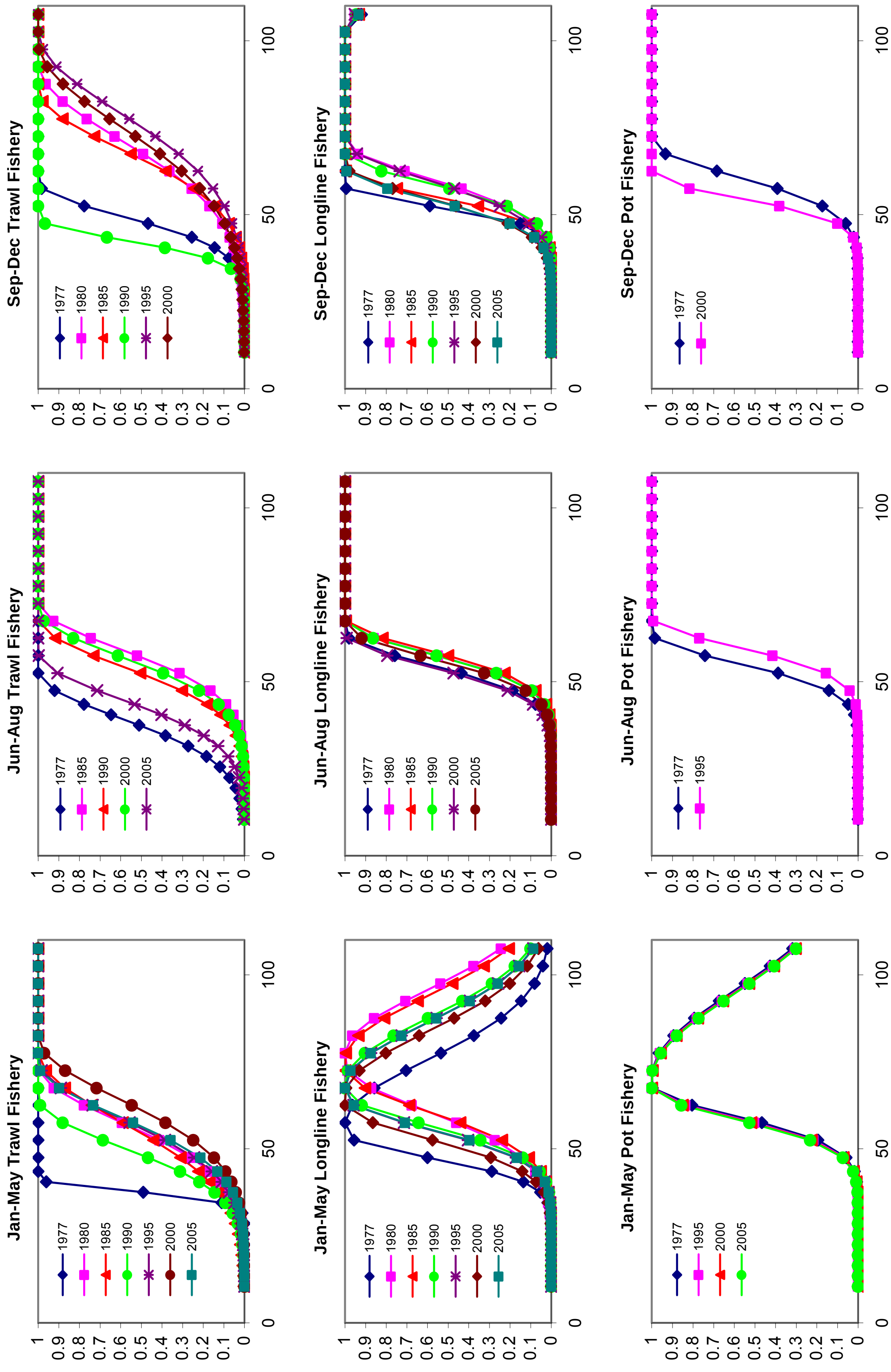

Figure 2.9D1—Fishery selectivities as estimated by Model D1.

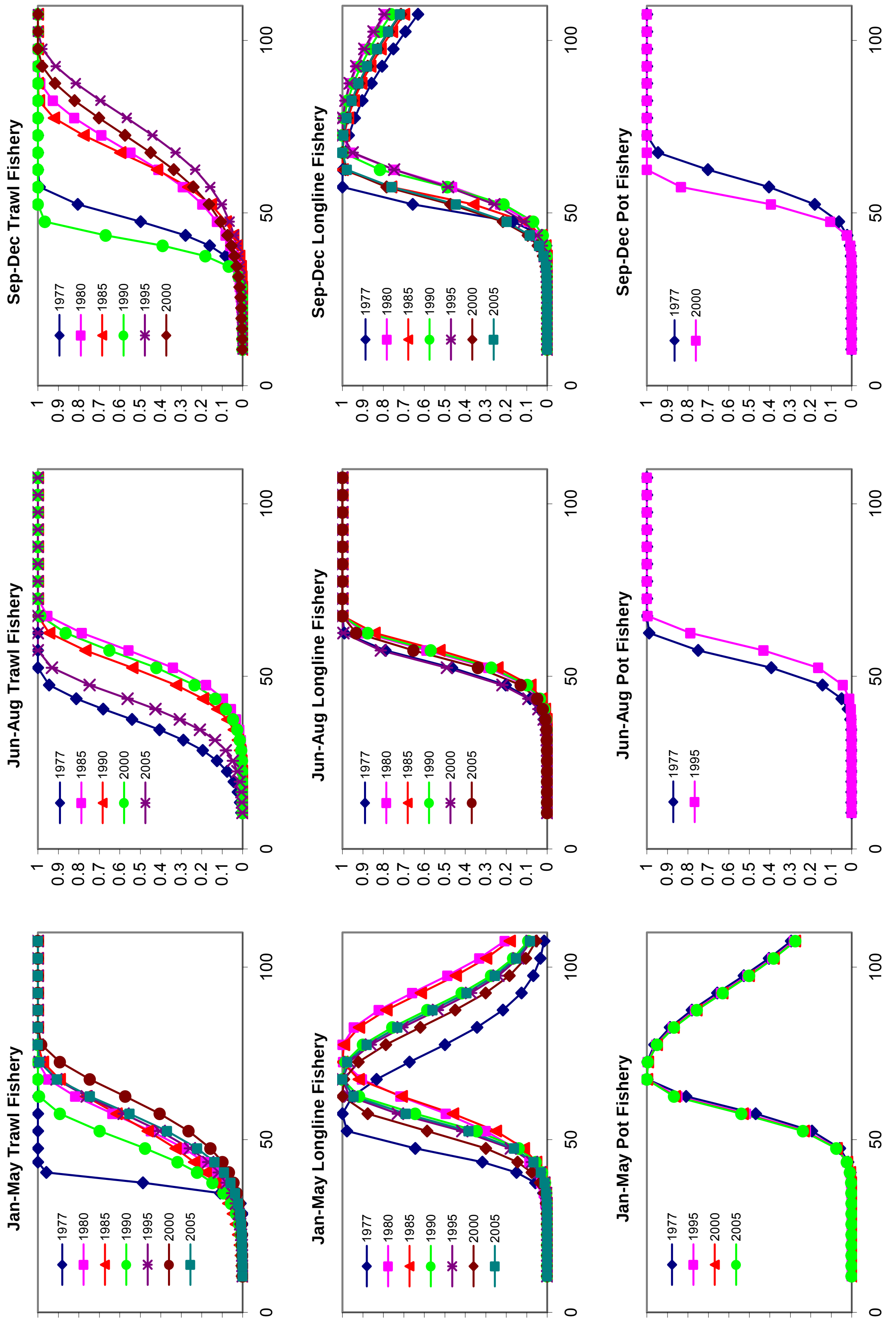

Figure 2.9D2—Fishery selectivities as estimated by Model D2.

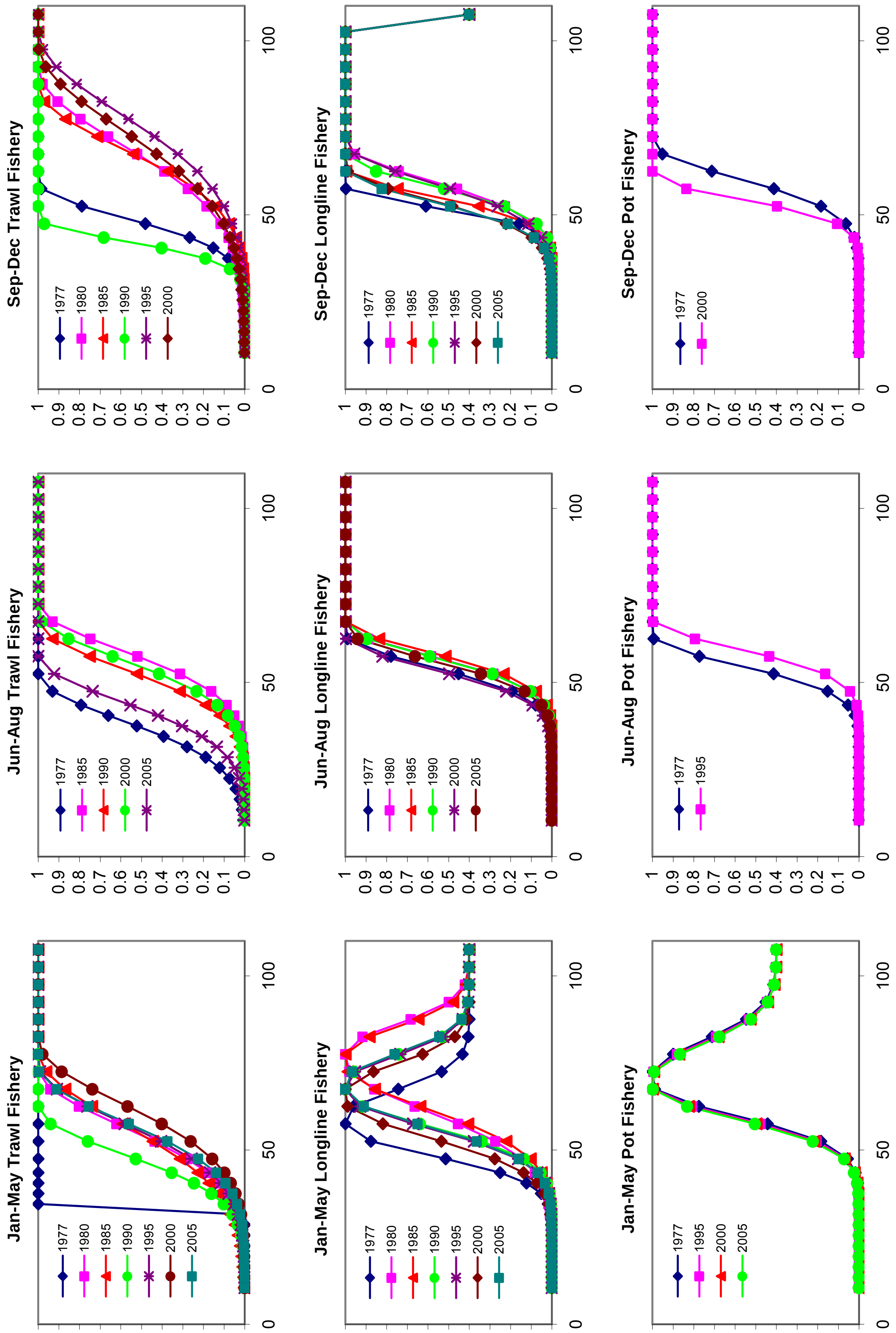

Figure 2.9E1—Fishery selectivities as estimated by Model E1.

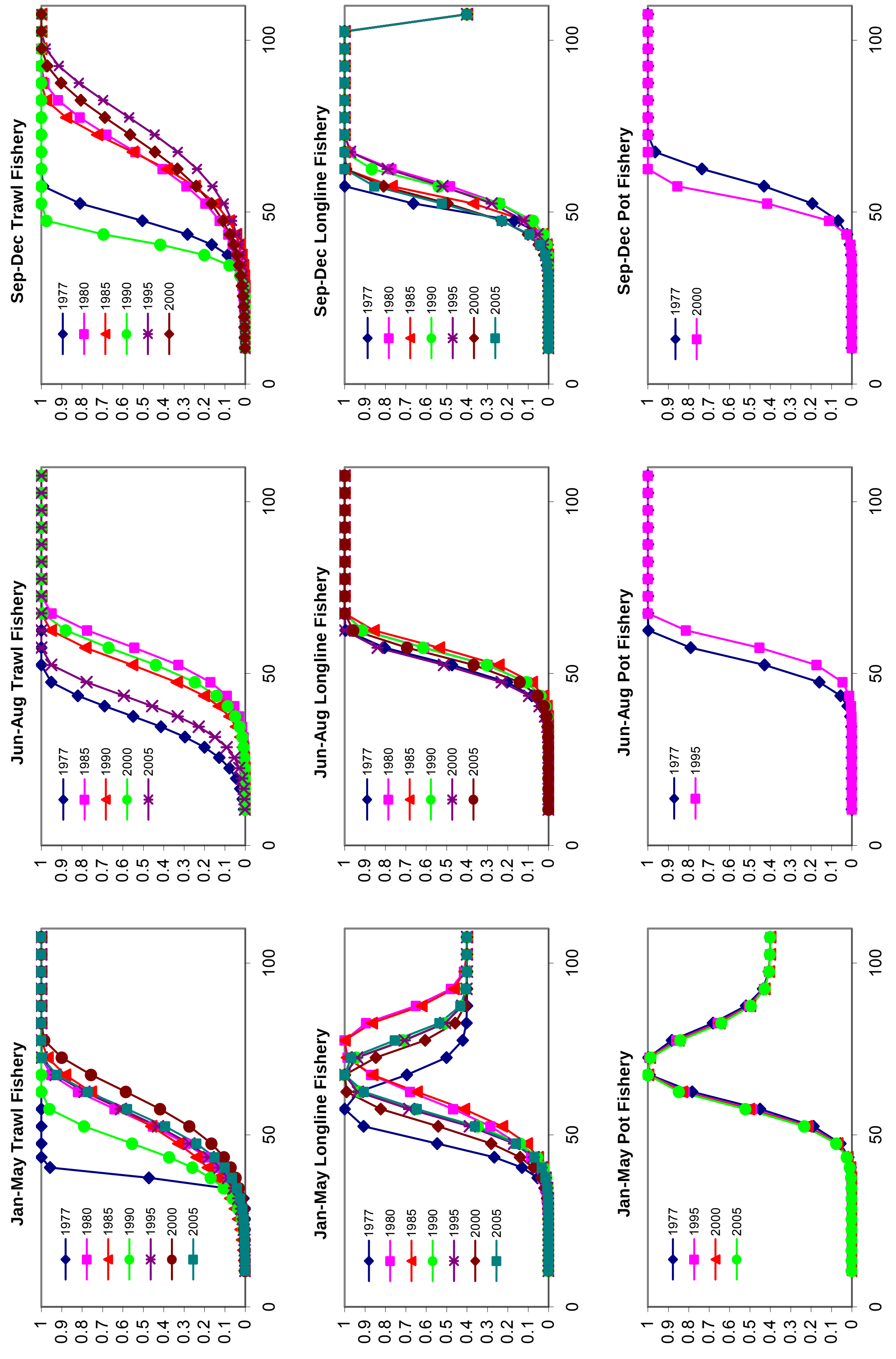

Figure 2.9E2—Fishery selectivities as estimated my Model E2.

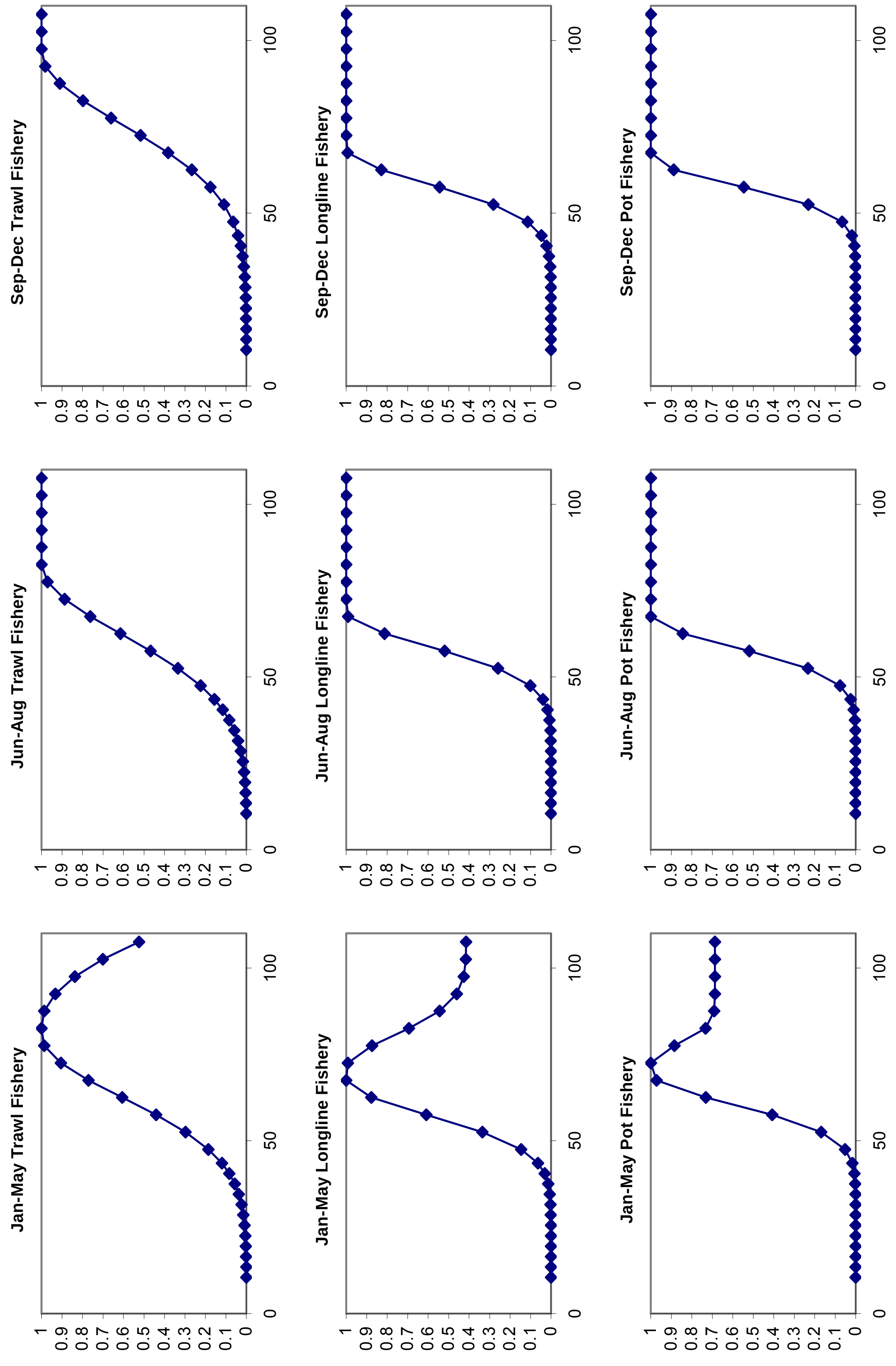

Figure 2.9F2—Fishery selectivities as estimated by Model F2.

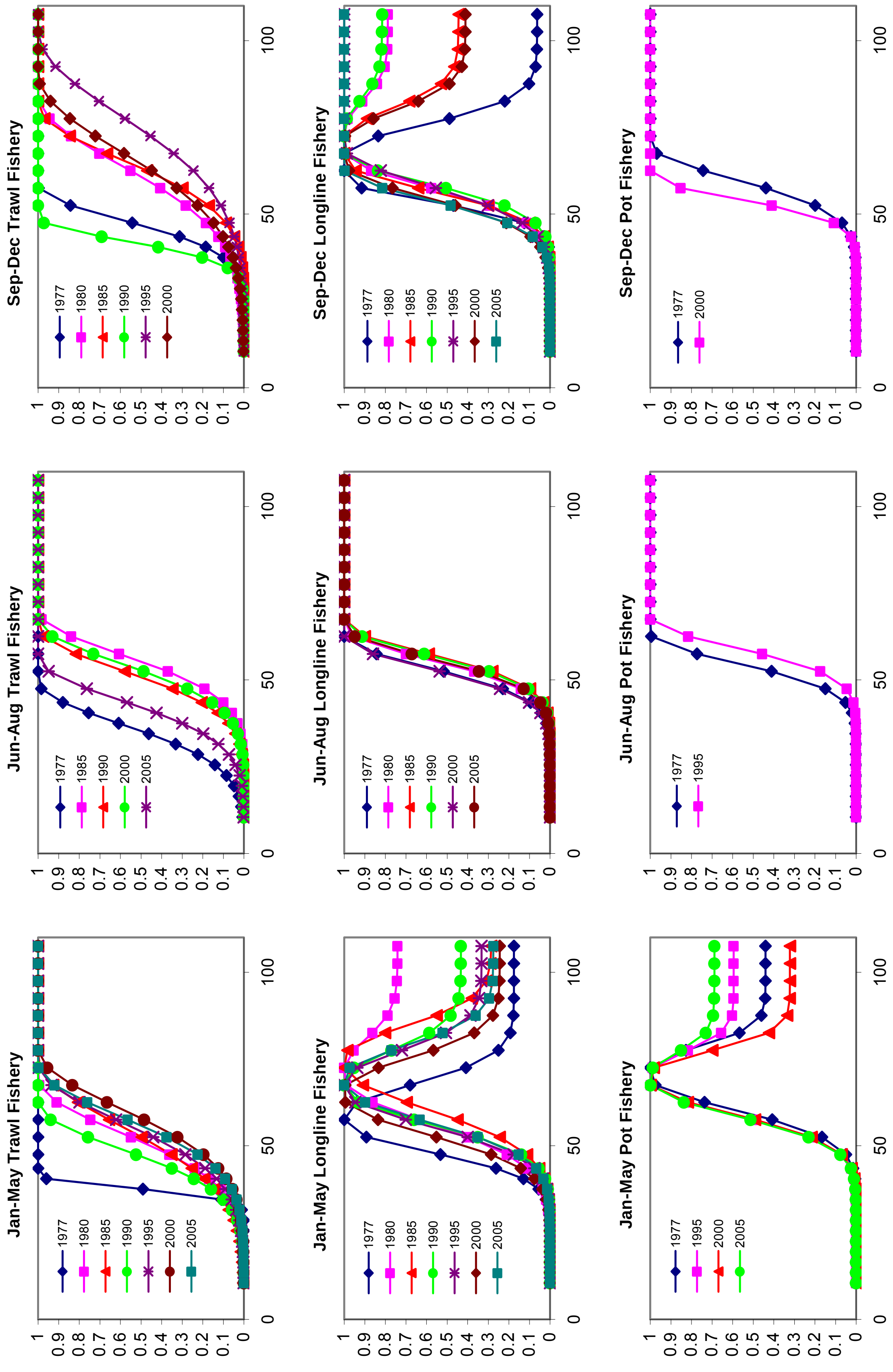

Figure 2.9G1—Fishery selectivities as estimated by Model G1.

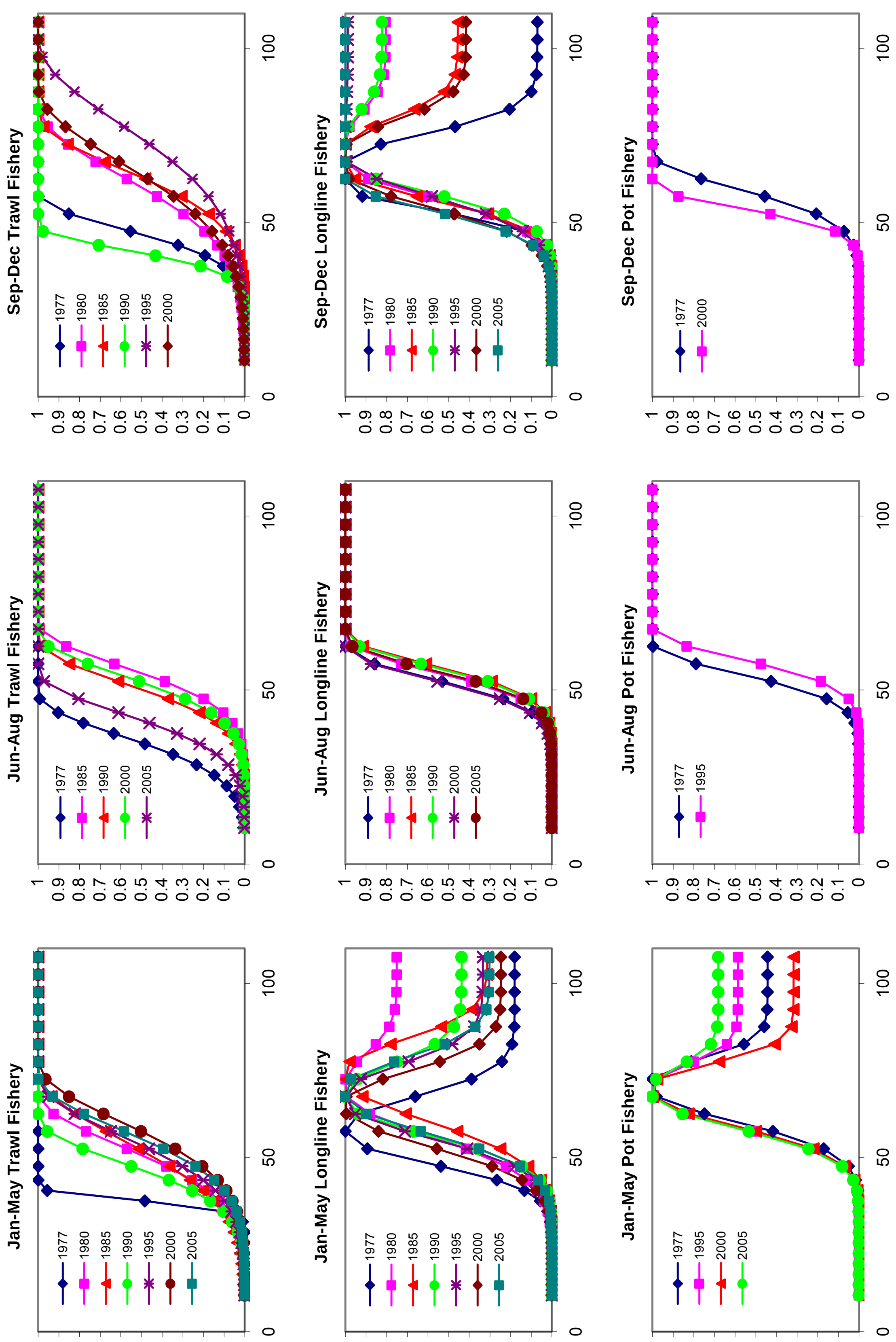

Figure 2.9G2—Fishery selectivities as estimated by Model G2.

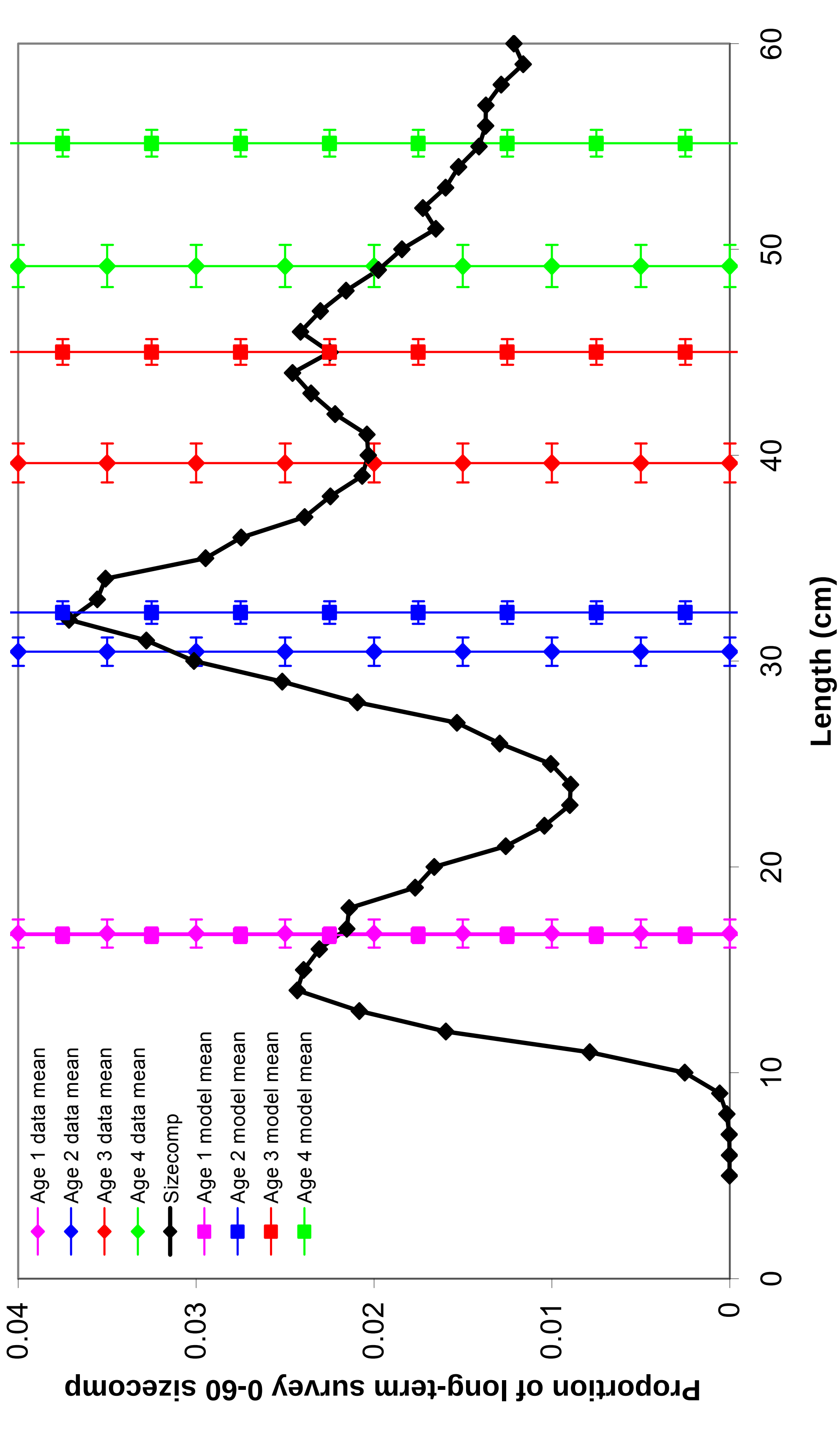

Figure 2.10—Long-term trawl survey size composition, mean lengths for ages 1-4 from age data, and mean lengths for ages 1-4 from Model B1.

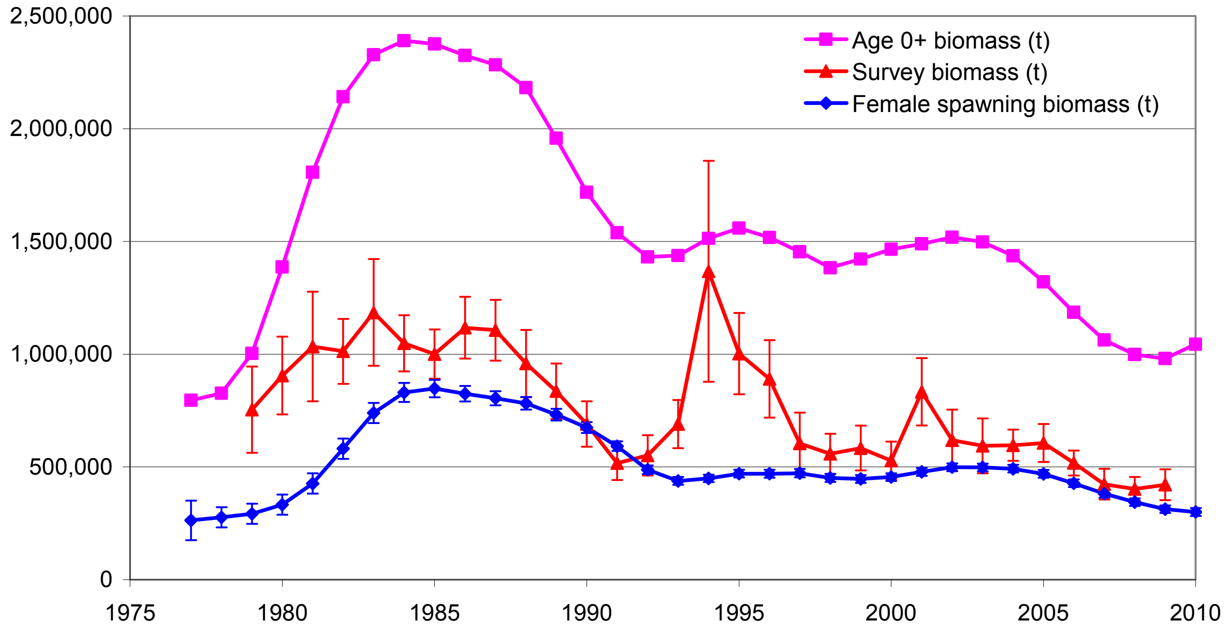

Figure 2.11—Biomass time trends (age 0+ biomass, female spawning biomass, survey biomass) of EBS Pacific cod as estimated by Model B1. Female spawning biomass and survey biomass show 95% CI.

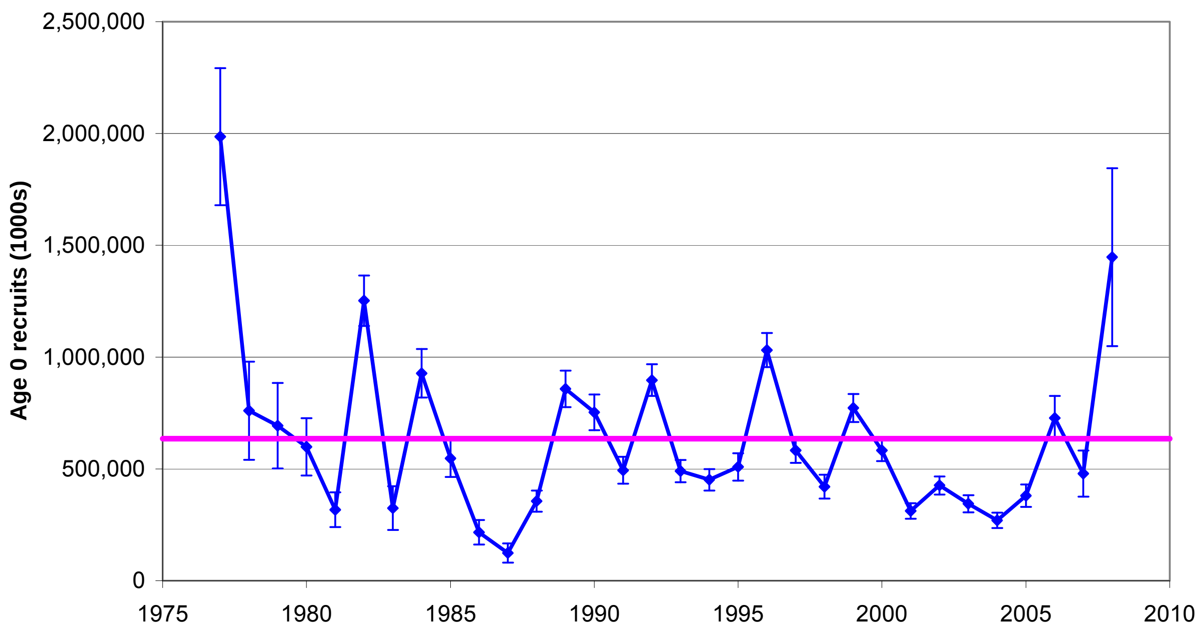

Figure 2.12—Time series of EBS Pacific cod recruitment at age 0, with 95% confidence intervals, as estimated by Model B1. Magenta line = 1977-2008 average.

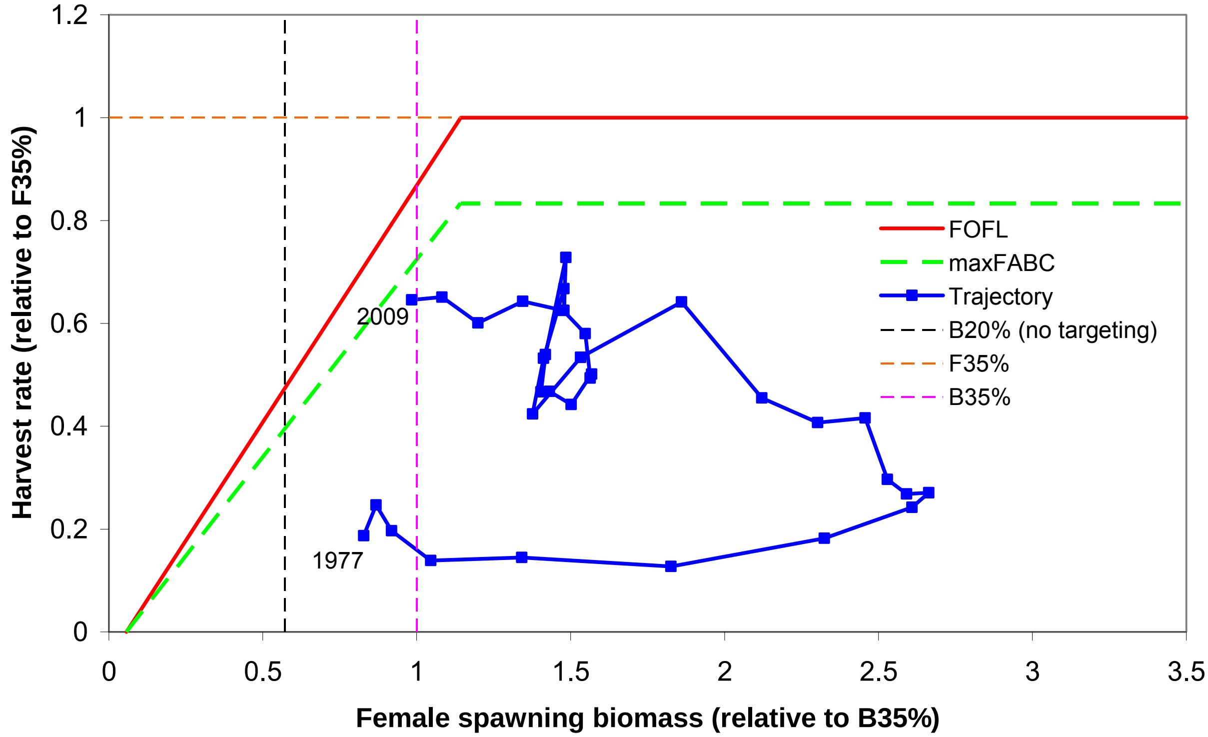

Figure 2.13—Trajectory of Pacific cod fishing mortality and female spawning biomass as estimated by Model B1, 1977-present. Because Pacific cod is a key prey of Steller sea lions, harvests of Pacific cod would be restricted to incidental catch in the event that spawning biomass fell below $B_{20\%}$.

Attachment 2.1

An exploration of alternative models of the Bering Sea Pacific cod stock

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Introduction

This document represents an effort to respond to comments made by the joint BSAI and GOA Plan Teams, the BSAI Plan Team, and the SSC on the 2008 assessment of the Pacific cod (*Gadus macrocephalus*) stock in the Bering Sea and Aleutian Islands (Thompson et al. 2008). Because this document focuses on stock assessment modeling and because an official assessment model of the Aleutian Islands portion of the stock has not yet been developed, this document pertains only to the Bering Sea portion of the stock.

Eight models are presented here. These include the model that was recommended in the 2008 assessment and adopted by the BSAI Plan Team and the SSC ("Model A"), plus seven alternative models.

Joint Plan Team Comments from the September, 2008 Minutes

JPT1: "*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.*" In response to this request, Stock Synthesis (SS) now includes a version of the exponential-logistic selectivity function (Thompson 1994) as an option, and this preliminary assessment considers several new models that use the exponential-logistic selectivity function, as described in the "Analytic Approach" section, under the heading "Model Structure," subheading "Alternative Models."

BSAI Plan Team Comments from the November, 2008 Minutes

BPT1: *"The Team encouraged the AFSC to document the accuracy of the age data."* A comparison of mean lengths at age under different methods of estimation is described in the "Data" section. An AFSC response to the issue of ageing accuracy will be provided separately.

BSAI Plan Team Comments from the 2008 BSAI SAFE Report Introduction

BPT2: *"The authors describe a reasonable method for selecting which fisheries should exhibit asymptotic selectivity.... The Plan Team recommends that the authors apply this method in next year's model(s) and examine whether assuming asymptotic selectivity also is appropriate for the shelf bottom trawl survey."* All eight of the models presented in this preliminary assessment assume the same set of fisheries exhibiting asymptotic selectivity as in the model adopted last year by the BSAI Plan Team and SSC. In addition, four of the models presented in this preliminary assessment assume that the shelf bottom trawl survey also exhibits asymptotic selectivity.

SSC Comments on Assessments in General

SSC1: *"The BSAI Plan Team recommended that all authors of stocks managed in Tiers 1 through 3 should estimate the probability of the spawning stock biomass falling below* $B_{20\%}$*. The recommended time frame for this projection was 3-5 years. The SSC agrees with this recommendation and encourages authors to provide estimates of the probability of falling below biologically relevant thresholds such as* $B_{20\%}$*."* This request will be addressed in the final assessment.

SSC Comments Specific to the BSAI Pacific Cod Assessment

The SSC "further work along the following lines to attempt to reduce the wide range of variation among alternative models."

SSC2: *"Perform analytical work to resolve the discrepancy between reader-based and model-estimated mean length at age. In particular, does the discrepancy result from calculating the reader-based mean length at age from length-stratified otolith samples rather than from keyed-out joint age-length distributions?"* A comparison of mean lengths at age under different methods of estimation is described in the "Data" section. Briefly, the discrepancy does *not* result from the difference between the two estimation methods mentioned in the above minute.

SSC3: *"Age cod otoliths from the fishery. Commercial age data going back ten or fifteen years should help estimate the historical abundance."* The AFSC Age Reading Program has begun to age otoliths from the fishery. A sample of otoliths from the 2008 fishery should be available in time for use in the final assessment.

SSC4: *"Consider a return to models with survey Q fixed, or restrained by an influential prior. This would be a retreat for the cod assessment but we still rely on this device in other assessments (including GOA cod), and in the present circumstances a temporary retreat may be in order."* Some alternative models with fixed survey catchability are presented in this preliminary assessment, as described in the "Analytic Approach" section, under the heading "Model Structure," subheading "Alternative Models." A prior distribution based on results of archival tagging was also examined but not carried forward because it had very little impact on model results, as described in the "Analytic Approach" section, under the heading "Model Structure," subheading "Other Models Evaluated but not Carried Forward" (see also Annex 2.1.1, "Development of a Prior Distribution for Log Catchability").

SSC5: *"Conduct mark-recapture experiments to make direct estimates of fishery selectivity and length at known age."* A summary of previous and ongoing mark-recapture experiments is provided in the "Discussion" section.

SSC6: *"Consider the strengths and weaknesses of model averaging as an alternative to model selection and provide a rationale for or against use of this method in future assessments."* Strengths and weaknesses of model averaging, together with an explanation of why this method is currently not recommended for use, are described in the "Discussion" section.

Data

Background

The basic data sources in the 11 models examined here are the NMFS bottom trawl survey and the fisheries. In all models, fisheries are structured by gear (trawl, longline, and pot) and season (Jan-May, Jun-Aug, Sep-Dec). Data types include relative abundance from the survey, catch from the fisheries, size composition from the survey and fisheries, and age composition from the survey. Catch per unit effort data from the fisheries are included for purposes of comparison, but are not used in parameter estimation. The data set was described in the 2008 assessment.

Alternative Methods for Estimating Mean Length at Age

As noted in the 2008 assessment (Attachment 2.2, Figure 2.2.3), the aggregated post-1981 trawl survey size composition shows fairly distinct modes fairly distinct modes at about 16 cm, 33 cm, and 46 cm; which might 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). However, the mean lengths at ages 2 and 3 from the otolith collection are only 30 cm and 40 cm, respectively. This discrepancy led to a decision not to use mean length at age data in the assessment.

The SSC (comment SSC2) has suggested that the above discrepancy might simply be an artifact resulting from the use of mean length at age in the otolith collection as an estimator of mean length at age in the population. The SSC is correct in noting that mean length at age in the otolith sample can be a biased estimator. Bettoli and Miranda (2001) describe an alternative method of computing mean length at age, based on the age-length key, that is superior from a statistical perspective. This method was applied to the age and length data from the 1995-2006 surveys (split by sex, in case the difference between the two methods was stronger for one sex than the other), and the results are compared with the mean lengths at age from the otolith collection for ages 1-4 in Figures 2.1.1a (males) and 2.1.1b (females). The bottom line is that, for ages 1-4, the absolute value of the average (across years) difference between the mean lengths at age resulting from the two methods was never greater than 0.6 cm. The average difference in mean lengths for ages 1-4 ranged from –0.2 cm to 0.5 cm in the case of males and -0.6 cm to 0.4 cm in the case of females. The root mean squared error for ages 1-4 ranged from 0.7 cm to 1.0 cm in the case of males and 0.7 to 1.2 cm in the case of females. In conclusion, use of the age-length keys to correct for bias in mean length at age does not explain the discrepancy described in the 2008 assessment.

Analytic Approach

Model Structure

Assessment Software

The 2008 assessment used SS V3.01-f. In this preliminary assessment, SS V3.03-c was used. A completely up-to-date user manual is not available. However, Methot (2009) provides an *almost* up-to-date list of available features.

Base Model

The model recommended by the authors and adopted by the BSAI Plan Team and SSC in 2008 was described by Thompson et al. (2008). Briefly, the main features that characterized the 2008 model were as follows:

1. The 2008 model used an algorithm developed in the 2007 BSAI Pacific cod assessment (Thompson et al. 2007) to set the input sample size for the size composition data.
2. The 2008 model set the input sample size for the age composition data proportional to the number of fish aged, with the proportionality constant chosen so as to result in an average input sample size of 300.
3. The 2008 model treated the standard deviation of length at age as a linear function of length at age.
4. The 2008 model specified seasonal weight-at-length relationships.
5. The 2008 model estimated log recruitment variability, iteratively, as the standard deviation of the recruitment “devs” from 1977 to 2007.
6. The 2008 model specified separate recruitment “dev” vectors for the pre-1977 and post-1976 environmental regimes.
7. The 2008 model treated catchabilities of the pre-1982 and post-1981 portions of the bottom trawl survey time series as two free parameters.
8. The 2008 model allowed individual fishery selectivity parameters to vary between blocks of years only if the cost of the additional parameters was outweighed by a sufficient improvement in the model’s fit to the data (this resulted in some parameters being held constant over all years, while others varied at 5-year, 10-year, and 20-year intervals).
9. The 2008 model estimated individual year class strengths in the initial numbers at age vector only if the cost of the additional parameters was outweighed by a sufficient improvement in the model’s fit to the data (this resulted in three individual year class strengths being estimated).
10. The 2008 model forced all fisheries to exhibit asymptotic selectivity during all time blocks except for the January-May longline fishery, the September-December longline fishery, and the January-May pot fishery, based on an algorithm described in the 2008 assessment (Thompson et al. 2008).
11. The 2008 model treated selectivity of the bottom trawl survey as a function of age, but treated selectivities of the fisheries and the IPHC longline survey as functions of length.
12. The 2008 model allowed one of the parameters governing the ascending limb of the trawl survey selectivity function to vary annually, constrained by a σ value of 0.2.

As the new base model in this preliminary assessment, the 2008 model is labeled Model A (not to be confused with the models labeled A1 and in the 2008 assessment).

Alternative Models

Seven alternatives to the base model are presented here. They are labeled Models B, C, D, E, F, G, and H. As summarized in Table 2.1.1, the base model and the seven alternative models comprise a factorial design of models focusing on the functional form of the selectivity curve, trawl survey catchability, and constraints on trawl survey selectivity. More specifically, the factors are as follow:

1. Does selectivity follow the double normal form or the exponential-logistic form? Consideration of this factor was motivated by comment JPT1.
2. Is trawl survey catchability a free parameter or set equal to 1.00? Consideration of this factor was motivated by comment SSC4.
3. Is selectivity for the trawl survey free or constrained to be asymptotic? Consideration of this factor was motivated by comment BPT2.

To keep the base model and the alternative models as comparable as possible (given the differences listed above), the σ parameter constraining the amount of recruitment variability, the time blocks governing time-varying selectivity parameters, and the set of fisheries constrained to exhibit asymptotic selectivity were held constant across all models to the extent possible.

Other Models Evaluated but not Carried Forward

A total of 57 other models (not counting hundreds of "jitter" runs) were evaluated but not carried forward into the present document. Many of these contained one or more of the following features (list is not exhaustive):

- Imposing a normal prior distribution on trawl survey catchability based on the results of Nichol et al. (2007). Development of this prior distribution is described in Annex 2.1.1. Although the numbers of depth readings per tag in the data set tended to be large, the number of tags was very small (11). When uncertainty due to the small number of tags was incorporated, the prior distribution became so diffuse as to have almost no impact on model results. Also, because the results of Nichol et al. describe the product of catchability *and selectivity*, the applicability of such a prior distribution is unclear in models where survey selectivity does not remain at unity over the length range spanned by the tagging data (60-81 cm).
- Fixing trawl survey catchability at the mean of the above normal prior distribution.
- Allowing trawl survey catchability to vary as a random walk.
- Fixing trawl survey catchability at a value of 1.00 for the pre-1982 portion of the time series, but allowing it to be estimated freely for the post-1981 portion of the time series.
- Reducing the number of survey selectivity parameters subject to annual deviations.
- Use of additive, rather than multiplicative, deviations for certain survey selectivity parameters.
- Decreasing the value of the σ parameter used to constrain annual survey selectivity deviations.
- Turning off annual deviations in survey selectivity parameters for the three most recent years.
- Turning off all annual deviations in survey selectivity parameters.
- Forcing trawl survey selectivity to peak at age 6.5, the approximate mid-point of the size range of 60-81 cm spanned by the results of Nichol et al. (2007).
- Imposing a beta prior distribution on the shape parameter of the exponential-logistic selectivity in the trawl survey.

Parameters Estimated Independently

All parameters estimated independently are fixed at the values used in the 2008 assessment. These include the natural mortality rate, mean length at age 1 in July, the coefficient of variation in length at age 1 in July, parameters of the seasonal weight-at-length relationship, parameters of the maturity-at-age relationship, and stock-recruitment "steepness."

Parameters Estimated Conditionally

Parameters estimated within SS include the Brody growth coefficient, mean length at age 20 in July, the standard deviation of length at age 20 in July, log mean recruitment under two environmental regimes (pre-1977 and post-1976), annual log recruitment deviations, annual fishing mortality rates, log catchability in the pre-1982 and post-1981 portions of the trawl survey abundance time series (Models A, B, E, and F only), and all selectivity parameters except those that are fixed at values necessary to force asymptotic behavior as specified in the respective model.

Two selectivity patterns were used in the suite of models considered here:

I. For the fisheries and surveys in Models A-D, double normal selectivity was assumed. As configured in SS, double normal selectivity 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. Selectivity at minimum length (or age) was fixed at 0 for all fisheries.

II. For the fisheries and surveys in Models E-H, exponential-logistic selectivity was assumed. As configured in SS, exponential-logistic selectivity uses the following three parameters:
   1. Inverse scale (ranging from $-\infty$ to $+\infty$)
   2. Location of peak (the single point at which the curve reaches a value of 1.0)
   3. Shape (ranging from 0 to 1; to achieve a curve with selectivities close to unity for sizes/ages greater than the location of the peak, set the shape close to 0 if the scale is positive and close to 1 if the scale is negative)

   Parameter #2 is transformed by scaling it relative to the minimum and maximum length (or age).

As in the 2008 assessment, uniform prior distributions were used for all parameters.

Results

Goodness of Fit

Table 2.1.2 shows number of parameters, Akaike information criterion (AIC), and likelihoods for the eight models. It should be noted that values for the fishery CPUE data (shown under "CPUE – ln(likelihood)") are provided for information only; these data are not used in parameter estimation. Values for a negligible "likelihood" component corresponding to forecast recruitments are not shown in Table 2.1.2.

As shown in Table 2.1.2, Model E has the most parameters and Model D the fewest (note that annual fishing mortality rates do not count as parameters). In general, the four models that use exponential-logistic selectivity have more parameters than the four models that use double normal selectivity, despite the fact that the double normal functional form has twice as many parameters (6) than the exponential-logistic functional form (3). The reason for the greater number of parameters in the four exponential-logistic models is that all three of the exponential-logistic parameters were allowed to vary annually in the trawl survey (or two of the three parameters, in cases where trawl survey selectivity was constrained to be asymptotic), whereas only one of the double normal parameters was allowed to vary annually in the trawl survey. The reason for this, in turn, was that it is not possible to isolate parameters governing only the ascending limb of the selectivity curve when using the exponential-logistic form, so all three parameters (or two, in the asymptotic cases) were allowed to vary.

Despite having many fewer parameters, all four double normal models have better (lower) negative log likelihoods than all four exponential logistic models. Model A has the lowest total negative log likelihood and Model H the highest. The same rankings hold with respect to AIC.

On a component-by-component basis, and using log likelihood as the measure of goodness of fit, Table 2.1.2 indicates that Model E has the best fit to the survey abundance data and Model D the worst, Model A has the best fit to the size composition data and Model H the worst, and Model G has the best fit to the age composition data and Model D the worst. The models are not strictly comparable in terms of the "deviations" log likelihood component because of the fact that the exponential-logistic models have so many more selectivity deviations than the double normal models (note, however, that this lack of comparability does not explain the lower overall negative log likelihoods obtained by the double normal models).

In terms of fitting the size composition data on a fleet-by-fleet basis (9 fisheries plus 3 surveys = 12 fleets), and again using log likelihood as the measure of goodness of fit, Table 2.1.2 indicates that Model B performed the best in four instances, Model A performed the best in three instances, Models D and E each performed the best in two instances, and Model C performed the best in one instance. Model E performed the worst in six instances; Model F performed the worst in three instances; and Models B, G, and H each performed the worst in one instance.

Table 2.1.3 provides an alternative way of evaluating goodness of fit for the size composition data, based on the relationship between input sample size and effective sample size. Four measures are presented: mean effective sample size, harmonic mean effective sample size, the mean of the ratio between effective sample size and input sample size, and the ratio between mean effective sample size and mean input sample size. Some of the performances are fairly robust across these four measures. For example, the following results emerge:

- Model A does the best job of fitting the January-May longline fishery data and the post-1981 trawl survey data under three of the four measures.
- Model B does the best job of fitting the January-May trawl fishery data and the IPHC longline survey data under all four measures, and the best job of fitting the September-December trawl fishery data under three of the four measures.
- Model F does the best job of fitting the June-August longline fishery data under all four measures.
- Model G does the best job of fitting the pre-1982 trawl survey data under three of the four measures.
- Model H does the best job of fitting the September-December longline fishery data and the September-December pot fishery data under three of the four measures.

Similarly, Table 2.1.4 evaluates goodness of fit for the age composition data based on the relationship between input sample size and effective sample size. Generally, the four exponential-logistic models (E-H) tend to do a much better job of fitting the age data by these measures than the four double normal models (A-D). Model G gives the best fit in seven years (out of 14), while Models F and H give the best fit in terms of overall average (across years) effective sample size.

Figure 2.1.2 shows the residual patterns from each model's fit to the post-1981 trawl survey abundance (measured in numbers of fish) time series. Note that the residuals in Figure 2.1.2 have been standardized by expressing them relative to the standard error. The patterns are very similar across models, with the lowest between-model correlation being 0.77 (Model G versus Model A).

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

Table 2.1.5 shows estimated mean length (cm) at age and standard deviation of length at age for each model. Values correspond to July, the approximate mid-point of the survey season. With respect to mean length at age, the range of values across models is no more than about 3 cm for ages 0-6. Model G exhibits the largest mean lengths at ages 2-3, Model F exhibits the largest mean lengths at ages 4-7, and Model B exhibits the largest mean lengths at ages 8-12. Model E has the smallest mean lengths at ages 5-12. With respect to the standard deviation of length at age, Model E has the largest values for all ages ≥ 2, while Model F has the smallest values for all ages ≥ 2.

Trawl survey catchabilities as estimated (Models A, B, E, and F) or assumed (Models C, D, G, and H) are shown below:

Time series	Model A	Model B	Model C	Model D	Model E	Model F	Model G	Model H
Pre-1982	0.98	2.31	1.00	1.00	0.27	1.73	1.00	1.00
Post-1981	0.71	1.02	1.00	1.00	0.45	0.99	1.00	1.00

Note that Models B and F both estimate catchability at values far greater than unity (implying the existence of herding) for the pre-1982 portion of the time series. Model A estimates a value for catchability very close to unity for the pre-1982 portion of the time series, while Models B and F estimate values for catchability very close to unity for the post-1981 portion of the time series.

Figure 2.1.3 shows estimated selectivity at age in the pre-1982 portion of the trawl survey time series. All four models in which survey selectivity is not constrained to be asymptotic (Models A, C, E, and G) show very narrow ranges in which survey selectivity is close to unity. (Note that the age of peak selectivity in the exponential-logistic function is not constrained to take integer values, so it is possible for selectivity at all integer ages to be noticeably less than unity.)

Figure 2.1.4 shows estimated selectivity at age in the post-1981 portion of the trawl survey time series. Variability in the four exponential-logistic models (E-H) is considerably higher than in the four double normal models (A-D), owing at least in part to the fact that three parameters are free in the former group, but only one in the latter.

Table 2.1.6 shows estimates of trawl survey catchability (part I), and three ways of looking at the product of trawl survey catchability and selectivity at age (parts II-IV).

As shown in part I of Table 2.1.6, Models B and F estimate values of catchability well in excess of unity for the pre-1982 portion of the time series. Model A estimates catchability at a value close to unity for the pre-1982 portion of the time series, while Models B and F estimate catchability at values close to unity for the post-1981 portion of the time series. Model B's estimates are the highest of all models for both portions of the time series, and Model E's estimates are the lowest of all models for both portions of the time series.

The average (across age, weighted by average (across years) numbers at age) of the product of catchability and selectivity for the 60-81 cm size range is shown in part II of Table 2.1.6. Model E has by far the lowest value in part II, while Models B, D, F, and H all have values close to unity. Model G gives the value closest to the estimate of 0.473 calculated by Nichol et al. (2007).

The average, standard deviation, and coefficient of variation for the product of catchability and selectivity for all ages are shown in part III of Table 2.1.6 (for each year, an average (across age, weighted by annual biomass at age) was computed, then the average and standard deviation were computed across year). Again Model E has the lowest average by far, while Models B, D, F, and H all have values close to unity. Between-year variability, as measured by either standard deviation or coefficient of variation, is lowest in Models B and D (SD = CV = 0.008) and highest in Model G (SD = 0.129, CV = 0.273).

The between-year variability expressed in part III of Table 2.1.6 may seem modest for most, if not all, models. If such a conclusion were reached, it would be due in part to the fact that four of the models are forced to exhibit asymptotic selectivity for the trawl survey, which, when combined with an assumption of constant catchability, obviously places a strong constraint on inter-annual variability, especially when the results are weighted by biomass at age (giving the largest weight to the portion of the selectivity curve that is not allowed to vary at all). To provide another perspective on the issue of between-year variability, part IV of Table 2.1.6 focuses only on variability at age 1. In part IV, variability is much larger, with no standard deviation smaller than 0.076 (Model E), and no CV smaller than 0.529 (Model A).

Figures 2.1.5A-2.1.5H show estimated selectivity at length for all time blocks in all nine fisheries (3 gears × 3 seasons), with one figure for each model. Some of the curves for the models using double normal selectivity (Models A-D) drop abruptly at large sizes, then level off just as abruptly. The models using exponential-logistic selectivity (Models E-H) are show declines at large size, but these tend not to be as steep as in the double normal models and there is no subsequent abrupt leveling.

Estimates of Time Series

Figure 2.1.6 shows estimated spawning biomass relative to the model-specific estimate of $B_{100\%}$ for each model. The time trends are similar for all models except Models E and G, which peak at much higher values than the others (1.83-2.46 for Models E and G, versus 0.59-0.96 for the others). The range of relative spawning biomass for 2008 extends from 0.27 (Model B) to 0.56 (Model E).

Figure 2.1.7 shows estimated total (ages 0+) biomass for each model. Survey biomass is shown for comparison. However, it should be emphasized that survey biomass is a different quantity than total biomass, involving not only the total population biomass but the effects of catchability and selectivity as well. As with the relative spawning biomass trajectories in Figure 2.1.6, Model E is noticeably different from the other models, estimating biomass more than twice as high as any other model in all years. Model G is also distinct from the other models in the early years of the time series. All models estimate that total biomass is much higher than the biomass measured by the survey: The average (across years 1982-2008) of the ratio between total biomass and survey biomass ranges from 1.34 for Model B to 7.16 for Model E, as shown below:

Model A	Model B	Model C	Model D	Model E	Model F	Model G	Model H
2.37	1.34	1.70	1.44	7.16	1.61	2.94	1.65

Figure 2.1.8 shows log recruitment (numbers of age 0 fish, in 1000s) for each model. Qualitatively, considerable agreement is evident among all models, although Model E gives a higher estimate in every year than any other model, and Model B gives a lower estimate than any other model in 23 out of 32 years. Of the 28 pair-wise comparisons between models, 22 have correlations higher than 90%. The lowest correlation is between Models B and E (71%). All models agree that the 2006 year class appears to be large.

Discussion

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

Potential Issues with Selectivity Deviations

In all eight models, between one and three parameters governing the trawl survey selectivity schedule were subject to multiplicative deviations in all years, with the σ parameter constraining the amount of variation set equal to a value of 0.2. Four key assumptions regarding use of selectivity deviations may merit further investigation:

i. Which parameters should be subject to annual deviations? For example, part IV of Table 2.1.6 shows that all models considered here exhibit a high degree of relative interannual variability at age 1, but this contributes very little to the biomass-weighted interannual variability shown in part III, which is quite low for the double normal models (A-D). Perhaps more (or different) parameters of the double normal selectivity function should be subject to annual deviations.

ii. Should the deviations be multiplicative or additive, or does the answer depend on the parameter being adjusted? In the version of SS used to conduct the 2008 assessment, use of additive deviations was not an option. In more recent versions, however, options exist for both types. For parameters whose natural range includes both positive and negative values, it might be preferable to use additive deviations (because with multiplicative deviations, all annual realizations of a parameter will be forced to have the same sign as the corresponding base parameter).

iii. Should deviations be applied in all years, or should parameter values for the most recent years in the time series be held at their respective base values? For example, the exponential-logistic models (E-H) in Figure 2.1.4 all show an "outlier" curve with high selectivity at ages 0 and 1. In all four of these models, the outlier curve corresponds to 2007. Ages 0 and 1 in 2007 correspond to the 2007 and 2006 cohorts, respectively. Given that the survey catches very few age 0 fish, by the time the assessment was conducted in 2008, the 2006 cohort had been observed by the survey only twice (at age 1 in 2007 and at age 2 in 2008) and the 2007 cohort had been observed by the survey only once (at age 1 in 2008). Rather than attempt to estimate selectivity deviations for cohorts whose strengths have not been confirmed through repeated observation, it might be better to return the selectivity schedule to the underlying "base" values in the last few (e.g., three or so) years of the time series.

iv. How should the value of σ be set? The value of 0.2 used here was chosen in an *ad hoc* attempt to reflect the result of Francis et al. (2003), who determined that interannual variability in survey catchability, expressed as a coefficient of variation, was typically about 20% (because post-1981 catchability is constant in the models considered here, the "20% rule" was applied to the parameters governing the selectivity schedule rather than to catchability itself). However, setting $\sigma = 0.2$ does not guarantee that interannual variability in survey performance will have a CV of 20%. In part III of Table 2.1.6, Models B and D have CVs of around 1%, Models F and G have CVs of around 2%, Models A and C have CVs of around 8-9%, while Models E and G come

1. The value of σ could be adjusted iteratively until the CV (computed according to the method used to generate part III of Table 2.1.6) equals 0.2.
2. Different values of σ could be used for different selectivity parameters.
3. Applicability of the result obtained by Francis et al. to the BSAI trawl survey could be investigated. One reason why their result may not be entirely applicable is that it was based only on data from surveys conducted in New Zealand. Another reason is that it was based on a model that did not make explicit allowance for age structure (i.e., their model assumed that survey biomass = catchability × true biomass × random error). If selectivity were to vary with age, the effects of age structure changing through time would appear as changes in catchability, even if true catchability were constant.

Previous and Ongoing Mark-Recapture Research

The SSC has suggested (comment SSC5) that mark-recapture experiments be conducted to make direct estimates of fishery selectivity and length at known age. One mark-recapture experiment capable of providing information on fishery selectivity has already been completed (Shi et al. 2007). Although the authors accompanied their conclusions with some caveats, the results of this study failed to provide support for the existence of asymptotic fishery selectivity, regardless of gear type (Figure 2.1.9).

Other mark-recapture studies of Pacific cod being conducted by scientists at the AFSC and ADFG include the following:

A. Peter Munro and Elizabeth Conners (AFSC) are conducting a mark-recapture experiment to estimate Pacific cod movement rates in the eastern Bering Sea between pre-spawning distributions in the fall to spawning distributions in the late winter and early spring. The experimental design is expected to permit estimation of geographically specific movement rates, exploitation rates, and growth rates. Under a stratified design, movement rates among strata will be estimated using a model developed by Anganuzzi et al. (1994) for Pacific halibut. The experiment consists of a dedicated late autumn cruise aboard a factory longliner to tag and release cod, tag recovery by commercial fisheries from January through April, and a spring cruise aboard a factory longliner to estimate fishery independent tag recovery rates. Dedicated cruises would allow tag mixing, calibration of commercial recovery rates, and provide data for estimating stratum specific exploitation rates.

B. Olav Ormseth and Susanne McDermott (AFSC) are conducting research to determine the utility of electronic archival tags for studying movement in Pacific cod. These tags have light, depth, and temperature sensors and store data from these sensors at user-determined time intervals. When the tag is recovered, the light record can be used to obtain daily estimates of latitude and longitude for the tagged fish. Lotek Wireless Inc. (Newfoundland, Canada) has developed a new type of tag that is smaller than previous models and uses an improved algorithm for estimating geographic position. Because these tags have not been tested in high latitudes, funds were obtained through a cooperative research grant to conduct a pilot study. This study is in two parts: 1) testing the position estimates provided by tags moored at a known, fixed location; 2) testing capture methods and tag implantation procedures on captive Pacific cod in Juneau, Alaska.
   1. For part 1, moorings were deployed during May 2009 in approximately 100 m water depth in Resurrection Bay, Alaska (in the vicinity of Seward) and Captain's Bay outside of Unalaska in the eastern Aleutian Islands. Tags were deployed at three depths on each mooring. In each location, a set of tags at each depth was recovered after only 4 days on the mooring. A second set remained in place and as of the end of August are still on the moorings. This approach provided data in case the moorings are lost. Preliminary results from the Unalaska

tags suggested that the tags might not work at depths greater than 50 m, so additional tags were placed at shallow depths in Resurrection Bay to provide a greater range of light intensity values. The moorings will be recovered in September and October of 2009.

2. The work involved in part 2 began in August 2009. A local fishing vessel was chartered to capture live Pacific cod using pot gear in the vicinity of Juneau, Alaska. Between August 24-28, five Pacific cod were captured and transferred to a laboratory tank at the Ted Stevens Marine Research Institute. These fish are currently in a recovery period, and archival tags will be implanted in three of the five individuals in September. To reduce impacts on swimming ability and streamlining, the tags will be placed inside the body cavity. The tags have a sensor stalk approximately 10 cm long that extends out through the body wall and allows the recording of external light and temperature. The fish will be kept in the live tanks for up to a year. In addition to the tag testing, these fish will be part of a controlled study linking otolith microchemistry to water temperature and fish growth. Thomas Helser of the AFSC Age and Growth Program is also a partner in this research.

C. Scientists at ADFG have been conducting an ongoing Pacific cod tagging program since 1997 (Spalinger 2009). The study's goal is to determine migration and growth patterns and to differentiate inshore and offshore Pacific cod populations. Fluorescent spaghetti tags were inserted into the dorsal musculature of fish determined to be in good condition. Tags were placed anterior to the first dorsal fin. Fish that had distended eyes or stomachs, or were lethargic were not tagged. Length, tag number, and release location were recorded prior to release. During the 2008 trawl survey, 962 Pacific cod captured by the trawl were tagged with an orange spaghetti tag anterior to the first dorsal fin and immediately released. The majority (59%) of the Pacific cod tagged were in the Kodiak Area. Recoveries occur throughout the year from the various commercial cod fisheries.

Finally, it should be noted that some other tagging studies have recently been proposed but did not receive funding. One such study proposed to do acoustic tagging of young cod and then attempt to track them as they grow up. Another proposed to tag cod on their spawning aggregates and then see in subsequent years how many cod were recaptured in the same aggregates as a measure of spawning site fidelity.

Model Averaging

What is Model Averaging?

As with many contemporary statistical issues, the subject of model averaging has been approached from both Bayesian and frequentist perspectives.

Chatfield (1995), Draper (1995), and Hoeting et al. (1999) provide overviews of Bayesian model averaging, which, conceptually at least, is a fairly straightforward extension of conventional Bayesian statistics. Concepts used in conventional Bayesian statistics include a data set D, a parameter vector θ, a joint prior distribution on the parameters $pri(\theta)$, and a likelihood $lik(D|\theta)$. Bayes' theorem states that the joint posterior distribution of the parameters $pos(\theta)$ is proportional to the product of the prior distribution and the likelihood. Bayesian model averaging generalizes these concepts by acknowledging that: 1) the parameter vector θ is invariably associated with some model M, and 2) there will typically be many models that can be fit to the data. Thus, in Bayesian model averaging, each model M_k ($k = 1, ..., n$) is associated with a (potentially unique) parameter vector θ_k. This requires specification of a prior distribution not only for each parameter vector θ_k, but a prior probability for each model M_k as well. Let the prior distribution for θ_k be written $pri(\theta_k| M_k)$, the prior probability for M_k be written $pri(M_k)$, and the likelihood be written $lik(D|\theta_k,M_k)$. Given these generalizations, Bayesian model averaging can be summarized in the following three steps:

1. The integrated likelihood of the data given the kth model is:

$$lik\left(D\middle|M_k\right)=\int_{-\infty}^{\infty} lik\left(D\middle|\boldsymbol{\theta}_k,M_k\right)\cdot pri\left(\boldsymbol{\theta}_k\middle|M_k\right)d\boldsymbol{\theta}_k \quad .$$

2. The posterior probability of M_k is then:

$$pos\left(M_k\middle|D\right)=\frac{lik\left(D\middle|M_k\right)\cdot pri\left(M_k\right)}{\sum_{j=1}^{n} lik\left(D\middle|M_j\right)\cdot pri\left(M_j\right)} \quad .$$

3. Finally, the posterior distribution of some quantity of interest, say, ABC, is:

$$pos\left(ABC\middle|D\right)=\sum_{k=1}^{n} pos\left(ABC\middle|M_k,D\right)\cdot pos\left(M_k\middle|D\right) \quad ,$$

where $pos(ABC|M_k,D)$ is the posterior distribution of ABC given model M_k and the data, computed in the conventional (Bayesian) way.

For frequentist approaches to model averaging, see Buckland et al. (1997), Hjort and Claeskens (2003), and Burnham and Anderson (2004). A typical frequentist approach to model averaging is to use "Akaike weights," w, defined for each model k as:

$$w_k=\frac{\exp\left(\left(\min(AIC)-AIC_k\right)/2\right)}{\sum_{j=1}^{n}\exp\left(\left(\min(AIC)-AIC_j\right)/2\right)} \quad .$$

The Akaike weights are then used to give a weighted average estimate of whatever quantity happens to be of interest. For example, the weighted average ABC could be obtained by computing the best point estimate of ABC under each model, ABC_k, then producing an overall best estimate, $ABC*$, as follows:

$$ABC*=\sum_{k=1}^{n} ABC_k\cdot w_k \quad .$$

What are the Strengths and Weaknesses of Model Averaging?

The main strengths of model averaging are that: 1) when conducted properly, it tends to give both better point estimates and more realistic characterizations of the amount of uncertainty associated with those estimates than results based on a single model; and 2) it avoids the need to choose between models that might be indistinguishable in terms of their statistical performance but that might imply significantly different levels of population abundance or harvest potential.

The main weaknesses of model averaging, either in application to BSAI and GOA groundfish stock assessments or in general, are that: 1) it is unfamiliar to most participants in the stock assessment process and would involve a steep learning curve; 2) it is more complicated than the present practice of basing estimates on a single model; 3) the computational overhead associated with the required summations and integrations can be immense; 4) it requires specifying a prior probability for each model, if a Bayesian approach is taken, or justifying a probabilistic interpretation of the Akaike weights, if a frequentist approach is taken; and 5) it requires obtaining a representative subset of models for consideration, as it is never feasible to consider all possible models.

Should Model Averaging be Used in the Pacific Cod Assessments?

Figure 2.1.10 illustrates, in heuristic fashion, how model averaging can improve estimates when the averaging is based on a truly random sample from the universe of models, but also how model averaging can degrade estimates when the averaging is based on a non-random sample. In panel A, a single model is used to estimate ABC. Fortunately, the single model happens to be the true model, and the ABC estimate is the estimate with the highest probability of being true across the universe of models. In panel B, a single model is used again, but this time it is not the true model, and the ABC estimate is about 0.48 standard deviations removed from the ABC estimate associated with the true model (the assessment scientist, however, does not know this). In panel C, a random sample of nine other models is added to the single model from panel B. The probability-weighted average of the ten individual ABC estimates in panel C is less than 0.01 standard deviation removed from the ABC estimate associated with the true model. In panel D, a decidedly *non*-random sample of nine other models is added to the single model from panel B. The probability-weighted average of the ten individual ABC estimates in panel D is 1.66 standard deviations removed from the ABC estimate associated with the true model.

The AFSC's current protocol for public involvement in the Pacific cod assessments encourages inclusion of models suggested by members of the public. This policy makes it difficult to ensure that the set of models included in the assessment is a random sample from the universe of possible models. Even without this policy, it is not clear how a representative set of models would be chosen. Therefore, even though model averaging appears to have considerable potential in principle, the approach should not be implemented for the Pacific cod assessments until outstanding issues, such as a protocol for choosing a representative set of models, have been resolved.

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Table 2.1.1. List of models. The set of models spans a 3-way factorial design, with the factors being functional form of the selectivity curves (double normal or exponential-logistic), survey catchability (free or set equal to 1.00), and survey selectivity (free or constrained to be asymptotic).

Model	Selectivity form	Catchability	Survey selectivity
A	double normal	free	free
B	double normal	free	asymptotic
C	double normal	1	free
D	double normal	1	asymptotic
E	exponential-logistic	free	free
F	exponential-logistic	free	asymptotic
G	exponential-logistic	1	free
H	exponential-logistic	1	asymptotic

Table 2.1.2. Number of parameters, Akaike information criterion (AIC), and likelihoods for the 8 models. Values for the fishery CPUE data (under "CPUE –ln(likelihood)") are provided for information only; these data are not used in parameter estimation. Fits to the size composition data are broken down by fleet under the heading "Length –ln(likelihood)." Pink = row maximum, green = row minimum.

	A	B	C	D	E	F	G	H
Total no. parameters	190	184	188	182	257	225	255	223
Bound parameters	0	0	0	0	13	20	14	18
Net no. parameters	190	184	188	182	244	205	241	205
Total -ln(likelihood)	1597.2	1677.1	1625.4	1703.3	1808.0	2035.0	1833.4	2048.9
AIC	3574.5	3722.1	3626.7	3770.6	4103.9	4480.0	4148.7	4507.7
Survey nos. -ln(like.)	52.3	52.7	68.0	71.1	25.1	39.3	25.9	50.3
Size comp. -ln(like.)	1326.1	1349.3	1326.7	1356.1	1580.5	1743.4	1602.3	1745.7
Age comp. -ln(like.)	178.8	228.1	187.6	228.9	132.4	196.0	131.5	198.0
Recruitment -ln(like.)	26.4	31.0	28.8	32.9	28.7	33.3	28.1	33.6
Deviations -ln(like.)	13.6	16.0	14.2	14.1	40.9	22.8	45.2	21.0
"Softbounds" -ln(like.)	0.0	0.0	0.0	0.0	0.1	0.2	0.1	0.2
CPUE -ln(likelihood)								
Jan-May trawl fishery	120.0	104.7	112.1	102.0	116.1	133.5	121.7	131.3
Jun-Aug trawl fishery	16.4	17.3	17.6	17.2	14.2	16.6	15.6	16.6
Sep-Dec trawl fishery	29.0	27.2	27.4	26.6	13.6	16.1	12.9	15.6
Jan-May longl. fishery	256.0	319.7	322.3	318.9	200.1	303.3	303.9	311.0
Jun-Aug longl. fishery	119.6	153.3	136.7	145.6	73.7	138.3	93.4	134.4
Sep-Dec longl. fishery	152.0	241.0	170.0	226.5	53.9	172.7	65.7	161.8
Jan-May pot fishery	29.1	29.3	34.0	29.8	22.0	25.8	29.1	26.6
Jun-Aug pot fishery	3.3	2.4	2.8	2.5	3.6	2.6	3.2	2.6
Sep-Dec pot fishery	35.5	37.0	37.2	36.6	31.6	35.0	34.4	35.0
Pre82 trawl survey	3.4	5.5	11.9	22.1	0.0	4.7	0.2	14.8
Post81 trawl survey	48.9	47.2	56.1	49.0	25.0	34.6	25.6	35.5
IPHC longline survey	13.0	13.8	16.0	14.4	12.5	13.4	16.4	14.2
Length -ln(likelihood)								
Jan-May trawl fishery	409.2	429.3	421.1	429.1	401.4	562.3	446.4	557.0
Jun-Aug trawl fishery	61.1	61.1	60.8	60.9	66.0	61.7	65.2	61.7
Sep-Dec trawl fishery	56.4	55.0	55.4	54.3	62.1	78.9	62.9	74.5
Jan-May longl. fishery	191.7	197.4	192.6	196.6	326.3	323.8	317.1	322.0
Jun-Aug longl. fishery	123.9	105.1	112.3	104.6	139.4	111.2	126.3	110.7
Sep-Dec longl. fishery	212.4	226.6	214.0	226.8	268.4	263.5	264.5	267.4
Jan-May pot fishery	35.4	39.0	37.6	38.3	47.8	49.8	48.6	49.6
Jun-Aug pot fishery	21.3	19.3	20.6	19.6	23.1	21.0	23.4	21.0
Sep-Dec pot fishery	40.3	36.2	38.4	36.7	46.2	40.0	44.0	40.0
Pre82 trawl survey	31.9	44.2	32.2	39.9	23.4	39.0	27.0	36.3
Post81 trawl survey	138.4	133.0	138.0	145.6	170.1	188.7	171.3	201.5
IPHC longline survey	4.2	3.2	3.7	3.7	6.3	3.6	5.5	3.9

Table 2.1.3. Goodness of fit with respect to size composition, as measured by the relationship between input sample size and effective sample size. "Rec." = number of records. Fleets are indexed as follows: 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. Pink = row maximum, green = row minimum.

			Mean effective sample size							
Fleet	Rec.	Input	A	B	C	D	E	F	G	H
1	30	373	317	335	322	331	265	177	237	181
2	18	29	106	111	106	109	121	107	117	105
3	21	29	108	120	114	120	109	95	110	98
4	29	667	713	684	667	659	425	458	441	447
5	22	247	300	348	338	363	266	477	288	468
6	28	696	937	907	991	959	1086	1158	1220	1226
7	17	153	510	479	486	485	533	407	528	419
8	7	60	190	185	180	183	199	194	200	191
9	16	54	278	297	301	299	204	341	260	351
10	3	103	58	74	61	56	99	70	103	64
11	13	169	273	256	269	238	221	189	224	168
12	1	81	144	169	156	150	104	167	117	156

			Harmonic mean effective sample size							
Fleet	Rec.	Input	A	B	C	D	E	F	G	H
1	30	373	97	114	98	106	85	73	79	72
2	18	29	38	34	37	35	36	34	36	35
3	21	29	14	15	15	15	13	14	14	14
4	29	667	234	223	232	224	243	212	255	216
5	22	247	109	123	114	116	112	127	118	121
6	28	696	176	179	177	167	148	174	156	166
7	17	153	302	269	280	274	246	234	241	235
8	7	60	128	136	133	135	122	124	122	125
9	16	54	100	114	107	113	88	102	94	102
10	3	103	56	58	57	53	78	60	77	60
11	13	169	177	189	178	180	144	139	137	129
12	1	81	144	169	156	150	104	167	117	156

			Mean (effective sample size / input sample size)							
Fleet	Rec.	Input	A	B	C	D	E	F	G	H
1	30	373	1.26	1.42	1.27	1.31	1.04	0.73	0.96	0.75
2	18	29	8.19	8.03	8.31	8.32	10.13	7.83	10.20	7.92
3	21	29	4.08	4.50	4.25	4.43	6.11	5.63	6.10	5.73
4	29	667	2.41	2.18	2.07	1.83	2.00	1.65	2.08	1.55
5	22	247	3.04	4.00	3.20	3.56	2.82	4.15	2.91	3.62
6	28	696	1.87	1.90	1.94	1.89	2.13	2.28	2.34	2.36
7	17	153	3.36	3.16	3.22	3.20	3.16	2.77	3.18	2.81
8	7	60	4.15	4.09	4.02	4.07	4.60	4.19	4.58	4.15
9	16	54	5.47	5.75	5.77	5.82	4.82	5.98	5.21	6.11
10	3	103	0.66	0.89	0.70	0.66	1.15	0.79	1.19	0.72
11	13	169	2.04	1.79	1.97	1.72	1.62	1.39	1.53	1.21
12	1	81	1.77	2.08	1.93	1.85	1.28	2.06	1.44	1.92

			(Mean effective sample size) / (mean input sample size)							
Fleet	Rec.	Input	A	B	C	D	E	F	G	H
1	30	373	0.85	0.90	0.86	0.89	0.71	0.47	0.64	0.48
2	18	29	3.65	3.82	3.64	3.76	4.15	3.68	4.02	3.62
3	21	29	3.73	4.16	3.95	4.14	3.76	3.27	3.81	3.39
4	29	667	1.07	1.03	1.00	0.99	0.64	0.69	0.66	0.67
5	22	247	1.21	1.41	1.37	1.47	1.07	1.93	1.16	1.89
6	28	696	1.35	1.30	1.42	1.38	1.56	1.66	1.75	1.76
7	17	153	3.32	3.12	3.17	3.16	3.47	2.65	3.44	2.73
8	7	60	3.17	3.10	3.01	3.06	3.33	3.25	3.35	3.20
9	16	54	5.14	5.50	5.58	5.54	3.77	6.32	4.81	6.49
10	3	103	0.56	0.72	0.60	0.55	0.96	0.68	1.01	0.63
11	13	169	1.61	1.51	1.59	1.40	1.31	1.12	1.33	0.99
12	1	81	1.77	2.08	1.93	1.85	1.28	2.06	1.44	1.92

Table 2.1.4. Goodness of fit with respect to age composition (all age data are from the bottom trawl survey), as measured by the relationship between input sample size and effective sample size. Pink = row maximum, green = row minimum.

		Effective sample size							
Year	Input	A	B	C	D	E	F	G	H
1994	256	72	76	68	78	109	117	98	119
1995	215	125	131	147	126	121	94	168	90
1996	90	47	42	49	41	82	58	85	56
1997	258	59	64	61	64	230	168	245	169
1998	228	94	92	85	95	343	690	365	681
1999	308	30	26	27	27	29	33	31	33
2000	310	29	22	25	23	69	53	75	56
2001	341	51	47	49	48	89	78	96	79
2002	339	28	24	25	25	82	51	85	51
2003	487	491	360	483	373	260	328	206	347
2004	373	31	32	31	32	44	37	40	37
2005	218	156	174	148	170	238	173	216	168
2006	466	293	273	254	278	380	884	460	890
2007	310	68	66	70	67	969	1136	1156	1132
Ave.	300	112	102	109	103	217	279	238	279

		Effective sample size / input sample size							
Year	Input	A	B	C	D	E	F	G	H
1994	256	0.28	0.30	0.26	0.30	0.43	0.46	0.38	0.47
1995	215	0.58	0.61	0.68	0.59	0.56	0.44	0.78	0.42
1996	90	0.52	0.47	0.55	0.46	0.91	0.64	0.95	0.62
1997	258	0.23	0.25	0.24	0.25	0.89	0.65	0.95	0.65
1998	228	0.41	0.40	0.37	0.42	1.50	3.03	1.60	2.99
1999	308	0.10	0.08	0.09	0.09	0.09	0.11	0.10	0.11
2000	310	0.09	0.07	0.08	0.08	0.22	0.17	0.24	0.18
2001	341	0.15	0.14	0.14	0.14	0.26	0.23	0.28	0.23
2002	339	0.08	0.07	0.07	0.07	0.24	0.15	0.25	0.15
2003	487	1.01	0.74	0.99	0.77	0.53	0.67	0.42	0.71
2004	373	0.08	0.09	0.08	0.09	0.12	0.10	0.11	0.10
2005	218	0.71	0.80	0.68	0.78	1.09	0.80	0.99	0.77
2006	466	0.63	0.59	0.55	0.60	0.81	1.90	0.99	1.91
2007	310	0.22	0.21	0.23	0.21	3.12	3.67	3.73	3.65
Ave.	300	0.36	0.34	0.36	0.35	0.77	0.93	0.84	0.93

Table 2.1.5. Estimated mean length (cm) at age and standard deviation of length at age. Values correspond to July, the approximate mid-point of the survey season. Pink = row maximum (excluding ages 0 and 1, which are identical across models), green = row minimum (excluding ages 0 and 1, which are identical across models).

	Mean length in July							
Age	A	B	C	D	E	F	G	H
0	11.5	11.5	11.5	11.5	11.5	11.5	11.5	11.5
1	16.1	16.1	16.1	16.1	16.1	16.1	16.1	16.1
2	32.5	32.2	32.5	32.2	33.1	32.9	33.3	32.9
3	45.3	45.2	45.5	45.2	45.9	46.2	46.3	46.1
4	55.4	55.6	55.8	55.5	55.6	56.7	56.3	56.5
5	63.4	64.1	64.0	63.9	62.9	64.9	64.0	64.8
6	69.7	70.9	70.5	70.5	68.4	71.5	69.8	71.2
7	74.6	76.4	75.6	75.9	72.5	76.6	74.2	76.3
8	78.4	80.8	79.7	80.2	75.6	80.7	77.6	80.3
9	81.5	84.4	82.9	83.6	78.0	83.9	80.2	83.5
10	83.9	87.3	85.5	86.4	79.8	86.5	82.2	86.0
11	85.8	89.6	87.6	88.6	81.1	88.5	83.7	88.0
12	87.3	91.5	89.2	90.4	82.1	90.1	84.9	89.5

	Standard deviation of length in July							
Age	A	B	C	D	E	F	G	H
0	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7
1	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7
2	5.0	4.9	4.9	4.9	5.3	4.8	5.1	4.9
3	6.0	5.9	5.9	5.9	6.6	5.8	6.3	5.8
4	6.8	6.7	6.7	6.7	7.5	6.5	7.1	6.5
5	7.4	7.3	7.3	7.4	8.2	7.1	7.7	7.1
6	7.9	7.8	7.8	7.9	8.7	7.5	8.2	7.6
7	8.3	8.2	8.2	8.3	9.1	7.9	8.6	7.9
8	8.6	8.6	8.5	8.6	9.4	8.1	8.9	8.2
9	8.9	8.9	8.7	8.9	9.6	8.4	9.1	8.5
10	9.1	9.1	8.9	9.1	9.8	8.5	9.3	8.6
11	9.2	9.2	9.1	9.3	9.9	8.7	9.4	8.8
12	9.3	9.4	9.2	9.4	10.0	8.8	9.5	8.9

Table 2.1.6. Estimates of trawl survey catchability (part I), and three ways of looking at the product of trawl survey catchability and selectivity at age (parts II-IV). Parts II-IV pertain only to the post-1981 portion of the survey time series. “SD” = standard deviation, “CV” = coefficient of variation. Pink = row maximum, green = row minimum.

I. Trawl survey catchability

Years	Model A	Model B	Model C	Model D	Model E	Model F	Model G	Model H
Pre-1982	0.982	2.307	1.000	1.000	0.266	1.731	1.000	1.000
Post-1981	0.714	1.021	1.000	1.000	0.451	0.985	1.000	1.000

II. Numbers-weighted product of trawl survey catchability and selectivity at age (length range 60-81 cm)

Statistic	Model A	Model B	Model C	Model D	Model E	Model F	Model G	Model H
Mean	0.593	1.021	0.880	1.000	0.188	0.984	0.489	0.999

III. Biomass-weighted product of trawl survey catchability and selectivity at age (all ages)

Statistic	Model A	Model B	Model C	Model D	Model E	Model F	Model G	Model H
Mean	0.530	1.003	0.791	0.983	0.185	0.954	0.472	0.968
SD	0.046	0.008	0.062	0.008	0.049	0.022	0.129	0.023
CV	0.088	0.008	0.078	0.008	0.266	0.023	0.273	0.024

IV. Product of trawl survey catchability and selectivity at age 1

Statistic	Model A	Model B	Model C	Model D	Model E	Model F	Model G	Model H
Mean	0.292	0.412	0.389	0.405	0.118	0.341	0.253	0.342
SD	0.154	0.224	0.219	0.220	0.076	0.228	0.170	0.231
CV	0.529	0.543	0.564	0.543	0.641	0.668	0.670	0.675

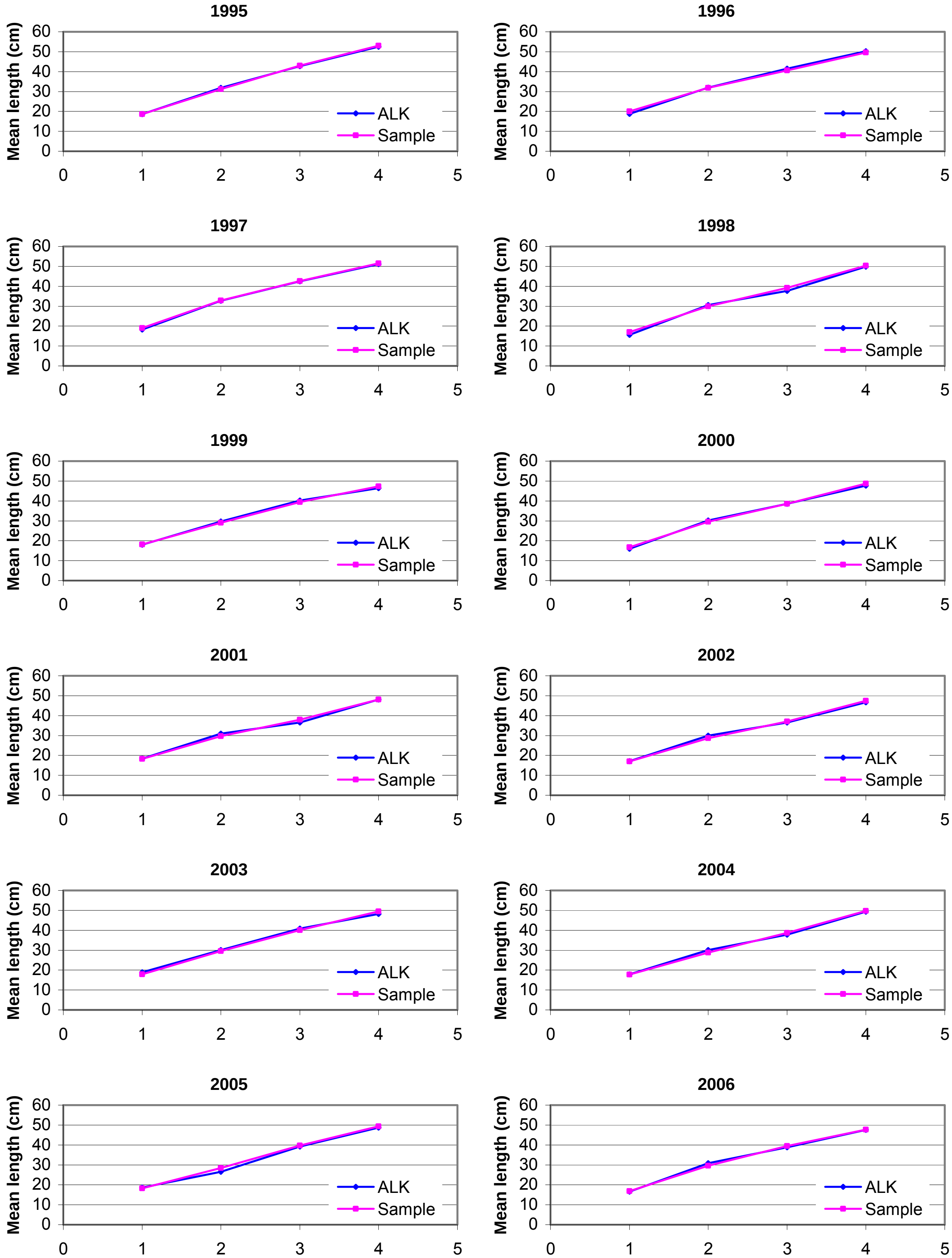


Figure 2.1.1a. Mean lengths at age (males) as estimated by the otolith sample and age-length key (ALK).

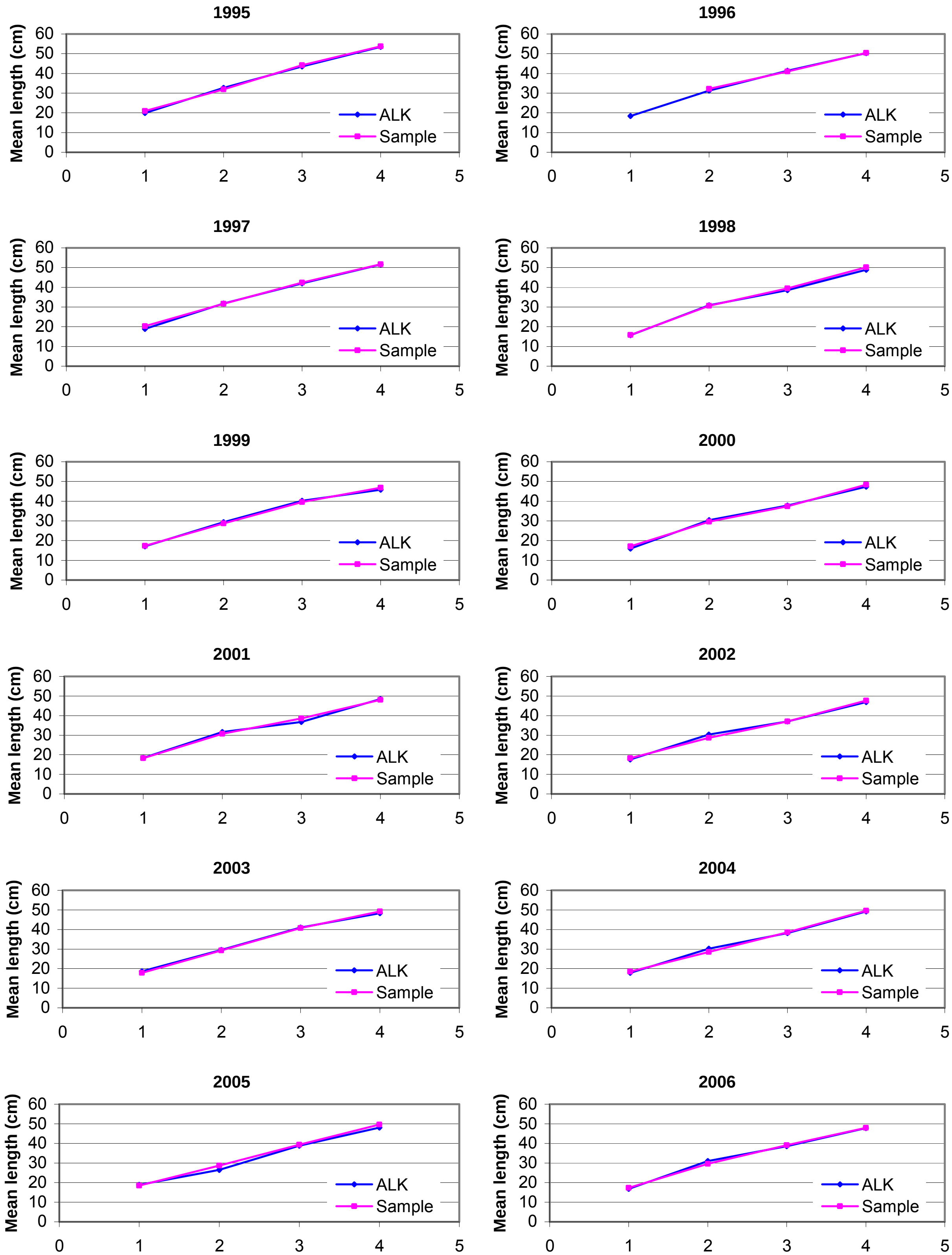


Figure 2.1.1b. Mean lengths at age (females) as estimated by the otolith sample and age-length key.

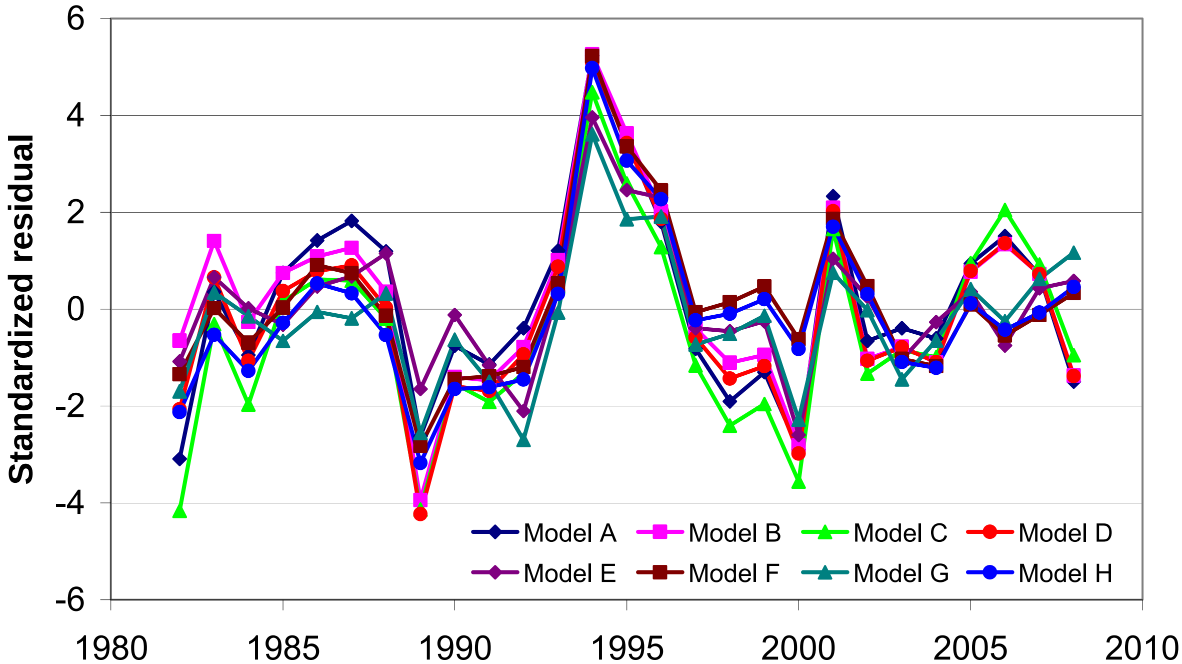


Figure 2.1.2. Standardized residuals from fits to post-1981 trawl survey abundance.

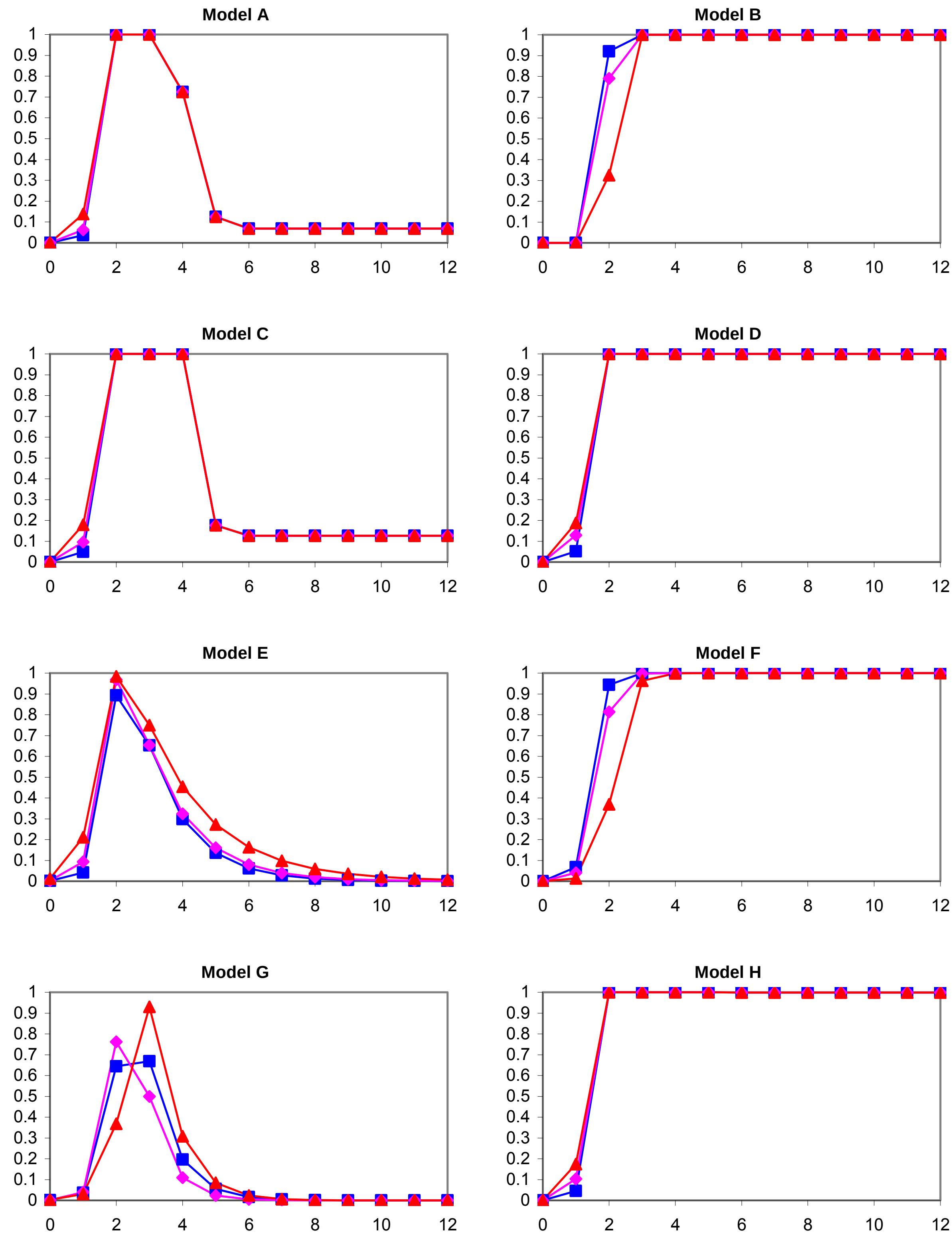


Figure 2.1.3. Pre-1982 trawl survey selectivities.

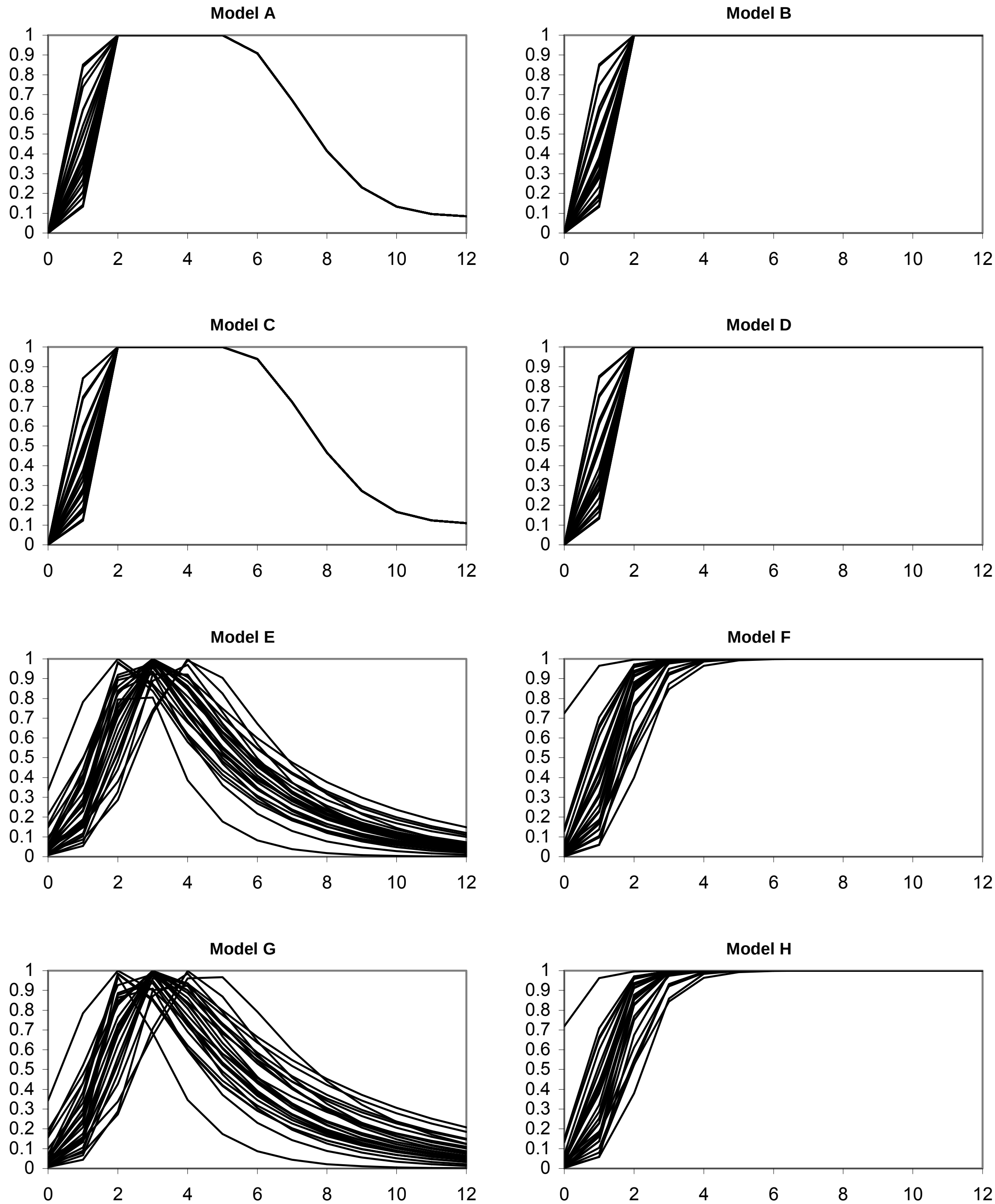


Figure 2.1.4. Post-1981 trawl survey selectivities.

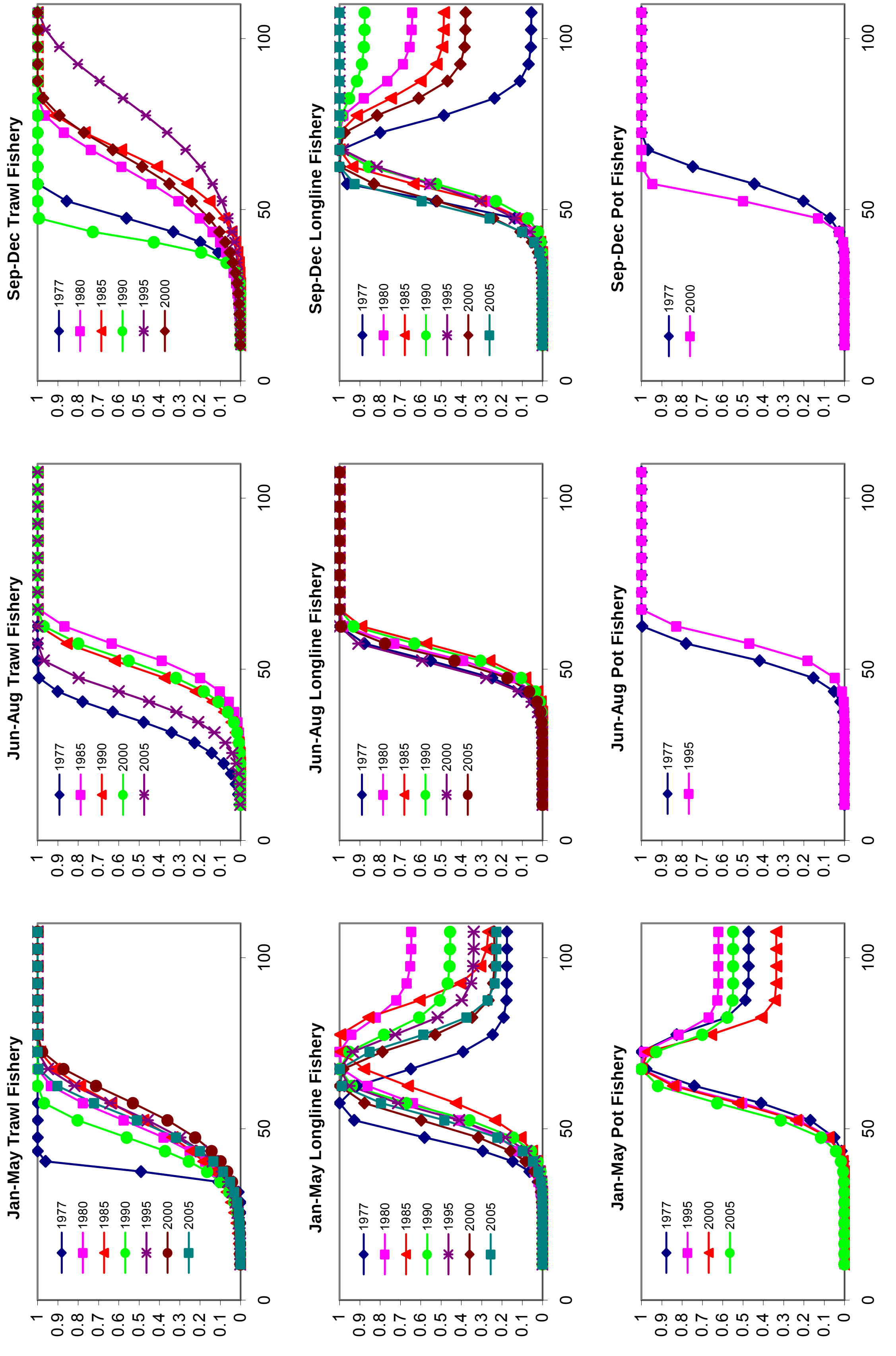


Figure 2.1.5A. Fishery selectivities as estimated by Model A.

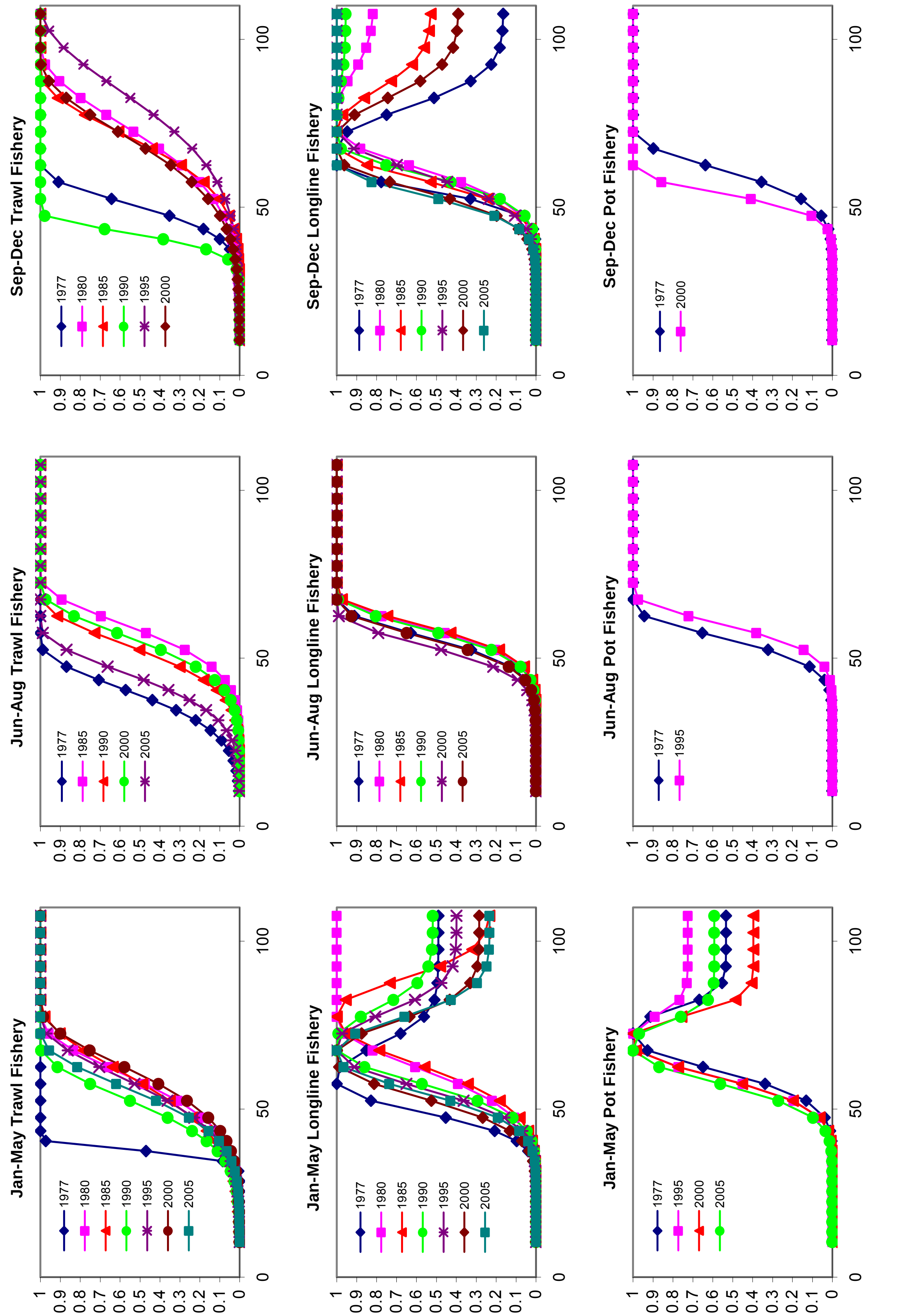


Figure 2.1.5B. Fishery selectivities as estimated by Model B.

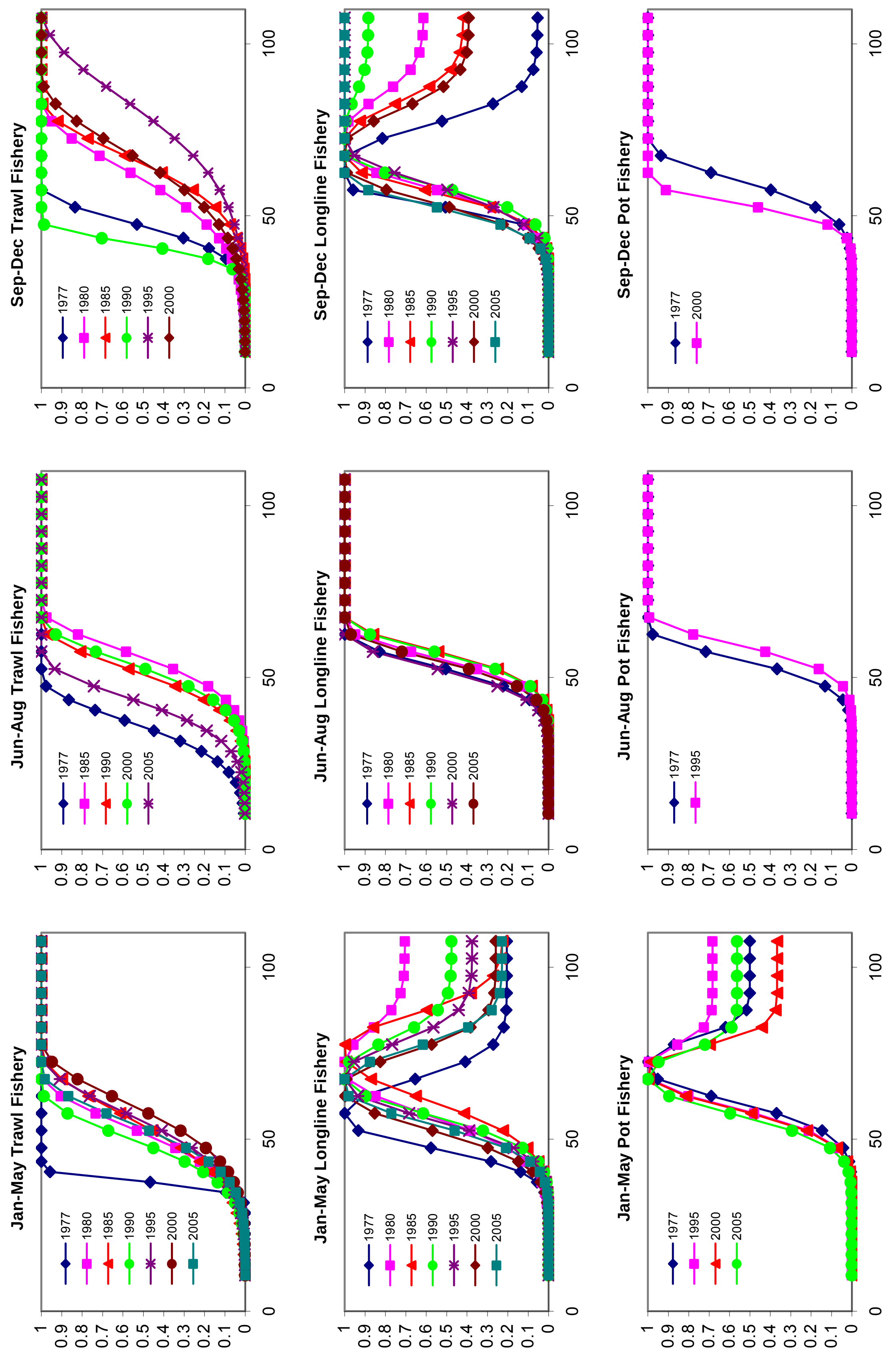


Figure 2.1.5C. Fishery selectivities as estimated by Model C.

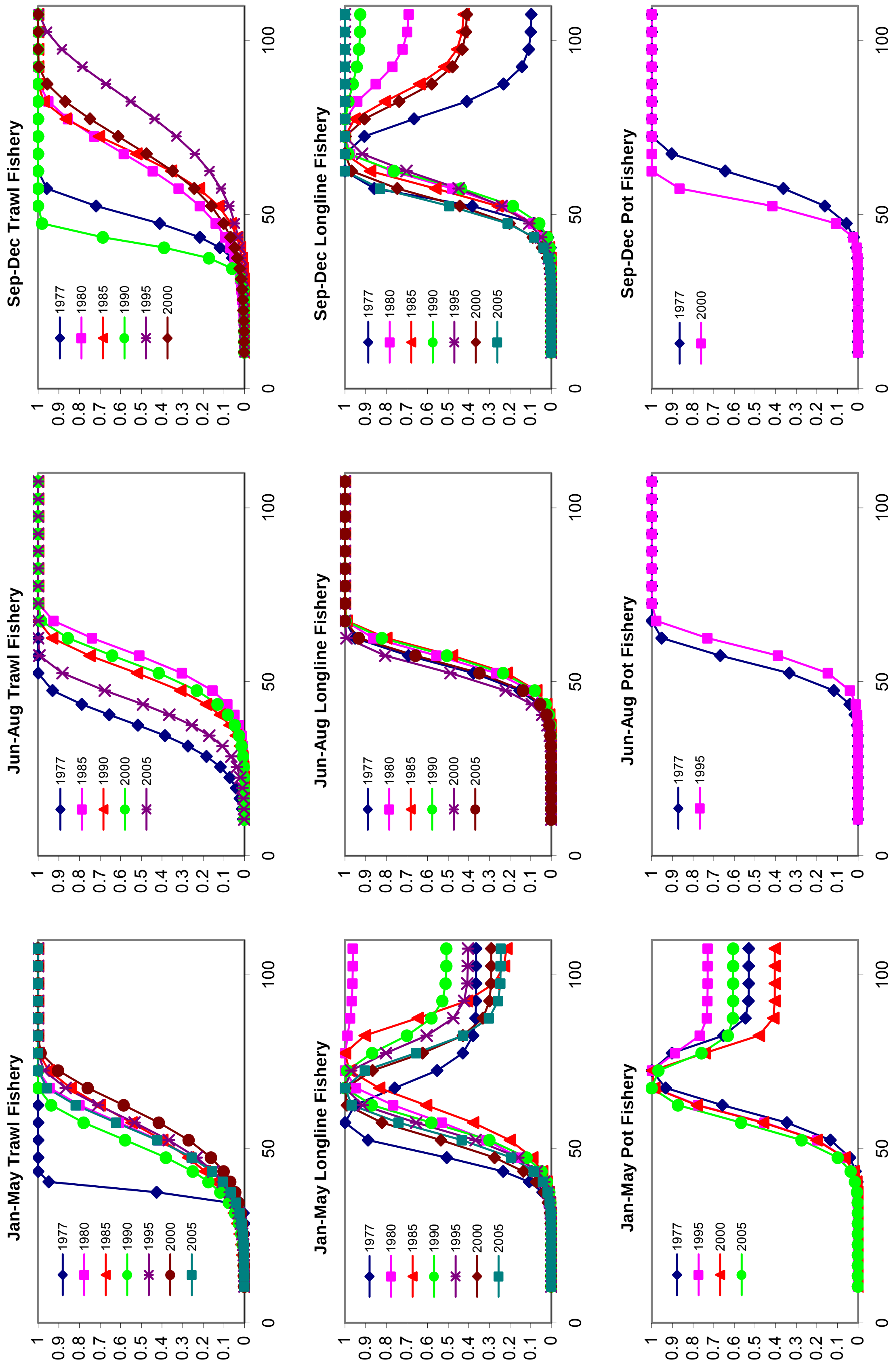


Figure 2.1.5D. Fishery selectivities as estimated by Model D.

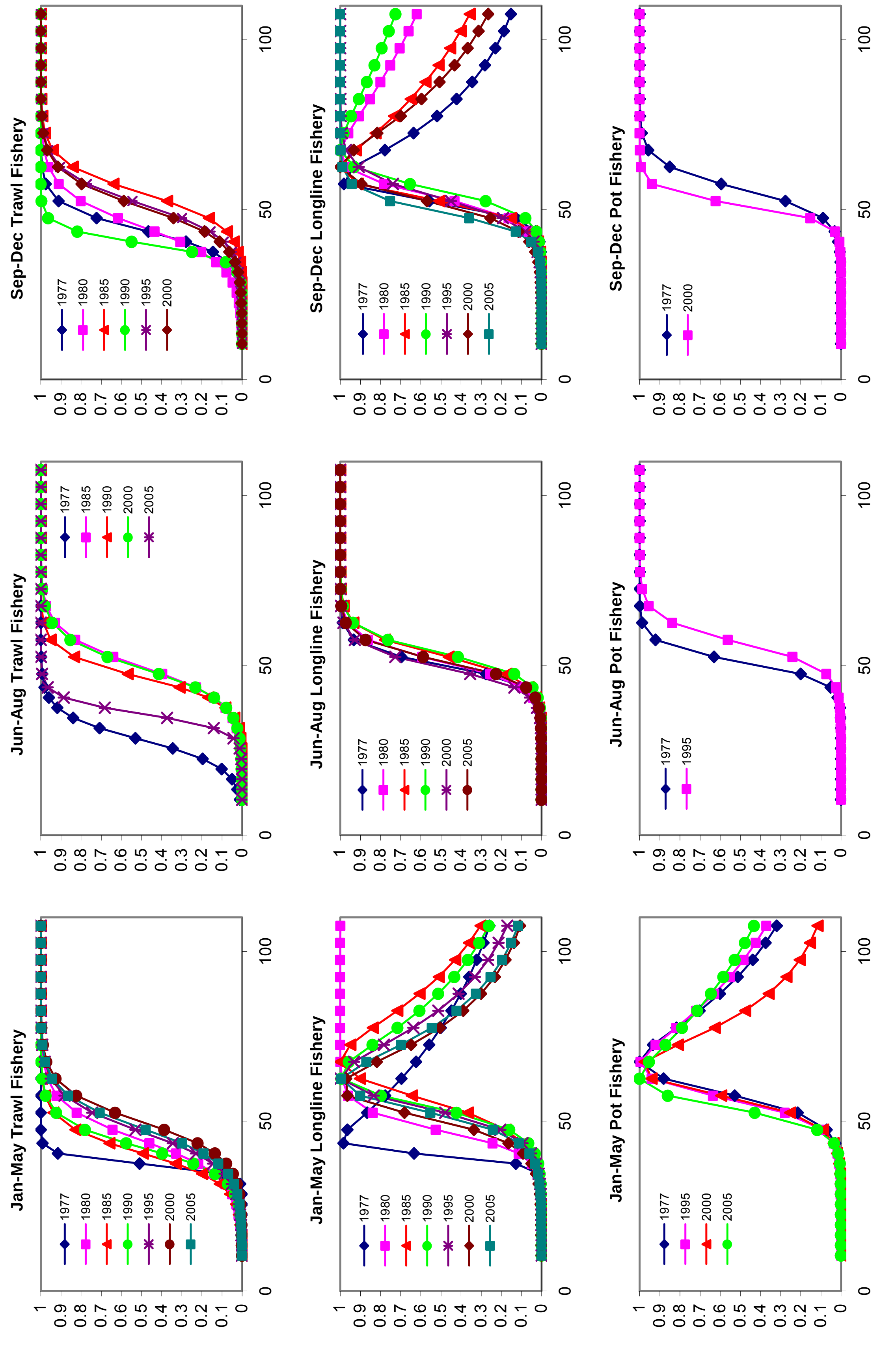


Figure 2.1.5E. Fishery selectivities as estimated by Model E.

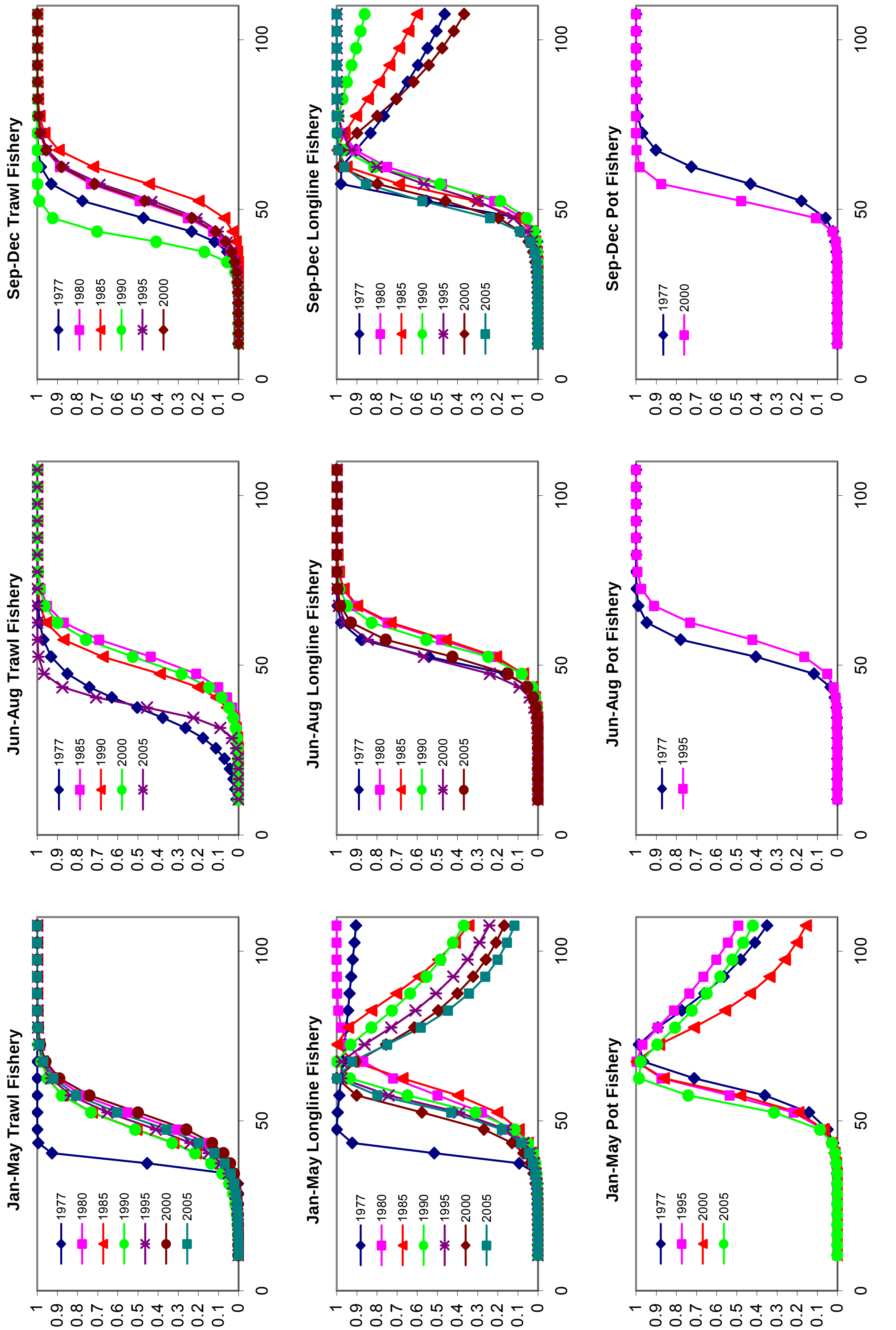


Figure 2.1.5F. Fishery selectivities as estimated by Model F.

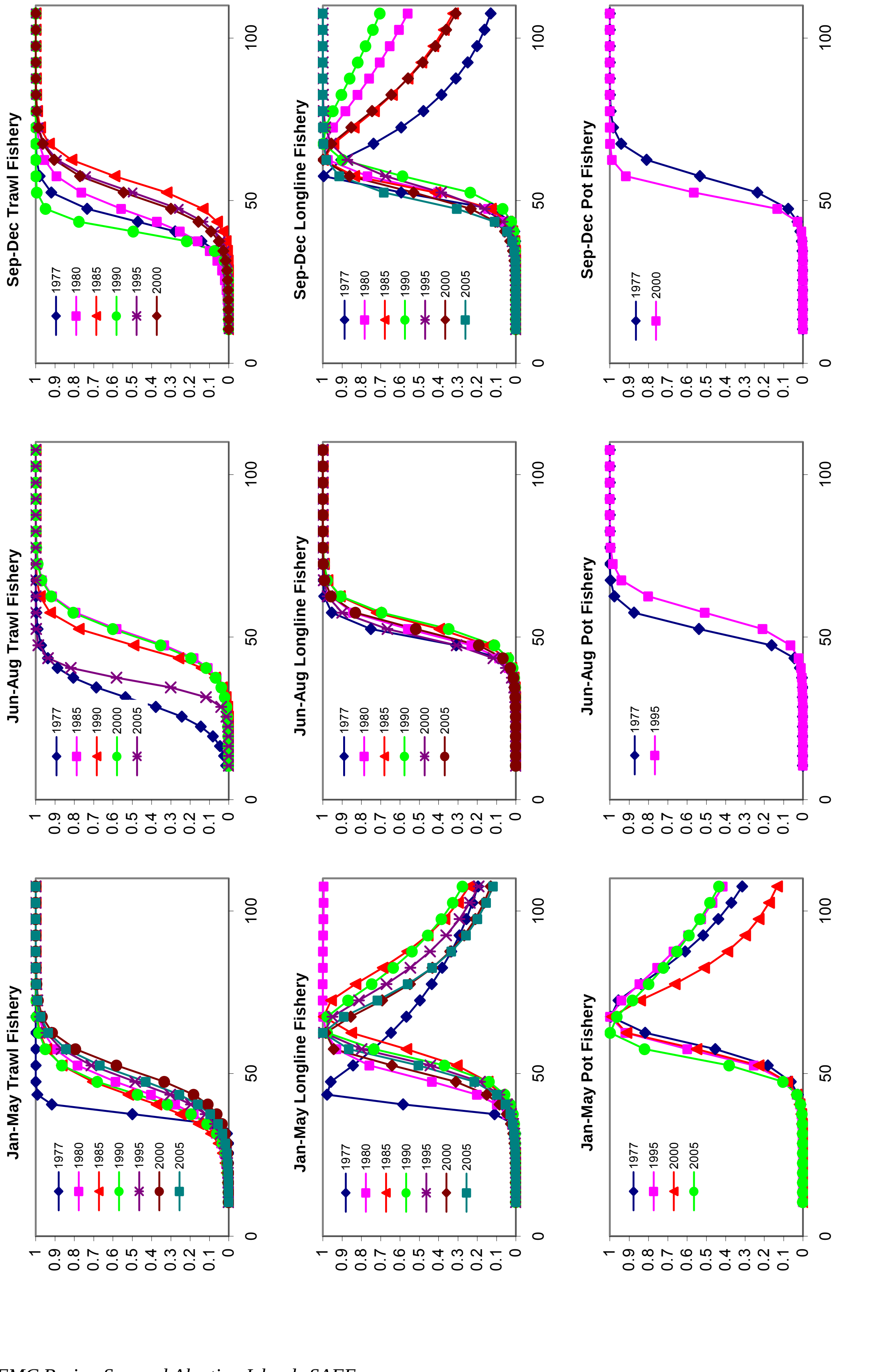


Figure 2.1.5G. Fishery selectivities as estimated by Model G.

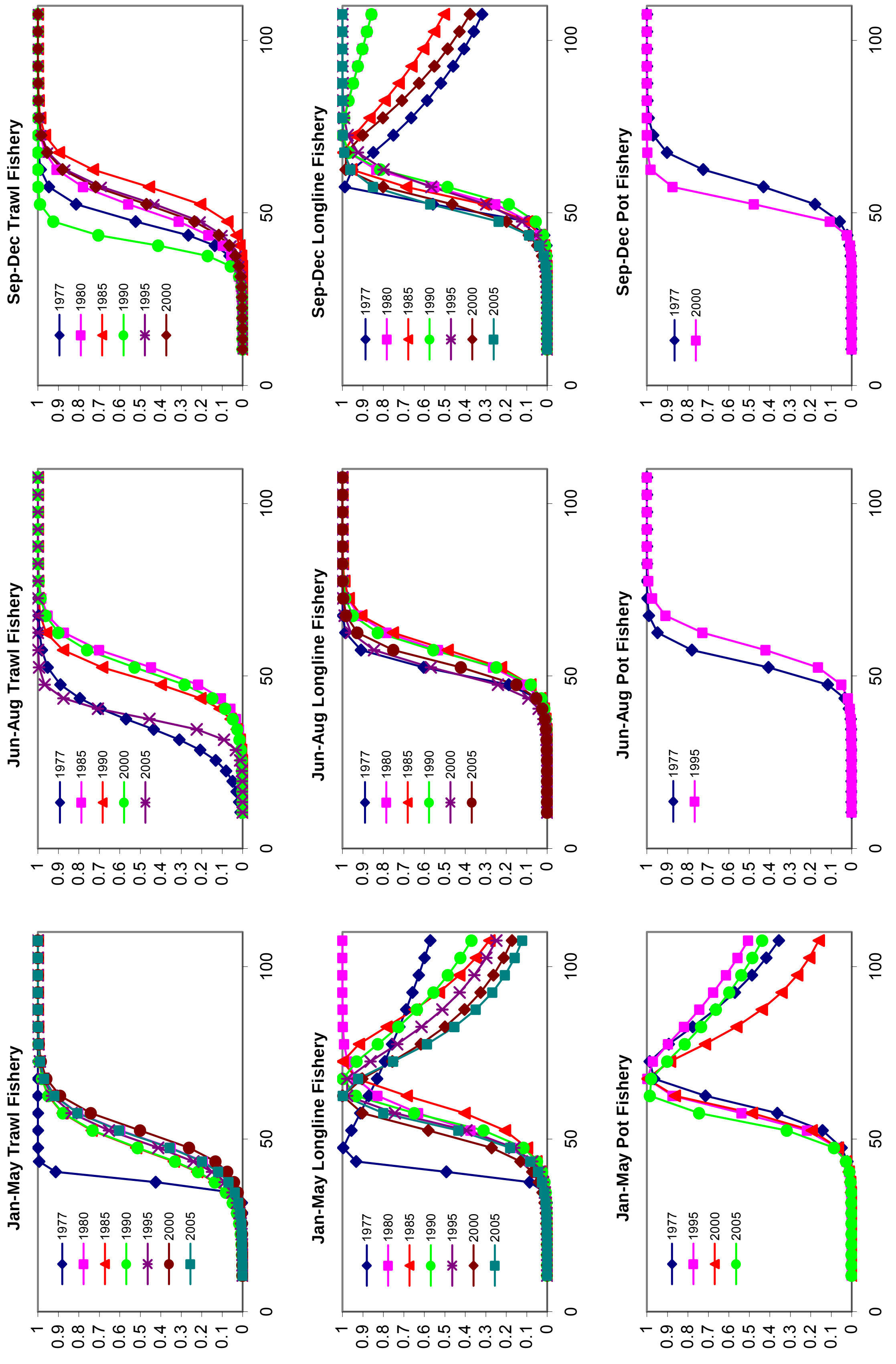


Figure 21.5H. Fishery selectivities as estimated by Model H.

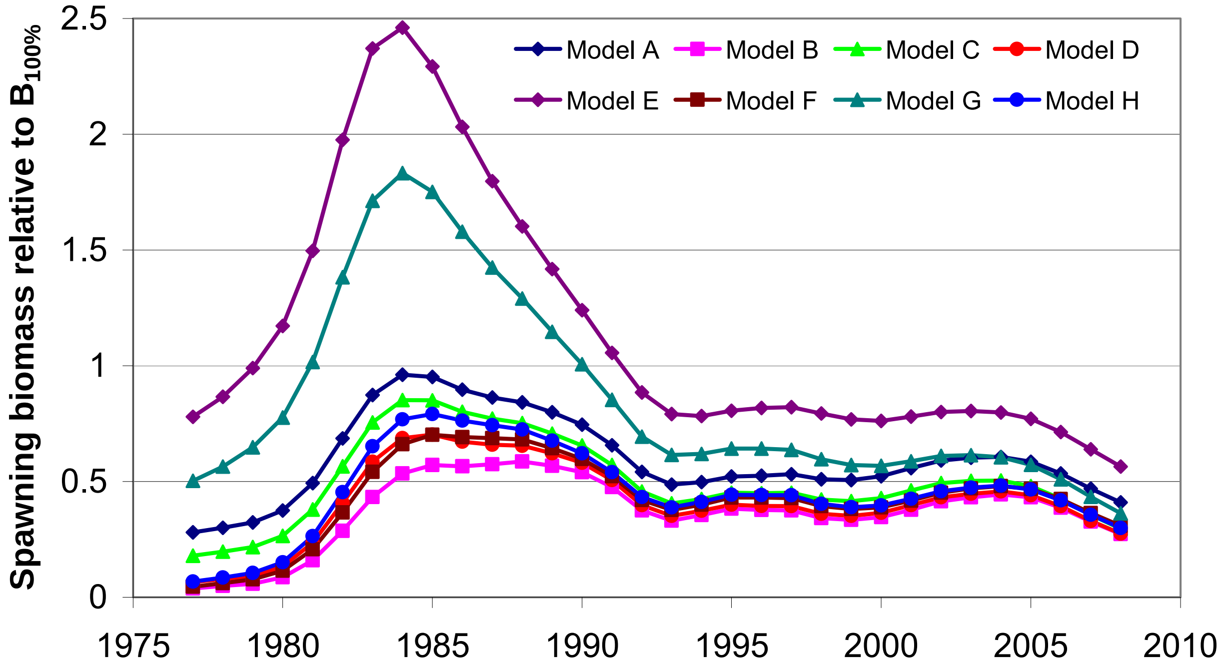


Figure 2.1.6. Comparison of estimated relative spawning biomass time series.

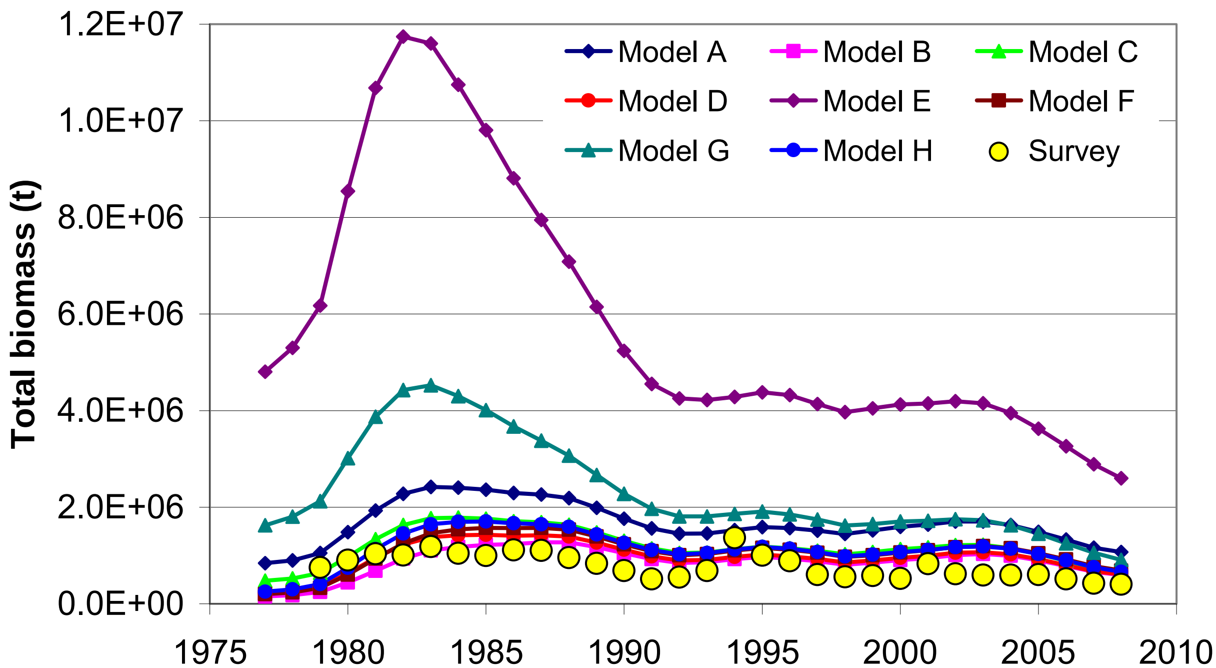


Figure 2.1.7. Comparison of estimated total biomass time series.

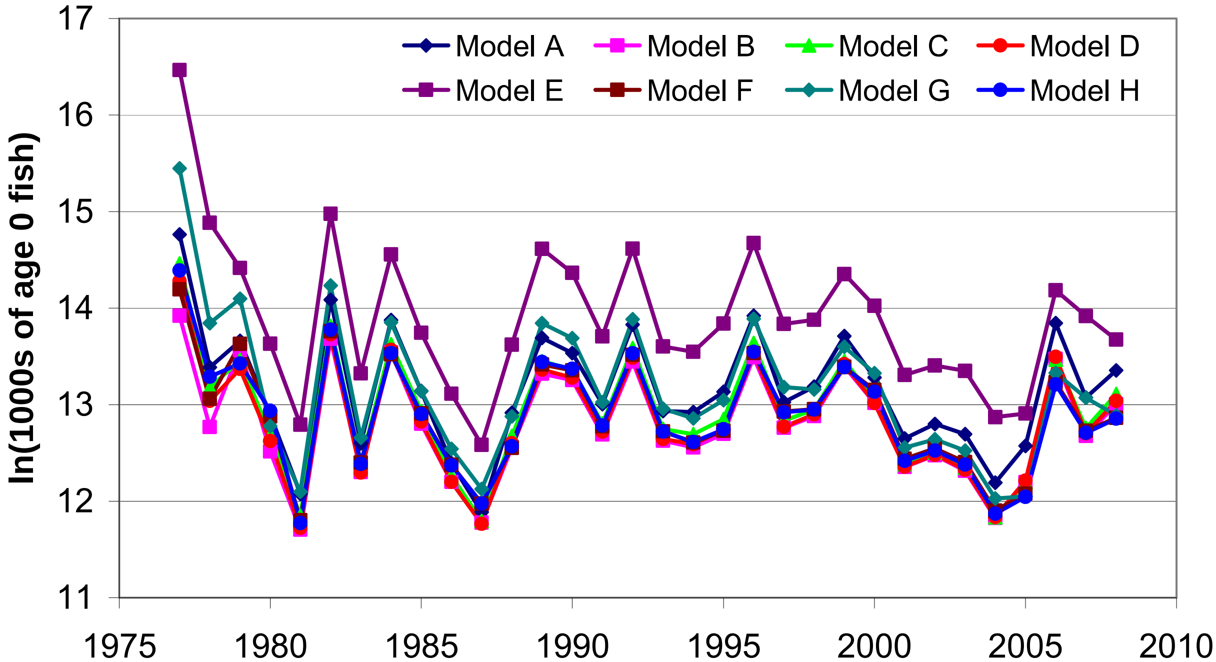


Figure 2.1.8. Comparison of estimated log recruitment time series.

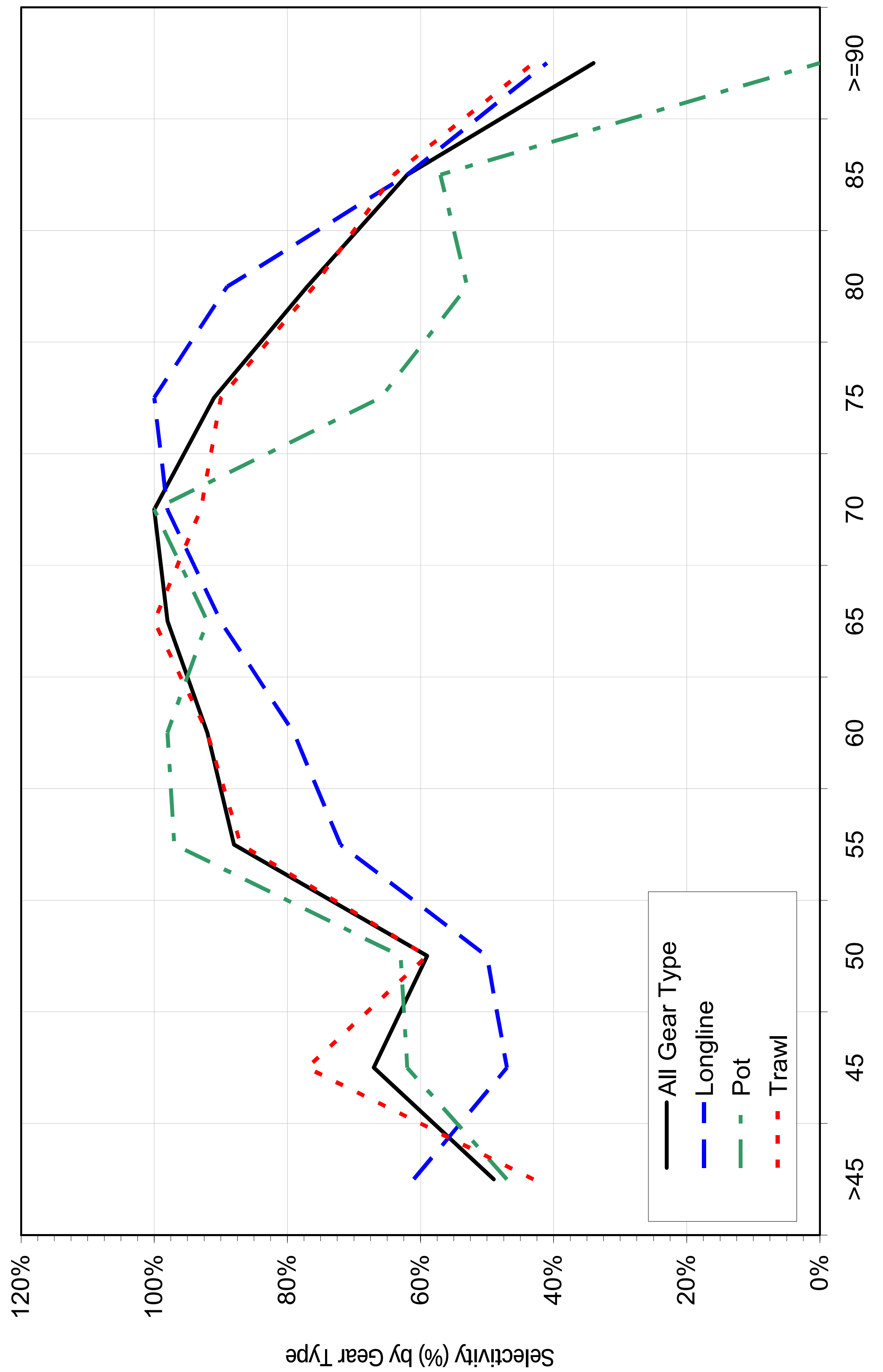


Figure 2.1.9. Fishery selectivity as estimated from tagging data (copied from Figure 12 of Shi et al. 2007).

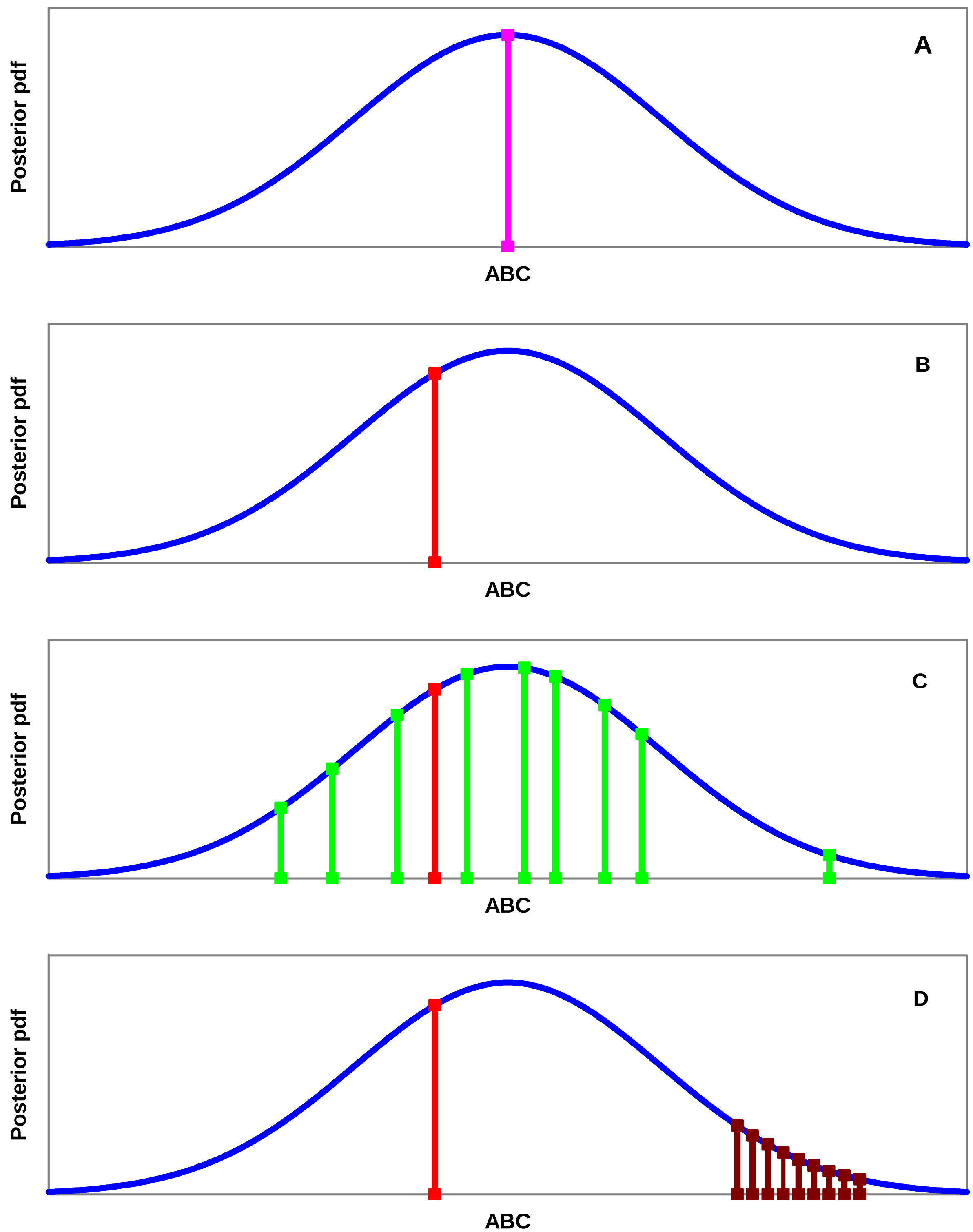
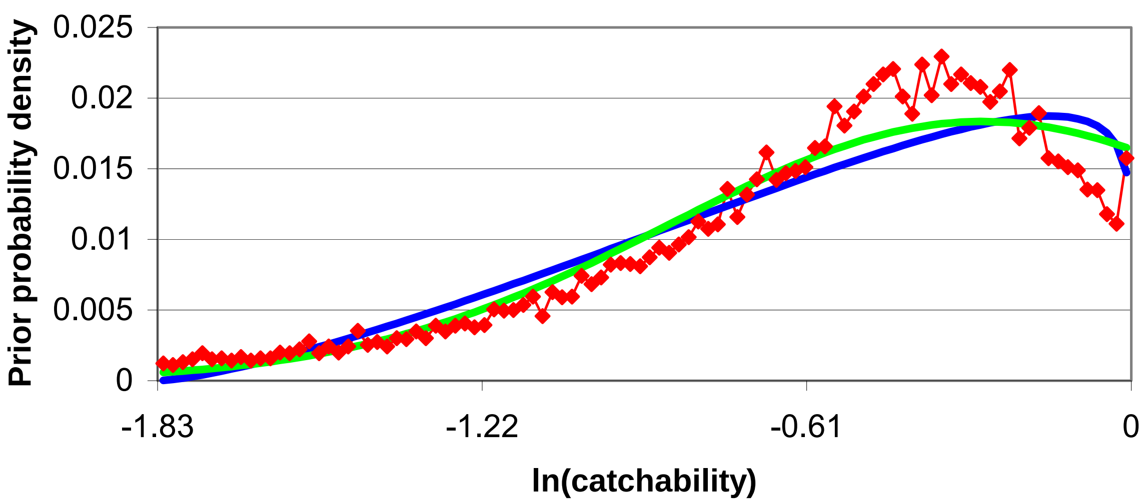


Figure 2.1.10. Hypothetical examples of model averaging. A. One model is used, which happens to be the true model. B. One model is used, but it is not the true model. C. A random sample of 9 other (green) models is added to panel B. D. A non-random sample of nine other models (brown) is added to panel B.

Annex 2.1.1: Development of a Prior Distribution for Log Catchability

1) The depth data from each tag (n=11) were assumed to be drawn from a tag-specific lognormal distribution with parameters μ and σ^2. This required doing something about the 3.7% of the observations that had value 0 or less. These values were replaced by a value of 0.1, the smallest positive value recordable by the tags.
2) After log-transforming the σ^2 parameters, the set of μ and $\ln(\sigma^2)$ values was assumed to be drawn from a bivariate normal joint prior distribution with parameters mean(μ), var(μ), mean($\ln(\sigma^2)$), var($\ln(\sigma^2)$), and cor(μ,$\ln(\sigma^2)$).
3) After log-transforming the prior variance parameters and logit-transforming the prior correlation parameter, each parameter of the joint prior was assumed to be drawn from a normal hyperprior with mean zero and large variance.
4) MCMC was used to obtain a sample of 1,000,000 sets of values for the five parameters of the joint prior distribution. Of these, the first 200,000 were discarded, and every 400th of the remaining 800,000 was retained, giving a final sample of 2,000 sets of values (within this final sample of 2,000, none of the parameters had an autocorrelation less than -0.02 or greater than 0.02).
5) For each of the 2,000 realizations of the joint prior distribution, 10 sets of μ and $\ln(\sigma^2)$ values were drawn. After back-transforming the $\ln(\sigma^2)$ parameters, the cdf was evaluated at x=2.5 (the height of the Bering Sea survey trawl headrope). The resulting set of 2,000×10=20,000 cdf values was assumed to represent the prior distribution of catchability.
6) Because SS operates in terms of ln(catchability) rather than catchability *per se*, the 20,000 cdf values were log-transformed. Because SS requires all prior distributions to be bounded, it was necessary to choose upper and lower bounds for the range of ln(catchability). An upper bound of zero was a natural choice, and the lower bound was set equal to the lower 5th percentile of the data (= –1.86). SS allows for uniform, beta, and truncated normal priors. It was obvious that a uniform distribution would not fit the data well. Parameters of beta and truncated normal distributions were estimated by maximum likelihood, resulting in α = 2.37 and β = 1.13 for the beta distribution, and mean = –0.28 and standard deviation = 0.59) for the truncated normal distribution. The log likelihood for the normal distribution was about 766 points better than the log likelihood for the beta distribution. The data (red), beta model fit (blue), and truncated normal model fit (green) are shown below:



Attachment 2.2:

Tables and figures for the "Time Series Results" and "Projections and Harvest Alternatives" sections based on the SSC's reference model (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 2.2.25a—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 2010 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	842,241	254,248	62,006	724,376	218,257	52,265
1978	899,016	271,985	62,963	771,927	232,880	52,788
1979	1,052,030	292,994	64,980	908,479	249,342	54,054
1980	1,482,030	340,179	68,171	1,300,000	290,483	56,244
1981	1,932,570	447,717	74,062	1,710,000	387,737	60,580
1982	2,276,670	622,090	84,594	2,030,000	545,000	68,708
1983	2,418,520	792,125	93,742	2,170,000	705,000	75,784
1984	2,403,580	872,225	94,261	2,170,000	780,000	75,819
1985	2,363,850	862,640	87,626	2,140,000	775,000	70,077
1986	2,293,060	813,255	78,960	2,090,000	735,000	62,752
1987	2,262,680	782,455	71,900	2,070,000	710,000	56,721
1988	2,188,110	763,180	66,731	2,010,000	695,000	52,199
1989	1,992,030	724,445	62,300	1,840,000	665,000	48,319
1990	1,762,410	675,640	57,352	1,620,000	620,000	44,170
1991	1,563,070	595,695	51,131	1,440,000	545,000	39,166
1992	1,450,780	491,365	44,997	1,330,000	446,956	34,309
1993	1,459,860	440,882	41,164	1,340,000	400,578	31,220
1994	1,528,360	451,689	40,324	1,410,000	412,020	30,371
1995	1,589,790	473,295	41,339	1,460,000	431,856	30,885
1996	1,569,500	475,938	43,007	1,430,000	431,147	31,855
1997	1,515,220	481,913	44,522	1,360,000	432,881	32,642
1998	1,449,180	462,345	45,141	1,290,000	409,368	32,741
1999	1,522,510	459,272	45,424	1,340,000	402,339	32,629
2000	1,595,780	474,130	46,453	1,400,000	411,872	33,029
2001	1,641,550	505,955	48,285	1,430,000	437,133	33,944
2002	1,702,650	535,905	49,744	1,480,000	461,058	34,536
2003	1,707,180	546,815	50,377	1,480,000	467,192	34,516
2004	1,630,540	549,570	50,640	1,420,000	471,066	34,295
2005	1,491,060	530,935	50,182	1,300,000	452,844	33,733
2006	1,331,050	484,612	48,476	1,170,000	411,649	32,653
2007	1,165,190	425,560	45,797	1,040,000	363,528	31,281
2008	1,075,950	372,037	42,886	970,328	323,910	30,025
2009	1,115,780	334,283	40,843	969,725	290,293	29,378
2010				1,040,000	278,704	30,131

Table 2.2.25b—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	2,577,100	312,291	2,340,000	261,255
1978	651,724	136,257	594,536	122,524
1979	855,987	115,728	807,729	104,627
1980	398,064	65,379	376,430	60,530
1981	175,500	36,606	167,653	34,209
1982	1,312,260	101,877	1,250,000	84,397
1983	296,381	43,943	280,126	40,360
1984	1,062,620	82,816	1,020,000	70,395
1985	509,878	51,303	476,187	45,584
1986	241,701	29,914	229,158	27,744
1987	145,513	22,956	144,175	21,822
1988	406,441	37,804	386,925	33,172
1989	884,194	69,872	841,582	57,736
1990	754,655	55,679	709,775	46,666
1991	444,549	39,206	420,570	34,147
1992	1,014,130	72,658	939,012	55,405
1993	414,229	34,677	376,943	28,056
1994	409,616	34,346	371,833	27,042
1995	506,237	45,551	453,292	35,685
1996	1,110,340	85,107	999,294	62,966
1997	454,069	35,349	409,250	28,511
1998	533,278	40,779	480,101	31,508
1999	901,297	65,843	802,802	47,566
2000	586,787	42,102	532,036	31,213
2001	312,067	26,662	278,053	20,293
2002	361,796	30,906	381,318	26,656
2003	325,788	31,611	324,877	26,016
2004	197,043	21,591	247,010	22,111
2005	288,607	31,737	291,529	27,384
2006	1,029,020	116,919	707,605	66,493
2007	475,798	192,125	469,627	74,897
2008			1,050,000	246,646
Average	633,441		598,732	

Table 2.2.26—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	2340000	188444	21699	184884	52622	34846	23049	15245	10083	6669	4411	2918	1930	1276	844	558	369	244	162	107	209
1978	594536	1660000	134091	15356	126996	35527	23463	15548	10308	6830	4523	2994	1981	1311	867	574	380	251	166	110	215
1979	807729	423173	1180000	94729	10444	84536	23570	15599	10366	6887	4570	3029	2007	1329	879	582	385	255	168	111	218
1980	376430	574917	301129	837447	65136	7059	56986	15918	10560	7031	4677	3106	2060	1365	904	598	396	262	173	115	224
1981	167653	267932	409087	213542	587749	45052	4826	38735	10796	7157	4764	3169	2105	1396	925	613	406	268	178	118	230
1982	1250000	119330	190626	289755	149720	407413	30951	3299	26413	7353	4872	3242	2157	1432	950	630	417	276	183	121	236
1983	280126	886248	84903	135041	203409	104167	281584	21315	2268	18145	5050	3345	2226	1481	983	652	432	286	189	125	245
1984	1020000	199385	630487	60051	94305	140159	71055	191052	14428	1534	12264	3412	2260	1504	1000	664	441	292	193	128	250
1985	476187	725235	141839	445638	41764	64306	94160	47384	127042	9586	1019	8148	2268	1502	1000	665	442	293	194	129	252
1986	229158	338936	516080	100728	312215	28486	42821	61843	30937	82795	6246	664	5316	1480	981	653	435	289	192	127	249
1987	144175	163108	241182	366450	70579	213246	19014	28199	40479	20205	54047	4078	434	3473	967	641	427	284	189	125	246
1988	386925	102620	116063	171231	256391	47963	141077	12382	18243	26144	13056	34960	2641	281	2253	628	416	277	185	123	241
1989	841582	275402	73000	82233	118950	171956	31096	89428	7753	11350	16211	8081	21617	1632	174	1391	388	257	171	114	225
1990	709775	599013	195910	51735	57197	79999	112047	19861	56539	4879	7128	10171	5068	13555	1023	109	872	243	161	107	212
1991	420570	505197	426312	138761	35522	37401	50747	70354	12445	35437	3060	4473	6387	3184	8518	643	68	548	153	101	201
1992	939012	299349	359534	301829	94261	22373	22382	29831	41230	7302	20835	1802	2638	3770	1881	5034	380	40	324	90	179
1993	376943	668361	213048	254886	207193	60317	13535	13269	17666	24527	4365	12504	1085	1591	2277	1137	3046	230	25	197	163
1994	371833	268297	475672	150995	175731	135451	37805	8361	8203	10976	15315	2736	7860	683	1003	1438	718	1926	146	16	228
1995	453292	264660	190948	336601	103354	113206	83101	22787	5040	4970	6685	9367	1679	4833	421	619	887	444	1190	90	150
1996	999294	322640	188324	135366	231417	65786	66858	47391	12906	2864	2838	3834	5389	968	2791	243	358	514	257	689	139
1997	409250	711268	229589	133598	93535	149169	39574	38938	27430	7495	1671	1663	2253	3173	571	1647	144	212	304	152	490
1998	480101	291292	506135	162776	91758	59286	87518	22411	21912	15498	4258	954	952	1293	1825	329	950	83	122	175	371
1999	802802	341722	207293	359198	112837	59900	36561	52630	13425	13172	9358	2580	580	580	788	1113	201	580	51	75	334
2000	532036	571410	243194	147201	249684	74034	37185	22171	31857	8169	8062	5754	1592	358	359	489	691	125	360	31	254
2001	278053	378687	406662	172553	101517	162296	45985	22783	13649	19795	5119	5083	3644	1011	228	229	312	442	80	231	183
2002	381318	197910	269510	288543	118947	66196	101954	28650	14285	8638	12626	3284	3274	2354	655	148	149	203	287	52	269
2003	324877	271411	140852	191221	198356	76660	40781	62115	17565	8846	5395	7935	2073	2073	1494	416	94	95	129	183	205
2004	247010	231238	193166	99953	131612	128270	47436	24962	38271	10934	5555	3409	5038	1320	1323	955	266	60	61	83	249
2005	291529	175814	164572	137011	68456	83961	77867	28448	15077	23376	6743	3450	2128	3155	829	832	601	168	38	38	209
2006	707605	207502	125127	116703	93921	43733	50682	46037	16836	8991	14044	4074	2093	1295	1924	506	509	368	103	23	152
2007	469627	503652	147678	88747	80122	59887	26174	29619	26936	9937	5353	8418	2454	1265	784	1168	308	309	224	63	107
2008	1050000	334267	358434	104691	60986	51339	36126	15439	17501	16059	5977	3241	5121	1498	774	481	717	189	190	138	104
2009	595950	746564	237883	254051	71506	38404	30236	20776	8903	10197	9451	3544	1932	3065	899	466	290	432	114	115	146

Table 2.2.27—Projections for BSAI Pacific cod catch (t), spawning biomass (t), and fishing mortality under the assumption that $F = max\ F_{ABC}$ in 2010-2022 (Scenarios 1 and 2), with random variability in future recruitment under Model A1.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2010	159,000	159,000	159,000	159,000	0
2011	201,000	201,000	201,000	202,000	82
2012	266,000	267,000	267,000	270,000	1,649
2013	285,000	294,000	296,000	317,000	11,490
2014	252,000	285,000	293,000	359,000	37,610
2015	200,000	273,000	283,000	387,000	61,810
2016	170,000	266,000	273,000	399,000	75,083
2017	151,000	263,000	267,000	404,000	78,417
2018	141,000	260,000	263,000	399,000	78,692
2019	136,000	260,000	261,000	397,000	79,422
2020	140,000	259,000	260,000	396,000	79,900
2021	141,000	256,000	260,000	401,000	79,837
2022	143,000	259,000	261,000	407,000	80,936

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2010	319,000	319,000	319,000	319,000	0
2011	346,000	346,000	346,000	347,000	138
2012	389,000	390,000	390,000	393,000	1,591
2013	418,000	427,000	429,000	447,000	9,934
2014	411,000	439,000	446,000	501,000	31,609
2015	375,000	433,000	445,000	551,000	60,833
2016	345,000	421,000	439,000	585,000	82,368
2017	324,000	415,000	434,000	599,000	90,914
2018	312,000	412,000	430,000	603,000	91,632
2019	305,000	410,000	427,000	603,000	90,848
2020	304,000	409,000	425,000	592,000	91,014
2021	307,000	407,000	425,000	595,000	91,502
2022	312,000	404,000	425,000	596,000	92,415

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2010	0.23	0.23	0.23	0.23	0.00
2011	0.25	0.25	0.25	0.25	0.00
2012	0.28	0.28	0.28	0.28	0.00
2013	0.29	0.29	0.29	0.29	0.00
2014	0.29	0.29	0.29	0.29	0.00
2015	0.27	0.29	0.29	0.29	0.01
2016	0.25	0.29	0.28	0.29	0.02
2017	0.23	0.29	0.28	0.29	0.02
2018	0.22	0.29	0.28	0.29	0.02
2019	0.22	0.29	0.27	0.29	0.03
2020	0.22	0.29	0.27	0.29	0.03
2021	0.22	0.29	0.27	0.29	0.03
2022	0.22	0.29	0.27	0.29	0.03

Table 2.2.28—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 the most recent five-year average fishing mortality rate in 2010-2022 (Scenario 3), with random variability in future recruitment under Model A1.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2010	107,000	107,000	107,000	107,000	0
2011	131,000	131,000	131,000	131,000	2
2012	160,000	160,000	160,000	161,000	332
2013	175,000	180,000	181,000	192,000	6,078
2014	167,000	185,000	189,000	225,000	20,493
2015	151,000	185,000	191,000	250,000	33,937
2016	141,000	183,000	192,000	266,000	41,332
2017	134,000	184,000	191,000	273,000	43,791
2018	127,000	184,000	190,000	269,000	44,367
2019	124,000	182,000	189,000	273,000	44,923
2020	124,000	183,000	188,000	271,000	45,454
2021	126,000	182,000	189,000	272,000	45,733
2022	128,000	181,000	189,000	281,000	46,477

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2010	322,000	322,000	322,000	322,000	0
2011	368,000	368,000	368,000	368,000	142
2012	436,000	437,000	438,000	441,000	1,676
2013	502,000	510,000	513,000	531,000	10,360
2014	532,000	561,000	569,000	627,000	33,132
2015	520,000	585,000	598,000	712,000	67,769
2016	490,000	591,000	610,000	788,000	99,881
2017	463,000	593,000	614,000	832,000	119,813
2018	441,000	596,000	614,000	851,000	128,712
2019	423,000	592,000	612,000	853,000	132,285
2020	413,000	593,000	609,000	849,000	134,536
2021	414,000	592,000	608,000	851,000	136,328
2022	418,000	590,000	608,000	847,000	137,992

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2010	0.15	0.15	0.15	0.15	0.00
2011	0.15	0.15	0.15	0.15	0.00
2012	0.15	0.15	0.15	0.15	0.00
2013	0.15	0.15	0.15	0.15	0.00
2014	0.15	0.15	0.15	0.15	0.00
2015	0.15	0.15	0.15	0.15	0.00
2016	0.15	0.15	0.15	0.15	0.00
2017	0.15	0.15	0.15	0.15	0.00
2018	0.15	0.15	0.15	0.15	0.00
2019	0.15	0.15	0.15	0.15	0.00
2020	0.15	0.15	0.15	0.15	0.00
2021	0.15	0.15	0.15	0.15	0.00
2022	0.15	0.15	0.15	0.15	0.00

Table 2.2.29—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 2010-2022 (Scenario 4), with random variability in future recruitment under Model A1.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2010	104,000	104,000	104,000	104,000	0
2011	127,000	127,000	127,000	127,000	2
2012	156,000	156,000	156,000	156,000	321
2013	171,000	175,000	176,000	187,000	5,873
2014	163,000	180,000	185,000	220,000	19,833
2015	148,000	180,000	187,000	244,000	32,917
2016	138,000	179,000	187,000	260,000	40,172
2017	131,000	180,000	187,000	266,000	42,627
2018	125,000	180,000	186,000	263,000	43,223
2019	122,000	179,000	185,000	267,000	43,778
2020	122,000	179,000	184,000	264,000	44,303
2021	124,000	178,000	184,000	266,000	44,582
2022	125,000	177,000	185,000	274,000	45,307

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2010	322,000	322,000	322,000	322,000	0
2011	369,000	369,000	369,000	370,000	142
2012	439,000	440,000	441,000	444,000	1,676
2013	506,000	515,000	517,000	536,000	10,363
2014	538,000	567,000	575,000	633,000	33,178
2015	527,000	592,000	605,000	720,000	68,019
2016	497,000	598,000	618,000	797,000	100,524
2017	471,000	602,000	623,000	841,000	120,875
2018	449,000	604,000	623,000	861,000	130,081
2019	430,000	602,000	621,000	865,000	133,823
2020	420,000	602,000	619,000	862,000	136,157
2021	421,000	601,000	618,000	864,000	138,003
2022	425,000	600,000	617,000	860,000	139,703

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
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
2022	0.14	0.14	0.14	0.14	0.00

Table 2.2.30—Projections for BSAI Pacific cod catch (t), spawning biomass (t), and fishing mortality under the assumption that F = 0 in 2010-2022 (Scenario 5), with random variability in future recruitment under Model A1.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
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
2022	0	0	0	0	0

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2010	328,000	328,000	328,000	328,000	0
2011	412,000	413,000	413,000	413,000	142
2012	528,000	529,000	530,000	533,000	1,677
2013	651,000	659,000	662,000	680,000	10,437
2014	742,000	772,000	780,000	841,000	34,493
2015	780,000	851,000	866,000	997,000	75,581
2016	779,000	899,000	924,000	1,140,000	121,042
2017	769,000	933,000	961,000	1,240,000	156,733
2018	753,000	958,000	984,000	1,310,000	178,734
2019	731,000	968,000	998,000	1,350,000	190,873
2020	717,000	977,000	1,010,000	1,370,000	198,135
2021	720,000	989,000	1,010,000	1,370,000	203,160
2022	723,000	991,000	1,020,000	1,380,000	207,028

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
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
2022	0.00	0.00	0.00	0.00	0.00

Table 2.2.31—Projections for BSAI Pacific cod catch (t), spawning biomass (t), and fishing mortality under the assumption that $F = F_{OFL}$ in 2010-2022 (Scenario 6), with random variability in future recruitment under Model A1.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2010	186,000	186,000	186,000	186,000	0
2011	225,000	225,000	225,000	225,000	93
2012	288,000	289,000	290,000	293,000	1,866
2013	310,000	326,000	329,000	357,000	16,350
2014	260,000	313,000	318,000	398,000	47,833
2015	199,000	288,000	299,000	426,000	76,390
2016	172,000	273,000	286,000	432,000	88,606
2017	153,000	267,000	280,000	439,000	90,492
2018	146,000	265,000	277,000	437,000	90,282
2019	142,000	267,000	275,000	432,000	90,913
2020	144,000	265,000	274,000	433,000	91,395
2021	145,000	262,000	275,000	435,000	91,437
2022	147,000	265,000	276,000	443,000	92,696

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2010	317,000	317,000	317,000	317,000	0
2011	335,000	336,000	336,000	336,000	137
2012	370,000	371,000	372,000	375,000	1,580
2013	393,000	400,000	403,000	420,000	9,703
2014	378,000	403,000	410,000	462,000	29,922
2015	342,000	391,000	403,000	502,000	55,735
2016	314,000	378,000	396,000	529,000	72,575
2017	297,000	374,000	391,000	534,000	77,832
2018	287,000	374,000	388,000	534,000	77,264
2019	283,000	372,000	386,000	534,000	76,507
2020	282,000	372,000	384,000	532,000	77,008
2021	284,000	371,000	385,000	529,000	77,527
2022	287,000	371,000	386,000	539,000	78,270

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2010	0.27	0.27	0.27	0.27	0.00
2011	0.29	0.29	0.29	0.29	0.00
2012	0.32	0.32	0.32	0.32	0.00
2013	0.34	0.35	0.35	0.35	0.00
2014	0.33	0.35	0.34	0.35	0.01
2015	0.29	0.34	0.33	0.35	0.02
2016	0.27	0.33	0.32	0.35	0.03
2017	0.25	0.32	0.32	0.35	0.04
2018	0.24	0.32	0.31	0.35	0.04
2019	0.24	0.32	0.31	0.35	0.04
2020	0.24	0.32	0.31	0.35	0.04
2021	0.24	0.32	0.31	0.35	0.04
2022	0.24	0.32	0.31	0.35	0.04

Table 2.2.32—Projections for BSAI Pacific cod catch (t), spawning biomass (t), and fishing mortality under the assumption that $F = max\ F_{ABC}$ in each year 2010-2011 and $F = F_{OFL}$ thereafter (Scenario 7), with random variability in future recruitment under Model A1.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2010	159,000	159,000	159,000	159,000	0
2011	201,000	201,000	201,000	202,000	82
2012	310,000	312,000	312,000	315,000	1,927
2013	321,000	334,000	337,000	362,000	14,185
2014	263,000	316,000	321,000	401,000	47,488
2015	200,000	289,000	300,000	428,000	76,615
2016	172,000	273,000	287,000	433,000	88,832
2017	152,000	267,000	281,000	439,000	90,612
2018	146,000	265,000	277,000	437,000	90,335
2019	142,000	267,000	275,000	432,000	90,935
2020	144,000	265,000	274,000	433,000	91,404
2021	146,000	262,000	275,000	435,000	91,441
2022	147,000	265,000	276,000	443,000	92,698

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2010	319,000	319,000	319,000	319,000	0
2011	346,000	346,000	346,000	347,000	138
2012	386,000	387,000	388,000	391,000	1,580
2013	401,000	409,000	411,000	429,000	9,824
2014	382,000	407,000	415,000	468,000	30,659
2015	343,000	393,000	405,000	506,000	56,518
2016	314,000	379,000	397,000	530,000	73,134
2017	297,000	375,000	391,000	534,000	78,147
2018	287,000	374,000	388,000	535,000	77,412
2019	282,000	372,000	386,000	534,000	76,566
2020	282,000	372,000	384,000	531,000	77,029
2021	284,000	371,000	385,000	529,000	77,535
2022	287,000	371,000	386,000	539,000	78,272

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2010	0.23	0.23	0.23	0.23	0.00
2011	0.25	0.25	0.25	0.25	0.00
2012	0.33	0.33	0.33	0.34	0.00
2013	0.35	0.35	0.35	0.35	0.00
2014	0.33	0.35	0.35	0.35	0.01
2015	0.29	0.34	0.33	0.35	0.02
2016	0.27	0.33	0.32	0.35	0.03
2017	0.25	0.32	0.32	0.35	0.04
2018	0.24	0.32	0.31	0.35	0.04
2019	0.24	0.32	0.31	0.35	0.04
2020	0.24	0.32	0.31	0.35	0.04
2021	0.24	0.32	0.31	0.35	0.04
2022	0.24	0.32	0.31	0.35	0.04

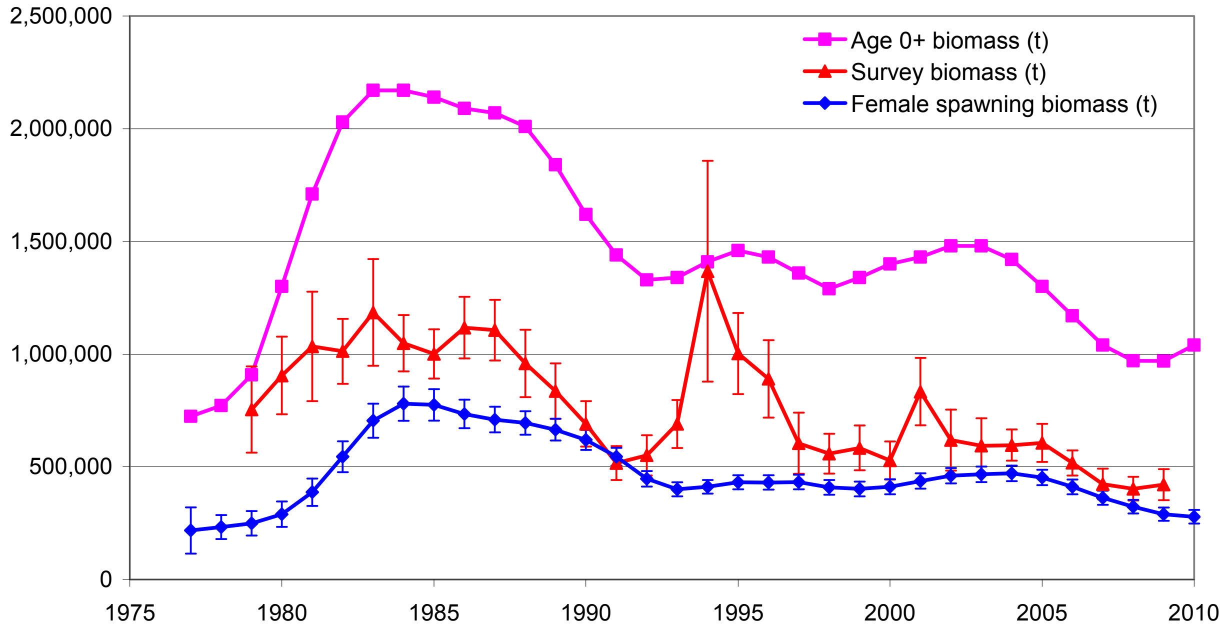


Figure 2.2.11—Biomass time trends (age 0+ biomass, female spawning biomass, survey biomass) of EBS Pacific cod as estimated by Model A1. Female spawning biomass and survey biomass show 95% CI.

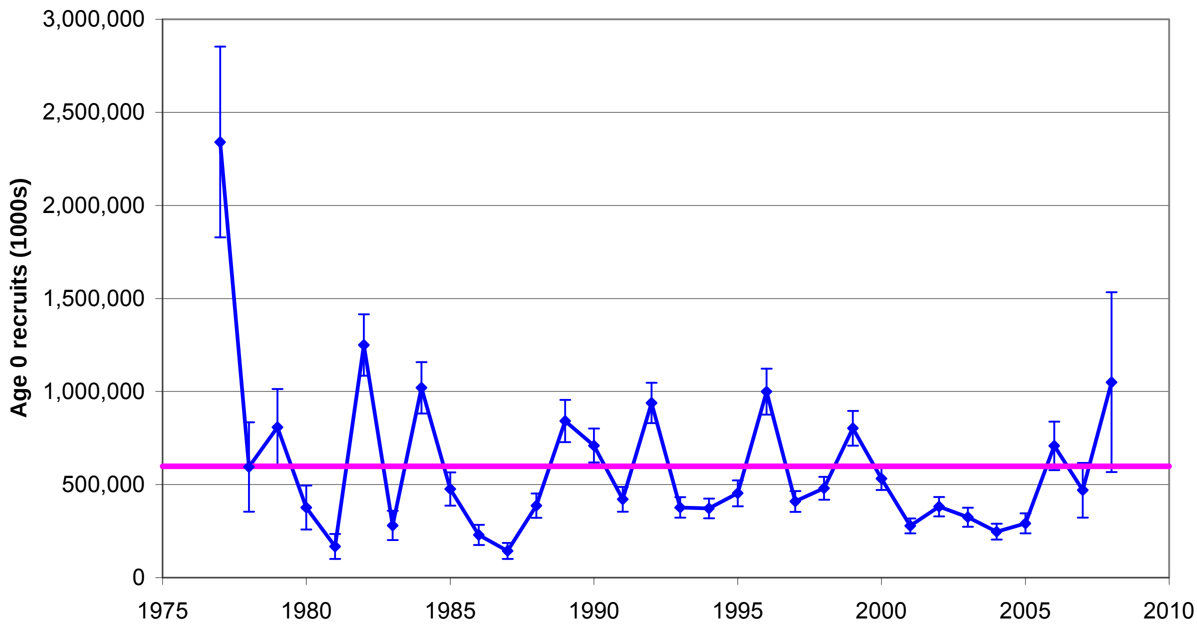


Figure 2.2.12—Time series of EBS Pacific cod recruitment at age 0, with 95% confidence intervals, as estimated by Model A1. Magenta line = 1977-2008 average.

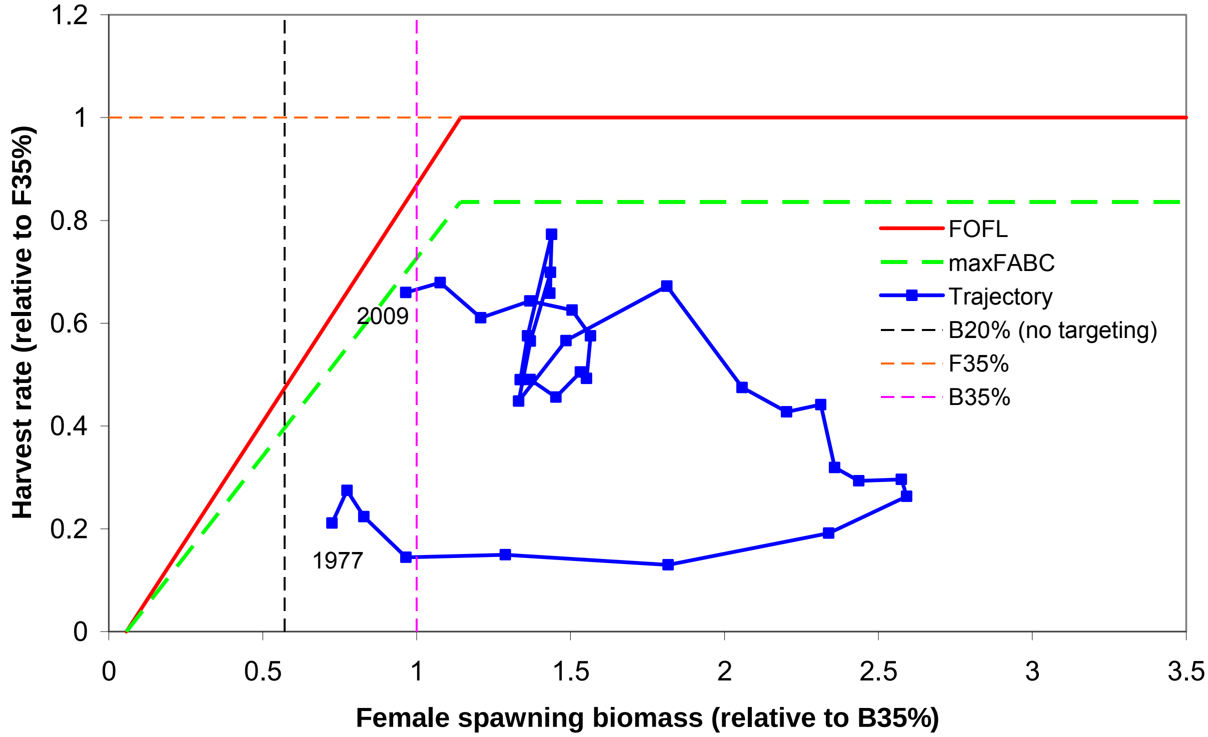


Figure 2.2.13—Trajectory of Pacific cod fishing mortality and female spawning biomass as estimated by Model A1, 1977-present. Because Pacific cod is a key prey of Steller sea lions, harvests of Pacific cod would be restricted to incidental catch in the event that spawning biomass fell below $B_{20\%}$.

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