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 2003-2010 were updated, and preliminary catch data for 2011 were incorporated.
2) Commercial fishery size composition data for 2010 were updated, and preliminary size composition data from the 2011 commercial fisheries were incorporated.
3) Size composition data from the 2011 EBS shelf bottom trawl survey were incorporated.
4) The numeric abundance estimate from the 2011 EBS shelf bottom trawl survey was incorporated (the 2011 estimate of 837 million fish was down about 6% from the 2010 estimate).
5) Age composition data from the 2010 EBS shelf bottom trawl survey were incorporated.
6) Mean length at age data from the 2010 EBS shelf bottom trawl survey were incorporated.
7) Seasonal catch per unit effort (CPUE) data for the trawl, longline, and pot fisheries from 2010 were updated, and preliminary catch rates for the trawl, longline, and pot fisheries from 2011 were incorporated.

Changes in the Assessment Methodology

Many changes have been made or considered in the stock assessment model since the 2010 assessment (Thompson et al. 2010). Seven models were presented in this year's preliminary assessment (Attachment 2.1). The set of seven models in the preliminary assessment was requested by the Plan Teams in May of this year, with subsequent concurrence by the SSC in June. Following review in August and September, four of these models (Models 1, 2b, 3, and 4) were requested by the Plan Teams or SSC to be included in the final assessment. In addition, the SSC requested one new model, which is labeled here as Model 3b.

Model 1 is identical to the model accepted for use by the BSAI Plan Team and SSC last year, except for inclusion of new data and corrections to old data.

Model 2b is identical to Model 1, except that the pre-1982 portion of the AFSC bottom trawl time series is omitted, the 1977-1979 and 1980-1984 time blocks for the January-April trawl fishery selectivity parameters were combined, the age corresponding to the *L1* parameter in the length-at-age equation was increased from 0 to 1.4167 (to correspond to the age of a 1-year-old fish at the time of the survey, when the age data are collected), the parameters governing variability in length at age were re-tuned, and a column for age 0 fish was added to the age composition and mean-size-at-age portions of the data file.

Model 3 is identical to Model 2b, except that ageing bias was estimated internally and the parameters governing variability in length at age were re-tuned (again).

Model 3b is identical to Model 3, except that the parameters governing variability in length were estimated internally, all size composition records were included in the log likelihood function, and the fit to the mean-size-at-age data was not included in the log likelihood function.

Model 4 is identical to Model 3b, except that ageing bias was not estimated internally and the fit to the age composition data was not included in the log-likelihood function.

Version 3.22b (as compiled on 8/3/11) of Stock Synthesis (SS) was used to run all the models in this assessment.

Model 3b 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.

Quantity	As estimated or *specified last* year for:		As estimated or *recommended this* year for:	
	2011	2012	2012	2013
M (natural mortality rate)	0.34	0.34	0.34	0.34
Tier	3b	3a	3a	3a
Projected total (age 0+) biomass (t)	1,560,000	1,750,000	1,690,000	1,720,000
Female spawning biomass (t)				
Projected	358,000	389,000	410,000	437,000
$B_{100\%}$	961,000	961,000	889,000	889,000
$B_{40\%}$	384,000	384,000	355,000	355,000
$B_{35\%}$	336,000	336,000	311,000	311,000
F_{OFL}	0.29	0.31	0.36	0.36
$maxF_{ABC}$	0.25	0.26	0.30	0.30
F_{ABC}	0.25	0.26	0.30	0.30
OFL (t)	272,000	329,000	369,000	374,000
maxABC (t)	235,000	281,000	314,000	319,000
ABC (t)	235,000	281,000	314,000	319,000
Status	As determined *last* year for:		As determined *this* year for:	
	2009	2010	2010	2011
Overfishing	No	n/a	No	n/a
Overfished	n/a	No	n/a	No
Approaching overfished	n/a	No	n/a	No

Responses to Comments from the Plan Teams and SSC

The Pacific cod stock assessment models were reviewed in March of this year by three scientists contracted by the Center for Independent Experts (CIE). A total of 128 unique recommendations from the CIE reviewers and 5 model proposals from a member of the public were included among information considered by the Joint Plan Teams and SSC in developing the recommendations from their respective May and June meetings. The CIE recommendations and public proposals were summarized in Appendix A of the minutes from the May Joint Plan Team meeting. In the interest of efficiency, they are not repeated here.

A total of 21 comments from the November, 2010 meetings of the Joint Plan Teams (1 comment) and the GOA Plan Team (1 comment); the December, 2010 meeting of the SSC (12 comments); the February, 2011 meeting of the SSC (1 comment); the May, 2011 meeting of the Joint Plan Teams (5 comments); and the June, 2011 meeting of the SSC (1 comment) were addressed in the preliminary EBS and AI assessments (included here as Attachments 2.1 and 2.2, respectively). In the interest of efficiency, they are not repeated in this section.

Plan Team and SSC comments from the August, 2011 and September, 2011 meetings, respectively, are addressed below.

Joint Plan Team Comments

JPT1 (8/11 minutes): *"Performance of a model was measured by: (i) how often the fits with random starting points reached the MLE (match rate), (ii) the root mean squared deviation of the negative log likelihood from the minimum (likelihood variation), and (iii) the CV of the estimate of present biomass. … Model 3 had a zero match rate and astronomical variability. … The extent that the variability shown by some models was due to a few extreme values rather than a lot of moderate deviations was raised and should be examined in future presentations of this sort."* The possibility that SS might be able to find the true MLE most of the time but occasionally miss it by a lot was the reason for reporting the match rate along with the other two measures. To provide an even more complete description of the jitter tests, the present assessment includes a graph (Figure 2.12) profiling the cumulative likelihood variation (with individual runs sorted in order of increasing deviation) for each model. Also, just to be clear, the "CV" of present biomass is measured as the ratio between: A) the square root of the average squared deviation from the biomass estimated by the best run and B) the biomass estimated by the best run. It is *not* the CV of the biomass estimated by the best run.

JPT2 (8/11 minutes): *"A number of concerns about the models and the convergence tests were raised during the Teams' discussion:*

- *i. "The jitter tests, at least with a jitter rate of 0.1, are not necessarily meaningful because they can produce wild and perhaps even impermissible starting values. In particular, it seems possible that the the hugely variable performance of Model 3 in jitter tests is the result of some quirk.*
- *ii. "In Model A (and Model 5), the catchability and selectivity deviations are treated as random effects but they are not properly integrated out. The MLEs are therefore suspect, and the iterative tuning may produce pathological results.*
- *iii. "Allowing survey catchability to vary from year to year, perhaps substantially, achieves a better fit to the data but at the expense of discounting the relative abundance data. Some members felt strongly that this was a mistake. The survey catchability estimates produced by Model A seemed to be missing in the presentation.*

iv. *"The great variability of survey selectivity estimates from Model A is a clear indication that the model is overfitting the data.*

"In view of the many new features in Model A and several concerns about it, the Teams do not favor including it (or Model 5) as one of the candidates in November. The Teams requested Models 2b and 4 in November, and requested a brief investigation into the reasons for the wild performance of Model 3. If it turns out that the uneven performance of Model 3 was the result of some quirk in the jitter tests, the Teams … would like Model 3 included as well. (If a short investigation is unproductive, the Teams recommend dropping Model 3 rather than taking time this year for a long investigation.)" Some of the theoretical issues involved with the Teams' concerns will be explored next year. In practical terms relating to the present assessment, these concerns have been addressed as follows:

i. Following the Plan Team meeting, further explorations involving tighter bounds on the ageing bias parameters improved the robustness of Model 3 considerably, resulting in a lower likelihood variation than all other models except Model 4.
ii. Models A and 5 are not included in the present assessment. Moreover, in keeping with a Plan Team request from September, 2010, input standard deviations for all *dev* vectors in the present assessment were held at the values estimated in the 2009 assessment.
iii. None of the models in the present assessment allows survey catchability (Q) to vary. While it is true that the preliminary assessment did not report Q estimates *per se* for Model A, the base value of ln(Q) for Model A is shown in Table 2.1.4a and the annual (random walk) changes in ln(Q) for Model A are shown in Table 2.1.4d.
iv. Model A is not included in the present assessment. However, the degree of variability in survey selectivity exhibited by Model A is used as a reference point against which the other models are evaluated.

Models 2b, 3 (given the improved robustness that was estimated following the Plan Team meeting), and 4 are included in the present assessment. Per SSC request, Model 1 is also included and a new model based on Model 3 (Model 3b) has been added. See also comments SSC2 and SSC3.

JPT3 (8/11 minutes): *"The Teams recommend that the IPHC continue to collect cod length frequencies on its survey."* The IPHC continues to collect cod length frequencies on its survey, as requested by the SSC during its June, 2010 meeting.

BSAI Plan Team Comments

BPT1 (8/11 minutes): *"At this point, in view of the different abundance trends, our preference is for separate age-structured assessments of the EBS and AI. The Team expects that both the Kalman filter and Tier 5 approach* [will] *be up for discussion in November."* The preliminary assessment of the AI Pacific cod stock that was reviewed by the Plan Team and SSC in August and September of this year is included here as Attachment 2.2. It uses a simple Kalman filter to estimate current biomass. This biomass estimate can then be used to compute Tier 5 reference points. Unless Team/SSC guidance to the contrary is forthcoming, work on an age-structured model for the AI Pacific cod stock is expected to begin next year. An expected completion date for this model has not been established. See also comment SSC1.

SSC Comments

SSC1 (9/11 minutes): *"The SSC anticipates that finer geographical divisions of BSAI Pacific cod ABC and OFL will be considered during next year's specification process. The SSC supports the GPT recommendations* [to include] *… AI cod model alternatives in the short term (Kalman filter approach for the next assessment cycle) and long term (age structured model)."* While a preliminary assessment of the AI Pacific cod stock is included as Attachment 2.2, the present assessment is structured under the assumption that EBS and AI Pacific cod will continue to be treated as a combined (BSAI-wide) stock during the current specifications cycle. See also comment BPT1.

SSC2 (9/11 minutes): [The author] *"resolved the issue with Model 3 and presented the results to the SSC and the SSC agrees that this model should be brought forward for consideration."* Model 3 is included in the present assessment. See also comment JPT2.

SSC3 (9/11 minutes): *"The SSC supports the Team's suite of models and two additional model runs. First, the SSC would like last year's base model (Model 1) brought forward for consideration. Second, the SSC also requests an additional run using Model 3, but excluding the mean-size-at-age composition data, because of concerns with incorporation of this dataset. The conclusion may be that excluding these data sources is not a good idea, but at least an evaluation will have been done. The SSC notes that the author has discretion for modest changes to the above models to improve performance."* Model 1 and the SSC's new requested model (labeled here as Model 3b) are included in the present assessment, along with Models 2b, 3, and 4. The following modest changes have been made to these models, to improve performance: A) the 1977-1979 and 1980-1984 time blocks for the January-April trawl fishery selectivity parameters have been combined in all models except Model 1, B) the age corresponding to the *L1* parameter in the length-at-age equation was increased from 0 to 1.4167, C) a column for age 0 fish has been added to the age composition and mean-size-at-age portions of the data file in all models except Model 1, and D) the parameters governing variability in length at age have been re-tuned in Models 2b and 3 and estimated internally in Model 3b (these parameters were already being estimated internally in Model 4). See also comment JPT2.

INTRODUCTION

General

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). Recent research indicates the existence of discrete stocks in the EBS and AI (Canino et al. 2005, Cunningham et al. 2009, Canino et al. 2010, Spies in review). 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.

Review of Life History

Pacific cod eggs are demersal and adhesive. Eggs hatch in about 15 to 20 days. Spawning takes place in the sublittoral-bathyal zone (40 to 290 m) near bottom. Eggs sink to the bottom after fertilization and are somewhat adhesive. Optimal temperature for incubation is 3° to 6°C, optimal salinity is 13 to 23 parts per thousand (ppt), and optimal oxygen concentration is from 2 to 3 ppm to saturation. Little is known about the optimal substrate type for egg incubation.

Little is known about the distribution of Pacific cod larvae, which undergo metamorphosis at about 25 to 35 mm. Larvae are epipelagic, occurring primarily in the upper 45 m of the water column shortly after hatching, moving downward in the water column as they grow.

Juveniles occur mostly over the inner continental shelf at depths of 60 to 150 m. Adults occur in depths from the shoreline to 500 m, although occurrence in depths greater than 300 m is fairly rare. Preferred substrate is soft sediment, from mud and clay to sand. Average depth of occurrence tends to vary directly with age for at least the first few years of life.

It is conceivable that mortality rates, both fishing and natural, may vary with age in Pacific cod. In particular, very young fish likely have higher natural mortality rates than older fish (note that this may not be particularly important from the perspective of single-species stock assessment, so long as these higher natural mortality rates do not occur at ages or sizes that are present in substantial numbers in the data). For example, Leslie matrix analysis of a Pacific cod stock occurring off Korea estimated the instantaneous natural mortality rate of 0-year-olds at 2.49% per day (Jung et al. 2009). This may be compared to a mean estimate for age 0 Atlantic cod (*Gadus morhua*) in Newfoundland of 4.42% per day, with a 95% confidence interval ranging from about 3.32% to 5.52% (Gregory et al. in review); and age 0 Greenland cod (*Gadus ogac*) of 2.12% per day, with a 95% confidence interval ranging from about 1.56% to 2.68% (Robert Gregory and Corey Morris, *pers. commun.*).

Although little is known about the likelihood of age-dependent natural mortality in adult Pacific cod, it has been suggested that Atlantic cod may exhibit increasing natural mortality with age (Greer-Walker 1970).

At least one study (Ueda et al. 2006) indicates that age 2 Pacific cod may congregate more, relative to age 1 Pacific cod, in areas where trawling efficiency is reduced (e.g., areas of rough substrate), causing their selectivity to decrease. Also, Atlantic cod have been shown to dive in response to a passing vessel (Ona and Godø 1990), which may complicate attempts to estimate catchability or selectivity. It is not known whether Pacific cod undertake a similar response.

As noted above, Pacific cod are known to undertake seasonal migrations, the timing and duration of which may be variable (Savin 2008).

FISHERY

Catches of Pacific cod taken in the EBS for the periods 1964-1980 and 1981-2011 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 1991-2011 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 1991-2011 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-April, May-July, and August-

December, 2010. Figures 2.1d-2.1e show the corresponding information for January-April and May-July, 2011 (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 chapter entitled "Pacific Cod Market Profile" in the economic section of the SAFE Report (Hiatt et al., 2010) provides additional information on the Pacific cod fishery.

The history of acceptable biological catch (ABC), overfishing level (OFL), 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 2011 TAC averaged about 83% of ABC (ABC was not specified prior to 1980), and from 1980 through 2011 aggregate commercial catch averaged about 90% of TAC (remembering that 2011 catch data are not yet final). In 10 of these 32 years (31%), TAC equaled ABC exactly, and in 7 of these 32 years (22%), catch exceeded TAC (by an average of 4%). However, two of those overages occurred in 2007 and 2010, when TAC was reduced by 3% to account for a small, State-managed fishery inside State of Alaska waters (similar reductions have been made in all years since 2006); thus, while the combined Federal and State catch exceeded the Federal TAC in 2007 and 2010 by about 2%, the overall target catch (Federal TAC plus State GHL) was not exceeded. Total catch has been less than OFL in every year since 1994.

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. Assessments conducted prior to 1985 consisted of simple projections of survey numbers at age. In 1985, the assessment was expanded to consider all survey numbers at age from 1979-1985. From 1985-1991, the assessment was conducted using an *ad hoc* separable age-structured model. In 1992, the assessment was conducted using the Stock Synthesis 1 modeling software (Methot 1986, 1990) with age-based data. All assessments from 1992 through 2003 continued to use the Stock Synthesis 1 modeling software, but with length-based data. Age data based on a revised ageing protocol were added to the model in the 2004 assessment. The assessment was migrated to Stock Synthesis 2 in 2005 (Methot 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 (2006-2010), the EBS accounted for an average of about 83% of the BSAI catch.

The catches shown in Tables 2.1-2.4 include estimated discards. Discard rates of Pacific cod in the various EBS and AI target fisheries are shown for each year 1991-2002 in Table 2.5a, and in the various BSAI target fisheries for each year 2003-2011 in Table 2.5b (2011 data are partial). Although the catches shown in Tables 2.1-2.4 do include discards, they do not account for all removals. For example, they do not include removals taken in fisheries managed under other FMPs or international agreements, or removals taken in the process of conducting scientific research. Attachment 2.3 summarizes current efforts toward accounting for such "other" removals.

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

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

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

(B) B season. From 1200 hours, A.l.t., June 10 through 2400 hours, A.l.t., Dec. 31.

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

(A) A season. From 1200 hours, A.l.t., Jan. 20 through 1200 hours, A.l.t., Apr. 1;
(B) B season. From 1200 hours, A.l.t., Apr. 1 through 1200 hours, A.l.t., June 10; and
(C) C season. From 1200 hours, A.l.t., June 10 through 1200 hours, A.l.t., Nov. 1.

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

(A) A season. From 0001 hours, A.l.t., January 1 through 1200 hours, A.l.t., June 10; and
(B) B season. From 1200 hours, A.l.t., September 1 through 2400 hours, A.l.t., Dec. 31.

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

(A) A season. From 0001 hours, A.l.t., Jan. 1 through 1200 hours, A.l.t., Apr. 30;
(B) B season. From 1200 hours, A.l.t., Apr. 30 through 1200 hours, A.l.t., Aug. 31; and

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

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

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

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

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

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 1977-2011 are shown for the three main gear types in Table 2.6. Table 2.6 makes use of two different types of season: catch seasons and selectivity seasons. The catch seasons are defined as January-February, March-April, May-July, August-October, and November-December. Three selectivity seasons are defined by combining catch seasons 1 and 2 into selectivity season 1, equating catch season 3 with selectivity season 2, and combining catch seasons 4 and 5 into selectivity season 3. The catch seasons used in Table 2.6 were the result of a statistical analysis described in the 2010 preliminary assessment (Thompson et al. 2010), and the selectivity seasons were chosen to correspond as closely as possible to the traditional seasons used in previous assessments (given the revised catch seasons).

In years for which estimates of the distribution by gear or period were not available, proxies based on other years' distributions were used to create Table 2.6. Catches for the years 1977-1980 may or may not include discards.

Catch Per Unit Effort

Fishery catch per unit effort data are available by gear and season for the years 1991-2011 and are shown in Table 2.7. Units are kg/minute for trawl gear, kg/hook for longline gear, and kg/pot for pot gear; data for 2011 are partial. The "sigma" values shown in the tables are intended only to give an idea of the relative variability of the respective point estimates, and are not actually used in any of the analyses presented here.

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 2011. Beginning with the 2010 assessment (Thompson et al. 2010), size composition data are based on 1-cm bins ranging from 4 to 120 cm. Because displaying these data would add a large number of pages to the present document, they are not shown here but are available at: http://www.afsc.noaa.gov/REFM/Docs/2011/EBS_Pcod_fishery_sizecomp_data.xlsx.

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 from 1979-1981 (i.e., the three years before the current gear configuration was standardized in 1982) are shown below. These data are shown according to the 3- and 5-cm size bins used in assessments prior to 2010, because data at 1-cm resolution do not exist for the period 1979-1981.

Year	N	9	12	15	18	21	24	27	30	33	36	39	42
1979	100	0	5	44	186	374	457	694	1764	2393	1884	1171	618
1980	100	0	6	85	241	82	42	224	687	929	1320	1542	2062
1981	100	0	20	156	330	278	32	100	330	653	724	511	1063

Year	45	50	55	60	65	70	75	80	85	90	95	100	105
1979	202	70	44	51	29	8	0	3	1	1	0	0	0
1980	1364	893	333	100	33	31	19	6	2	0	0	0	0
1981	1396	1746	1215	812	398	156	39	27	13	1	0	0	0

The data for each year in the above table sum to 10,000, which is close to the average sample size from the first several years of the survey following 1981.

The relative size compositions from the years 1982-2011 are shown in Table 2.8. The 1982-2011 time series is shown according to the 1-cm bins described above for fishery size composition data. Rows in Table 2.8 sum to the actual number of fish measured in each year.

Age compositions from the 1994-2010 surveys are available. The age compositions and actual sample sizes are shown in Table 2.9.

Estimates of total abundance (both in biomass and numbers of fish) obtained from the trawl surveys are shown in Table 2.10a (1979-1981) and 2.10b (1982-2011), 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 1979 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. Biomass estimates have increased every year since 2008, with the 2010 biomass estimate being more than double the 2009 estimate.

Numerical abundance has shown more variability than biomass. The 2007 estimate was the highest since 2001 the time series, but the 2008 estimate was down considerably. The 2009-2011 estimates are all above the time series average, with the 2010 estimate being the highest since 2001.

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 2.11. Figure 2.2 shows the time series of age 1 size distributions, as computed from the age data and also by fitting normal distributions to the lengths surrounding the apparent age 1 mode in each year’s survey size composition.

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, 2006, and 2010. 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 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
2010	U.S.	68,161

The 2010 estimate is the lowest in the time series.

For many years, the assessments of Pacific cod in the BSAI have used a weighted average formed from EBS and AI survey biomass estimates to provide a conversion factor which is 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 (Thompson and Dorn 2004), the SSC recommended that an approach based on a simple Kalman filter be used. Applying this approach to the updated (through 2010) time series indicates that the best estimate of the current biomass distribution is 91% EBS and 9% AI, replacing the previous proportions of 84% and 16% respectively.

ANALYTIC APPROACH

Model Structure

History of Previous Model Structures Developed Under Stock Synthesis

Stock Synthesis 1 (SS1, Methot 1986, 1990, 1998, 2000) was first applied to the EBS Pacific cod stock in the 1992 assessment (Thompson 1992). This first application used age-structured data. Beginning with the 1993 SAFE report (Thompson and Methot 1993) and continuing through the 2004 SAFE report (Thompson and Dorn 2004), SS1 continued to be used, but based largely on length-structured data. 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 was 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 were 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 was the product of the likelihoods for each of the model components. In part because the overall likelihood could be a very small number, SS1 used the logarithm of the likelihood as the objective function. Each likelihood component was 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 were 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 permitted 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, 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.

Until 2010, each year was partitioned into three seasons defined as 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 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 (Thompson et al. 2008).

The 2009 assessment (Thompson et al. 2009) featured a total of 14 models reflecting a great many alternative assumptions and use or non-use of certain data, particularly age composition data. Relative to the 2008 assessment, the main changes in the model accepted by the Plan Team and SSC were as follow: 1) input standard deviations of all "dev" vectors were set iteratively by matching the standard deviations of the set of estimated "devs;" 2) the standard deviation of length at age was estimated outside the model as a linear function of mean length at age; 3) 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); 4) 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, resulting in a positive bias of 0.4 years for these ages (age-specific bias values were also examined, but did not improve the fit significantly); and 5) cohort-specific growth devs were estimated for all years through 2008.

Many changes were made or considered in the 2010 stock assessment model (Thompson et al. 2010). Six models were presented in the preliminary assessment, as requested by the Plan Teams in May, with subsequent concurrence (given two minor modifications) by the SSC in June. Following review in September and October, three of these models, or modifications thereof, were requested by the Plan Teams or SSC to be included in the final assessment. Relative to the 2009 assessment, the main changes in the model that was ultimately accepted by the Plan Team and SSC in 2010 were as follow: 1) exclude relative abundance data and the two records of size composition data from the IPHC longline survey, 2) exclude the single record (each) of fishery age composition and mean length-at-age data, 3) use a finer length bin structure than previous models, 4) re-evaluate the existing seasonal structure used in the model and revise it as appropriate, and 5) remove cohort-specific growth rates (these were introduced for the first time in the 2009 assessment). The new length bin structure consisted of 1-cm bins, replacing the combination of 3-cm and 5-cm bins used in previous assessments. The new seasonal structure consisted of five catch seasons defined as January-February, March-April, May-July, August-October, and November-December; and three selectivity seasons defined as January-April, May-July, and August-December; with spawning identified as occurring at the beginning of the second catch season (March).

Model Structures Considered in This Year's Assessment

The Pacific cod stock assessment models were reviewed in March of this year by three scientists contracted by the CIE. A total of 128 unique recommendations were received from the CIE reviewers. Following the review in March, a set of seven models was requested for inclusion in the preliminary assessment (Attachment 2.1) by the Plan Teams in May, with subsequent concurrence by the SSC in June. Following review in August and September, four of these models (Models 1, 2b, 3, and 4) were requested by the Plan Teams or SSC to be included in the final assessment. In addition, the SSC requested one new model, which is labeled here as Model 3b.

Model 1 is identical to the model accepted for use by the BSAI Plan Team and SSC last year, except for inclusion of new data and corrections to old data.

In the preliminary assessment (Attachment 2.1), the only difference between Model 1 and Model 2b was that the pre-1982 portion of the AFSC bottom trawl time series was omitted from the latter. In the present assessment, the following additional changes were made relative to Model 1:

- The 1977-1979 and 1980-1984 time blocks for the January-April trawl fishery selectivity parameters were combined. This change was made because the selectivity curve for the 1977-1979 time block tended to have a very difficult-to-rationalize shape (almost constant across length, even at very small sizes), which led to very high and also difficult-to-rationalize initial fishing mortality rates.
- The age corresponding to the *L1* parameter in the length-at-age equation was increased from 0 to 1.4167, to correspond to the age of a 1-year-old fish at the time of the survey, which is when the age data are collected. This change was adopted to prevent mean size at age from going negative (as sometimes happened for age 0 fish in previous assessments, and as happened even for age 1 fish in one of the models from the 2010 assessment), and to facilitate comparison of estimated and observed length at age and variability in length at age.
- The parameters governing variability in length at age were re-tuned. This was necessitated by the change in the age corresponding to the *L1* parameter (above).
- A column for age 0 fish was added to the age composition and mean-size-at-age portions of the data file. Even though there are virtually no age 0 fish represented in these two portions of the data file, unless a column for age 0 is included, SS will interpret age 1 fish as being ages 0 and 1 combined, which can bias the estimates of year class strength.

Model 3 is identical to Model 2b, except that ageing bias was estimated internally and the parameters governing variability in length were re-tuned (again).

Model 3b is identical to Model 3, except that the parameters governing variability in length were estimated internally, all size composition records were included in the log-likelihood function, and the fit to the mean-size-at-age data was not included in the log-likelihood function.

Model 4 is identical to Model 3b, except that ageing bias was not estimated internally and the fit to the age composition data was not included in the log-likelihood function.

It should also be noted that, consistent with Plan Team policy adopted in 2010, quantities that were estimated iteratively in the 2009 assessment were not re-estimated in the present assessment (with the exception of the parameters governing variability in length at age, for the reason listed above).

Version 3.22b (as compiled on 8/3/11) of Stock Synthesis was used to run all the models in this assessment. The most recent user manual is for version 3.21d (Methot 2011). Although slightly outdated, the best source for documentation of equations is Methot (2005).

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 (Thompson et al. 2008). 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 set *M* independently at the SSC-approved value of 0.34.

Catchability

In the 2009 assessment (Thompson et al. 2009), catchability for the post-1981 trawl survey was estimated iteratively by matching 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). The resulting value of 0.77 was retained for all models in the present assessment. Catchability for the pre-1982 trawl survey in Model 1 is fixed at 1.00, following last year's assessment.

Variability in Estimated Age

Variability in estimated age in SS is based on the standard deviation of estimated age. Weighted least squares regression has been used in the past several assessments to estimate a proportional relationship between standard deviation and age. The regression was recomputed this year, yielding an estimated slope of 0.087 (i.e, the standard deviation of estimated age was modeled as 0.087 × age), which gives a weighted R^2 of 0.92. This regression was used for all models in the present assessment.

Variability in Length at Age

The last few assessments have used a regression approach to estimate the parameters of the schedule of variability in length at age, based on the outside-the-model estimates of standard deviation of length at age and mean length at age from the survey age data (Thompson et al. 2009). The best fit was obtained by assuming that the standard deviation is a linear function of length at age. The regression was re-estimated this year after updating with the most recent data, giving an intercept of 1.687 and a slope of 0.071.

Use of this regression requires 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).

For Model 1, the standard deviations of length at ages 0 and 20 were set at 0.01 and 8.68, corresponding to the values estimated in the 2009 assessment and retained in the 2010 assessment.

In Models 2b and 3, the age corresponding to the *L1* parameter in the length-at-age equation was increased from 0 to 1.4167 (to correspond to the age of a 1-year-old fish at the time of the survey, when the age data are collected). This made it necessary to re-do the iterative tuning process for Models 2b and 3 (it should also be noted that two more years' worth of age data have been collected since the values used in Model 1 were initially estimated).

In Models 3b and 4, the parameters governing variability in length at age were estimated conditionally.

Weight at Length

Season-specific parameters governing the weight-at-length schedule were estimated in the 2010 assessment (based on data through 2008), giving the following values:

Season:	Jan-Feb	Mar-Apr	May-Jul	Aug-Oct	Nov-Dec
α:	3.741×10^{-6}	7.221×10^{-6}	9.406×10^{-6}	6.987×10^{-6}	4.356×10^{-6}
β:	3.296	3.122	3.054	3.134	3.253
Samples:	21,616	25,818	20,734	12,754	9,956

The above parameters were retained for all models in the present assessment.

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. However, in 2007, changes in SS allowed for use of either a length-based or an age-based maturity schedule. Beginning with the 2007 assessment, 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 maturity study's author (James Stark, Alaska Fisheries Science Center, personal communication). The age-based parameters were retained for all models in the present assessment.

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 von Bertalanffy growth parameters, log mean recruitment before and since the 1976-1977 regime shift, annual recruitment deviations, initial fishing mortality, gear-season-and-block-specific fishery selectivity parameters, survey selectivity parameters, and annual deviations in the ascending limb of the trawl survey selectivity schedule. In addition, Models 3 and 3b estimate two parameters describing ageing bias as a linear function of age (in Models 1, 2b, and 4, these parameters are fixed at the levels estimated by trial and error in the 2008 assessment), and Models 3b and 4 estimate two parameters describing the standard deviation of length at age as a linear function of length at age (in Model 1, these parameters are fixed at the values estimated iteratively in the 2008 assessment, and in Models 2b and 3, they are estimated iteratively).

The same functional form (pattern 24 for length-based selectivity, pattern 20 for age-based selectivity) used to define the selectivity schedules in all assessments since 2007 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.

Fishery selectivities are length-based and trawl survey selectivities are age-based in all models considered in this assessment.

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 in the 2009 assessment (Thompson et al. 2009) by matching the standard deviations of the estimated *dev*s. The same input standard deviations were used in all models in the present assessment.

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 five models included likelihood components for trawl survey relative abundance, fishery and survey size composition, survey age composition, survey mean size at age, recruitment, parameter deviations, and "softbounds" (equivalent to an extremely weak prior distribution used to keep parameters from hitting bounds), and 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 given an emphasis of 1.0 in the present assessment, except that the mean size at age component is given zero emphasis in Models 3b and 4 and the age composition component is given zero emphasis in Model 4.

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 (Thompson et al. 2007b). 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 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 and 2009 assessments. For the 2010 assessment, however, this procedure had to be modified somewhat, because the bootstrap values for the 1990-2006 size composition data did not match the new bin and seasonal structures. To be as consistent as possible with the approach used to set sample sizes in the 2008 and 2009 assessments, the 2010 assessment set sample sizes by applying the 16/34% rule for *all* size composition records (not just those lying outside the set of 1990-2006 fishery data), then rescaling proportionally to achieve an average sample size of 300. The same procedure was used for all models in the present assessment. Input sample sizes for all size composition records are shown in Table 2.12.

Use of Age Composition Data in Parameter Estimation

Like the size composition data, the age composition data are assumed to be drawn from a multinomial distribution specific to a particular 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 1, 2b, and 3 ignore survey size composition data from each year in which survey age composition data are available. Model 3b keeps all size composition data active in the estimation, even though this amounts (strictly speaking) to double counting, in order to enable a realistic estimation of size at age (recall that Model 3b turns off the mean-size-at-age data). Model 4, which ignores both the mean-size-at-age data and the age composition data, uses 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.

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 (except for the input standard deviation, which is fixed at the value estimated in the 2009 assessment).

RESULTS

Model Evaluation

As described above, five models are evaluated in the present assessment.

Comparing and Contrasting the Models

Table 2.13 shows numbers of parameters and negative log-likelihoods for each of the models. It should be emphasized that, although the negative log-likelihood values for the models are displayed next to one another, they are not strictly comparable, because the data sets are different for every model. The first part of Table 2.13 shows the number of parameters for each model, which range from a low of 178 for Model 2b to a high of 185 for Model 1. The second part shows negative log-likelihoods for the aggregate data components. The value for the age composition component is shaded under Model 4, and the values for the mean-size-at-age component are shaded under Models 3b and 4, because these values do not count toward the respective models' total. The third and fourth parts of the table break down the CPUE and size composition components into fleet-specific values. For the CPUE component, the fishery values are shown for completeness, but they are shaded to indicate that they do not count toward the total.

Tables 2.14 and 2.15 provide alternative measures of how well the models are fitting the fishery CPUE and survey relative abundance data. Table 2.14 shows root mean squared errors (lower values are better) and correlations between observed and estimated values (higher values are better). The most important parts of this table are the rows for the post-1981 trawl survey, where all five models give an RMSE between 0.21 and 0.23 and a correlation between 0.67 and 0.68. Although none of the models actually attempts to fit the fishery CPUE data (only the survey CPUE are used), of the 45 correlations with fishery CPUE (9 fleets × 5 models), all but 5 are positive. Table 2.15 shows the means and standard deviations of the normalized residuals. For the post-1981 trawl survey, all models have a positive value for mean normalized residual (ranging from 0.25 to 0.88), and the standard deviations tend to be quite a bit larger than unity (ranging from 1.96 to 2.08).

Figure 2.3 shows the fits of the five models to the trawl survey abundance data. For the post-1981 portion of the time series, the five models tended to fall within the 95% confidence intervals of the surveys except for 1994-1996 and 2001, where the survey was higher than the models; and 2008, where the models were higher than the survey (mixed results were obtained for 1982, 1987, 1989, 1991, and 2009, where some models fell within the confidence interval but at least one did not).

Table 2.16 shows the mean of the ratios and the ratio of the means between output "effective" sample size (McAllister and Ianelli 1997) and input sample size for the size composition data, thus providing an alternative measure of how well the models are fitting these data (higher values are better, all else being equal). Models 2b and 3 appear to do the worst of the five models by either measure, but the *best* performing model appears to depend on which measure is used: When measured by the mean of the ratios, Model 1 tends to do the best, but when measured by the ratio of the means, Models 3b and 4 tend to do the best. However, as with the likelihood table, such comparisons are problematic, because different data sets are used for the different models. For example, Models 3b and 4 attempt to fit all the available size composition data, whereas Models 1, 2b, and 3 ignore all size composition records for which a corresponding age composition record exists.

Table 2.17 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 (all age composition data come from the survey). The bottom two rows show the overall mean of the ratios and ratio of the means for the post-1981 trawl survey age compositions. By either measure, Model 3b tends to do much better than any other model, and Model 3 tends to do much worse. Interestingly, Model 4 does about as well as Models 1 or 2b even though it does not attempt to fit these data.

The five models' fits to the age composition data are shown in Figure 2.4 (five pages, one for each model). Estimates of mean sizes at age 1 (at the time of the survey) from each model are compared to the long-term average survey size composition (through 50 cm) in Figure 2.5. All models tend to undershoot the first three modes, but only by about 1-2 cm. Models 3, 3b, and 4 tend to estimate very similar mean sizes at the first three ages, and come closer to the modes than Models 1 or 2b. The five models' fits to the mean-size-at-age data are shown in Figure 2.6 (recall that Models 3b and 4 do not attempt to fit these data).

Table 2.18 displays all of the quantities listed in the "parameters" section of the SS report file, including quantities whose values are set externally. Quantities for which values ("Est.") and standard deviations ("SD") are listed represent parameters that are estimated internally, quantities for which only values are listed represent coefficients that are fixed externally, and quantities for which values are not listed represent items that are not used in the respective model.

Most labels are either fairly straightforward to interpret or probably correspond to quantities that are not essential to understanding the analysis. It should be noted that the post-1976 recruitment mean *R0* and all catchability coefficients are reported on natural log scales and that the *R1 offset* parameter describes the log ratio of the recruitment means before and after the 1976-1977 regime shift. Log-scale recruitment deviations are labeled "Main_RecrDev" followed by the year. Labels for selectivity ("Sel") parameters include the parameter number (see "Parameters Estimated Conditionally") and fleet name. Note that many selectivity parameters get overwritten by other selectivity parameters specific to blocks of years. The labels for block-specific parameters end in a four-digit year, representing the starting point for the respective block. Labels for survey selectivity deviations end in a four-digit year followed by "d."

Table 2.19 (five pages, one for each model) show estimates of full-selection fishing mortality rates (note that these are not counted as parameters in SS).

Figure 2.7 shows the time series of log recruitment *dev*s as estimated by the five models. All five models show a high degree of synchrony throughout most of the time series, with Models 3b and 4 tending to exhibit slightly higher variability than the other models.

Figure 2.8 shows the time series of spawning biomass relative to $B_{35\%}$ as estimated by the five models. Qualitatively, all models exhibit approximately the same trend. Models 3b and 4 tend to be higher than Models 2b and 3 throughout the time series, while Model 1 starts close to Models 3b and 4 and ends close to Models 2b and 3.

Figure 2.9 shows the time series of total (age 0+) biomass as estimated by the five models, with the trawl survey biomass estimates included for comparison. Except for 1979, 1980, and 1994, all models estimate a higher total biomass than was observed by the survey. The average ratio of model biomass to survey biomass ranges from a low of 1.65 for Model 2b to a high of 2.06 for Models 1 and 4. Given that the post-1981 catchability coefficient is fixed at 0.77 for all models, estimation of a higher biomass (on average) than observed by the survey is expected.

Figure 2.10 shows post-1981 trawl survey selectivity as estimated by the five models. The red line in each figure corresponds to 2010-2011, which is fixed at the baseline level to avoid confounding the ascending slope with incoming recruitment. The plateau is a bit wider under Models 2b and 3 than the others, and the decline in Model 3b is more gradual than the others.

As shown in Figure 2.10, all five models exhibit variation in survey selectivity over time. An index of temporal variability for survey selectivity and catchability can be computed as follows: 1) For each age, compute the mean and variance (over time) of the product of selectivity and catchability. 2) Weight each age-specific mean and variance by the long-term average proportion of population numbers at age. 3) Compute the average of the means and variances over all ages. 4) Compute a weighted average coefficient of variation (CV) as the square root of the average variance over the average mean. This results in the following CVs:

Model 1	Model 2b	Model 3	Model 3b	Model 4
0.193	0.195	0.196	0.208	0.201

For comparison, Model A from the preliminary assessment (Attachment 2.1), which the Plan Teams viewed as exhibiting an impermissibly high estimate of survey variability, produced a CV of 0.330.

Figure 2.11 (five pages, one for each model) shows fishery selectivity as estimated by all five models. Visually, there does not appear to be a great deal of difference between the curves estimated by the various models, except that Model 1 exhibits an almost constant (across length) selectivity for the 1977-1979 January-April trawl fishery (this block was merged with the 1980-1984 block in the other models), and Models 2b and 3 estimate a more gradual increase in the 1990-1994 August-December trawl fishery than Models 1, 3b, or 4. In general, selectivities that are not forced to be asymptotic tend to show decreasing selectivity at large size.

Because the catchability coefficient for the post-1981 trawl survey was held constant for all models at the value estimated in the 2009 assessment (0.77), it may be wondered how well this value continues to achieve the intended result of matching the value of 0.47 obtained by Nichol et al. (2007) for the weighted average of the product of trawl survey catchability and selectivity across the 60-81 cm size range. This weighted average product was computed for each year of the post-1981 survey (i.e., 1982-2011), which resulted in the following statistics:

Statistic	Model 1	Model 2b	Model 3	Model 3b	Model 4
Average:	0.45	0.58	0.53	0.51	0.45
Minimum:	0.39	0.51	0.45	0.42	0.36
Maximum:	0.51	0.64	0.61	0.58	0.54
Standard deviation:	0.03	0.03	0.04	0.04	0.04
Coefficient of variation:	0.07	0.06	0.08	0.08	0.09

All models except Models 2b and 3 come within 0.05 of the target value, and the range of values spanned by each model except Model 2b includes the target value.

Table 2.20 contains selected output from the standard projection model, based on SS parameter estimates from the five models, along with the probability that the maximum permissible ABC in each of the next two years will exceed the corresponding true-but-unknown OFL and the probability that the stock will fall below $B_{20\%}$ in each of the next five years (probabilities are given by SS rather than the standard projection model). Recruitments, numbers at age, and biomasses have been divided by the conversion factor of 0.91 described in the "Aleutian Bottom Trawl Survey" subsection, so as to represent quantities relevant to the entire BSAI management region, rather than the EBS area on the basis of which the models are configured. Model 1 tends to produce the lowest ratios of projected spawning biomass to $B_{100\%}$, Model 2b tends to produce the lowest spawning biomass reference points, projected spawning biomasses, maximum permissible ABCs, and OFLs, and Model 3 tends to produce the lowest fishing mortality reference points. Model 1 tends to produce the highest spawning biomass reference points, Model 3b tends to produce the highest ratios of projected spawning biomass to $B_{100\%}$ and the highest fishing mortality reference points, and Model 4 tends to produce the highest projected spawning biomasses, maximum permissible ABCs, and OFLs. The probability of exceeding the true-but-unknown OFL in either of the next two years and the probability of falling below $B_{20\%}$ in any of the next five years is very small under all models.

All models converged successfully and the Hessian matrices from all models were positive definite. Once each model appeared to have converged, a set of (typically 50) "jitter" runs were made with initial parameter values displaced randomly from their converged values to provide additional assurance that another (better) solution did not exist. If a better solution was found, the process was repeated until such time as no further improvement was obtained. No model was considered final until a set of 50 jitter runs failed to find a better value of the objective function.

In the table below, the row labeled "Success" shows the proportion of jitters that ran successfully (i.e., that returned a numeric value for the objective function). The row labeled "Match" shows the proportion of successful jitters that matched the final version. The row labeled "-lnL 'RMSE'" shows a statistic for the objective function that is similar to a root-mean-squared-error, but in which the squared difference is taken with respect to the *minimum* value (across jitters) rather than the *mean*; this statistic is reported in units of log-likelihood. Finally, the row labeled "SB2011 'CV'" shows a statistic for 2011 spawning biomass that is similar to a coefficient of variation, but in which (as with the preceding column) the mean is replaced by the value corresponding to the final (i.e., best case) version of the model. Green shading denotes the cell with the minimum value in the row, and pink shading denotes the cell with the maximum.

Quantity	Model 1	Model 2b	Model 3	Model 3b	Model 4
Success	1.000	1.000	1.000	1.000	1.000
Match	0.140	0.360	0.340	0.460	0.460
-lnL "RMSE"	1084.630	104.162	1635.813	738.169	66.156
SB2011 "CV"	0.083	0.033	0.054	0.084	0.044

Models 3b and 4 had the best match rate, Model 4 had the best –lnL "RMSE," and Model 2b had the best SB2011 "CV" (although all four models had values less than 10%).

Figure 2.12 sorts the jitter runs for each model in order of decreasing log likelihood, and shows how the running (cumulative) value of –lnL "RMSE" changes with each additional (sorted) jitter run. This figure is included to address the Plan Teams' concern that the reported value of –lnL "RMSE" may be due to a small number of outliers.

In response to requests from individual Plan Team and SSC members, five retrospective runs were conducted for each of the five models. For each model, results of the retrospective runs were compared in a 2×2 factorial design. The first factor involved a choice of which model output to analyze. Spawning biomass and age 0 recruitment (as assessed at age 1) were chosen for this purpose. The second factor involved a choice of baseline to use in computing bias. Bias relative to the subsequent run (e.g., treating the 4-year retrospective as an estimator of the 3-year retrospective) and bias relative to the current run (e.g., treating the 4-year retrospective as an estimator of the 0-year retrospective) were chosen for this purpose. Bias was calculated for each model, each retrospective run, each choice of model output, each choice of baseline, and each year from 1977 through the end of the respective retrospective run. The results are shown in Figure 2.13 (five pages, one for each model; note that colors in this figure correspond to different retrospective runs, not different models).

To distill the information contained in Figure 2.13 into more manageable form, the following set of summary statistics was computed for each model, each retrospective run, each choice of model output, and each choice of baseline: the average bias (across all years), the end-year bias, and the root-mean-squared-error (across all years). These statistics are reported in Tables 2.21 and 2.22 for spawning biomass and age 0 recruitment, respectively; and in Figures 2.14 and 2.15 for spawning biomass and age 0 recruitment, respectively.

With respect to spawning biomass, all five models have biases or RMSEs close to zero under a 1-year retrospective. For longer retrospectives, biases and RMSEs tend to increase, with relative rankings among the models changing across retrospective year. When averaged across retrospective years, Model 2b tends to do the best in terms of average bias, Model 1 tends to do the best in terms of end-year bias, and Models 2b and 3b tend to do the best in terms of RMSE.

With respect to age 0 recruitment, in terms of average bias, all five models again have biases close to zero under a 1-year retrospective, generally increasing with the number of retrospective years. However, end-year biases are not always close to zero, even for a 1-year retrospective. Models 2b and 3b tend to do better than the other three models in this respect, and Model 1 tends to do especially bad, exhibiting end-year biases greater than 50%. In terms of RMSE, Model 1 clearly does worse than the other models. Model 1's poor retrospective performance in terms of recruitment is likely due at least in part to the absence of an age 0 column in the age composition and mean-size-at-age portions of Model 1's data file.

Evaluation Criteria

The following criteria were considered in selecting the final model:

1. The model should continue to use the age composition data and, if possible, achieve a good fit to those data. Of the 128 unique recommendations received from the three CIE reviews, only 4 were common to all three, and continued use of the age composition data was among those.
2. The model should estimate ageing bias internally. Assuming that this new feature of SS is working properly, internal estimation of ageing bias is vastly more efficient than estimation by trial and error, and it also provides estimates of variance around the estimated parameters.
3. The mean sizes at age estimated by the model should give a reasonably good fit to the first few modes in the long-term average survey size composition data and the mean-size-at-age data, regardless of whether the latter are actually used in the estimation.
4. The model should exhibit an average (across the 61-80 cm size range) value for the product of survey catchability and selectivity that comes reasonably close to the value estimated by Nichol et al. (2007).
5. The parameters governing variability in length at age in the model should account for between-cohort (or between-year) variability as well as between-individual variability. Regardless of whether the age data or the normal distributions fitted to the survey size composition are used, Figure 2.2 gives strong evidence that the distribution of size at age 1 is not constant over time. However, the regression approach used in the last few assessments to estimate variability in length at age assumes that this distribution *is* constant over time, which should tend to underestimate the true amount of variability.
6. The time series of survey selectivity and catchability should exhibit a level of temporal variability lower than that estimated by Model A in the preliminary assessment. The Plan Teams felt that the level of temporal variability estimated by Model A constituted “a clear indication that the .model is overfitting the data” (see comment JPT2).
7. The model should exhibit reasonable retrospective behavior.

Selection of Final Model

The five models can be evaluated by the six criteria as follows:

1. All models except Model 4 continue to use the age composition data. Model 3b gives the best fit to the age composition data, whether measured in terms of log likelihood or effective sample size (effective sample sizes under Model 3b are at least 40% higher than any other model).
2. Models 3 and 3b estimate ageing bias internally. The other models do not.
3. Estimates of mean size at age are fairly similar across all models (see Figures 2.5 and 2.6). Log likelihood values for the mean-size-at-age data from Models 3b and 4, which do not attempt to fit those data, fall within the range of log likelihood values from the other models, which do attempt to fit those data.
4. All models except Models 2b and 3 come within 0.05 of Nichol et al.’s (2007) estimate of the average (across the 61-80 cm size range) value for the product of survey catchability and selectivity.
5. Models 3b and 4 estimate the parameters governing variability in length at age internally. The other models do not; instead, they estimate those parameters based on an outside-the-model regression. Given the extent of between-individual and between-cohort variability depicted in Figure 2.2, the standard deviation of length at age 1 at the time of the survey could be as high as 3.55 (based on the age data) or 3.71 (based on the normal fits to the size compositions). For comparison, the five models imply, assume, or estimate the following values:

Model 1	Model 2b	Model 3	Model 3b	Model 4
2.47	2.67	2.69	3.50	3.51

From the above, it appears that Models 3b and 4 are doing a reasonable job of incorporating both between-individual and between-cohort variability in the parameters governing variability in length at age, whereas the other models appear to be underestimating variability in length at age.

6. As noted previously, all five models estimate levels of inter-temporal variability in survey and catchability that are substantially lower (0.193-0.201) than that exhibited by Model A in the preliminary assessment (0.330).
7. While none of the models exhibits perfect retrospective behavior, avoiding the type of bias exhibited by Model 1 in estimation of the most recent recruitment is something would be desirable. According to several measures, Models 2b and 3b tended to exhibit slightly better retrospective performance than the other models.

On the basis of the above, Model 3b is selected as the final model.

Final Parameter Estimates and Associated Schedules

As noted previously, estimates of all statistically estimated parameters in Model 3b are shown in Table 2.18. Estimates of year-, gear-, and season-specific fishing mortality rates from Model 3b are shown in Table 2.19d.

Schedules of selectivity at length for the commercial fisheries from Model 3b are shown in Table 2.23, and schedules of selectivity at age for the trawl surveys from Model 3b are shown in Table 2.24. Trawl survey and all fishery selectivity schedules for Model 3b are plotted in Figures 2.10 and 2.11d, respectively.

Schedules of length at age and weight at age for the population, length at age for each gear-and-season-specific fishery and each survey, and weight at age for each gear-and-season-specific fishery and each survey from Model 3b are shown in Tables 2.25, and 2.26, and 2.27, respectively.

Time Series Results

Note: Because the preferred model differs substantively from last year's model (Model 1), the tables and figures referenced in this section are reproduced using Model 1 in Attachment 2.4.

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. To supplement the full-selection fishing mortality rates already shown in Table 2.19d, an alternative "effective" fishing mortality rate will be provided here, defined for each age and time by $-\ln(N_{a+1,t+1}/N_{a,t})-M$, where N = number of fish, a = age measured in years, t = time measured in years, and M = instantaneous natural mortality rate. In addition, the ratio of full-selection fishing mortality to $F_{35\%}$ will be provided.

Biomass

Table 2.28 shows the time series of EBS (not expanded to BSAI) Pacific cod age 0+ and female spawning biomass for the years 1977-2012 as estimated last year and this year under Model 3b. 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 3b are shown, together with the observed time series of trawl survey biomass (assuming a catchability of 1.0), in

Figure 2.16. 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 2.29 shows the time series of EBS (not expanded to BSAI) Pacific cod age 0 recruitment (1000s of fish) for the years 1977-2010 as estimated last year and this year under Model 3b. Both estimated time series are accompanied by their respective standard deviations. For the time series as a whole, the largest year class appears to have been the 1977 cohort. Other cohorts that are estimated to be at least 50% larger than the average include the 1979, 1982, 1984, 1996, 2006, 2008, and 2010 year classes. Based on current estimates, the five most recent year classes include three of the top five year classes of all time. However, it should be emphasized that the estimate of the 2010 year class is based entirely on the 2011 survey.

Model 3b's recruitment estimates for the entire time series (1977-2010) are shown in Figure 2.17, along with their respective 95% confidence intervals.

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 3b is shown in Table 2.30.

Fishing Mortality

Table 2.31 shows "effective" fishing mortality by age and year for ages 1-19 and years 1977-2010.

Figure 2.18 plots the trajectory of relative fishing mortality and relative female spawning biomass from 1977 through 2011 based on Model 3b, 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). Nearly the entire trajectory lies underneath the $maxF_{ABC}$ control rule. While the ratio of $F_{40\%}$ to $F_{35\%}$ shown in Figure 2.18 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 (Model 1), the tables referenced in this section are reproduced using Model 1 in Attachment 2.4.

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 3b:

Reference point:	$B_{35\%}$	$B_{40\%}$	$B_{100\%}$
BSAI:	311,000 t	355,000 t	899,000 t
EBS:	283,000 t	323,000 t	809,000 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 3b's estimates of fishing mortality by gear for the five most recent complete years of data (2006-2010). 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 25.5%, longline 61.9%, and pot 12.6%. This apportionment results in estimates of $F_{35\%}$ and $F_{40\%}$ equal to 0.36 and 0.30, respectively.

Specification of OFL and Maximum Permissible ABC

BSAI spawning biomass for 2012 is estimated by Model 3b at a value of 410,000 t. This is about 6% above the BSAI $B_{40\%}$ value of 355,000 t, thereby placing Pacific cod in sub-tier "s" of Tier 3. Given this, Model 3b estimates OFL, maximum permissible ABC, and the associated fishing mortality rates for 2012 and 2013 as follows (2013 values are predicated on the assumption that 2012 catch will equal 2012 maximum permissible ABC; catches are for the entire BSAI):

Year	Overfishing Level	Maximum Permissible ABC
2012	369,000 t	314,000 t
2013	374,000 t	319,000 t
2012	0.36	0.30
2013	0.36	0.30

The age 0+ biomass BSAI projections for 2012 and 2013 from Model 3b (using SS) are 1,690,000 t and 1,720,000 t.

For comparison, the age 3+ BSAI projections for 2012 and 2013 from Model 3b (using SS) are 1,620,000 t and 1,620,000 t.

ABC Recommendation

In 2005, the Plan Team and SSC selected a model that resulted in a maximum permissible ABC of 194,000 t (Tier 3b), which was adopted as the 2006 ABC.

Similarly, the maximum permissible ABC was selected in 2006, giving a 2007 ABC of 176,000 t (Tier 3b).

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 (Tier 3b for both years).

In 2009, the SSC again recommended the maximum permissible ABC, which resulted in specifications of 174,000 t for 2010 and 214,000 t for 2011 (Tier 3b for both years).

In 2010, the SSC again recommended the maximum permissible ABC, which resulted in specifications of 235,000 t for 2011 (Tier 3b) and 281,000 t for 2012 (Tier 3a).

This year, spawning biomass is estimated to be well above $B_{40\%}$, and is projected to increase further. These increases are fueled largely by the 2006 and 2008 year classes, whose strengths have now been confirmed by multiple surveys. In addition, the 2010 year class also appears to be very strong, although this estimate must be regarded as highly preliminary. One caution to be noted is that the estimate of survey catchability upon which these projections depend is based on an extremely small sample size (Nichol et al. 2007), implying that there is considerable uncertainty surrounding the point estimate. Nevertheless, use of this point estimate has been subjected to multiple peer reviews and remains the best scientific information available. The maximum permissible values of 314,000 t and 319,000 t are therefore the recommended ABCs for 2012 and 2013, respectively.

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. A draft assessment of the AI stock (using Tier 5 methodology) is presented here as Attachment 2.2, for purposes of evaluation only.

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 2012 numbers at age. 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 TACs for 2012 and 2013, 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 2012 recommended in the assessment to the *max* F_{ABC} for 2012. (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 2006-2010 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 1) above its MSY level in 2011 or 2) above 1/2 of its MSY level in 2011 and expected to be above its MSY level in 2021 under this scenario, then the stock is not overfished.)
>
> *Scenario 7*: In 2012 and 2013, 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 2024 under this scenario, then the stock is not approaching an overfished condition.)

Projections and Status Determination

Projections corresponding to the standard scenarios are shown for Model 3b in Tables 2.32-2.37 (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 2012, it does not provide the best estimate of OFL for 2013, because the mean 2013 catch under Scenario 6 is predicated on the 2012 catch being equal to the 2012 OFL, whereas the actual 2012 catch will likely be less than the 2012 OFL. Table 2.20 contains the appropriate one- and two-year ahead projections for both ABC and OFL under any of the five models considered in the present assessment.

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 (2010) is 171,857 t. This is less than the 2010 OFL of 205,000 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 2012:

a. If spawning biomass for 2011 is estimated to be below ½ $B_{35\%}$, the stock is below its MSST.
b. If spawning biomass for 2011 is estimated to be above $B_{35\%}$ the stock is above its MSST.
c. If spawning biomass for 2011 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 2.36). If the mean spawning biomass for 2021 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 2.37):

a. If the mean spawning biomass for 2014 is below 1/2 $B_{35\%}$, the stock is approaching an overfished condition.
b. If the mean spawning biomass for 2014 is above $B_{35\%}$, the stock is not approaching an overfished condition.
c. If the mean spawning biomass for 2014 is above 1/2 $B_{35\%}$ but below $B_{35\%}$, the determination depends on the mean spawning biomass for 2024. If the mean spawning biomass for 2024 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 2.36 and 2.37, the stock is not overfished and is not approaching an overfished condition.

ECOSYSTEM CONSIDERATIONS

This section is largely unchanged from recent assessments, except for the subsection on "Incidental Catch of 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.

Incidental Catch of Nontarget Species

Incidental catches of nontarget species in each year 2003-2011 are shown Table 2.38. In terms of average catch over the time series, only giant grenadiers, Scyphozoa jellyfish, and sea stars account for more than 200 t per year. However, it may be noted that catches of giant grenadiers have increased approximately exponentially over the last few years.

Incidental catches of prohibited species in each year 2003-2011 are shown in Table 2.39a, and the halibut portion of Table 2.39a is translated into units of halibut mortality in Table 2.39b.

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

Significant improvements in the quality of this assessment could be made 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) age determination; 5) ecology of species taken as bycatch in the Pacific cod fisheries, including estimation of biomass, carrying capacity, and resilience; and 6) ecology of species that interact with Pacific cod, including estimation of biomass, carrying capacity, and resilience.

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REFERENCES

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

Bakkala, R. G., and V. G. Wespestad. 1985. Pacific cod. *In* R. G. Bakkala and L. L. Low (editors), Condition of groundfish resources of the eastern Bering Sea and Aleutian Islands region in 1984, p. 37-49. U.S. Dep. Commer., NOAA Tech. Memo. NMFS F/NWC-83.

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

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

Canino, M. F., I. B. Spies, and L. Hauser. 2005. Development and characterization of novel di- and tetranucleotide microsatellite markers in Pacific cod (*Gadus macrocephalus*). Molecular Ecology Notes 5:908-910.

Canino, M. F., I. B. Spies, K. M. Cunningham, L. Hauser, and W. S. Grant. 2010. Multiple ice-age refugia in Pacific cod, *Gadus macrocephalus*. Molecular Ecology 19:4339-4351.

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

Cunningham, K. M., M. F. Canino, I. B. Spies, and L. Hauser. 2009. Genetic isolation by distance and localized fjord population structure in Pacific cod (*Gadus macrocephalus*): limited effective dispersal in the northeastern Pacific Ocean. Can. J. Fish. Aquat. Sci. 66:153-166.

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

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

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

Greer-Walker, M. 1970. Growth and development of the skeletal muscle fibres of the cod (*Gadus morhua L.*). Journal du Conseil 33:228-244.

Gregory, R. S., C. Morris, and B. Newton. In review. Relative strength of the 2007 and 2008 year-classes, from nearshore surveys of demersal age 0 Atlantic cod in Newman Sound, Bonavista Bay. Can. Sci. Advis. Sec. Res. Doc. 2009/xxx.

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

Hiatt, T., M. Dalton, R. Felthoven, B. Fissel, B. Garber-Yonts, A. Haynie, S. Kasperski, D. Lew, C. Package, J. Sepez, and C. Seung. 2010. Stock Assessment and Fishery Evaluation Report for the Groundfish Fisheries of the Gulf of Alaska and Bering Sea/Aleutian Islands Area: Economic Status of the Groundfish Fisheries off Alaska, 2009. Economic and Social Sciences Research Program, Resource Ecology and Fisheries Management Division, Alaska Fisheries Science Center, NMFS, NOAA, 7600 Sand Point Way N.E., Seattle, Washington 98115-6349. 253 p.

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

Jung, S., I. Choi, H. Jin, D.-w. Lee, H.-k. Cha, Y. Kim, and J.-y. Lee. 2009. Size-dependent mortality formulation for isochronal fish species based on their fecundity: an example of Pacific cod (*Gadus macrocephalus*) in the eastern coastal areas of Korea. Fisheries Research 97:77-85.

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

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

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

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

Livingston, P. A. (editor). 2002. Ecosystem Considerations for 2003. North Pacific Fishery Management Council, 605 West 4th Ave., Suite 306, Anchorage, AK 99501.

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

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

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

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

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

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

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

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

Methot, R. D. 2011. User Manual for Stock Synthesis, Model Version 3.21d. Unpublished manuscript, available from NOAA Fisheries Stock Assessment Toolbox website: http://nft.nefsc.noaa.gov/. 165 p.

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

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

Ona, E., and O. R. Godø. 1990. Fish reaction to trawling noise: the significance for trawl sampling. Rapports et Procès-Verbaux des Réunions du Conseil International pour l'Exploration de la Mer 189: 159–166.

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

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

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

Savin, A. B. 2008. Seasonal distribution and Migrations of Pacific cod *Gadus macrocephalus* (Gadidae) in Anadyr Bay and adjacent waters. Journal of Ichythyology 48:610-621.

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

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

Spies I. B. In review. A landscape genetics approach to Pacific cod (*Gadus macrocephalus*) population structure in the Bering Sea and Aleutian Islands reveals isolation-by-distance and distinct populations. Submitted to Canadian Journal of Fisheries and Aquatic Sciences.

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

Thompson, G. G. 1992. Pacific cod. *In* Plan Team for the Groundfish Fisheries of the Bering Sea and Aleutian Islands (compiler), Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the Bering Sea/Aleutian Islands Regions as Projected for 1993, p. 2-1 through 2-37. North Pacific Fishery Management Council, 605 West 4th Ave., Suite 306, Anchorage, AK 99501.

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

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

Thompson, G. G., and M. W. Dorn. 2004. Assessment of the Pacific cod stock in the Eastern Bering Sea and Aleutian Islands Area. *In* Plan Team for Groundfish Fisheries of the Bering Sea/Aleutian Islands (compiler), Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands regions, p. 185-302. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.

Thompson, G. G., and M. W. Dorn. 2005. Assessment of the Pacific cod stock in the Eastern Bering Sea and Aleutian Islands Area. *In* Plan Team for Groundfish Fisheries of the Bering Sea/Aleutian Islands (compiler), Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands regions, p. 219-330. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.

Thompson, G. G., M. W. Dorn, S. Gaichas, and K. Aydin. 2006. Assessment of the Pacific cod stock in the Eastern Bering Sea and Aleutian Islands Area. *In* Plan Team for Groundfish Fisheries of the Bering Sea/Aleutian Islands (compiler), Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands regions, p. 237-339. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.

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

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

Thompson, G., J. Ianelli, R. Lauth, S. Gaichas, and K. Aydin. 2008. Assessment of the Pacific cod stock in the Eastern Bering Sea and Aleutian Islands Area. *In* Plan Team for Groundfish Fisheries of the Bering Sea/Aleutian Islands (compiler), Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands regions, p. 221-401. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.

Thompson, G., J. Ianelli, and R. Lauth. 2009. Assessment of the Pacific cod stock in the Eastern Bering Sea and Aleutian Islands Area. *In* Plan Team for Groundfish Fisheries of the Bering Sea/Aleutian

Islands (compiler), Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands regions, p. 235-439. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.

Thompson, G., J. Ianelli, and R. Lauth. 2010. Assessment of the Pacific cod stock in the Eastern Bering Sea and Aleutian Islands Area. *In* Plan Team for Groundfish Fisheries of the Bering Sea/Aleutian Islands (compiler), Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands regions, p. 243-424. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.

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

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

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

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

Ueda, Y., Y. Narimatsu, T. Hattori, M. Ito, D. Kitagawa, N. Tomikawa, and T. Matsuishi. 2006. Fishing efficiency estimated based on the abundance from virtual population analysis and bottom-trawl surveys of Pacific cod (Gadus macrocephalus) in the waters off the Pacific coast of northern Honshu, Japan. Nippon Suisan Gakkaishi 72:201-209.

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

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

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

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 1981-2011 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 2011 are through October 3.

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	95059	21959	155	164305	178600
2004	0	0	0	0	0	57794	108021	17242	231	183288	183288
2005	0	0	0	0	0	52604	113120	17104	108	182936	182936
2006	0	0	0	0	0	53209	96559	18957	81	168806	168806
2007	0	0	0	0	0	45673	77104	17222	82	140081	140079
2008	0	0	0	0	0	33493	88915	17366	19	139793	139604
2009	0	0	0	0	0	36956	96611	13586	13	147166	147166
2010	0	0	0	0	0	41152	81663	19655	388	142857	118618
2011	0	0	0	0	0	56900	87918	25376	505	170700	170700

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 1991-2011 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 2011 are through October 3.

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	3073	0	13	22699						22699
2006	16956	3128	401	8	20493	3106	455	156	0	3717	24210
2007	25725	4182	313	1	30221	2907	529	383	6	3824	34045
2008	19291	5471	1679	156	26597	2540	234	1634	53	4462	31059
2009	20284	5469	754	0	26507	537	279	1237	20	2074	28580
2010	16757	7638	727	0	25122	2113	77	1688	0	3878	29000
2011	9250	1194	1	0	10444	4	14	30	0	48	10492

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 1991-2011 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 2011 are through October 3.

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	96035	21961	156	196498						196498
2004	83564	111124	17242	231	212161						212161
2005	72217	116193	17104	121	205635						205635
2006	70166	99688	19358	89	189300	3106	455	156	0	3717	193017
2007	71398	81287	17534	83	170302	2907	529	383	6	3824	174126
2008	52784	94386	19045	176	166390	2540	234	1634	53	4462	170852
2009	57241	102080	14339	13	173672	537	279	1237	20	2074	175746
2010	57909	89301	20381	388	167979	2113	77	1688	0	3878	171857
2011	66150	89112	25377	505	181144	4	14	30	0	48	181192

Table 2.4—History of BSAI Pacific cod catch, TAC, ABC, and OFL. Catch for 2011 is through October 3. Source: NPFMC staff.

Year	Catch	TAC	ABC	OFL
1977	36,597	58,000	-	-
1978	45,838	70,500	-	-
1979	39,354	70,500	-	-
1980	51,649	70,700	148,000	-
1981	63,941	78,700	160,000	-
1982	69,501	78,700	168,000	-
1983	103,231	120,000	298,200	-
1984	133,084	210,000	291,300	-
1985	150,384	220,000	347,400	-
1986	142,511	229,000	249,300	-
1987	163,110	280,000	400,000	-
1988	208,236	200,000	385,300	-
1989	182,865	230,681	370,600	-
1990	179,608	227,000	417,000	-
1991	172,158	229,000	229,000	-
1992	206,129	182,000	182,000	188,000
1993	167,390	164,500	164,500	142,000
1994	196,572	191,000	191,000	228,000
1995	245,030	250,000	328,000	390,000
1996	240,590	270,000	305,000	420,000
1997	234,641	270,000	306,000	418,000
1998	195,645	210,000	210,000	336,000
1999	162,361	177,000	177,000	264,000
2000	191,056	193,000	193,000	240,000
2001	176,659	188,000	188,000	248,000
2002	197,353	200,000	223,000	294,000
2003	211,059	207,500	223,000	324,000
2004	212,161	215,500	223,000	350,000
2005	205,635	206,000	206,000	265,000
2006	193,017	194,000	194,000	230,000
2007	174,124	170,720	176,000	207,000
2008	170,661	170,720	176,000	154,000
2009	175,746	176,540	182,000	212,000
2010	171,857	168,780	174,000	205,000
2011	181,192	227,950	235,000	272,000

Table 2.5a—Pacific cod discard rates by area, target fishery, and year for the period 1991-2002 (see Table 2.5b for the period 2003-2011). 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 fishery	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 fishery	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 target fishery and year for the period 2003-2011, for the BSAI as a whole (see Table 2.5a for the period 1991-2002, where the data are partitioned by area in addition to the above categories). The discard rate is the ratio of discarded Pacific cod catch to total Pacific cod catch for a given target/year combination. An empty cell indicates that no Pacific cod were observed in that target/year combination. Note that the absolute amount of discards may be small even if the discard rate is large.

	Discard rate									
Target fishery	2003	2004	2005	2006	2007	2008	2009	2010	2011	Ave.
Alaska Plaice					0.000	0.000	0.004		0.017	0.016
Arrowtooth Flounder	0.000	0.004	0.050	0.006	0.000	0.001	0.024	0.021	0.007	0.018
Atka Mackerel	0.031	0.017	0.059	0.030	0.026	0.002	0.019	0.005	0.007	0.024
Flathead Sole	0.000	0.020	0.019	0.085	0.004	0.028	0.029	0.010	0.002	0.023
Greenland Turbot	0.072	0.030	0.010	0.157	0.026	0.039	0.013	0.185	0.006	0.072
Halibut	0.485	0.391	0.848	0.328	0.189	0.564	0.005	0.001	0.056	0.513
Kamchatka Flounder									0.056	0.056
Other Flatfish	0.014	0.004	0.072	0.015	0.018	0.027	0.000			0.022
Other Species	0.017	0.052	0.067	0.323	0.002					0.037
Pacific Cod	0.013	0.012	0.016	0.011	0.013	0.011	0.012	0.012	0.011	0.012
Pollock - bottom	0.000	0.001	0.000	0.000	0.000	0.001	0.002	0.003	0.001	0.002
Pollock - midwater	0.005	0.016	0.005	0.008	0.010	0.002	0.008	0.002	0.005	0.007
Rock Sole - BSAI	0.078	0.028	0.019	0.027	0.045	0.015	0.024	0.021	0.007	0.026
Rockfish	0.000	0.016	0.000	0.107	0.089	0.002	0.226	0.059	0.119	0.052
Sablefish	0.353	0.000	0.288	0.569	0.330	0.385	0.021	0.821	0.434	0.358
Yellowfin Sole	0.056	0.020	0.045	0.097	0.057	0.061	0.020	0.086	0.015	0.045
All	0.015	0.013	0.018	0.014	0.015	0.013	0.013	0.017	0.011	0.014

Table 2.6 (p. 1 of 4)— EBS catch (t) of Pacific cod by year, gear, and season for the years 1977-2011 as configured in the stock assessment models. 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. Aug-Oct and Nov-Dec catches for 2011 are extrapolated.

		Trawl fishery			Longline fishery			Pot fishery		
Year	Season	Jan-Apr	May-Jul	Aug-Dec	Jan-Apr	May-Jul	Aug-Dec	Jan-Apr	May-Jul	Aug-Dec
1977	Jan-Feb	5974	0	0	740	0	0	0	0	0
1977	Mar-Apr	5974	0	0	740	0	0	0	0	0
1977	May-Jul	0	7080	0	0	544	0	0	0	0
1977	Aug-Oct	0	0	5475	0	0	1733	0	0	0
1977	Nov-Dec	0	0	3429	0	0	1646	0	0	0
1978	Jan-Feb	7884	0	0	977	0	0	0	0	0
1978	Mar-Apr	7884	0	0	977	0	0	0	0	0
1978	May-Jul	0	9343	0	0	717	0	0	0	0
1978	Aug-Oct	0	0	7226	0	0	2286	0	0	0
1978	Nov-Dec	0	0	4526	0	0	2172	0	0	0
1979	Jan-Feb	6452	0	0	800	0	0	0	0	0
1979	Mar-Apr	6452	0	0	800	0	0	0	0	0
1979	May-Jul	0	7646	0	0	587	0	0	0	0
1979	Aug-Oct	0	0	5914	0	0	1871	0	0	0
1979	Nov-Dec	0	0	3704	0	0	1778	0	0	0
1980	Jan-Feb	7355	0	0	912	0	0	0	0	0
1980	Mar-Apr	7355	0	0	912	0	0	0	0	0
1980	May-Jul	0	8716	0	0	669	0	0	0	0
1980	Aug-Oct	0	0	6741	0	0	2133	0	0	0
1980	Nov-Dec	0	0	4222	0	0	2027	0	0	0
1981	Jan-Feb	6027	0	0	514	0	0	0	0	0
1981	Mar-Apr	6027	0	0	514	0	0	0	0	0
1981	May-Jul	0	12405	0	0	673	0	0	0	0
1981	Aug-Oct	0	0	15439	0	0	2179	0	0	0
1981	Nov-Dec	0	0	10743	0	0	1971	0	0	0
1982	Jan-Feb	8697	0	0	145	0	0	0	0	0
1982	Mar-Apr	8697	0	0	145	0	0	0	0	0
1982	May-Jul	0	16449	0	0	389	0	0	0	0
1982	Aug-Oct	0	0	14224	0	0	1312	0	0	0
1982	Nov-Dec	0	0	8174	0	0	1154	0	0	0
1983	Jan-Feb	16303	0	0	1176	0	0	0	0	0
1983	Mar-Apr	16303	0	0	1176	0	0	0	0	0
1983	May-Jul	0	24351	0	0	1087	0	0	0	0
1983	Aug-Oct	0	0	19453	0	0	1627	0	0	0
1983	Nov-Dec	0	0	11353	0	0	1378	0	0	0
1984	Jan-Feb	19295	0	0	2005	0	0	0	0	0
1984	Mar-Apr	19295	0	0	2005	0	0	0	0	0
1984	May-Jul	0	26290	0	0	2421	0	0	0	0
1984	Aug-Oct	0	0	20844	0	0	10463	0	0	0
1984	Nov-Dec	0	0	12523	0	0	9754	0	0	0
1985	Jan-Feb	22269	0	0	5481	0	0	0	0	0
1985	Mar-Apr	22269	0	0	5481	0	0	0	0	0
1985	May-Jul	0	30250	0	0	3881	0	0	0	0
1985	Aug-Oct	0	0	20713	0	0	11260	0	0	0
1985	Nov-Dec	0	0	11155	0	0	10690	0	0	0

Table 2.6 (p. 2 of 4)— EBS catch (t) of Pacific cod by year, gear, and season for the years 1977-2011 as configured in the stock assessment models.

		Trawl fishery			Longline fishery			Pot fishery		
Year	Season	Jan-Apr	May-Jul	Aug-Dec	Jan-Apr	May-Jul	Aug-Dec	Jan-Apr	May-Jul	Aug-Dec
1986	Jan-Feb	23914	0	0	3558	0	0	0	0	0
1986	Mar-Apr	23914	0	0	3558	0	0	0	0	0
1986	May-Jul	0	29689	0	0	2071	0	0	0	0
1986	Aug-Oct	0	0	20057	0	0	8785	0	0	0
1986	Nov-Dec	0	0	11191	0	0	8639	0	0	0
1987	Jan-Feb	25765	0	0	8379	0	0	0	0	0
1987	Mar-Apr	25765	0	0	8379	0	0	0	0	0
1987	May-Jul	0	23285	0	0	4671	0	0	0	0
1987	Aug-Oct	0	0	15932	0	0	13617	0	0	0
1987	Nov-Dec	0	0	10731	0	0	13376	0	0	0
1988	Jan-Feb	50988	0	0	214	0	0	0	0	0
1988	Mar-Apr	50988	0	0	214	0	0	0	0	0
1988	May-Jul	0	42602	0	0	571	0	0	0	0
1988	Aug-Oct	0	0	32137	0	0	1005	0	0	0
1988	Nov-Dec	0	0	23583	0	0	773	0	0	0
1989	Jan-Feb	50984	0	0	1524	0	0	13	0	0
1989	Mar-Apr	50984	0	0	1524	0	0	13	0	0
1989	May-Jul	0	36816	0	0	4074	0	0	49	0
1989	Aug-Oct	0	0	15561	0	0	4235	0	0	46
1989	Nov-Dec	0	0	9899	0	0	2579	0	0	25
1990	Jan-Feb	40658	0	0	5268	0	0	0	0	0
1990	Mar-Apr	40658	0	0	5268	0	0	0	0	0
1990	May-Jul	0	27930	0	0	13730	0	0	657	0
1990	Aug-Oct	0	0	9063	0	0	14197	0	0	526
1990	Nov-Dec	0	0	5262	0	0	8650	0	0	198
1991	Jan-Feb	35012	0	0	8232	0	0	1	0	0
1991	Mar-Apr	65705	0	0	12398	0	0	12	0	0
1991	May-Jul	0	16403	0	0	20115	0	0	410	0
1991	Aug-Oct	0	0	12271	0	0	21276	0	0	2306
1991	Nov-Dec	0	0	2	0	0	15484	0	0	614
1992	Jan-Feb	23287	0	0	13646	0	0	50	0	0
1992	Mar-Apr	32239	0	0	22401	0	0	149	0	0
1992	May-Jul	0	11784	0	0	27045	0	0	5321	0
1992	Aug-Oct	0	0	8182	0	0	16319	0	0	1992
1992	Nov-Dec	0	0	1788	0	0	0	0	0	0
1993	Jan-Feb	28010	0	0	22406	0	0	1	0	0
1993	Mar-Apr	35631	0	0	21654	0	0	1010	0	0
1993	May-Jul	0	6095	0	0	5208	0	0	1086	0
1993	Aug-Oct	0	0	9943	0	0	3	0	0	0
1993	Nov-Dec	0	0	2084	0	0	23	0	0	0
1994	Jan-Feb	13856	0	0	22458	0	0	0	0	0
1994	Mar-Apr	44222	0	0	29481	0	0	3179	0	0
1994	May-Jul	0	4453	0	0	6210	0	0	1792	0
1994	Aug-Oct	0	0	20070	0	0	20718	0	0	3133
1994	Nov-Dec	0	0	2691	0	0	0	0	0	0
1995	Jan-Feb	31919	0	0	29918	0	0	62	0	0
1995	Mar-Apr	58159	0	0	34516	0	0	7715	0	0
1995	May-Jul	0	1145	0	0	4161	0	0	7342	0
1995	Aug-Oct	0	0	19770	0	0	21305	0	0	2927
1995	Nov-Dec	0	0	108	0	0	8039	0	0	1413

Table 2.6 (p. 3 of 4)— EBS catch (t) of Pacific cod by year, gear, and season for the years 1977-2011 as configured in the stock assessment models.

		Trawl fishery			Longline fishery			Pot fishery		
Year	Season	Jan-Apr	May-Jul	Aug-Dec	Jan-Apr	May-Jul	Aug-Dec	Jan-Apr	May-Jul	Aug-Dec
1996	Jan-Feb	21160	0	0	28848	0	0	4	0	0
1996	Mar-Apr	50436	0	0	29471	0	0	12571	0	0
1996	May-Jul	0	8398	0	0	3755	0	0	10423	0
1996	Aug-Oct	0	0	10543	0	0	23629	0	0	4347
1996	Nov-Dec	0	0	1475	0	0	3278	0	0	728
1997	Jan-Feb	25706	0	0	31962	0	0	46	0	0
1997	Mar-Apr	52321	0	0	30578	0	0	9639	0	0
1997	May-Jul	0	5049	0	0	8211	0	0	7411	0
1997	Aug-Oct	0	0	9321	0	0	21323	0	0	3780
1997	Nov-Dec	0	0	1585	0	0	25011	0	0	658
1998	Jan-Feb	16120	0	0	30359	0	0	31	0	0
1998	Mar-Apr	26963	0	0	19925	0	0	5550	0	0
1998	May-Jul	0	4180	0	0	4022	0	0	5770	0
1998	Aug-Oct	0	0	12586	0	0	16155	0	0	1890
1998	Nov-Dec	0	0	999	0	0	13928	0	0	53
1999	Jan-Feb	18354	0	0	31749	0	0	5	0	0
1999	Mar-Apr	24661	0	0	20876	0	0	4937	0	0
1999	May-Jul	0	3028	0	0	3283	0	0	5420	0
1999	Aug-Oct	0	0	5658	0	0	20571	0	0	2054
1999	Nov-Dec	0	0	231	0	0	5040	0	0	0
2000	Jan-Feb	18935	0	0	30652	0	0	11647	0	0
2000	Mar-Apr	23194	0	0	8195	0	0	4105	0	0
2000	May-Jul	0	4588	0	0	1683	0	0	0	0
2000	Aug-Oct	0	0	6540	0	0	23325	0	0	107
2000	Nov-Dec	0	0	590	0	0	17816	0	0	0
2001	Jan-Feb	8588	0	0	19639	0	0	150	0	0
2001	Mar-Apr	13895	0	0	16568	0	0	11279	0	0
2001	May-Jul	0	3687	0	0	4089	0	0	611	0
2001	Aug-Oct	0	0	8701	0	0	30261	0	0	3878
2001	Nov-Dec	0	0	807	0	0	19831	0	0	558
2002	Jan-Feb	13410	0	0	35198	0	0	1845	0	0
2002	Mar-Apr	21130	0	0	14486	0	0	8407	0	0
2002	May-Jul	0	7772	0	0	1811	0	0	1013	0
2002	Aug-Oct	0	0	8594	0	0	34463	0	0	2997
2002	Nov-Dec	0	0	263	0	0	14360	0	0	804
2003	Jan-Feb	16298	0	0	35429	0	0	13711	0	0
2003	Mar-Apr	16351	0	0	10867	0	0	1661	0	0
2003	May-Jul	0	7048	0	0	96	0	0	0	0
2003	Aug-Oct	0	0	7577	0	0	33460	0	0	5143
2003	Nov-Dec	0	0	0	0	0	15218	0	0	1444
2004	Jan-Feb	21886	0	0	37436	0	0	9023	0	0
2004	Mar-Apr	17432	0	0	16627	0	0	2854	0	0
2004	May-Jul	0	9773	0	0	2914	0	0	946	0
2004	Aug-Oct	0	0	8766	0	0	30938	0	0	3841
2004	Nov-Dec	0	0	75	0	0	20181	0	0	596
2005	Jan-Feb	27360	0	0	46935	0	0	9034	0	0
2005	Mar-Apr	15119	0	0	6612	0	0	3114	0	0
2005	May-Jul	0	7190	0	0	3510	0	0	0	0
2005	Aug-Oct	0	0	2892	0	0	35344	0	0	4549
2005	Nov-Dec	0	0	113	0	0	20756	0	0	407

Table 2.6 (p. 4 of 4)— EBS catch (t) of Pacific cod by year, gear, and season for the years 1977-2011 as configured in the stock assessment models.

		Trawl fishery			Longline fishery			Pot fishery		
Year	Season	Jan-Apr	May-Jul	Aug-Dec	Jan-Apr	May-Jul	Aug-Dec	Jan-Apr	May-Jul	Aug-Dec
2006	Jan-Feb	28595	0	0	45149	0	0	10608	0	0
2006	Mar-Apr	13917	0	0	6017	0	0	3297	0	0
2006	May-Jul	0	6345	0	0	1903	0	0	363	0
2006	Aug-Oct	0	0	4357	0	0	42489	0	0	3885
2006	Nov-Dec	0	0	49	0	0	1025	0	0	808
2007	Jan-Feb	15851	0	0	42910	0	0	10686	0	0
2007	Mar-Apr	16398	0	0	1917	0	0	1139	0	0
2007	May-Jul	0	10223	0	0	1213	0	0	479	0
2007	Aug-Oct	0	0	3192	0	0	30306	0	0	4922
2007	Nov-Dec	0	0	68	0	0	777	0	0	0
2008	Jan-Feb	15514	0	0	41628	0	0	8850	0	0
2008	Mar-Apr	7159	0	0	3657	0	0	1951	0	0
2008	May-Jul	0	3868	0	0	2633	0	0	225	0
2008	Aug-Oct	0	0	6306	0	0	33040	0	0	6218
2008	Nov-Dec	0	0	655	0	0	7966	0	0	124
2009	Jan-Feb	12183	0	0	44727	0	0	9387	0	0
2009	Mar-Apr	9612	0	0	3726	0	0	1722	0	0
2009	May-Jul	0	4269	0	0	2292	0	0	108	0
2009	Aug-Oct	0	0	10492	0	0	35381	0	0	1288
2009	Nov-Dec	0	0	403	0	0	10494	0	0	1081
2010	Jan-Feb	16343	0	0	40592	0	0	10692	0	0
2010	Mar-Apr	8153	0	0	2050	0	0	1726	0	0
2010	May-Jul	0	4281	0	0	2562	0	0	309	0
2010	Aug-Oct	0	0	10929	0	0	23952	0	0	5163
2010	Nov-Dec	0	0	1601	0	0	12702	0	0	1801
2011	Jan-Feb	21215	0	0	28984	0	0	15345	0	0
2011	Mar-Apr	20798	0	0	26311	0	0	2297	0	0
2011	May-Jul	0	6984	0	0	13492	0	0	1456	0
2011	Aug-Oct	0	0	9242	0	0	30791	0	0	6340
2011	Nov-Dec	0	0	886	0	0	10387	0	0	1002

Table 2.7 (page 1 of 3)— Fishery CPUE as configured in the stock assessment models. Units are kg/minute for trawl gear, kg/hook for longline gear, and kg/pot for pot gear.

Jan-Apr trawl fishery				May-Jul trawl fishery				Aug-Dec trawl fishery			
Year	Season	CPUE	Sigma	Year	Season	CPUE	Sigma	Year	Season	CPUE	Sigma
1991	Jan-Feb	55.864	0.092	1991	May-Jul	36.761	0.205	1991	Aug-Oct	71.702	0.607
1992	Jan-Feb	60.427	0.163	1992	May-Jul	38.568	0.293	1992	Aug-Oct	57.517	0.778
1993	Jan-Feb	62.047	0.158	1993	May-Jul	39.902	0.472	1993	Aug-Oct	113.970	0.507
1994	Jan-Feb	51.965	0.224	1994	May-Jul	26.767	0.250	1994	Aug-Oct	56.308	0.393
1995	Jan-Feb	88.482	0.123	1995	May-Jul	59.393	1.682	1995	Aug-Oct	60.164	0.326
1996	Jan-Feb	48.331	0.133	1996	May-Jul	29.174	0.316	1996	Aug-Oct	34.896	0.293
1997	Jan-Feb	75.605	0.123	1997	May-Jul	24.880	0.261	1997	Aug-Oct	62.619	0.571
1998	Jan-Feb	59.920	0.160	1998	May-Jul	26.245	0.305	1998	Aug-Oct	38.995	0.307
1999	Jan-Feb	42.399	0.120	1999	May-Jul	15.672	0.429	1999	Aug-Oct	20.611	0.370
2000	Jan-Feb	34.522	0.124	2000	May-Jul	32.694	0.296	2000	Aug-Oct	15.070	0.532
2001	Jan-Feb	25.452	0.167	2001	May-Jul	60.120	0.300	2001	Aug-Oct	16.662	0.251
2002	Jan-Feb	35.892	0.142	2002	May-Jul	39.985	0.211	2002	Aug-Oct	15.141	0.197
2003	Jan-Feb	24.642	0.170	2003	May-Jul	49.493	0.212	2003	Aug-Oct	19.171	0.157
2004	Jan-Feb	62.609	0.139	2004	May-Jul	34.588	0.165	2004	Aug-Oct	21.519	0.155
2005	Jan-Feb	43.993	0.117	2005	May-Jul	24.100	0.173	2005	Aug-Oct	15.932	0.841
2006	Jan-Feb	36.397	0.108	2006	May-Jul	30.653	0.188	2006	Aug-Oct	26.772	0.379
2007	Jan-Feb	30.849	0.096	2007	May-Jul	39.485	0.115	2007	Aug-Oct	18.147	0.687
2008	Jan-Feb	24.385	0.153	2008	May-Jul	40.650	0.253	2008	Aug-Oct	60.047	0.339
2009	Jan-Feb	37.853	0.172	2009	May-Jul	33.932	0.294	2009	Aug-Oct	54.154	0.227
2010	Jan-Feb	41.949	0.135	2010	May-Jul	32.031	0.332	2010	Aug-Oct	73.484	0.195
2011	Jan-Feb	51.988	0.122	2011	May-Jul	51.567	0.299	2011	Aug-Oct	54.862	0.550
1991	Mar-Apr	61.454	0.059					1993	Nov-Dec	32.678	0.921
1992	Mar-Apr	48.269	0.070					1996	Nov-Dec	29.543	0.485
1993	Mar-Apr	48.840	0.074					1997	Nov-Dec	31.309	1.101
1994	Mar-Apr	52.428	0.053					1998	Nov-Dec	16.891	0.651
1995	Mar-Apr	55.463	0.062					1999	Nov-Dec	12.994	0.971
1996	Mar-Apr	33.954	0.052					2009	Nov-Dec	28.369	1.189
1997	Mar-Apr	45.985	0.063					2010	Nov-Dec	40.079	0.673
1998	Mar-Apr	31.809	0.072								
1999	Mar-Apr	35.675	0.087								
2000	Mar-Apr	31.397	0.086								
2001	Mar-Apr	21.213	0.107								
2002	Mar-Apr	26.640	0.104								
2003	Mar-Apr	28.131	0.096								
2004	Mar-Apr	42.816	0.117								
2005	Mar-Apr	48.932	0.114								
2006	Mar-Apr	56.188	0.142								
2007	Mar-Apr	45.097	0.093								
2008	Mar-Apr	40.343	0.198								
2009	Mar-Apr	55.557	0.185								
2010	Mar-Apr	55.766	0.263								
2011	Mar-Apr	78.413	0.154								

Table 2.7 (page 2 of 3)— Fishery CPUE as configured in the stock assessment models. Units are kg/minute for trawl gear, kg/hook for longline gear, and kg/pot for pot gear.

Jan-Apr longline fishery			
Year	Season	CPUE	Sigma
1991	Jan-Feb	1.124	0.157
1992	Jan-Feb	0.873	0.089
1993	Jan-Feb	0.654	0.066
1994	Jan-Feb	0.728	0.068
1995	Jan-Feb	0.895	0.069
1996	Jan-Feb	0.878	0.069
1997	Jan-Feb	0.989	0.073
1998	Jan-Feb	0.888	0.074
1999	Jan-Feb	0.743	0.068
2000	Jan-Feb	0.730	0.070
2001	Jan-Feb	0.586	0.080
2002	Jan-Feb	0.680	0.062
2003	Jan-Feb	0.517	0.053
2004	Jan-Feb	0.562	0.061
2005	Jan-Feb	0.626	0.055
2006	Jan-Feb	0.747	0.063
2007	Jan-Feb	0.734	0.046
2008	Jan-Feb	0.794	0.068
2009	Jan-Feb	0.893	0.069
2010	Jan-Feb	0.781	0.066
2011	Jan-Feb	0.722	0.086
1991	Mar-Apr	0.993	0.111
1992	Mar-Apr	0.858	0.071
1993	Mar-Apr	0.669	0.062
1994	Mar-Apr	0.735	0.061
1995	Mar-Apr	0.841	0.062
1996	Mar-Apr	0.756	0.067
1997	Mar-Apr	0.829	0.078
1998	Mar-Apr	0.619	0.076
1999	Mar-Apr	0.617	0.068
2000	Mar-Apr	0.617	0.097
2001	Mar-Apr	0.539	0.073
2002	Mar-Apr	0.676	0.083
2003	Mar-Apr	0.530	0.068
2004	Mar-Apr	0.579	0.076
2005	Mar-Apr	0.678	0.113
2006	Mar-Apr	0.796	0.113
2007	Mar-Apr	0.693	0.156
2008	Mar-Apr	0.774	0.147
2009	Mar-Apr	1.159	0.173
2010	Mar-Apr	0.829	0.193
2011	Mar-Apr	0.713	0.079

May-Jul longline fishery			
Year	Season	CPUE	Sigma
1991	May-Jul	0.771	0.076
1992	May-Jul	0.530	0.053
1993	May-Jul	0.551	0.177
1994	May-Jul	0.713	0.134
1995	May-Jul	0.760	0.180
1996	May-Jul	0.669	0.179
1997	May-Jul	0.657	0.121
1998	May-Jul	0.496	0.185
1999	May-Jul	0.637	0.144
2000	May-Jul	0.610	0.170
2001	May-Jul	0.514	0.108
2002	May-Jul	0.405	0.138
2003	May-Jul	0.376	0.110
2004	May-Jul	0.367	0.116
2005	May-Jul	0.385	0.107
2006	May-Jul	0.366	0.163
2007	May-Jul	0.406	0.143
2008	May-Jul	0.366	0.141
2009	May-Jul	0.384	0.152
2010	May-Jul	0.419	0.154
2011	May-Jul	0.378	0.123

Aug-Dec longline fishery			
Year	Season	CPUE	Sigma
1991	Aug-Oct	0.595	0.063
1992	Aug-Oct	0.512	0.070
1994	Aug-Oct	0.576	0.068
1995	Aug-Oct	0.587	0.070
1996	Aug-Oct	0.542	0.061
1997	Aug-Oct	0.580	0.065
1998	Aug-Oct	0.398	0.064
1999	Aug-Oct	0.481	0.061
2000	Aug-Oct	0.404	0.053
2001	Aug-Oct	0.398	0.052
2002	Aug-Oct	0.372	0.046
2003	Aug-Oct	0.342	0.045
2004	Aug-Oct	0.312	0.048
2005	Aug-Oct	0.330	0.046
2006	Aug-Oct	0.391	0.047
2007	Aug-Oct	0.402	0.039
2008	Aug-Oct	0.307	0.048
2009	Aug-Oct	0.348	0.049
2010	Aug-Oct	0.352	0.059
2011	Aug-Oct	0.377	0.270
1991	Nov-Dec	0.551	0.094
1995	Nov-Dec	0.648	0.111
1996	Nov-Dec	0.590	0.279
1997	Nov-Dec	0.577	0.073
1998	Nov-Dec	0.501	0.073
1999	Nov-Dec	0.541	0.121
2000	Nov-Dec	0.416	0.067
2001	Nov-Dec	0.432	0.066
2002	Nov-Dec	0.394	0.073
2003	Nov-Dec	0.365	0.060
2004	Nov-Dec	0.441	0.066
2005	Nov-Dec	0.385	0.065
2006	Nov-Dec	0.433	0.215
2007	Nov-Dec	0.449	0.334
2008	Nov-Dec	0.449	0.088
2009	Nov-Dec	0.428	0.091
2010	Nov-Dec	0.447	0.086

Table 2.7 (page 3 of 3)— Fishery CPUE as configured in the stock assessment models. Units are kg/minute for trawl gear, kg/hook for longline gear, and kg/pot for pot gear.

Jan-Apr pot fishery				May-Jul pot fishery				Aug-Dec pot fishery			
Year	Season	CPUE	Sigma	Year	Season	CPUE	Sigma	Year	Season	CPUE	Sigma
2000	Jan-Feb	56.553	0.153	1991	May-Jul	64.037	0.253	1991	Aug-Oct	88.556	0.133
2001	Jan-Feb	72.207	0.507	1992	May-Jul	66.730	0.077	1992	Aug-Oct	30.252	0.114
2002	Jan-Feb	81.893	0.266	1993	May-Jul	90.669	0.230	1994	Aug-Oct	97.172	0.152
2003	Jan-Feb	73.858	0.140	1994	May-Jul	75.421	0.174	1995	Aug-Oct	57.783	0.154
2004	Jan-Feb	78.980	0.171	1995	May-Jul	72.065	0.099	1996	Aug-Oct	49.758	0.137
2005	Jan-Feb	85.328	0.169	1996	May-Jul	55.819	0.090	1997	Aug-Oct	47.938	0.168
2006	Jan-Feb	83.292	0.155	1997	May-Jul	46.843	0.115	1998	Aug-Oct	32.057	0.283
2007	Jan-Feb	64.671	0.109	1998	May-Jul	49.999	0.130	1999	Aug-Oct	37.675	0.214
2008	Jan-Feb	81.642	0.210	1999	May-Jul	47.466	0.125	2001	Aug-Oct	46.493	0.170
2009	Jan-Feb	92.345	0.190					2002	Aug-Oct	42.331	0.190
2010	Jan-Feb	88.535	0.165					2003	Aug-Oct	57.632	0.176
2011	Jan-Feb	131.208	0.154					2004	Aug-Oct	48.802	0.212
1992	Mar-Apr	86.412	0.425					2005	Aug-Oct	45.872	0.194
1993	Mar-Apr	84.191	0.137					2006	Aug-Oct	55.342	0.187
1994	Mar-Apr	89.313	0.108					2007	Aug-Oct	65.356	0.152
1995	Mar-Apr	91.679	0.095					2008	Aug-Oct	57.252	0.165
1996	Mar-Apr	73.485	0.077					2009	Aug-Oct	72.836	0.268
1997	Mar-Apr	93.226	0.121					2010	Aug-Oct	82.936	0.207
1998	Mar-Apr	77.558	0.185					2011	Aug-Oct	66.824	0.952
1999	Mar-Apr	67.604	0.196					1991	Nov-Dec	91.633	0.264
2000	Mar-Apr	45.310	0.164					1995	Nov-Dec	53.251	0.189
2001	Mar-Apr	69.247	0.138					1996	Nov-Dec	46.456	0.425
2002	Mar-Apr	61.628	0.177					1997	Nov-Dec	41.829	0.416
2004	Mar-Apr	65.936	0.393					1998	Nov-Dec	41.138	0.808
2006	Mar-Apr	116.202	0.425					2001	Nov-Dec	40.740	0.636
								2002	Nov-Dec	55.955	0.420
								2003	Nov-Dec	60.093	0.336
								2004	Nov-Dec	66.375	0.455
								2006	Nov-Dec	37.187	0.425
								2010	Nov-Dec	104.985	0.369

Table 2.8—Relative size composition from the 1982-2011 trawl surveys (page 1 of 3).

Year	N	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1982	250	0	0	0	0	0	1	8	9	19	26	52	59	109	66	51	52	46
1983	311	0	0	0	0	0	7	96	291	455	458	484	461	433	395	253	250	120
1984	287	0	0	0	0	0	7	26	37	56	45	28	26	26	31	47	31	63
1985	399	0	0	0	0	0	4	56	102	179	145	216	287	304	372	503	507	526
1986	364	0	0	0	0	1	23	38	93	133	130	202	175	177	150	93	34	27
1987	251	0	0	0	0	0	0	14	3	7	24	38	60	80	110	122	122	154
1988	236	0	0	0	0	0	0	1	8	7	28	13	27	26	23	42	27	18
1989	237	0	0	0	0	0	3	3	19	47	37	70	86	108	105	101	66	39
1990	133	0	0	0	0	0	26	71	104	154	150	185	236	259	205	149	117	89
1991	171	0	0	0	0	0	6	31	94	112	140	137	163	133	136	128	107	135
1992	227	0	0	0	0	0	0	1	17	82	184	190	173	148	196	218	232	248
1993	246	0	0	0	0	1	3	30	82	194	433	296	409	356	322	321	346	314
1994	330	0	0	0	0	0	3	10	5	27	42	76	92	100	100	116	136	111
1995	218	0	0	0	0	0	3	12	15	13	19	41	37	42	56	59	81	68
1996	221	0	0	0	0	0	1	2	11	9	23	33	48	64	53	66	69	63
1997	217	0	0	0	0	0	8	17	65	114	167	193	192	196	212	284	226	218
1998	227	0	0	0	0	0	1	4	24	56	87	119	106	137	91	45	23	6
1999	277	0	0	0	0	0	1	15	54	101	110	122	94	113	79	42	30	41
2000	297	0	0	0	4	10	23	51	99	137	298	478	582	442	278	274	141	87
2001	467	0	0	0	0	5	6	27	62	127	205	314	452	661	714	768	681	663
2002	290	0	0	0	0	1	3	6	22	45	65	81	102	160	112	168	111	72
2003	292	0	0	1	0	1	3	5	11	56	93	138	203	231	205	247	252	280
2004	256	0	2	0	0	0	1	4	19	44	84	149	106	193	186	218	212	136
2005	267	0	0	0	0	0	0	1	4	22	43	87	138	201	248	304	284	301
2006	287	0	1	0	4	7	40	101	336	405	427	453	401	343	330	359	280	243
2007	303	0	0	0	0	7	7	129	481	1163	1425	1398	1141	731	715	511	326	400
2008	307	0	0	1	0	0	6	54	168	350	379	390	350	313	227	151	75	40
2009	395	1	0	0	7	36	106	401	971	1057	1087	878	744	651	485	460	318	220
2010	179	0	0	0	0	0	1	5	18	24	29	50	50	56	46	31	15	17
2011	491	0	0	0	0	0	8	20	76	142	257	307	385	413	598	627	905	887

Year	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38
1982	19	8	9	2	8	18	25	40	67	87	123	193	221	240	305	317	237	197
1983	74	44	29	9	5	18	34	46	56	100	125	145	173	166	212	145	127	108
1984	71	89	123	229	310	381	465	580	608	656	577	480	395	349	297	222	156	107
1985	647	559	555	321	212	130	91	100	106	159	220	216	272	300	309	311	288	343
1986	20	22	72	114	218	360	449	697	629	616	638	653	580	557	448	402	349	332
1987	125	81	61	46	63	76	118	123	200	273	302	324	292	281	205	232	202	173
1988	26	35	48	68	77	88	86	110	84	124	122	137	179	191	269	216	196	211
1989	19	21	30	4	15	16	35	13	34	30	24	33	37	70	33	107	109	134
1990	57	35	41	42	33	47	76	77	96	103	97	92	118	124	80	113	96	67
1991	86	72	72	78	100	97	166	192	265	285	325	289	373	308	251	261	196	173
1992	216	228	113	119	134	182	262	288	303	349	375	351	310	304	242	217	177	149
1993	324	217	136	97	62	55	67	85	95	175	207	232	292	316	239	245	226	195
1994	103	91	132	120	171	154	205	320	430	552	638	732	766	672	643	471	362	288
1995	34	24	19	37	47	89	108	158	194	228	218	245	225	198	155	217	249	239
1996	54	36	20	22	23	58	64	130	162	193	229	276	236	251	190	199	168	158
1997	226	177	105	58	41	41	34	70	109	103	154	223	231	222	174	159	155	138
1998	4	17	24	57	72	181	275	382	494	598	626	612	514	538	343	261	229	165
1999	49	39	53	109	110	196	227	222	311	269	296	309	241	228	198	191	239	289
2000	33	9	12	25	39	77	119	170	197	220	258	305	222	197	184	188	174	199
2001	441	350	219	136	112	160	225	313	364	506	655	828	825	916	802	697	509	407
2002	52	35	17	42	62	105	159	240	266	433	473	553	552	519	379	400	313	293
2003	251	235	198	217	154	119	67	57	59	79	58	115	145	318	216	320	241	275
2004	143	113	64	55	73	90	102	186	195	219	236	273	301	318	311	341	313	326
2005	290	362	362	387	376	289	210	136	135	141	115	158	178	197	197	207	231	288
2006	146	105	65	54	56	55	64	86	115	168	189	246	243	264	245	303	263	298
2007	230	121	122	42	44	65	86	124	117	154	122	140	147	124	114	93	93	76
2008	21	40	70	162	307	479	550	707	745	719	681	559	461	341	281	200	161	151
2009	114	35	28	33	82	94	173	253	336	397	468	436	339	306	221	214	215	225
2010	9	13	31	60	126	193	242	355	431	417	394	394	323	269	183	165	106	95
2011	851	536	286	110	34	37	55	48	56	72	121	136	188	164	232	229	272	287

Table 2.8—Relative size composition from the 1982-2011 trawl surveys (page 2 of 3).

Year	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59
1982	144	146	126	137	180	202	282	302	272	328	328	280	284	270	254	239	278	258	267	225	260
1983	61	62	86	94	143	157	212	269	301	287	298	316	254	248	246	225	299	277	258	263	245
1984	102	89	58	94	76	92	93	95	108	135	105	108	95	108	140	128	155	164	194	198	153
1985	351	389	413	514	500	514	482	470	359	323	244	192	168	128	96	93	103	101	104	85	87
1986	220	194	138	126	136	163	185	216	205	246	218	248	269	258	275	288	299	226	252	251	175
1987	186	222	209	297	328	334	332	319	323	251	250	262	157	156	134	120	146	140	98	122	92
1988	141	184	165	239	222	197	318	277	294	277	247	308	266	230	250	250	260	220	214	226	194
1989	115	125	101	115	114	139	176	165	176	183	176	200	253	235	260	247	234	326	293	219	222
1990	57	67	51	47	38	38	31	35	48	39	41	25	51	31	62	53	66	58	74	72	75
1991	143	118	84	68	64	61	51	61	53	61	74	49	61	42	71	89	58	75	40	34	42
1992	125	179	147	216	187	219	240	186	185	160	143	153	119	108	88	78	57	63	29	42	51
1993	150	159	179	180	217	218	229	266	204	183	190	157	150	128	112	117	107	87	63	64	78
1994	196	115	133	114	221	188	164	233	256	264	299	173	189	230	189	181	175	219	251	252	162
1995	314	378	371	417	421	394	343	335	293	199	189	153	142	115	98	108	95	88	93	86	72
1996	168	155	175	214	240	290	263	292	323	300	299	324	273	282	283	243	253	205	166	151	132
1997	145	136	125	127	135	135	171	194	228	152	172	134	150	180	187	160	167	124	213	164	173
1998	146	134	100	117	116	133	125	168	118	114	134	111	94	88	82	82	72	61	78	90	76
1999	307	379	484	508	585	557	505	395	409	312	234	199	165	142	145	117	117	93	104	93	86
2000	223	256	267	303	306	347	308	355	321	391	342	351	262	315	239	256	194	202	183	159	159
2001	299	217	189	176	152	157	187	229	281	229	266	251	230	264	274	257	236	219	225	189	208
2002	249	287	256	405	357	453	393	387	278	330	189	228	184	167	137	162	130	157	90	109	123
2003	291	320	361	343	390	457	426	461	415	391	278	276	235	246	260	198	185	167	149	124	144
2004	254	244	213	208	188	181	156	149	152	176	172	207	201	162	182	172	186	167	192	142	157
2005	252	204	194	203	207	216	167	205	168	193	132	170	127	144	129	134	111	111	101	99	100
2006	253	244	209	200	161	171	145	151	127	157	147	191	169	175	145	174	137	182	105	128	90
2007	61	73	77	74	68	82	76	85	79	80	60	75	74	82	68	72	59	54	48	52	47
2008	133	130	117	143	129	138	138	139	113	135	121	124	127	134	114	108	101	111	90	113	103
2009	302	303	361	380	379	347	334	280	289	247	181	147	144	117	103	93	82	75	78	85	88
2010	64	75	78	124	132	231	154	165	159	156	123	134	106	148	114	155	151	139	95	140	112
2011	403	457	673	801	859	925	872	790	634	511	347	349	278	265	185	230	225	265	184	276	241

Year	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80
1982	264	261	225	227	202	193	190	198	122	172	124	132	73	73	72	64	45	34	37	30	20
1983	262	245	201	224	196	200	191	166	188	176	145	180	126	122	78	81	79	68	59	39	48
1984	212	167	196	199	187	159	195	181	177	168	151	143	82	118	96	104	74	81	56	66	45
1985	90	85	148	110	110	113	171	123	134	146	147	135	135	120	138	107	135	99	95	59	75
1986	171	120	146	111	81	99	76	84	70	87	105	99	89	70	90	86	69	81	71	62	84
1987	141	136	124	132	121	133	123	132	134	111	115	94	59	90	53	55	54	24	43	34	34
1988	198	165	206	164	116	123	99	138	106	105	81	116	84	83	56	79	71	48	41	55	71
1989	197	290	186	228	242	184	167	241	213	136	201	105	184	198	167	154	143	107	151	108	63
1990	85	89	89	78	78	54	80	55	60	34	64	43	53	52	53	49	33	38	38	25	37
1991	41	34	52	44	43	26	45	41	47	46	48	32	31	25	40	32	27	14	16	19	22
1992	50	66	45	36	25	32	31	47	35	32	24	14	21	23	21	15	24	15	18	25	29
1993	66	56	57	52	36	67	36	37	62	28	28	14	15	15	14	16	12	12	11	12	12
1994	219	153	204	164	180	160	126	84	133	62	102	49	67	30	41	20	29	13	21	9	9
1995	93	99	104	100	87	70	54	60	72	71	69	50	54	45	36	28	22	37	20	25	21
1996	141	98	95	86	78	57	60	59	56	56	45	56	62	32	44	36	27	29	34	22	21
1997	122	130	107	111	115	101	99	92	80	69	56	61	53	29	18	31	20	28	16	11	10
1998	66	77	88	86	75	65	98	59	64	48	46	52	55	38	52	29	37	21	21	25	13
1999	72	116	86	93	80	95	63	69	48	61	70	49	45	51	37	28	28	23	26	27	25
2000	149	112	101	90	85	54	65	58	52	36	50	33	38	31	34	29	22	12	14	22	22
2001	185	149	198	132	155	151	106	82	106	68	78	57	51	33	38	26	19	27	20	31	17
2002	125	101	113	107	99	57	107	72	64	66	57	48	35	36	31	25	31	24	13	10	20
2003	138	116	96	71	94	64	72	69	66	67	76	47	56	40	40	36	35	27	28	16	18
2004	166	148	141	138	121	102	100	86	104	81	63	72	58	57	33	49	44	42	44	31	27
2005	117	84	118	83	127	104	112	101	101	77	83	74	70	59	72	51	72	54	65	49	44
2006	97	105	95	106	90	88	98	61	96	51	71	60	58	64	67	57	59	42	57	44	58
2007	61	50	60	49	49	45	46	32	43	40	31	24	32	23	38	21	19	14	12	17	17
2008	113	91	81	81	88	62	71	64	71	44	53	35	39	23	43	19	23	21	23	13	16
2009	72	84	77	53	65	71	52	38	48	30	40	29	21	24	13	17	14	15	14	4	13
2010	100	71	90	60	67	41	42	29	22	16	19	18	10	7	7	9	10	3	7	2	2
2011	301	228	294	184	249	172	205	152	159	115	126	61	78	51	50	27	25	21	15	14	18

Table 2.8—Relative size composition from the 1982-2011 trawl surveys (page 3 of 3).

Year	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99
1982	27	24	12	8	7	9	3	6	4	1	2	3	0	2	0	1	2	1	0
1983	32	29	24	18	12	1	7	8	3	12	1	1	2	4	0	3	0	1	0
1984	39	31	32	26	21	27	12	16	18	12	9	4	7	6	0	4	3	2	1
1985	59	50	48	21	37	22	22	16	14	10	8	7	8	4	1	3	7	2	4
1986	56	53	43	29	26	35	18	21	18	30	10	16	13	5	4	6	2	7	2
1987	45	28	29	29	29	9	7	15	9	10	13	6	10	10	2	4	6	3	1
1988	62	53	30	30	11	27	15	6	15	2	16	2	6	6	6	5	1	4	8
1989	53	85	61	74	88	43	60	41	14	43	30	19	24	28	32	14	10	21	11
1990	39	10	24	19	23	19	10	11	18	11	6	5	5	7	11	10	3	1	1
1991	33	24	21	12	13	8	13	7	8	6	3	5	4	1	6	8	3	2	3
1992	14	16	15	11	13	14	6	10	8	13	6	7	7	4	7	8	3	9	1
1993	11	9	4	12	10	4	7	7	8	4	3	4	7	3	7	5	5	4	3
1994	10	12	5	9	8	9	7	4	6	34	13	9	3	1	3	6	4	2	1
1995	20	18	12	13	10	7	8	7	7	4	11	3	4	4	10	1	3	2	3
1996	24	25	15	25	10	13	22	17	9	3	3	7	10	3	5	5	3	2	2
1997	9	12	17	12	10	8	9	9	4	3	8	7	2	6	3	2	4	0	1
1998	16	9	15	11	8	10	7	4	3	5	5	10	3	6	3	1	2	2	1
1999	19	13	17	15	12	11	17	16	6	16	6	5	5	5	2	5	6	6	3
2000	12	18	19	8	9	5	9	26	7	7	7	4	4	10	2	8	5	3	1
2001	17	12	11	13	5	10	6	6	5	7	5	4	2	4	6	1	2	1	5
2002	14	6	6	3	7	2	4	5	2	2	4	5	5	1	3	2	3	6	1
2003	21	22	11	14	7	9	6	7	5	4	4	3	2	1	0	1	1	0	0
2004	23	23	16	22	10	25	13	19	14	13	6	4	8	4	3	4	4	2	2
2005	40	40	32	25	17	28	20	23	14	10	14	10	8	4	9	5	3	4	0
2006	50	51	37	42	39	34	20	35	16	23	15	18	10	10	6	11	9	1	7
2007	18	10	10	9	25	11	8	9	15	10	13	8	3	8	4	6	2	3	2
2008	12	16	14	12	8	20	11	10	8	12	5	10	10	10	9	3	8	9	2
2009	6	8	4	4	7	6	6	3	4	5	1	1	1	2	3	5	2	3	1
2010	5	2	2	1	3	4	0	2	1	2	1	1	2	0	0	2	1	1	1
2011	7	14	10	7	3	4	4	4	4	1	5	3	4	7	2	1	0	1	0

Year	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118+
1982	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1983	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1984	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1985	2	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1986	4	3	0	4	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1987	1	2	3	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1988	3	1	3	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0
1989	10	22	1	22	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1990	5	0	6	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
1991	0	0	0	6	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0
1992	4	3	3	3	2	1	1	1	0	0	0	0	0	0	0	0	0	1	0
1993	1	2	2	1	8	3	0	1	0	0	0	0	0	0	0	2	0	0	0
1994	2	9	6	3	1	7	0	0	1	0	1	0	0	0	0	0	0	0	0
1995	5	1	3	0	0	1	0	1	0	0	0	1	0	0	0	0	0	0	0
1996	4	1	2	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0
1997	2	0	0	1	2	0	0	0	0	0	0	0	0	0	1	0	0	0	0
1998	1	1	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1999	2	1	0	2	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0
2000	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2001	1	1	0	2	1	3	1	0	1	0	0	0	0	0	0	0	0	0	0
2002	1	0	0	1	0	2	0	0	0	0	0	0	0	1	0	0	0	0	0
2003	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2004	0	1	0	5	0	1	0	0	2	0	1	0	0	0	0	0	0	0	0
2005	4	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2006	5	3	2	3	2	0	1	0	0	2	0	0	0	0	0	0	0	0	0
2007	3	2	8	1	2	1	2	0	1	0	0	0	1	0	0	0	0	0	0
2008	4	3	7	1	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0
2009	2	1	1	0	1	2	0	0	1	0	0	0	0	0	0	0	0	0	0
2010	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	2	2	1	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 2.9—Age compositions observed by the EBS shelf bottom trawl survey, 1994-2010. Nact = actual sample size (these get rescaled so that the average across all age compositions equals 300).

Year	Nact	0	1	2	3	4	5	6	7	8	9	10	11	12+
1994	715	0.0000	0.0885	0.3828	0.1712	0.1204	0.1174	0.0823	0.0216	0.0077	0.0050	0.0013	0.0010	0.0007
1995	599	0.0000	0.0507	0.2648	0.4213	0.0978	0.0763	0.0503	0.0182	0.0104	0.0066	0.0017	0.0010	0.0008
1996	711	0.0000	0.0538	0.2079	0.2042	0.2937	0.1337	0.0568	0.0289	0.0119	0.0049	0.0021	0.0015	0.0008
1997	719	0.0000	0.2500	0.1680	0.1822	0.1548	0.1218	0.0811	0.0246	0.0113	0.0035	0.0014	0.0009	0.0004
1998	635	0.0000	0.0775	0.4405	0.2020	0.1119	0.0572	0.0594	0.0287	0.0166	0.0043	0.0008	0.0008	0.0003
1999	860	0.0000	0.0791	0.2001	0.3018	0.2314	0.0803	0.0570	0.0281	0.0130	0.0058	0.0014	0.0014	0.0006
2000	864	0.0000	0.2335	0.1267	0.1516	0.2417	0.1464	0.0609	0.0137	0.0145	0.0063	0.0029	0.0014	0.0005
2001	950	0.0000	0.2874	0.2358	0.1935	0.0915	0.0833	0.0677	0.0269	0.0086	0.0025	0.0015	0.0008	0.0003
2002	947	0.0001	0.0809	0.1872	0.3168	0.2330	0.0717	0.0586	0.0345	0.0110	0.0040	0.0011	0.0006	0.0006
2003	1360	0.0000	0.1732	0.1564	0.2514	0.2099	0.1190	0.0410	0.0299	0.0139	0.0038	0.0006	0.0006	0.0005
2004	1040	0.0000	0.1431	0.1655	0.2717	0.1292	0.1279	0.0899	0.0392	0.0195	0.0086	0.0022	0.0025	0.0005
2005	1280	0.0000	0.1830	0.2444	0.2094	0.1212	0.0659	0.0792	0.0546	0.0236	0.0108	0.0037	0.0036	0.0006
2006	1300	0.0000	0.3243	0.1428	0.1650	0.1214	0.0927	0.0632	0.0463	0.0286	0.0101	0.0032	0.0013	0.0011
2007	1441	0.0000	0.6993	0.0959	0.0674	0.0415	0.0462	0.0177	0.0143	0.0084	0.0051	0.0017	0.0016	0.0010
2008	1213	0.0002	0.2137	0.4448	0.1449	0.0829	0.0484	0.0328	0.0100	0.0104	0.0059	0.0030	0.0013	0.0017
2009	1412	0.0010	0.4539	0.1895	0.2309	0.0641	0.0287	0.0146	0.0094	0.0040	0.0021	0.0009	0.0006	0.0003
2010	1285	0.0000	0.0496	0.4436	0.1878	0.1965	0.0782	0.0275	0.0108	0.0034	0.0017	0.0004	0.0003	0.0001

Table 2.10a—Abundance measured in units of biomass and numbers, with standard deviations, 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 deviations for abundance measured in numbers during these years are unknown; the standard deviations 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	Std. deviation	Lower 95% CI	Upper 95% CI	Estimate	Std. deviation
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	791,855	1,277,373	794,619,624	95,118,971

Table 2.10b— Abundance measured in units of biomass and numbers, with standard deviations, as estimated by EBS shelf bottom trawl surveys, 1982-2011. 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	Std. deviation	Lower 95% CI	Upper 95% CI	Estimate	Std. deviation
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	113,437,207
1986	1,117,774	69,604	979,957	1,255,590	838,123,105	83,854,636
1987	1,104,868	68,304	969,627	1,240,109	728,974,096	48,488,143
1988	959,401	76,118	808,688	1,110,114	507,103,872	35,468,296
1989	833,314	62,709	709,150	957,477	292,168,063	19,985,495
1990	691,255	51,455	589,375	793,136	423,835,267	36,466,423
1991	514,498	38,038	439,183	589,813	488,869,180	51,108,708
1992	551,369	45,780	460,725	642,013	601,795,262	70,551,400
1993	691,311	54,581	583,240	799,383	852,288,385	106,915,855
1994	1,368,120	250,044	868,032	1,868,209	1,237,758,281	153,120,867
1995	1,002,850	91,622	821,437	1,184,262	757,826,810	75,473,174
1996	892,377	87,532	719,064	1,065,690	609,986,848	88,407,579
1997	604,439	68,120	468,199	740,678	485,642,845	70,801,836
1998	558,419	45,182	468,960	647,879	537,278,347	48,428,298
1999	584,762	50,591	484,592	684,932	501,496,289	46,612,230
2000	531,171	43,160	445,714	616,627	483,808,002	44,188,234
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	593,258	62,153	468,951	717,564	499,365,769	62,354,631
2004	596,279	35,216	526,552	666,007	424,662,313	36,140,006
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
2010	859,642	102,264	657,157	1,062,127	887,456,665	117,008,547
2011	896,039	66,843	763,690	1,028,388	836,794,171	79,204,167

Table 2.11—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 (not shown for age 0).

Average length (cm) at age:

Year	0	1	2	3	4	5	6	7	8	9	10	11	12
1994	11.00	19.01	31.76	39.91	49.30	58.04	64.05	70.72	80.88	87.31	93.59	91.46	95.51
1995	11.00	17.33	32.35	43.21	53.00	61.83	69.46	74.12	81.20	85.00	92.64	92.26	94.19
1996	11.00	17.64	31.63	41.43	50.28	57.59	66.97	75.24	81.90	88.10	90.37	90.97	94.39
1997	n/a	17.19	31.76	41.76	51.42	59.39	64.68	71.86	78.78	85.59	91.58	92.59	95.19
1998	11.00	15.47	30.77	37.82	49.33	58.92	66.28	70.26	77.56	88.93	88.64	91.69	91.99
1999	11.00	15.79	29.66	40.33	46.23	56.60	65.25	71.42	79.75	82.62	91.48	90.32	97.28
2000	11.00	15.25	30.30	39.01	47.71	53.70	59.71	72.91	74.70	79.70	82.38	82.49	95.20
2001	11.00	17.88	31.36	36.70	48.31	55.24	61.86	65.96	77.07	82.69	79.05	88.36	95.19
2002	11.00	16.53	30.08	36.95	46.92	55.68	62.58	68.78	72.23	80.04	92.03	89.15	95.35
2003	11.00	18.00	29.82	40.87	48.29	56.51	65.30	70.28	75.44	81.77	85.82	84.01	93.85
2004	11.00	17.26	30.23	37.99	48.98	56.99	64.01	70.95	75.84	83.31	88.13	86.15	95.65
2005	n/a	18.59	26.70	39.16	48.56	57.04	64.07	72.45	78.46	82.05	88.47	87.30	92.31
2006	n/a	15.33	30.89	38.55	47.57	55.90	64.98	73.78	82.35	85.63	88.82	93.83	96.98
2007	n/a	15.04	31.03	41.18	50.60	59.34	66.64	74.68	81.58	84.30	94.00	88.32	91.33
2008	11.00	15.39	29.78	41.31	53.39	60.87	66.06	72.39	79.10	84.16	90.23	95.66	96.14
2009	11.00	14.14	31.10	42.51	51.63	59.78	65.89	71.77	75.68	83.52	90.11	89.45	91.35
2010	n/a	15.77	30.31	41.54	52.33	59.55	66.13	72.17	79.52	84.30	90.10	96.40	79.64

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

Year	0	1	2	3	4	5	6	7	8	9	10	11	12
1994	0	40	213	143	109	89	73	26	12	7	1	2	0
1995	0	25	153	202	90	57	38	14	9	6	1	1	2
1996	0	34	143	138	183	101	65	37	5	2	0	1	2
1997	0	94	92	109	125	120	110	38	21	5	3	2	0
1998	0	56	145	97	94	73	88	47	28	6	0	1	0
1999	0	84	167	195	162	105	77	44	17	8	0	1	0
2000	0	112	102	131	204	177	83	21	20	7	6	1	0
2001	0	173	161	159	135	127	119	43	15	7	4	5	1
2002	1	114	165	206	189	85	91	70	16	6	2	0	2
2003	0	193	222	205	198	206	129	114	68	17	1	4	0
2004	0	150	134	205	133	160	136	62	35	17	4	4	0
2005	0	141	218	238	171	112	146	121	73	30	18	10	0
2006	0	205	176	179	168	155	140	133	93	36	10	4	1
2007	0	114	87	88	56	105	31	40	21	17	7	3	2
2008	0	141	262	244	188	134	97	45	45	28	13	8	6
2009	0	222	259	325	187	133	100	82	47	23	13	12	4
2010	0	105	344	228	292	144	70	48	30	13	5	6	0

Table 2.12—Multinomial sample sizes for length compositions.

	Trawl fishery					Longline fishery					Pot fishery					Srv.
Year	S1	S2	S3	S4	S5	S1	S2	S3	S4	S5	S1	S2	S3	S4	S5	
1977			10	13												
1978				35		8	24		43	18						
1979			17		6	76	25	33	12	20						100
1980	24	66				8	6	31	13	19						100
1981			53		16	7	5	27		12						100
1982		26	21	5	14		13	16	35	20						250
1983	20	74	28	11	157	86	90	50	56	61						311
1984	81	101	94	23	35	70	94	85	198	761						287
1985	76	255	10	16	6	326	70	8	390	1122						399
1986	88	208	82	47		238	29	102	210	985			12	14		364
1987	265	185	107	159	84	720	209	104	643	1318			5	15		251
1988	754	332	35	6	36	13										236
1989	649		71		12				39					9		237
1990	230	589	286	6		14	85	646	650	319			7	74		133
1991	447	1068	55			173	257	582	957	299			17	124	14	171
1992	111	764	58			411	758	1078	561		6	10	255	121		227
1993	173	946				510	753	87				95	38			246
1994	115	1408	86			620	894	188	459			213	110	72		330
1995	93	933		8		629	807	105	516	227	7	281	354	100	64	218
1996	69	1349	100	42	15	774	773	108	778	39		454	478	185	21	221
1997	132	1151	31			787	834	278	869	742		281	360	133	24	217
1998	79	984	33	39	5	675	602	116	1035	899		221	252	53		227
1999	249	593	13	16		776	827	250	1023	257		124	306	87		277
2000	208	552	38			717	414	136	1325	870	318	176				297
2001	77	320	43	55		584	702	343	1488	896	28	305	20	145	10	467
2002	169	332	94	127		1028	576	220	1796	733	84	170	17	131	17	290
2003	127	434	105	156		1339	840	338	1987	1054	277	13		142	41	292
2004	153	267	140	89		1094	700	291	1742	872	165	36	14	122	19	256
2005	215	285	117			1274	314	330	1739	858	150	23		142		267
2006	292	165	86	14		1007	308	158	1739	85	209	51	12	144	30	287
2007	197	221	152			924	79	93	1276	59	221	24		105		303
2008	173	96	33	22		843	199	217	1626	484	126	27		129		307
2009	89	60	29	70		755	121	171	1554	452	128	22		55	16	395
2010	171	38	18	61		813	79	155	1006	455	149			120	38	179
2011	190	130	22	10		467	574	207	25		169					491

Table 2.13—Number of parameters and negative log-likelihoods. Note that the data sets for each model are different, so log-likelihoods are not comparable. Shaded cells indicate values that are not used in computing the total; "n/a" indicates that the data are not included in the file for the respective model.

	Model 1	Model 2b	Model 3	Model 3b	Model 4
Number of parameters	185	178	180	182	180

Obj. func. component	Model 1	Model 2b	Model 3	Model 3b	Model 4
Equilibrium catch	0.01	0.02	0.01	0.00	0.00
Catch per unit effort	-8.16	-0.47	-0.18	-4.20	-7.13
Size composition	4336.15	4291.53	4145.82	4192.75	4177.78
Age composition	171.34	173.99	227.17	117.70	180.98
Mean size at age	1439.91	1237.79	1104.34	1248.21	1381.88
Recruitment	10.55	22.86	16.39	20.65	21.34
"Softbounds"	0.03	0.04	0.03	0.03	0.04
Deviations	15.67	17.51	17.85	16.83	13.08
Total	5965.48	5743.27	5511.42	4343.76	4205.10

CPUE component	Model 1	Model 2b	Model 3	Model 3b	Model 4
Jan-Apr trawl fishery	74.37	54.87	56.20	55.11	54.58
May-Jul trawl fishery	-10.08	-12.79	-12.21	-12.16	-11.97
Aug-Dec trawl fishery	53.34	65.88	55.63	53.47	52.20
Jan-Apr longline fishery	139.81	136.78	123.10	139.40	133.52
May-Jul longline fishery	-6.49	3.76	-0.24	5.29	2.43
Aug-Dec longline fishery	36.81	84.78	56.16	80.68	69.17
Jan-Apr pot fishery	-18.67	-22.13	-23.85	-22.91	-23.49
May-Jul pot fishery	-8.62	-8.98	-9.05	-7.91	-8.08
Aug-Dec pot fishery	7.16	1.43	1.78	1.37	1.63
Post-1981 trawl survey	-5.03	-0.47	-0.18	-4.20	-7.13
Pre-1982 trawl survey	-3.13	n/a	n/a	n/a	n/a

Sizecomp component	Model 1	Model 2b	Model 3	Model 3b	Model 4
Jan-Apr trawl fishery	1093.31	1116.45	1086.18	932.95	924.36
May-Jul trawl fishery	216.00	214.64	209.43	181.97	181.14
Aug-Dec trawl fishery	233.60	235.94	229.72	221.46	222.34
Jan-Apr longline fishery	699.95	712.76	690.51	638.76	636.52
May-Jul longline fishery	235.02	230.59	230.73	206.76	206.22
Aug-Dec longline fishery	1030.85	1064.63	970.14	891.28	883.24
Jan-Apr pot fishery	110.71	111.02	110.55	112.19	111.04
May-Jul pot fishery	74.68	75.06	77.24	70.60	71.63
Aug-Dec pot fishery	203.50	197.00	198.60	191.39	190.84
Post-1981 trawl survey	390.45	333.45	342.72	745.40	750.45
Pre-1982 trawl survey	48.10	n/a	n/a	n/a	n/a

Table 2.14—Root mean squared errors and observed:expected correlations for fishery CPUE and survey relative abundance time series. Green = row minimum, pink = row maximum (not shown for the pre-1982 survey row). Fishery CPUE data are not used in fitting the models; fishery CPUE results are shown for comparison only.

	Root mean squared error				
Fleet	Model 1	Model 2b	Model 3	Model 3b	Model 4
Jan-Apr trawl fishery	0.36	0.33	0.33	0.33	0.33
May-Jul trawl fishery	0.32	0.29	0.29	0.30	0.30
Aug-Dec trawl fishery	0.69	0.82	0.74	0.70	0.69
Jan-Apr longline fishery	0.29	0.28	0.28	0.28	0.28
May-Jul longline fishery	0.22	0.25	0.24	0.25	0.25
Aug-Dec longline fishery	0.17	0.20	0.19	0.20	0.20
Jan-Apr pot fishery	0.25	0.23	0.22	0.23	0.23
May-Jul pot fishery	0.22	0.21	0.21	0.22	0.22
Aug-Dec pot fishery	0.35	0.32	0.32	0.32	0.32
Post81 shelf survey	0.21	0.23	0.23	0.22	0.22
Pre82 shelf survey	0.19	n/a	n/a	n/a	n/a
	Correlation (observed versus expected)				
Fleet	Model 1	Model 2b	Model 3	Model 3b	Model 4
Jan-Apr trawl fishery	0.33	0.38	0.39	0.38	0.39
May-Jul trawl fishery	0.32	0.43	0.41	0.40	0.40
Aug-Dec trawl fishery	0.21	-0.23	-0.02	0.22	0.23
Jan-Apr longline fishery	0.01	-0.03	0.00	-0.07	-0.05
May-Jul longline fishery	0.55	0.36	0.43	0.35	0.39
Aug-Dec longline fishery	0.61	0.31	0.46	0.30	0.37
Jan-Apr pot fishery	-0.04	0.11	0.18	0.16	0.17
May-Jul pot fishery	0.14	0.16	0.19	0.11	0.13
Aug-Dec pot fishery	0.05	0.17	0.20	0.18	0.18
Post81 shelf survey	0.67	0.67	0.68	0.67	0.68
Pre82 shelf survey	0.80	n/a	n/a	n/a	n/a

Table 2.15—Average and standard deviation of normalized residuals for fishery CPUE and survey relative abundance time series. In the upper ("average") portion of the table, blue = row value closest to 0, yellow = row value furthest from 0; in the lower ("standard deviation") portion of the table, blue = row value closest to 1, yellow = row value furthest from 1. Fishery CPUE data are not used in fitting the models; fishery CPUE results are shown for comparison only.

	Average of normalized residuals				
Fleet	Model 1	Model 2b	Model 3	Model 3b	Model 4
Jan-Apr trawl fishery	0.30	0.22	0.24	0.21	0.23
May-Jul trawl fishery	-0.15	-0.11	-0.13	-0.12	-0.13
Aug-Dec trawl fishery	0.37	0.50	0.43	0.39	0.38
Jan-Apr longline fishery	0.27	0.28	0.26	0.26	0.26
May-Jul longline fishery	0.01	-0.04	-0.03	-0.07	-0.05
Aug-Dec longline fishery	0.28	0.36	0.31	0.34	0.33
Jan-Apr pot fishery	0.08	0.05	0.06	0.04	0.05
May-Jul pot fishery	0.04	0.04	0.04	0.03	0.03
Aug-Dec pot fishery	0.03	0.01	0.01	0.00	0.01
Post81 shelf survey	0.25	0.78	0.88	0.69	0.63
Pre82 shelf survey	0.05	n/a	n/a	n/a	n/a
	Standard deviation of normalized residuals				
Fleet	Model 1	Model 2b	Model 3	Model 3b	Model 4
Jan-Apr trawl fishery	2.83	2.66	2.67	2.67	2.66
May-Jul trawl fishery	1.30	1.19	1.22	1.22	1.23
Aug-Dec trawl fishery	2.35	2.51	2.37	2.35	2.33
Jan-Apr longline fishery	3.46	3.44	3.34	3.46	3.42
May-Jul longline fishery	1.91	2.16	2.07	2.20	2.13
Aug-Dec longline fishery	2.71	3.15	2.90	3.12	3.02
Jan-Apr pot fishery	1.44	1.33	1.28	1.31	1.29
May-Jul pot fishery	1.56	1.53	1.52	1.61	1.60
Aug-Dec pot fishery	1.84	1.72	1.73	1.72	1.73
Post81 shelf survey	2.08	2.02	1.98	1.99	1.96
Pre82 shelf survey	1.84	n/a	n/a	n/a	n/a

Table 2.16—Number of records, average input sample size ("Ave. N"), average ratio of effective multinomial sample size to input sample size ("Mean of ratios"), and ratio of average effective multinomial sample size to average input sample size ("Ratio of means") 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 in Models 1, 2b, and 3; but not in Models 3b or 4. Green = row minimum, pink = row maximum.

			Mean of ratios				
Fleet	Records	Ave. N	Model 1	Model 2b	Model 3	Model 3b	Model 4
Jan-Apr trawl fishery	60	327	5.46	5.34	5.33	5.70	5.72
May-Jul trawl fishery	31	67	8.41	8.02	8.49	9.30	9.26
Aug-Dec trawl fishery	34	42	13.89	12.76	12.97	13.21	13.19
Jan-Apr longline fishery	64	466	8.96	9.01	8.71	9.02	9.06
May-Jul longline fishery	31	211	8.94	9.73	9.15	9.51	9.46
Aug-Dec longline fishery	59	673	7.19	6.85	7.14	6.89	7.00
Jan-Apr pot fishery	32	143	13.38	12.83	13.25	13.00	13.15
May-Jul pot fishery	16	141	18.24	17.52	17.42	17.94	17.81
Aug-Dec pot fishery	33	76	11.29	10.85	10.91	10.94	10.98
Post-1981 shelf survey	30	277	2.50	2.44	2.50	2.11	2.13
Pre-1982 shelf survey	3	100	0.49	n/a	n/a	n/a	n/a

			Ratio of means				
Fleet	Records	Ave. N	Model 1	Model 2b	Model 3	Model 3b	Model 4
Jan-Apr trawl fishery	60	327	3.19	3.14	3.09	3.42	3.43
May-Jul trawl fishery	31	67	6.64	6.36	6.71	7.28	7.24
Aug-Dec trawl fishery	34	42	6.61	6.43	6.37	6.68	6.66
Jan-Apr longline fishery	64	466	3.94	3.93	3.94	4.25	4.31
May-Jul longline fishery	31	211	5.15	5.50	5.17	5.66	5.62
Aug-Dec longline fishery	59	673	3.05	2.72	3.14	3.33	3.43
Jan-Apr pot fishery	32	143	9.72	9.12	10.06	8.85	9.17
May-Jul pot fishery	16	141	8.10	7.12	7.86	7.58	7.59
Aug-Dec pot fishery	33	76	8.97	8.97	8.77	8.89	9.00
Post-1981 shelf survey	30	277	2.15	2.09	2.08	1.83	1.86
Pre-1982 shelf survey	3	100	0.49	n/a	n/a	n/a	n/a

Table 2.17—Input sample size ("Input N") and ratio of effective multinomial sample size ("effective N") to input N for each record of age composition data. The mean of the ratios and ratio of the means are shown in the bottom two rows. Green = row minimum, pink = row maximum.

		Ratio of effective N to input N				
Year	Input N	Model 1	Model 2b	Model 3	Model 3b	Model 4
1994	210	0.29	0.24	0.23	2.24	0.61
1995	176	0.12	0.10	0.10	0.17	0.13
1996	209	0.78	0.80	0.57	1.05	1.84
1997	212	0.55	0.70	1.02	1.03	1.51
1998	187	0.32	0.26	0.23	3.72	0.83
1999	253	1.56	3.22	0.75	0.77	0.45
2000	254	0.34	0.37	0.38	0.56	0.72
2001	280	1.02	0.87	0.90	0.47	1.44
2002	279	1.00	1.09	0.47	0.33	0.45
2003	400	1.03	0.47	0.47	0.60	0.26
2004	306	0.24	0.25	0.23	0.11	0.13
2005	377	0.55	0.48	0.20	1.68	0.28
2006	383	0.42	0.63	0.27	0.41	0.32
2007	424	0.05	0.04	0.03	0.18	0.20
2008	357	0.11	0.10	0.10	0.58	0.16
2009	416	0.16	0.16	0.11	0.20	0.10
2010	378	0.21	0.21	0.10	0.89	0.49
	Mean of ratios:	0.51	0.59	0.36	0.88	0.58
	Ratio of means:	0.50	0.54	0.33	0.78	0.51

Table 2.18 (page 1 of 6)—All of the quantities listed in the “parameters” section of the SS report file.

	Model 1		Model 2b		Model 3		Model 3b		Model 4	
Label	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD
NatM	0.34	_	0.34	_	0.34	_	0.34	_	0.34	_
L_at_Amin	-18	0.2319	13.932	0.0584	14.13	0.0604	14.243	0.1108	14.24	0.1119
L_at_Amax	93.258	0.3068	99.127	0.4666	95.791	0.3921	91.021	0.5254	90.379	0.5356
VonBert_K	0.2353	0.0017	0.2066	0.002	0.2312	0.0023	0.2481	0.0029	0.2511	0.0031
CV_young	0.01	_	2.67	_	2.69	_	3.4976	0.0719	3.5083	0.0723
CV_old	8.68	_	8.62	_	8.38	_	10.514	0.1719	10.503	0.17
Wtlen_1	6E-06	_	6E-06	_	6E-06	_	6E-06	_	6E-06	_
Wtlen_2	3.165	_	3.165	_	3.165	_	3.165	_	3.165	_
Mat50%_Fem	4.8832	_	4.8832	_	4.8832	_	4.8832	_	4.8832	_
Mat_slope_Fem	-0.965	_	-0.965	_	-0.965	_	-0.965	_	-0.965	_
Eggs/kg_inter	1	_	1	_	1	_	1	_	1	_
Eggs/kg_slope	0	_	0	_	0	_	0	_	0	_
RecrDist_GP_1	0	_	0	_	0	_	0	_	0	_
RecrDist_Area_1	0	_	0	_	0	_	0	_	0	_
RecrDist_Seas_1	0	_	0	_	0	_	0	_	0	_
RecrDist_Seas_2	0	_	0	_	0	_	0	_	0	_
RecrDist_Seas_3	0	_	0	_	0	_	0	_	0	_
RecrDist_Seas_4	0	_	0	_	0	_	0	_	0	_
RecrDist_Seas_5	0	_	0	_	0	_	0	_	0	_
CohortGrowDev	1	_	1	_	1	_	1	_	1	_
AgeKeyParm1					1	_	1	_		
AgeKeyParm2					0.3954	0.0031	0.3355	0.0133		
AgeKeyParm3					1.0566	0.066	0.849	0.1735		
AgeKeyParm4					0	_	0	_		
AgeKeyParm5					0.087	_	0.087	_		
AgeKeyParm6					1.74	_	1.74	_		
AgeKeyParm7					0	_	0	_		
F-WL1_seas_1	-0.499	_	-0.499	_	-0.499	_	-0.499	_	-0.499	_
F-WL1_seas_2	0.1587	_	0.1587	_	0.1587	_	0.1587	_	0.1587	_
F-WL1_seas_3	0.4588	_	0.4588	_	0.4588	_	0.4588	_	0.4588	_
F-WL1_seas_4	0.1793	_	0.1793	_	0.1793	_	0.1793	_	0.1793	_
F-WL1_seas_5	-0.347	_	-0.347	_	-0.347	_	-0.347	_	-0.347	_
F-WL2_seas_1	0.0406	_	0.0406	_	0.0406	_	0.0406	_	0.0406	_
F-WL2_seas_2	-0.014	_	-0.014	_	-0.014	_	-0.014	_	-0.014	_
F-WL2_seas_3	-0.039	_	-0.039	_	-0.039	_	-0.039	_	-0.039	_
F-WL2_seas_4	-0.014	_	-0.014	_	-0.014	_	-0.014	_	-0.014	_
F-WL2_seas_5	0.0276	_	0.0276	_	0.0276	_	0.0276	_	0.0276	_
SR_LN(R0)	13.34	0.0173	13.238	0.0166	13.231	0.0166	13.224	0.0203	13.241	0.0226
SR_BH_steep	1	_	1	_	1	_	1	_	1	_
SR_sigmaR	0.57	_	0.57	_	0.57	_	0.57	_	0.57	_
SR_envlink	0	_	0	_	0	_	0	_	0	_
SR_R1_offset	-0.971	0.1031	-1.506	0.1059	-1.358	0.1112	-1.159	0.1347	-1.086	0.1352
SR_autocorr	0	_	0	_	0	_	0	_	0	_
Early_InitAge_3	1.3697	0.1779	1.2932	0.1619	1.3382	0.1628	1.2746	0.1953	1.2996	0.1971
Early_InitAge_2	-0.874	0.3908	-0.826	0.3934	-0.664	0.385	-0.684	0.4231	-0.662	0.4263
Early_InitAge_1	1.6326	0.1502	2.055	0.1442	1.6744	0.1666	1.2068	0.23	1.2242	0.2341
Main_RecrDev_1977	1.4059	0.0678	0.8026	0.1067	0.9892	0.0949	1.4063	0.1092	1.5137	0.1121
Main_RecrDev_1978	0.4792	0.1092	0.4821	0.1154	0.4803	0.1242	0.518	0.2191	0.5643	0.2256

Table 2.18 (page 2 of 6)—All of the quantities listed in the “parameters” section of the SS report file.

	Model 1		Model 2b		Model 3		Model 3b		Model 4	
Label	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD
Main_RecrDev_1979	0.5093	0.0783	0.5325	0.0747	0.5787	0.0747	0.6707	0.1184	0.6761	0.1224
Main_RecrDev_1980	-0.357	0.0983	-0.544	0.1068	-0.285	0.0901	-0.385	0.1372	-0.365	0.1379
Main_RecrDev_1981	-0.365	0.0861	-0.161	0.0711	-0.59	0.0934	-1.047	0.1532	-1.04	0.155
Main_RecrDev_1982	0.7551	0.0389	0.6449	0.0389	0.738	0.0356	0.9897	0.0418	1.0076	0.0429
Main_RecrDev_1983	-0.226	0.0685	-0.148	0.0636	-0.311	0.0674	-0.557	0.118	-0.545	0.1198
Main_RecrDev_1984	0.5736	0.0417	0.5396	0.0402	0.5786	0.039	0.7766	0.047	0.7889	0.0482
Main_RecrDev_1985	-0.143	0.0581	-0.191	0.0567	-0.067	0.0539	-0.066	0.073	-0.048	0.0735
Main_RecrDev_1986	-0.807	0.0734	-0.744	0.0674	-0.705	0.066	-0.865	0.0992	-0.87	0.1007
Main_RecrDev_1987	-0.922	0.0692	-0.867	0.0634	-0.914	0.0645	-1.288	0.1222	-1.312	0.1265
Main_RecrDev_1988	-0.114	0.0433	-0.076	0.0402	-0.257	0.0441	-0.271	0.0589	-0.258	0.0601
Main_RecrDev_1989	0.4585	0.0346	0.4028	0.0338	0.3948	0.033	0.5262	0.0403	0.5473	0.0417
Main_RecrDev_1990	0.1916	0.039	0.1305	0.0374	0.202	0.0363	0.3578	0.0455	0.3782	0.0472
Main_RecrDev_1991	-0.037	0.0413	-0.005	0.0375	-0.114	0.0392	-0.349	0.0653	-0.328	0.0679
Main_RecrDev_1992	0.4379	0.029	0.3915	0.0281	0.4215	0.0271	0.6255	0.0331	0.6534	0.036
Main_RecrDev_1993	-0.387	0.0426	-0.401	0.0404	-0.33	0.0385	-0.384	0.0595	-0.478	0.0734
Main_RecrDev_1994	-0.379	0.0408	-0.394	0.039	-0.411	0.0384	-0.343	0.053	-0.316	0.0582
Main_RecrDev_1995	-0.051	0.0384	-0.015	0.0357	-0.191	0.0392	-0.298	0.0567	-0.302	0.0625
Main_RecrDev_1996	0.4808	0.0276	0.4315	0.0269	0.4641	0.0258	0.7131	0.0328	0.7331	0.036
Main_RecrDev_1997	-0.161	0.0362	-0.132	0.0343	-0.107	0.0329	-0.181	0.0526	-0.172	0.0595
Main_RecrDev_1998	-0.177	0.0355	-0.094	0.0331	-0.19	0.034	-0.265	0.0529	-0.257	0.0583
Main_RecrDev_1999	0.3082	0.0268	0.3502	0.0255	0.312	0.0255	0.491	0.0331	0.4836	0.0367
Main_RecrDev_2000	-0.186	0.0326	-0.175	0.0316	-0.069	0.0304	0.0564	0.039	0.1161	0.0438
Main_RecrDev_2001	-0.686	0.0396	-0.597	0.0374	-0.661	0.0377	-0.811	0.0624	-1.039	0.0883
Main_RecrDev_2002	-0.332	0.0328	-0.284	0.0317	-0.293	0.031	-0.223	0.0411	-0.138	0.0439
Main_RecrDev_2003	-0.471	0.0381	-0.432	0.0371	-0.477	0.037	-0.391	0.0493	-0.446	0.0596
Main_RecrDev_2004	-0.528	0.0414	-0.47	0.0401	-0.445	0.0375	-0.523	0.0561	-0.44	0.0613
Main_RecrDev_2005	-0.172	0.0432	-0.057	0.0421	-0.199	0.0426	-0.398	0.0555	-0.384	0.0642
Main_RecrDev_2006	0.5833	0.0407	0.6213	0.0413	0.632	0.0396	0.8964	0.04	0.9188	0.0435
Main_RecrDev_2007	-0.131	0.0602	-0.049	0.0607	0.0094	0.0554	-0.201	0.0762	-0.389	0.0941
Main_RecrDev_2008	0.7588	0.0603	0.8567	0.061	0.8151	0.0613	1.0616	0.0612	1.079	0.0666
Main_RecrDev_2009	-0.857	0.1396	-1.092	0.1563	-0.572	0.1272	-1.027	0.1597	-1.123	0.2058
Main_RecrDev_2010	0.5475	0.1239	0.7428	0.1324	0.5742	0.1184	0.7851	0.1298	0.79	0.1355
Late_RecrDev_2011	0	_	0	_	0	_	0	_	0	_
ForeRecr_2012	0	_	0	_	0	_	0	_	0	_
ForeRecr_2013	0	_	0	_	0	_	0	_	0	_
ForeRecr_2014	0	_	0	_	0	_	0	_	0	_
ForeRecr_2015	0	_	0	_	0	_	0	_	0	_
ForeRecr_2016	0	_	0	_	0	_	0	_	0	_
Impl_err_2012	0	_	0	_	0	_	0	_	0	_
Impl_err_2013	0	_	0	_	0	_	0	_	0	_
Impl_err_2014	0	_	0	_	0	_	0	_	0	_
Impl_err_2015	0	_	0	_	0	_	0	_	0	_
Impl_err_2016	0	_	0	_	0	_	0	_	0	_
InitF_Jan-Apr_Trawl	0.443	0.0853	1.2033	0.3008	0.7965	0.1624	0.6129	0.1309	0.5397	0.111
InitF_May-Jul_Trawl	0	_	0	_	0	_	0	_	0	_
InitF_Aug-Dec_Trawl	0	_	0	_	0	_	0	_	0	_
InitF_Jan-Apr_Longline	0	_	0	_	0	_	0	_	0	_
InitF_May-Jul_Longline	0	_	0	_	0	_	0	_	0	_

Table 2.18 (page 3 of 6)—All of the quantities listed in the "parameters" section of the SS report file.

	Model 1		Model 2b		Model 3		Model 3b		Model 4	
Label	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD
InitF_Aug-Dec_Longline	0	_	0	_	0	_	0	_	0	_
InitF_Jan-Apr_Pot	0	_	0	_	0	_	0	_	0	_
InitF_May-Jul_Pot	0	_	0	_	0	_	0	_	0	_
InitF_Aug-Dec_Pot	0	_	0	_	0	_	0	_	0	_
Q_base_Pre82_Survey	0	_	-0.261	_	-0.261	_	-0.261	_	-0.261	_
Q_base_Post81_Survey	-0.261	_								
Sel1_Jan-Apr_TWL	0	_	0	_	0	_	0	_	0	_
Sel2_Jan-Apr_TWL	0	_	0	_	0	_	0	_	0	_
Sel3_Jan-Apr_TWL	0	_	0	_	0	_	0	_	0	_
Sel4_Jan-Apr_TWL	0	_	0	_	0	_	0	_	0	_
Sel5_Jan-Apr_TWL	-999	_	-999	_	-999	_	-999	_	-999	_
Sel6_Jan-Apr_TWL	10	_	10	_	10	_	10	_	10	_
Sel1_May-Jul_TWL	0	_	0	_	0	_	0	_	0	_
Sel2_May-Jul_TWL	0	_	0	_	0	_	0	_	0	_
Sel3_May-Jul_TWL	5.6761	0.1065	5.8059	0.0977	5.6975	0.1021	5.6476	0.1058	5.622	0.1091
Sel4_May-Jul_TWL	0	_	0	_	0	_	0	_	0	_
Sel5_May-Jul_TWL	-999	_	-999	_	-999	_	-999	_	-999	_
Sel6_May-Jul_TWL	10	_	10	_	10	_	10	_	10	_
Sel1_Aug-Dec_TWL	0	_	0	_	0	_	0	_	0	_
Sel2_Aug-Dec_TWL	0	_	0	_	0	_	0	_	0	_
Sel3_Aug-Dec_TWL	0	_	0	_	0	_	0	_	0	_
Sel4_Aug-Dec_TWL	0	_	0	_	0	_	0	_	0	_
Sel5_Aug-Dec_TWL	-999	_	-999	_	-999	_	-999	_	-999	_
Sel6_Aug-Dec_TWL	10	_	10	_	10	_	10	_	10	_
Sel1_Jan-Apr_LGL	0	_	0	_	0	_	0	_	0	_
Sel2_Jan-Apr_LGL	-4.716	1.7313	-9.465	13.681	-5.245	2.9395	-5.158	2.7293	-4.77	1.8194
Sel3_Jan-Apr_LGL	0	_	0	_	0	_	0	_	0	_
Sel4_Jan-Apr_LGL	4.9407	0.141	5.1171	0.0957	5.0215	0.1367	5.1096	0.141	5.0873	0.1393
Sel5_Jan-Apr_LGL	-999	_	-999	_	-999	_	-999	_	-999	_
Sel6_Jan-Apr_LGL	0	_	0	_	0	_	0	_	0	_
Sel1_May-Jul_LGL	0	_	0	_	0	_	0	_	0	_
Sel2_May-Jul_LGL	0	_	0	_	0	_	0	_	0	_
Sel3_May-Jul_LGL	4.9831	0.0574	5.0759	0.0527	4.9965	0.0565	4.9992	0.0549	4.9839	0.0554
Sel4_May-Jul_LGL	0	_	0	_	0	_	0	_	0	_
Sel5_May-Jul_LGL	-999	_	-999	_	-999	_	-999	_	-999	_
Sel6_May-Jul_LGL	10	_	10	_	10	_	10	_	10	_
Sel1_Aug-Dec_LGL	0	_	0	_	0	_	0	_	0	_
Sel2_Aug-Dec_LGL	-1.993	0.2089	-2.07	0.2552	-2.014	0.2196	-2.2	0.237	-2.165	0.2361
Sel3_Aug-Dec_LGL	0	_	0	_	0	_	0	_	0	_
Sel4_Aug-Dec_LGL	4.6311	0.3029	4.9227	0.3308	4.7524	0.3018	5.2409	0.2882	5.2087	0.2934
Sel5_Aug-Dec_LGL	-999	_	-999	_	-999	_	-999	_	-999	_
Sel6_Aug-Dec_LGL	0	_	0	_	0	_	0	_	0	_
Sel1_Jan-Apr_POT	0	_	0	_	0	_	0	_	0	_
Sel2_Jan-Apr_POT	-7.225	35.139	-9.051	21.709	-8.824	25.501	-8.764	26.446	-8.601	28.892
Sel3_Jan-Apr_POT	4.9983	0.0574	5.0061	0.0509	4.9998	0.0516	4.9944	0.0523	4.9939	0.0528
Sel4_Jan-Apr_POT	4.4572	0.3507	4.6294	0.2905	4.5374	0.2672	4.5716	0.2861	4.5653	0.2844
Sel5_Jan-Apr_POT	-999	_	-999	_	-999	_	-999	_	-999	_
Sel6_Jan-Apr_POT	0	_	0	_	0	_	0	_	0	_

Table 2.18 (page 4 of 6)—All of the quantities listed in the "parameters" section of the SS report file.

	Model 1		Model 2b		Model 3		Model 3b		Model 4	
Label	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD
Sel1_May-Jul_POT	0	_	0	_	0	_	0	_	0	_
Sel2_May-Jul_POT	0	_	0	_	0	_	0	_	0	_
Sel3_May-Jul_POT	4.9236	0.0827	4.9712	0.0767	4.9175	0.0813	4.9184	0.0818	4.9102	0.0825
Sel4_May-Jul_POT	0	_	0	_	0	_	0	_	0	_
Sel5_May-Jul_POT	-999	_	-999	_	-999	_	-999	_	-999	_
Sel6_May-Jul_POT	10	_	10	_	10	_	10	_	10	_
Sel1_Aug-Dec_POT	0	_	0	_	0	_	0	_	0	_
Sel2_Aug-Dec_POT	0	_	0	_	0	_	0	_	0	_
Sel3_Aug-Dec_POT	0	_	0	_	0	_	0	_	0	_
Sel4_Aug-Dec_POT	0	_	0	_	0	_	0	_	0	_
Sel5_Aug-Dec_POT	-999	_	-999	_	-999	_	-999	_	-999	_
Sel6_Aug-Dec_POT	10	_	10	_	10	_	10	_	10	_
Sel1_Pre82__SRV	1.945	0.0335								
Sel2_Pre82__SRV	-9.048	21.788								
Sel3_Pre82__SRV	-7.677	20.569								
Sel4_Pre82__SRV	0.694	0.4713								
Sel5_Pre82__SRV	-2.287	0.3552								
Sel6_Pre82__SRV	-2.21	1.0537								
Sel1_Post81_SRV	1.2925	0.0679	1.2718	0.0577	1.2879	0.0641	1.2904	0.0647	1.3494	0.0947
Sel2_Post81_SRV	-3.499	0.5627	-1.952	0.157	-2.008	0.141	-11.49	107.11	-3.383	0.6819
Sel3_Post81_SRV	-2.241	0.4974	-2.381	0.4614	-1.947	0.4803	-2.189	0.4817	-1.846	0.5702
Sel4_Post81_SRV	1.9499	0.29	0.6124	0.5943	0.3014	0.6118	3.1851	0.1745	1.8639	0.4377
Sel5_Post81_SRV	-4.466	0.1635	-8.772	1.519	-8.717	1.4728	-9.564	1.7165	-9.995	0.1699
Sel6_Post81_SRV	-0.47	0.133	0.1091	0.151	-0.217	0.1282	-1.667	0.4153	-0.668	0.1873
Sel1_Jan-Apr_TWL1977	14.424	28.321	72.855	3.0347	69.556	3.0184	68.697	3.0553	68.077	3.0242
Sel1_Jan-Apr_TWL1980	68.209	3.1401								
Sel1_Jan-Apr_TWL1985	73.558	1.7032	76.841	1.5265	74.449	1.5955	76.587	1.7029	75.736	1.7457
Sel1_Jan-Apr_TWL1990	69.206	0.9935	71.605	0.952	69.134	0.9998	68.186	1.0934	67.609	1.1425
Sel1_Jan-Apr_TWL1995	73.785	0.9512	75.298	0.9064	73.296	0.9063	73.708	0.9259	73.235	0.9295
Sel1_Jan-Apr_TWL2000	77.449	1.1754	78.685	1.1421	77.514	1.1286	78.227	1.1796	78.131	1.1876
Sel1_Jan-Apr_TWL2005	74.284	0.9561	74.974	0.933	74.237	0.9324	74.221	0.9592	74.064	0.9623
Sel3_Jan-Apr_TWL1977	9.8145	5.4661	6.2867	0.1543	6.2052	0.168	6.1552	0.1732	6.1415	0.1751
Sel3_Jan-Apr_TWL1980	6.1694	0.1851								
Sel3_Jan-Apr_TWL1985	6.548	0.0862	6.5835	0.0701	6.5325	0.0777	6.642	0.0769	6.6245	0.08
Sel3_Jan-Apr_TWL1990	6.1167	0.0547	6.1827	0.0484	6.1071	0.0537	6.0578	0.0592	6.0326	0.0624
Sel3_Jan-Apr_TWL1995	6.3145	0.0477	6.3193	0.0433	6.2768	0.0457	6.2854	0.0457	6.2752	0.0462
Sel3_Jan-Apr_TWL2000	6.2894	0.0621	6.2703	0.0578	6.2659	0.0592	6.3003	0.06	6.3036	0.0604
Sel3_Jan-Apr_TWL2005	6.0335	0.059	6.0231	0.056	6.0237	0.0573	6.0324	0.0583	6.0313	0.0587
Sel1_May-Jul_TWL1977	49.554	1.7729	53.223	1.8683	50.854	1.7508	50.334	1.7175	49.728	1.7185
Sel1_May-Jul_TWL1985	51.332	1.7523	54.205	1.725	52.227	1.7007	51.318	1.7681	50.808	1.7903
Sel1_May-Jul_TWL1990	62.59	1.5675	65.594	1.6134	62.997	1.5516	61.914	1.5576	61.377	1.5851
Sel1_May-Jul_TWL2000	53.233	1.5259	55.851	1.5528	53.892	1.514	53.196	1.5374	52.758	1.5627
Sel1_May-Jul_TWL2005	59.523	1.5391	62.074	1.5603	59.991	1.516	58.916	1.534	58.605	1.5454
Sel1_Aug-Dec_TWL1977	63.432	4.0602	64.5	4.0099	63.173	4.056	62.324	3.9435	62.316	3.9371
Sel1_Aug-Dec_TWL1980	81.036	6.3844	87.676	6.3104	83.357	5.9321	81.378	5.4312	80.392	5.6407
Sel1_Aug-Dec_TWL1985	81.997	4.4507	85.871	4.6975	82.84	4.3556	87.202	5.3742	86.282	5.3653
Sel1_Aug-Dec_TWL1990	52.617	21.34	102.37	4.0939	85.982	32.902	45.799	15.035	45.89	15.189
Sel1_Aug-Dec_TWL1995	102.5	_	102.41	2.6358	102.42	2.4035	102.47	0.8275	102.47	0.8096

Table 2.18 (page 5 of 6)—All of the quantities listed in the “parameters” section of the SS report file.

	Model 1		Model 2b		Model 3		Model 3b		Model 4	
Label	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD
Sel1_Aug-Dec_TWL2000	60.992	2.3904	64.302	3.0954	61.781	2.4683	62.151	2.7048	61.66	2.5365
Sel3_Aug-Dec_TWL1977	5.5624	0.319	5.5281	0.3007	5.5579	0.3234	5.5561	0.3258	5.5574	0.3257
Sel3_Aug-Dec_TWL1980	6.6757	0.2615	6.7594	0.2213	6.6996	0.2325	6.6466	0.2245	6.6353	0.2373
Sel3_Aug-Dec_TWL1985	6.4664	0.2221	6.5462	0.2087	6.4692	0.2121	6.6371	0.2271	6.618	0.2325
Sel3_Aug-Dec_TWL1990	4.3706	3.2448	7.1054	0.4269	6.7782	1.3565	3.2547	4.2491	3.28	4.2447
Sel3_Aug-Dec_TWL1995	7.0315	0.0883	6.9789	0.1074	7.0285	0.1064	7.013	0.09	7.0234	0.0905
Sel3_Aug-Dec_TWL2000	5.5657	0.2032	5.7514	0.225	5.6098	0.2024	5.6312	0.2171	5.6071	0.2087
Sel1_Jan-Apr_LGL1977	59.851	2.2764	60.685	2.3389	59.297	2.1751	58.582	2.059	58.539	2.0665
Sel1_Jan-Apr_LGL1980	70.428	3.0634	74.196	2.6827	72.356	2.5777	72.354	2.4266	71.832	2.4906
Sel1_Jan-Apr_LGL1985	73.439	0.8917	75.184	0.8495	74.247	0.8705	75.315	0.9093	74.927	0.9181
Sel1_Jan-Apr_LGL1990	66.087	0.459	67.021	0.4438	66.372	0.4689	65.935	0.4781	65.754	0.478
Sel1_Jan-Apr_LGL1995	65.76	0.4271	66.519	0.3789	65.758	0.425	65.698	0.4277	65.506	0.4291
Sel1_Jan-Apr_LGL2000	63.377	0.4391	64.222	0.3705	63.695	0.4369	63.51	0.4484	63.418	0.4499
Sel1_Jan-Apr_LGL2005	67.706	0.4039	68.467	0.3502	67.873	0.403	67.471	0.4081	67.301	0.4098
Sel3_Jan-Apr_LGL1977	5.1855	0.2275	5.1415	0.2288	5.133	0.2278	5.1335	0.2082	5.1317	0.2086
Sel3_Jan-Apr_LGL1980	5.8459	0.2245	5.9239	0.1785	5.8933	0.185	5.9119	0.1762	5.9056	0.1825
Sel3_Jan-Apr_LGL1985	5.7937	0.0708	5.8229	0.0645	5.8132	0.0671	5.8683	0.0666	5.8611	0.0678
Sel3_Jan-Apr_LGL1990	5.2245	0.0455	5.2717	0.043	5.2504	0.0452	5.2172	0.0467	5.2064	0.0469
Sel3_Jan-Apr_LGL1995	5.3281	0.0398	5.3495	0.0357	5.3173	0.0396	5.2992	0.0397	5.2907	0.04
Sel3_Jan-Apr_LGL2000	5.3604	0.0419	5.38	0.0362	5.3699	0.0409	5.3587	0.0418	5.3583	0.042
Sel3_Jan-Apr_LGL2005	5.3735	0.0356	5.3951	0.0315	5.3775	0.0352	5.3512	0.036	5.3451	0.0363
Sel6_Jan-Apr_LGL1977	-1.112	0.8181	-1.053	0.9399	-1.135	0.812	-1.375	0.7923	-1.363	0.7852
Sel6_Jan-Apr_LGL1980	1.4361	1.7681	1.1323	1.826	0.7664	1.242	0.2843	1.0078	0.334	0.9939
Sel6_Jan-Apr_LGL1985	-0.694	0.34	-1.143	0.4359	-0.946	0.3774	-1.377	0.4815	-1.298	0.4552
Sel6_Jan-Apr_LGL1990	-0.504	0.1274	-0.549	0.1382	-0.584	0.1307	-0.499	0.1371	-0.503	0.1349
Sel6_Jan-Apr_LGL1995	-0.612	0.1327	-0.668	0.144	-0.706	0.1345	-0.747	0.1404	-0.755	0.1379
Sel6_Jan-Apr_LGL2000	-1.129	0.1336	-1.2	0.1453	-1.215	0.1397	-1.209	0.1467	-1.2	0.1447
Sel6_Jan-Apr_LGL2005	-0.929	0.1418	-1.166	0.1572	-1.07	0.148	-1.05	0.1552	-1.012	0.1518
Sel1_May-Jul_LGL1977	63.468	2.1516	65.696	2.0271	63.623	2.1108	63.004	2.2244	62.861	2.252
Sel1_May-Jul_LGL1980	61.837	1.3452	64.188	1.334	62.274	1.3567	62.302	1.3678	61.921	1.3645
Sel1_May-Jul_LGL1985	62.584	1.129	64.317	1.1105	63.032	1.1255	63.188	1.1272	62.852	1.1299
Sel1_May-Jul_LGL1990	63.211	0.5522	64.683	0.5513	63.409	0.5526	63.395	0.544	63.144	0.545
Sel1_May-Jul_LGL2000	59.476	0.5754	60.889	0.5806	59.772	0.5783	59.731	0.5755	59.534	0.5774
Sel1_May-Jul_LGL2005	63.916	0.6259	65.218	0.6196	64.124	0.6214	64.076	0.6089	63.851	0.6109
Sel1_Aug-Dec_LGL1977	62.369	2.3111	63.188	2.3406	61.864	2.2604	60.183	2.1616	60.153	2.139
Sel1_Aug-Dec_LGL1980	67.58	1.5198	71.432	1.7231	69.028	1.6261	69.8	1.5539	69.23	1.578
Sel1_Aug-Dec_LGL1985	62.783	0.6518	64.506	0.7977	63.599	0.6726	64.625	0.7506	64.168	0.7752
Sel1_Aug-Dec_LGL1990	66.808	0.7165	68.175	0.7165	67.173	0.6945	66.975	0.7247	66.773	0.7295
Sel1_Aug-Dec_LGL1995	68.934	0.7012	70.459	0.6825	68.873	0.6791	69.367	0.6883	68.953	0.6929
Sel1_Aug-Dec_LGL2000	63.324	0.4104	64.651	0.4201	63.684	0.4133	63.527	0.4264	63.367	0.4356
Sel1_Aug-Dec_LGL2005	62.639	0.4098	63.579	0.4175	62.85	0.4053	62.342	0.4106	62.235	0.4163
Sel3_Aug-Dec_LGL1977	4.7163	0.3056	4.7045	0.2992	4.6761	0.3082	4.478	0.3272	4.4743	0.3253
Sel3_Aug-Dec_LGL1980	5.2884	0.1416	5.4887	0.1362	5.3715	0.1396	5.4156	0.1307	5.3879	0.1352
Sel3_Aug-Dec_LGL1985	4.7082	0.086	4.861	0.0918	4.7768	0.0842	4.9021	0.0849	4.864	0.0894
Sel3_Aug-Dec_LGL1990	4.9948	0.0788	5.0775	0.073	5.0285	0.0747	5.0326	0.0765	5.0214	0.0774
Sel3_Aug-Dec_LGL1995	5.485	0.0551	5.5437	0.0502	5.4708	0.0534	5.499	0.0525	5.4772	0.0534
Sel3_Aug-Dec_LGL2000	5.166	0.041	5.232	0.0389	5.1823	0.0402	5.1742	0.0409	5.1675	0.0416
Sel3_Aug-Dec_LGL2005	4.9318	0.0434	4.9869	0.042	4.9465	0.0424	4.8999	0.0431	4.8957	0.0437

Table 2.18 (page 6 of 6)—All of the quantities listed in the “parameters” section of the SS report file.

	Model 1		Model 2b		Model 3		Model 3b		Model 4	
Label	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD
Sel6_Aug-Dec_LGL1977	-2.194	1.6343	-2.557	2.3432	-2.225	1.7147	-2.841	2.526	-2.787	2.4254
Sel6_Aug-Dec_LGL1980	1.9872	1.3563	1.3999	1.4204	1.4583	1.1027	0.164	0.7367	0.241	0.7116
Sel6_Aug-Dec_LGL1985	0.3199	0.1894	0.3154	0.2382	0.2646	0.2031	0.1432	0.2578	0.1308	0.2477
Sel6_Aug-Dec_LGL1990	2.4882	0.8337	2.2458	0.7699	2.0586	0.5937	2.35	0.8534	2.3153	0.8168
Sel6_Aug-Dec_LGL1995	9.6445	9.6785	9.5357	12.178	9.4605	13.814	9.3791	15.512	9.3346	16.413
Sel6_Aug-Dec_LGL2000	-0.192	0.1441	-0.361	0.1841	-0.306	0.1539	-0.439	0.1952	-0.413	0.1915
Sel6_Aug-Dec_LGL2005	9.7968	5.8663	9.7989	5.8104	9.7257	7.6974	9.7718	6.5214	9.7826	6.2397
Sel1_Jan-Apr_POT1977	68.768	0.9448	69.353	0.8973	68.902	0.9016	68.513	0.9248	68.434	0.9254
Sel1_Jan-Apr_POT1995	68.243	0.623	68.722	0.5566	68.308	0.5535	68.325	0.5631	68.224	0.5666
Sel1_Jan-Apr_POT2000	67.827	0.6011	68.39	0.5309	68.052	0.5247	67.975	0.5347	67.93	0.538
Sel1_Jan-Apr_POT2005	68.217	0.6085	68.7	0.5516	68.333	0.5493	68.103	0.5564	68.014	0.561
Sel6_Jan-Apr_POT1977	-0.002	0.494	-0.101	0.5178	-0.091	0.4914	0.2156	0.5631	0.1975	0.5532
Sel6_Jan-Apr_POT1995	-0.211	0.2546	-0.244	0.273	-0.315	0.2488	-0.313	0.2534	-0.325	0.2503
Sel6_Jan-Apr_POT2000	-0.604	0.235	-0.677	0.2562	-0.704	0.2335	-0.62	0.2435	-0.622	0.2414
Sel6_Jan-Apr_POT2005	0.3501	0.2568	0.2899	0.2632	0.2545	0.2466	0.3535	0.2585	0.3664	0.2587
Sel1_May-Jul_POT1977	67.161	0.8502	68.075	0.8257	67.155	0.845	67.178	0.8522	67.019	0.857
Sel1_May-Jul_POT1995	65.755	0.7196	66.722	0.7035	65.773	0.7104	65.901	0.7169	65.711	0.717
Sel1_Aug-Dec_POT1977	68.146	1.1732	69.297	1.1615	68.197	1.1567	68.394	1.1661	68.159	1.1644
Sel1_Aug-Dec_POT2000	62.007	0.7957	62.871	0.808	62.2	0.79	62.159	0.7753	62.08	0.7744
Sel3_Aug-Dec_POT1977	5.1755	0.1207	5.2248	0.1134	5.1718	0.1189	5.1869	0.1181	5.1773	0.1191
Sel3_Aug-Dec_POT2000	4.4504	0.1269	4.5255	0.1205	4.4712	0.1239	4.4795	0.1211	4.4773	0.1214
Sel3_Post81_SRV1982d	-0.087	0.0227	-0.094	0.022	-0.091	0.026	-0.028	0.035	-0.027	0.034
Sel3_Post81_SRV1983d	-0.015	0.0186	0.0077	0.0215	-0.041	0.0197	-0.042	0.0177	-0.042	0.0175
Sel3_Post81_SRV1984d	-0.101	0.0225	-0.099	0.0227	-0.11	0.0237	-0.075	0.028	-0.072	0.0271
Sel3_Post81_SRV1985d	0.0097	0.0209	0.0227	0.0229	-0.006	0.0229	0.0028	0.021	0.0043	0.0208
Sel3_Post81_SRV1986d	-0.045	0.0212	-0.035	0.0227	-0.075	0.0215	-0.044	0.0228	-0.041	0.0224
Sel3_Post81_SRV1987d	0.0185	0.0347	0.027	0.036	0.0052	0.0378	0.0401	0.0408	0.0404	0.0401
Sel3_Post81_SRV1988d	-0.098	0.0268	-0.093	0.0272	-0.112	0.0277	-0.062	0.0339	-0.057	0.0334
Sel3_Post81_SRV1989d	-0.124	0.0185	-0.117	0.0189	-0.136	0.019	-0.11	0.0192	-0.105	0.0189
Sel3_Post81_SRV1990d	-0.032	0.0197	-0.013	0.0221	-0.04	0.0224	-0.028	0.0209	-0.028	0.0204
Sel3_Post81_SRV1991d	-0.03	0.0222	-0.015	0.0244	-0.051	0.0236	-0.041	0.022	-0.04	0.0216
Sel3_Post81_SRV1992d	0.029	0.0287	0.0331	0.0294	0.0322	0.0349	0.0939	0.0407	0.0936	0.0403
Sel3_Post81_SRV1993d	0.0727	0.0312	0.0958	0.0347	0.0658	0.0359	0.0471	0.0283	0.046	0.0277
Sel3_Post81_SRV1994d	-0.029	0.027	-9E-04	0.0317	-0.004	0.0343	-0.041	0.0214	-0.035	0.0266
Sel3_Post81_SRV1995d	-0.065	0.0248	-0.066	0.0272	-0.088	0.0263	-0.088	0.0201	-0.073	0.0244
Sel3_Post81_SRV1996d	-0.1	0.0187	-0.113	0.0209	-0.117	0.0208	-0.107	0.0185	-0.098	0.022
Sel3_Post81_SRV1997d	-0.04	0.0184	-0.028	0.0203	-0.068	0.0192	-0.067	0.0159	-0.064	0.0178
Sel3_Post81_SRV1998d	-0.069	0.0212	-0.072	0.0227	-0.059	0.0249	-0.072	0.0193	-0.07	0.0222
Sel3_Post81_SRV1999d	-0.065	0.0189	-0.079	0.0202	-0.044	0.0225	-0.071	0.0183	-0.067	0.0214
Sel3_Post81_SRV2000d	-0.03	0.0184	-0.022	0.0197	-0.041	0.0201	-0.041	0.0163	-0.038	0.0182
Sel3_Post81_SRV2001d	0.1422	0.039	0.1634	0.0392	0.1344	0.0406	0.1353	0.0348	0.1097	0.035
Sel3_Post81_SRV2002d	-0.018	0.024	-0.033	0.0245	0.0103	0.032	-0.012	0.024	0.0188	0.0351
Sel3_Post81_SRV2003d	-0.017	0.019	0.0016	0.0216	-0.002	0.0231	-0.002	0.0194	0.0006	0.0237
Sel3_Post81_SRV2004d	-0.021	0.0203	-0.016	0.0221	-0.013	0.0249	-0.026	0.0191	-0.015	0.0244
Sel3_Post81_SRV2005d	-0.008	0.02	0.0126	0.0233	0.1237	0.0386	0.0368	0.025	0.0503	0.033
Sel3_Post81_SRV2006d	0.0472	0.0229	0.044	0.0233	0.047	0.028	0.1335	0.0356	0.109	0.0367
Sel3_Post81_SRV2007d	0.2125	0.0369	0.2265	0.0366	0.1719	0.0384	0.1967	0.0367	0.1503	0.0384
Sel3_Post81_SRV2008d	0.0404	0.0259	0.036	0.0264	0.0814	0.0364	0.0866	0.0335	0.0903	0.0394
Sel3_Post81_SRV2009d	0.056	0.0249	0.0701	0.027	0.0351	0.026	0.0445	0.0219	0.0273	0.0223

Table 2.19a— Estimates of seasonal full-selection fishing mortality rates, expressed on an annual time scale (Model 1). Sea1=Jan-Feb, Sea2=Mar-Apr, Sea3=May-Jul, Sea4=Aug-Oct, Sea5=Nov-Dec. Rates have been multiplied by relative season length before summing to get total.

	Trawl fishery					Longline fishery					Pot fishery					
Year	Sea1	Sea2	Sea3	Sea4	Sea5	Sea1	Sea2	Sea3	Sea4	Sea5	Sea1	Sea2	Sea3	Sea4	Sea5	Total
1977	0.052	0.054	0.045	0.042	0.036	0.014	0.015	0.005	0.021	0.028	0	0	0	0	0	0.061
1978	0.059	0.060	0.053	0.046	0.041	0.014	0.014	0.005	0.021	0.028	0	0	0	0	0	0.068
1979	0.036	0.035	0.033	0.032	0.027	0.010	0.010	0.004	0.015	0.019	0	0	0	0	0	0.044
1980	0.048	0.048	0.024	0.031	0.026	0.007	0.007	0.003	0.010	0.013	0	0	0	0	0	0.042
1981	0.026	0.026	0.026	0.050	0.047	0.003	0.003	0.002	0.006	0.008	0	0	0	0	0	0.040
1982	0.027	0.028	0.029	0.035	0.028	0.001	0.001	0.001	0.003	0.004	0	0	0	0	0	0.032
1983	0.044	0.047	0.042	0.043	0.035	0.004	0.004	0.002	0.003	0.004	0	0	0	0	0	0.046
1984	0.050	0.055	0.048	0.046	0.039	0.006	0.006	0.005	0.022	0.029	0	0	0	0	0	0.061
1985	0.062	0.069	0.057	0.051	0.039	0.019	0.022	0.008	0.029	0.040	0	0	0	0	0	0.078
1986	0.071	0.078	0.058	0.052	0.041	0.014	0.016	0.005	0.024	0.033	0	0	0	0	0	0.077
1987	0.079	0.088	0.047	0.043	0.041	0.035	0.039	0.011	0.038	0.054	0	0	0	0	0	0.091
1988	0.163	0.182	0.091	0.092	0.097	0.001	0.001	0.001	0.003	0.003	0	0	0	0	0	0.122
1989	0.176	0.198	0.090	0.049	0.044	0.007	0.008	0.011	0.013	0.012	0.000	0.000	0.000	0.000	0.000	0.115
1990	0.154	0.175	0.084	0.026	0.022	0.028	0.032	0.042	0.046	0.041	0.000	0.000	0.002	0.002	0.001	0.126
1991	0.156	0.341	0.060	0.043	0.000	0.054	0.096	0.077	0.087	0.093	0.000	0.000	0.002	0.009	0.004	0.194
1992	0.126	0.198	0.049	0.030	0.009	0.115	0.214	0.123	0.080	0.000	0.000	0.001	0.026	0.009	0.000	0.190
1993	0.161	0.228	0.025	0.035	0.010	0.195	0.206	0.024	0.000	0.000	0.000	0.010	0.006	0.000	0.000	0.157
1994	0.075	0.264	0.017	0.068	0.013	0.168	0.240	0.026	0.091	0.000	0.000	0.028	0.008	0.014	0.000	0.188
1995	0.181	0.374	0.004	0.169	0.001	0.210	0.272	0.018	0.093	0.050	0.000	0.067	0.034	0.013	0.009	0.277
1996	0.122	0.327	0.033	0.092	0.018	0.205	0.232	0.016	0.103	0.020	0.000	0.111	0.048	0.020	0.005	0.251
1997	0.152	0.353	0.021	0.085	0.021	0.230	0.249	0.037	0.099	0.167	0.000	0.086	0.036	0.018	0.004	0.284
1998	0.105	0.197	0.019	0.119	0.013	0.247	0.183	0.020	0.081	0.100	0.000	0.055	0.030	0.010	0.000	0.220
1999	0.125	0.187	0.014	0.055	0.003	0.281	0.205	0.017	0.105	0.036	0.000	0.053	0.030	0.011	0.000	0.206
2000	0.139	0.188	0.017	0.025	0.003	0.262	0.075	0.007	0.114	0.123	0.115	0.044	0.000	0.000	0.000	0.199
2001	0.059	0.103	0.013	0.033	0.004	0.150	0.137	0.016	0.141	0.134	0.001	0.104	0.003	0.016	0.003	0.172
2002	0.089	0.156	0.028	0.032	0.001	0.275	0.125	0.007	0.166	0.100	0.015	0.078	0.005	0.013	0.005	0.204
2003	0.109	0.122	0.025	0.028	0.000	0.285	0.095	0.000	0.160	0.105	0.121	0.016	0.000	0.022	0.009	0.203
2004	0.147	0.132	0.038	0.035	0.000	0.302	0.149	0.012	0.157	0.151	0.079	0.028	0.005	0.017	0.004	0.231
2005	0.193	0.122	0.033	0.013	0.001	0.411	0.066	0.018	0.173	0.149	0.076	0.030	0.000	0.023	0.003	0.240
2006	0.228	0.128	0.033	0.023	0.000	0.464	0.071	0.011	0.239	0.008	0.104	0.037	0.002	0.022	0.007	0.257
2007	0.143	0.169	0.059	0.018	0.001	0.501	0.025	0.008	0.188	0.007	0.119	0.014	0.003	0.031	0.000	0.240
2008	0.153	0.080	0.023	0.037	0.006	0.527	0.052	0.018	0.216	0.075	0.108	0.027	0.002	0.042	0.001	0.256
2009	0.127	0.112	0.024	0.056	0.003	0.587	0.054	0.016	0.222	0.092	0.122	0.025	0.001	0.009	0.010	0.270
2010	0.159	0.085	0.020	0.049	0.010	0.466	0.025	0.015	0.123	0.091	0.129	0.022	0.002	0.028	0.014	0.226
2011	0.173	0.185	0.029	0.037	0.005	0.261	0.255	0.070	0.143	0.067	0.145	0.024	0.008	0.031	0.007	0.266

Table 2.19b—Estimates of seasonal full-selection fishing mortality rates, expressed on an annual time scale (Model 2b). Sea1=Jan-Feb, Sea2=Mar-Apr, Sea3=May-Jul, Sea4=Aug-Oct, Sea5=Nov-Dec. Rates have been multiplied by relative season length before summing to get total.

	Trawl fishery					Longline fishery					Pot fishery					
Year	Sea1	Sea2	Sea3	Sea4	Sea5	Sea1	Sea2	Sea3	Sea4	Sea5	Sea1	Sea2	Sea3	Sea4	Sea5	Total
1977	0.153	0.164	0.092	0.087	0.075	0.026	0.027	0.011	0.041	0.054	0	0	0	0	0	0.141
1978	0.175	0.186	0.105	0.096	0.084	0.027	0.028	0.012	0.042	0.056	0	0	0	0	0	0.156
1979	0.120	0.125	0.062	0.062	0.052	0.018	0.019	0.008	0.029	0.037	0	0	0	0	0	0.102
1980	0.099	0.099	0.044	0.072	0.060	0.016	0.016	0.006	0.021	0.026	0	0	0	0	0	0.088
1981	0.052	0.052	0.044	0.109	0.102	0.006	0.006	0.004	0.013	0.015	0	0	0	0	0	0.081
1982	0.052	0.053	0.047	0.072	0.057	0.001	0.001	0.001	0.005	0.007	0	0	0	0	0	0.060
1983	0.075	0.080	0.064	0.080	0.065	0.006	0.007	0.003	0.006	0.007	0	0	0	0	0	0.078
1984	0.080	0.087	0.070	0.079	0.067	0.009	0.010	0.007	0.034	0.046	0	0	0	0	0	0.097
1985	0.095	0.104	0.081	0.079	0.061	0.029	0.032	0.012	0.041	0.056	0	0	0	0	0	0.116
1986	0.104	0.115	0.079	0.078	0.062	0.020	0.022	0.007	0.032	0.045	0	0	0	0	0	0.111
1987	0.113	0.125	0.062	0.063	0.060	0.050	0.055	0.015	0.050	0.070	0	0	0	0	0	0.126
1988	0.227	0.253	0.119	0.133	0.139	0.001	0.001	0.002	0.004	0.004	0	0	0	0	0	0.169
1989	0.239	0.270	0.115	0.069	0.062	0.010	0.011	0.014	0.017	0.015	0.000	0.000	0.000	0.000	0.000	0.155
1990	0.201	0.229	0.108	0.060	0.050	0.035	0.040	0.055	0.060	0.053	0.000	0.000	0.003	0.002	0.001	0.174
1991	0.201	0.442	0.078	0.097	0.000	0.067	0.119	0.100	0.114	0.122	0.000	0.000	0.002	0.012	0.005	0.260
1992	0.164	0.259	0.065	0.077	0.024	0.144	0.271	0.161	0.105	0.000	0.001	0.002	0.034	0.013	0.000	0.258
1993	0.213	0.304	0.033	0.099	0.029	0.249	0.265	0.031	0.000	0.000	0.000	0.014	0.007	0.000	0.000	0.222
1994	0.098	0.349	0.022	0.199	0.038	0.213	0.305	0.034	0.120	0.000	0.000	0.037	0.011	0.018	0.000	0.274
1995	0.237	0.493	0.006	0.225	0.002	0.263	0.344	0.023	0.122	0.065	0.001	0.086	0.044	0.017	0.012	0.360
1996	0.160	0.433	0.044	0.123	0.024	0.258	0.296	0.021	0.137	0.027	0.000	0.142	0.064	0.026	0.006	0.328
1997	0.200	0.469	0.028	0.114	0.028	0.291	0.318	0.049	0.131	0.222	0.000	0.110	0.047	0.024	0.006	0.372
1998	0.139	0.264	0.025	0.160	0.018	0.316	0.235	0.026	0.107	0.133	0.000	0.071	0.040	0.013	0.001	0.289
1999	0.166	0.252	0.019	0.074	0.004	0.359	0.265	0.022	0.141	0.048	0.000	0.069	0.040	0.014	0.000	0.271
2000	0.187	0.255	0.021	0.033	0.004	0.332	0.095	0.009	0.146	0.157	0.149	0.057	0.000	0.001	0.000	0.259
2001	0.077	0.137	0.016	0.041	0.006	0.186	0.168	0.021	0.176	0.166	0.002	0.132	0.004	0.020	0.004	0.216
2002	0.115	0.201	0.034	0.041	0.002	0.331	0.150	0.009	0.203	0.122	0.019	0.097	0.006	0.016	0.006	0.251
2003	0.139	0.155	0.030	0.035	0.000	0.339	0.113	0.000	0.192	0.126	0.147	0.020	0.000	0.026	0.011	0.246
2004	0.183	0.164	0.045	0.043	0.001	0.352	0.173	0.015	0.185	0.177	0.094	0.033	0.005	0.020	0.005	0.275
2005	0.232	0.147	0.039	0.016	0.001	0.488	0.078	0.021	0.205	0.176	0.090	0.036	0.000	0.027	0.004	0.286
2006	0.273	0.154	0.039	0.027	0.000	0.550	0.085	0.013	0.283	0.010	0.123	0.044	0.003	0.027	0.008	0.306
2007	0.171	0.203	0.069	0.022	0.001	0.597	0.030	0.009	0.221	0.008	0.141	0.017	0.004	0.037	0.000	0.285
2008	0.181	0.095	0.027	0.044	0.007	0.624	0.062	0.022	0.254	0.088	0.127	0.032	0.002	0.049	0.001	0.302
2009	0.150	0.133	0.028	0.067	0.004	0.693	0.064	0.019	0.260	0.108	0.143	0.029	0.001	0.010	0.012	0.319
2010	0.188	0.101	0.023	0.058	0.012	0.549	0.029	0.018	0.143	0.105	0.150	0.026	0.002	0.032	0.016	0.265
2011	0.201	0.214	0.033	0.043	0.006	0.301	0.294	0.081	0.162	0.076	0.167	0.027	0.009	0.035	0.008	0.306

Table 2.19c—Estimates of seasonal full-selection fishing mortality rates, expressed on an annual time scale (Model 3). Sea1=Jan-Feb, Sea2=Mar-Apr, Sea3=May-Jul, Sea4=Aug-Oct, Sea5=Nov-Dec. Rates have been multiplied by relative season length before summing to get total.

	Trawl fishery					Longline fishery					Pot fishery					
Year	Sea1	Sea2	Sea3	Sea4	Sea5	Sea1	Sea2	Sea3	Sea4	Sea5	Sea1	Sea2	Sea3	Sea4	Sea5	Total
1977	0.102	0.109	0.065	0.059	0.051	0.020	0.020	0.007	0.030	0.038	0	0	0	0	0	0.097
1978	0.116	0.122	0.077	0.066	0.058	0.020	0.020	0.008	0.029	0.040	0	0	0	0	0	0.107
1979	0.081	0.085	0.048	0.045	0.038	0.014	0.015	0.005	0.021	0.027	0	0	0	0	0	0.073
1980	0.071	0.072	0.035	0.048	0.040	0.011	0.011	0.004	0.015	0.019	0	0	0	0	0	0.063
1981	0.039	0.039	0.037	0.076	0.072	0.004	0.004	0.003	0.010	0.012	0	0	0	0	0	0.059
1982	0.040	0.041	0.040	0.052	0.041	0.001	0.001	0.001	0.004	0.005	0	0	0	0	0	0.046
1983	0.061	0.064	0.056	0.061	0.050	0.005	0.005	0.003	0.005	0.005	0	0	0	0	0	0.063
1984	0.067	0.073	0.062	0.062	0.053	0.008	0.009	0.006	0.029	0.039	0	0	0	0	0	0.081
1985	0.081	0.089	0.072	0.065	0.051	0.025	0.028	0.011	0.037	0.051	0	0	0	0	0	0.100
1986	0.090	0.099	0.072	0.065	0.052	0.018	0.020	0.006	0.029	0.041	0	0	0	0	0	0.096
1987	0.098	0.109	0.057	0.053	0.051	0.044	0.049	0.013	0.046	0.065	0	0	0	0	0	0.111
1988	0.199	0.221	0.108	0.112	0.118	0.001	0.001	0.002	0.003	0.004	0	0	0	0	0	0.147
1989	0.210	0.236	0.105	0.058	0.053	0.008	0.009	0.013	0.016	0.014	0.000	0.000	0.000	0.000	0.000	0.137
1990	0.179	0.203	0.097	0.038	0.032	0.033	0.037	0.049	0.054	0.048	0.000	0.000	0.002	0.002	0.001	0.150
1991	0.180	0.395	0.070	0.063	0.000	0.063	0.111	0.090	0.103	0.110	0.000	0.000	0.002	0.011	0.004	0.229
1992	0.146	0.231	0.057	0.049	0.015	0.135	0.253	0.144	0.095	0.000	0.000	0.002	0.031	0.011	0.000	0.227
1993	0.188	0.267	0.029	0.061	0.018	0.231	0.244	0.028	0.000	0.000	0.000	0.012	0.007	0.000	0.000	0.191
1994	0.087	0.307	0.020	0.119	0.022	0.196	0.280	0.030	0.107	0.000	0.000	0.033	0.010	0.016	0.000	0.230
1995	0.209	0.434	0.005	0.196	0.002	0.245	0.321	0.021	0.108	0.058	0.001	0.079	0.040	0.015	0.010	0.323
1996	0.141	0.380	0.039	0.107	0.021	0.240	0.274	0.019	0.121	0.024	0.000	0.131	0.057	0.023	0.005	0.294
1997	0.176	0.412	0.025	0.099	0.024	0.270	0.295	0.044	0.116	0.197	0.000	0.101	0.042	0.021	0.005	0.334
1998	0.123	0.233	0.023	0.140	0.016	0.295	0.220	0.024	0.096	0.118	0.000	0.065	0.036	0.011	0.000	0.261
1999	0.148	0.223	0.017	0.065	0.004	0.339	0.249	0.020	0.125	0.043	0.000	0.065	0.036	0.013	0.000	0.247
2000	0.166	0.225	0.020	0.030	0.004	0.312	0.089	0.008	0.134	0.145	0.139	0.053	0.000	0.001	0.000	0.237
2001	0.069	0.121	0.015	0.038	0.005	0.175	0.159	0.019	0.164	0.156	0.002	0.123	0.003	0.019	0.004	0.200
2002	0.103	0.181	0.032	0.037	0.002	0.317	0.144	0.009	0.191	0.115	0.018	0.091	0.005	0.015	0.006	0.235
2003	0.125	0.139	0.028	0.032	0.000	0.325	0.108	0.000	0.181	0.118	0.139	0.019	0.000	0.025	0.010	0.231
2004	0.166	0.148	0.042	0.039	0.000	0.338	0.166	0.014	0.175	0.168	0.089	0.031	0.005	0.019	0.004	0.259
2005	0.213	0.135	0.037	0.015	0.001	0.460	0.074	0.020	0.191	0.164	0.085	0.034	0.000	0.025	0.003	0.267
2006	0.252	0.142	0.037	0.025	0.000	0.518	0.079	0.012	0.263	0.009	0.116	0.042	0.002	0.025	0.007	0.285
2007	0.157	0.186	0.064	0.020	0.001	0.559	0.028	0.009	0.206	0.008	0.132	0.016	0.004	0.034	0.000	0.265
2008	0.167	0.087	0.025	0.040	0.006	0.584	0.058	0.020	0.235	0.081	0.119	0.030	0.002	0.046	0.001	0.281
2009	0.137	0.120	0.025	0.060	0.003	0.643	0.059	0.017	0.237	0.097	0.133	0.027	0.001	0.009	0.011	0.292
2010	0.168	0.090	0.021	0.051	0.011	0.496	0.026	0.016	0.128	0.094	0.137	0.023	0.002	0.029	0.014	0.238
2011	0.177	0.188	0.030	0.038	0.005	0.270	0.263	0.072	0.144	0.067	0.150	0.024	0.008	0.031	0.007	0.273

Table 2.19d—Estimates of seasonal full-selection fishing mortality rates, expressed on an annual time scale (Model 3b). Sea1=Jan-Feb, Sea2=Mar-Apr, Sea3=May-Jul, Sea4=Aug-Oct, Sea5=Nov-Dec. Rates have been multiplied by relative season length before summing to get total.

	Trawl fishery					Longline fishery					Pot fishery					
Year	Sea1	Sea2	Sea3	Sea4	Sea5	Sea1	Sea2	Sea3	Sea4	Sea5	Sea1	Sea2	Sea3	Sea4	Sea5	Total
1977	0.080	0.085	0.052	0.046	0.040	0.016	0.016	0.005	0.023	0.030	0	0	0	0	0	0.076
1978	0.092	0.097	0.064	0.053	0.048	0.016	0.017	0.006	0.024	0.033	0	0	0	0	0	0.087
1979	0.067	0.071	0.042	0.038	0.032	0.012	0.013	0.005	0.018	0.024	0	0	0	0	0	0.062
1980	0.060	0.061	0.030	0.039	0.033	0.010	0.010	0.004	0.014	0.017	0	0	0	0	0	0.053
1981	0.032	0.032	0.031	0.060	0.057	0.004	0.004	0.002	0.008	0.010	0	0	0	0	0	0.048
1982	0.033	0.034	0.034	0.042	0.033	0.001	0.001	0.001	0.004	0.005	0	0	0	0	0	0.038
1983	0.051	0.055	0.049	0.050	0.041	0.004	0.005	0.002	0.004	0.005	0	0	0	0	0	0.053
1984	0.058	0.064	0.055	0.053	0.046	0.007	0.008	0.006	0.027	0.037	0	0	0	0	0	0.072
1985	0.074	0.082	0.064	0.064	0.049	0.023	0.026	0.010	0.033	0.045	0	0	0	0	0	0.092
1986	0.083	0.091	0.064	0.064	0.051	0.016	0.018	0.005	0.026	0.037	0	0	0	0	0	0.089
1987	0.091	0.101	0.051	0.052	0.050	0.040	0.045	0.012	0.041	0.058	0	0	0	0	0	0.103
1988	0.184	0.205	0.098	0.110	0.116	0.001	0.001	0.002	0.003	0.003	0	0	0	0	0	0.138
1989	0.195	0.219	0.096	0.057	0.052	0.008	0.009	0.012	0.014	0.013	0.000	0.000	0.000	0.000	0.000	0.127
1990	0.164	0.187	0.090	0.028	0.024	0.030	0.034	0.046	0.050	0.045	0.000	0.000	0.002	0.002	0.001	0.135
1991	0.169	0.371	0.066	0.047	0.000	0.058	0.103	0.085	0.097	0.104	0.000	0.000	0.002	0.010	0.004	0.212
1992	0.139	0.219	0.054	0.032	0.010	0.126	0.236	0.138	0.089	0.000	0.000	0.002	0.030	0.011	0.000	0.211
1993	0.177	0.250	0.027	0.036	0.011	0.213	0.224	0.026	0.000	0.000	0.000	0.011	0.006	0.000	0.000	0.172
1994	0.081	0.286	0.019	0.073	0.014	0.180	0.258	0.029	0.100	0.000	0.000	0.030	0.009	0.015	0.000	0.203
1995	0.200	0.414	0.005	0.188	0.001	0.233	0.304	0.020	0.103	0.055	0.001	0.075	0.038	0.015	0.010	0.307
1996	0.134	0.359	0.036	0.102	0.020	0.226	0.255	0.018	0.114	0.022	0.000	0.123	0.053	0.021	0.005	0.277
1997	0.166	0.386	0.023	0.093	0.023	0.252	0.274	0.041	0.109	0.185	0.000	0.094	0.039	0.020	0.005	0.312
1998	0.115	0.218	0.021	0.132	0.015	0.274	0.203	0.022	0.090	0.111	0.000	0.061	0.033	0.011	0.000	0.243
1999	0.138	0.208	0.015	0.061	0.003	0.314	0.229	0.019	0.116	0.040	0.000	0.060	0.033	0.012	0.000	0.229
2000	0.154	0.207	0.018	0.027	0.003	0.277	0.078	0.008	0.120	0.130	0.124	0.047	0.000	0.000	0.000	0.213
2001	0.063	0.112	0.014	0.035	0.005	0.157	0.143	0.017	0.149	0.142	0.001	0.109	0.003	0.017	0.004	0.181
2002	0.096	0.168	0.029	0.034	0.002	0.290	0.132	0.008	0.174	0.104	0.016	0.083	0.005	0.014	0.005	0.215
2003	0.116	0.129	0.026	0.029	0.000	0.292	0.097	0.000	0.163	0.106	0.126	0.017	0.000	0.022	0.009	0.209
2004	0.153	0.136	0.038	0.036	0.000	0.301	0.148	0.012	0.157	0.151	0.079	0.028	0.005	0.017	0.004	0.233
2005	0.193	0.122	0.033	0.013	0.001	0.412	0.066	0.018	0.173	0.149	0.076	0.030	0.000	0.023	0.003	0.240
2006	0.228	0.128	0.033	0.023	0.000	0.465	0.071	0.011	0.238	0.008	0.103	0.037	0.002	0.022	0.007	0.257
2007	0.142	0.168	0.059	0.019	0.001	0.502	0.025	0.008	0.187	0.007	0.118	0.014	0.003	0.031	0.000	0.240
2008	0.153	0.080	0.023	0.038	0.006	0.533	0.053	0.019	0.220	0.077	0.107	0.027	0.002	0.043	0.001	0.259
2009	0.128	0.113	0.023	0.056	0.003	0.606	0.055	0.016	0.219	0.089	0.124	0.025	0.001	0.009	0.010	0.273
2010	0.154	0.082	0.019	0.047	0.010	0.448	0.023	0.014	0.116	0.086	0.124	0.021	0.002	0.026	0.013	0.216
2011	0.160	0.169	0.026	0.034	0.005	0.242	0.234	0.064	0.127	0.059	0.134	0.022	0.008	0.028	0.006	0.243

Table 2.19e—Estimates of seasonal full-selection fishing mortality rates, expressed on an annual time scale (Model 4). Sea1=Jan-Feb, Sea2=Mar-Apr, Sea3=May-Jul, Sea4=Aug-Oct, Sea5=Nov-Dec. Rates have been multiplied by relative season length before summing to get total.

	Trawl fishery					Longline fishery					Pot fishery					
Year	Sea1	Sea2	Sea3	Sea4	Sea5	Sea1	Sea2	Sea3	Sea4	Sea5	Sea1	Sea2	Sea3	Sea4	Sea5	Total
1977	0.070	0.075	0.046	0.041	0.035	0.014	0.014	0.005	0.020	0.026	0	0	0	0	0	0.067
1978	0.081	0.086	0.056	0.047	0.042	0.014	0.015	0.005	0.022	0.029	0	0	0	0	0	0.077
1979	0.059	0.062	0.037	0.034	0.028	0.011	0.011	0.004	0.016	0.021	0	0	0	0	0	0.055
1980	0.053	0.053	0.026	0.033	0.028	0.009	0.009	0.003	0.012	0.015	0	0	0	0	0	0.046
1981	0.028	0.028	0.027	0.052	0.049	0.003	0.003	0.002	0.007	0.009	0	0	0	0	0	0.042
1982	0.029	0.030	0.031	0.037	0.029	0.001	0.001	0.001	0.003	0.004	0	0	0	0	0	0.033
1983	0.046	0.049	0.044	0.044	0.037	0.004	0.004	0.002	0.004	0.004	0	0	0	0	0	0.048
1984	0.052	0.058	0.050	0.048	0.041	0.006	0.007	0.005	0.024	0.033	0	0	0	0	0	0.065
1985	0.067	0.074	0.059	0.057	0.044	0.021	0.023	0.009	0.030	0.042	0	0	0	0	0	0.084
1986	0.076	0.083	0.060	0.058	0.046	0.015	0.017	0.005	0.024	0.034	0	0	0	0	0	0.082
1987	0.084	0.093	0.048	0.048	0.046	0.037	0.041	0.011	0.038	0.054	0	0	0	0	0	0.095
1988	0.170	0.190	0.092	0.101	0.106	0.001	0.001	0.001	0.003	0.003	0	0	0	0	0	0.128
1989	0.182	0.204	0.091	0.053	0.048	0.007	0.008	0.011	0.013	0.012	0.000	0.000	0.000	0.000	0.000	0.119
1990	0.154	0.176	0.085	0.027	0.023	0.028	0.032	0.043	0.047	0.042	0.000	0.000	0.002	0.002	0.001	0.128
1991	0.159	0.350	0.062	0.044	0.000	0.055	0.098	0.080	0.091	0.098	0.000	0.000	0.002	0.010	0.004	0.200
1992	0.131	0.206	0.051	0.030	0.009	0.120	0.223	0.130	0.084	0.000	0.000	0.001	0.028	0.010	0.000	0.198
1993	0.166	0.235	0.025	0.034	0.010	0.201	0.212	0.025	0.000	0.000	0.000	0.010	0.006	0.000	0.000	0.162
1994	0.076	0.269	0.017	0.069	0.013	0.171	0.244	0.027	0.094	0.000	0.000	0.028	0.009	0.014	0.000	0.191
1995	0.188	0.387	0.005	0.176	0.001	0.221	0.287	0.019	0.097	0.052	0.001	0.071	0.036	0.014	0.009	0.289
1996	0.126	0.336	0.033	0.095	0.019	0.213	0.241	0.017	0.107	0.021	0.000	0.115	0.050	0.020	0.005	0.260
1997	0.156	0.363	0.022	0.087	0.021	0.239	0.260	0.038	0.103	0.174	0.000	0.089	0.037	0.019	0.005	0.294
1998	0.109	0.206	0.020	0.124	0.014	0.262	0.194	0.021	0.085	0.105	0.000	0.058	0.031	0.010	0.000	0.231
1999	0.131	0.196	0.014	0.057	0.003	0.301	0.220	0.018	0.110	0.038	0.000	0.057	0.031	0.011	0.000	0.218
2000	0.146	0.197	0.017	0.026	0.003	0.265	0.075	0.007	0.114	0.124	0.118	0.045	0.000	0.000	0.000	0.203
2001	0.060	0.107	0.013	0.033	0.004	0.150	0.137	0.017	0.143	0.136	0.001	0.105	0.003	0.016	0.003	0.174
2002	0.091	0.160	0.028	0.033	0.001	0.278	0.126	0.008	0.167	0.100	0.016	0.080	0.005	0.013	0.005	0.206
2003	0.111	0.123	0.025	0.028	0.000	0.281	0.093	0.000	0.156	0.102	0.121	0.016	0.000	0.021	0.009	0.200
2004	0.146	0.130	0.037	0.035	0.000	0.289	0.142	0.012	0.151	0.145	0.076	0.027	0.004	0.016	0.004	0.224
2005	0.185	0.117	0.032	0.013	0.001	0.395	0.063	0.017	0.167	0.143	0.073	0.029	0.000	0.022	0.003	0.231
2006	0.219	0.123	0.032	0.022	0.000	0.447	0.068	0.011	0.229	0.008	0.099	0.036	0.002	0.022	0.006	0.247
2007	0.136	0.161	0.056	0.018	0.001	0.481	0.024	0.008	0.180	0.007	0.113	0.014	0.003	0.030	0.000	0.230
2008	0.146	0.077	0.022	0.036	0.005	0.508	0.050	0.018	0.210	0.073	0.102	0.026	0.002	0.041	0.001	0.247
2009	0.121	0.106	0.022	0.053	0.003	0.572	0.052	0.015	0.207	0.084	0.117	0.024	0.001	0.008	0.009	0.258
2010	0.145	0.077	0.018	0.045	0.009	0.422	0.022	0.014	0.111	0.082	0.116	0.020	0.002	0.025	0.012	0.205
2011	0.153	0.162	0.025	0.033	0.004	0.233	0.226	0.062	0.124	0.057	0.128	0.021	0.007	0.027	0.006	0.234

Table 2.20—Summary of key management reference points from the standard projection algorithm (last seven rows are from SS). All biomass figures are in t. Green = row minimum, pink = row maximum.

Quantity	Model 1	Model 2b	Model 3	Model 3b	Model 4
B100%	919,000	842,000	856,000	889,000	913,000
B40%	367,000	337,000	342,000	355,000	365,000
B35%	322,000	295,000	300,000	311,000	319,000
B(2012)	384,000	354,000	370,000	410,000	421,000
B(2013)	402,000	384,000	399,000	437,000	444,000
B(2012)/B100%	0.42	0.42	0.43	0.46	0.46
B(2013)/B100%	0.44	0.46	0.47	0.49	0.49
F40%	0.29	0.29	0.28	0.30	0.30
F35%	0.35	0.35	0.34	0.36	0.36
maxFABC(2012)	0.29	0.29	0.28	0.30	0.30
maxFABC(2013)	0.29	0.29	0.28	0.30	0.30
maxABC(2012)	275,000	245,000	266,000	314,000	322,000
maxABC(2013)	275,000	252,000	272,000	319,000	324,000
FOFL(2012)	0.35	0.35	0.34	0.36	0.36
FOFL(2013)	0.35	0.35	0.34	0.36	0.36
OFL(2012)	323,000	288,000	313,000	369,000	378,000
OFL(2013)	323,000	297,000	319,000	374,000	380,000
Pr(maxABC(2012)>truOFL(2012))	0.004	0.005	0.005	0.003	0.004
Pr(maxABC(2013)>truOFL(2013))	0.016	0.005	0.017	0.014	0.018
Pr(B(2012)<B20%)	~0	~0	~0	~0	~0
Pr(B(2013)<B20%)	~0	~0	~0	~0	~0
Pr(B(2014)<B20%)	~0	~0	~0	~0	~0
Pr(B(2015)<B20%)	~0	~0	~0	~0	~0
Pr(B(2016)<B20%)	~0	~0	~0	~0	~0

Legend:
B100% = equilibrium unfished spawning biomass
B40% = 40% of B100% (the inflection point of the harvest control rules in Tier 3)
B35% = 35% of B100% (the BMSY proxy for Tier 3)
B(year) = projected spawning biomass for year (assuming catch = maxABC)
B(year)/B100% = ratio of spawning biomass to B100%
F40% = fishing mortality that reduces equilibrium spawning per recruit to 40% of unfished
F35% = fishing mortality that reduces equilibrium spawning per recruit to 35% of unfished
maxFABC(year) = maximum permissible ABC fishing mortality rate under Tier 3
maxABC(year) = maximum permissible ABC under Tier 3
FOFL(year) = OFL fishing mortality rate under Tier 3
OFL(year) = OFL under Tier 3 (second year assumes catch = maxABC in first year)
Pr(maxABC(year)>truOFL(year)) = probability that maxABC is greater than the "true" OFL
Pr(B(year)<B20%) = probability that spawning biomass is less than 20% of unfished

Table 2.21—Spawning biomass retrospective statistics for each of the five models. For average (across five retrospective years) and end-year bias, blue = row value closes to zero, yellow = row value furthest from zero. For root mean squared error, green = row minimum, pink = row maximum.

	Average bias									
	Relative to subsequent run					Relative to current run				
Retro	M1	M2b	M3	M3b	M4	M1	M2b	M3	M3b	M4
1	-0.022	-0.004	0.004	0.019	0.026	-0.022	-0.004	0.004	0.019	0.026
2	0.040	0.046	0.054	0.076	0.081	0.017	0.042	0.059	0.097	0.111
3	0.025	-0.026	-0.006	0.004	-0.009	0.046	0.018	0.055	0.104	0.103
4	0.083	0.080	0.103	0.063	0.083	0.133	0.098	0.161	0.173	0.194
5	0.061	0.071	0.119	0.017	0.023	0.191	0.157	0.281	0.180	0.208
Mean:	0.037	0.033	0.055	0.036	0.041	0.073	0.062	0.112	0.115	0.129

	End-year bias									
	Relative to subsequent run					Relative to current run				
Retro	M1	M2b	M3	M3b	M4	M1	M2b	M3	M3b	M4
1	-0.040	-0.018	-0.008	-0.008	-0.003	-0.040	-0.018	-0.008	-0.008	-0.003
2	-0.062	-0.040	0.004	0.028	0.042	-0.092	-0.052	0.001	0.028	0.049
3	0.132	0.127	0.134	0.123	0.095	0.097	0.138	0.193	0.210	0.205
4	0.172	0.216	0.232	0.207	0.227	0.340	0.431	0.505	0.498	0.521
5	-0.045	-0.058	0.007	-0.027	-0.026	0.294	0.341	0.503	0.446	0.474
Mean:	0.031	0.045	0.074	0.065	0.067	0.120	0.168	0.239	0.235	0.249

	Root mean squared error									
	Relative to subsequent run					Relative to current run				
Retro	M1	M2b	M3	M3b	M4	M1	M2b	M3	M3b	M4
1	0.027	0.008	0.005	0.021	0.028	0.027	0.008	0.005	0.021	0.028
2	0.047	0.053	0.058	0.079	0.085	0.030	0.049	0.062	0.102	0.115
3	0.054	0.078	0.061	0.053	0.051	0.072	0.083	0.093	0.121	0.121
4	0.091	0.095	0.114	0.082	0.098	0.162	0.165	0.207	0.214	0.233
5	0.101	0.111	0.152	0.033	0.038	0.205	0.174	0.302	0.202	0.227
Mean:	0.064	0.069	0.078	0.054	0.060	0.100	0.096	0.134	0.132	0.145

Table 2.22—Age 0 recruitment (as assessed at age 1) retrospective statistics for each of the five models. For average (across five retrospective years) and end-year bias, blue = row value closes to zero, yellow = row value furthest from zero. For root mean squared error, green = row minimum, pink = row maximum.

	Average bias									
	Relative to subsequent run					Relative to current run				
Retro	M1	M2b	M3	M3b	M4	M1	M2b	M3	M3b	M4
1	0.003	-0.003	0.007	0.010	0.019	0.003	-0.003	0.007	0.010	0.019
2	0.002	0.009	0.019	0.030	0.035	-0.012	0.000	0.012	0.037	0.044
3	0.109	0.017	0.020	0.018	0.010	0.104	0.019	0.035	0.057	0.061
4	0.064	0.075	0.072	0.062	0.071	0.090	0.097	0.101	0.113	0.119
5	0.072	0.045	0.047	0.023	0.024	0.127	0.101	0.134	0.119	0.132
Mean:	0.050	0.029	0.033	0.029	0.032	0.063	0.043	0.058	0.067	0.075

	End-year bias									
	Relative to subsequent run					Relative to current run				
Retro	M1	M2b	M3	M3b	M4	M1	M2b	M3	M3b	M4
1	0.558	0.162	0.418	0.165	0.391	0.558	0.162	0.418	0.165	0.391
2	0.037	0.216	0.228	0.020	-0.042	-0.175	-0.042	-0.049	-0.084	-0.172
3	2.442	0.084	0.145	-0.043	-0.002	2.508	0.026	0.225	0.389	0.540
4	0.712	1.017	0.718	0.572	0.510	0.512	0.923	0.481	0.618	0.447
5	1.724	0.906	0.514	0.630	0.586	0.766	0.176	0.307	0.737	0.675
Mean:	1.095	0.477	0.405	0.269	0.289	0.834	0.249	0.276	0.365	0.376

	Root mean squared error									
	Relative to subsequent run					Relative to current run				
Retro	M1	M2b	M3	M3b	M4	M1	M2b	M3	M3b	M4
1	0.105	0.047	0.083	0.042	0.078	0.105	0.047	0.083	0.042	0.078
2	0.061	0.069	0.061	0.072	0.083	0.076	0.063	0.052	0.101	0.121
3	0.441	0.049	0.047	0.053	0.048	0.459	0.083	0.077	0.098	0.121
4	0.146	0.199	0.146	0.121	0.117	0.176	0.226	0.154	0.173	0.165
5	0.322	0.172	0.107	0.119	0.112	0.197	0.144	0.160	0.186	0.189
Mean:	0.215	0.107	0.089	0.081	0.088	0.203	0.113	0.105	0.120	0.135

Table 2.23 (page 1 of 8)—Schedules of Pacific cod selectivity at length (cm) in the commercial fisheries as defined by parameter estimates under Model 3b. Years correspond to beginnings of blocks.

	January-April trawl fishery						May-July trawl fishery				
Len.	1977	1985	1990	1995	2000	2005	1977	1985	1990	2000	2005
1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	0.000	0.001	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000
5	0.000	0.001	0.000	0.000	0.000	0.000	0.001	0.001	0.000	0.000	0.000
6	0.000	0.002	0.000	0.000	0.000	0.000	0.001	0.001	0.000	0.000	0.000
7	0.000	0.002	0.000	0.000	0.000	0.000	0.001	0.001	0.000	0.001	0.000
8	0.000	0.002	0.000	0.000	0.000	0.000	0.002	0.001	0.000	0.001	0.000
9	0.001	0.003	0.000	0.000	0.000	0.000	0.002	0.002	0.000	0.001	0.000
10	0.001	0.003	0.000	0.001	0.000	0.000	0.003	0.002	0.000	0.001	0.000
11	0.001	0.004	0.000	0.001	0.000	0.000	0.004	0.003	0.000	0.002	0.000
12	0.001	0.004	0.001	0.001	0.000	0.000	0.006	0.004	0.000	0.003	0.000
13	0.001	0.005	0.001	0.001	0.000	0.000	0.007	0.006	0.000	0.003	0.001
14	0.002	0.006	0.001	0.001	0.001	0.000	0.010	0.007	0.000	0.004	0.001
15	0.002	0.007	0.001	0.002	0.001	0.000	0.012	0.010	0.000	0.006	0.001
16	0.003	0.008	0.002	0.002	0.001	0.000	0.016	0.012	0.001	0.008	0.002
17	0.003	0.010	0.002	0.002	0.001	0.000	0.020	0.016	0.001	0.010	0.002
18	0.004	0.011	0.003	0.003	0.001	0.001	0.025	0.020	0.001	0.013	0.003
19	0.005	0.013	0.003	0.004	0.002	0.001	0.031	0.025	0.002	0.016	0.004
20	0.007	0.015	0.004	0.005	0.002	0.001	0.039	0.031	0.002	0.021	0.005
21	0.008	0.018	0.005	0.006	0.002	0.001	0.048	0.039	0.003	0.026	0.006
22	0.010	0.021	0.007	0.007	0.003	0.001	0.059	0.048	0.004	0.032	0.008
23	0.012	0.024	0.008	0.008	0.004	0.002	0.072	0.059	0.005	0.040	0.011
24	0.014	0.027	0.010	0.010	0.005	0.002	0.087	0.072	0.006	0.050	0.014
25	0.017	0.031	0.013	0.012	0.006	0.003	0.104	0.087	0.008	0.061	0.017
26	0.021	0.036	0.016	0.014	0.007	0.004	0.124	0.104	0.011	0.074	0.022
27	0.025	0.040	0.019	0.017	0.008	0.005	0.147	0.124	0.014	0.089	0.028
28	0.030	0.046	0.023	0.020	0.010	0.006	0.172	0.147	0.017	0.107	0.034
29	0.035	0.052	0.028	0.024	0.012	0.007	0.201	0.173	0.022	0.127	0.043
30	0.042	0.059	0.033	0.028	0.014	0.009	0.233	0.201	0.028	0.150	0.052
31	0.049	0.066	0.039	0.033	0.017	0.011	0.268	0.233	0.034	0.176	0.064
32	0.057	0.075	0.047	0.039	0.020	0.014	0.306	0.268	0.043	0.205	0.078
33	0.067	0.084	0.055	0.046	0.023	0.017	0.347	0.306	0.052	0.237	0.094
34	0.078	0.094	0.065	0.053	0.028	0.021	0.390	0.347	0.064	0.273	0.112
35	0.090	0.105	0.076	0.061	0.032	0.025	0.436	0.391	0.078	0.311	0.133
36	0.103	0.117	0.089	0.071	0.038	0.030	0.485	0.437	0.094	0.353	0.157
37	0.119	0.129	0.103	0.081	0.044	0.036	0.534	0.485	0.112	0.397	0.184
38	0.135	0.143	0.119	0.093	0.051	0.043	0.585	0.535	0.133	0.443	0.214
39	0.154	0.158	0.136	0.106	0.059	0.051	0.636	0.586	0.157	0.491	0.247
40	0.174	0.174	0.156	0.120	0.068	0.060	0.686	0.637	0.184	0.541	0.283
41	0.196	0.192	0.177	0.136	0.079	0.071	0.735	0.687	0.214	0.592	0.322
42	0.220	0.210	0.201	0.154	0.090	0.083	0.783	0.736	0.247	0.643	0.365
43	0.246	0.230	0.227	0.173	0.102	0.096	0.827	0.783	0.283	0.693	0.409
44	0.274	0.250	0.254	0.193	0.116	0.112	0.868	0.828	0.323	0.742	0.456
45	0.304	0.272	0.284	0.215	0.132	0.129	0.905	0.869	0.365	0.789	0.505
46	0.335	0.295	0.316	0.239	0.149	0.148	0.936	0.905	0.409	0.833	0.555
47	0.368	0.319	0.350	0.265	0.167	0.169	0.962	0.936	0.456	0.873	0.606
48	0.403	0.344	0.385	0.292	0.187	0.192	0.981	0.962	0.505	0.909	0.657
49	0.439	0.371	0.423	0.321	0.208	0.217	0.994	0.981	0.555	0.940	0.707
50	0.476	0.398	0.461	0.351	0.232	0.245	1.000	0.994	0.606	0.965	0.756
51	0.514	0.426	0.501	0.383	0.256	0.274	1.000	1.000	0.657	0.983	0.802
52	0.553	0.454	0.542	0.416	0.283	0.306	1.000	1.000	0.707	0.995	0.845
53	0.593	0.484	0.583	0.450	0.311	0.339	1.000	1.000	0.756	1.000	0.884
54	0.632	0.514	0.624	0.485	0.340	0.375	1.000	1.000	0.802	1.000	0.918
55	0.672	0.545	0.666	0.521	0.371	0.412	1.000	1.000	0.845	1.000	0.947
56	0.710	0.575	0.707	0.558	0.404	0.451	1.000	1.000	0.884	1.000	0.970
57	0.748	0.606	0.746	0.594	0.437	0.491	1.000	1.000	0.918	1.000	0.987
58	0.784	0.637	0.784	0.631	0.472	0.532	1.000	1.000	0.947	1.000	0.997
59	0.819	0.668	0.821	0.668	0.507	0.574	1.000	1.000	0.971	1.000	1.000
60	0.852	0.698	0.855	0.705	0.543	0.615	1.000	1.000	0.987	1.000	1.000

Table 2.23 (page 2 of 8)—Schedules of Pacific cod selectivity at length (cm) in the commercial fisheries as defined by parameter estimates under Model 3b. Years correspond to beginnings of blocks.

	January-April trawl fishery						May-July trawl fishery				
Len.	1977	1985	1990	1995	2000	2005	1977	1985	1990	2000	2005
61	0.882	0.728	0.886	0.740	0.580	0.657	1.000	1.000	0.997	1.000	1.000
62	0.909	0.758	0.914	0.775	0.617	0.699	1.000	1.000	1.000	1.000	1.000
63	0.933	0.786	0.939	0.808	0.653	0.739	1.000	1.000	1.000	1.000	1.000
64	0.954	0.813	0.960	0.839	0.690	0.778	1.000	1.000	1.000	1.000	1.000
65	0.971	0.839	0.977	0.868	0.725	0.815	1.000	1.000	1.000	1.000	1.000
66	0.985	0.864	0.989	0.895	0.760	0.850	1.000	1.000	1.000	1.000	1.000
67	0.994	0.887	0.997	0.920	0.793	0.882	1.000	1.000	1.000	1.000	1.000
68	0.999	0.908	1.000	0.941	0.825	0.911	1.000	1.000	1.000	1.000	1.000
69	1.000	0.928	1.000	0.960	0.855	0.937	1.000	1.000	1.000	1.000	1.000
70	1.000	0.945	1.000	0.975	0.883	0.958	1.000	1.000	1.000	1.000	1.000
71	1.000	0.960	1.000	0.986	0.909	0.975	1.000	1.000	1.000	1.000	1.000
72	1.000	0.973	1.000	0.995	0.931	0.988	1.000	1.000	1.000	1.000	1.000
73	1.000	0.983	1.000	0.999	0.951	0.996	1.000	1.000	1.000	1.000	1.000
74	1.000	0.991	1.000	1.000	0.968	1.000	1.000	1.000	1.000	1.000	1.000
75	1.000	0.997	1.000	1.000	0.981	1.000	1.000	1.000	1.000	1.000	1.000
76	1.000	1.000	1.000	1.000	0.991	1.000	1.000	1.000	1.000	1.000	1.000
77	1.000	1.000	1.000	1.000	0.997	1.000	1.000	1.000	1.000	1.000	1.000
78	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
79	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
80	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
81	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
82	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
83	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
84	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
85	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
86	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
87	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
88	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
89	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
90	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
91	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
92	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
93	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
94	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
95	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
96	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
97	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
98	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
99	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
100	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
101	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
102	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
103	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
104	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
105	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
106	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
107	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
108	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
109	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
110	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
111	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
112	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
113	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
114	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
115	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
116	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
117	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
118	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
119	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
120	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Table 2.23 (page 3 of 8)—Schedules of Pacific cod selectivity at length (cm) in the commercial fisheries as defined by parameter estimates under Model 3b. Years correspond to beginnings of blocks.

	August-December trawl fishery						January-April longline fishery						
Len.	1977	1980	1985	1990	1995	2000	1977	1980	1985	1990	1995	2000	2005
1	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
2	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
3	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
4	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
5	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
7	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
8	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
9	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
10	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
11	0.000	0.002	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
12	0.000	0.002	0.001	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
13	0.000	0.002	0.001	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14	0.000	0.003	0.001	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
15	0.000	0.003	0.001	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
16	0.000	0.004	0.001	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
17	0.000	0.005	0.002	0.000	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000
18	0.001	0.005	0.002	0.000	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000
19	0.001	0.006	0.002	0.000	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000
20	0.001	0.008	0.003	0.000	0.002	0.002	0.000	0.001	0.000	0.000	0.000	0.000	0.000
21	0.001	0.009	0.003	0.000	0.003	0.002	0.000	0.001	0.000	0.000	0.000	0.000	0.000
22	0.002	0.010	0.004	0.000	0.003	0.003	0.000	0.001	0.000	0.000	0.000	0.000	0.000
23	0.003	0.012	0.005	0.000	0.003	0.004	0.001	0.001	0.000	0.000	0.000	0.000	0.000
24	0.003	0.014	0.005	0.000	0.004	0.005	0.001	0.002	0.001	0.000	0.000	0.001	0.000
25	0.005	0.016	0.006	0.000	0.005	0.007	0.001	0.002	0.001	0.000	0.000	0.001	0.000
26	0.006	0.019	0.007	0.000	0.005	0.009	0.002	0.003	0.001	0.000	0.000	0.001	0.000
27	0.008	0.022	0.009	0.000	0.006	0.012	0.003	0.004	0.001	0.000	0.001	0.002	0.000
28	0.011	0.025	0.010	0.000	0.007	0.015	0.004	0.005	0.002	0.000	0.001	0.003	0.001
29	0.014	0.028	0.012	0.000	0.008	0.019	0.006	0.006	0.002	0.001	0.001	0.004	0.001
30	0.018	0.032	0.014	0.000	0.009	0.025	0.008	0.008	0.003	0.001	0.002	0.005	0.001
31	0.023	0.037	0.016	0.000	0.010	0.031	0.011	0.010	0.004	0.001	0.002	0.007	0.002
32	0.029	0.042	0.018	0.001	0.011	0.038	0.016	0.012	0.005	0.002	0.003	0.009	0.003
33	0.036	0.048	0.021	0.002	0.013	0.048	0.021	0.015	0.006	0.003	0.005	0.013	0.004
34	0.045	0.054	0.024	0.005	0.015	0.058	0.028	0.019	0.008	0.004	0.007	0.017	0.005
35	0.056	0.061	0.028	0.011	0.017	0.071	0.038	0.023	0.010	0.006	0.009	0.022	0.007
36	0.069	0.069	0.032	0.025	0.019	0.086	0.049	0.028	0.013	0.008	0.012	0.028	0.009
37	0.084	0.078	0.037	0.050	0.021	0.104	0.064	0.034	0.016	0.011	0.016	0.037	0.012
38	0.102	0.087	0.042	0.096	0.024	0.124	0.082	0.041	0.020	0.015	0.022	0.047	0.016
39	0.122	0.097	0.048	0.168	0.027	0.146	0.104	0.049	0.024	0.020	0.028	0.059	0.021
40	0.146	0.108	0.054	0.273	0.030	0.172	0.131	0.059	0.029	0.026	0.037	0.074	0.028
41	0.173	0.120	0.061	0.411	0.033	0.201	0.162	0.070	0.036	0.034	0.047	0.092	0.036
42	0.203	0.134	0.069	0.573	0.037	0.233	0.198	0.083	0.043	0.045	0.060	0.113	0.046
43	0.236	0.148	0.077	0.739	0.041	0.269	0.239	0.097	0.052	0.058	0.076	0.138	0.058
44	0.273	0.163	0.087	0.883	0.046	0.307	0.285	0.113	0.062	0.074	0.095	0.167	0.073
45	0.314	0.179	0.097	0.976	0.051	0.348	0.337	0.132	0.074	0.093	0.118	0.199	0.091
46	0.357	0.197	0.108	1.000	0.057	0.393	0.393	0.153	0.088	0.116	0.144	0.236	0.112
47	0.404	0.216	0.120	1.000	0.063	0.439	0.453	0.175	0.104	0.143	0.174	0.277	0.137
48	0.453	0.235	0.133	1.000	0.069	0.488	0.517	0.201	0.121	0.175	0.209	0.322	0.166
49	0.504	0.256	0.148	1.000	0.076	0.538	0.582	0.228	0.141	0.211	0.248	0.371	0.198
50	0.556	0.278	0.163	1.000	0.084	0.589	0.648	0.259	0.163	0.252	0.292	0.424	0.235
51	0.609	0.302	0.179	1.000	0.092	0.640	0.713	0.291	0.188	0.298	0.340	0.479	0.276
52	0.662	0.326	0.197	1.000	0.101	0.691	0.775	0.326	0.215	0.349	0.392	0.536	0.321
53	0.715	0.351	0.216	1.000	0.110	0.741	0.832	0.363	0.245	0.404	0.447	0.595	0.370
54	0.765	0.378	0.236	1.000	0.121	0.788	0.884	0.402	0.277	0.462	0.505	0.653	0.423
55	0.813	0.405	0.257	1.000	0.132	0.833	0.927	0.443	0.311	0.523	0.565	0.711	0.478
56	0.857	0.433	0.279	1.000	0.143	0.873	0.961	0.485	0.348	0.585	0.625	0.767	0.536
57	0.896	0.462	0.302	1.000	0.155	0.909	0.985	0.528	0.387	0.649	0.685	0.819	0.595
58	0.930	0.492	0.327	1.000	0.169	0.940	0.998	0.572	0.428	0.711	0.744	0.867	0.653
59	0.958	0.522	0.353	1.000	0.182	0.965	1.000	0.617	0.471	0.770	0.799	0.909	0.712
60	0.979	0.552	0.379	1.000	0.197	0.984	1.000	0.662	0.515	0.826	0.850	0.944	0.767

Table 2.23 (page 4 of 8)—Schedules of Pacific cod selectivity at length (cm) in the commercial fisheries as defined by parameter estimates under Model 3b. Years correspond to beginnings of blocks.

	August-December trawl fishery						January-April longline fishery						
Len.	1977	1980	1985	1990	1995	2000	1977	1980	1985	1990	1995	2000	2005
61	0.993	0.583	0.407	1.000	0.213	0.995	0.994	0.705	0.560	0.876	0.896	0.971	0.820
62	1.000	0.614	0.435	1.000	0.229	1.000	0.979	0.748	0.606	0.919	0.934	0.989	0.868
63	1.000	0.645	0.464	1.000	0.246	1.000	0.956	0.789	0.651	0.954	0.964	0.999	0.910
64	1.000	0.676	0.494	1.000	0.264	1.000	0.924	0.828	0.696	0.980	0.986	1.000	0.944
65	1.000	0.706	0.524	1.000	0.283	1.000	0.885	0.864	0.740	0.995	0.998	1.000	0.971
66	1.000	0.736	0.555	1.000	0.302	1.000	0.840	0.896	0.782	1.000	1.000	0.994	0.990
67	1.000	0.765	0.586	1.000	0.322	1.000	0.792	0.925	0.822	1.000	1.000	0.978	0.999
68	1.000	0.793	0.617	1.000	0.343	1.000	0.740	0.950	0.860	0.998	0.996	0.954	1.000
69	1.000	0.820	0.648	1.000	0.365	1.000	0.687	0.970	0.893	0.988	0.984	0.923	1.000
70	1.000	0.845	0.678	1.000	0.387	1.000	0.634	0.985	0.923	0.972	0.964	0.885	0.993
71	1.000	0.869	0.709	1.000	0.410	1.000	0.582	0.995	0.949	0.949	0.937	0.841	0.978
72	1.000	0.892	0.739	1.000	0.433	1.000	0.533	1.000	0.969	0.920	0.905	0.794	0.954
73	1.000	0.913	0.768	1.000	0.458	1.000	0.486	1.000	0.985	0.887	0.867	0.744	0.924
74	1.000	0.932	0.796	1.000	0.482	1.000	0.443	1.000	0.995	0.850	0.826	0.693	0.887
75	1.000	0.949	0.823	1.000	0.507	1.000	0.404	0.995	1.000	0.810	0.782	0.642	0.845
76	1.000	0.963	0.848	1.000	0.532	1.000	0.369	0.985	1.000	0.769	0.737	0.592	0.799
77	1.000	0.975	0.872	1.000	0.558	1.000	0.339	0.971	0.999	0.728	0.692	0.544	0.751
78	1.000	0.985	0.895	1.000	0.583	1.000	0.313	0.953	0.990	0.687	0.648	0.500	0.702
79	1.000	0.993	0.916	1.000	0.609	1.000	0.290	0.931	0.972	0.647	0.606	0.459	0.652
80	1.000	0.998	0.934	1.000	0.635	1.000	0.272	0.906	0.945	0.610	0.566	0.421	0.605
81	1.000	1.000	0.951	1.000	0.660	1.000	0.256	0.879	0.910	0.576	0.529	0.388	0.559
82	1.000	1.000	0.965	1.000	0.686	1.000	0.244	0.851	0.869	0.545	0.496	0.359	0.516
83	1.000	1.000	0.977	1.000	0.711	1.000	0.234	0.823	0.823	0.516	0.466	0.335	0.477
84	1.000	1.000	0.987	1.000	0.736	1.000	0.226	0.794	0.773	0.492	0.440	0.313	0.441
85	1.000	1.000	0.994	1.000	0.760	1.000	0.220	0.767	0.721	0.470	0.417	0.296	0.410
86	1.000	1.000	0.998	1.000	0.783	1.000	0.215	0.741	0.668	0.452	0.398	0.281	0.382
87	1.000	1.000	1.000	1.000	0.806	1.000	0.211	0.716	0.615	0.437	0.382	0.269	0.358
88	1.000	1.000	1.000	1.000	0.828	1.000	0.209	0.694	0.564	0.424	0.369	0.260	0.338
89	1.000	1.000	1.000	1.000	0.849	1.000	0.207	0.673	0.515	0.413	0.358	0.252	0.322
90	1.000	1.000	1.000	1.000	0.869	1.000	0.205	0.655	0.470	0.405	0.349	0.247	0.308
91	1.000	1.000	1.000	1.000	0.888	1.000	0.204	0.640	0.428	0.398	0.342	0.242	0.297
92	1.000	1.000	1.000	1.000	0.906	1.000	0.203	0.626	0.391	0.393	0.337	0.239	0.288
93	1.000	1.000	1.000	1.000	0.922	1.000	0.203	0.615	0.358	0.389	0.333	0.236	0.280
94	1.000	1.000	1.000	1.000	0.937	1.000	0.203	0.606	0.329	0.386	0.330	0.234	0.275
95	1.000	1.000	1.000	1.000	0.951	1.000	0.202	0.598	0.304	0.384	0.327	0.233	0.271
96	1.000	1.000	1.000	1.000	0.963	1.000	0.202	0.591	0.283	0.382	0.326	0.232	0.268
97	1.000	1.000	1.000	1.000	0.973	1.000	0.202	0.586	0.265	0.381	0.324	0.231	0.265
98	1.000	1.000	1.000	1.000	0.982	1.000	0.202	0.582	0.251	0.380	0.324	0.231	0.263
99	1.000	1.000	1.000	1.000	0.989	1.000	0.202	0.579	0.240	0.379	0.323	0.231	0.262
100	1.000	1.000	1.000	1.000	0.995	1.000	0.202	0.577	0.230	0.379	0.322	0.230	0.261
101	1.000	1.000	1.000	1.000	0.998	1.000	0.202	0.575	0.223	0.378	0.322	0.230	0.261
102	1.000	1.000	1.000	1.000	1.000	1.000	0.202	0.574	0.217	0.378	0.322	0.230	0.260
103	1.000	1.000	1.000	1.000	1.000	1.000	0.202	0.573	0.213	0.378	0.322	0.230	0.260
104	1.000	1.000	1.000	1.000	1.000	1.000	0.202	0.572	0.210	0.378	0.322	0.230	0.260
105	1.000	1.000	1.000	1.000	1.000	1.000	0.202	0.572	0.207	0.378	0.322	0.230	0.259
106	1.000	1.000	1.000	1.000	1.000	1.000	0.202	0.571	0.206	0.378	0.322	0.230	0.259
107	1.000	1.000	1.000	1.000	1.000	1.000	0.202	0.571	0.204	0.378	0.322	0.230	0.259
108	1.000	1.000	1.000	1.000	1.000	1.000	0.202	0.571	0.203	0.378	0.321	0.230	0.259
109	1.000	1.000	1.000	1.000	1.000	1.000	0.202	0.571	0.203	0.378	0.321	0.230	0.259
110	1.000	1.000	1.000	1.000	1.000	1.000	0.202	0.571	0.202	0.378	0.321	0.230	0.259
111	1.000	1.000	1.000	1.000	1.000	1.000	0.202	0.571	0.202	0.378	0.321	0.230	0.259
112	1.000	1.000	1.000	1.000	1.000	1.000	0.202	0.571	0.202	0.378	0.321	0.230	0.259
113	1.000	1.000	1.000	1.000	1.000	1.000	0.202	0.571	0.202	0.378	0.321	0.230	0.259
114	1.000	1.000	1.000	1.000	1.000	1.000	0.202	0.571	0.202	0.378	0.321	0.230	0.259
115	1.000	1.000	1.000	1.000	1.000	1.000	0.202	0.571	0.202	0.378	0.321	0.230	0.259
116	1.000	1.000	1.000	1.000	1.000	1.000	0.202	0.571	0.202	0.378	0.321	0.230	0.259
117	1.000	1.000	1.000	1.000	1.000	1.000	0.202	0.571	0.201	0.378	0.321	0.230	0.259
118	1.000	1.000	1.000	1.000	1.000	1.000	0.202	0.571	0.201	0.378	0.321	0.230	0.259
119	1.000	1.000	1.000	1.000	1.000	1.000	0.202	0.571	0.201	0.378	0.321	0.230	0.259
120	1.000	1.000	1.000	1.000	1.000	1.000	0.202	0.571	0.201	0.378	0.321	0.230	0.259

Table 2.23 (page 5 of 8)—Schedules of Pacific cod selectivity at length (cm) in the commercial fisheries as defined by parameter estimates under Model 3b. Years correspond to beginnings of blocks.

	May-July longline fishery						August-December longline fishery						
Len.	1977	1980	1985	1990	2000	2005	1977	1980	1985	1990	1995	2000	2005
1	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
2	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
3	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
4	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
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
6	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
7	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
8	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
9	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
10	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
11	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
12	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	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
14	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
15	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	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
17	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
18	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	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
20	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
21	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	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
23	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
24	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	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
26	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
27	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.000
28	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.000
29	0.000	0.001	0.000	0.000	0.002	0.000	0.000	0.001	0.000	0.000	0.001	0.001	0.000
30	0.001	0.001	0.001	0.001	0.003	0.000	0.000	0.001	0.000	0.000	0.002	0.002	0.000
31	0.001	0.001	0.001	0.001	0.004	0.001	0.000	0.001	0.000	0.000	0.002	0.003	0.001
32	0.002	0.002	0.001	0.001	0.006	0.001	0.000	0.002	0.000	0.000	0.003	0.004	0.001
33	0.002	0.003	0.002	0.002	0.008	0.001	0.000	0.002	0.001	0.001	0.004	0.005	0.002
34	0.003	0.005	0.003	0.003	0.012	0.002	0.000	0.003	0.001	0.001	0.006	0.007	0.003
35	0.005	0.007	0.005	0.004	0.016	0.003	0.001	0.005	0.001	0.001	0.008	0.010	0.004
36	0.007	0.009	0.007	0.006	0.022	0.005	0.001	0.006	0.002	0.002	0.011	0.014	0.006
37	0.010	0.013	0.010	0.009	0.031	0.007	0.002	0.008	0.003	0.003	0.014	0.019	0.008
38	0.015	0.019	0.014	0.013	0.041	0.010	0.004	0.011	0.005	0.004	0.018	0.025	0.012
39	0.021	0.026	0.019	0.018	0.055	0.014	0.006	0.015	0.008	0.006	0.023	0.033	0.017
40	0.028	0.035	0.027	0.025	0.072	0.020	0.010	0.019	0.011	0.009	0.029	0.044	0.024
41	0.038	0.047	0.036	0.034	0.094	0.028	0.015	0.025	0.016	0.012	0.037	0.057	0.034
42	0.051	0.062	0.048	0.046	0.120	0.037	0.023	0.032	0.022	0.017	0.047	0.073	0.046
43	0.067	0.081	0.064	0.061	0.151	0.050	0.035	0.041	0.031	0.024	0.058	0.092	0.062
44	0.088	0.104	0.083	0.079	0.188	0.066	0.051	0.052	0.042	0.032	0.072	0.115	0.082
45	0.112	0.133	0.107	0.102	0.231	0.086	0.073	0.065	0.057	0.043	0.088	0.143	0.106
46	0.142	0.167	0.136	0.130	0.280	0.110	0.102	0.081	0.076	0.057	0.107	0.176	0.137
47	0.178	0.206	0.171	0.163	0.335	0.140	0.139	0.099	0.099	0.074	0.129	0.213	0.173
48	0.219	0.252	0.211	0.202	0.395	0.175	0.185	0.121	0.128	0.096	0.154	0.255	0.216
49	0.266	0.303	0.257	0.247	0.460	0.216	0.242	0.146	0.163	0.122	0.183	0.303	0.266
50	0.320	0.360	0.309	0.298	0.528	0.263	0.308	0.175	0.204	0.153	0.216	0.355	0.322
51	0.378	0.423	0.367	0.355	0.598	0.316	0.384	0.208	0.252	0.189	0.252	0.411	0.384
52	0.442	0.489	0.430	0.417	0.668	0.374	0.467	0.244	0.306	0.232	0.291	0.471	0.451
53	0.509	0.558	0.497	0.483	0.737	0.437	0.557	0.285	0.366	0.280	0.334	0.534	0.522
54	0.579	0.628	0.566	0.551	0.801	0.504	0.648	0.330	0.432	0.334	0.381	0.598	0.596
55	0.649	0.698	0.636	0.622	0.860	0.574	0.737	0.378	0.502	0.393	0.430	0.663	0.669
56	0.718	0.765	0.706	0.692	0.910	0.644	0.820	0.429	0.575	0.456	0.481	0.726	0.741
57	0.784	0.827	0.772	0.759	0.951	0.713	0.891	0.483	0.649	0.523	0.535	0.786	0.809
58	0.845	0.883	0.834	0.822	0.980	0.780	0.947	0.538	0.722	0.591	0.589	0.841	0.869
59	0.898	0.929	0.888	0.878	0.996	0.841	0.984	0.595	0.790	0.660	0.644	0.890	0.920
60	0.941	0.965	0.934	0.925	1.000	0.894	1.000	0.652	0.853	0.728	0.698	0.932	0.960

Table 2.23 (page 6 of 8)—Schedules of Pacific cod selectivity at length (cm) in the commercial fisheries as defined by parameter estimates under Model 3b. Years correspond to beginnings of blocks.

May-July longline fishery						August-December longline fishery						
1977	1980	1985	1990	2000	2005	1977	1980	1985	1990	1995	2000	2005
0.973	0.989	0.968	0.962	1.000	0.938	1.000	0.709	0.907	0.792	0.751	0.964	0.987
0.993	0.999	0.991	0.987	1.000	0.971	1.000	0.763	0.950	0.851	0.801	0.987	0.999
1.000	1.000	1.000	0.999	1.000	0.992	1.000	0.814	0.981	0.902	0.847	0.998	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.861	0.997	0.944	0.889	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.903	1.000	0.975	0.925	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.938	1.000	0.994	0.955	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.966	1.000	1.000	0.977	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	0.994	0.986	1.000	1.000	0.992	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	0.979	0.997	1.000	1.000	0.999	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	0.954	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	0.921	1.000	1.000	1.000	1.000	0.996	1.000
1.000	1.000	1.000	1.000	1.000	1.000	0.880	1.000	0.997	1.000	1.000	0.987	1.000
1.000	1.000	1.000	1.000	1.000	1.000	0.833	1.000	0.990	1.000	1.000	0.971	1.000
1.000	1.000	1.000	1.000	1.000	1.000	0.780	1.000	0.977	1.000	1.000	0.949	1.000
1.000	1.000	1.000	1.000	1.000	1.000	0.724	1.000	0.961	0.998	1.000	0.923	1.000
1.000	1.000	1.000	1.000	1.000	1.000	0.666	1.000	0.941	0.996	1.000	0.893	1.000
1.000	1.000	1.000	1.000	1.000	1.000	0.607	0.995	0.918	0.993	1.000	0.859	1.000
1.000	1.000	1.000	1.000	1.000	1.000	0.549	0.986	0.892	0.989	1.000	0.823	1.000
1.000	1.000	1.000	1.000	1.000	1.000	0.492	0.973	0.865	0.985	1.000	0.786	1.000
1.000	1.000	1.000	1.000	1.000	1.000	0.438	0.955	0.836	0.980	1.000	0.748	1.000
1.000	1.000	1.000	1.000	1.000	1.000	0.386	0.934	0.807	0.975	1.000	0.710	1.000
1.000	1.000	1.000	1.000	1.000	1.000	0.339	0.910	0.778	0.970	1.000	0.673	1.000
1.000	1.000	1.000	1.000	1.000	1.000	0.296	0.884	0.750	0.964	1.000	0.638	1.000
1.000	1.000	1.000	1.000	1.000	1.000	0.257	0.857	0.724	0.959	1.000	0.605	1.000
1.000	1.000	1.000	1.000	1.000	1.000	0.223	0.828	0.698	0.954	1.000	0.575	1.000
1.000	1.000	1.000	1.000	1.000	1.000	0.193	0.799	0.675	0.949	1.000	0.547	1.000
1.000	1.000	1.000	1.000	1.000	1.000	0.167	0.771	0.654	0.944	1.000	0.522	1.000
1.000	1.000	1.000	1.000	1.000	1.000	0.145	0.744	0.635	0.940	1.000	0.500	1.000
1.000	1.000	1.000	1.000	1.000	1.000	0.127	0.718	0.618	0.936	1.000	0.481	1.000
1.000	1.000	1.000	1.000	1.000	1.000	0.112	0.694	0.603	0.932	1.000	0.464	1.000
1.000	1.000	1.000	1.000	1.000	1.000	0.099	0.671	0.591	0.929	1.000	0.450	1.000
1.000	1.000	1.000	1.000	1.000	1.000	0.089	0.651	0.580	0.926	1.000	0.438	1.000
1.000	1.000	1.000	1.000	1.000	1.000	0.081	0.633	0.571	0.924	1.000	0.428	1.000
1.000	1.000	1.000	1.000	1.000	1.000	0.075	0.617	0.563	0.921	1.000	0.420	1.000
1.000	1.000	1.000	1.000	1.000	1.000	0.070	0.603	0.557	0.920	1.000	0.414	1.000
1.000	1.000	1.000	1.000	1.000	1.000	0.066	0.591	0.552	0.918	1.000	0.409	1.000
1.000	1.000	1.000	1.000	1.000	1.000	0.063	0.581	0.548	0.917	1.000	0.405	1.000
1.000	1.000	1.000	1.000	1.000	1.000	0.061	0.573	0.545	0.916	1.000	0.401	1.000
1.000	1.000	1.000	1.000	1.000	1.000	0.059	0.566	0.543	0.915	1.000	0.399	1.000
1.000	1.000	1.000	1.000	1.000	1.000	0.058	0.560	0.541	0.915	1.000	0.397	1.000
1.000	1.000	1.000	1.000	1.000	1.000	0.057	0.556	0.540	0.914	1.000	0.396	1.000
1.000	1.000	1.000	1.000	1.000	1.000	0.057	0.552	0.539	0.914	1.000	0.395	1.000
1.000	1.000	1.000	1.000	1.000	1.000	0.056	0.549	0.538	0.914	1.000	0.394	1.000
1.000	1.000	1.000	1.000	1.000	1.000	0.056	0.547	0.537	0.913	1.000	0.393	1.000
1.000	1.000	1.000	1.000	1.000	1.000	0.056	0.546	0.537	0.913	1.000	0.393	1.000
1.000	1.000	1.000	1.000	1.000	1.000	0.055	0.544	0.536	0.913	1.000	0.393	1.000
1.000	1.000	1.000	1.000	1.000	1.000	0.055	0.543	0.536	0.913	1.000	0.392	1.000
1.000	1.000	1.000	1.000	1.000	1.000	0.055	0.543	0.536	0.913	1.000	0.392	1.000
1.000	1.000	1.000	1.000	1.000	1.000	0.055	0.542	0.536	0.913	1.000	0.392	1.000
1.000	1.000	1.000	1.000	1.000	1.000	0.055	0.542	0.536	0.913	1.000	0.392	1.000
1.000	1.000	1.000	1.000	1.000	1.000	0.055	0.541	0.536	0.913	1.000	0.392	1.000
1.000	1.000	1.000	1.000	1.000	1.000	0.055	0.541	0.536	0.913	1.000	0.392	1.000
1.000	1.000	1.000	1.000	1.000	1.000	0.055	0.541	0.536	0.913	1.000	0.392	1.000
1.000	1.000	1.000	1.000	1.000	1.000	0.055	0.541	0.536	0.913	1.000	0.392	1.000
1.000	1.000	1.000	1.000	1.000	1.000	0.055	0.541	0.536	0.913	1.000	0.392	1.000
1.000	1.000	1.000	1.000	1.000	1.000	0.055	0.541	0.536	0.913	1.000	0.392	1.000
1.000	1.000	1.000	1.000	1.000	1.000	0.055	0.541	0.536	0.913	1.000	0.392	1.000
1.000	1.000	1.000	1.000	1.000	1.000	0.055	0.541	0.536	0.913	1.000	0.392	1.000
1.000	1.000	1.000	1.000	1.000	1.000	0.055	0.541	0.536	0.913	1.000	0.392	1.000

Table 2.23 (page 7 of 8)—Schedules of Pacific cod selectivity at length (cm) in the commercial fisheries as defined by parameter estimates under Model 3b. Years correspond to beginnings of blocks.

	January-April pot fishery				May-July pot		Sep-Dec pot	
Len.	1977	1995	2000	2005	1977	1995	1977	2000
1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
7	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
8	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
11	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
12	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
13	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
15	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
16	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
17	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
18	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
19	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
20	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
21	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
22	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
23	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
24	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
25	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
26	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
27	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
28	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
29	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
30	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
31	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
32	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000
33	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000
34	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.000
35	0.000	0.001	0.001	0.001	0.001	0.001	0.002	0.000
36	0.001	0.001	0.001	0.001	0.001	0.001	0.003	0.000
37	0.001	0.001	0.002	0.001	0.001	0.002	0.004	0.001
38	0.002	0.002	0.002	0.002	0.002	0.003	0.006	0.001
39	0.003	0.003	0.003	0.003	0.003	0.005	0.008	0.002
40	0.004	0.004	0.005	0.005	0.005	0.007	0.011	0.004
41	0.006	0.006	0.007	0.007	0.007	0.011	0.015	0.006
42	0.009	0.009	0.010	0.010	0.010	0.015	0.020	0.010
43	0.012	0.013	0.015	0.014	0.014	0.022	0.027	0.016
44	0.017	0.018	0.020	0.020	0.020	0.030	0.036	0.024
45	0.024	0.025	0.028	0.027	0.027	0.041	0.047	0.035
46	0.032	0.034	0.038	0.036	0.038	0.055	0.061	0.052
47	0.043	0.046	0.051	0.049	0.051	0.073	0.077	0.074
48	0.058	0.061	0.067	0.065	0.068	0.096	0.098	0.103
49	0.076	0.080	0.087	0.084	0.089	0.124	0.122	0.140
50	0.098	0.103	0.112	0.109	0.116	0.158	0.151	0.187
51	0.125	0.131	0.142	0.138	0.148	0.197	0.184	0.244
52	0.158	0.164	0.177	0.173	0.186	0.244	0.223	0.310
53	0.196	0.204	0.219	0.213	0.230	0.296	0.266	0.386
54	0.240	0.249	0.266	0.260	0.281	0.355	0.314	0.470
55	0.290	0.300	0.320	0.312	0.338	0.420	0.367	0.559
56	0.346	0.357	0.378	0.371	0.401	0.488	0.424	0.650
57	0.407	0.419	0.442	0.434	0.469	0.560	0.484	0.739
58	0.473	0.486	0.510	0.501	0.540	0.634	0.547	0.822
59	0.542	0.555	0.579	0.570	0.613	0.706	0.611	0.893
60	0.612	0.625	0.650	0.641	0.686	0.775	0.674	0.949

Table 2.23 (page 8 of 8)—Schedules of Pacific cod selectivity at length (cm) in the commercial fisheries as defined by parameter estimates under Model 3b. Years correspond to beginnings of blocks.

	January-April pot fishery				May-July pot		Sep-Dec pot	
Len.	1977	1995	2000	2005	1977	1995	1977	2000
61	0.682	0.695	0.719	0.710	0.757	0.839	0.737	0.985
62	0.750	0.763	0.785	0.777	0.822	0.895	0.796	1.000
63	0.814	0.825	0.846	0.838	0.880	0.940	0.850	1.000
64	0.871	0.881	0.898	0.892	0.929	0.974	0.898	1.000
65	0.920	0.928	0.942	0.937	0.966	0.994	0.938	1.000
66	0.958	0.964	0.974	0.970	0.990	1.000	0.968	1.000
67	0.985	0.988	0.994	0.992	1.000	1.000	0.989	1.000
68	0.998	0.999	1.000	1.000	1.000	1.000	0.999	1.000
69	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
70	0.999	0.997	0.993	0.997	1.000	1.000	1.000	1.000
71	0.990	0.984	0.973	0.985	1.000	1.000	1.000	1.000
72	0.973	0.959	0.942	0.966	1.000	1.000	1.000	1.000
73	0.947	0.925	0.900	0.940	1.000	1.000	1.000	1.000
74	0.916	0.883	0.851	0.910	1.000	1.000	1.000	1.000
75	0.881	0.837	0.797	0.876	1.000	1.000	1.000	1.000
76	0.843	0.787	0.741	0.840	1.000	1.000	1.000	1.000
77	0.804	0.737	0.684	0.804	1.000	1.000	1.000	1.000
78	0.766	0.688	0.630	0.770	1.000	1.000	1.000	1.000
79	0.730	0.642	0.580	0.738	1.000	1.000	1.000	1.000
80	0.697	0.600	0.535	0.709	1.000	1.000	1.000	1.000
81	0.668	0.564	0.496	0.683	1.000	1.000	1.000	1.000
82	0.643	0.532	0.463	0.661	1.000	1.000	1.000	1.000
83	0.622	0.506	0.435	0.644	1.000	1.000	1.000	1.000
84	0.605	0.485	0.413	0.629	1.000	1.000	1.000	1.000
85	0.591	0.468	0.396	0.618	1.000	1.000	1.000	1.000
86	0.581	0.455	0.382	0.609	1.000	1.000	1.000	1.000
87	0.573	0.445	0.372	0.603	1.000	1.000	1.000	1.000
88	0.567	0.438	0.365	0.598	1.000	1.000	1.000	1.000
89	0.563	0.433	0.360	0.594	1.000	1.000	1.000	1.000
90	0.560	0.429	0.357	0.592	1.000	1.000	1.000	1.000
91	0.557	0.427	0.354	0.590	1.000	1.000	1.000	1.000
92	0.556	0.425	0.353	0.589	1.000	1.000	1.000	1.000
93	0.555	0.424	0.352	0.589	1.000	1.000	1.000	1.000
94	0.555	0.423	0.351	0.588	1.000	1.000	1.000	1.000
95	0.554	0.423	0.350	0.588	1.000	1.000	1.000	1.000
96	0.554	0.423	0.350	0.588	1.000	1.000	1.000	1.000
97	0.554	0.423	0.350	0.588	1.000	1.000	1.000	1.000
98	0.554	0.422	0.350	0.588	1.000	1.000	1.000	1.000
99	0.554	0.422	0.350	0.588	1.000	1.000	1.000	1.000
100	0.554	0.422	0.350	0.587	1.000	1.000	1.000	1.000
101	0.554	0.422	0.350	0.587	1.000	1.000	1.000	1.000
102	0.554	0.422	0.350	0.587	1.000	1.000	1.000	1.000
103	0.554	0.422	0.350	0.587	1.000	1.000	1.000	1.000
104	0.554	0.422	0.350	0.587	1.000	1.000	1.000	1.000
105	0.554	0.422	0.350	0.587	1.000	1.000	1.000	1.000
106	0.554	0.422	0.350	0.587	1.000	1.000	1.000	1.000
107	0.554	0.422	0.350	0.587	1.000	1.000	1.000	1.000
108	0.554	0.422	0.350	0.587	1.000	1.000	1.000	1.000
109	0.554	0.422	0.350	0.587	1.000	1.000	1.000	1.000
110	0.554	0.422	0.350	0.587	1.000	1.000	1.000	1.000
111	0.554	0.422	0.350	0.587	1.000	1.000	1.000	1.000
112	0.554	0.422	0.350	0.587	1.000	1.000	1.000	1.000
113	0.554	0.422	0.350	0.587	1.000	1.000	1.000	1.000
114	0.554	0.422	0.350	0.587	1.000	1.000	1.000	1.000
115	0.554	0.422	0.350	0.587	1.000	1.000	1.000	1.000
116	0.554	0.422	0.350	0.587	1.000	1.000	1.000	1.000
117	0.554	0.422	0.350	0.587	1.000	1.000	1.000	1.000
118	0.554	0.422	0.350	0.587	1.000	1.000	1.000	1.000
119	0.554	0.422	0.350	0.587	1.000	1.000	1.000	1.000
120	0.554	0.422	0.350	0.587	1.000	1.000	1.000	1.000

Table 2.24—Schedules of Pacific cod selectivity at age in the bottom trawl survey as defined by final parameter estimates under Model 3b.

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1982	0.000	0.381	1.000	0.983	0.904	0.780	0.635	0.495	0.377	0.289	0.231	0.195	0.176	0.166	0.162	0.160	0.159	0.159	0.159	0.159	0.159
1983	0.000	0.335	1.000	0.983	0.904	0.780	0.635	0.495	0.377	0.289	0.231	0.195	0.176	0.166	0.162	0.160	0.159	0.159	0.159	0.159	0.159
1984	0.000	0.229	1.000	0.983	0.904	0.780	0.635	0.495	0.377	0.289	0.231	0.195	0.176	0.166	0.162	0.160	0.159	0.159	0.159	0.159	0.159
1985	0.000	0.486	1.000	0.983	0.904	0.780	0.635	0.495	0.377	0.289	0.231	0.195	0.176	0.166	0.162	0.160	0.159	0.159	0.159	0.159	0.159
1986	0.000	0.327	1.000	0.983	0.904	0.780	0.635	0.495	0.377	0.289	0.231	0.195	0.176	0.166	0.162	0.160	0.159	0.159	0.159	0.159	0.159
1987	0.000	0.604	1.000	0.983	0.904	0.780	0.635	0.495	0.377	0.289	0.231	0.195	0.176	0.166	0.162	0.160	0.159	0.159	0.159	0.159	0.159
1988	0.000	0.269	1.000	0.983	0.904	0.780	0.635	0.495	0.377	0.289	0.231	0.195	0.176	0.166	0.162	0.160	0.159	0.159	0.159	0.159	0.159
1989	0.000	0.134	1.000	0.983	0.904	0.780	0.635	0.495	0.377	0.289	0.231	0.195	0.176	0.166	0.162	0.160	0.159	0.159	0.159	0.159	0.159
1990	0.000	0.381	1.000	0.983	0.904	0.780	0.635	0.495	0.377	0.289	0.231	0.195	0.176	0.166	0.162	0.160	0.159	0.159	0.159	0.159	0.159
1991	0.000	0.336	1.000	0.983	0.904	0.780	0.635	0.495	0.377	0.289	0.231	0.195	0.176	0.166	0.162	0.160	0.159	0.159	0.159	0.159	0.159
1992	0.000	0.741	1.000	0.983	0.904	0.780	0.635	0.495	0.377	0.289	0.231	0.195	0.176	0.166	0.162	0.160	0.159	0.159	0.159	0.159	0.159
1993	0.000	0.624	1.000	0.983	0.904	0.780	0.635	0.495	0.377	0.289	0.231	0.195	0.176	0.166	0.162	0.160	0.159	0.159	0.159	0.159	0.159
1994	0.000	0.337	1.000	0.983	0.904	0.780	0.635	0.495	0.377	0.289	0.231	0.195	0.176	0.166	0.162	0.160	0.159	0.159	0.159	0.159	0.159
1995	0.000	0.190	1.000	0.983	0.904	0.780	0.635	0.495	0.377	0.289	0.231	0.195	0.176	0.166	0.162	0.160	0.159	0.159	0.159	0.159	0.159
1996	0.000	0.141	1.000	0.983	0.904	0.780	0.635	0.495	0.377	0.289	0.231	0.195	0.176	0.166	0.162	0.160	0.159	0.159	0.159	0.159	0.159
1997	0.000	0.254	1.000	0.983	0.904	0.780	0.635	0.495	0.377	0.289	0.231	0.195	0.176	0.166	0.162	0.160	0.159	0.159	0.159	0.159	0.159
1998	0.000	0.235	1.000	0.983	0.904	0.780	0.635	0.495	0.377	0.289	0.231	0.195	0.176	0.166	0.162	0.160	0.159	0.159	0.159	0.159	0.159
1999	0.000	0.239	1.000	0.983	0.904	0.780	0.635	0.495	0.377	0.289	0.231	0.195	0.176	0.166	0.162	0.160	0.159	0.159	0.159	0.159	0.159
2000	0.000	0.339	1.000	0.983	0.904	0.780	0.635	0.495	0.377	0.289	0.231	0.195	0.176	0.166	0.162	0.160	0.159	0.159	0.159	0.159	0.159
2001	0.000	0.816	1.000	0.983	0.904	0.780	0.635	0.495	0.377	0.289	0.231	0.195	0.176	0.166	0.162	0.160	0.159	0.159	0.159	0.159	0.159
2002	0.000	0.437	1.000	0.983	0.904	0.780	0.635	0.495	0.377	0.289	0.231	0.195	0.176	0.166	0.162	0.160	0.159	0.159	0.159	0.159	0.159
2003	0.000	0.471	1.000	0.983	0.904	0.780	0.635	0.495	0.377	0.289	0.231	0.195	0.176	0.166	0.162	0.160	0.159	0.159	0.159	0.159	0.159
2004	0.000	0.388	1.000	0.983	0.904	0.780	0.635	0.495	0.377	0.289	0.231	0.195	0.176	0.166	0.162	0.160	0.159	0.159	0.159	0.159	0.159
2005	0.000	0.594	1.000	0.983	0.904	0.780	0.635	0.495	0.377	0.289	0.231	0.195	0.176	0.166	0.162	0.160	0.159	0.159	0.159	0.159	0.159
2006	0.000	0.814	1.000	0.983	0.904	0.780	0.635	0.495	0.377	0.289	0.231	0.195	0.176	0.166	0.162	0.160	0.159	0.159	0.159	0.159	0.159
2007	0.000	0.884	1.000	0.983	0.904	0.780	0.635	0.495	0.377	0.289	0.231	0.195	0.176	0.166	0.162	0.160	0.159	0.159	0.159	0.159	0.159
2008	0.000	0.725	1.000	0.983	0.904	0.780	0.635	0.495	0.377	0.289	0.231	0.195	0.176	0.166	0.162	0.160	0.159	0.159	0.159	0.159	0.159
2009	0.000	0.616	1.000	0.983	0.904	0.780	0.635	0.495	0.377	0.289	0.231	0.195	0.176	0.166	0.162	0.160	0.159	0.159	0.159	0.159	0.159
2010	0.000	0.477	1.000	0.983	0.904	0.780	0.635	0.495	0.377	0.289	0.231	0.195	0.176	0.166	0.162	0.160	0.159	0.159	0.159	0.159	0.159
2011	0.000	0.477	1.000	0.983	0.904	0.780	0.635	0.495	0.377	0.289	0.231	0.195	0.176	0.166	0.162	0.160	0.159	0.159	0.159	0.159	0.159

Table 2.25—Schedules of population length (cm) and weight (kg) by season and age as estimated by Model 3b. Sea1=Jan-Feb, Sea2=Mar-Apr, Sea3=May-Jul, Sea4=Aug-Oct, Sea5=Nov=Dec. Lengths and weights correspond to season mid-points.

	Population length (cm)					Population weight (kg)				
Age	Sea1	Sea2	Sea3	Sea4	Sea5	Sea1	Sea2	Sea3	Sea4	Sea5
1	9.39	11.01	13.03	16.59	20.34	0.01	0.02	0.03	0.05	0.09
2	23.20	25.95	29.22	32.94	35.86	0.13	0.21	0.31	0.43	0.54
3	38.10	40.24	42.80	45.70	47.98	0.66	0.79	0.96	1.19	1.37
4	49.72	51.40	53.39	55.66	57.44	1.56	1.68	1.87	2.18	2.45
5	58.80	60.10	61.66	63.42	64.81	2.70	2.72	2.88	3.26	3.61
6	65.88	66.89	68.11	69.49	70.57	3.91	3.79	3.89	4.32	4.75
7	71.40	72.19	73.14	74.22	75.06	5.09	4.80	4.83	5.30	5.80
8	75.71	76.33	77.07	77.91	78.57	6.17	5.71	5.65	6.16	6.72
9	79.07	79.56	80.14	80.79	81.30	7.11	6.49	6.36	6.89	7.50
10	81.70	82.08	82.53	83.04	83.44	7.91	7.15	6.95	7.51	8.16
11	83.75	84.04	84.39	84.79	85.10	8.58	7.69	7.44	8.01	8.70
12	85.34	85.57	85.85	86.16	86.40	9.13	8.14	7.83	8.42	9.13
13	86.59	86.77	86.98	87.23	87.42	9.57	8.49	8.15	8.74	9.48
14	87.56	87.70	87.87	88.06	88.21	9.92	8.78	8.40	9.00	9.76
15	88.32	88.43	88.56	88.71	88.83	10.21	9.01	8.61	9.21	9.99
16	88.92	89.00	89.10	89.22	89.31	10.43	9.19	8.77	9.38	10.16
17	89.38	89.44	89.52	89.61	89.69	10.61	9.33	8.89	9.50	10.30
18	89.74	89.79	89.85	89.92	89.98	10.75	9.44	8.99	9.61	10.41
19	90.02	90.06	90.11	90.16	90.21	10.86	9.53	9.07	9.69	10.50
20	90.40	90.43	90.46	90.49	90.52	11.01	9.66	9.18	9.80	10.62

Table 2.26—Schedules of fleet-specific length (cm) by season and age as estimated by Model 3b. Sea1=Jan-Feb, Sea2=Mar-Apr, Sea3=May-Jul, Sea4=Aug-Oct, Sea5=Nov=Dec.

	Trawl fishery					Longline fishery					Pot fishery					Survey
Age	Sea1	Sea2	Sea3	Sea4	Sea5	Sea1	Sea2	Sea3	Sea4	Sea5	Sea1	Sea2	Sea3	Sea4	Sea5	
1	13.02	14.54	16.70	20.70	24.76	15.44	16.90	20.22	24.41	28.63	12.94	16.44	20.32	25.54	31.66	16.59
2	27.40	30.35	33.49	37.70	40.52	29.87	32.83	37.68	41.41	44.05	32.28	35.26	38.68	44.08	46.52	32.94
3	42.95	45.08	46.17	49.42	51.36	44.99	46.97	49.93	52.00	53.66	47.24	49.13	50.96	53.63	55.09	45.70
4	54.12	55.64	55.12	57.71	59.19	55.08	56.41	57.87	59.09	60.38	56.74	57.97	58.80	59.91	61.08	55.66
5	62.15	63.26	62.32	64.33	65.57	61.95	62.87	63.91	64.98	66.12	63.05	63.91	64.60	65.35	66.44	63.42
6	68.13	68.99	68.35	69.87	70.89	66.85	67.53	69.16	70.16	71.14	67.73	68.41	69.58	70.34	71.29	69.49
7	72.83	73.52	73.24	74.39	75.21	70.53	71.06	73.65	74.53	75.34	71.59	72.18	73.90	74.62	75.41	74.22
8	76.63	77.19	77.11	78.00	78.65	73.45	73.88	77.34	78.07	78.72	74.93	75.44	77.49	78.12	78.75	77.91
9	79.69	80.14	80.16	80.84	81.35	75.86	76.22	80.29	80.89	81.39	77.82	78.25	80.39	80.91	81.42	80.79
10	82.14	82.49	82.54	83.07	83.47	77.89	78.19	82.63	83.10	83.50	80.25	80.61	82.69	83.12	83.51	83.04
11	84.08	84.36	84.40	84.81	85.13	79.59	79.84	84.46	84.83	85.15	82.25	82.55	84.51	84.85	85.16	84.79
12	85.61	85.83	85.85	86.18	86.42	81.00	81.21	85.90	86.19	86.44	83.87	84.10	85.94	86.20	86.44	86.16
13	86.81	86.98	86.99	87.24	87.43	82.15	82.32	87.03	87.25	87.44	85.15	85.34	87.06	87.26	87.45	87.23
14	87.75	87.89	87.87	88.07	88.22	83.09	83.22	87.91	88.08	88.23	86.17	86.31	87.93	88.09	88.24	88.06
15	88.49	88.59	88.56	88.72	88.83	83.84	83.95	88.59	88.73	88.84	86.97	87.08	88.62	88.73	88.85	88.71
16	89.06	89.15	89.10	89.22	89.31	84.43	84.52	89.13	89.23	89.32	87.59	87.68	89.15	89.24	89.33	89.21
17	89.52	89.58	89.52	89.62	89.69	84.91	84.98	89.55	89.63	89.70	88.08	88.15	89.57	89.63	89.70	89.61
18	89.87	89.92	89.85	89.93	89.98	85.28	85.34	89.87	89.93	89.99	88.47	88.52	89.89	89.94	89.99	89.92
19	90.14	90.18	90.11	90.17	90.21	85.58	85.62	90.13	90.17	90.22	88.77	88.81	90.14	90.18	90.22	90.16
20	90.52	90.55	90.45	90.49	90.52	85.98	85.98	90.47	90.50	90.53	89.18	89.19	90.49	90.50	90.53	90.48

Table 2.27—Schedules of fleet-specific weight (kg) by season and age as estimated by Model 3b. Sea1=Jan-Feb, Sea2=Mar-Apr, Sea3=May-Jul, Sea4=Aug-Oct, Sea5=Nov=Dec.

	Trawl fishery					Longline fishery					Pot fishery					Survey
Age	Sea1	Sea2	Sea3	Sea4	Sea5	Sea1	Sea2	Sea3	Sea4	Sea5	Sea1	Sea2	Sea3	Sea4	Sea5	
1	0.02	0.04	0.06	0.10	0.16	0.04	0.06	0.10	0.17	0.25	0.03	0.06	0.10	0.21	0.35	0.05
2	0.22	0.33	0.45	0.64	0.78	0.29	0.41	0.64	0.85	1.01	0.37	0.51	0.69	1.02	1.20	0.43
3	0.95	1.10	1.19	1.48	1.68	1.10	1.24	1.49	1.72	1.91	1.28	1.42	1.58	1.88	2.07	1.19
4	2.03	2.11	2.03	2.40	2.66	2.13	2.19	2.33	2.56	2.81	2.33	2.37	2.44	2.66	2.91	2.18
5	3.19	3.15	2.96	3.38	3.72	3.13	3.07	3.16	3.47	3.80	3.30	3.22	3.26	3.52	3.85	3.26
6	4.31	4.13	3.92	4.38	4.80	4.02	3.84	4.04	4.43	4.85	4.19	3.99	4.11	4.45	4.87	4.32
7	5.38	5.04	4.84	5.33	5.83	4.81	4.51	4.90	5.35	5.85	5.06	4.74	4.95	5.37	5.86	5.30
8	6.37	5.87	5.66	6.18	6.73	5.51	5.10	5.70	6.19	6.75	5.91	5.47	5.72	6.20	6.76	6.16
9	7.25	6.61	6.36	6.90	7.51	6.15	5.64	6.39	6.91	7.52	6.72	6.15	6.41	6.92	7.53	6.89
10	8.02	7.24	6.95	7.51	8.17	6.74	6.13	6.97	7.52	8.17	7.46	6.76	6.98	7.52	8.18	7.51
11	8.66	7.76	7.44	8.01	8.70	7.26	6.56	7.45	8.02	8.71	8.10	7.29	7.46	8.02	8.71	8.01
12	9.19	8.19	7.83	8.42	9.14	7.71	6.93	7.84	8.42	9.14	8.65	7.73	7.85	8.42	9.14	8.42
13	9.63	8.54	8.15	8.75	9.49	8.09	7.25	8.16	8.75	9.49	9.10	8.10	8.17	8.75	9.49	8.74
14	9.98	8.82	8.41	9.01	9.77	8.41	7.51	8.41	9.01	9.77	9.46	8.39	8.42	9.01	9.77	9.00
15	10.26	9.05	8.61	9.21	9.99	8.68	7.72	8.61	9.22	9.99	9.75	8.63	8.62	9.22	9.99	9.21
16	10.48	9.22	8.77	9.38	10.16	8.89	7.89	8.77	9.38	10.17	9.99	8.81	8.78	9.38	10.17	9.38
17	10.65	9.36	8.89	9.51	10.30	9.06	8.03	8.90	9.51	10.30	10.17	8.96	8.90	9.51	10.31	9.50
18	10.79	9.47	8.99	9.61	10.41	9.20	8.14	8.99	9.61	10.41	10.32	9.08	9.00	9.61	10.41	9.61
19	10.90	9.56	9.07	9.69	10.50	9.30	8.22	9.07	9.69	10.50	10.44	9.17	9.08	9.69	10.50	9.69
20	11.05	9.69	9.18	9.80	10.62	9.45	8.34	9.18	9.80	10.62	10.59	9.30	9.19	9.80	10.62	9.80

Table 2.28—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 3b. Values for 2012 listed under this year's assessment represent Stock Synthesis projections, and may not correspond exactly 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	834,627	216,589	37,927	603,325	167,932	32,923
1978	968,676	243,639	37,560	678,315	184,828	32,986
1979	1,282,910	290,302	37,886	838,368	211,489	34,053
1980	1,767,440	369,757	38,756	1,222,200	265,442	36,480
1981	2,249,760	500,315	39,867	1,678,620	371,918	40,280
1982	2,593,560	670,040	41,598	2,059,300	527,065	45,111
1983	2,738,400	817,145	42,222	2,260,620	674,910	47,832
1984	2,740,820	882,575	39,969	2,275,930	749,745	46,103
1985	2,668,450	867,150	35,638	2,251,210	743,760	41,277
1986	2,574,910	816,915	30,812	2,197,870	704,810	35,677
1987	2,499,160	773,980	26,600	2,178,530	679,380	30,800
1988	2,373,550	733,295	23,292	2,111,080	658,570	26,952
1989	2,130,630	679,105	20,717	1,908,730	621,130	23,800
1990	1,878,370	622,710	18,566	1,665,820	572,130	20,943
1991	1,680,260	545,890	16,396	1,445,410	492,812	17,975
1992	1,547,260	454,646	14,291	1,293,070	396,146	15,222
1993	1,536,830	406,254	12,776	1,280,630	346,825	13,358
1994	1,610,980	419,403	12,255	1,331,190	361,202	12,711
1995	1,651,460	426,772	12,508	1,364,360	366,660	12,836
1996	1,599,380	427,849	13,040	1,314,450	362,738	13,167
1997	1,524,880	423,471	13,384	1,239,070	354,144	13,276
1998	1,451,680	401,978	13,429	1,137,180	327,975	13,114
1999	1,498,780	393,734	13,300	1,171,350	314,810	12,871
2000	1,558,300	400,034	13,278	1,229,130	318,443	12,819
2001	1,602,420	434,215	13,528	1,264,600	351,344	13,016
2002	1,645,100	449,783	13,715	1,311,320	364,353	12,935
2003	1,627,360	448,342	13,756	1,316,290	362,894	12,547
2004	1,547,710	440,618	13,872	1,270,660	364,881	12,216
2005	1,428,430	412,921	14,088	1,164,770	341,597	11,974
2006	1,299,170	373,573	14,168	1,046,930	304,374	11,635
2007	1,189,470	338,856	14,089	946,021	271,623	11,212
2008	1,166,660	313,534	14,152	921,565	248,405	11,001
2009	1,208,150	298,073	14,718	1,015,500	238,735	11,424
2010	1,323,180	303,883	16,280	1,174,880	261,659	13,178
2011	1,517,480	331,545	16,707	1,404,570	323,273	16,861
2012				1,536,900	373,130	20,349

Table 2.29—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 3b.

	Last year's values		This year's values	
Year	Recruits	Std. dev.	Recruits	Std. dev.
1977	2,173,820	141,849	1,919,980	214,017
1978	701,641	88,122	789,850	175,892
1979	865,775	73,124	920,088	106,957
1980	482,379	43,633	320,098	44,467
1981	187,485	25,641	165,074	25,931
1982	1,098,730	40,442	1,265,810	51,580
1983	345,339	26,643	269,659	32,820
1984	863,779	35,918	1,022,900	45,981
1985	521,494	28,749	440,392	32,381
1986	273,598	19,196	198,123	19,558
1987	193,316	14,522	129,762	15,884
1988	336,546	16,504	358,662	21,249
1989	751,861	25,314	796,327	33,085
1990	695,184	25,148	672,909	30,677
1991	444,630	18,422	331,892	22,165
1992	834,553	24,219	879,481	29,674
1993	424,298	16,888	320,330	19,544
1994	361,508	14,711	333,946	17,937
1995	402,104	16,543	349,207	20,580
1996	905,191	26,483	960,010	33,455
1997	513,004	18,026	392,718	20,919
1998	416,374	15,675	361,078	19,124
1999	675,222	20,531	768,780	26,044
2000	570,900	18,896	497,785	19,633
2001	271,300	11,762	209,153	13,379
2002	371,140	14,271	376,293	16,154
2003	355,402	15,505	318,135	16,747
2004	311,781	15,238	278,904	16,408
2005	331,043	17,298	316,148	18,937
2006	809,072	41,200	1,153,060	52,018
2007	425,480	35,511	384,879	31,017
2008	1,040,250	94,823	1,360,280	88,227
2009	789,492	140,368	168,400	28,060
2010			1,031,600	140,861
Average	598,294		590,050	

Table 2.30—Numbers (1000s) at age at time of spawning (March) as estimated by Model 3b.

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1977	1919980	351378	37749	189681	43426	29297	19258	12493	8062	5191	3340	2148	1381	888	571	367	236	152	97	63	113
1978	789850	1366570	249992	26658	130628	29166	19458	12762	8285	5353	3450	2222	1429	919	591	380	244	157	101	65	117
1979	920088	562186	972294	176504	18324	87417	19286	12835	8424	5476	3542	2285	1472	948	610	392	252	162	104	67	121
1980	320098	654886	400023	688072	122547	12471	58942	12976	8638	5674	3692	2389	1542	994	640	412	265	170	110	70	127
1981	165074	227835	465998	283583	482351	84813	8552	40227	8837	5879	3861	2511	1625	1049	676	435	280	180	116	75	134
1982	1265810	117494	162111	330184	198641	333807	58186	5838	27393	6011	3996	2624	1707	1104	713	459	296	190	122	79	142
1983	269659	900959	83600	114845	231282	137683	229787	39906	3997	18738	4110	2732	1793	1166	755	487	314	202	130	84	151
1984	1022900	191934	641000	59142	80036	158939	93756	155717	26980	2699	12649	2774	1843	1210	787	509	329	212	136	88	158
1985	440392	728041	136524	452963	41030	54411	106501	62352	103229	17867	1787	8376	1837	1221	802	522	338	218	140	90	163
1986	198123	313444	517867	96482	313742	27756	36185	70161	40895	67586	11691	1169	5481	1202	799	525	342	221	143	92	166
1987	129762	141011	222946	365820	66758	212015	18437	23805	45944	26730	44149	7637	764	3581	786	522	343	223	145	93	169
1988	358662	92352	100258	157236	252067	44680	138894	11939	15333	29536	17175	28369	4908	491	2303	505	336	221	144	93	169
1989	796327	255258	65642	70415	107019	166233	28769	88050	7500	9583	18405	10684	17629	3048	305	1429	314	208	137	89	162
1990	672909	566795	181549	46185	47978	70607	107375	18369	55899	4748	6060	11631	6749	11135	1925	193	902	198	132	86	159
1991	331892	478950	403274	128266	31498	31211	44588	67054	11438	34796	2957	3775	7249	4208	6944	1201	120	563	124	82	153
1992	879481	236228	340786	284941	86545	19724	18568	26016	38952	6647	20250	1723	2203	4233	2459	4060	702	70	329	72	138
1993	320330	625980	168072	240607	192197	53966	11636	10745	15027	22568	3865	11810	1007	1290	2482	1443	2384	413	41	194	123
1994	333946	228000	445462	118994	164955	125454	34032	7256	6704	9408	14180	2435	7457	637	816	1572	915	1512	262	26	201
1995	349207	237688	162213	314284	79843	102822	74213	19764	4209	3904	5502	8322	1433	4397	376	483	930	541	895	155	135
1996	960010	248551	169110	114646	213417	49985	60097	42038	11098	2362	2194	3098	4692	809	2483	212	273	526	306	506	164
1997	392718	683295	176834	119452	77658	133105	29121	33993	23619	6243	1333	1241	1756	2663	460	1412	121	155	299	174	382
1998	361078	279522	486178	124938	80600	47832	76177	16152	18719	13022	3452	739	690	977	1484	256	788	68	87	167	311
1999	768780	257001	198880	343509	84775	50834	28535	44426	9375	10878	7585	2015	432	404	572	870	150	462	40	51	281
2000	497785	547191	182878	140503	232764	53382	30344	16717	26005	5512	6425	4496	1198	257	241	342	520	90	276	24	198
2001	209153	354308	389420	129417	96068	151323	33674	18983	10481	16387	3490	4084	2866	765	165	154	219	333	58	177	143
2002	376293	148868	252137	274919	87073	60222	91184	20157	11450	6387	10073	2159	2539	1788	479	103	97	138	210	36	202
2003	318135	267833	105936	177830	183843	53851	35644	53526	11918	6840	3850	6113	1317	1554	1098	294	64	60	85	129	147
2004	278904	226437	190587	74710	119237	115003	32502	21392	32332	7261	4198	2376	3789	819	968	685	184	40	37	53	173
2005	316148	198515	161140	134471	49771	72695	66621	18619	12335	18838	4271	2488	1416	2267	491	582	413	111	24	23	137
2006	1153060	225024	141274	113851	89894	30383	42017	37868	10585	7047	10819	2463	1439	821	1317	286	339	240	65	14	93
2007	384879	820710	160146	99899	76435	55243	17697	24095	21747	6115	4095	6316	1443	846	483	776	169	200	142	38	63
2008	1360280	273945	584079	113183	66987	47054	32336	10209	13916	12626	3569	2401	3715	851	499	286	460	100	119	84	60
2009	168400	968206	194962	412634	75377	40485	26904	18231	5774	7929	7243	2059	1390	2158	495	291	167	269	58	69	85
2010	1031600	119862	689050	137793	276177	46147	23520	15392	10438	3323	4586	4207	1199	812	1262	290	171	98	158	34	91
2011	553501	734262	85304	487764	93723	176003	28286	14238	9309	6328	2020	2794	2568	733	497	773	178	105	60	97	77

Table 2.31—Estimates of "effective" fishing mortality (= $-\ln(N_{a+1,t+1}/N_{a,t})-M$) at age and year for Model 3b.

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1977	0.000	0.005	0.027	0.052	0.066	0.069	0.069	0.068	0.067	0.066	0.065	0.065	0.064	0.064	0.064	0.064	0.064	0.064	0.064
1978	0.000	0.006	0.031	0.060	0.076	0.080	0.080	0.078	0.077	0.076	0.076	0.075	0.075	0.075	0.075	0.074	0.074	0.074	0.074
1979	0.000	0.004	0.022	0.043	0.054	0.057	0.057	0.056	0.055	0.054	0.054	0.053	0.053	0.053	0.053	0.053	0.053	0.053	0.052
1980	0.000	0.003	0.014	0.029	0.041	0.047	0.049	0.050	0.051	0.051	0.051	0.051	0.051	0.050	0.050	0.050	0.050	0.050	0.050
1981	0.000	0.004	0.014	0.027	0.036	0.042	0.044	0.046	0.046	0.046	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.047
1982	0.000	0.003	0.013	0.022	0.029	0.033	0.035	0.036	0.037	0.037	0.037	0.037	0.037	0.037	0.037	0.037	0.037	0.037	0.037
1983	0.000	0.005	0.018	0.031	0.042	0.047	0.050	0.051	0.051	0.052	0.052	0.052	0.052	0.052	0.052	0.052	0.052	0.052	0.052
1984	0.000	0.005	0.021	0.041	0.056	0.063	0.067	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.067	0.067	0.067	0.067	0.067
1985	0.000	0.005	0.023	0.046	0.065	0.075	0.081	0.083	0.083	0.084	0.083	0.083	0.083	0.083	0.083	0.082	0.082	0.082	0.082
1986	0.000	0.005	0.023	0.045	0.062	0.073	0.078	0.081	0.082	0.082	0.082	0.082	0.082	0.082	0.082	0.081	0.081	0.081	0.081
1987	0.000	0.005	0.023	0.049	0.071	0.084	0.090	0.092	0.092	0.092	0.091	0.091	0.090	0.090	0.090	0.089	0.089	0.089	0.089
1988	0.001	0.009	0.036	0.067	0.093	0.111	0.121	0.127	0.130	0.132	0.133	0.134	0.134	0.135	0.135	0.135	0.135	0.135	0.135
1989	0.001	0.008	0.035	0.065	0.090	0.106	0.114	0.119	0.121	0.122	0.122	0.123	0.123	0.123	0.123	0.123	0.123	0.123	0.123
1990	0.000	0.003	0.031	0.076	0.110	0.125	0.129	0.130	0.130	0.130	0.129	0.129	0.129	0.129	0.129	0.129	0.128	0.128	0.128
1991	0.000	0.003	0.040	0.113	0.169	0.193	0.200	0.201	0.200	0.199	0.198	0.197	0.196	0.196	0.196	0.196	0.195	0.195	0.195
1992	0.000	0.003	0.033	0.103	0.164	0.188	0.193	0.191	0.188	0.185	0.183	0.182	0.181	0.180	0.179	0.179	0.178	0.178	0.178
1993	0.000	0.003	0.027	0.081	0.131	0.151	0.153	0.150	0.146	0.142	0.140	0.138	0.137	0.136	0.135	0.134	0.134	0.134	0.133
1994	0.000	0.003	0.036	0.100	0.156	0.179	0.182	0.179	0.175	0.171	0.168	0.166	0.165	0.164	0.163	0.162	0.162	0.162	0.161
1995	0.000	0.003	0.031	0.113	0.196	0.238	0.250	0.251	0.249	0.247	0.246	0.244	0.244	0.243	0.242	0.242	0.242	0.242	0.241
1996	0.000	0.003	0.029	0.106	0.184	0.221	0.230	0.230	0.227	0.224	0.221	0.220	0.218	0.217	0.217	0.216	0.216	0.216	0.215
1997	0.000	0.003	0.036	0.125	0.212	0.253	0.264	0.264	0.261	0.258	0.255	0.254	0.252	0.251	0.251	0.250	0.250	0.249	0.249
1998	0.000	0.002	0.026	0.093	0.159	0.190	0.199	0.198	0.195	0.193	0.191	0.190	0.189	0.188	0.187	0.187	0.187	0.187	0.186
1999	0.000	0.002	0.023	0.089	0.156	0.186	0.192	0.189	0.184	0.180	0.177	0.175	0.173	0.172	0.171	0.171	0.170	0.170	0.169
2000	0.000	0.003	0.032	0.096	0.152	0.172	0.171	0.164	0.156	0.150	0.145	0.142	0.139	0.137	0.136	0.135	0.134	0.134	0.133
2001	0.000	0.003	0.033	0.095	0.139	0.152	0.147	0.139	0.131	0.125	0.121	0.117	0.115	0.113	0.112	0.111	0.110	0.110	0.109
2002	0.000	0.004	0.037	0.108	0.162	0.178	0.174	0.164	0.155	0.148	0.143	0.139	0.137	0.135	0.133	0.132	0.131	0.131	0.130
2003	0.000	0.003	0.034	0.101	0.155	0.172	0.168	0.159	0.150	0.143	0.138	0.134	0.131	0.129	0.128	0.127	0.126	0.125	0.124
2004	0.000	0.004	0.041	0.117	0.175	0.193	0.189	0.179	0.169	0.162	0.156	0.152	0.150	0.147	0.146	0.145	0.144	0.143	0.142
2005	0.000	0.002	0.031	0.104	0.173	0.206	0.213	0.210	0.205	0.200	0.196	0.194	0.192	0.190	0.189	0.188	0.187	0.187	0.186
2006	0.000	0.002	0.029	0.106	0.181	0.218	0.226	0.222	0.216	0.211	0.207	0.204	0.201	0.200	0.198	0.197	0.197	0.196	0.195
2007	0.000	0.002	0.028	0.099	0.169	0.203	0.210	0.206	0.200	0.195	0.191	0.188	0.185	0.184	0.182	0.181	0.181	0.180	0.179
2008	0.000	0.002	0.032	0.112	0.187	0.222	0.228	0.223	0.217	0.210	0.206	0.202	0.200	0.198	0.196	0.195	0.194	0.194	0.193
2009	0.000	0.002	0.034	0.116	0.196	0.233	0.239	0.233	0.225	0.218	0.213	0.209	0.206	0.204	0.202	0.201	0.200	0.199	0.198
2010	0.000	0.002	0.027	0.090	0.153	0.184	0.190	0.186	0.180	0.175	0.171	0.168	0.166	0.165	0.163	0.163	0.162	0.161	0.161
2011	0.000	0.002	0.028	0.101	0.172	0.207	0.214	0.211	0.206	0.201	0.197	0.194	0.192	0.190	0.189	0.188	0.188	0.187	0.187

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 2012-2024 (Scenarios 1 and 2), with random variability in future recruitment.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2012	314,000	314,000	314,000	314,000	0
2013	319,000	319,000	319,000	319,000	0
2014	313,000	313,000	313,000	313,000	2
2015	301,000	302,000	303,000	304,000	1,058
2016	275,000	285,000	289,000	315,000	13,875
2017	237,000	267,000	275,000	342,000	34,915
2018	185,000	255,000	262,000	376,000	57,470
2019	146,000	249,000	251,000	380,000	73,626
2020	128,000	244,000	247,000	380,000	80,669
2021	123,000	243,000	246,000	387,000	82,784
2022	124,000	242,000	245,000	388,000	82,132
2023	125,000	240,000	244,000	386,000	80,501
2024	126,000	243,000	243,000	388,000	79,566

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2012	410,000	410,000	410,000	410,000	0
2013	437,000	437,000	437,000	437,000	0
2014	441,000	441,000	441,000	441,000	54
2015	431,000	432,000	433,000	435,000	1,199
2016	410,000	417,000	419,000	434,000	8,393
2017	371,000	394,000	400,000	454,000	26,977
2018	324,000	371,000	384,000	485,000	52,711
2019	288,000	359,000	373,000	516,000	72,779
2020	266,000	353,000	369,000	522,000	83,083
2021	259,000	348,000	368,000	524,000	87,672
2022	259,000	350,000	368,000	528,000	88,794
2023	257,000	347,000	367,000	534,000	87,203
2024	259,000	347,000	366,000	533,000	85,032

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2012	0.30	0.30	0.30	0.30	0.00
2013	0.30	0.30	0.30	0.30	0.00
2014	0.30	0.30	0.30	0.30	0.00
2015	0.30	0.30	0.30	0.30	0.00
2016	0.30	0.30	0.30	0.30	0.00
2017	0.30	0.30	0.30	0.30	0.00
2018	0.27	0.30	0.29	0.30	0.01
2019	0.24	0.30	0.28	0.30	0.02
2020	0.22	0.30	0.28	0.30	0.03
2021	0.21	0.29	0.27	0.30	0.03
2022	0.21	0.29	0.27	0.30	0.03
2023	0.21	0.29	0.27	0.30	0.03
2024	0.21	0.29	0.27	0.30	0.03

Table 2.33—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 2012-2024 (Scenario 3), with random variability in future recruitment.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2012	268,000	268,000	268,000	268,000	0
2013	279,000	279,000	279,000	279,000	0
2014	280,000	280,000	280,000	280,000	2
2015	274,000	274,000	275,000	276,000	888
2016	253,000	262,000	265,000	287,000	11,713
2017	221,000	247,000	255,000	312,000	29,872
2018	191,000	237,000	246,000	344,000	46,682
2019	168,000	234,000	241,000	348,000	57,128
2020	154,000	229,000	239,000	347,000	62,696
2021	149,000	228,000	237,000	354,000	65,195
2022	146,000	226,000	235,000	353,000	65,176
2023	147,000	224,000	233,000	352,000	63,918
2024	145,000	223,000	232,000	353,000	63,076

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2012	414,000	414,000	414,000	414,000	0
2013	455,000	455,000	455,000	455,000	0
2014	471,000	471,000	471,000	471,000	54
2015	471,000	472,000	472,000	474,000	1,200
2016	455,000	461,000	463,000	479,000	8,422
2017	418,000	441,000	448,000	502,000	27,391
2018	369,000	418,000	432,000	537,000	54,939
2019	322,000	406,000	419,000	573,000	79,061
2020	288,000	397,000	411,000	583,000	94,254
2021	269,000	389,000	407,000	582,000	102,629
2022	259,000	388,000	403,000	597,000	106,124
2023	257,000	384,000	400,000	595,000	105,818
2024	251,000	383,000	397,000	597,000	104,090

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2012	0.25	0.25	0.25	0.25	0.00
2013	0.25	0.25	0.25	0.25	0.00
2014	0.25	0.25	0.25	0.25	0.00
2015	0.25	0.25	0.25	0.25	0.00
2016	0.25	0.25	0.25	0.25	0.00
2017	0.25	0.25	0.25	0.25	0.00
2018	0.25	0.25	0.25	0.25	0.00
2019	0.25	0.25	0.25	0.25	0.00
2020	0.25	0.25	0.25	0.25	0.00
2021	0.25	0.25	0.25	0.25	0.00
2022	0.25	0.25	0.25	0.25	0.00
2023	0.25	0.25	0.25	0.25	0.00
2024	0.25	0.25	0.25	0.25	0.00

Table 2.34—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 2012-2024 (Scenario 4), with random variability in future recruitment.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2012	163,000	163,000	163,000	163,000	0
2013	180,000	180,000	180,000	180,000	0
2014	190,000	190,000	190,000	190,000	1
2015	192,000	193,000	193,000	194,000	523
2016	184,000	189,000	191,000	204,000	6,973
2017	167,000	183,000	187,000	222,000	18,309
2018	148,000	177,000	183,000	244,000	29,743
2019	132,000	175,000	180,000	252,000	37,718
2020	122,000	172,000	179,000	253,000	42,415
2021	117,000	170,000	177,000	256,000	44,855
2022	113,000	170,000	176,000	258,000	45,474
2023	113,000	168,000	175,000	259,000	44,954
2024	112,000	169,000	174,000	258,000	44,399

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2012	421,000	421,000	421,000	421,000	0
2013	496,000	496,000	496,000	496,000	0
2014	545,000	545,000	545,000	545,000	54
2015	571,000	572,000	572,000	574,000	1,200
2016	573,000	580,000	582,000	598,000	8,484
2017	547,000	571,000	578,000	633,000	28,307
2018	499,000	553,000	567,000	679,000	59,292
2019	448,000	540,000	556,000	735,000	89,473
2020	406,000	532,000	548,000	753,000	110,904
2021	376,000	523,000	543,000	754,000	124,071
2022	363,000	521,000	539,000	769,000	130,899
2023	355,000	515,000	535,000	771,000	132,543
2024	346,000	513,000	531,000	773,000	131,398

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
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
2023	0.15	0.15	0.15	0.15	0.00
2024	0.15	0.15	0.15	0.15	0.00

Table 2.35—Projections for BSAI Pacific cod catch (t), spawning biomass (t), and fishing mortality under the assumption that *F* = 0 in 2012-2024 (Scenario 5), with random variability in future recruitment.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
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
2023	0	0	0	0	0
2024	0	0	0	0	0

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2012	432,000	432,000	432,000	432,000	0
2013	561,000	561,000	561,000	561,000	0
2014	674,000	674,000	674,000	675,000	54
2015	761,000	762,000	762,000	764,000	1,202
2016	815,000	822,000	824,000	840,000	8,574
2017	828,000	853,000	860,000	917,000	29,673
2018	803,000	861,000	877,000	1,000,000	66,242
2019	756,000	864,000	884,000	1,100,000	107,575
2020	709,000	865,000	887,000	1,160,000	142,345
2021	664,000	863,000	888,000	1,190,000	167,483
2022	642,000	862,000	888,000	1,200,000	183,827
2023	622,000	860,000	887,000	1,230,000	192,278
2024	613,000	864,000	884,000	1,220,000	194,960

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
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
2023	0.00	0.00	0.00	0.00	0.00
2024	0.00	0.00	0.00	0.00	0.00

Table 2.36—Projections for BSAI Pacific cod catch (t), spawning biomass (t), and fishing mortality under the assumption that $F = F_{OFL}$ in 2012-2024 (Scenario 6), with random variability in future recruitment.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2012	369,000	369,000	369,000	369,000	0
2013	362,000	362,000	362,000	362,000	0
2014	347,000	347,000	347,000	347,000	2
2015	328,000	329,000	330,000	332,000	1,264
2016	294,000	307,000	311,000	342,000	16,471
2017	228,000	277,000	286,000	372,000	46,982
2018	175,000	254,000	267,000	408,000	73,137
2019	144,000	248,000	259,000	412,000	86,591
2020	129,000	245,000	258,000	410,000	92,512
2021	126,000	246,000	259,000	422,000	93,966
2022	129,000	246,000	259,000	416,000	92,877
2023	127,000	246,000	257,000	426,000	91,138
2024	131,000	248,000	257,000	421,000	90,291

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2012	406,000	406,000	406,000	406,000	0
2013	417,000	417,000	417,000	417,000	0
2014	407,000	407,000	407,000	407,000	54
2015	389,000	390,000	390,000	393,000	1,199
2016	363,000	369,000	372,000	387,000	8,358
2017	324,000	346,000	352,000	404,000	25,938
2018	286,000	327,000	339,000	431,000	47,833
2019	259,000	321,000	333,000	459,000	63,402
2020	243,000	319,000	332,000	462,000	71,112
2021	238,000	319,000	333,000	463,000	74,681
2022	239,000	320,000	334,000	472,000	75,449
2023	239,000	319,000	333,000	478,000	73,830
2024	241,000	319,000	332,000	481,000	71,993

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2012	0.36	0.36	0.36	0.36	0.00
2013	0.36	0.36	0.36	0.36	0.00
2014	0.36	0.36	0.36	0.36	0.00
2015	0.36	0.36	0.36	0.36	0.00
2016	0.36	0.36	0.36	0.36	0.00
2017	0.32	0.35	0.34	0.36	0.01
2018	0.28	0.33	0.33	0.36	0.03
2019	0.25	0.32	0.32	0.36	0.04
2020	0.24	0.32	0.31	0.36	0.04
2021	0.23	0.32	0.31	0.36	0.04
2022	0.23	0.32	0.31	0.36	0.04
2023	0.23	0.32	0.31	0.36	0.04
2024	0.24	0.32	0.31	0.36	0.04

Table 2.37—Projections for BSAI Pacific cod catch (t), spawning biomass (t), and fishing mortality under the assumption that $F = max\ F_{ABC}$ in each year 2012-2013 and $F = F_{OFL}$ thereafter (Scenario 7), with random variability in future recruitment.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2012	314,000	314,000	314,000	314,000	0
2013	319,000	319,000	319,000	319,000	0
2014	367,000	367,000	367,000	367,000	2
2015	342,000	343,000	343,000	345,000	1,264
2016	303,000	315,000	319,000	350,000	16,471
2017	238,000	288,000	295,000	377,000	44,859
2018	178,000	257,000	270,000	411,000	72,950
2019	145,000	250,000	260,000	413,000	86,744
2020	129,000	246,000	258,000	410,000	92,638
2021	126,000	246,000	259,000	422,000	94,043
2022	129,000	246,000	258,000	417,000	92,919
2023	127,000	246,000	257,000	426,000	91,160
2024	131,000	248,000	257,000	421,000	90,300

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2012	410,000	410,000	410,000	410,000	0
2013	437,000	437,000	437,000	437,000	0
2014	436,000	436,000	436,000	436,000	54
2015	411,000	411,000	412,000	414,000	1,199
2016	377,000	384,000	386,000	402,000	8,358
2017	333,000	354,000	361,000	413,000	26,122
2018	290,000	331,000	343,000	437,000	48,523
2019	260,000	322,000	335,000	462,000	64,019
2020	243,000	319,000	333,000	464,000	71,497
2021	238,000	319,000	333,000	464,000	74,873
2022	239,000	320,000	334,000	472,000	75,532
2023	239,000	318,000	333,000	478,000	73,863
2024	241,000	319,000	332,000	481,000	72,005

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2012	0.30	0.30	0.30	0.30	0.00
2013	0.30	0.30	0.30	0.30	0.00
2014	0.36	0.36	0.36	0.36	0.00
2015	0.36	0.36	0.36	0.36	0.00
2016	0.36	0.36	0.36	0.36	0.00
2017	0.33	0.35	0.35	0.36	0.01
2018	0.29	0.33	0.33	0.36	0.02
2019	0.26	0.32	0.32	0.36	0.04
2020	0.24	0.32	0.31	0.36	0.04
2021	0.23	0.32	0.31	0.36	0.04
2022	0.23	0.32	0.31	0.36	0.04
2023	0.23	0.32	0.31	0.36	0.04
2024	0.24	0.32	0.31	0.36	0.04

Table 2.38—Incidental catch (t) of non-target species groups by BSAI Pacific cod fisheries, 2003-2011.

Species/group	2003	2004	2005	2006	2007	2008	2009	2010	2011
Benthic urochordata	14	4	11	5	1	2	0	10	34
Birds	5	5	6	5	6	4	8	3	3
Bivalves	19	17	6	7	4	11	10	3	9
Brittle star unidentified	1	1	0	1	1	0	0	0	1
Capelin		0			0	0		0	0
Corals bryozoans	26	14	14	13	18	13	14	12	7
Dark rockfish						3	4	4	0
Eelpouts	48	36	42	17	18	7	2	3	3
Eulachon		0	0	0	0	0		0	0
Giant grenadier	2	15	144	195	126	158	213	515	1,067
Greenlings	7	3	2	6	1	1	0	1	0
Grenadier	285	238	193	50	94	15	2	116	10
Gunnels		0	0		0				
Hermit crab unidentified	6	4	2	2	2	1	1	1	1
Invertebrate unidentified	19	6	3	31	22	5	12	45	46
Lanternfishes (myctophidae)		0							
Misc crabs	9	5	5	17	29	6	2	6	3
Misc crustaceans	0	0	1	1	1	0	0	0	0
Misc fish	260	244	225	109	114	54	63	58	92
Misc inverts (worms etc)	0	0	0	0	0	0	0	0	0
Other osmerids	0	0	0	0	0		0	0	0
Pacific sand lance	0	0	0	0	0	0		0	0
Pandalid shrimp	0	0	0	0	0	0	0	0	0
Polychaete unidentified	0	0	0	0	0	0	0	0	0
Scypho jellies	669	710	401	67	113	42	87	42	180
Sea anemone unidentified	92	114	114	87	38	49	119	85	123
Sea pens whips	6	12	30	16	7	9	35	23	24
Sea star	448	429	446	323	244	189	164	154	148
Snails	27	21	13	17	16	20	28	18	18
Sponge unidentified	31	31	32	39	21	6	24	14	13
Stichaeidae	0	0	0	0	0	0	0	0	
Urchins dollars cucumbers	12	12	13	5	14	3	2	2	4

Table 2.39a—Catches of prohibited species by BSAI Pacific cod fisheries, 2003-2011. Halibut and herring are in kg, salmon and crab are in number of individuals.

Species/group	2003	2004	2005	2006	2007	2008	2009	2010	2011
Halibut	6,897,789	7,026,420	7,747,294	6,219,348	6,480,156	7,604,845	6,682,934	6,647,739	3,961,810
Herring	13,834	9,154	17,619	7,902	1,065	382	3	94	6
Chinook salmon	3,990	5,648	3,812	3,649	6,361	2,072	1,065	1,264	480
Non-chinook salmon	1,047	6,866	967	7,986	1,787	289	135	47	287
Bairdi tanner crab	283,106	265,658	293,669	596,139	647,156	1,601,762	488,876	433,461	319,889
Blue king crab	3,054	3,151	1,334	3,770	222,882	8,858	15,023	54,091	1,146
Golden (brown) king crab	427	45	330	684	865	1,001	1,883	903	385
Opilio tanner (snow) crab	164,983	219,925	194,444	350,954	970,743	767,855	701,190	382,117	195,678
Red king crab	21,704	17,043	24,017	19,499	35,803	52,835	12,482	6,195	18,104

Table 2.39b—Halibut mortality (t) resulting from BSAI Pacific cod fisheries, 2003-2011.

	2003	2004	2005	2006	2007	2008	2009	2010	2011
Halibut mortality (t)	1,951	2,123	2,045	1,893	1,610	1,111	946	914	616

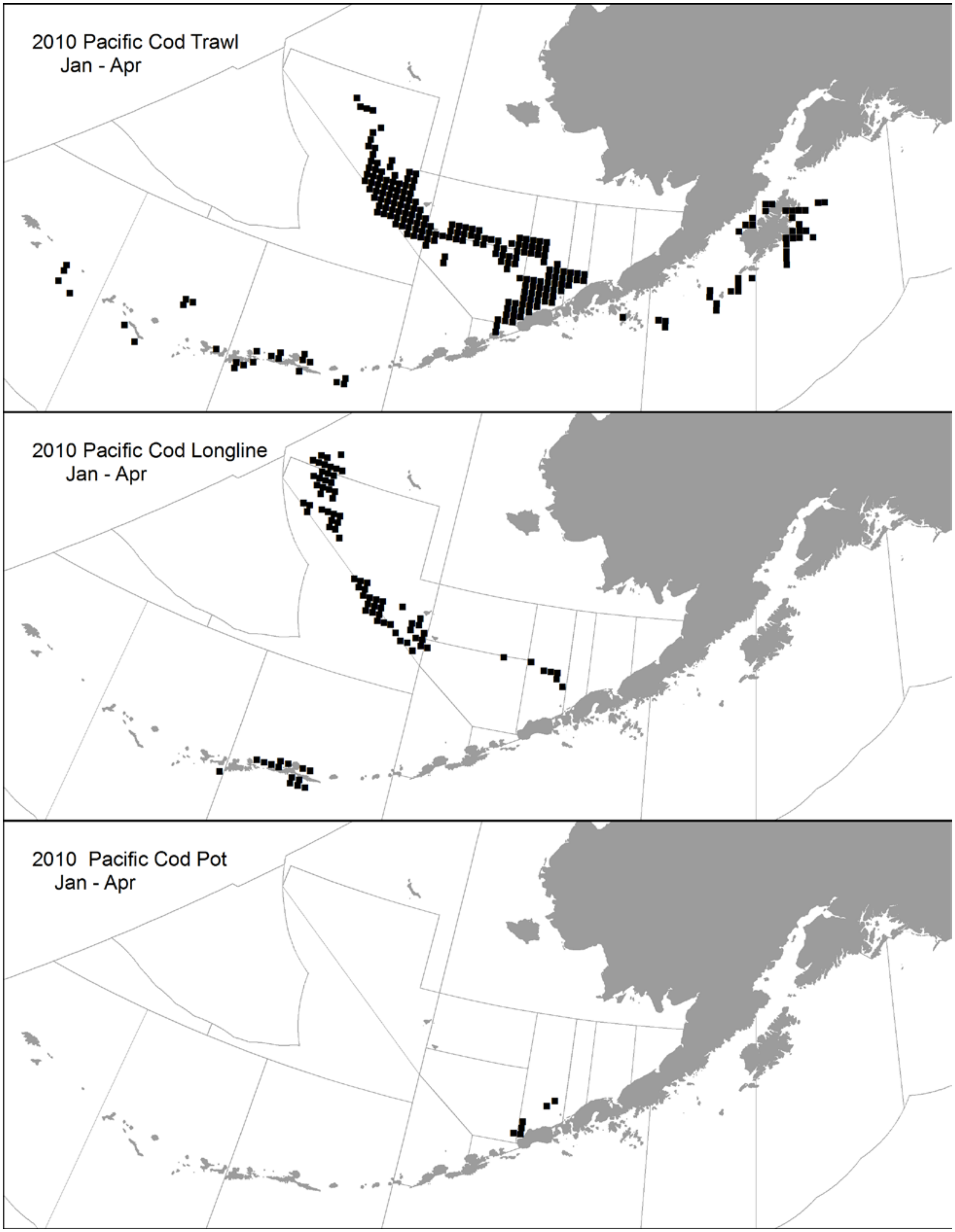

Figure 2.1a—Maps showing each 400 square kilometer cell with hauls/sets containing Pacific cod from at least 3 distinct vessels, January-April 2010, by gear type, overlaid against NMFS 3-digit statistical areas.

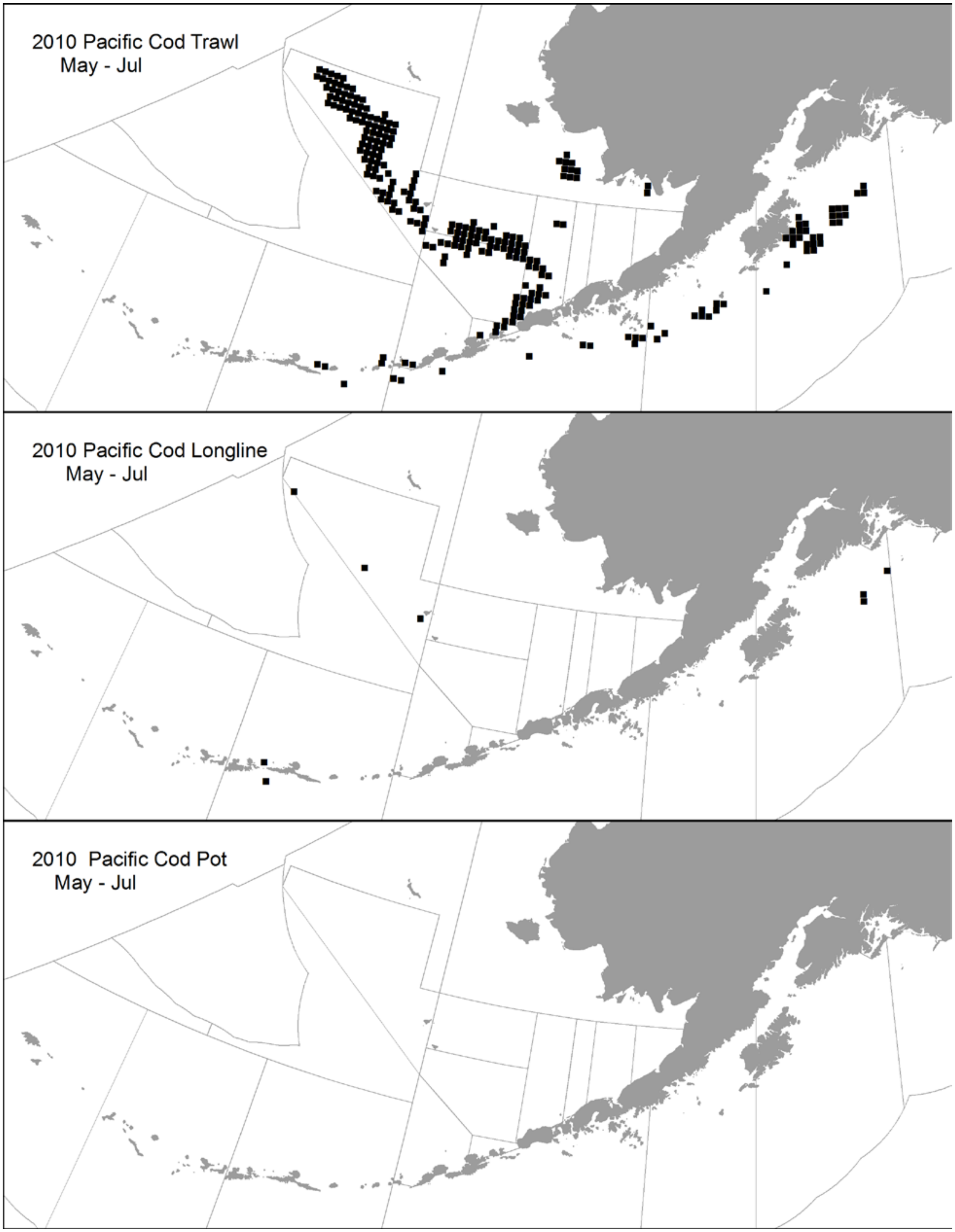

Figure 2.1b—Maps showing each 400 square kilometer cell with hauls/sets containing Pacific cod from at least 3 distinct vessels, May-July 2010, by gear type, overlaid against NMFS 3-digit statistical areas.

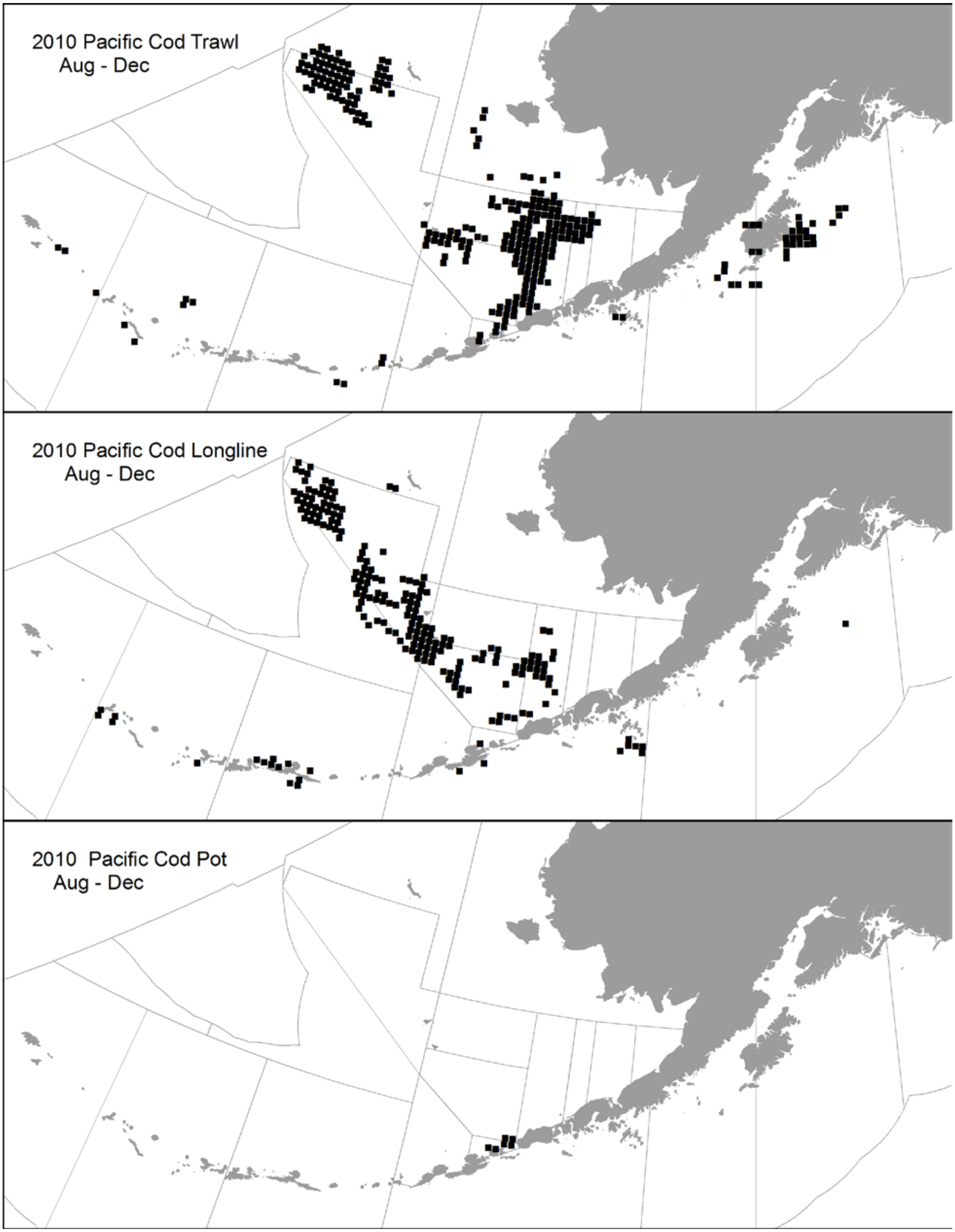

Figure 2.1c—Maps showing each 400 square kilometer cell with hauls/sets containing Pacific cod from at least 3 distinct vessels, Aug.-Dec. 2010, by gear type, overlaid against NMFS 3-digit statistical areas.

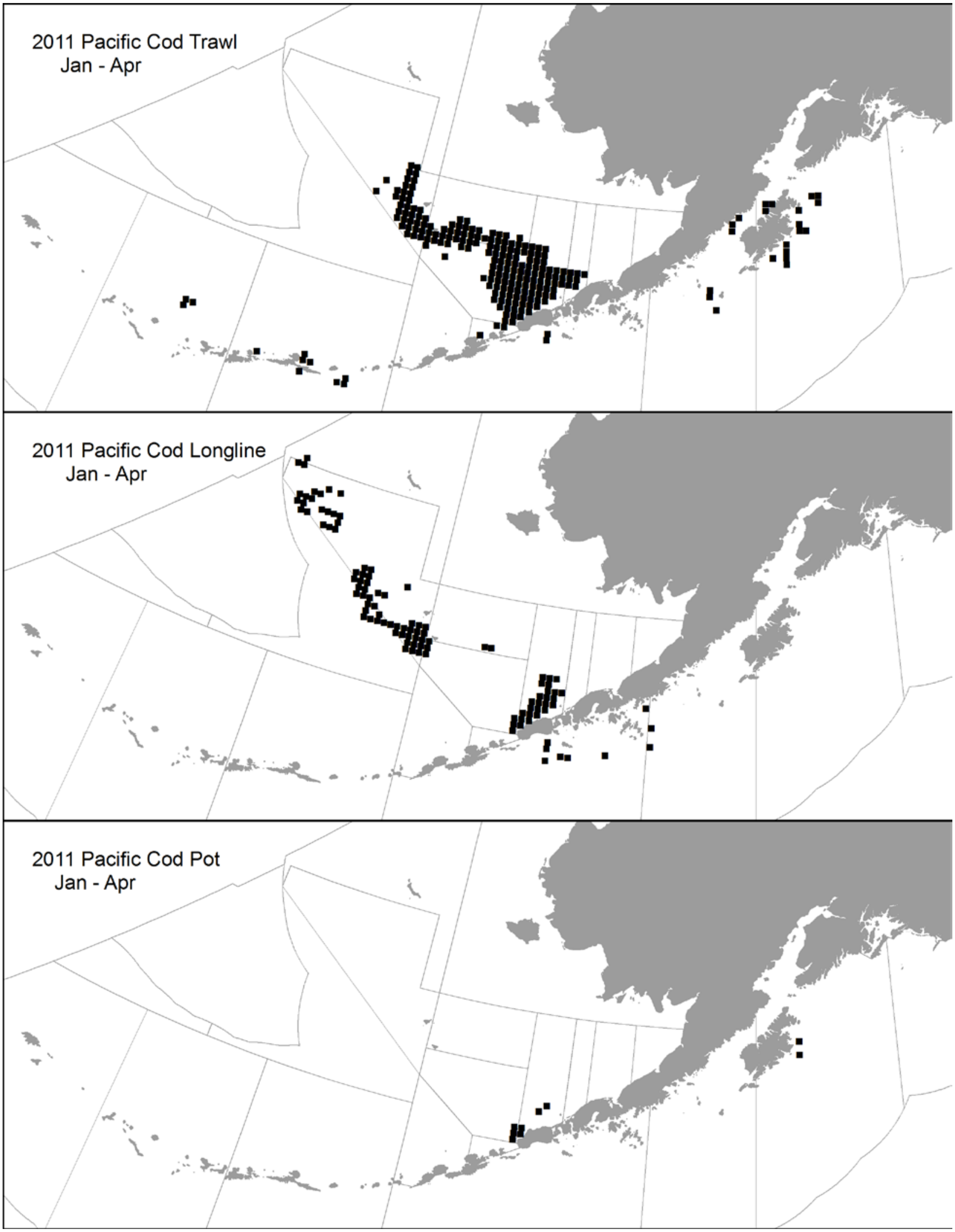

Figure 2.1d—Maps showing each 400 square kilometer cell with hauls/sets containing Pacific cod from at least 3 distinct vessels, January-Apr 2011, by gear type, overlaid against NMFS 3-digit statistical areas.

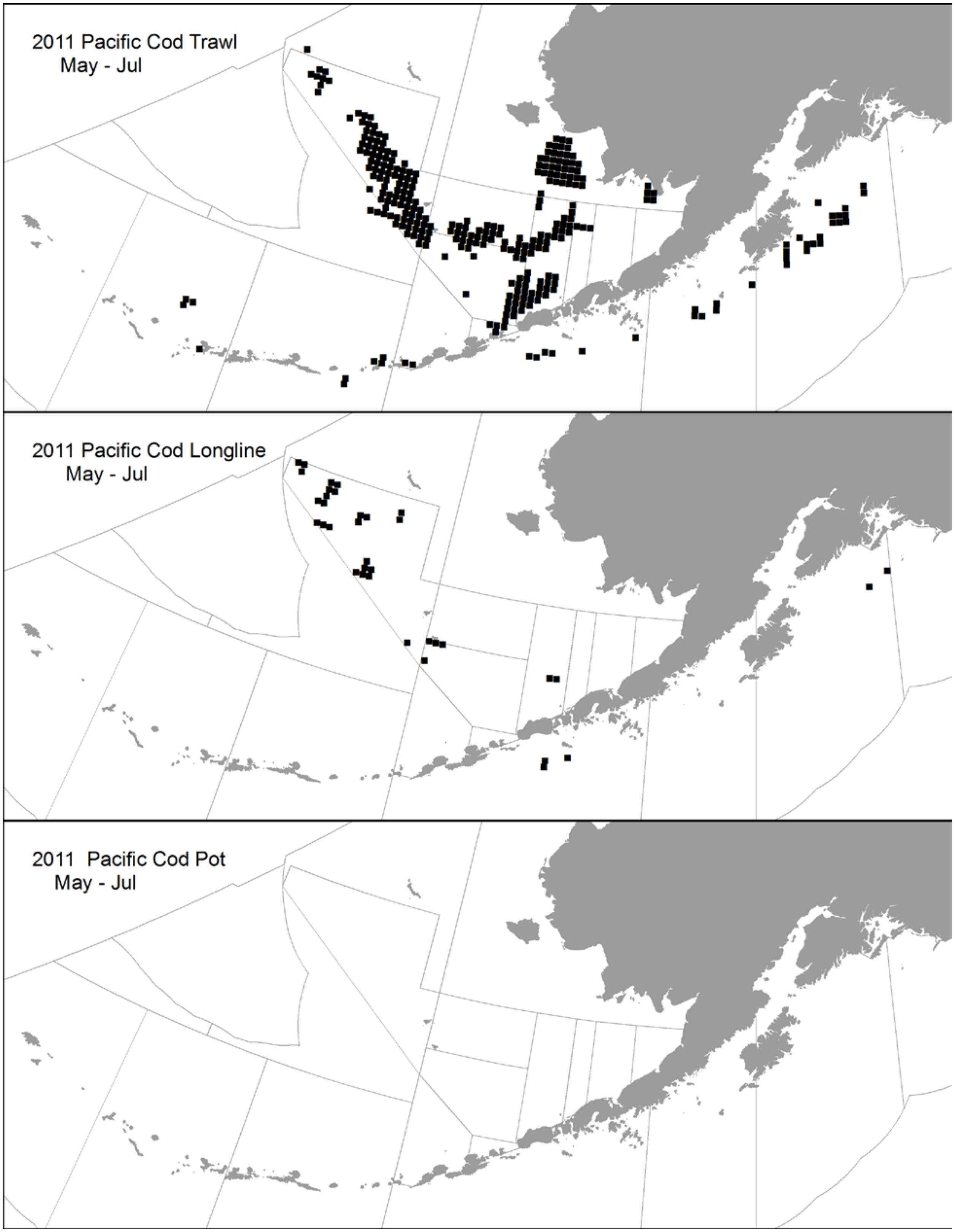

Figure 2.1e—Maps showing each 400 square kilometer cell with hauls/sets containing Pacific cod from at least 3 distinct vessels, May-July 2011, by gear type, overlaid against NMFS 3-digit statistical areas.

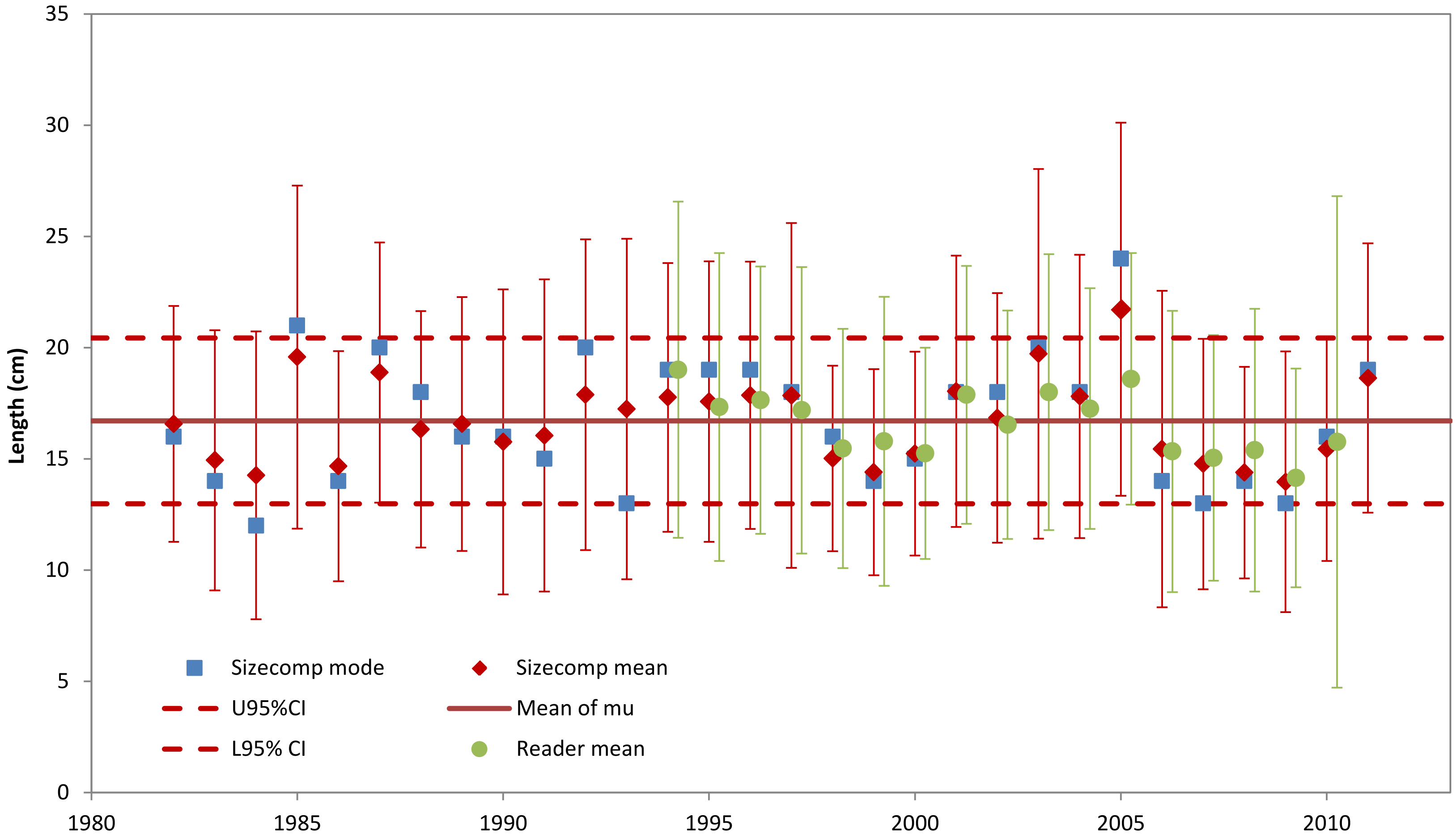

Figure 2.2—Time series of age 1 size distributions as estimated from survey size composition data and age readings.

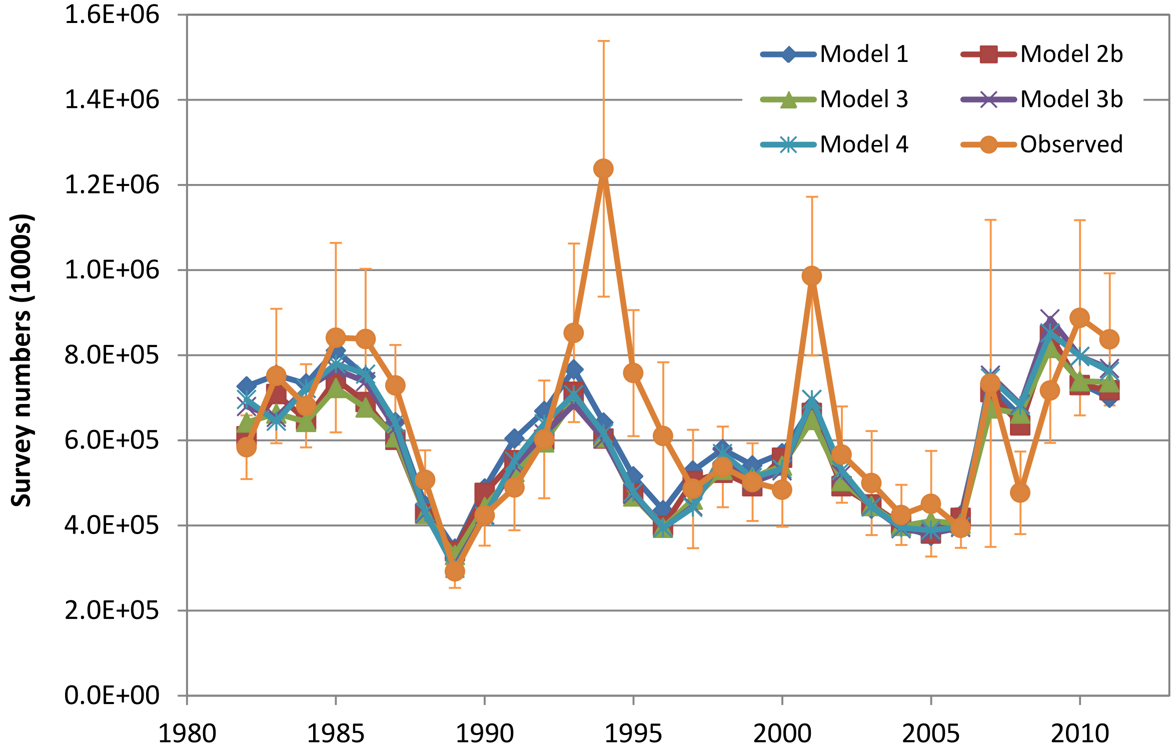

Figure 2.3—Fits of the five models to the trawl survey abundance time series.

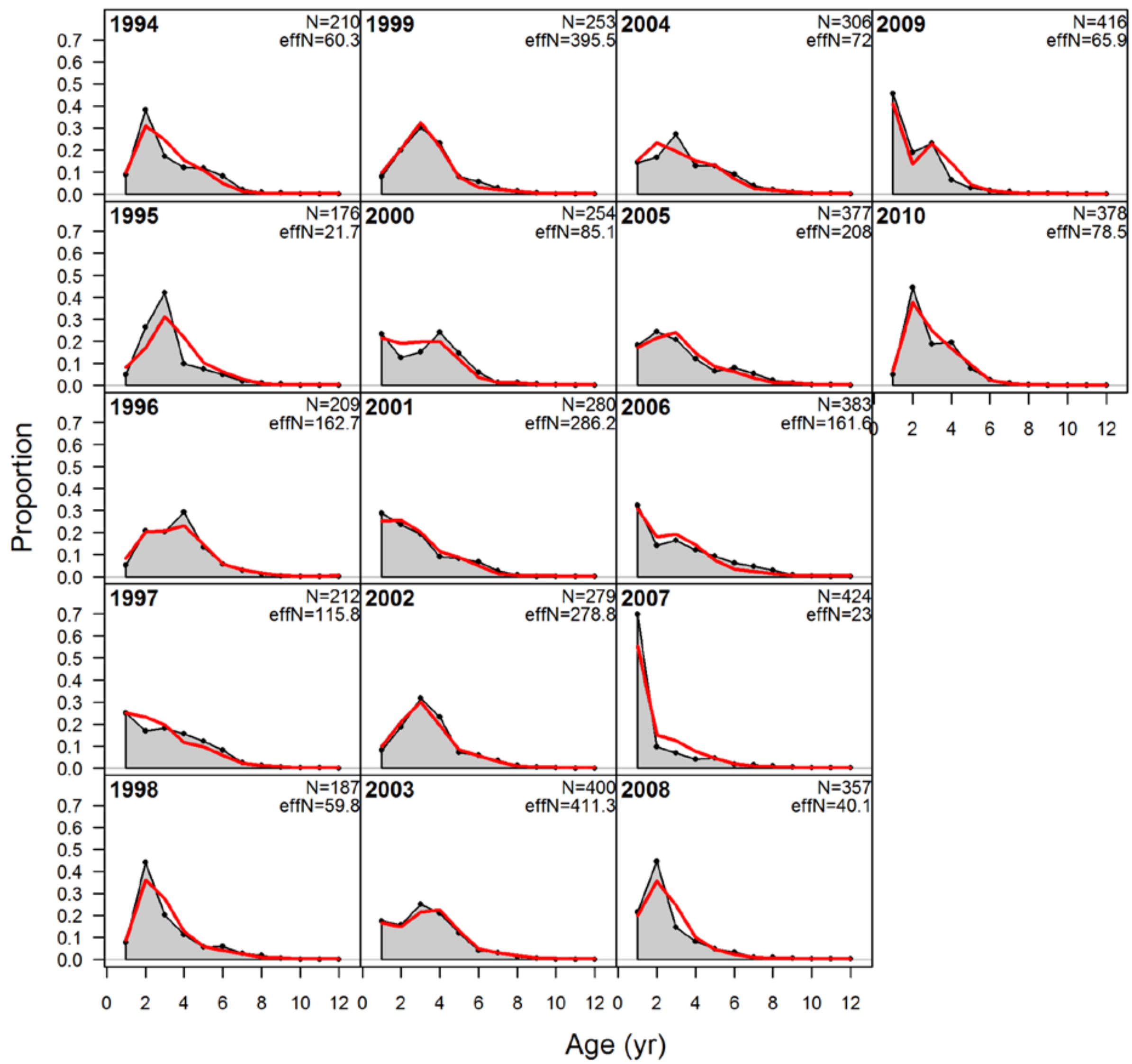

Figure 2.4a—Fit to trawl survey age composition data obtained by Model 1.

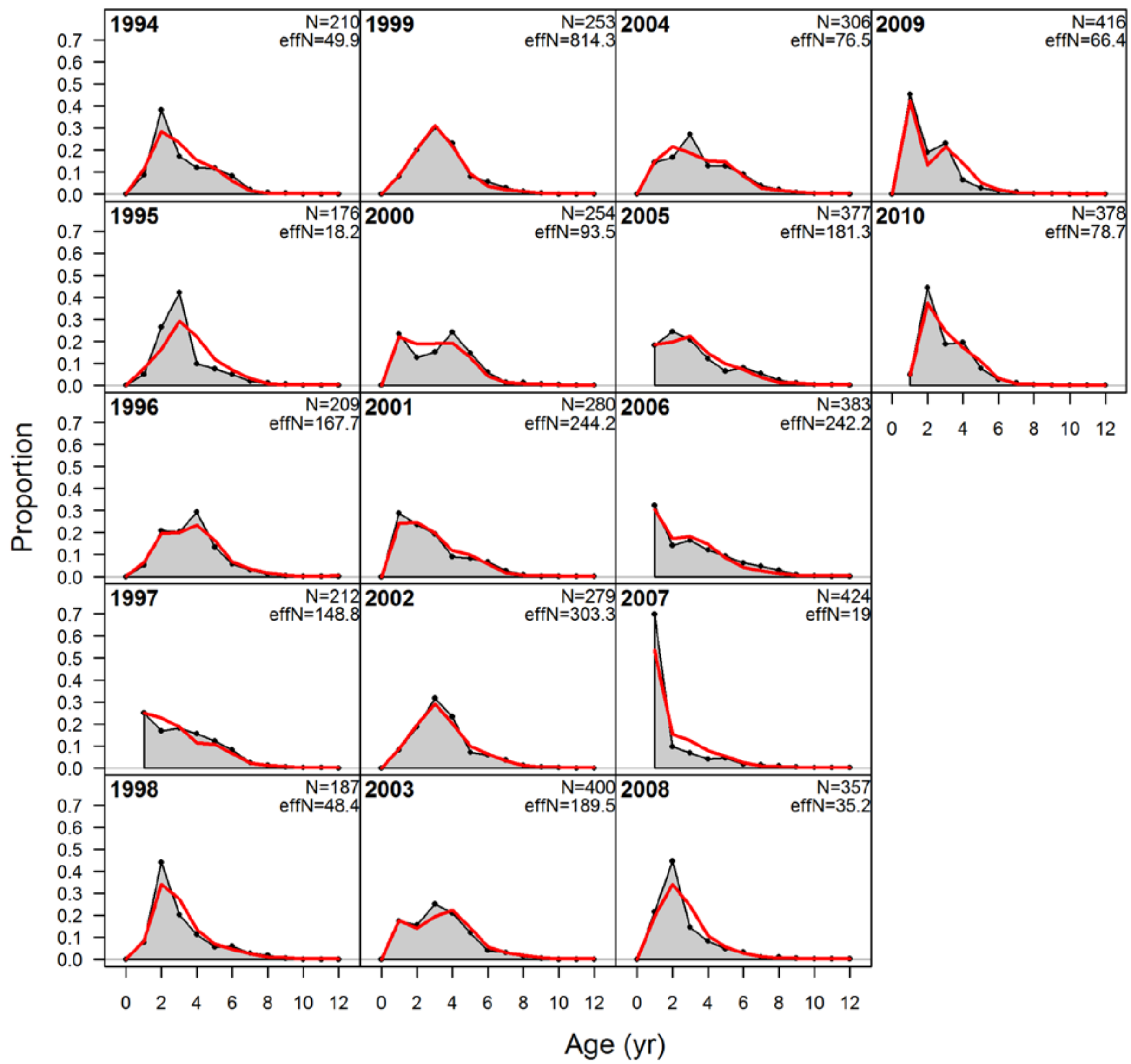

Figure 2.4b—Fit to trawl survey age composition data obtained by Model 2b.

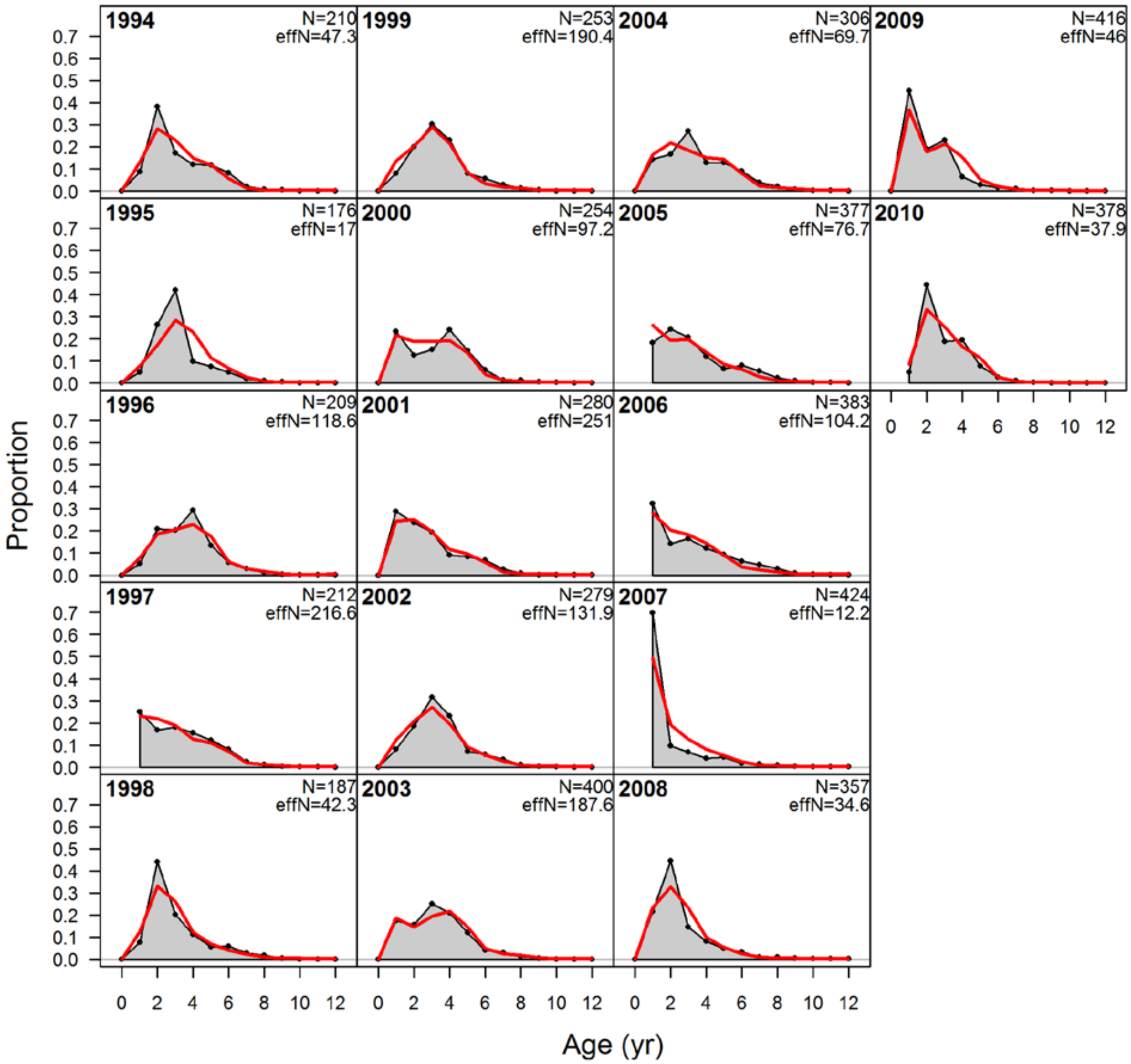

Figure 2.4c—Fit to trawl survey age composition data obtained by Model 3.

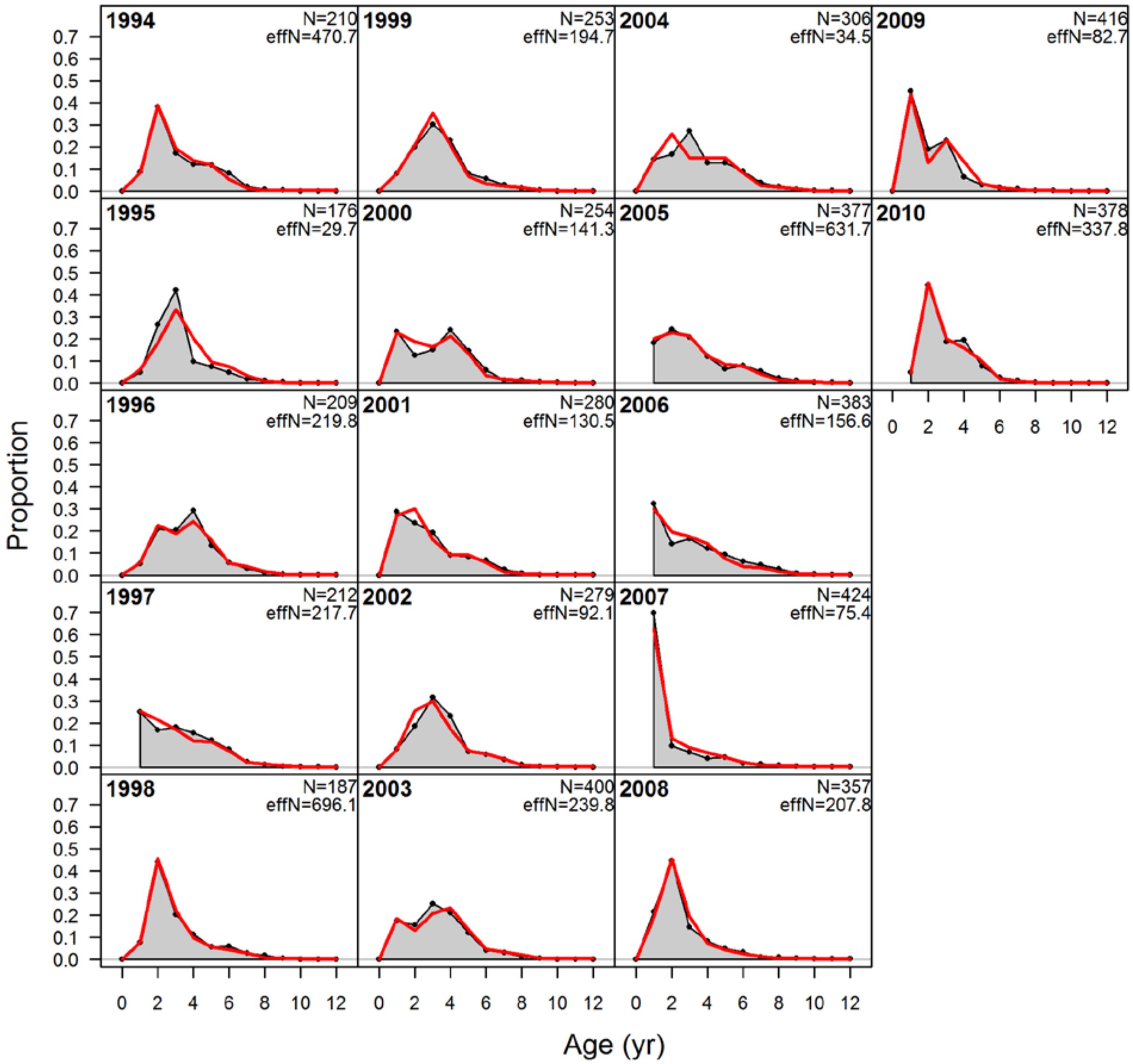

Figure 2.4d—Fit to trawl survey age composition data obtained by Model 3b.

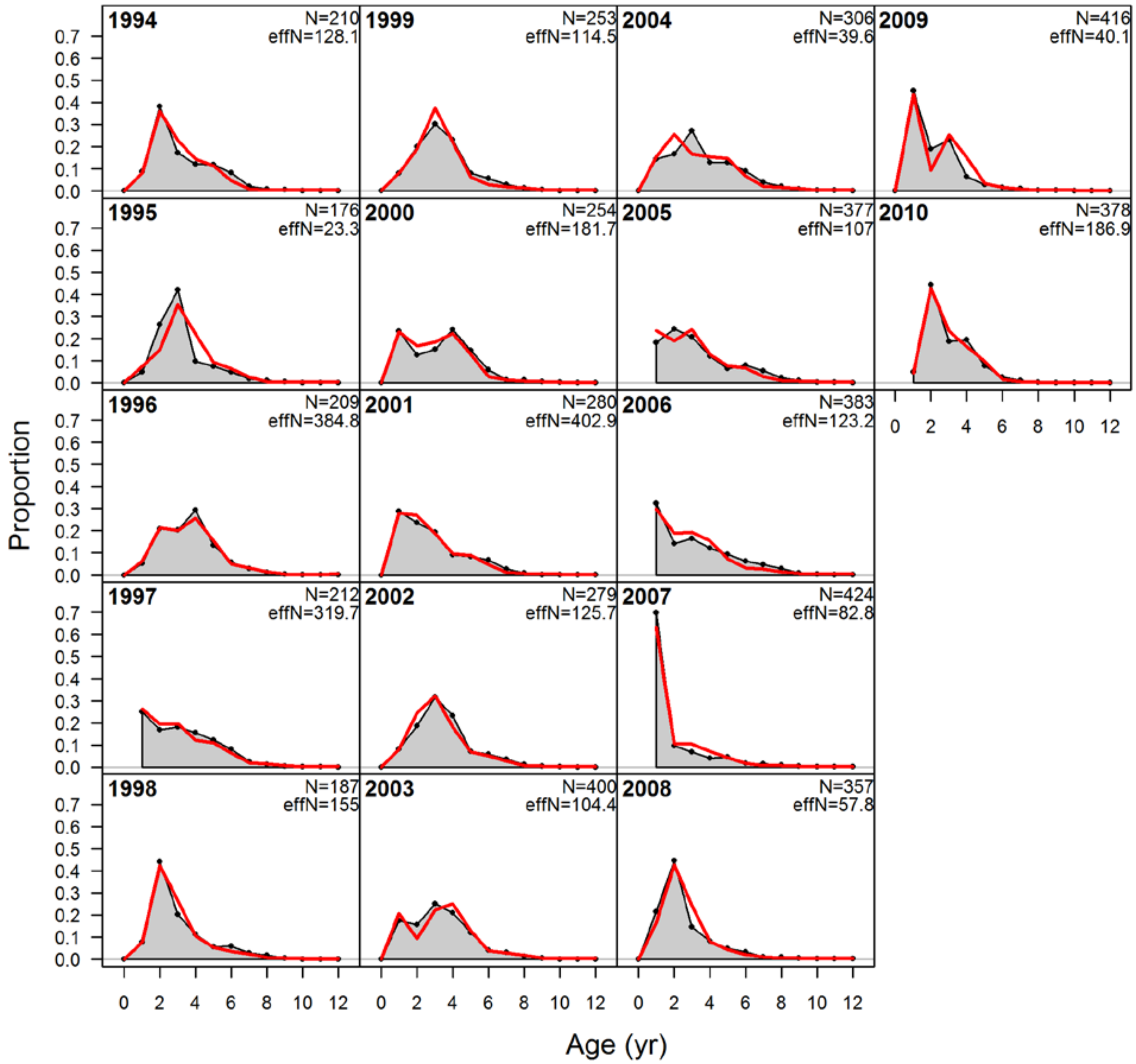

Figure 2.4e—Fit to trawl survey age composition data obtained by Model 4.

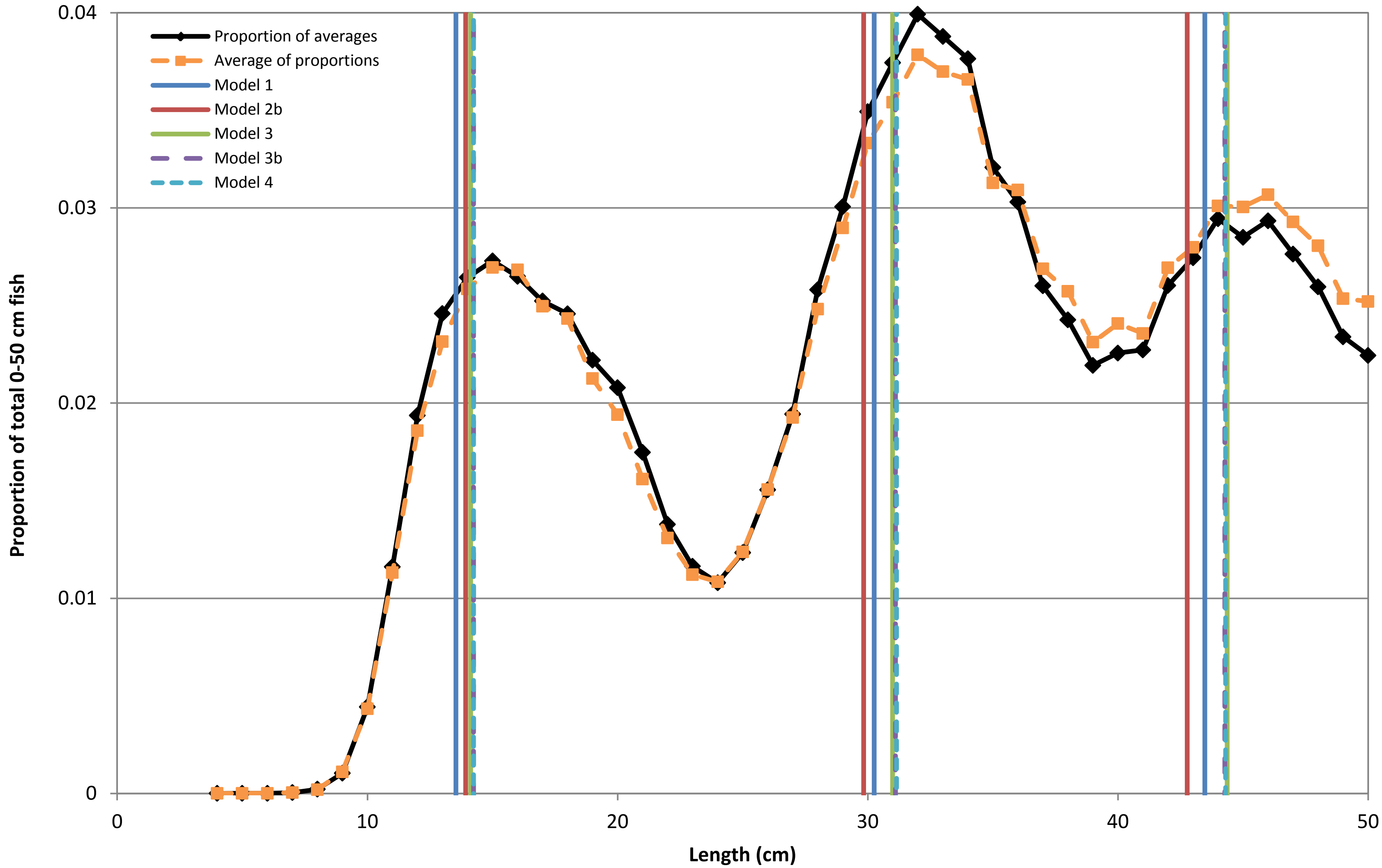

Figure 2.5—Estimates of mean size at ages 1-3 from each of the models, compared to long-term average survey size (0-50 cm) composition.

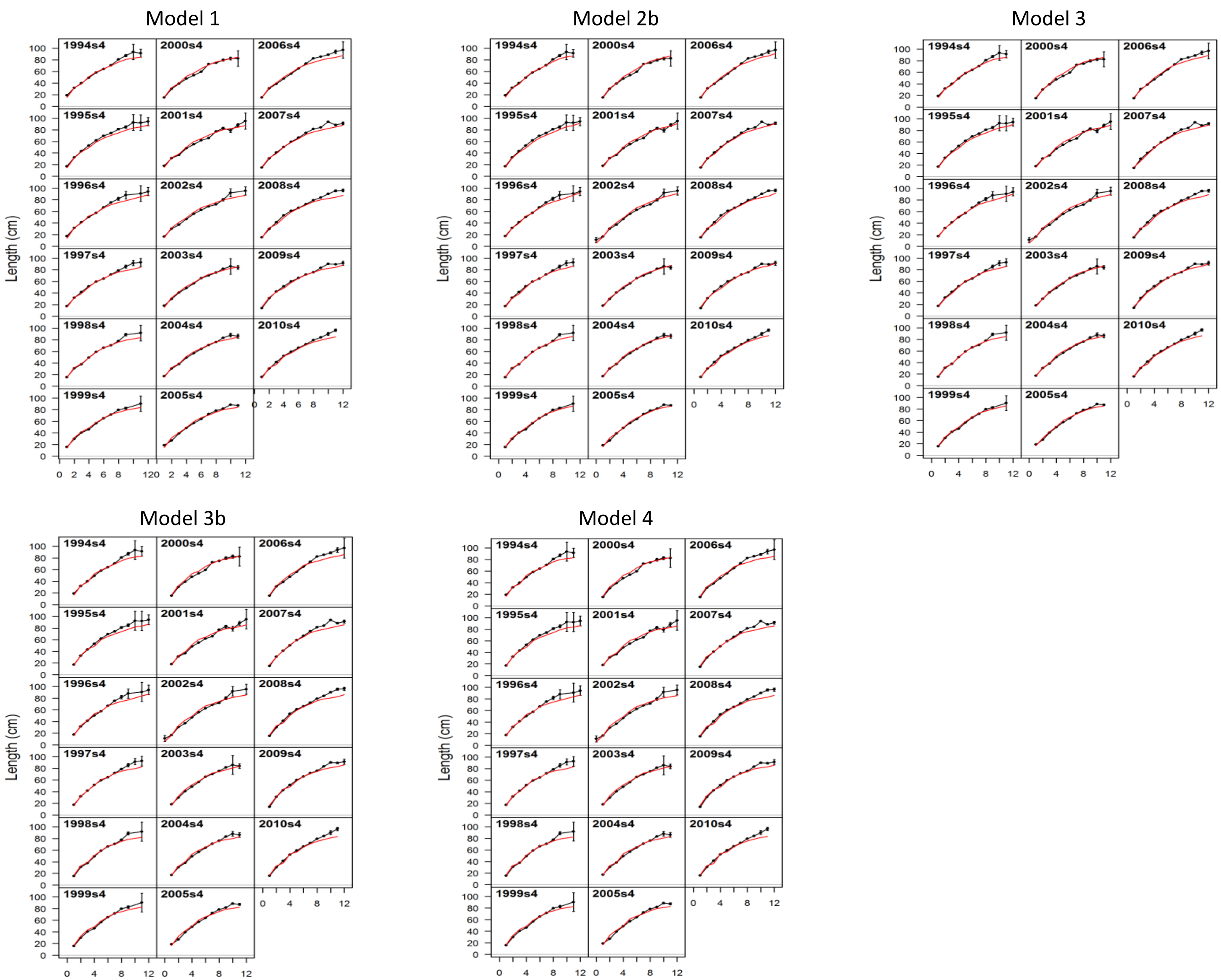

Figure 2.6—Fit to size-at-age data from all five models.

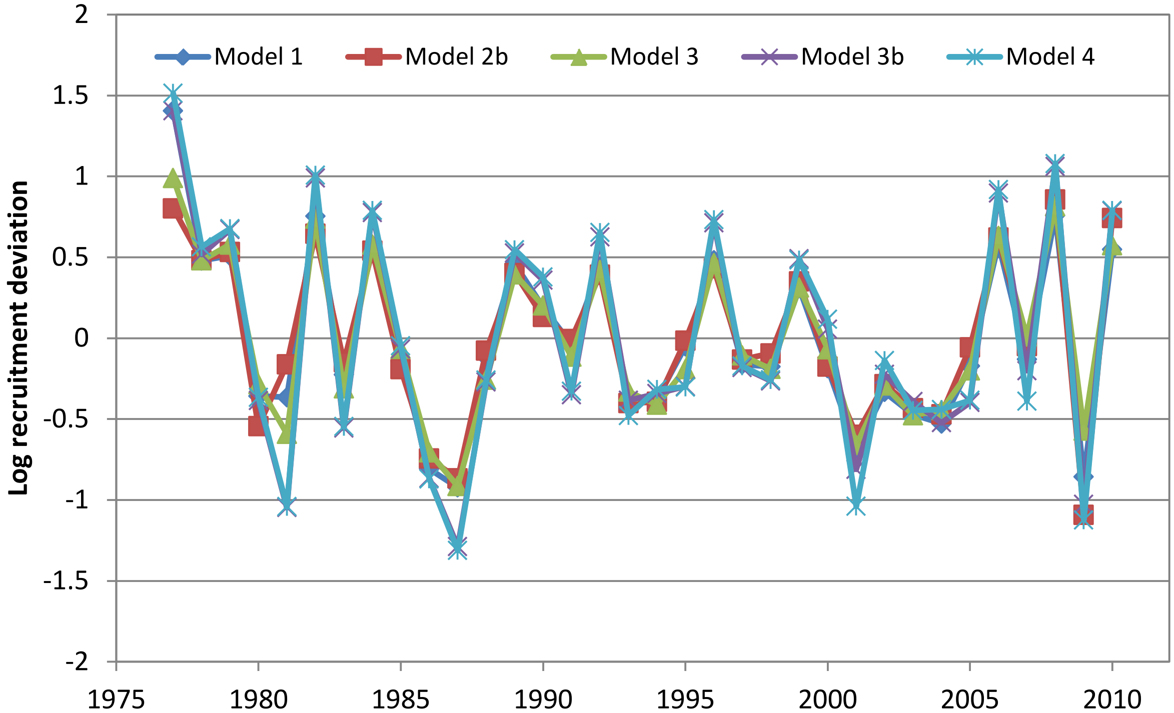

Figure 2.7—Time series of estimated log recruitment deviations from the five models.

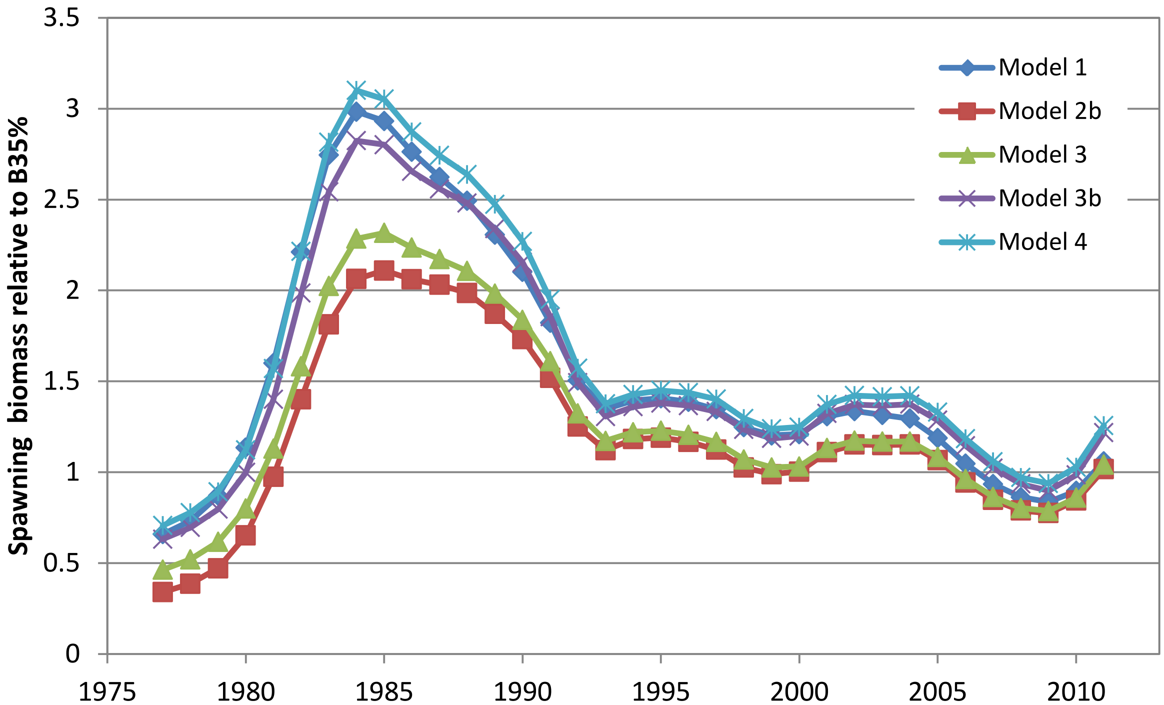

Figure 2.8—Time series of spawning biomass relative to $B_{35\%}$ as estimated by the five models.

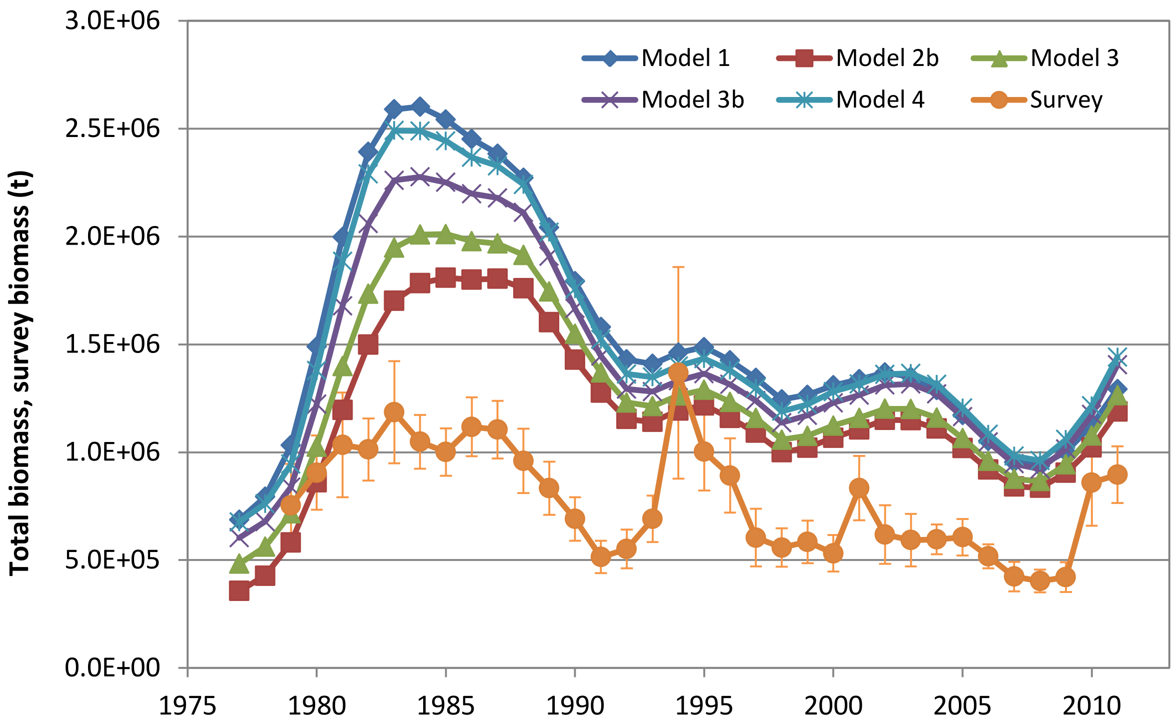

Figure 2.9—Time series of total (age 0+) biomass as estimated by the five models. Survey biomass is shown for comparison.

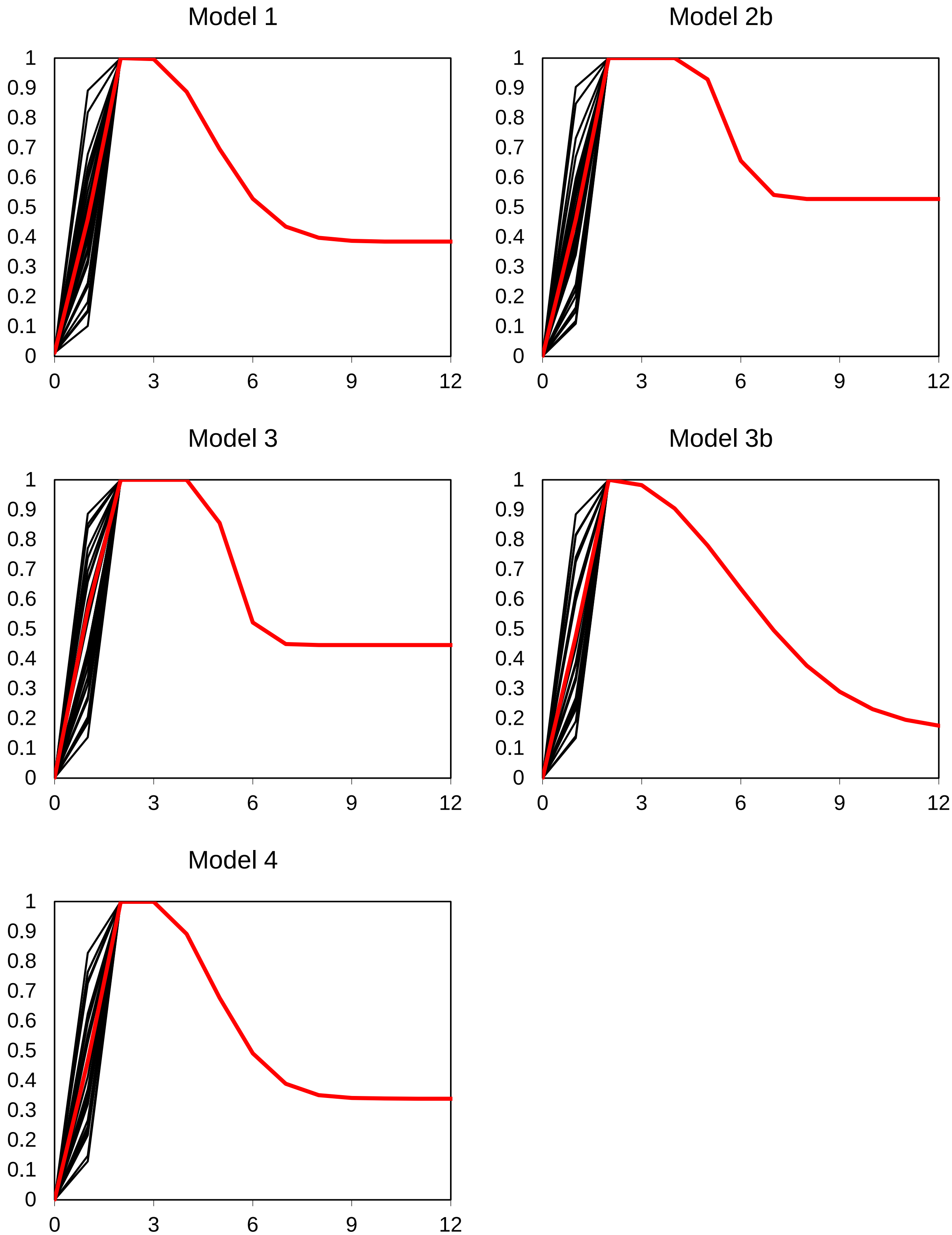

Figure 2.10—Post-1981 trawl survey selectivity at age as estimated by the five models. "*Dev*" parameters affect the ascending limb annually in all models. Selectivity for 2010-2011 is shown in red.

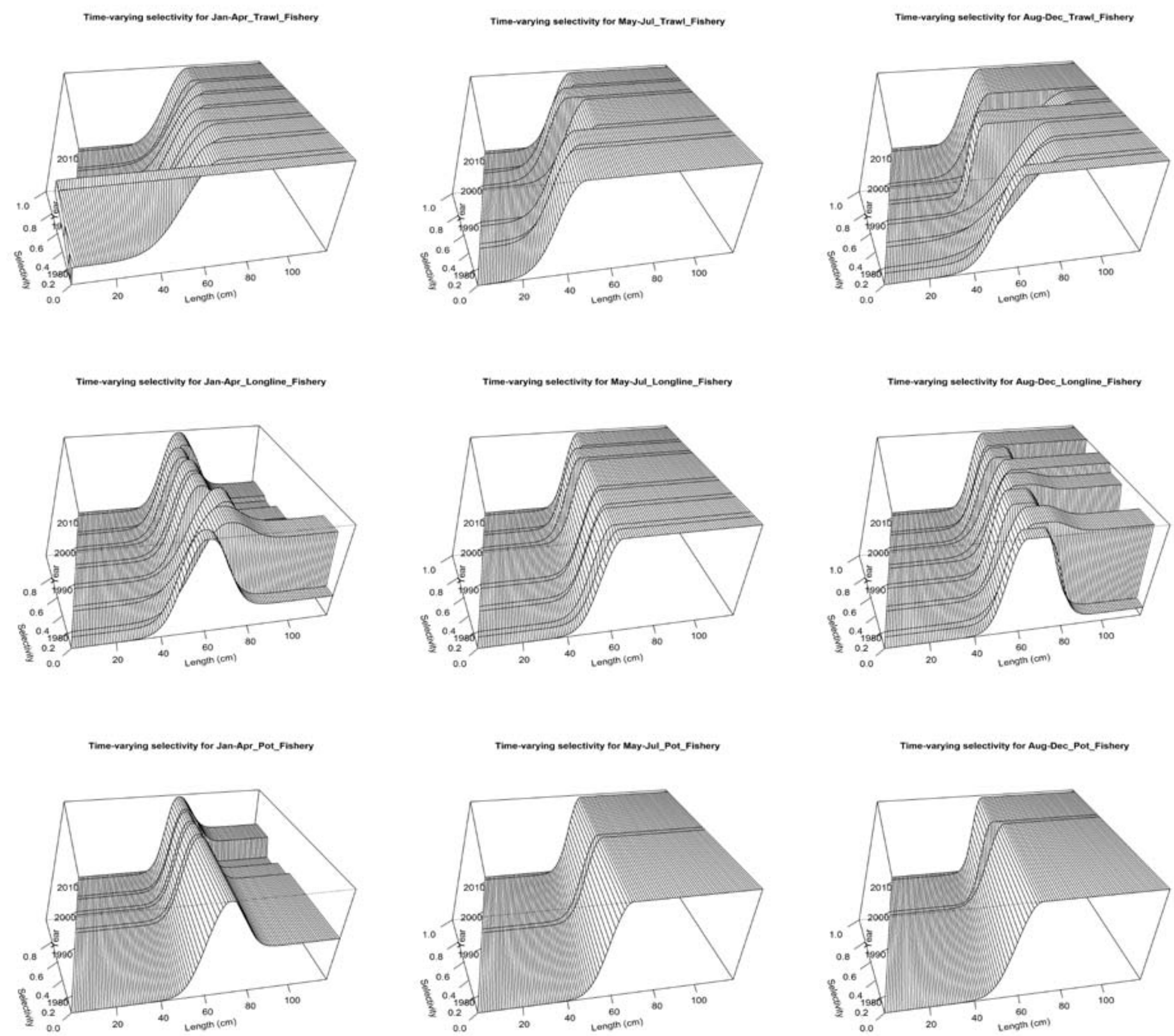

Figure 2.11a—Fishery selectivity at length (cm) as estimated by Model 1.

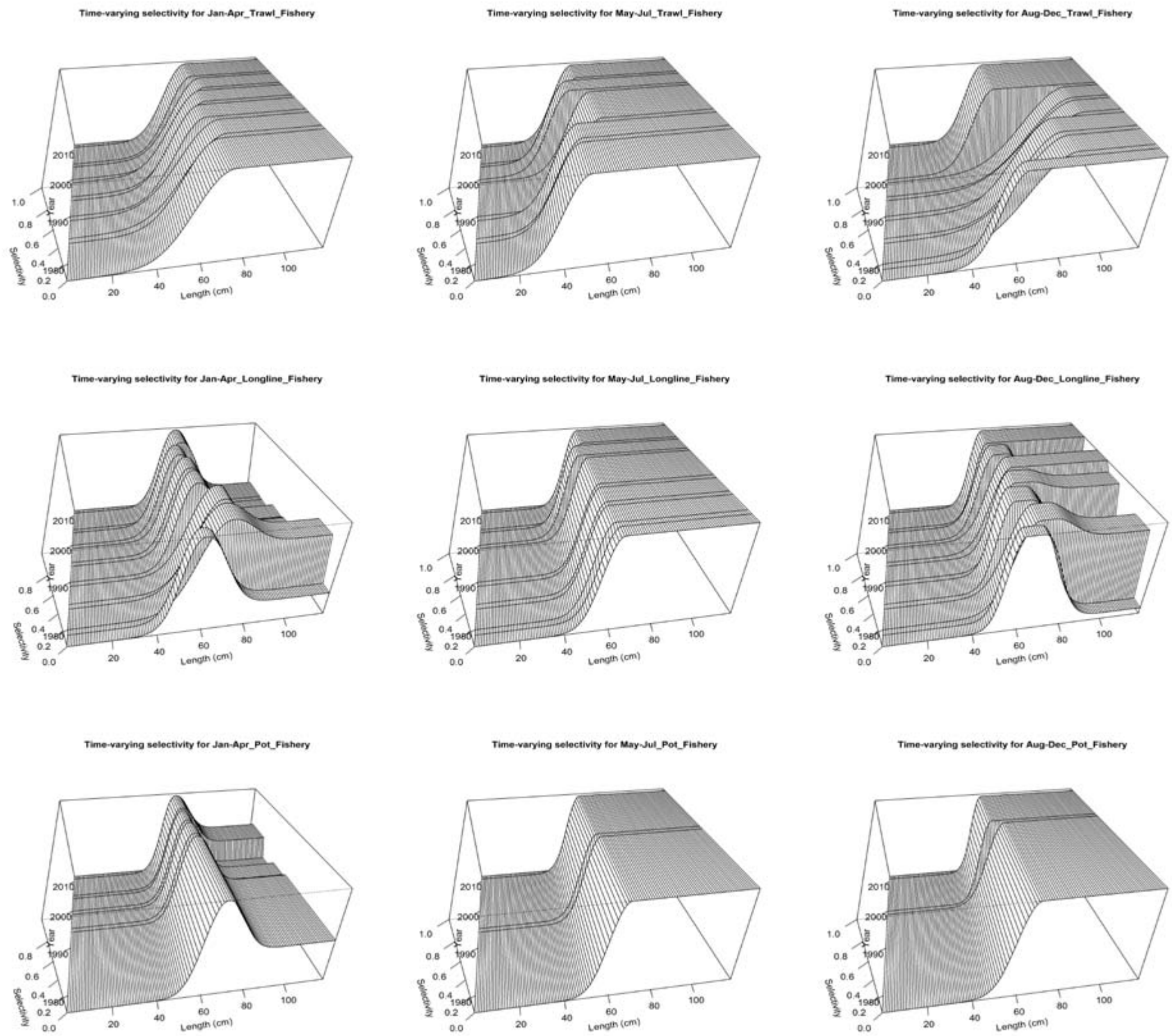

Figure 2.11b—Fishery selectivity at length (cm) as estimated by Model 2b.

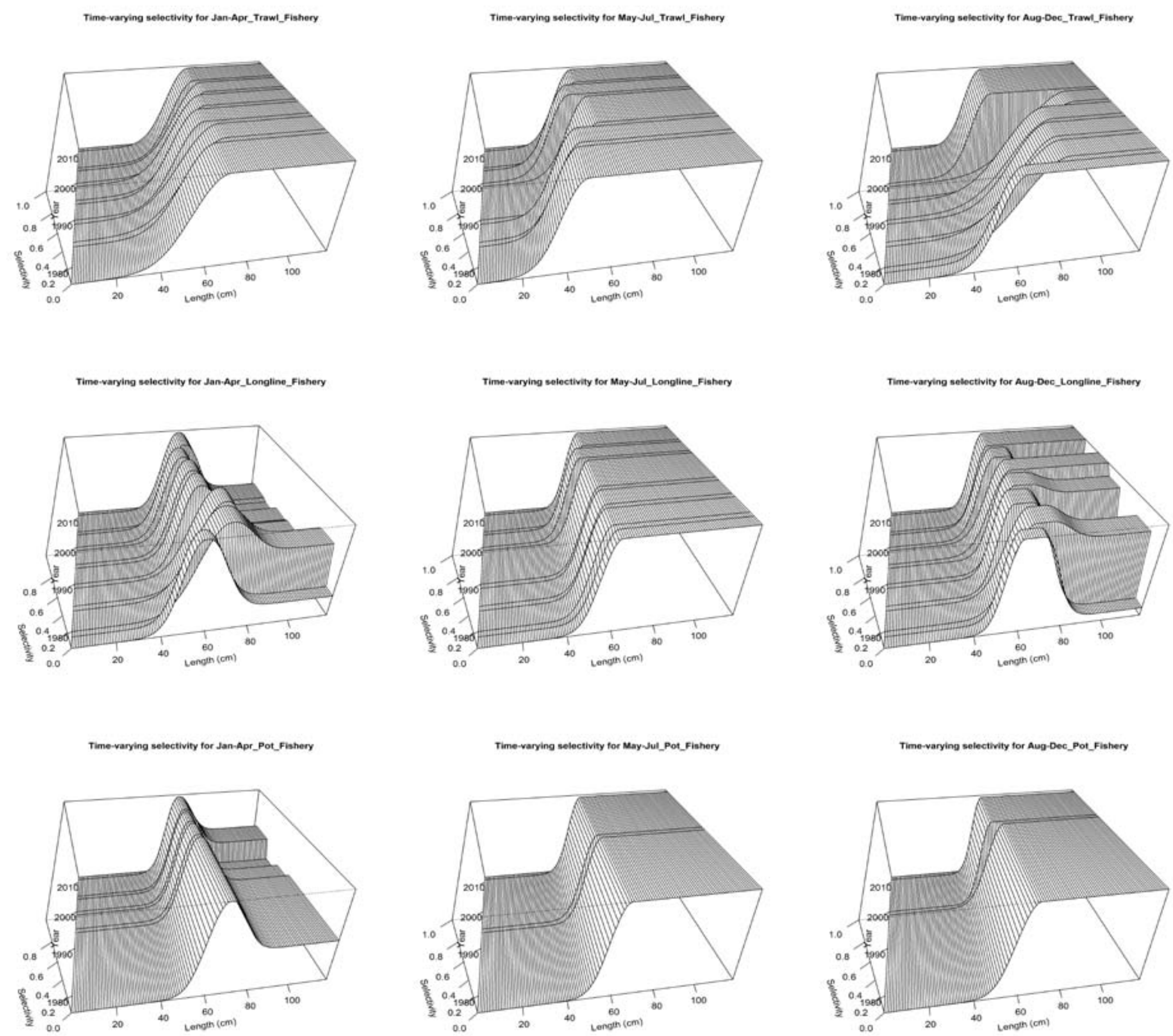

Figure 2.11c—Fishery selectivity at length (cm) as estimated by Model 3.

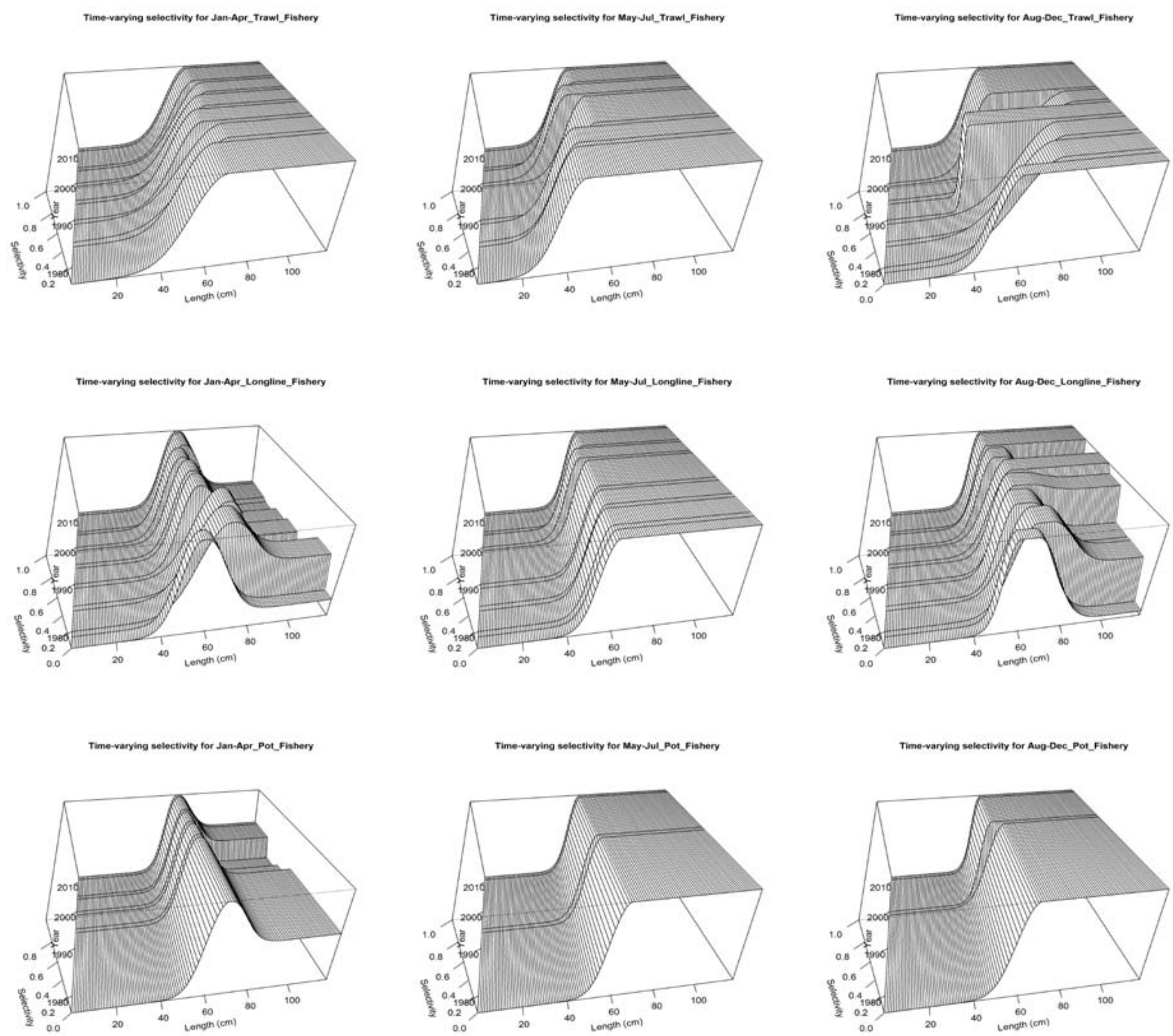

Figure 2.11d—Fishery selectivity at length (cm) as estimated by Model 3b.

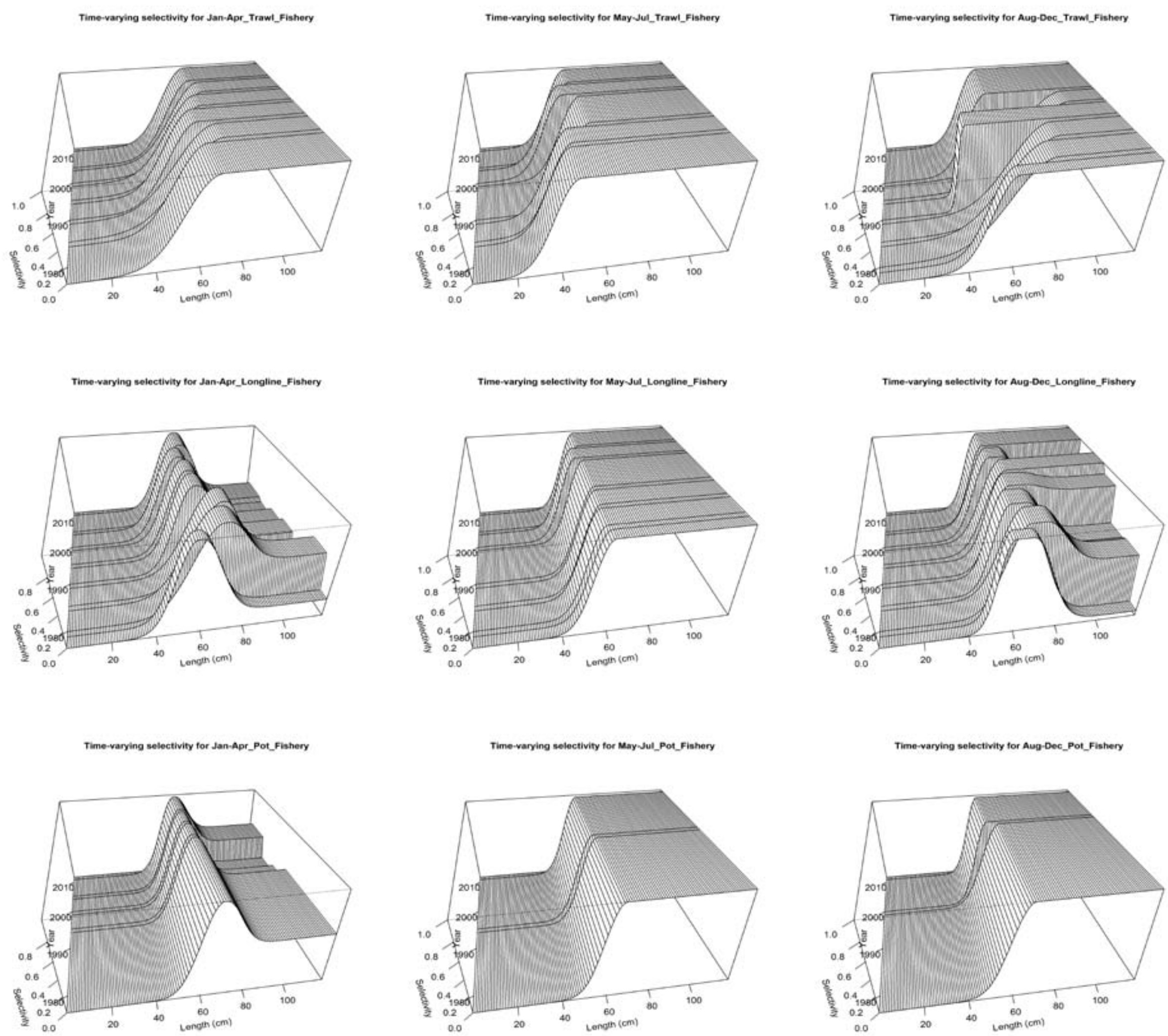

Figure 2.11e—Fishery selectivity at length (cm) as estimated by Model 4.

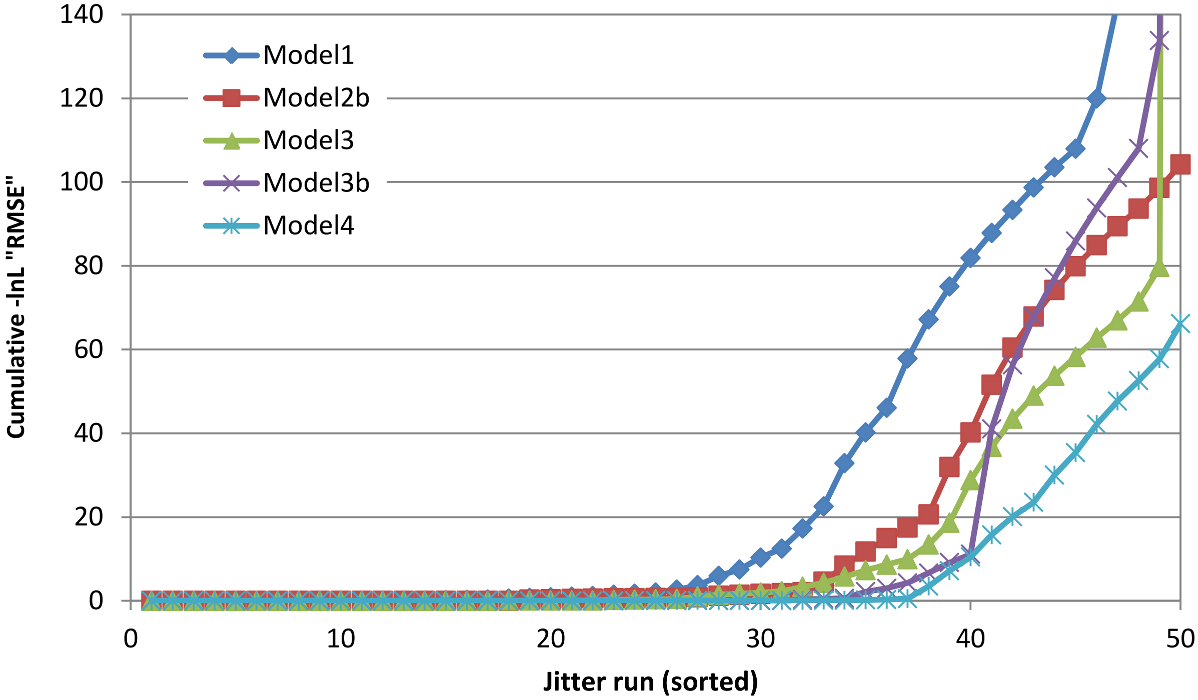

Figure 2.12—Variability in objective function value for each of the five models. See text for details.

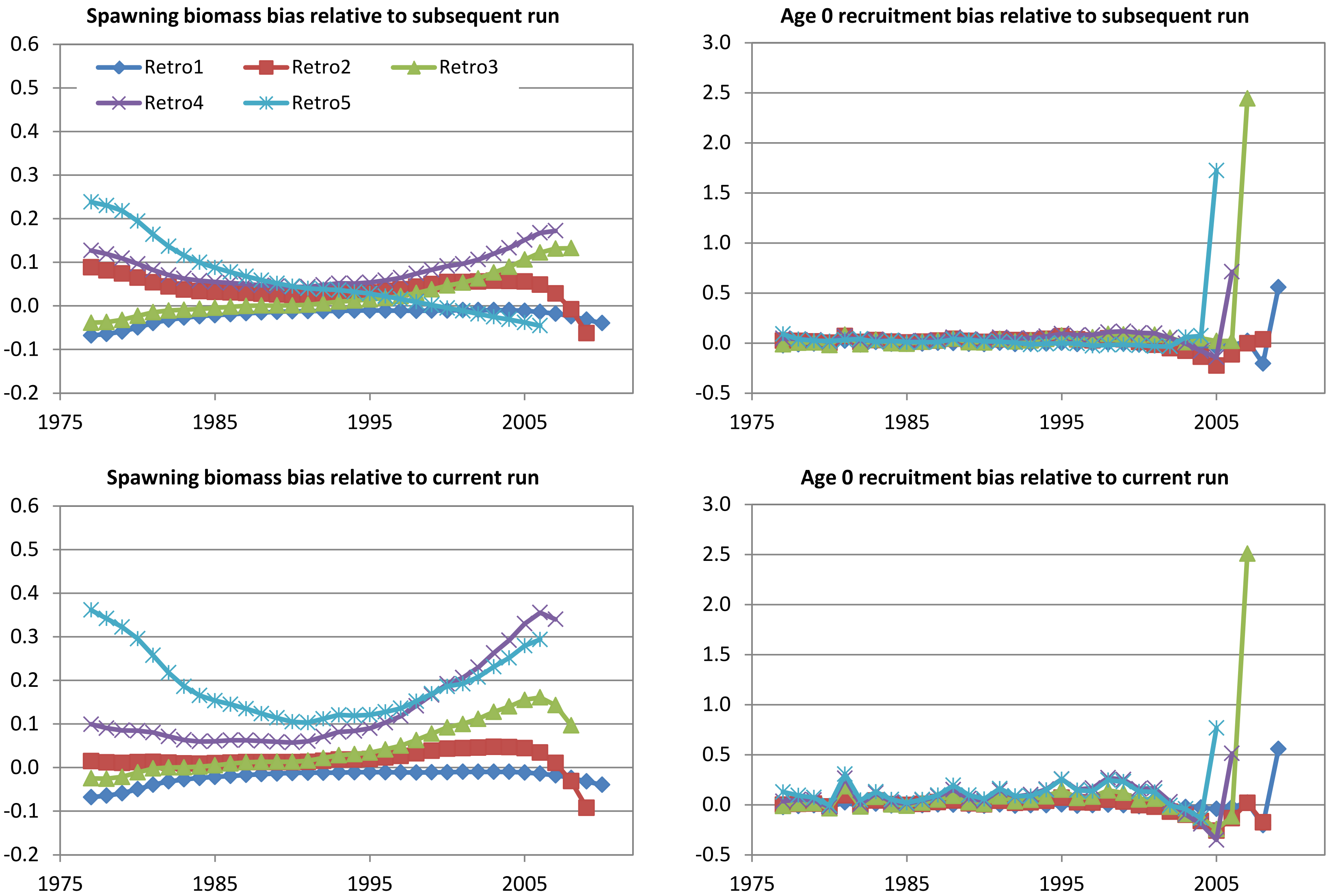

Figure 2.13a—Retrospective bias in spawning biomass and age 0 recruitment (assessed at age 1) in Model 1.

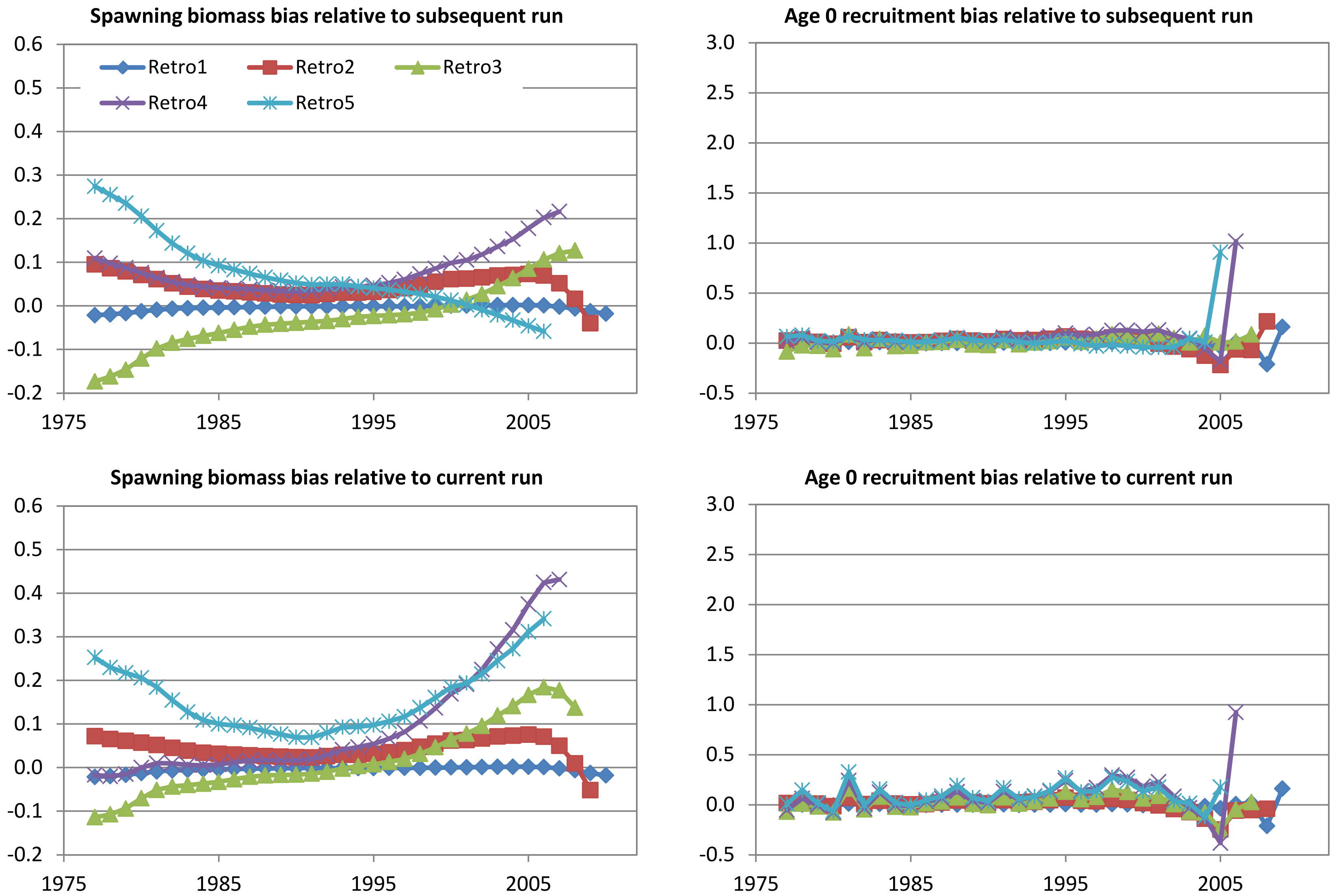

Figure 2.13b—Retrospective bias in spawning biomass and age 0 recruitment (assessed at age 1) in Model 2b.

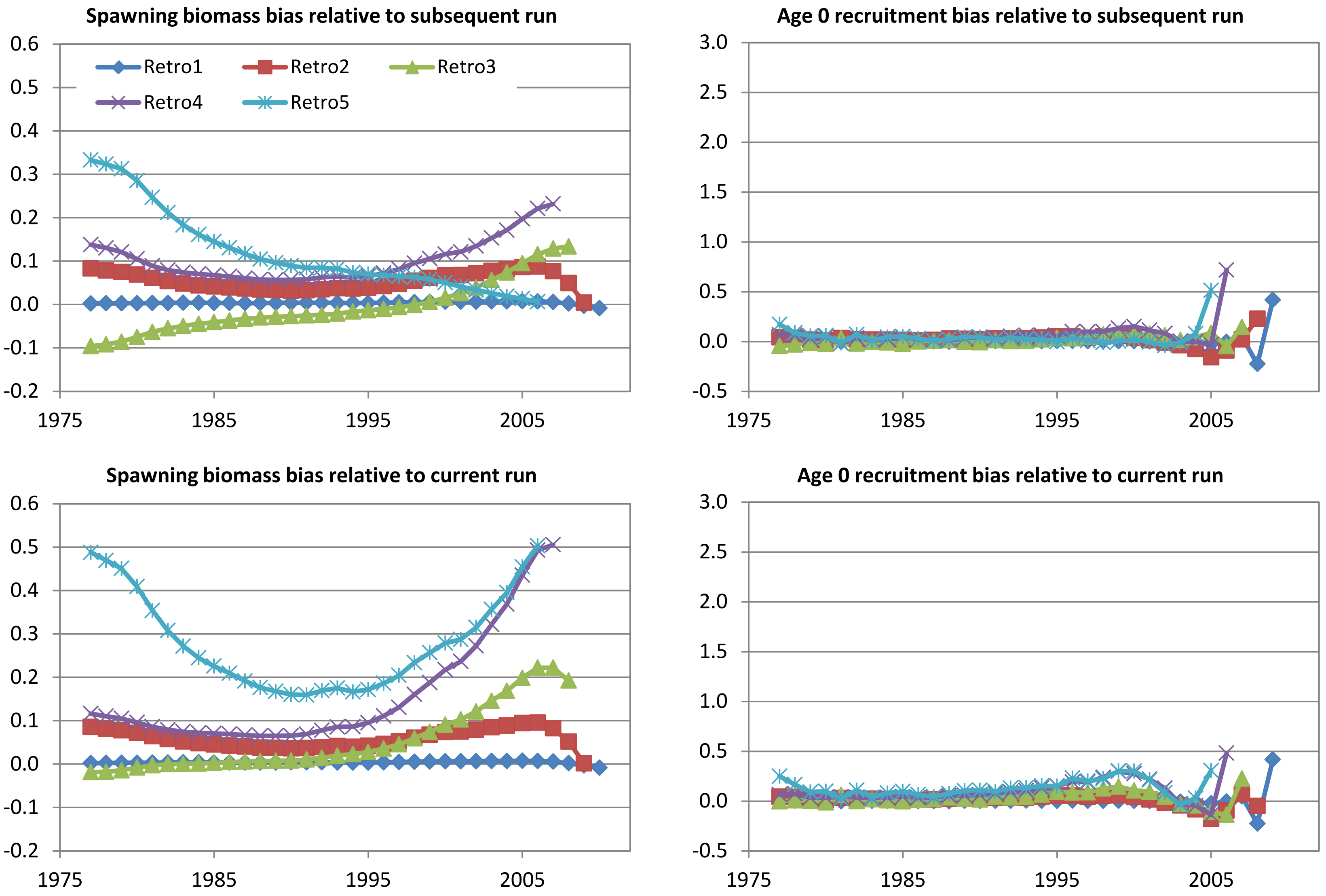

Figure 2.13c—Retrospective bias in spawning biomass and age 0 recruitment (assessed at age 1) in Model 3.

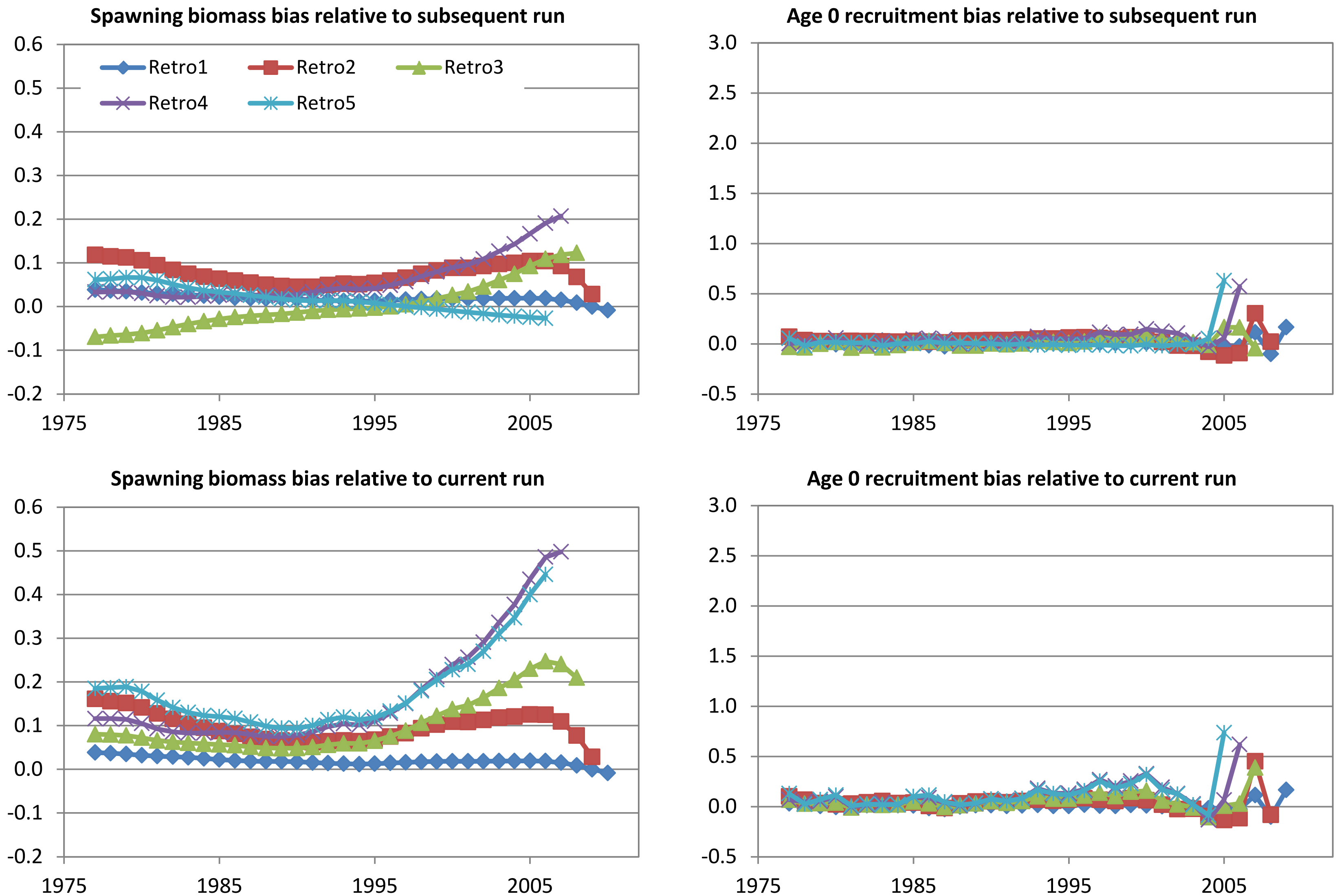

Figure 2.13d—Retrospective bias in spawning biomass and age 0 recruitment (assessed at age 1) in Model 3b.

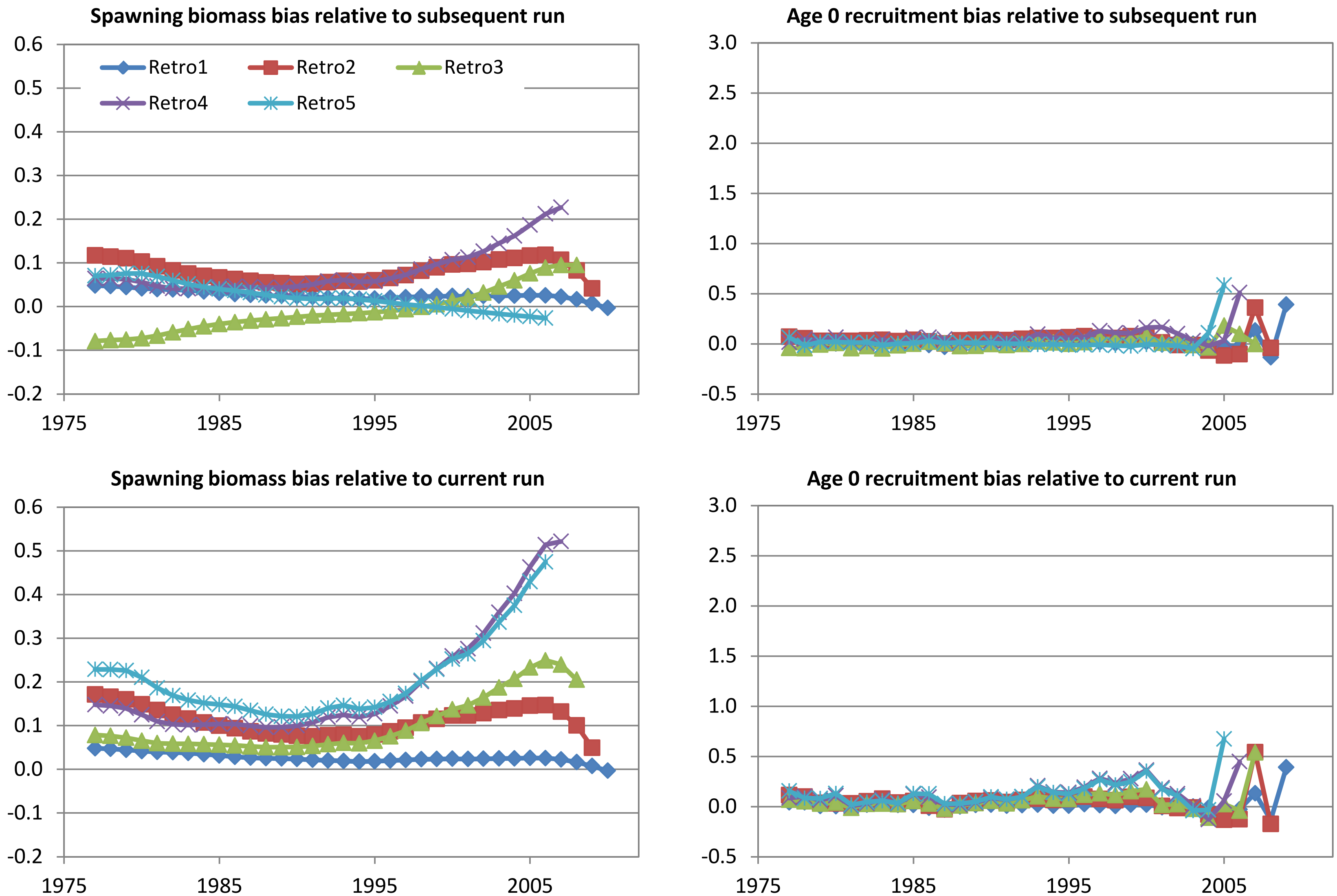

Figure 2.13e—Retrospective bias in spawning biomass and age 0 recruitment (assessed at age 1) in Model 4.

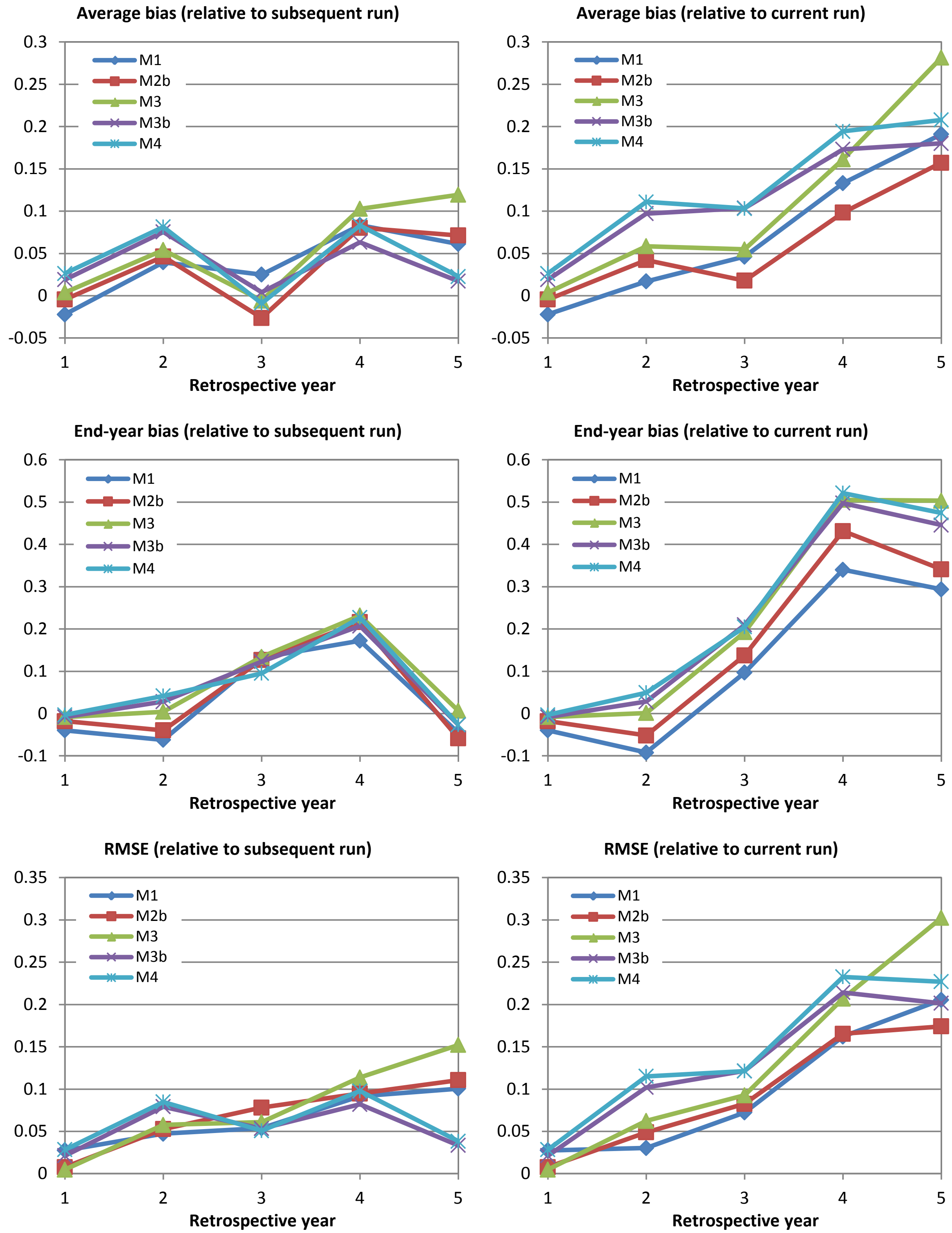

Figure 2.14—Retrospective bias and variability in spawning biomass. See text for details.

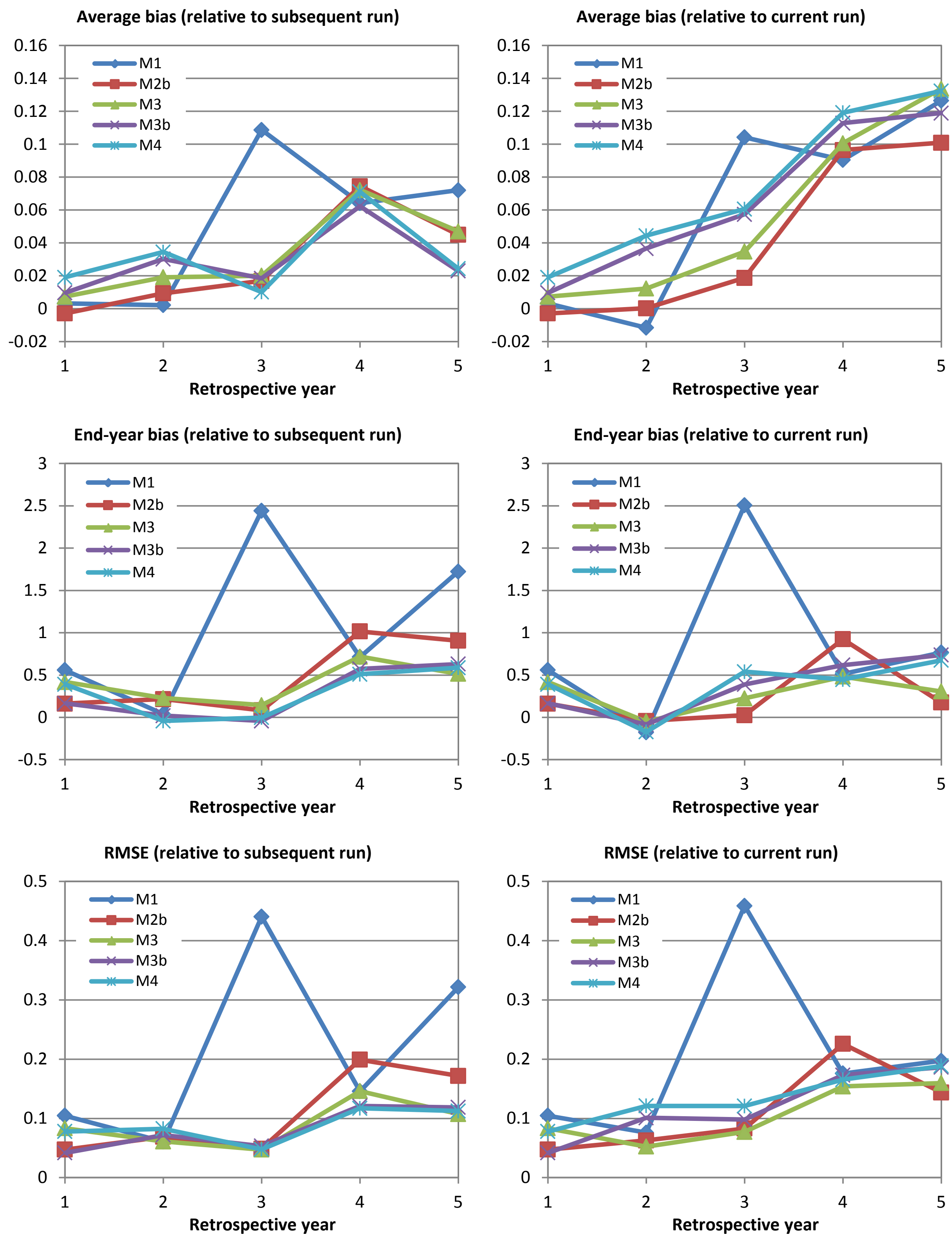

Figure 2.15—Retrospective bias and variability in age 0 recruitment. See text for details.

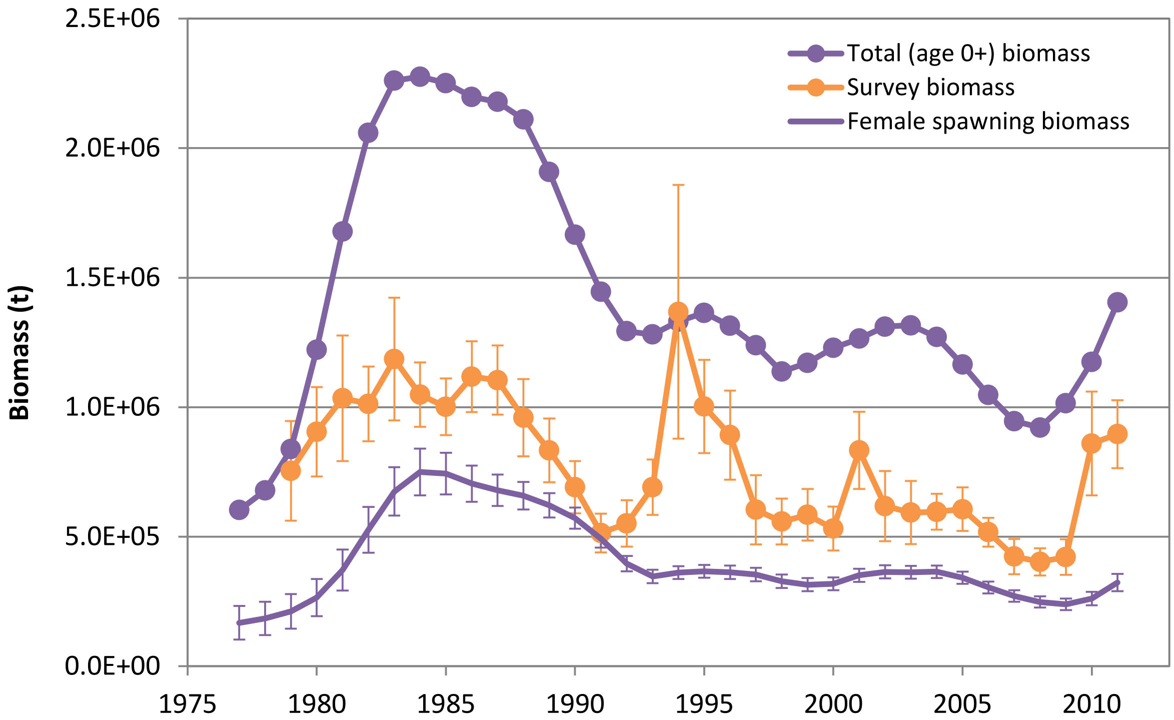

Figure 2.16—Biomass time trends (age 0+ biomass, female spawning biomass, survey biomass) of EBS Pacific cod as estimated by Model 3b. Spawning biomass and survey biomass show 95% CI.

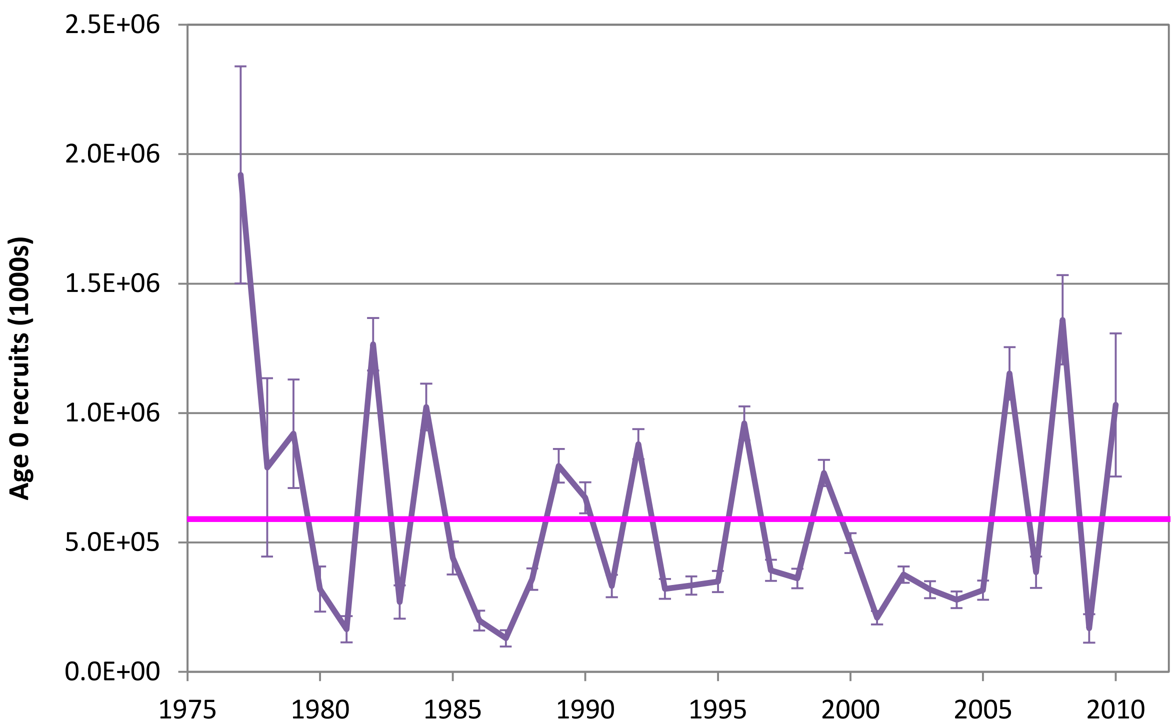

Figure 2.17—Time series of EBS Pacific cod recruitment at age 0 as estimated by Model 3b.

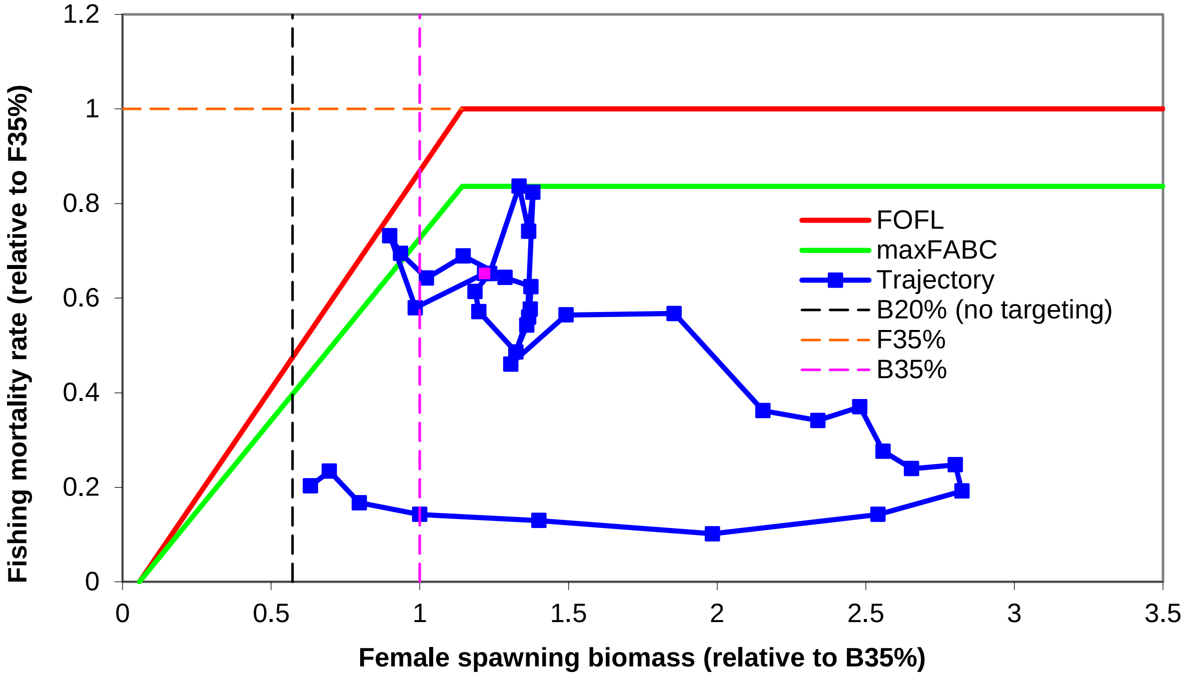

Figure 2.18—Trajectory of Pacific cod fishing mortality and female spawning biomass as estimated by Model 3b, 1977-present (magenta square = 2011).

Attachment 2.1
An exploration of alternative Pacific cod stock assessment models

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Introduction

This document represents an effort to respond to comments made by the BSAI Plan Team, the GOA Plan Team, the joint BSAI and GOA Plan Teams, and the SSC on the 2010 assessments of the Pacific cod (*Gadus macrocephalus*) stocks in the eastern Bering Sea (EBS) and Aleutian Islands area (Thompson et al. 2010a) and the Gulf of Alaska (Thompson et al. 2010b). In order to allow for exploration of a wide variety of modeling assumptions, this preliminary assessment focuses on model development rather than application of the same model(s) to multiple data sets. Specifically, the models presented here are applied to data for the EBS stock only. Even though the models have not been applied to data for the GOA stock (except, of course, for last year's model), it is hoped that the results and accompanying discussion will be useful for suggesting sets of models to be included in the final assessments for both the EBS and GOA stocks.

Comments from the Plan Teams and SSC

Joint Plan Team Comments from the November, 2010 Minutes

JPT1: *"In view of the impending CIE review, the Teams did not attempt at this meeting to formulate any requests for modeling work. But we do want the Teams and the SSC to review the CIE recommendations (and any public submissions) in the May/June period before Grant settles on a program of work for the September/October meetings. We would ask REFM to schedule the CIE review accordingly."* The Pacific cod stock assessment models were reviewed during the dates March 14-18, 2011 by three scientists contracted by the Center for Independent Experts (CIE). The reviewers were Drs. Yong Chen, Chris Darby, and Jose DeOliveira. The reviewers' reports were made available to individuals who requested them on April 22 and were posted on the Council website on April 26 (with an e-mail to all Plan Team and SSC members alerting them of the reports' availability), well in advance of the joint Plan Teams' May 17 meeting.

GOA Plan Team Comments from the November, 2010 Minutes

GPT1: *"The Team noted that it would be useful to have a presentation of the estimates relative to the data, particularly for the most recent survey (and sub-27 cm abundance index)."* The GOA assessment will present model estimates relative to the survey abundance data, including the sub-27 cm index.

SSC Comments Specific to the Pacific Cod Assessments from the December, 2010 Minutes

SSC1: *"Evaluate reduced catch season and size bin structures that are more parsimonious, but do not diminish the information content."* After consideration by the Teams at their joint meeting in May and further consideration by the SSC at its June meeting, this recommendation was not included in the models to be included in the present assessment. However, during the CIE review and in subsequent model explorations, the possibility of accumulating data across the first several size bins—in cases where the proportions in those bins are very small—has been explored to some extent. Although more work can be done along these lines, the initial explorations did not indicate significant decreases in run time when size composition data were pooled across the first several bins. Coarser seasonal structures have not been evaluated since last year's assessment.

SSC2: "*Trawl survey catchability used in the assessment and model sensitivity to model estimates or plausible alternatives should be evaluated.*" After consideration by the Teams at their joint meeting in May and further consideration by the SSC at its June meeting, this recommendation was not included in the models to be included in the present assessment. However, in preparation for the CIE review, during the CIE review itself, and in subsequent model explorations, plausible alternatives regarding catchability have been examined. Generally speaking, model estimates can be quite sensitive to assumptions regarding trawl survey catchability.

SSC3: "*Simplifying trawl survey selectivity should be investigated and model fit to data components evaluated.*" For the present assessment, this recommendation was incorporated (to some extent) into Models 2a and 5. The traditional double-normal selectivity curves are replaced by spline-based selectivity curves in Model 2a. Spline-based curves can have (almost) any number of parameters, and so could be either simpler or more complex than the double-normal curve. However, the Teams' main interest in suggesting the use of spline-based curves was not so much in obtaining a *simpler* curve, but in obtaining a curve with *more robust* parameter estimates ("robust" in this context means that ADMB is able to find the true maximum likelihood estimates of the parameters consistently). Model 5 re-evaluates the breakpoints used in recent models to define "blocks" of years within which certain selectivity parameters are assumed to remain constant, which, in principle, could result in a model with more parameters or fewer parameters.

Moreover, the concept of "simplicity," at least in the context of mathematical modeling, may mean different things to different people. For example, given a particular parametric form for the selectivity curve, fixing one or more parameters at some specified value(s) obviously results in an equation with fewer free parameters, and so might be regarded as a "simpler" equation, but the number of assumptions regarding selectivity increases by at least the same amount, thus raising the question, "Which is simpler—an equation with more parameters but fewer assumptions, or an equation with fewer parameters but more assumptions?" As an alternative to parametric functional forms, selectivity at age could be modeled by assigning one parameter to each age. Again, this could involve a tradeoff between number of parameters and number of assumptions. In preparation for the CIE review and in subsequent model explorations, models with age-specific selectivities were explored, using both random *dev* vectors and random walks. However, the resulting estimates often suggested highly multimodal selectivity curves, sometimes with enormous and difficult-to-rationalize differences in selectivity even at intermediate and older ages, and so were not carried forward into the present assessment.

SSC4: "*Re-tune ageing bias to try to better match the observed age modes.*" Models A, 3, and 5 in the present assessment re-tune the ageing bias, although they do so internally rather than by trial and error (see also Comment SSC5).

SSC5: "*Evaluate estimating ageing bias within the model.*" As noted above, Models A, 3, and 5 in the present assessment estimate ageing bias within the model.

SSC6: "*Evaluate Richards growth curve alternative.*" Models A and 5 in the present assessment utilize the Richards growth curve alternative.

SSC7: "*Continued research that would provide information on age-determination errors and potential biases.*" In early 2012 the AFSC Age and Growth Unit will receive funding from NPRB to conduct an age validation study of Pacific cod using stable oxygen isotopes. The Age and Growth Unit is also in the process of conducting a bomb-radiocarbon C-14 analysis of GOA Pacific cod otoliths taken from fish during the early 1960s.

SSC8: *"Given the divergence in population abundance between the AI and BS the SSC recommends that an AI assessment be brought forward for evaluation (only) during the next assessment cycle. Biomass distribution is currently estimated at 91% EBS and 9% AI compared to previous proportions of 84% and 16%, respectively."* A preliminary assessment of the AI stock is provided as a separate attachment.

SSC9: *"For the GOA, apply a simple Kalman filter approach, as adopted by the SSC in 2004 for BSAI for estimation of current biomass distribution."* This approach will be applied in the final GOA assessment.

SSC10: *"Constant growth should be brought forward in future models (run times reduced back to 2-3 minutes)."* All models in the present assessment assume constant growth. Models with randomly varying growth parameters (either the Brody growth coefficient *K* or length at the first reference age) were considered to some extent in the process of developing the present assessment, but were not carried forward because there was insufficient time to conduct a thorough evaluation of their properties.

SSC11: *"The SSC offers the following modeling issues that could be considered during the CIE review: 1. The process of iteratively estimating input standard deviations to match output standard deviations. 2. Convergence continues to be an issue for most models and this should be examined. 3. Ways to reduce the number of parameters that may help address issues of convergence."* All three of these issues were considered during the CIE review.

Joint Plan Team Comments from the May, 2011 Minutes

In the following, labels such as "JPT4" and "CD33" refer to comments from the review of the Pacific cod assessments conducted by the Center for Independent Experts in March of this year, as systematized in Appendix A of the minutes.

JPT2: *"The Teams assumed that last year's model would be included automatically as Model 1."* Last year's model is carried forward in the present assessment as Model 1.

JPT3: *"Model 2 would test two unrelated features: JPT4—One Team member noted that the ability to model selectivity by using splines has very recently been added to Stock Synthesis (SS). The Teams felt that this feature might improve the models' convergence properties significantly. CD33—For many years, inclusion of the pre-1982 survey data in the EBS model was considered to be important because those data helped to monitor the strength of the extremely large 1977 year class as it moved through the population. However, because of a change to the survey gear in 1982, use of the pre-1982 data requires estimation of an additional six selectivity parameters. Given the fact that the 1977 years class left the population many years ago, the Teams felt that testing the effect of removing the pre-1982 survey data would be worthwhile. The Teams viewed both of these recommendations (JPT4 and CD33) as "conditional" changes, meaning that if they resulted in Model 2 being an improvement over Model 1, then they would be used in Models 3-5 also…. Recommendation CD33 would obviously apply only to the EBS models."* Models 2a (use spline-based selectivity) and 2b (exclude pre-1982 survey data) in the present assessment correspond to this request.

JPT4: *"Model 3 would be devoted to exploring the possibility of estimating ageing bias inside the model (JD6, SSC6). The ability to model ageing bias in terms of internally estimable parameters was added to SS late last year, and was tested in the EBS Pacific cod model to a small extent prior to and during the CIE review. The Teams felt that internal estimation of ageing bias could potentially be much more* *efficient and accurate than the manual estimation (i.e., trial and error tuning "by hand") that was used in the 2009 assessments and retained in last year's assessments."* Model 3 in the present assessment corresponds to this request.

JPT5: *"Model 4 would be similar to Model 4 (or perhaps Model 5) from last year's preliminary assessments, in that it would omit age-based data to a very large extent, including elimination of all size-a-age data (JPT1) and all age composition data (JPT2). The only difference between this year's Model 4 and Model 4 from last year's preliminary assessment is that this year's Model 4 describes maturity as a function of age rather than length, as in last year's final models. If the author has time to examine the possibility of estimating length-at-age variance internally and if the results appear reasonable, the Plan Teams would be happy to see this included as a feature of Model 4 (which would make it more like Model 5 from last year's preliminary assessment)."* Model 4 in the present assessment corresponds to this request. It includes internal estimation of the parameters describing the between-individual (not between-year) variance in length at age.

JPT6: *"Model 5* (author's preferred model, but with time blocks determined by initially modeling fishery and survey selectivity as a random walk) *would likely result in a reconfiguration of the time blocks currently used to define multiple selectivity schedules for most fisheries, and would likely result in less time variation in the survey selectivity schedules. The approach to be used (JPT5) is very similar to one of Mark* (Maunder)*'s proposals (MM2), except that survey selectivity is included along with fishery selectivity. Recommendation JPT5 is also concordant with SSC4 ("simplifying trawl survey selectivity should be investigated and model fit to data components evaluated"). As with some other recommendations, the desire to simplify the model and achieve improved convergence was a major factor in the Plan Teams' decision to rate JPT5 as high priority."* Model 5 in the present assessment corresponds to this request. Note that this request is conditional on the author's preferred model. For the purpose of this preliminary assessment, the author's preferred model is Model A.

SSC Comments from the June, 2011 Minutes

SSC8: *"The SSC is satisfied with the* (Plan Teams') *model choices and does not propose any additional ones."* See responses to Comments JPT2-JPT6 above.

Model Structures

Five models (labeled 1-5) were requested by the Plan Teams, one of which (Model 1) was identical to last year's model, one of which (Model 2) was to consist of two parts (Models 2a and 2b), and one of which (Model 5) was conditional on the author's preferred model, which is included here as Model A. Models 2a and 2b consisted of "conditional" modifications to Model 1, in the sense that, if the modifications examined in Models 2a or 2b were found to result in improvements relative to Model 1, those modifications would be retained for all other models (3-5 and A). The models are described in more detail below.

The software used to run the final versions of all models was SS V3.22b, as compiled on 8/3/2011 (Methot 2011).

Model 1

The details of last year's model were described by Thompson et al. (2010a). The only changes in the control file for Model 1 were some minor technical alterations necessary for the code to run under SS V3.22b. The only change in the data file consisted of correcting an error in last year's file, where the season assignment for the mean-size-at-age data had not been updated following the adoption of a new seasonal structure in last year's assessment. Because of this correction to the data file, the results shown here for Model 1 are different from the results shown in last year's assessment.

Model 1 uses a double-normal curve to model selectivity. This functional form is constructed from two underlying and linearly rescaled normal distributions, with a horizontal line segment joining the two peaks. As configured in SS, the equation uses the following six parameters:

1) *beginning_of_peak_region* (where the curve first reaches a value of 1.0)
2) *width_of_peak_region* (where the curve first departs from a value of 1.0)
3) *ascending_width* (equal to twice the variance of the underlying normal distribution)
4) *descending_width* (equal to twice the variance of the underlying normal distribution)
5) *initial_selectivity* (at minimum length/age)
6) *final_selectivity* (at maximum length/age)

All but *beginning_of_peak_region* are transformed: The *ascending_width* and *descending_width* are log-transformed and the other three parameters are logit-transformed.

The data file used in Model 1 was labeled Data1.

Model 2a

The distinguishing feature of this model was the use of splines to model selectivity, rather than the usual double-normal curve. A spline fits a sequence of cubic polynomials, end to end, such that the heights, first derivatives, and second derivatives all match at each of a pre-specified series of points called "knots" or "nodes." As configured in SS, spline-based selectivity requires the following parameters: 1) a code for selecting optional routines governing auto-generation of certain parameters (not estimable), 2) the slope (*not* the relative height) at the first node, 3) the slope at the last node, 4) the locations of the nodes (not estimable), and 5) the relative log-scale heights at the nodes. There must be at least three nodes, and none of them can occur at either the minimum or maximum size or age.

To configure a spline-based model with approximately the same number of parameters as Model 1, five knots were used in Model 2a. For the length-based selectivity schedules (the fisheries), knots were placed according to an arithmetic scale consisting of approximate 20-cm intervals, starting at 40 cm (SS will not allow a knot to be placed at maximum size or maximum age, so the fifth knot was placed at 118 cm rather than 120 cm). For the age-based selectivity schedules (the surveys), knots were placed according to a geometric scale, at ages 1, 2, 4, 8, and 16. These scales were established after a great deal of experimentation with alternative knot placements. For all selectivity schedules, the value at knot 2 was fixed at -1 (because the curve is automatically scaled to reach a maximum of unity, it is necessary to fix the value at one knot; this fixed value can be set arbitrarily).

For each fleet, the slope at the first knot was estimated as a free parameter, with one exception. When the slope at the first knot in the selectivity schedule for the pre-1982 survey was estimated freely, selectivity tended to become very high below age 1 (for reasons that remain unknown). In an attempt to minimize this behavior, the slope at the first knot for the pre-1982 survey was set equal (iteratively) to the slope at the first knot for the post-1981 survey.

For each fleet, the slope at the last knot was fixed at zero. The decision to fix the slope at the last knot followed a great deal of experimentation, during which selectivity was often found to increase dramatically after the last knot if the slope were not strongly constrained. Even with this constraint, selectivity often tended to increase dramatically at large size or old age. To prevent this behavior, the value at knot 5 was forced (iteratively) to equal the value at knot 4.

For all fisheries except the three May-July fisheries, the values at knots 1 and 3 were estimated in blocks, using the same block structure specified in Model 1 (the one exception is that the 1977-1979 block for the January-April trawl fishery was merged with the 1980-1984 block; otherwise, SS tended to estimate very sharply peaked selectivity for the 1977-1979 block, which in turn led to enormous estimates of initial fishing mortality). For the three May-July fisheries, only the values at knot 1 were estimated in blocks (again, using the block structure specified in Model 1).

Like Model 1, Model 2a used data file Data1.

Model 2b

The only substantive differences between Model 2b and Model 1 are the elimination of the pre-1982 trawl survey abundance and size composition data from the data file and the elimination of selectivity and catchability parameters for the pre-1982 trawl survey from the control file. However, to make the data file more streamlined and to facilitate the possibility of making adjustments to the input sample sizes from within the control file, the data file was reconfigured by moving all of the remaining size composition data from the "generalized size composition" section to the regular size composition section. (In last year's assessment, a new size structure was adopted for all fisheries and surveys to the maximum extent possible, in which size composition data were binned at 1-cm intervals. However, data for the pre-1982 survey are not available at this resolution, which meant that multiple bin structures had to be used in last year's assessment. The only way in which multiple bin structures can be used in SS is by placing at least some of the size composition data in the "generalized size composition" section. Unfortunately, SS does not allow the input sample sizes for "generalized size composition" data to be adjusted from within the control file.)

The data file used in Model 2b was labeled Data2.

Evaluation of "Conditional" Features Contained in Models 2a and 2b

As noted above, Models 2a and 2b were "conditional" models, with the expectation that any improvements identified relative to Model 1 would be implemented in the remaining models. The primary motivation for Model 2a was to improve robustness of parameter estimates ("robust" in this context means that ADMB is able to find the true maximum likelihood estimates of the parameters consistently). The primary motivations for Model 2b were to eliminate parameters that had very little effect on other estimated quantities; to eliminate the need to deal with a small, non-conforming (in the sense of bin structure) subset of the overall size composition data set; and, perhaps, to improve robustness of parameter estimates.

As in previous assessments, the primary method for evaluating robustness was to use the "jitter" option contained in SS. This option creates random starting values for all of the estimated parameters in the model. The random values are drawn from a logit-normal distribution (recall that all parameters in SS are bounded both above and below) with μ equal to the logit-transformed initial value and σ equal to 2 times the jitter rate.

The table below summarizes the results of 50 jitters run on the final versions of Models 1, 2a, and 2b. Versions were considered "final" only if no jitter resulted in a lower value for the objective function (in the event that a jitter *did* result in a lower value for the objective function, that jitter became the new base case, and the process was repeated until no further improvement was found). The column labeled "Jitter" shows the jitter rate, which was fixed at 0.10 for all of these models (although it is not possible to describe an exact relationship between the jitter rate and the coefficient of variation, a rough approximation can be obtained by noting that, in the special case where the initial parameter value is midway between the upper and lower bound and the jitter rate is sufficiently small, the jitter rate is approximately equal to the coefficient of variation). The column labeled “Success” shows the proportion of jitters that ran successfully (i.e., that returned a numeric value for the objective function). The column labeled “Match” shows the proportion of successful jitters that matched the final version. The column labeled “-lnL ‘RMSE’” shows a statistic for the objective function that is similar to a root-mean-squared-error, but in which the squared difference is taken with respect to the *minimum* value (across jitters) rather than the *mean*; this statistic is reported in units of log-likelihood. Finally, the column labeled “SB2010 ‘CV’” shows a statistic for 2010 spawning biomass that is similar to a coefficient of variation, but in which (as with the preceding column) the mean is replaced by the value corresponding to the final (i.e., best case) version of the model.

Model	Description	Jitter	Success	Match	-lnL "RMSE"	SB2010 "CV"
1	Last year's model	0.10	1	0.16	342.86	0.11
2a	Model 1, with splines	0.10	1	0.16	4393.38	1.02
2b	Model 1, without pre-1982 survey	0.10	1	0.28	1198.59	0.11

The use of spline-based selectivity in Model 2a does not appear to result in improved robustness relative to Model 1. Although Model 2a does as well as Model 1 in terms of the probability of finding the (apparent) true minimum, when it fails to find it, it tends to miss by a greater margin, as both the –lnL “RMSE” and the SB2010 “CV” are an order of magnitude higher under Model 2a than Model 1. It may still be the case that spline-based selectivity offers potential improvements over the double-normal curve, but, at least for Pacific cod, more research appears to be needed before a move to spline-based selectivity is justified. Models 3-5 and A therefore do not incorporate spline-based selectivity.

Omission of the pre-1982 survey in Model 2b appears to have mixed results with respect to robustness. The probability of finding the (apparent) true minimum is 75% higher under Model 2b than Model 1, but it is still not particularly high in absolute terms (only 28%). Also, when Model 2b fails to find the true minimum it tends to miss it by a much greater margin (in terms of log-likelihood units) than Model 1. In terms of the robustness of the 2010 spawning biomass estimate, Models 1 and 2b perform about the same (“CV” = 0.11).

In terms of the resulting estimates of parameters and other quantities of interest, Models 1 and 2b tend to be very similar. For example, Figures 2.1.1a and 2.1.1b show the estimated female spawning biomass and age 0 recruitment time series produced by the two models. Treating Model 1 as the baseline model, the absolute relative difference resulting from Model 2b is less than 5% in all years since 1987 for the female spawning biomass time series, and less than 5% in all years since 1981 for the age 0 recruitment time series. Overall, the root-mean-squared-relative-difference is less than 5% for both time series. While absolute relative differences are higher than 5% for the first years of both time series, it should be noted that this is due in part to an assumed catchability of 1.00 for the pre-1982 survey in Model 1, an assumption for which there is little statistical basis. In terms of the overall set of 177 estimated parameters common to both Models 1 and 2b, the absolute relative differences are less than 5% for 147 (83%) of the parameters.

On the basis of higher probability of finding the true objective function minimum, negligible impact on the most significant model estimates, and less cumbersome data structure, Models 3-5 and A eliminate the pre-1982 survey data from the respective data files and the pre-1982 survey selectivity and catchability parameters from the respective control files.

Model 3

In the 2009 assessment, ageing bias was estimated manually, by trial and error (the resulting bias estimates were retained in the 2010 assessment). This was an extremely cumbersome process, and involved several simplifying assumptions (e.g., that the amount of ageing bias was constant across the range of biased ages). However, recent improvements to SS have made it possible to estimate ageing bias internally. Internal estimation of ageing bias is activated by placing a flag in the data file (this flag is the only thing that distinguishes the data file used in Model 3 from that used in Model 2b). In the control file, seven parameters govern the estimation: 1) the age at which the estimated relationship between bias and age begins (a linear ramp, beginning with zero bias at age zero, is assumed for lower ages), 2) the amount of bias at the age specified in (1), 3) the amount of bias at the maximum age, 4) the exponent of a power function for interpolating bias between the age specified in (1) and the maximum age (e.g., an exponent of zero forces a linear relationship), 5) the standard deviation of ageing error at the age specified in (1), 6) the standard deviation of ageing error at the maximum age, and 7) the exponent of a power function for interpolating standard deviation between the age specified in (1) and the maximum age.

Model 3 assumes that the power function exponents (4) and (7) are both zero, which seems to be appropriate given the available data, as described in last year's assessment. The standard deviations (5) and (6) were estimated externally from the data, as described in last year's assessment. The bias parameters (2) and (3) were estimated as free parameters, conditional on choice of initial age (1). Three values were examined for the initial age in the estimated relationship: 0, 1, and 2. Age 1 was chosen for the final configuration of Model 3 because it gave the lowest value of the objective function.

Model 3 also set the first reference age in the length-at-age relationship equal to 1.0 and tuned the standard deviation of length at this age iteratively to match the value from the regression of standard deviation against length at age presented in last year's assessment.

The data file used in Model 3 (identical to Data2 except for the flag activating internal estimation of ageing error) was labeled Data3.

Model 4

Model 4 does not attempt to fit the age composition or mean-size-at-age data. While these data were retained in the corresponding data file so that the fit can be measured, the corresponding likelihood components were given zero emphasis. All size composition records in the data file were activated (in Models 1-3, size composition records were deactivated whenever a corresponding age composition record existed, to avoid double counting).

Model 4 also differs from Models 1-3 by estimating the standard deviations of length at the two reference ages internally.

In last year's assessment, the model that did not attempt to fit the age composition or mean-size-at-age data suffered from an inability to establish the age origin of the mean length-at-age relationship, resulting in a negative value for the mean size at age 1. This was due to specifying age 0 as the first reference age in the mean length-at-age relationship, which had been done for nearly all models in the last two assessments so as to enable estimation of cohort-specific or time-varying growth parameters, which required using age 0 as the first reference age in the versions of SS available at the time. The same requirement existed for use of the Richards growth function, which was not used in last year's assessment but which had been considered a likely candidate for future exploration. However, the most recent versions of SS have relaxed this requirement, so the first reference age for the mean length-at-age relationship in Model 4 was set at age 1. When the first reference age is greater than zero, SS substitutes a linear ramp from the lower end of the first population size bin up to the first reference age for all ages between 0 and the first reference age (so, for example, given age 1 as the first reference age, SS will set the mean length of age 0 fish equal to the lower end of the first population size bin for seasons up to the birth season, then increase the mean length linearly throughout the remainder of the year, until it reaches the mean length estimated for age 1 as estimated from the growth curve, where age is measured with respect to the beginning of the birth season).

The data file used in Model 4 was labeled Data4.

Model A

Model 5 is supposed to be based on the author's preferred model, so it was necessary to develop Model A before proceeding to Model 5.

Relative to Model 2b, the following items were changed in the data file:

1. Fisheries were defined with respect to each of the five seasons, but not with respect to gear (in Models 1-4, fisheries were defined with respect to both season and gear).
2. Fishery CPUE data were eliminated (in Models 1-4, fishery CPUE data were included for purposes of comparison, but were not used in estimation).
3. All size composition records were activated (as in the data file for Model 4; in Models 1-3, however, size composition records were deactivated whenever a corresponding age composition record existed).
4. Input sample sizes for size composition data were re-scaled to give a mean of 300 for each fishery and the survey (in Models 1-4, input sample sizes were re-scaled to give a mean of 300 across all fisheries and the survey).
5. A new population length bin was added for fish in the 0-0.5 cm range, which was used for extrapolating the length-at age curve below the first reference age (in Models 1-4, the lower bound of the first population length bin was 0.5 cm).
6. Mean-size-at-age data were eliminated (in Models 1-4, mean-size-at-age data were included).

The data file used in Model A was labeled Data5.

Relative to Model 2b, the following items were changed in the control file:

1. The first reference age in the mean length-at-age relationship was set at 1.41667, to coincide with age 1 at the time of year when the survey takes place (in Models 1-2b, the first reference age was set at 0; in Models 3-4, it was set at 1).
2. The Richards growth equation was used (in Models 1-4, the von Bertalanffy equation—a special case of the Richards equation—was used).
3. Ageing bias was estimated internally (as in Model 3; in Models 1-2 and 4, ageing bias was left at the values specified in the 2009 and 2010 assessments—although this was largely irrelevant in the case of Model 4, which did not attempt to fit the age data).
4. The log-scale standard deviation of recruitment (σ_R) was estimated internally (in Models 1-4, this parameter was left at the value used in last year's assessment, which in turn was left at the value estimated iteratively in the previous year's assessment).
5. Fishery selectivity curves were defined for each of the five seasons, but were not stratified by gear type (in Models 1-4, seasons 1-2 and 4-5 were lumped into a pair of "super" seasons, and fisheries were also *gear*-specific).
6. The selectivity curve for the fishery that came closest to being asymptotic on its own (in this case, the season 4 fishery) was forced to be asymptotic by fixing both *width_of_peak_region* and

final_selectivity at a value of 10.0 and *descending_width* at a value of 0.0 (in Models 1-4, the January-April trawl fishery was forced to exhibit asymptotic selectivity).
7. Survey selectivity was modeled as a function of length (in Models 1-4, survey selectivity was modeled as a function of age).
8. The number of estimated year class strengths in the initial numbers-at-age vector was set at 10 (in Models 1-4, only 3 elements of the initial numbers-at-age vector were estimated).

In addition to the above new features in the control file, the following parameters were tuned iteratively:

1. The standard deviation of length at the first reference age was tuned iteratively to match the value from the regression of standard deviation against length at age presented in last year's assessment (as in Model 3; in Models 1-2, this parameter was set at 0.01 because the first reference age was 0; in Model 4, it was estimated internally).
2. The base value for survey catchability was tuned iteratively to set the average of the product of catchability and survey selectivity across the 60-81 cm range equal to 0.47, corresponding to the Nichol et al. (2007) estimate (in Models 1-4, the base value was left at the value used in last year's assessment, which in turn was the value estimated iteratively in the previous year's assessment).
3. Survey catchability was given annual (but not random walk) *dev*s, with σ_{dev} tuned iteratively to set the root-mean-squared-standardized-residual (RMSSR) of the survey abundance estimates equal to 1.0 (in Models 1-4, survey catchability was constant).
4. All estimated selectivity parameters were given annual random walk *dev*s with σ_{dev} tuned iteratively to match the standard deviation of the estimated *dev*s, except that the *dev*s for any selectivity parameter with a tuned σ_{dev} less than 0.005 were removed (in Models 1-4, certain fishery selectivity parameters were estimated independently in pre-specified blocks of years; the only time-varying selectivity parameter for the survey was *ascending_width*, which had annual—but not random walk—*dev*s with σ_{dev} set at the value used in last year's assessment, which in turn was the value estimated iteratively in the previous year's assessment).
5. The age composition "variance adjustment" (a multiplier applied to the input sample sizes) was tuned iteratively to set the mean effective sample size equal to the mean input sample size (in Models 1-4, this multiplier was fixed at 1.0).

The iterative tuning was conducted (approximately) in the following manner:

A. First (without *dev*s) convergence loop: Initial values for the parameters in items 1 and 2 above were taken from last year's assessment, the multiplier in item 5 was set at 1.0, and a model was developed in which the *dev*s listed in items 3 and 4 were absent. New values for the parameters in items 1 and 2 were determined from the results, and the model was re-run. This process was repeated until the parameters converged (to two places beyond the decimal point)
B. Getting *dev*s into the model: Random walk *dev*s with large σ_{dev} values were added to each selectivity function, one fleet at a time. Ordinary (not random walk) *dev*s with a large σ_{dev} value were added to survey catchability. The base value for each parameter corresponds to the first year in the respective time series (1977 for the fisheries, 1982 for the survey), and the *dev*s begin in the subsequent year. Fishery selectivity *dev*s continue through 2010. However, to avoid confounding survey *dev*s with recent recruitments, the survey selectivity *dev* vectors end in 2008 for the *beginning_of_peak_region*, *ascending_width*, and *initial_selectivity* parameters.
C. Second (with *dev*s) convergence loop: New values for the parameters in items 1, 2, and 5 and the set of σ_{dev} parameters in items 3 and 4 were determined from the results of step B, and the model was re-run. This process was repeated until the parameters converged (to two places beyond the decimal point).

The process of tuning the σ_{dev} parameters for the selectivity *dev*s resulted in several of the *dev* vectors getting "tuned out" of the model entirely. At the conclusion of the tuning process, only six selectivity parameters still had annual random walk *dev*s:

1. *beginning_of_peak_region* for the fishery in season 1,
2. *ascending_width* for the fishery in season 1,
3. *beginning_of_peak_region* for the fishery in season 3,
4. *ascending_width* for the fishery in season 3,
5. *width_of_peak_region* for the survey, and
6. *initial_selectivity* for the survey.

Several other options were explored during the development of Model A, but not included in this preliminary assessment. These included the following:

1. Annually varying Brody growth parameter (*K*)
2. Annually varying length at the first reference age
3. Internal estimation of standard deviation of length at age
4. Ordinary (not random walk) *dev*s for annually varying selectivity parameters
5. One selectivity parameter for each age (up to some age-plus group) and fleet, either with ordinary or random walk *dev*s or constant
6. Not forcing any fleet to exhibit asymptotic selectivity
7. Internal estimation of survey catchability
8. Iterative re-weighting of size composition likelihood components
9. Internal estimation of the natural mortality rate
10. Changing the SS parameter *comp_tail_compression* (the tails of each age or size composition record are compressed until the specified amount is reached; sometimes referred to as "dynamic binning")
11. Changing the SS parameter *add_to_comp* (this amount is added to each element of each age or size composition vector—both observed and expected, which avoids taking the logarithm of zero and may also have robustness-related attributes)
12. Internal estimation of ageing error variances

Model 5

Model 5 uses the time series of selectivity parameters estimated (using random walk *dev*s) in Model A to identify appropriate breakpoints for defining block-specific selectivity parameters. The method used for identifying breakpoints in each time series was similar to that used last year to define the new seasonal structure, except that a constant variance (as opposed to block-specific variances) was assumed for each time series. Basically, the approach assumes that the data within any given block are drawn from a normal distribution with a block-specific mean, and that blocks must be at least 5 years in length. Final choice of blocks structure was determined on the basis of minimum AIC.

Using this procedure, the following blocks were identified for the time-varying selectivity parameters:

1. *beginning_of_peak_region* for the fishery in season 1: 1977-1983, 1984-1988, 1989-1994, 1995-2000, 2001-2005, and 2006-2010
2. *ascending_width* for the fishery in season 1: 1977-1985, 1986-1990, 1991-1995, 1996-2000, 2001-2005, and 2006-2010
3. *beginning_of_peak_region* for the fishery in season 3: 1977-1982, 1983-1988, 1989-1997, 1998-2002, and 2003-2010
4. *ascending_width* for the fishery in season 3: 1977-1983, 1984-1990, 1991-2001, and 2002-2010

5. *width_of_peak_region* for the survey: 1982-1990, 1991-1995, 1996-2004, and 2005-2010
6. *initial_selectivity* for the survey: 1982-1994, 1995-1999, and 2000-2008

The selectivity parameter time series estimated by Model A, along with the block divisions and block-specific means determined above, are shown in Figure 2.1.2.

Model 5 used the same data file (Data5) as Model A.

Results

Overview

The following table summarizes how the various models characterize the status of the stock:

Model	Description	SB(2010)	Ave(QxS)	SBratio
1	Last year's model	266,263	0.42	0.30
2a	Model 1, with spline-based selectivity	289,392	0.40	0.31
2b	Model 1, without pre-1982 survey	263,575	0.43	0.30
3	Model 2b, with internal ageing bias	260,165	0.48	0.30
4	Model 2b, without age-related data	300,597	0.39	0.38
A	Author's preferred model	308,959	0.47	0.36
5	Model A, with time blocks	422,940	0.46	0.47

The column labeled "SB(2010)" shows the estimate of 2010 female spawning biomass, the column labeled "Ave(QxS)" shows the average of the product of catchability and selectivity across the 60-81 cm size range (recall that this quantity was estimated to equal 0.47 by Nichol et al. (2007)), and the column labeled "SBratio" shows the ratio of 2010 female spawning biomass to $B_{100\%}$ (for comparison, the inflection in the maxABC harvest control rule occurs at 0.40 and the B_{MSY} proxy occurs at 0.35).

Goodness of Fit

For each model, the following table lists the data file used, the objective function value, the number of parameters (note that this number counts constrained *dev*s as full parameters), and the AIC value. It is important to keep in mind the following caveats regarding comparison of AIC values:

1. AIC values can be compared only for models that use the same data set. Thus, the table is color-coded to highlight those models that use the same data set (note that Data2 and Data3 are actually identical for the purpose of computing AIC, because the only difference between them is the existence of a flag in Data3 that activates internal estimation of ageing error bias).

2. Because the number of parameters was determined by counting constrained *dev*s as full parameters, the number of effective parameters tends to be overestimated. Thus, AIC can be misleading, even if the same data set is used in all of the models being compared.

Model	Description	Data file	-lnL	Parms.	AIC
1	Last year's model	Data1	5,388.35	183	11,142.70
2a	Model 1, with spline-based selectivity	Data1	5,399.43	174	11,146.86
2b	Model 1, without pre-1982 survey	Data2	5,377.41	177	11,108.82
3	Model 2b, with internal ageing bias	Data3	4,846.64	179	10,051.28
4	Model 2b, without age-related data	Data4	3,834.39	179	8,026.78
A	Author's preferred model	Data5	2,490.85	296	5,573.70
5	Model A, with time blocks	Data5	2,725.20	132	5,714.40

Objective function values are broken down by individual component in Table 2.1.1.

Model fits to the survey abundance data are shown in Figure 2.1.3, along with RMSSR values. Model A achieves the desired RMSSR value of 1.00, while Models 1-4 all give RMSSR values greater than 1.60 and Model 5 gives RMSSR=0.94.

Table 2.1.2 shows average input sample sizes and average effective sample sizes for the size composition likelihood components. Note that Models 1-3 all use the same average input sample sizes, Model 4 uses a different average input sample size for the post-1981 survey (because all size composition records were activated), and Models A and 5 use a different input sample size regime entirely. All models result in average (across fleets) effective sample sizes that are much larger than the average (across fleets) input sample sizes. Between Models 1-4, Model 4 gives the highest average effective sample size for four of the ten fleets common to all of these models (i.e., not counting the pre-1982 survey), while Model 1 gives the highest for three, and Model 2a gives the lowest for five. Between Models A and 5, Model A gives the higher average effective sample size for four of the six fleets.

Table 2.1.3 shows input sample sizes and effective sample sizes by year for the age composition likelihood component. Models 1-4 use the same vector of input sample sizes (but recall that Model 4 does not attempt to fit the age composition data), while Models A and 5 use a different vector. Between Models 1-4, Model 2b gives the highest ratio of average effective sample size to average input sample size (0.50), while Model 3 gives the lowest (0.33). Between Models A and 5, Model A achieves the desired ratio of 1.00, while Model 5 gives a ratio of 0.81.

Robustness

Results of 50 jitters for each model are shown below (the first three rows have already been shown, but are included here for completeness):

Model	Description	Jitter	Success	Match	-lnL "RMSE"	SB2010 "CV"
1	Last year's model	0.10	1	0.16	342.86	0.11
2a	Model 1, with splines	0.10	1	0.16	4393.38	1.02
2b	Model 1, without pre-1982 survey	0.10	1	0.28	1198.59	0.11
3	Model 1, with internal ageing bias	0.10	1	0.00	3.36E+18	33.57
4	Model 1, without age-related data	0.10	1	0.46	120.67	0.03
A	Author's preferred model	0.01	0.78	1.00	0.00	0.00
5	Model A, with time blocks	0.01	0.64	0.88	1.78	0.01

Between Models 1-4, Model 4 is the clear winner by all three measures listed above (highest “match” rate, lowest –lnL “RMSE,”, and lowest SB2010 “CV”), and Model 3 is the clear loser. A likely explanation for Model 4’s high degree of robustness is that it does not have to reconcile the age composition data, mean-size-at-age data, and size composition data. One possible reason for Model 3's poor performance is that it may be difficult to estimate ageing bias when the mean-size-at-age data are included (not in general, but because of the properties of this particular set of mean-size-at-age data, which were shown during the CIE review to pose significant problems).

Note that the results for Models A and 5 are not comparable to the results for Models 1-4, because a much smaller jitter rate was used for Models A and 5. This was necessary in order to achieve a reasonable success rate; a majority of jitters for Models A and 5 tended to yield non-numeric results when a jitter rate much higher than 0.01 was used. This fact by itself indicates that Models A and 5 tend to be less robust than Models 1-4. Between Models A and 5, however, Model A appears to be more robust than Model 5 (albeit perhaps only slightly) by any of the measures listed.

Parameter Values

All estimated parameter values (and many fixed values) are shown in Tables 2.1.4a-2.1.4m. Each estimated parameter is accompanied by a standard deviation (*Sdev*).

Table 2.1.4a shows parameters that are common to all models. Parameter *A1* is the first reference age in the mean length-at-age relationship. Parameter ln(*R0*) is the natural log of mean recruitment for the post-1976 environmental regime, and *R1_offset* is the amount by which log mean recruitment was reduced during the pre-1977 environmental regime. Parameter names of the form *InitAge_X_dev* are the equivalent of recruitment *dev*s for age *X* in the initial numbers-at-age vector (note that these *dev*s are with respect to the pre-1977 log mean).

Table 2.1.4b shows log recruitment *dev*s for the main portion of the time series (1977-2009).

Table 2.1.4c shows the remaining parameters, exclusive of selectivity parameters. Not all parameters are used by all models. The parameters governing ageing bias (items #2-8) were described in the section that introduces Model 3. These parameters exist in the control file for Models 3, A, and 5 only; but the "implied" values (i.e., implied by the corresponding items in the respective data files) for Models 1, 2a, 2b, and 4 are shown here to facilitate comparison.

Table 2.1.4d shows log catchability *dev*s for Models A and 5.

Table 2.1.4e shows base selectivity values for Models 1, 2b, 3, and 4. Parameter labels (e.g., *P_1*, *P_2*, etc.) are listed in the following order: *beginning_of_peak_region*, *width_of_peak_region*, *ascending_width*, *descending_width*, *initial_selectivity*, *final_selectivity*. Base values will be over-written if block-specific values are estimated.

Table 2.1.4f shows block-specific selectivity parameters for Models 1, 2b, 3, and 4. The year designation at the end of each parameter name denotes the first year of the block to which that parameter applies.

Table 2.1.4g shows survey *ascending_width* (selectivity parameter #3) *dev*s for Models 1, 2b, 3, and 4.

Table 2.1.4h shows base values for spline-based selectivity parameters in Model 2a. Values in this table will be over-written if block-specific values are estimated. Parameters are described in the section that introduces Model 2a.

Table 2.1.4i shows block-specific selectivity parameters for Model 2a.

Table 2.1.4j shows survey spline value at age 1 *dev*s for Model 2a.

Table 2.1.4k shows base selectivity parameters for Models A and 5. Values for Model A pertain only to the first year in the time series if *dev*s are defined, and values for Model 5 will be over-written if block-specific values are estimated.

Table 2.1.4l shows selectivity *dev*s for Model A.

Table 2.1.4m shows block-specific selectivity parameters for Model 5.

Estimates of Length at Age and Selectivity at Length or Age

Figure 2.1.4 shows the mean length-at-age relationships estimated by each model. Models 1, 2a, and 2b allow negative mean size at age 0, while Models 3, 4, A, and 5 do not. Note that Model 4 estimates a distinctly lower mean size than the other models at ages 10 and above.

Figures 2.1.5-2.1.11 show the selectivities estimated for each fleet (except the pre-1982 survey) by each model.

Estimates of Time Series

Figure 2.1.12 shows the time series of spawning biomass relative to $B_{100\%}$ as estimated by each model.

Figure 2.1.13 shows the time series of total (age 0+) biomass as estimated by each model. The observed survey biomass time series is shown for comparison.

Figure 2.1.14 shows the time series of age 0 recruitments as estimated by each model.

Discussion

This preliminary assessment presents all the models requested by the Plan Teams and SSC, including a new model that represents the author’s current preference. Comments on any of the models are welcome.

The Pacific cod assessment models have been able to track general trends with a fair amount of success over the years, particularly in terms of identifying strong and weak year classes. The models have always succeeded in fitting the size composition data very well. However, fitting *all* of the data sets at levels consistent with best estimates of their associated measurement errors has proven to be an elusive task. Two data sets have been especially problematic in this regard: First, the models have been unable to track the survey abundance data with a level of precision consistent with the observed sampling variance. Second, the models have been unable to track the age composition data with an effective sample size consistent with the input sample size, although it should be stressed that the “correct” input sample size is unknown *a priori*.

It would seem that there are only two possibilities in this regard: Either the data have been, to some extent, “wrong;” or the models have been, to some extent, “wrong.” Many changes have been explored over the years in an attempt to get the models to fit all data sets appropriately, but, for the most part, these have been restricted to changes that did not increase the number of parameters dramatically. Model A in this preliminary assessment represents a departure from this pattern. The general philosophy that motivated the development of Model A was to add parameters where they were warranted, and not to add parameters where they were not warranted. Model A is successful in that it continues to match the size composition data extremely well, but it also matches the survey abundance data and the age composition at levels consistent with the variances in the data. It might be argued that Model A’s success with respect to fitting the age composition data is somewhat artificial, because the appropriate input sample size was determined as part of the modeling process. On the other hand, there is no disputing the fact that Model A fits the age composition data better than any of the other models. It may also be noted that Model A focuses on achieving an appropriate match to the survey abundance and age composition data while ignoring the better-than-expected fit to the size composition data. This was a deliberate choice, as increasing the emphasis given to the size composition data severely degrades the fit to the survey abundance data. The philosophy underlying Model A emphasizes achieving a reasonable fit to the survey abundance data even if the fit to the size composition data suggests that greater emphasis might be given to the latter. A similar philosophy was articulated recently by Francis (2011).

Other approaches to improving the model's fit to the data are also possible, of course. For example, one of the CIE reviewers stressed that the actual (i.e., physical) mechanisms causing mismatches between the model and the data must be identified first; then these mechanisms can be built into the model. This method would run less risk of mis-identifying "noise" as a missing parameter. However, identification of all the missing mechanisms could be extremely time-consuming and expensive, especially considering that the decades' worth of research that has already been conducted has been insufficient to identify these mechanisms.

Over-parameterization, along with its likely fellow traveler lack-of-robustness, has been a long-standing concern regarding the Pacific cod models. Model A does nothing to ameliorate those concerns, as the number of parameters estimated by Model A exceeds that of the other models by over 100. It may be the case that there is a fundamental tradeoff between having a model that fits the data satisfactorily and having a model that can easily and consistently find the true minimum of the objective function.

Model A is, admittedly, an exploratory model at this stage. Many elements of this model could use further evaluation. For example, is the method of iteratively tuning σ_{dev} for the selectivity parameters appropriate? This method was adopted in the hope that it would identify the appropriate level of temporal variability to allow (including identification of those parameters that should not vary at all). While the method was successful in achieving convergence here, there is no guarantee that such convergence will always be achieved, nor that a similar degree of convergence could not be achieved at some other combination of parameter values.

Finally, the long-standing issue of catchability has yet to reach an entirely satisfying conclusion. Using the point estimate obtained by Nichol et al. (2007) to tune the model does provide an empirical benchmark, but one that is based on a very small sample (11 fish). When catchability is freed in the seven models presented here (without further retuning), the results change appreciably: catchability goes down and 2010 spawning biomass goes up in Models 1, 2a, and 2b; while the opposite trends are obtained under the other four models.

References

Francis, R. I. C. C. 2011. Data weighting in statistical fisheries stock assessment models. *Canadian Journal of Fisheries and Aquatic Sciences* 68:1124-1138.

Methot, R. D. 2011. *User Manual for Stock Synthesis, Model Version 3.21d.* Unpublished manuscript, available from NOAA Fisheries Stock Assessment Toolbox website: http://nft.nefsc.noaa.gov/. 165 p.

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

Thompson, G. G., J. N. Ianelli, and R. R. Lauth. 2010a. Assessment of the Pacific cod stock in the eastern Bering Sea and Aleutian Islands area. *In* Plan Team for the Groundfish Fisheries of the Bering Sea and Aleutian Islands (compiler), Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands regions, p. 243-424. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.

Thompson, G. G., J. N. Ianelli, and M. E. Wilkins. 2010b. Assessment of the Pacific cod stock in the Gulf of Alaska. *In* Plan Team for the Groundfish Fisheries of the Gulf of Alaska (compiler), Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska, p. 157-327. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.

Table 2.1.1. Objective function values for each model, broken down by component.

	Model 1	Model 2a	Model 2b	Model 3	Model 4	Model A	Model 5
Data file:	Data1	Data1	Data2	Data3	Data4	Data5	Data5

Obj. function component	Model 1	Model 2a	Model 2b	Model 3	Model 4	Model A	Model 5
Equilibrium catch	0.01	0.00	0.01	0.08	0.01	0.00	0.00
Survey CPUE	-12.27	-29.49	-12.57	-10.57	-16.43	-51.75	-53.59
Size composition	3981.64	4042.61	3973.87	3747.01	3820.35	2345.10	2653.30
Age composition	167.08	184.91	165.05	254.51	n/a	76.42	96.24
Mean size at age	1224.86	1183.56	1224.63	820.71	n/a	n/a	n/a
Recruitment	11.47	11.23	10.63	14.56	18.11	5.57	5.66
Priors	n/a	n/a	n/a	n/a	n/a	27.57	23.41
"Softbounds"	0.03	0.02	0.03	0.03	0.04	0.01	0.01
Deviations	15.53	6.58	15.76	20.29	12.31	87.94	0.17
Total	5388.35	5399.43	5377.41	4846.64	4181.78	2490.85	2725.20

Sizecomp component	Model 1	Model 2a	Model 2b	Model 3	Model 4	Model A	Model 5
Jan-Apr trawl fishery	1080.23	1014.15	1086.95	995.19	879.66	n/a	n/a
May-Jul trawl fishery	220.16	248.08	218.21	208.49	181.74	n/a	n/a
Aug-Dec trawl fishery	223.25	215.40	224.64	218.11	215.75	n/a	n/a
Jan-Apr longline fishery	664.37	686.17	673.42	630.59	601.81	n/a	n/a
May-Jul longline fishery	230.86	189.64	231.71	218.65	202.35	n/a	n/a
Aug-Dec longline fishery	993.39	1115.76	1006.32	888.36	846.72	n/a	n/a
Jan-Apr pot fishery	96.93	103.92	97.36	98.78	99.88	n/a	n/a
May-Jul pot fishery	77.04	59.74	76.99	77.44	74.38	n/a	n/a
Aug-Dec pot fishery	172.82	163.81	172.80	169.60	165.93	n/a	n/a
Pre-1982 trawl survey	46.83	45.28	n/a	n/a	n/a	n/a	n/a
Post-1981 trawl survey	175.76	200.66	185.48	241.82	552.13	768.36	882.91
Jan-Feb fishery	n/a	n/a	n/a	n/a	n/a	317.42	290.66
Mar-Apr fishery	n/a	n/a	n/a	n/a	n/a	360.87	363.45
May-Jul fishery	n/a	n/a	n/a	n/a	n/a	328.17	525.59
Aug-Oct fishery	n/a	n/a	n/a	n/a	n/a	305.04	324.12
Nov-Dec fishery	n/a	n/a	n/a	n/a	n/a	265.23	266.57

Table 2.1.2. Average input sample sizes and average effective sample sizes for the size composition likelihood components. Pink = highest value in the row, green = lowest value in the row.

	Models 1, 2a, 2b, 3		Mean effective N				Model 4		
Fleet	Records	Input N	Model 1	Model 2a	Model 2b	Model 3	Records	Input N	Eff. N
Jan-Apr Trawl Fishery	58	340	1029	1134	1026	1039	58	340	1140
May-Jul Trawl Fishery	30	70	445	412	436	461	30	70	493
Aug-Dec Trawl Fishery	33	42	293	283	276	286	33	42	286
Jan-Apr Longline Fishery	62	474	1834	1599	1832	1870	62	474	1975
May-Jul Longline Fishery	30	214	1072	1342	1086	1102	30	214	1153
Aug-Dec Longline Fishery	57	687	2098	1732	2045	2328	57	687	2494
Jan-Apr Pot Fishery	31	145	1409	1280	1408	1454	31	145	1316
May-Jul Pot Fishery	16	144	1144	1017	1129	1066	16	144	1069
Aug-Dec Pot Fishery	31	78	773	808	764	748	31	78	768
Post81 Shelf Survey	13	129	554	436	533	374	29	199	509
Pre82 Shelf Survey	3	100	74	54	n/a	n/a	n/a	n/a	n/a
Average:		220	975	918	1054	1073		239	1120
Relative to average:		1.00	4.43	4.17	4.79	4.87		1.00	4.68

	Models A, 5		Mean Effective N	
Fleet	Records	Input N	Model A	Model 5
Season 1 Fishery	32	300	2099	1915
Season 2 Fishery	32	300	1374	1306
Season 3 Fishery	33	300	1550	1087
Season 4 Fishery	32	300	1475	1536
Season 5 Fishery	29	300	1347	1374
Trawl Survey	29	300	571	498
Average:		300	1403	1286
Relative to average:		1.00	4.68	4.29

Table 2.1.3. Input sample sizes and effective sample sizes by year for the age composition likelihood component. Pink = highest value in the row (for Models 1-4 or Models A and 5), green = lowest value in the row (for Models 1-4 or Models A and 5).

		Effective N						Effective N	
Year	Input N	Mod. 1	Mod. 2a	Mod. 2b	Mod. 3	Mod. 4	Input N	Mod. A	Mod. 5
1994	214	59	48	58	33	125	120	162	121
1995	179	22	16	22	15	22	100	28	27
1996	213	121	35	146	63	259	119	107	111
1997	215	87	100	90	276	203	120	205	135
1998	190	54	36	54	28	127	106	280	286
1999	257	394	112	442	144	91	144	304	131
2000	258	73	52	73	81	138	144	79	58
2001	284	225	370	221	261	277	159	56	36
2002	283	314	216	338	155	91	158	104	74
2003	407	386	245	376	200	113	228	512	541
2004	311	77	96	77	92	40	174	40	41
2005	383	219	143	211	89	124	214	258	145
2006	389	198	217	185	76	97	218	112	156
2007	431	23	422	22	10	55	241	159	28
2008	363	42	32	42	23	66	203	166	170
2009	422	49	46	51	22	58	236	124	111
Average:	300	146	137	151	98	118	168	169	136
Relative:	1.00	0.49	0.46	0.50	0.33	0.39	1.00	1.00	0.81

Table 2.1.4a. Parameters common to all models, exclusive of recruitment *dev*s for the main portion of the time series. See text for details.

	Model 1		Model 2a		Model 2b		Model 3		Model 4		Model A		Model 5	
Parameter	Value	Sdev	Value	Sdev	Value	Sdev	Value	Sdev	Value	Sdev	Value	Sdev	Value	Sdev
A1	0.00	n/a	0.00	n/a	0.00	n/a	1.00	n/a	1.00	n/a	1.42	n/a	1.42	n/a
L_at_A1	-17.48	0.28	-16.84	0.31	-17.34	0.28	6.92	0.17	4.50	0.14	13.05	0.10	13.13	0.08
L_infinity	93.48	0.36	95.41	0.44	93.82	0.38	94.09	0.36	90.78	0.35	91.73	0.58	91.60	0.56
VonBert_K	0.23	0.00	0.22	0.00	0.23	0.00	0.24	0.00	0.26	0.00	0.27	0.01	0.27	0.01
SD_Len_at_A1	0.01	n/a	0.01	n/a	0.01	n/a	1.97	n/a	2.72	0.11	2.18	n/a	2.18	n/a
SD_Len_at_Amax	8.68	n/a	8.68	n/a	8.68	n/a	8.68	n/a	10.59	0.17	8.68	n/a	8.68	n/a
Post-81 survey ln(Q)	-0.261	n/a	-0.261	n/a	-0.261	n/a	-0.261	n/a	-0.261	n/a	-0.136	n/a	-0.136	n/a
ln(R0)	13.38	0.02	13.44	0.02	13.38	0.02	13.30	0.02	13.34	0.02	13.33	0.06	13.37	0.06
sigmaR	0.57	n/a	0.57	n/a	0.57	n/a	0.57	n/a	0.57	n/a	0.66	0.08	0.66	0.08
R1_offset	-0.92	0.11	-0.95	0.12	-0.97	0.11	-1.11	0.02	-0.89	0.12	-0.78	0.19	-0.78	0.19
InitAge_3_dev	1.38	0.18	1.26	0.18	1.40	0.18	1.82	0.14	1.46	0.18	1.29	0.25	1.17	0.25
InitAge_2_dev	-0.98	0.39	-1.00	0.38	-0.83	0.40	-0.30	0.39	-0.55	0.40	-0.56	0.47	-0.40	0.45
InitAge_1_dev	2.12	0.13	1.98	0.14	1.93	0.15	1.43	0.15	1.40	0.19	1.51	0.25	1.45	0.23

Table 2.1.4b. Recruitment *dev*s for the main portion of the time series.

	Model 1		Model 2a		Model 2b		Model 3		Model 4		Model A		Model 5	
Parameter	Value	Sdev	Value	Sdev	Value	Sdev	Value	Sdev	Value	Sdev	Value	Sdev	Value	Sdev
Main_RecrDev_1977	1.19	0.08	1.24	0.09	1.10	0.12	1.12	0.10	1.37	0.10	1.31	0.16	1.00	0.14
Main_RecrDev_1978	0.44	0.12	0.44	0.13	0.65	0.14	0.48	0.14	0.69	0.16	0.77	0.16	0.75	0.13
Main_RecrDev_1979	0.61	0.08	0.70	0.07	0.53	0.09	0.58	0.09	0.62	0.10	0.58	0.10	0.44	0.10
Main_RecrDev_1980	-0.69	0.14	-0.41	0.12	-0.63	0.14	-0.32	0.11	-0.28	0.11	-0.04	0.09	-0.16	0.09
Main_RecrDev_1981	-0.08	0.08	0.04	0.08	-0.09	0.08	-0.77	0.11	-0.79	0.12	-0.58	0.10	-0.65	0.10
Main_RecrDev_1982	0.69	0.05	0.84	0.05	0.68	0.05	0.75	0.04	0.85	0.04	0.85	0.05	0.79	0.04
Main_RecrDev_1983	-0.16	0.07	0.02	0.07	-0.16	0.07	-0.45	0.08	-0.39	0.08	-0.48	0.09	-0.39	0.07
Main_RecrDev_1984	0.54	0.05	0.52	0.05	0.54	0.05	0.55	0.04	0.62	0.05	0.58	0.05	0.51	0.05
Main_RecrDev_1985	-0.18	0.06	-0.25	0.07	-0.19	0.06	-0.08	0.06	0.02	0.06	-0.05	0.07	-0.17	0.06
Main_RecrDev_1986	-0.86	0.08	-0.84	0.08	-0.86	0.08	-0.79	0.08	-0.79	0.08	-0.55	0.08	-0.72	0.07
Main_RecrDev_1987	-0.83	0.07	-0.87	0.07	-0.83	0.07	-0.94	0.07	-0.95	0.08	-1.01	0.09	-1.14	0.09
Main_RecrDev_1988	-0.07	0.04	-0.14	0.04	-0.09	0.04	-0.37	0.05	-0.34	0.05	-0.26	0.07	-0.31	0.06
Main_RecrDev_1989	0.47	0.04	0.39	0.04	0.46	0.04	0.38	0.03	0.43	0.04	0.40	0.05	0.36	0.04
Main_RecrDev_1990	0.16	0.04	0.06	0.04	0.15	0.04	0.21	0.04	0.30	0.04	0.18	0.05	0.17	0.05
Main_RecrDev_1991	0.01	0.04	-0.07	0.04	-0.01	0.04	-0.19	0.04	-0.24	0.05	-0.26	0.06	-0.29	0.06
Main_RecrDev_1992	0.44	0.03	0.35	0.03	0.43	0.03	0.41	0.03	0.54	0.03	0.43	0.04	0.36	0.04
Main_RecrDev_1993	-0.38	0.04	-0.47	0.04	-0.39	0.04	-0.32	0.04	-0.37	0.05	-0.49	0.06	-0.49	0.05
Main_RecrDev_1994	-0.35	0.04	-0.42	0.04	-0.35	0.04	-0.43	0.04	-0.33	0.05	-0.53	0.05	-0.54	0.05
Main_RecrDev_1995	0.03	0.04	-0.04	0.04	0.02	0.04	-0.26	0.04	-0.24	0.05	-0.45	0.06	-0.53	0.05
Main_RecrDev_1996	0.50	0.03	0.49	0.03	0.49	0.03	0.49	0.03	0.60	0.03	0.49	0.04	0.43	0.03
Main_RecrDev_1997	-0.15	0.04	-0.13	0.04	-0.15	0.04	-0.10	0.03	-0.08	0.04	-0.06	0.05	-0.05	0.04
Main_RecrDev_1998	-0.12	0.04	-0.05	0.03	-0.12	0.04	-0.22	0.04	-0.21	0.04	-0.23	0.05	-0.19	0.05
Main_RecrDev_1999	0.35	0.03	0.38	0.03	0.35	0.03	0.31	0.03	0.37	0.03	0.46	0.03	0.43	0.03
Main_RecrDev_2000	-0.19	0.03	-0.20	0.04	-0.19	0.03	0.00	0.03	0.07	0.04	0.11	0.04	0.18	0.04
Main_RecrDev_2001	-0.66	0.04	-0.65	0.04	-0.66	0.04	-0.70	0.04	-0.75	0.05	-0.67	0.06	-0.58	0.06
Main_RecrDev_2002	-0.35	0.04	-0.36	0.04	-0.35	0.04	-0.33	0.03	-0.22	0.04	-0.23	0.05	-0.08	0.05
Main_RecrDev_2003	-0.49	0.04	-0.53	0.04	-0.49	0.04	-0.51	0.04	-0.42	0.05	-0.43	0.06	-0.10	0.06
Main_RecrDev_2004	-0.61	0.05	-0.63	0.05	-0.61	0.05	-0.50	0.04	-0.44	0.05	-0.31	0.07	-0.25	0.07
Main_RecrDev_2005	-0.33	0.05	-0.33	0.05	-0.33	0.05	-0.44	0.05	-0.41	0.06	-0.09	0.08	0.00	0.07
Main_RecrDev_2006	0.45	0.05	0.26	0.05	0.45	0.05	0.48	0.05	0.67	0.05	0.89	0.08	1.20	0.07
Main_RecrDev_2007	-0.27	0.09	-0.40	0.09	-0.26	0.09	0.00	0.07	-0.07	0.09	-0.16	0.11	0.35	0.10
Main_RecrDev_2008	0.90	0.09	0.93	0.10	0.92	0.09	1.01	0.09	1.02	0.09	0.89	0.11	0.99	0.09
Main_RecrDev_2009	0.00	0.26	0.13	0.25	-0.02	0.27	0.94	0.15	-0.87	0.28	-1.06	0.31	-1.33	0.28

Table 2.1.4c. Other parameters, exclusive of selectivity parameters. See text for details.

	Model 1		Model 2a		Model 2b		Model 3		Model 4		Model A		Model 5	
Parameter	Value	Sdev	Value	Sdev	Value	Sdev	Value	Sdev	Value	Sdev	Value	Sdev	Value	Sdev
Richards_growth_coef											0.92	0.03	0.91	0.03
1st_biased_age_(FBA)	2		2		2		1		2		1		1	
Ageing_bias_at_FBA	0.4		0.4		0.4		0.41	0.00	0.4		0.28	0.02	0.29	0.02
Ageing_bias_at_Amax	0.4		0.4		0.4		1.40	0.07	0.4		1.93	0.28	1.75	0.28
Bias_interp_power	0		0		0		0		0		0		0	
Age_err_SD_at_FBA	0.18		0.18		0.18		0.09		0.18		0.13		0.13	
Age_err_SD_at_Amax	1.76		1.76		1.76		1.76		1.76		1.76		1.76	
SD_interp_power	0		0		0		0		0		0		0	
InitAge_10_dev											-0.40	0.57	-0.42	0.56
InitAge_9_dev											-0.49	0.55	-0.51	0.55
InitAge_8_dev											-0.57	0.53	-0.59	0.53
InitAge_7_dev											-0.62	0.52	-0.64	0.52
InitAge_6_dev											-0.59	0.51	-0.60	0.51
InitAge_5_dev											-0.42	0.49	-0.38	0.50
InitAge_4_dev											-0.31	0.47	-0.12	0.46
InitF_Jan-Apr_Trawl	0.40	0.08	0.41	0.07	0.42	0.08	2.00	0.00	0.44	0.11				
InitF_May-Jul_Trawl	0		0		0		0		0					
InitF_Aug-Dec_Trawl	0		0		0		0		0					
InitF_Jan-Apr_Longl	0		0		0		0		0					
InitF_May-Jul_Longl	0		0		0		0		0					
InitF_Aug-Dec_Longl	0		0		0		0		0					
InitF_Jan-Apr_Pot	0		0		0		0		0					
InitF_May-Jul_Pot	0		0		0		0		0					
InitF_Aug-Dec_Pot	0		0		0		0		0					
InitF_Season1_Fishery											0.41	0.09	0.38	0.08
InitF_Season2_Fishery											0		0	
InitF_Season3_Fishery											0		0	
InitF_Season4_Fishery											0		0	
InitF_Season5_Fishery											0		0	
Pre-1982 survey ln(Q)	0		0											

Table 2.1.4d. Catchability *dev*s (Models A and 5 only).

	Model A		Model 5	
Parameter	Value	Sdev	Value	Sdev
Q_dev_1982	-0.43	0.08	-0.32	0.07
Q_dev_1983	-0.12	0.10	-0.04	0.09
Q_dev_1984	-0.22	0.07	-0.19	0.07
Q_dev_1985	0.20	0.10	0.02	0.10
Q_dev_1986	0.06	0.09	0.01	0.08
Q_dev_1987	0.02	0.07	0.06	0.06
Q_dev_1988	-0.03	0.07	-0.01	0.07
Q_dev_1989	-0.41	0.07	-0.29	0.07
Q_dev_1990	-0.15	0.09	-0.09	0.08
Q_dev_1991	-0.05	0.09	-0.09	0.09
Q_dev_1992	0.30	0.10	0.05	0.09
Q_dev_1993	0.26	0.10	0.27	0.10
Q_dev_1994	0.38	0.10	0.48	0.10
Q_dev_1995	0.45	0.09	0.40	0.09
Q_dev_1996	0.25	0.10	0.20	0.10
Q_dev_1997	0.05	0.11	0.08	0.10
Q_dev_1998	-0.06	0.08	-0.01	0.08
Q_dev_1999	-0.09	0.08	-0.06	0.08
Q_dev_2000	-0.17	0.09	-0.20	0.08
Q_dev_2001	0.22	0.08	0.23	0.08
Q_dev_2002	-0.06	0.09	-0.10	0.09
Q_dev_2003	0.10	0.10	-0.08	0.10
Q_dev_2004	0.01	0.09	-0.19	0.08
Q_dev_2005	0.16	0.11	0.16	0.10
Q_dev_2006	-0.23	0.08	0.13	0.07
Q_dev_2007	0.01	0.13	0.02	0.13
Q_dev_2008	-0.02	0.10	-0.24	0.09
Q_dev_2009	-0.06	0.10	-0.13	0.09
Q_dev_2010	0.00	0.11	0.20	0.11

Table 2.1.4e (page 1 of 2). Base selectivity parameters for Models 1, 2b, 3, and 4. Values in this table will be over-written if block-specific values are estimated (see Table 2.1.4f).

	Model 1		Model 2b		Model 3		Model 4	
Parameter	Value	Sdev	Value	Sdev	Value	Sdev	Value	Sdev
P_1_Jan-Apr_Trawl	0		0		0		0	
P_2_Jan-Apr_Trawl	0		0		0		0	
P_3_Jan-Apr_Trawl	0		0		0		0	
P_4_Jan-Apr_Trawl	0		0		0		0	
P_5_Jan-Apr_Trawl	-999		-999		-999		-999	
P_6_Jan-Apr_Trawl	10		10		10		10	
P_1_May-Jul_Trawl	0		0		0		0	
P_2_May-Jul_Trawl	0		0		0		0	
P_3_May-Jul_Trawl	5.68	0.11	5.70	0.11	5.69	0.10	5.60	0.11
P_4_May-Jul_Trawl	0		0		0		0	
P_5_May-Jul_Trawl	-999		-999		-999		-999	
P_6_May-Jul_Trawl	10		10		10		10	
P_1_Aug-Dec_Trawl	0		0		0		0	
P_2_Aug-Dec_Trawl	0		0		0		0	
P_3_Aug-Dec_Trawl	0		0		0		0	
P_4_Aug-Dec_Trawl	0		0		0		0	
P_5_Aug-Dec_Trawl	-999		-999		-999		-999	
P_6_Aug-Dec_Trawl	10		10		10		10	
P_1_Jan-Apr_Longline	0		0		0		0	
P_2_Jan-Apr_Longline	-4.36	1.18	-4.35	1.16	-4.27	1.08	-4.00	0.84
P_3_Jan-Apr_Longline	0		0		0		0	
P_4_Jan-Apr_Longline	4.92	0.14	4.93	0.14	4.94	0.13	5.01	0.14
P_5_Jan-Apr_Longline	-999		-999		-999		-999	
P_6_Jan-Apr_Longline	0		0		0		0	
P_1_May-Jul_Longline	0		0		0		0	
P_2_May-Jul_Longline	0		0		0		0	
P_3_May-Jul_Longline	4.95	0.06	4.96	0.06	4.95	0.06	4.93	0.06
P_4_May-Jul_Longline	0		0		0		0	
P_5_May-Jul_Longline	-999		-999		-999		-999	
P_6_May-Jul_Longline	10		10		10		10	
P_1_Aug-Dec_Longline	0		0		0		0	
P_2_Aug-Dec_Longline	-2.02	0.21	-2.02	0.21	-2.07	0.22	-2.15	0.23
P_3_Aug-Dec_Longline	0		0		0		0	
P_4_Aug-Dec_Longline	4.69	0.29	4.68	0.29	4.71	0.30	5.17	0.29
P_5_Aug-Dec_Longline	-999		-999		-999		-999	
P_6_Aug-Dec_Longline	0		0		0		0	

Table 2.1.4e (page 2 of 2). Base selectivity parameters for Models 1, 2b, 3, and 4. Values in this table will be over-written if block-specific values are estimated (see Table 2.1.4f).

	Model 1		Model 2b		Model 3		Model 4	
Parameter	Value	Sdev	Value	Sdev	Value	Sdev	Value	Sdev
P_1_Jan-Apr_Pot	0		0		0		0	
P_2_Jan-Apr_Pot	-4.72	4.49	-4.80	4.84	-7.10	34.09	-5.30	7.96
P_3_Jan-Apr_Pot	4.99	0.07	4.99	0.06	5.01	0.06	5.00	0.07
P_4_Jan-Apr_Pot	4.46	0.44	4.47	0.44	4.53	0.35	4.55	0.44
P_5_Jan-Apr_Pot	-999		-999		-999		-999	
P_6_Jan-Apr_Pot	0		0		0		0	
P_1_May-Jul_Pot	0		0		0		0	
P_2_May-Jul_Pot	0		0		0		0	
P_3_May-Jul_Pot	4.93	0.08	4.93	0.08	4.90	0.08	4.90	0.08
P_4_May-Jul_Pot	0		0		0		0	
P_5_May-Jul_Pot	-999		-999		-999		-999	
P_6_May-Jul_Pot	10		10		10		10	
P_1_Aug-Dec_Pot	0		0		0		0	
P_2_Aug-Dec_Pot	0		0		0		0	
P_3_Aug-Dec_Pot	0		0		0		0	
P_4_Aug-Dec_Pot	0		0		0		0	
P_5_Aug-Dec_Pot	-999		-999		-999		-999	
P_6_Aug-Dec_Pot	10		10		10		10	
P_1_Pre82_Shelf_Survey	2.14	0.09	n/a		n/a		n/a	
P_2_Pre82_Shelf_Survey	-9.36	15.97	n/a		n/a		n/a	
P_3_Pre82_Shelf_Survey	-6.32	21.85	n/a		n/a		n/a	
P_4_Pre82_Shelf_Survey	1.12	0.49	n/a		n/a		n/a	
P_5_Pre82_Shelf_Survey	-1.79	0.58	n/a		n/a		n/a	
P_6_Pre82_Shelf_Survey	-2.19	1.16	n/a		n/a		n/a	
P_1_Post81_Shelf_Survey	1.29	0.07	1.29	0.06	1.30	0.07	1.33	0.10
P_2_Post81_Shelf_Survey	-4.89	3.25	-4.42	2.10	-3.02	0.57	-3.71	1.31
P_3_Post81_Shelf_Survey	-2.40	0.49	-2.41	0.48	-2.49	0.45	-1.86	0.60
P_4_Post81_Shelf_Survey	2.25	0.37	2.21	0.39	1.75	0.50	1.67	0.61
P_5_Post81_Shelf_Survey	-4.31	0.13	-4.44	0.14	-3.58	0.11	-9.99	0.20
P_6_Post81_Shelf_Survey	-0.66	0.17	-0.61	0.18	-0.53	0.18	-0.77	0.21

Table 2.1.4f (page 1 of 2). Block-specific selectivity parameters for Models 1, 2b, 3, and 4.

	Model 1		Model 2b		Model 3		Model 4	
Parameter	Value	Sdev	Value	Sdev	Value	Sdev	Value	Sdev
P_1_Jan-Apr_Trawl_1977	14.17	20.82	14.39	27.28	13.70	6.11	14.50	30.51
P_1_Jan-Apr_Trawl_1980	68.73	3.17	69.18	3.21	71.61	3.25	67.28	3.27
P_1_Jan-Apr_Trawl_1985	72.76	1.77	73.55	1.72	74.98	1.68	75.77	1.86
P_1_Jan-Apr_Trawl_1990	69.27	1.01	69.48	1.03	68.93	1.04	66.94	1.24
P_1_Jan-Apr_Trawl_1995	73.81	0.95	73.90	0.95	73.13	0.91	72.88	0.96
P_1_Jan-Apr_Trawl_2000	77.21	1.16	77.34	1.15	77.34	1.14	77.92	1.20
P_1_Jan-Apr_Trawl_2005	73.15	1.06	73.24	1.06	72.94	1.06	72.80	1.11
P_3_Jan-Apr_Trawl_1977	9.88	3.75	9.82	5.32	9.95	1.59	9.78	6.49
P_3_Jan-Apr_Trawl_1980	6.25	0.18	6.24	0.18	6.29	0.17	6.13	0.19
P_3_Jan-Apr_Trawl_1985	6.52	0.09	6.54	0.09	6.59	0.08	6.67	0.08
P_3_Jan-Apr_Trawl_1990	6.11	0.05	6.12	0.05	6.11	0.06	6.02	0.07
P_3_Jan-Apr_Trawl_1995	6.31	0.05	6.31	0.05	6.29	0.05	6.28	0.05
P_3_Jan-Apr_Trawl_2000	6.28	0.06	6.28	0.06	6.28	0.06	6.32	0.06
P_3_Jan-Apr_Trawl_2005	6.07	0.07	6.07	0.06	6.06	0.07	6.09	0.07
P_1_May-Jul_Trawl_1977	49.31	1.79	49.94	1.83	51.03	1.76	49.17	1.72
P_1_May-Jul_Trawl_1985	51.28	1.73	51.63	1.75	51.81	1.73	50.13	1.79
P_1_May-Jul_Trawl_1990	62.74	1.55	63.10	1.59	62.71	1.55	60.75	1.56
P_1_May-Jul_Trawl_2000	53.11	1.51	53.41	1.53	53.38	1.52	52.00	1.57
P_1_May-Jul_Trawl_2005	59.12	1.54	59.45	1.56	59.31	1.53	57.53	1.55
P_1_Aug-Dec_Trawl_1977	63.60	3.82	63.90	3.97	71.81	5.89	62.97	4.06
P_1_Aug-Dec_Trawl_1980	77.11	6.47	81.03	6.01	85.18	6.85	77.81	6.37
P_1_Aug-Dec_Trawl_1985	81.40	4.23	82.40	4.57	83.95	4.86	86.59	5.61
P_1_Aug-Dec_Trawl_1990	73.31	42.52	70.80	47.98	46.86	18.31	48.99	23.37
P_1_Aug-Dec_Trawl_1995	102.50		102.50		102.50		102.50	
P_1_Aug-Dec_Trawl_2000	62.03	2.66	62.29	2.68	62.29	2.65	62.27	2.83
P_3_Aug-Dec_Trawl_1977	5.49	0.30	5.54	0.31	5.85	0.33	5.59	0.32
P_3_Aug-Dec_Trawl_1980	6.53	0.30	6.66	0.25	6.77	0.25	6.57	0.28
P_3_Aug-Dec_Trawl_1985	6.46	0.22	6.49	0.22	6.54	0.23	6.65	0.24
P_3_Aug-Dec_Trawl_1990	6.14	2.50	6.00	3.05	3.38	4.51	3.89	4.61
P_3_Aug-Dec_Trawl_1995	7.03	0.09	7.02	0.09	7.04	0.09	7.04	0.09
P_3_Aug-Dec_Trawl_2000	5.58	0.22	5.59	0.22	5.59	0.22	5.61	0.23
P_1_Jan-Apr_Pot_1977	68.68	1.00	68.74	0.99	68.80	0.96	68.22	1.02
P_1_Jan-Apr_Pot_1995	68.16	0.70	68.20	0.70	68.23	0.64	68.07	0.71
P_1_Jan-Apr_Pot_2000	67.68	0.69	67.74	0.68	67.94	0.62	67.77	0.70
P_1_Jan-Apr_Pot_2005	67.30	0.70	67.36	0.70	67.44	0.65	67.02	0.71
P_6_Jan-Apr_Pot_1977	-0.04	0.49	-0.04	0.49	-0.04	0.49	0.23	0.55
P_6_Jan-Apr_Pot_1995	-0.24	0.26	-0.23	0.26	-0.33	0.25	-0.36	0.26
P_6_Jan-Apr_Pot_2000	-0.64	0.25	-0.64	0.25	-0.71	0.24	-0.64	0.26
P_6_Jan-Apr_Pot_2005	0.45	0.28	0.45	0.28	0.37	0.26	0.48	0.28
P_1_May-Jul_Pot_1977	67.19	0.85	67.29	0.85	66.95	0.86	66.77	0.87
P_1_May-Jul_Pot_1995	65.78	0.71	65.87	0.71	65.50	0.71	65.44	0.71
P_1_Aug-Dec_Pot_1977	68.15	1.16	68.23	1.16	67.99	1.15	67.84	1.16
P_1_Aug-Dec_Pot_2000	60.44	0.82	60.61	0.82	60.73	0.80	60.62	0.82
P_3_Aug-Dec_Pot_1977	5.17	0.12	5.18	0.12	5.16	0.12	5.17	0.12
P_3_Aug-Dec_Pot_2000	4.31	0.14	4.34	0.14	4.36	0.14	4.37	0.14

Table 2.1.4f (page 2 of 2). Block-specific selectivity parameters for Models 1, 2b, 3, and 4.

	Model 1		Model 2b		Model 3		Model 4	
Parameter	Value	Sdev	Value	Sdev	Value	Sdev	Value	Sdev
P_1_Jan-Apr_Longline_1977	60.67	2.20	60.69	2.29	61.77	3.38	58.58	2.15
P_1_Jan-Apr_Longline_1980	69.72	2.66	71.30	2.64	72.24	2.98	70.87	2.50
P_1_Jan-Apr_Longline_1985	73.30	0.87	73.60	0.89	74.10	0.92	74.64	0.94
P_1_Jan-Apr_Longline_1990	66.13	0.46	66.18	0.46	66.10	0.46	65.41	0.48
P_1_Jan-Apr_Longline_1995	65.75	0.42	65.77	0.42	65.45	0.42	65.16	0.43
P_1_Jan-Apr_Longline_2000	63.26	0.43	63.31	0.43	63.37	0.43	63.03	0.45
P_1_Jan-Apr_Longline_2005	67.05	0.42	67.09	0.42	67.01	0.42	66.48	0.44
P_3_Jan-Apr_Longline_1977	5.13	0.22	5.19	0.23	5.29	0.27	5.15	0.21
P_3_Jan-Apr_Longline_1980	5.81	0.21	5.89	0.19	5.90	0.21	5.89	0.19
P_3_Jan-Apr_Longline_1985	5.79	0.07	5.80	0.07	5.82	0.07	5.86	0.07
P_3_Jan-Apr_Longline_1990	5.23	0.05	5.23	0.04	5.23	0.05	5.19	0.05
P_3_Jan-Apr_Longline_1995	5.33	0.04	5.32	0.04	5.30	0.04	5.27	0.04
P_3_Jan-Apr_Longline_2000	5.35	0.04	5.35	0.04	5.36	0.04	5.34	0.04
P_3_Jan-Apr_Longline_2005	5.33	0.04	5.33	0.04	5.33	0.04	5.31	0.04
P_6_Jan-Apr_Longline_1977	-1.24	0.82	-1.19	0.84	6.80	52.80	-1.17	0.79
P_6_Jan-Apr_Longline_1980	0.88	1.10	0.87	1.21	3.21	8.35	0.40	0.95
P_6_Jan-Apr_Longline_1985	-0.82	0.33	-0.75	0.34	-0.68	0.36	-1.21	0.43
P_6_Jan-Apr_Longline_1990	-0.52	0.13	-0.51	0.13	-0.53	0.13	-0.47	0.13
P_6_Jan-Apr_Longline_1995	-0.62	0.13	-0.62	0.13	-0.68	0.13	-0.75	0.13
P_6_Jan-Apr_Longline_2000	-1.15	0.13	-1.15	0.13	-1.19	0.13	-1.18	0.14
P_6_Jan-Apr_Longline_2005	-1.08	0.14	-1.09	0.14	-1.13	0.14	-1.11	0.14
P_1_May-Jul_Longline_1977	64.45	1.95	64.00	2.06	65.14	2.08	62.44	2.28
P_1_May-Jul_Longline_1980	60.86	1.38	61.23	1.38	62.16	1.36	61.01	1.41
P_1_May-Jul_Longline_1985	62.17	1.12	62.39	1.12	62.53	1.12	62.24	1.13
P_1_May-Jul_Longline_1990	62.93	0.58	63.07	0.57	62.97	0.55	62.53	0.57
P_1_May-Jul_Longline_2000	59.17	0.58	59.29	0.58	59.24	0.57	58.95	0.59
P_1_May-Jul_Longline_2005	63.51	0.65	63.63	0.65	63.55	0.64	63.05	0.65
P_1_Aug-Dec_Longline_1977	63.01	2.20	63.02	2.26	66.00	4.15	60.41	2.22
P_1_Aug-Dec_Longline_1980	67.47	1.48	68.01	1.58	67.86	1.59	68.05	1.59
P_1_Aug-Dec_Longline_1985	62.93	0.65	62.95	0.67	63.67	0.66	64.06	0.80
P_1_Aug-Dec_Longline_1990	66.94	0.71	67.12	0.69	66.94	0.70	66.48	0.73
P_1_Aug-Dec_Longline_1995	68.93	0.70	69.04	0.70	68.51	0.67	68.48	0.69
P_1_Aug-Dec_Longline_2000	63.26	0.41	63.36	0.41	63.39	0.41	62.97	0.44
P_1_Aug-Dec_Longline_2005	60.96	0.42	61.06	0.44	61.27	0.43	60.52	0.46
P_3_Aug-Dec_Longline_1977	4.70	0.29	4.74	0.29	5.00	0.39	4.51	0.33
P_3_Aug-Dec_Longline_1980	5.27	0.14	5.30	0.14	5.28	0.14	5.31	0.14
P_3_Aug-Dec_Longline_1985	4.74	0.08	4.73	0.09	4.80	0.08	4.87	0.09
P_3_Aug-Dec_Longline_1990	5.00	0.08	5.02	0.07	5.01	0.08	5.01	0.08
P_3_Aug-Dec_Longline_1995	5.48	0.05	5.49	0.05	5.45	0.05	5.46	0.05
P_3_Aug-Dec_Longline_2000	5.16	0.04	5.17	0.04	5.17	0.04	5.15	0.04
P_3_Aug-Dec_Longline_2005	4.80	0.05	4.81	0.05	4.84	0.05	4.78	0.05
P_6_Aug-Dec_Longline_1977	-2.45	1.84	-2.42	1.81	0.36	3.11	-2.49	2.17
P_6_Aug-Dec_Longline_1980	1.22	0.75	1.65	1.12	6.81	49.84	0.35	0.65
P_6_Aug-Dec_Longline_1985	0.18	0.18	0.32	0.20	0.44	0.21	0.14	0.24
P_6_Aug-Dec_Longline_1990	2.19	0.64	2.28	0.70	2.19	0.64	2.31	0.79
P_6_Aug-Dec_Longline_1995	9.63	9.91	9.63	9.98	9.46	13.77	9.25	18.15
P_6_Aug-Dec_Longline_2000	-0.25	0.14	-0.25	0.14	-0.27	0.15	-0.40	0.18
P_6_Aug-Dec_Longline_2005	9.80	5.68	9.81	5.57	9.73	7.52	9.78	6.20

Table 2.1.4g. Survey *ascending_width* (selectivity parameter #3) *dev*s for Models 1, 2b, 3, and 4.

	Model 1		Model 2b		Model 3		Model 4	
Parameter	Value	Sdev	Value	Sdev	Value	Sdev	Value	Sdev
P_3_Survey_DEVadd_1982	-0.10	0.03	-0.10	0.03	-0.03	0.03	-0.04	0.04
P_3_Survey_DEVadd_1983	0.00	0.02	0.00	0.02	0.01	0.02	-0.05	0.02
P_3_Survey_DEVadd_1984	-0.09	0.03	-0.09	0.03	-0.03	0.03	-0.07	0.03
P_3_Survey_DEVadd_1985	0.02	0.03	0.02	0.03	0.06	0.03	-0.01	0.02
P_3_Survey_DEVadd_1986	-0.02	0.03	-0.03	0.03	-0.01	0.03	-0.05	0.03
P_3_Survey_DEVadd_1987	0.04	0.04	0.04	0.04	0.07	0.04	0.04	0.05
P_3_Survey_DEVadd_1988	-0.07	0.03	-0.07	0.03	-0.03	0.04	-0.05	0.04
P_3_Survey_DEVadd_1989	-0.12	0.02	-0.12	0.02	-0.08	0.02	-0.11	0.02
P_3_Survey_DEVadd_1990	-0.03	0.02	-0.03	0.02	0.01	0.02	-0.04	0.02
P_3_Survey_DEVadd_1991	-0.03	0.03	-0.03	0.03	0.00	0.03	-0.06	0.02
P_3_Survey_DEVadd_1992	0.02	0.03	0.02	0.03	0.08	0.04	0.06	0.04
P_3_Survey_DEVadd_1993	0.07	0.03	0.08	0.04	0.11	0.04	0.03	0.03
P_3_Survey_DEVadd_1994	-0.02	0.03	-0.02	0.03	0.07	0.03	-0.02	0.04
P_3_Survey_DEVadd_1995	-0.06	0.02	-0.06	0.02	-0.01	0.02	-0.06	0.03
P_3_Survey_DEVadd_1996	-0.09	0.02	-0.09	0.02	-0.03	0.02	-0.09	0.03
P_3_Survey_DEVadd_1997	-0.03	0.02	-0.03	0.02	-0.02	0.02	-0.07	0.02
P_3_Survey_DEVadd_1998	-0.06	0.02	-0.06	0.02	0.01	0.02	-0.08	0.03
P_3_Survey_DEVadd_1999	-0.06	0.02	-0.06	0.02	0.03	0.02	-0.08	0.02
P_3_Survey_DEVadd_2000	-0.02	0.02	-0.02	0.02	0.00	0.02	-0.05	0.02
P_3_Survey_DEVadd_2001	0.15	0.04	0.15	0.04	0.17	0.04	0.08	0.03
P_3_Survey_DEVadd_2002	-0.01	0.02	-0.01	0.02	0.09	0.03	0.01	0.03
P_3_Survey_DEVadd_2003	0.00	0.02	0.00	0.02	0.07	0.02	-0.01	0.02
P_3_Survey_DEVadd_2004	-0.01	0.02	-0.01	0.02	0.06	0.02	-0.03	0.02
P_3_Survey_DEVadd_2005	0.01	0.02	0.01	0.02	0.18	0.03	0.04	0.03
P_3_Survey_DEVadd_2006	0.08	0.03	0.08	0.03	0.12	0.03	0.11	0.04
P_3_Survey_DEVadd_2007	0.23	0.04	0.23	0.04	0.22	0.04	0.16	0.04
P_3_Survey_DEVadd_2008	0.05	0.03	0.06	0.03	0.12	0.03	0.03	0.03

Table 2.1.4h (page 1 of 2). Base values for spline-based selectivity parameters in Model 2a. Values in this table will be over-written if block-specific values are estimated (see Table 2.1.4i).

	Model 2a			Model 2a	
Parameter	Value	Sdev	Parameter	Value	Sdev
Code_Jan-Apr_Trawl_1	0		Code_Jan-Apr_Longline_4	0	
GradLo_Jan-Apr_Trawl_1	0.13	0.00	GradLo_Jan-Apr_Longline_4	0.27	0.01
GradHi_Jan-Apr_Trawl_1	0		GradHi_Jan-Apr_Longline_4	0	
Knot_1_Jan-Apr_Trawl_1	40		Knot_1_Jan-Apr_Longline_4	40	
Knot_2_Jan-Apr_Trawl_1	60		Knot_2_Jan-Apr_Longline_4	60	
Knot_3_Jan-Apr_Trawl_1	80		Knot_3_Jan-Apr_Longline_4	80	
Knot_4_Jan-Apr_Trawl_1	100		Knot_4_Jan-Apr_Longline_4	100	
Knot_5_Jan-Apr_Trawl_1	118		Knot_5_Jan-Apr_Longline_4	118	
Val_1_Jan-Apr_Trawl_1	-2.46		Val_1_Jan-Apr_Longline_4	-4.04	
Val_2_Jan-Apr_Trawl_1	-1		Val_2_Jan-Apr_Longline_4	-1	
Val_3_Jan-Apr_Trawl_1	-0.34		Val_3_Jan-Apr_Longline_4	-1.10	
Val_4_Jan-Apr_Trawl_1	-1.40	0.05	Val_4_Jan-Apr_Longline_4	-2.71	0.06
Val_5_Jan-Apr_Trawl_1	-1.40		Val_5_Jan-Apr_Longline_4	-2.71	
Code_May-Jul_Trawl_2	0		Code_May-Jul_Longline_5	0	
GradLo_May-Jul_Trawl_2	0.10	0.00	GradLo_May-Jul_Longline_5	0.35	0.02
GradHi_May-Jul_Trawl_2	0		GradHi_May-Jul_Longline_5	0	
Knot_1_May-Jul_Trawl_2	40		Knot_1_May-Jul_Longline_5	40	
Knot_2_May-Jul_Trawl_2	60		Knot_2_May-Jul_Longline_5	60	
Knot_3_May-Jul_Trawl_2	80		Knot_3_May-Jul_Longline_5	80	
Knot_4_May-Jul_Trawl_2	100		Knot_4_May-Jul_Longline_5	100	
Knot_5_May-Jul_Trawl_2	118		Knot_5_May-Jul_Longline_5	118	
Val_1_May-Jul_Trawl_2	-1.84		Val_1_May-Jul_Longline_5	-4.54	
Val_2_May-Jul_Trawl_2	-1		Val_2_May-Jul_Longline_5	-1	
Val_3_May-Jul_Trawl_2	-0.94	0.07	Val_3_May-Jul_Longline_5	-1.21	0.04
Val_4_May-Jul_Trawl_2	-0.99	0.12	Val_4_May-Jul_Longline_5	-1.37	0.07
Val_5_May-Jul_Trawl_2	-0.99		Val_5_May-Jul_Longline_5	-1.37	
Code_Aug-Dec_Trawl_3	0		Code_Aug-Dec_Longline_6	0	
GradLo_Aug-Dec_Trawl_3	0.17	0.01	GradLo_Aug-Dec_Longline_6	0.34	0.01
GradHi_Aug-Dec_Trawl_3	0		GradHi_Aug-Dec_Longline_6	0	
Knot_1_Aug-Dec_Trawl_3	40		Knot_1_Aug-Dec_Longline_6	40	
Knot_2_Aug-Dec_Trawl_3	60		Knot_2_Aug-Dec_Longline_6	60	
Knot_3_Aug-Dec_Trawl_3	80		Knot_3_Aug-Dec_Longline_6	80	
Knot_4_Aug-Dec_Trawl_3	100		Knot_4_Aug-Dec_Longline_6	100	
Knot_5_Aug-Dec_Trawl_3	118		Knot_5_Aug-Dec_Longline_6	118	
Val_1_Aug-Dec_Trawl_3	-2.72		Val_1_Aug-Dec_Longline_6	-4.49	
Val_2_Aug-Dec_Trawl_3	-1		Val_2_Aug-Dec_Longline_6	-1	
Val_3_Aug-Dec_Trawl_3	-0.23		Val_3_Aug-Dec_Longline_6	-0.75	
Val_4_Aug-Dec_Trawl_3	-0.20	0.12	Val_4_Aug-Dec_Longline_6	-1.23	0.05
Val_5_Aug-Dec_Trawl_3	-0.20		Val_5_Aug-Dec_Longline_6	-1.23	

Table 2.1.4h (page 2 of 2). Base values for spline-based selectivity parameters in Model 2a. Values in this table will be over-written if block-specific values are estimated (see Table 2.1.4i).

	Model 2a			Model 2a	
Parameter	Value	Sdev	Parameter	Value	Sdev
Code_Jan-Apr_Pot_7	0		Code_Pre82_Survey_10	0	
GradLo_Jan-Apr_Pot_7	0.42	0.05	GradLo_Pre82_Survey_10	1.82	
GradHi_Jan-Apr_Pot_7	0		GradHi_Pre82_Survey_10	0	
Knot_1_Jan-Apr_Pot_7	40		Knot_1_Pre82_Survey_10	1	
Knot_2_Jan-Apr_Pot_7	60		Knot_2_Pre82_Survey_10	2	
Knot_3_Jan-Apr_Pot_7	80		Knot_3_Pre82_Survey_10	4	
Knot_4_Jan-Apr_Pot_7	100		Knot_4_Pre82_Survey_10	8	
Knot_5_Jan-Apr_Pot_7	118		Knot_5_Pre82_Survey_10	16	
Val_1_Jan-Apr_Pot_7	-6.20		Val_1_Pre82_Survey_10	-5.86	0.17
Val_2_Jan-Apr_Pot_7	-1		Val_2_Pre82_Survey_10	-1	
Val_3_Jan-Apr_Pot_7	-0.88		Val_3_Pre82_Survey_10	0.60	0.26
Val_4_Jan-Apr_Pot_7	-1.89	0.10	Val_4_Pre82_Survey_10	-0.78	0.59
Val_5_Jan-Apr_Pot_7	-1.89		Val_5_Pre82_Survey_10	-0.78	
Code_May-Jul_Pot_8	0		Code_Post81_Survey_11	0	
GradLo_May-Jul_Pot_8	0.40	0.06	GradLo_Post81_Survey_11	1.82	0.05
GradHi_May-Jul_Pot_8	0		GradHi_Post81_Survey_11	0	
Knot_1_May-Jul_Pot_8	40		Knot_1_Post81_Survey_11	1	
Knot_2_May-Jul_Pot_8	60		Knot_2_Post81_Survey_11	2	
Knot_3_May-Jul_Pot_8	80		Knot_3_Post81_Survey_11	4	
Knot_4_May-Jul_Pot_8	100		Knot_4_Post81_Survey_11	8	
Knot_5_May-Jul_Pot_8	118		Knot_5_Post81_Survey_11	16	
Val_1_May-Jul_Pot_8	-5.85		Val_1_Post81_Survey_11	-1.97	0.10
Val_2_May-Jul_Pot_8	-1		Val_2_Post81_Survey_11	-1	
Val_3_May-Jul_Pot_8	-0.97	0.07	Val_3_Post81_Survey_11	-1.10	0.03
Val_4_May-Jul_Pot_8	-1.37	0.12	Val_4_Post81_Survey_11	-1.97	0.08
Val_5_May-Jul_Pot_8	-1.37		Val_5_Post81_Survey_11	-1.97	
Code_Aug-Dec_Pot_9	0				
GradLo_Aug-Dec_Pot_9	0.47	0.07			
GradHi_Aug-Dec_Pot_9	0				
Knot_1_Aug-Dec_Pot_9	40				
Knot_2_Aug-Dec_Pot_9	60				
Knot_3_Aug-Dec_Pot_9	80				
Knot_4_Aug-Dec_Pot_9	100				
Knot_5_Aug-Dec_Pot_9	118				
Val_1_Aug-Dec_Pot_9	-5.96				
Val_2_Aug-Dec_Pot_9	-1				
Val_3_Aug-Dec_Pot_9	-0.87				
Val_4_Aug-Dec_Pot_9	-0.78	0.10			
Val_5_Aug-Dec_Pot_9	-0.78				

Table 2.1.4i. Block-specific selectivity parameters for Model 2a.

	Model 2a			Model 2a	
Parameter	Value	Sdev	Parameter	Value	Sdev
Val_1_Jan-Apr_Trawl_1977	-2.52	0.17	Val_1_Jan-Apr_Longl_1977	-3.39	0.28
Val_1_Jan-Apr_Trawl_1985	-1.92	0.07	Val_1_Jan-Apr_Longl_1980	-3.44	0.23
Val_1_Jan-Apr_Trawl_1990	-2.42	0.05	Val_1_Jan-Apr_Longl_1985	-3.76	0.12
Val_1_Jan-Apr_Trawl_1995	-2.56	0.05	Val_1_Jan-Apr_Longl_1990	-4.48	0.07
Val_1_Jan-Apr_Trawl_2000	-2.91	0.07	Val_1_Jan-Apr_Longl_1995	-4.11	0.05
Val_1_Jan-Apr_Trawl_2005	-2.99	0.06	Val_1_Jan-Apr_Longl_2000	-3.65	0.05
Val_3_Jan-Apr_Trawl_1977	-0.89	0.15	Val_1_Jan-Apr_Longl_2005	-4.29	0.06
Val_3_Jan-Apr_Trawl_1985	-0.45	0.06	Val_3_Jan-Apr_Longl_1977	-2.12	0.38
Val_3_Jan-Apr_Trawl_1990	-0.78	0.04	Val_3_Jan-Apr_Longl_1980	-0.71	0.16
Val_3_Jan-Apr_Trawl_1995	-0.56	0.04	Val_3_Jan-Apr_Longl_1985	-0.41	0.08
Val_3_Jan-Apr_Trawl_2000	-0.28	0.06	Val_3_Jan-Apr_Longl_1990	-1.50	0.05
Val_3_Jan-Apr_Trawl_2005	-0.64	0.06	Val_3_Jan-Apr_Longl_1995	-1.37	0.04
Val_1_May-Jul_Trawl_1977	-1.42	0.18	Val_3_Jan-Apr_Longl_2000	-1.61	0.05
Val_1_May-Jul_Trawl_1985	-1.33	0.15	Val_3_Jan-Apr_Longl_2005	-1.35	0.04
Val_1_May-Jul_Trawl_1990	-2.25	0.10	Val_1_May-Jul_Longl_1977	-5.11	0.59
Val_1_May-Jul_Trawl_2000	-1.54	0.13	Val_1_May-Jul_Longl_1980	-4.32	0.28
Val_1_May-Jul_Trawl_2005	-1.94	0.12	Val_1_May-Jul_Longl_1985	-4.72	0.29
Val_1_Aug-Dec_Trawl_1977	-3.14	0.30	Val_1_May-Jul_Longl_1990	-4.71	0.11
Val_1_Aug-Dec_Trawl_1980	-2.42	0.26	Val_1_May-Jul_Longl_2000	-3.92	0.12
Val_1_Aug-Dec_Trawl_1985	-3.03	0.23	Val_1_May-Jul_Longl_2005	-4.78	0.15
Val_1_Aug-Dec_Trawl_1990	-2.64	1.93	Val_1_Aug-Dec_Longl_1977	-5.34	0.48
Val_1_Aug-Dec_Trawl_1995	-3.32	0.33	Val_1_Aug-Dec_Longl_1980	-4.71	0.18
Val_1_Aug-Dec_Trawl_2000	-2.40	0.15	Val_1_Aug-Dec_Longl_1985	-4.86	0.08
Val_3_Aug-Dec_Trawl_1977	-1.55	0.37	Val_1_Aug-Dec_Longl_1990	-5.45	0.11
Val_3_Aug-Dec_Trawl_1980	-0.33	0.19	Val_1_Aug-Dec_Longl_1995	-4.41	0.06
Val_3_Aug-Dec_Trawl_1985	-0.37	0.15	Val_1_Aug-Dec_Longl_2000	-4.27	0.05
Val_3_Aug-Dec_Trawl_1990	-0.54	1.06	Val_1_Aug-Dec_Longl_2005	-4.33	0.05
Val_3_Aug-Dec_Trawl_1995	-0.64	0.25	Val_3_Aug-Dec_Longl_1977	-1.75	0.39
Val_3_Aug-Dec_Trawl_2000	-0.58	0.13	Val_3_Aug-Dec_Longl_1980	-0.68	0.10
Val_1_Jan-Apr_Pot_1977	-5.73	0.37	Val_3_Aug-Dec_Longl_1985	-1.02	0.06
Val_1_Jan-Apr_Pot_1995	-6.19	0.28	Val_3_Aug-Dec_Longl_1990	-0.97	0.06
Val_1_Jan-Apr_Pot_2000	-6.25	0.27	Val_3_Aug-Dec_Longl_1995	-0.64	0.04
Val_1_Jan-Apr_Pot_2005	-6.10	0.28	Val_3_Aug-Dec_Longl_2000	-1.15	0.04
Val_3_Jan-Apr_Pot_1977	-0.73	0.17	Val_3_Aug-Dec_Longl_2005	-1.15	0.04
Val_3_Jan-Apr_Pot_1995	-1.02	0.09			
Val_3_Jan-Apr_Pot_2000	-1.12	0.08			
Val_3_Jan-Apr_Pot_2005	-1.21	0.09			
Val_1_May-Jul_Pot_1977	-6.48	0.39			
Val_1_May-Jul_Pot_1995	-5.70	0.30			
Val_1_Aug-Dec_Pot_1977	-5.86	0.36			
Val_1_Aug-Dec_Pot_2000	-5.97	0.35			
Val_3_Aug-Dec_Pot_1977	-0.78	0.09			
Val_3_Aug-Dec_Pot_2000	-1.36	0.09			

Table 2.1.4j. Survey spline value at age 1 *dev*s for Model 2a.

	Model 2a	
Parameter	Value	Sdev
Val_1_Post81_Survey_1982	-0.08	0.02
Val_1_Post81_Survey_1983	0.00	0.02
Val_1_Post81_Survey_1984	-0.06	0.02
Val_1_Post81_Survey_1985	0.03	0.02
Val_1_Post81_Survey_1986	0.01	0.02
Val_1_Post81_Survey_1987	0.03	0.02
Val_1_Post81_Survey_1988	-0.01	0.02
Val_1_Post81_Survey_1989	-0.08	0.02
Val_1_Post81_Survey_1990	-0.01	0.02
Val_1_Post81_Survey_1991	-0.01	0.02
Val_1_Post81_Survey_1992	0.03	0.02
Val_1_Post81_Survey_1993	0.06	0.02
Val_1_Post81_Survey_1994	0.02	0.02
Val_1_Post81_Survey_1995	0.02	0.02
Val_1_Post81_Survey_1996	-0.03	0.02
Val_1_Post81_Survey_1997	-0.01	0.02
Val_1_Post81_Survey_1998	-0.01	0.02
Val_1_Post81_Survey_1999	-0.01	0.01
Val_1_Post81_Survey_2000	-0.03	0.01
Val_1_Post81_Survey_2001	0.09	0.02
Val_1_Post81_Survey_2002	0.03	0.02
Val_1_Post81_Survey_2003	-0.01	0.01
Val_1_Post81_Survey_2004	0.00	0.01
Val_1_Post81_Survey_2005	0.01	0.01
Val_1_Post81_Survey_2006	0.05	0.01
Val_1_Post81_Survey_2007	0.16	0.01
Val_1_Post81_Survey_2008	0.06	0.01

Table 2.1.4k. Base selectivity parameters for Models A and 5. Values for Model A pertain only to the first year in the time series if *dev*s are defined (see Table 2.1.4l), and values for Model 5 will be over-written if block-specific values are estimated (see Table 2.1.4m).

	Model A		Model 5	
Parameter	Value	Sdev	Value	Sdev
P_1_Season1_Fishery	65.93	2.00	65.93	
P_2_Season1_Fishery	-5.26	7.42	-3.40	1.04
P_3_Season1_Fishery	5.79	0.07	5.79	
P_4_Season1_Fishery	4.86	0.37	4.60	0.38
P_5_Season1_Fishery	-999		-999	
P_6_Season1_Fishery	-0.14	0.17	-0.11	0.16
P_1_Season2_Fishery	69.62	0.56	69.93	0.57
P_2_Season2_Fishery	-9.26	17.79	-9.18	19.31
P_3_Season2_Fishery	5.94	0.03	5.95	0.03
P_4_Season2_Fishery	4.31	0.30	4.15	0.33
P_5_Season2_Fishery	-999		-999	
P_6_Season2_Fishery	0.26	0.14	0.41	0.14
P_1_Season3_Fishery	58.02	3.94	58.02	
P_2_Season3_Fishery	-3.34	1.30	-2.19	0.83
P_3_Season3_Fishery	4.59	0.49	4.59	
P_4_Season3_Fishery	4.47	0.59	3.23	1.66
P_5_Season3_Fishery	-999		-999	
P_6_Season3_Fishery	0.74	0.19	1.67	0.28
P_1_Season4_Fishery	64.29	0.49	64.62	0.49
P_2_Season4_Fishery	10		10	
P_3_Season4_Fishery	5.09	0.05	5.11	0.05
P_4_Season4_Fishery	0		0	
P_5_Season4_Fishery	-999		-999	
P_6_Season4_Fishery	10		10	
P_1_Season5_Fishery	63.65	0.53	63.95	0.53
P_2_Season5_Fishery	-1.59	0.27	-1.53	0.30
P_3_Season5_Fishery	5.17	0.05	5.19	0.05
P_4_Season5_Fishery	4.07	0.68	3.90	0.83
P_5_Season5_Fishery	-999		-999	
P_6_Season5_Fishery	0.63	0.20	0.80	0.21
P_1_Trawl_Survey	20.33	0.27	19.04	0.02
P_2_Trawl_Survey	-0.34	0.23	-0.34	
P_3_Trawl_Survey	0.88	0.31	-8.45	15.02
P_4_Trawl_Survey	3.64	0.34	4.51	0.17
P_5_Trawl_Survey	-0.01	0.24	-0.01	
P_6_Trawl_Survey	-0.47	0.08	-0.32	0.08

Table 2.1.4l (page 1 of 2). Selectivity *dev*s for Model A.

Parameter	Model A Value	Model A Sdev	Parameter	Model A Value	Model A Sdev
P_1_Season1_DEVran_1978	0.02	0.72	P_3_Season1_DEVran_1993	-0.01	0.01
P_1_Season1_DEVran_1979	-0.01	0.72	P_3_Season1_DEVran_1994	-0.01	0.01
P_1_Season1_DEVran_1980	0.01	0.70	P_3_Season1_DEVran_1995	-0.01	0.01
P_1_Season1_DEVran_1981	0.18	0.70	P_3_Season1_DEVran_1996	-0.01	0.01
P_1_Season1_DEVran_1982	0.17	0.70	P_3_Season1_DEVran_1997	-0.01	0.01
P_1_Season1_DEVran_1983	0.17	0.70	P_3_Season1_DEVran_1998	-0.01	0.01
P_1_Season1_DEVran_1984	0.48	0.68	P_3_Season1_DEVran_1999	-0.01	0.01
P_1_Season1_DEVran_1985	0.56	0.67	P_3_Season1_DEVran_2000	-0.01	0.01
P_1_Season1_DEVran_1986	-0.31	0.64	P_3_Season1_DEVran_2001	-0.01	0.01
P_1_Season1_DEVran_1987	0.16	0.62	P_3_Season1_DEVran_2002	-0.01	0.01
P_1_Season1_DEVran_1988	-0.82	0.60	P_3_Season1_DEVran_2003	-0.01	0.01
P_1_Season1_DEVran_1989	1.78	0.61	P_3_Season1_DEVran_2004	-0.01	0.01
P_1_Season1_DEVran_1990	1.06	0.63	P_3_Season1_DEVran_2005	-0.01	0.01
P_1_Season1_DEVran_1991	0.47	0.63	P_3_Season1_DEVran_2006	-0.01	0.01
P_1_Season1_DEVran_1992	-0.17	0.62	P_3_Season1_DEVran_2007	-0.01	0.01
P_1_Season1_DEVran_1993	-0.30	0.59	P_3_Season1_DEVran_2008	-0.01	0.01
P_1_Season1_DEVran_1994	-0.21	0.58	P_3_Season1_DEVran_2009	0.00	0.01
P_1_Season1_DEVran_1995	-0.77	0.58	P_3_Season1_DEVran_2010	0.00	0.01
P_1_Season1_DEVran_1996	0.18	0.57	P_1_Season3_DEVran_1978	-4.67	4.35
P_1_Season1_DEVran_1997	-0.24	0.57	P_1_Season3_DEVran_1979	-4.72	4.35
P_1_Season1_DEVran_1998	0.19	0.57	P_1_Season3_DEVran_1980	5.32	2.71
P_1_Season1_DEVran_1999	-0.07	0.56	P_1_Season3_DEVran_1981	-10.00	0.00
P_1_Season1_DEVran_2000	-0.13	0.53	P_1_Season3_DEVran_1982	10.00	0.00
P_1_Season1_DEVran_2001	-0.63	0.56	P_1_Season3_DEVran_1983	8.14	2.59
P_1_Season1_DEVran_2002	-1.14	0.55	P_1_Season3_DEVran_1984	-10.00	0.00
P_1_Season1_DEVran_2003	-0.62	0.52	P_1_Season3_DEVran_1985	1.97	3.30
P_1_Season1_DEVran_2004	-0.24	0.52	P_1_Season3_DEVran_1986	1.89	3.30
P_1_Season1_DEVran_2005	0.45	0.52	P_1_Season3_DEVran_1987	4.90	2.80
P_1_Season1_DEVran_2006	1.28	0.52	P_1_Season3_DEVran_1988	-1.21	3.38
P_1_Season1_DEVran_2007	1.33	0.52	P_1_Season3_DEVran_1989	3.58	3.24
P_1_Season1_DEVran_2008	1.27	0.52	P_1_Season3_DEVran_1990	10.00	0.00
P_1_Season1_DEVran_2009	1.80	0.53	P_1_Season3_DEVran_1991	-4.70	1.81
P_1_Season1_DEVran_2010	0.13	0.56	P_1_Season3_DEVran_1992	-4.34	1.47
P_3_Season1_DEVran_1978	0.00	0.01	P_1_Season3_DEVran_1993	0.84	1.81
P_3_Season1_DEVran_1979	0.00	0.01	P_1_Season3_DEVran_1994	3.23	2.11
P_3_Season1_DEVran_1980	0.00	0.01	P_1_Season3_DEVran_1995	-1.06	1.94
P_3_Season1_DEVran_1981	0.00	0.01	P_1_Season3_DEVran_1996	0.65	1.77
P_3_Season1_DEVran_1982	0.00	0.01	P_1_Season3_DEVran_1997	-2.39	1.62
P_3_Season1_DEVran_1983	0.00	0.01	P_1_Season3_DEVran_1998	-0.56	1.51
P_3_Season1_DEVran_1984	0.00	0.01	P_1_Season3_DEVran_1999	-0.32	1.49
P_3_Season1_DEVran_1985	0.00	0.01	P_1_Season3_DEVran_2000	-3.89	2.07
P_3_Season1_DEVran_1986	0.00	0.01	P_1_Season3_DEVran_2001	-0.86	2.10
P_3_Season1_DEVran_1987	0.00	0.01	P_1_Season3_DEVran_2002	0.84	2.08
P_3_Season1_DEVran_1988	0.00	0.01	P_1_Season3_DEVran_2003	7.25	2.33
P_3_Season1_DEVran_1989	-0.01	0.01	P_1_Season3_DEVran_2004	6.32	3.00
P_3_Season1_DEVran_1990	-0.01	0.01	P_1_Season3_DEVran_2005	5.08	3.12
P_3_Season1_DEVran_1991	-0.01	0.01	P_1_Season3_DEVran_2006	-7.39	2.72
P_3_Season1_DEVran_1992	-0.01	0.01	P_1_Season3_DEVran_2007	-10.00	0.00

Table 2.1.4l (page 2 of 2). Selectivity *dev*s for Model A.

Parameter	Model A Value	Model A Sdev	Parameter	Model A Value	Model A Sdev
P_1_Season3_DEVran_2008	6.16	2.14	P_2_Survey_DEVran_1995	-0.96	0.14
P_1_Season3_DEVran_2009	-2.26	2.14	P_2_Survey_DEVran_1996	0.51	0.11
P_1_Season3_DEVran_2010	1.08	2.33	P_2_Survey_DEVran_1997	0.33	0.14
P_3_Season3_DEVran_1978	-0.03	0.30	P_2_Survey_DEVran_1998	0.21	0.18
P_3_Season3_DEVran_1979	-0.03	0.30	P_2_Survey_DEVran_1999	0.06	0.19
P_3_Season3_DEVran_1980	-0.05	0.28	P_2_Survey_DEVran_2000	-0.38	0.21
P_3_Season3_DEVran_1981	0.34	0.26	P_2_Survey_DEVran_2001	-0.02	0.20
P_3_Season3_DEVran_1982	0.23	0.26	P_2_Survey_DEVran_2002	0.07	0.16
P_3_Season3_DEVran_1983	0.19	0.27	P_2_Survey_DEVran_2003	-0.60	0.15
P_3_Season3_DEVran_1984	0.63	0.23	P_2_Survey_DEVran_2004	0.33	0.15
P_3_Season3_DEVran_1985	-0.08	0.25	P_2_Survey_DEVran_2005	-0.68	0.19
P_3_Season3_DEVran_1986	0.08	0.25	P_2_Survey_DEVran_2006	1.20	0.20
P_3_Season3_DEVran_1987	0.36	0.21	P_2_Survey_DEVran_2007	-3.47	0.42
P_3_Season3_DEVran_1988	0.07	0.24	P_2_Survey_DEVran_2008	0.30	0.46
P_3_Season3_DEVran_1989	-0.01	0.24	P_2_Survey_DEVran_2009	1.78	0.32
P_3_Season3_DEVran_1990	-0.26	0.18	P_2_Survey_DEVran_2010	1.01	0.20
P_3_Season3_DEVran_1991	-0.74	0.15	P_5_Survey_DEVran_1983	-0.49	0.30
P_3_Season3_DEVran_1992	-0.24	0.15	P_5_Survey_DEVran_1984	-0.93	0.34
P_3_Season3_DEVran_1993	0.20	0.19	P_5_Survey_DEVran_1985	-0.18	0.34
P_3_Season3_DEVran_1994	0.39	0.19	P_5_Survey_DEVran_1986	0.42	0.29
P_3_Season3_DEVran_1995	-0.52	0.18	P_5_Survey_DEVran_1987	-0.24	0.36
P_3_Season3_DEVran_1996	0.25	0.18	P_5_Survey_DEVran_1988	-0.44	0.41
P_3_Season3_DEVran_1997	-0.15	0.17	P_5_Survey_DEVran_1989	0.15	0.39
P_3_Season3_DEVran_1998	-0.08	0.17	P_5_Survey_DEVran_1990	0.97	0.33
P_3_Season3_DEVran_1999	-0.10	0.16	P_5_Survey_DEVran_1991	-0.26	0.32
P_3_Season3_DEVran_2000	0.44	0.18	P_5_Survey_DEVran_1992	-0.02	0.32
P_3_Season3_DEVran_2001	-0.29	0.19	P_5_Survey_DEVran_1993	0.31	0.31
P_3_Season3_DEVran_2002	0.76	0.18	P_5_Survey_DEVran_1994	-0.68	0.32
P_3_Season3_DEVran_2003	0.11	0.17	P_5_Survey_DEVran_1995	-0.80	0.36
P_3_Season3_DEVran_2004	0.46	0.17	P_5_Survey_DEVran_1996	-0.15	0.37
P_3_Season3_DEVran_2005	-0.12	0.16	P_5_Survey_DEVran_1997	0.69	0.32
P_3_Season3_DEVran_2006	-0.27	0.16	P_5_Survey_DEVran_1998	0.00	0.29
P_3_Season3_DEVran_2007	-0.35	0.11	P_5_Survey_DEVran_1999	0.16	0.31
P_3_Season3_DEVran_2008	-0.31	0.17	P_5_Survey_DEVran_2000	0.71	0.28
P_3_Season3_DEVran_2009	-0.06	0.18	P_5_Survey_DEVran_2001	0.70	0.26
P_3_Season3_DEVran_2010	-0.07	0.21	P_5_Survey_DEVran_2002	-0.70	0.31
P_2_Survey_DEVran_1983	-0.11	0.24	P_5_Survey_DEVran_2003	-0.37	0.31
P_2_Survey_DEVran_1984	0.18	0.15	P_5_Survey_DEVran_2004	0.05	0.29
P_2_Survey_DEVran_1985	-1.22	0.13	P_5_Survey_DEVran_2005	-0.15	0.30
P_2_Survey_DEVran_1986	0.73	0.12	P_5_Survey_DEVran_2006	1.61	0.31
P_2_Survey_DEVran_1987	0.49	0.17	P_5_Survey_DEVran_2007	0.18	0.32
P_2_Survey_DEVran_1988	-0.15	0.20	P_5_Survey_DEVran_2008	-0.77	0.34
P_2_Survey_DEVran_1989	0.58	0.18			
P_2_Survey_DEVran_1990	-0.51	0.19			
P_2_Survey_DEVran_1991	-1.28	0.24			
P_2_Survey_DEVran_1992	-1.25	0.34			
P_2_Survey_DEVran_1993	1.65	0.31			
P_2_Survey_DEVran_1994	0.91	0.16			

Table 2.1.4m. Block-specific selectivity parameters for Model 5.

	Model 5	
Parameter	Value	Sdev
P_1_Season1_Fishery_1977	66.40	2.45
P_1_Season1_Fishery_1984	72.53	1.20
P_1_Season1_Fishery_1989	72.98	1.01
P_1_Season1_Fishery_1995	68.12	0.79
P_1_Season1_Fishery_2001	65.10	0.83
P_1_Season1_Fishery_2006	68.31	0.70
P_3_Season1_Fishery_1977	6.07	0.11
P_3_Season1_Fishery_1986	6.36	0.07
P_3_Season1_Fishery_1991	5.89	0.07
P_3_Season1_Fishery_1996	5.59	0.07
P_3_Season1_Fishery_2001	5.49	0.07
P_3_Season1_Fishery_2006	5.34	0.06
P_1_Season3_Fishery_1977	38.51	1.35
P_1_Season3_Fishery_1983	52.04	1.17
P_1_Season3_Fishery_1989	65.67	0.59
P_1_Season3_Fishery_1998	62.78	0.63
P_1_Season3_Fishery_2003	70.18	1.03
P_3_Season3_Fishery_1977	3.12	0.41
P_3_Season3_Fishery_1984	5.73	0.07
P_3_Season3_Fishery_1991	5.18	0.05
P_3_Season3_Fishery_2002	6.03	0.06
P_2_Trawl_Survey_1982	-0.48	0.09
P_2_Trawl_Survey_1991	-1.26	0.10
P_2_Trawl_Survey_1996	-0.68	0.07
P_2_Trawl_Survey_2005	-9.86	4.18
P_5_Trawl_Survey_1982	-0.95	0.08
P_5_Trawl_Survey_1995	-1.78	0.12
P_5_Trawl_Survey_2000	-0.60	0.08

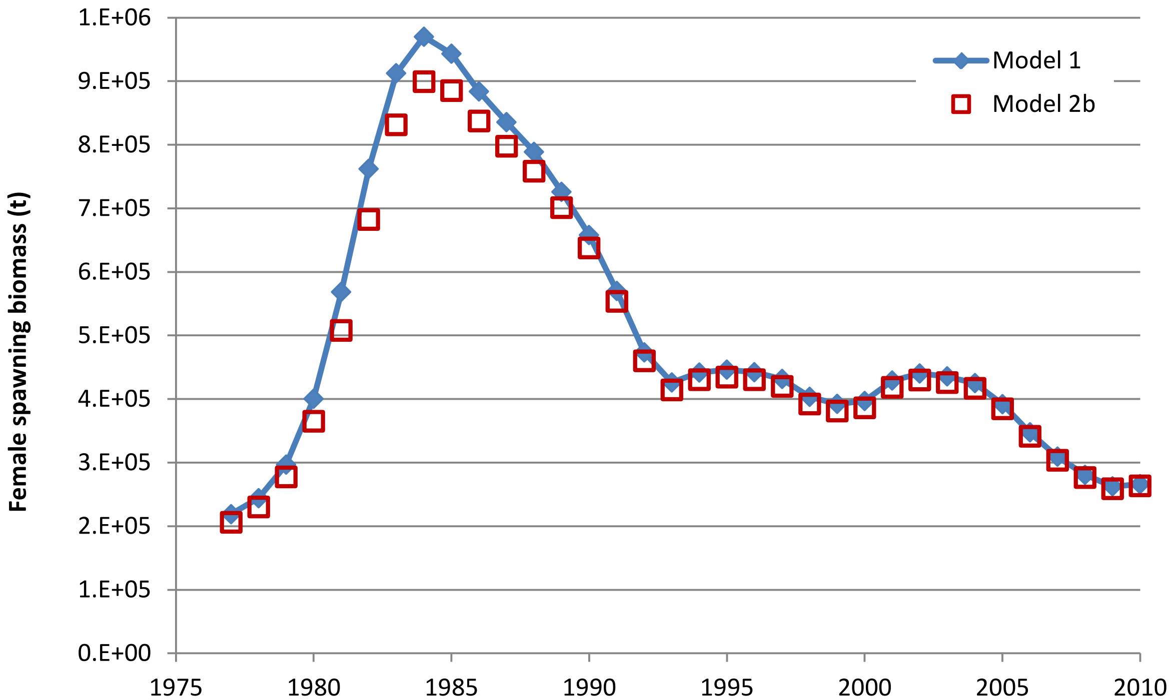

Figure 2.1.1a. Comparison of female spawning biomass as estimated by Models 1 and 2b.

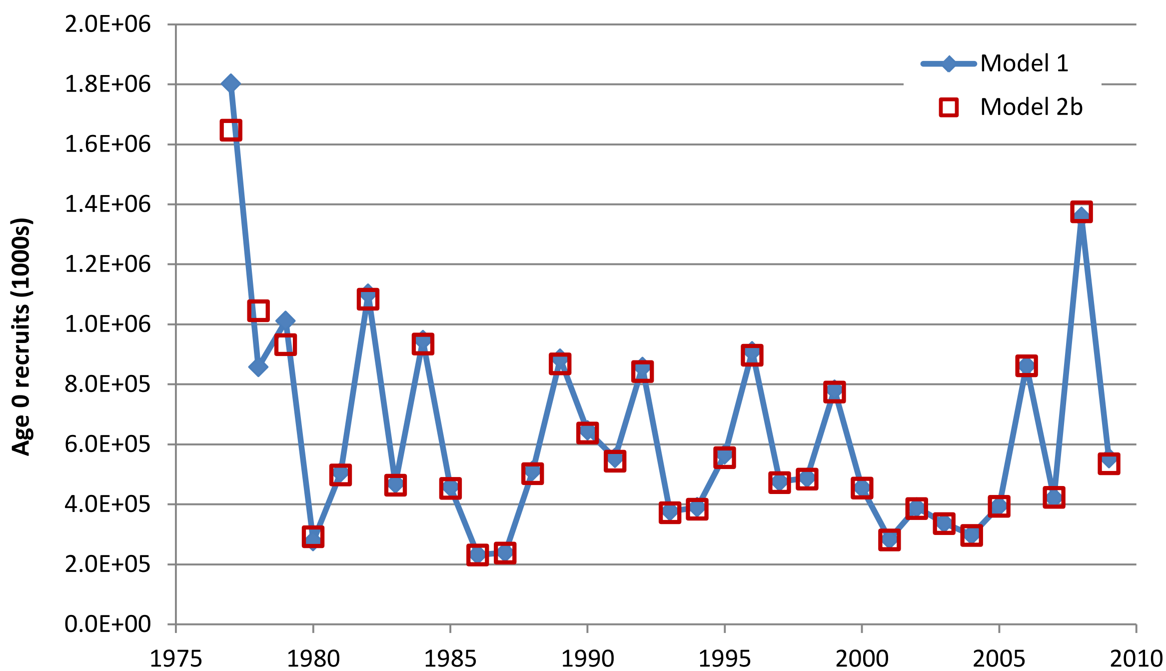

Figure 2.1.1b. Comparison of age 0 recruitment time series as estimated by Models 1 and 2b.

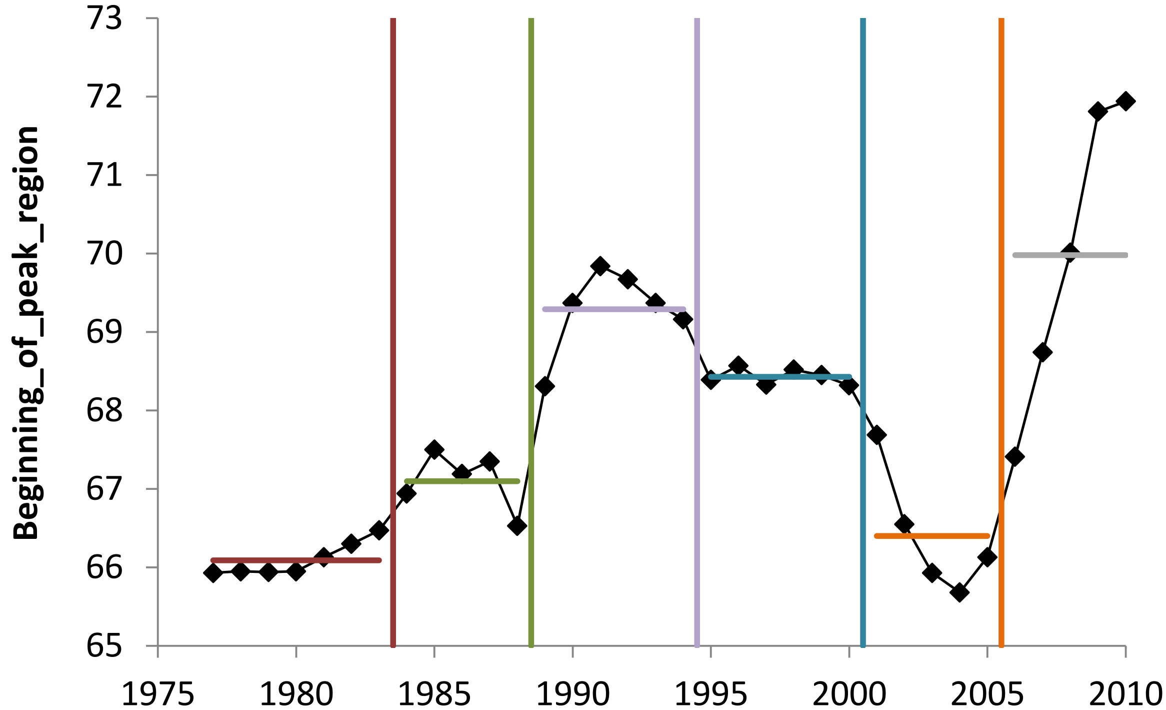

Figure 2.1.2a. Breakpoints for season 1 fishery *beginning_of_peak_region* used in Model 5.

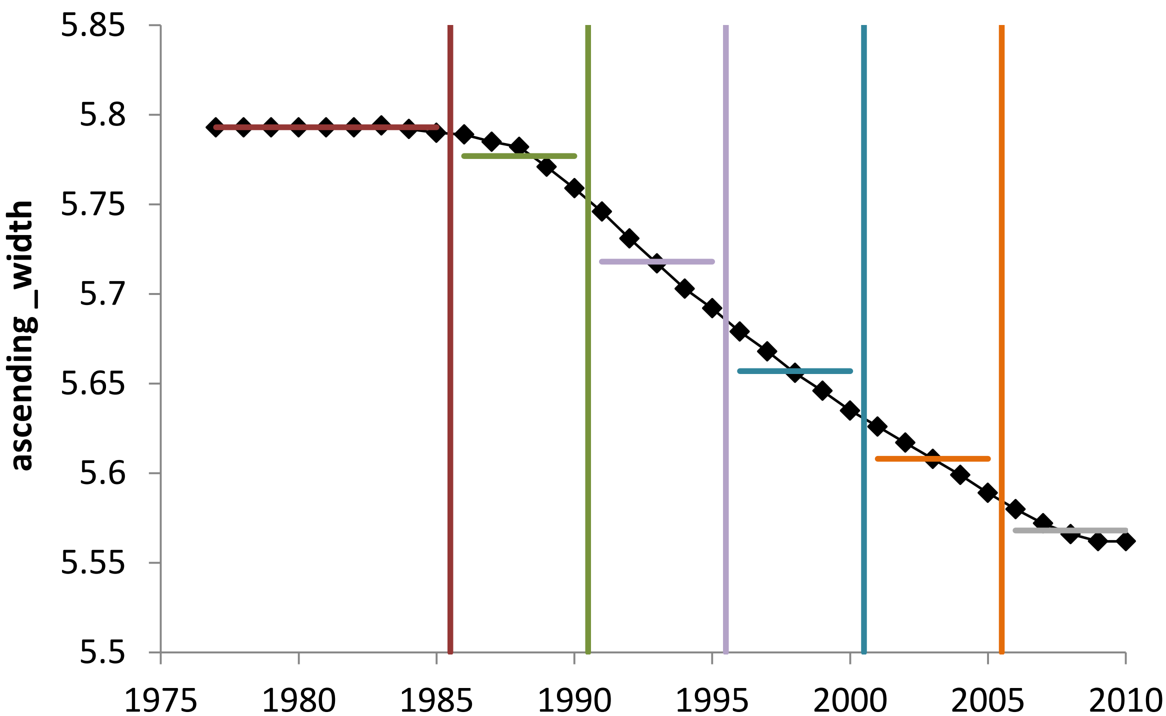

Figure 2.1.2b. Breakpoints for season 1 fishery ascending_*width* used in Model 5.

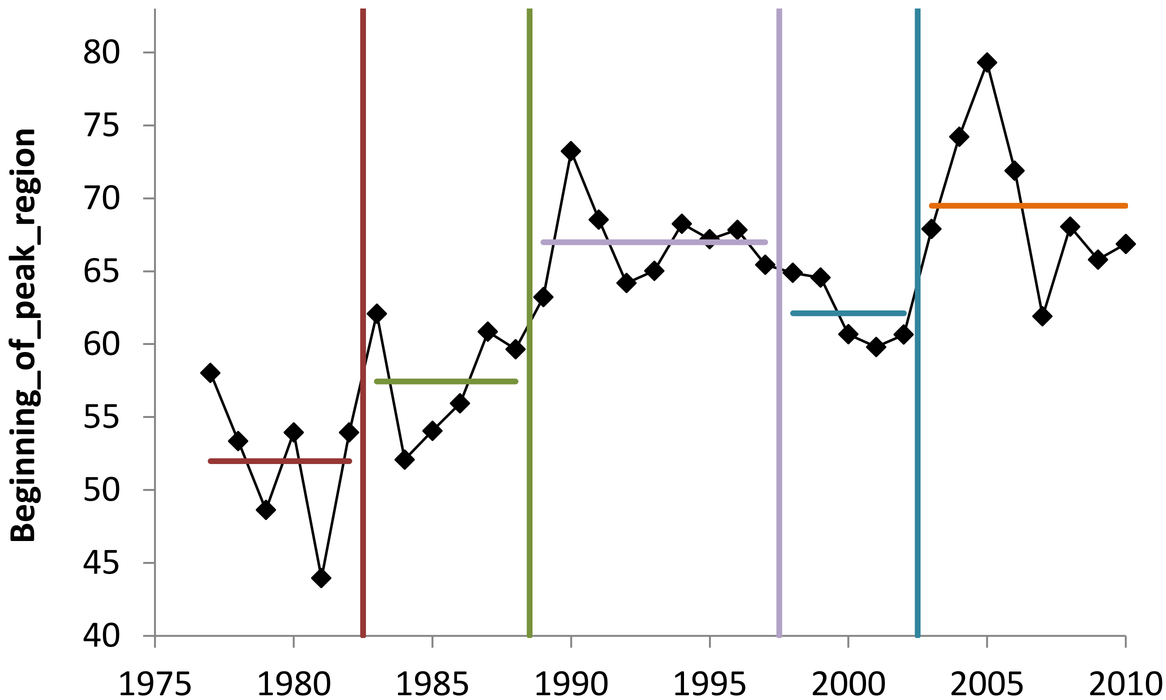

Figure 2.1.2c. Breakpoints for season 3 fishery *beginning_of_peak_region* used in Model 5.

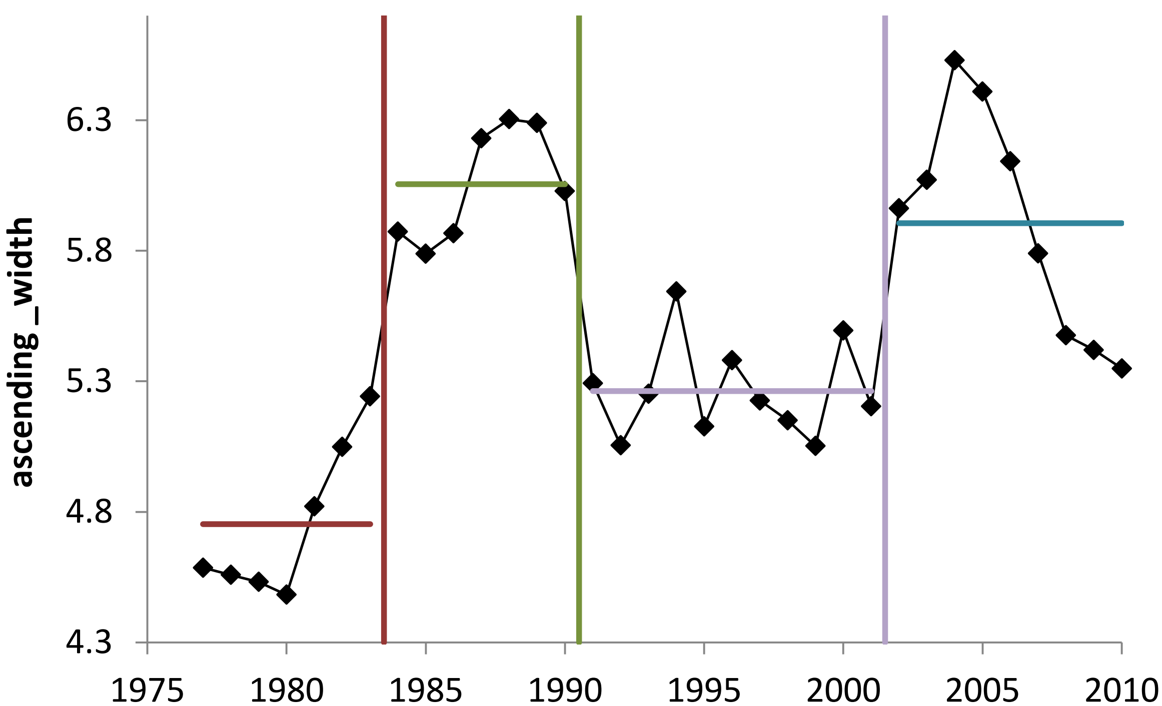

Figure 2.1.2d. Breakpoints for season 3 fishery *ascending_width* used in Model 5.

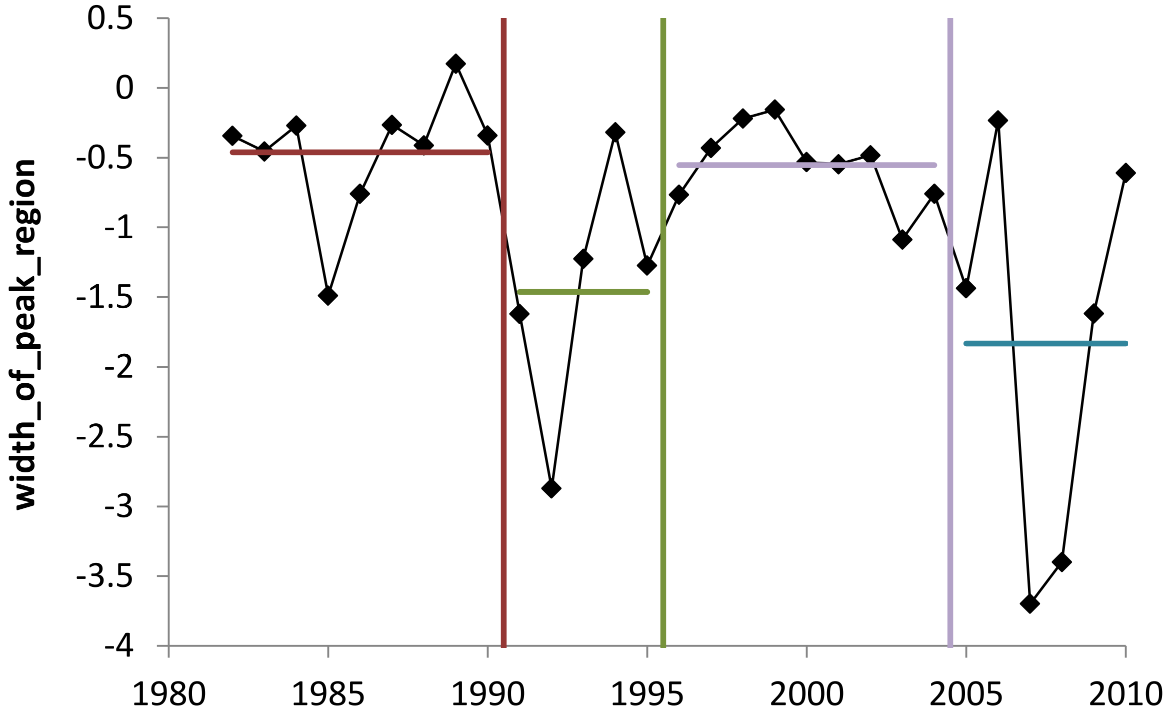

Figure 2.1.2e. Breakpoints for survey *width_of_peak_region* used in Model 5.

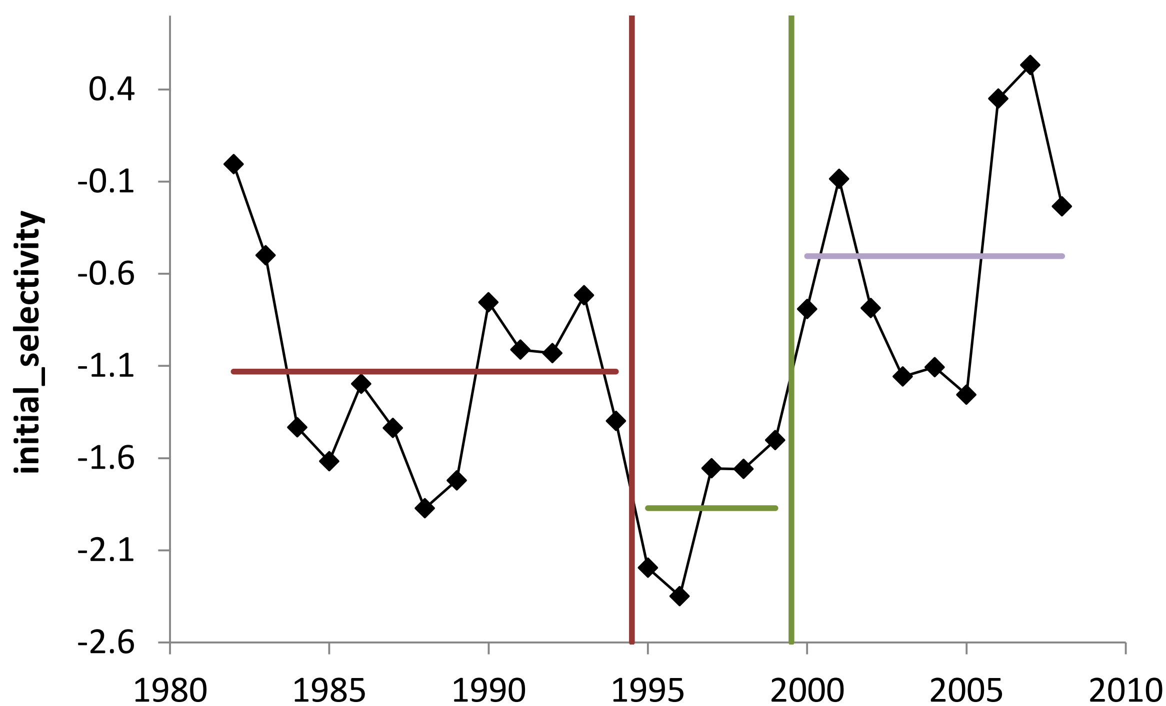

Figure 2.1.2f. Breakpoints for survey *initial_selectivity* used in Model 5.

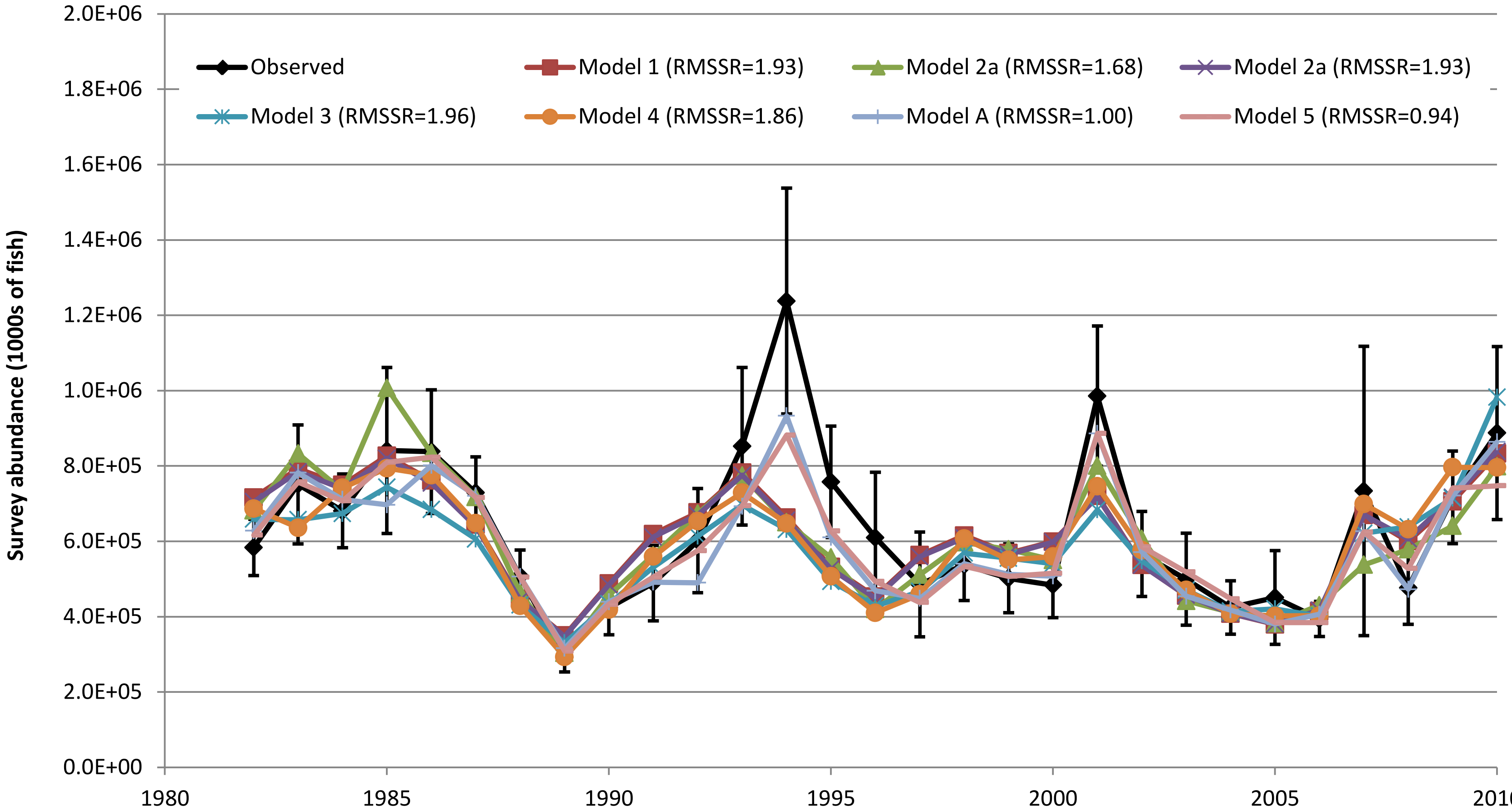

Figure 2.1.3. Model fits to the survey abundance data.

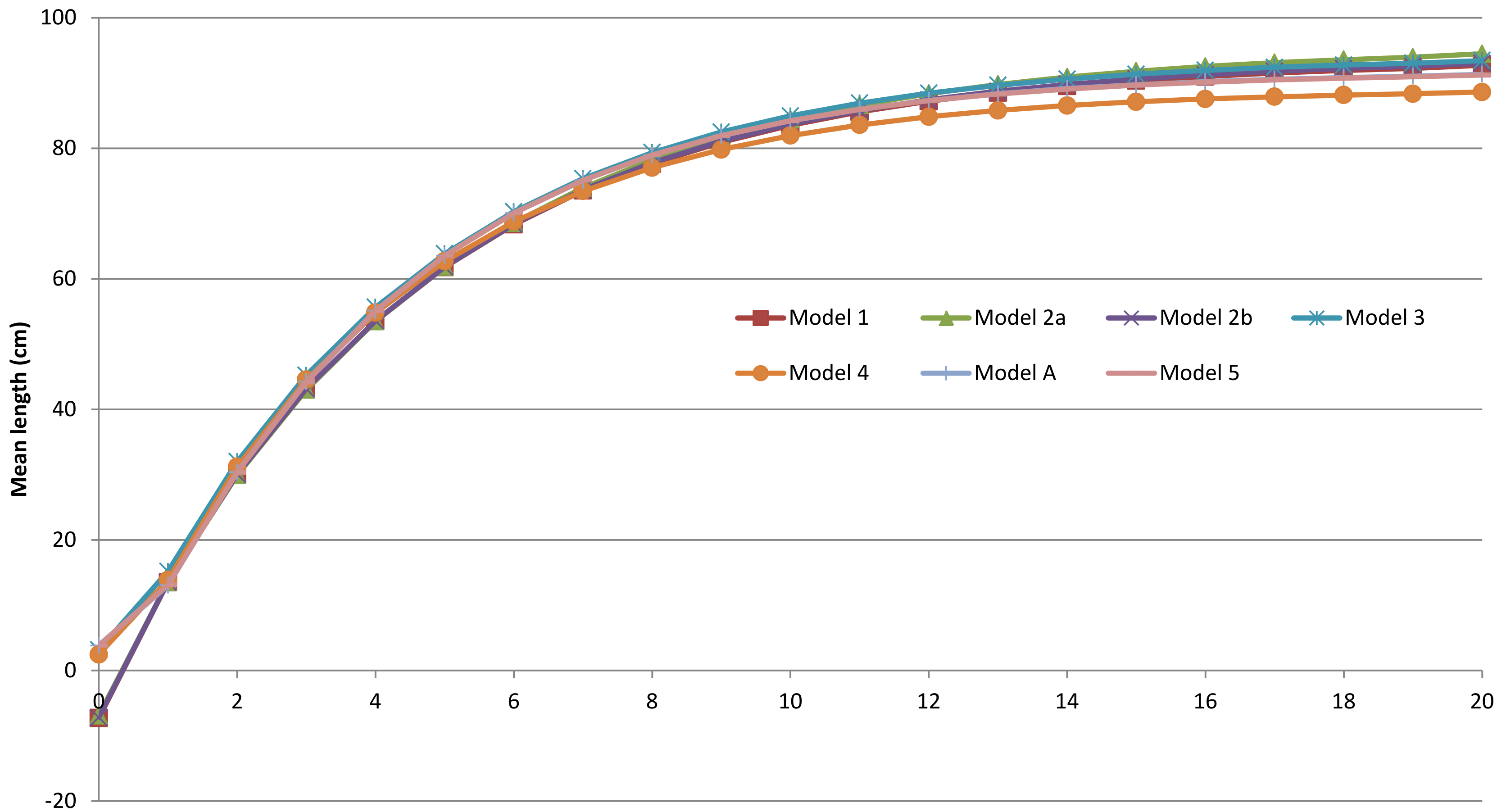

Figure 2.1.4. Model estimates of the mean length-at-age relationship.

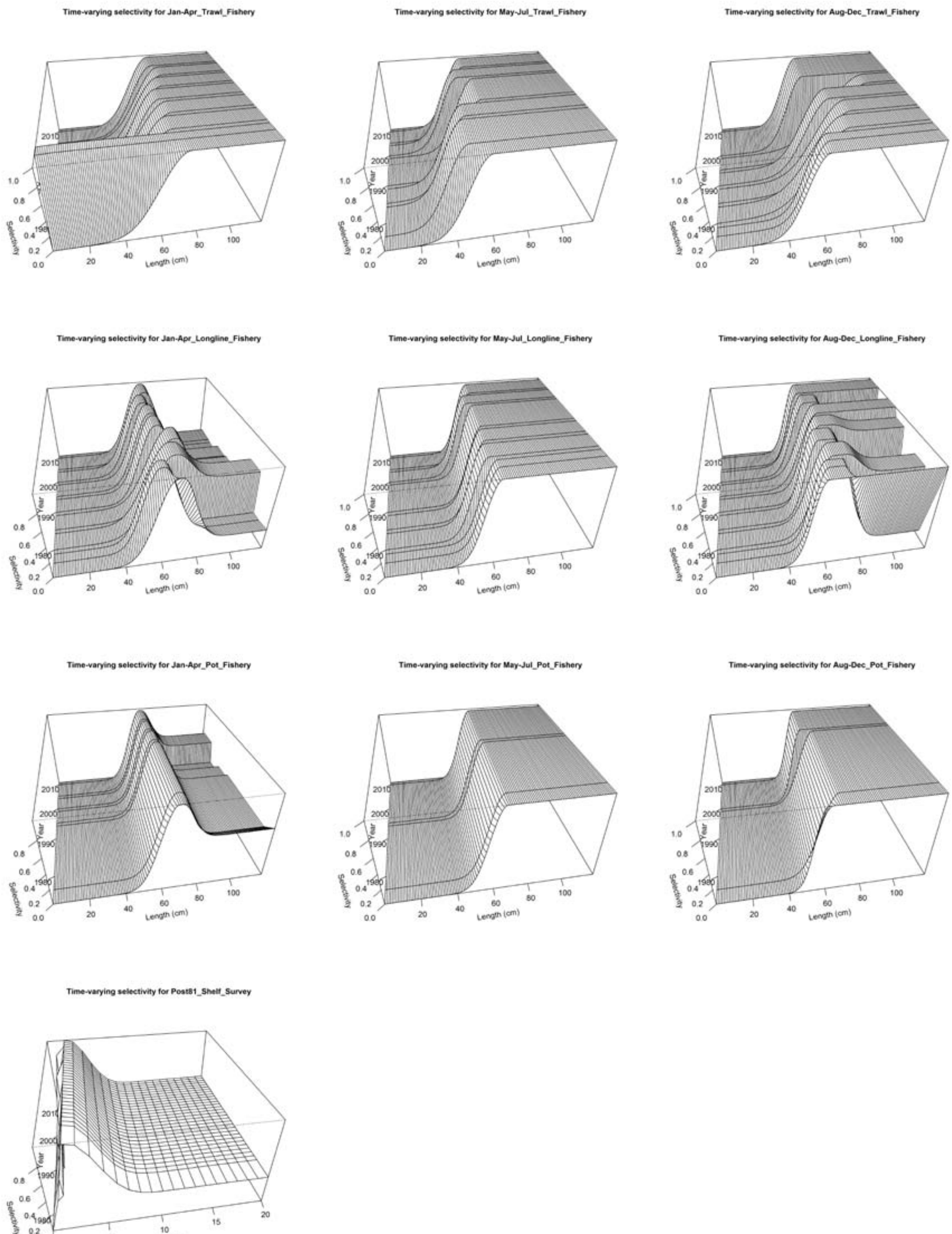

Figure 2.1.5. Fishery and survey selectivity as estimated by Model 1.

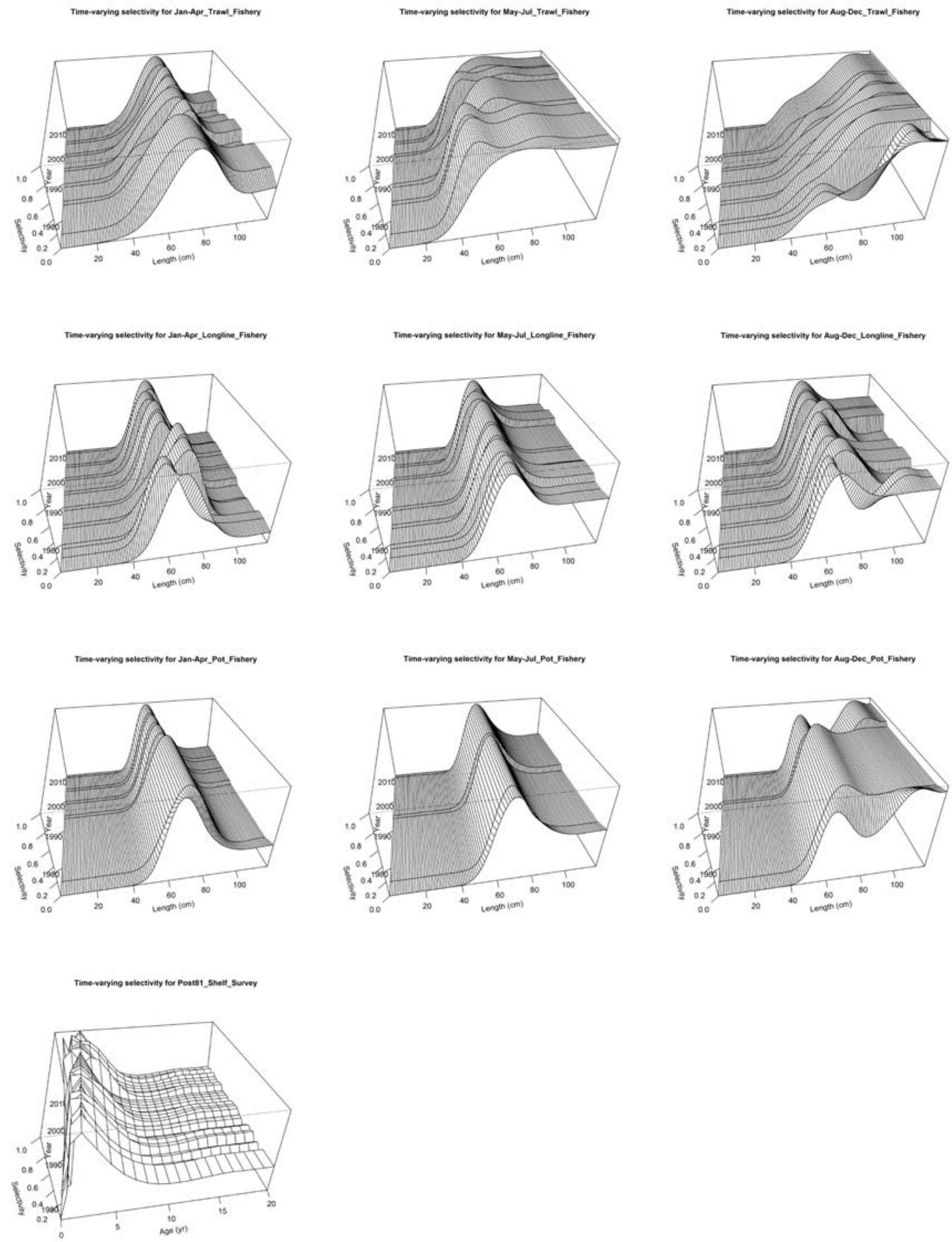

Figure 2.1.6. Fishery and survey selectivity as estimated by Model 2a.

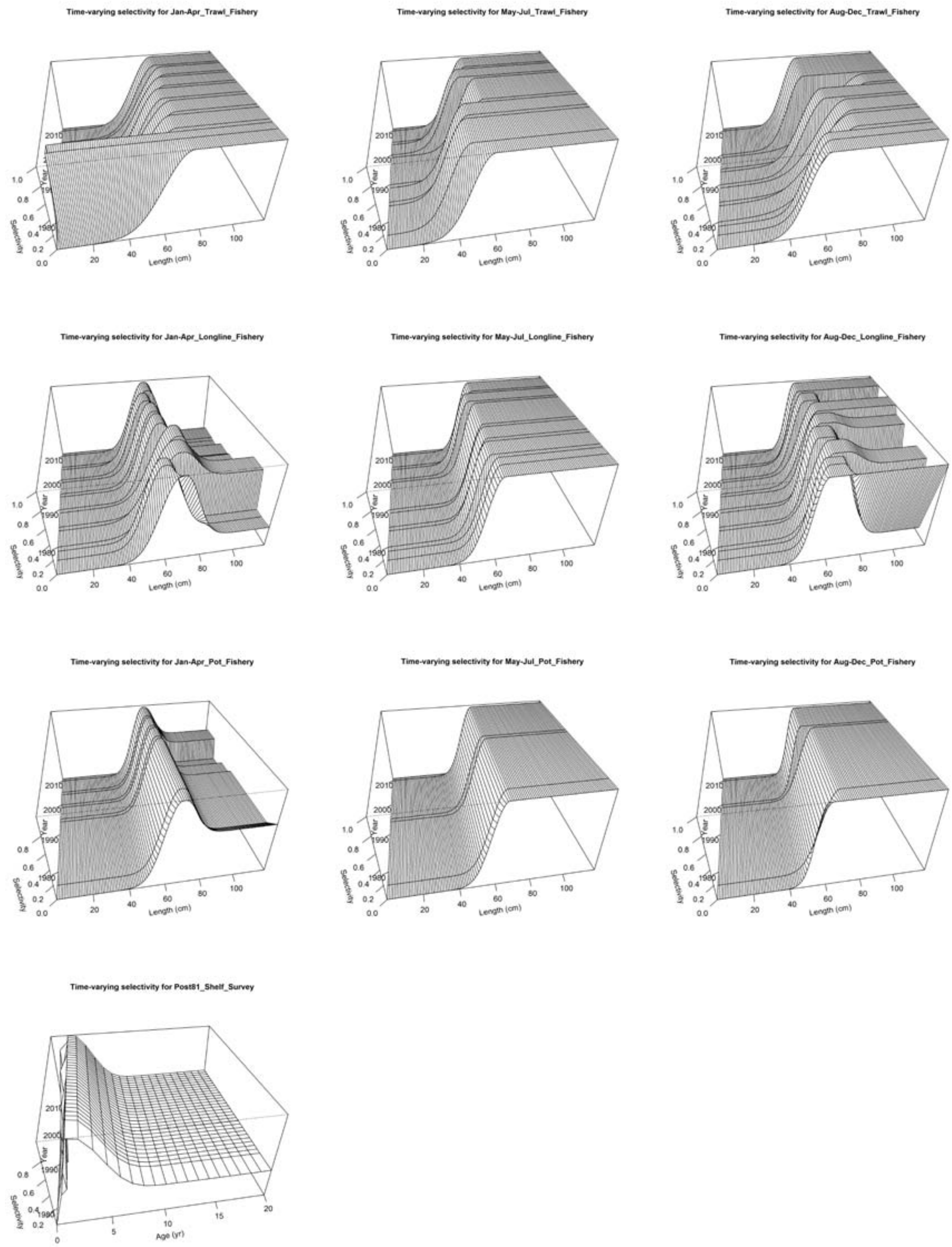

Figure 2.1.7. Fishery and survey selectivity as estimated by Model 2b.

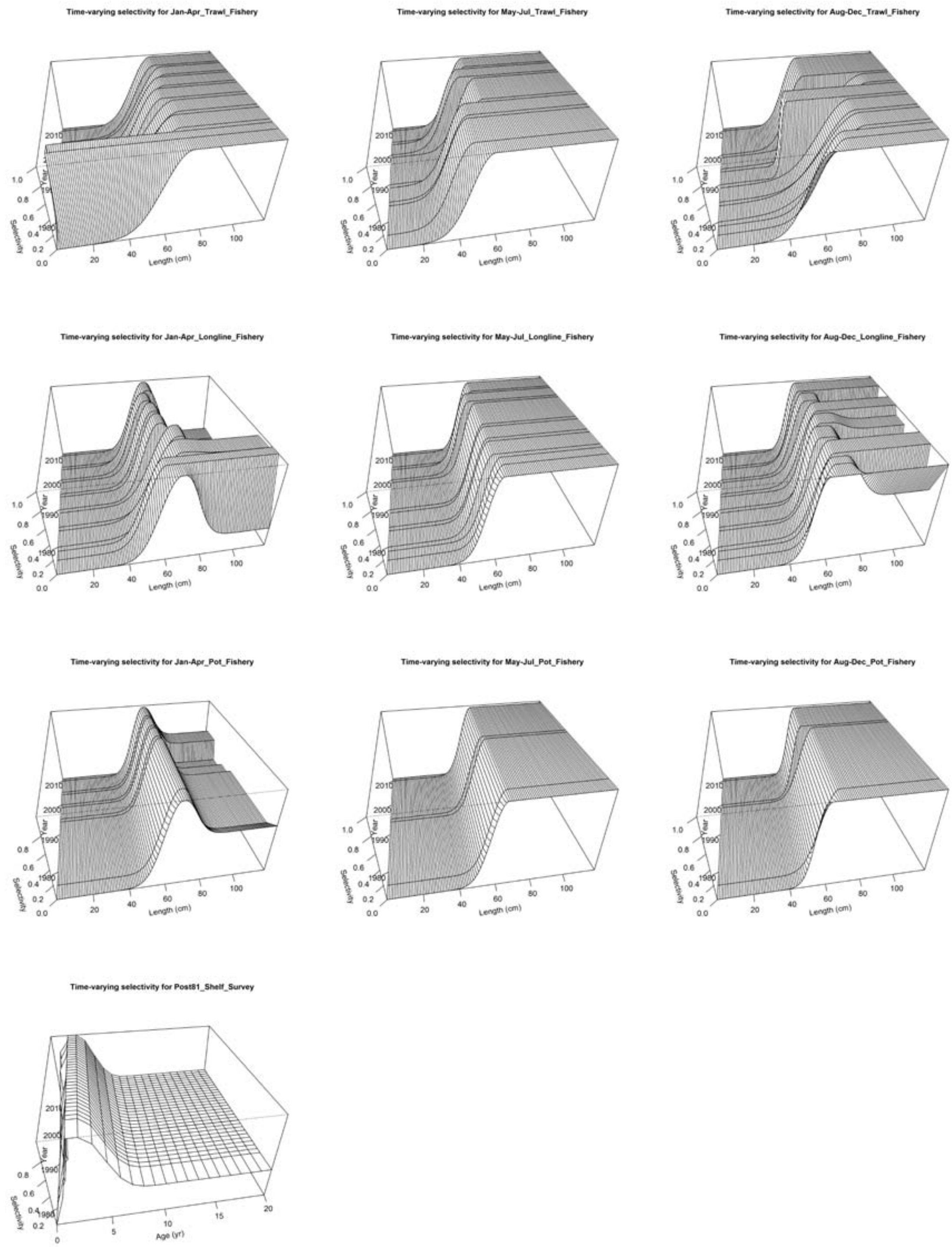

Figure 2.1.8. Fishery and survey selectivity as estimated by Model 3.

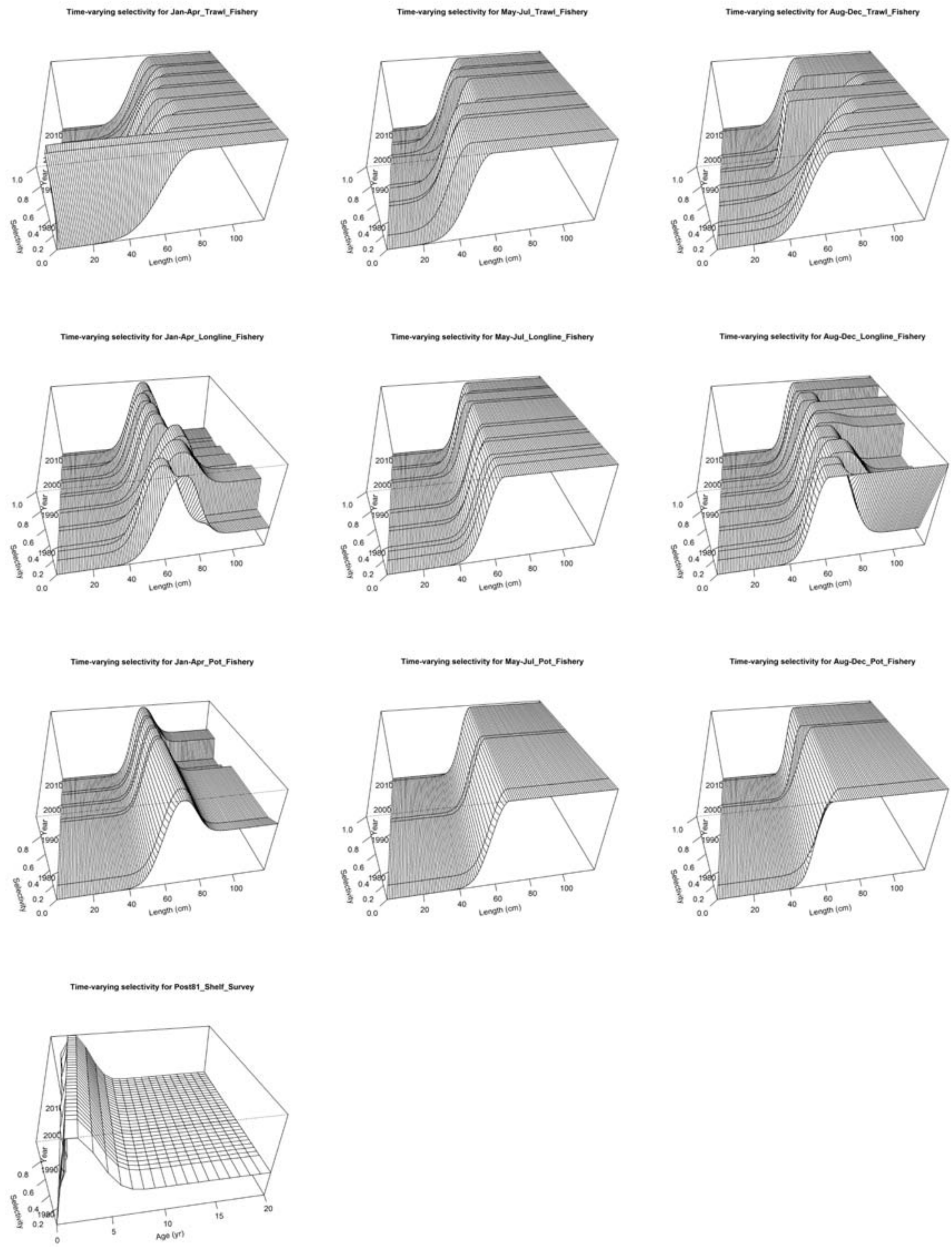

Figure 2.1.9. Fishery and survey selectivity as estimated by Model 4.

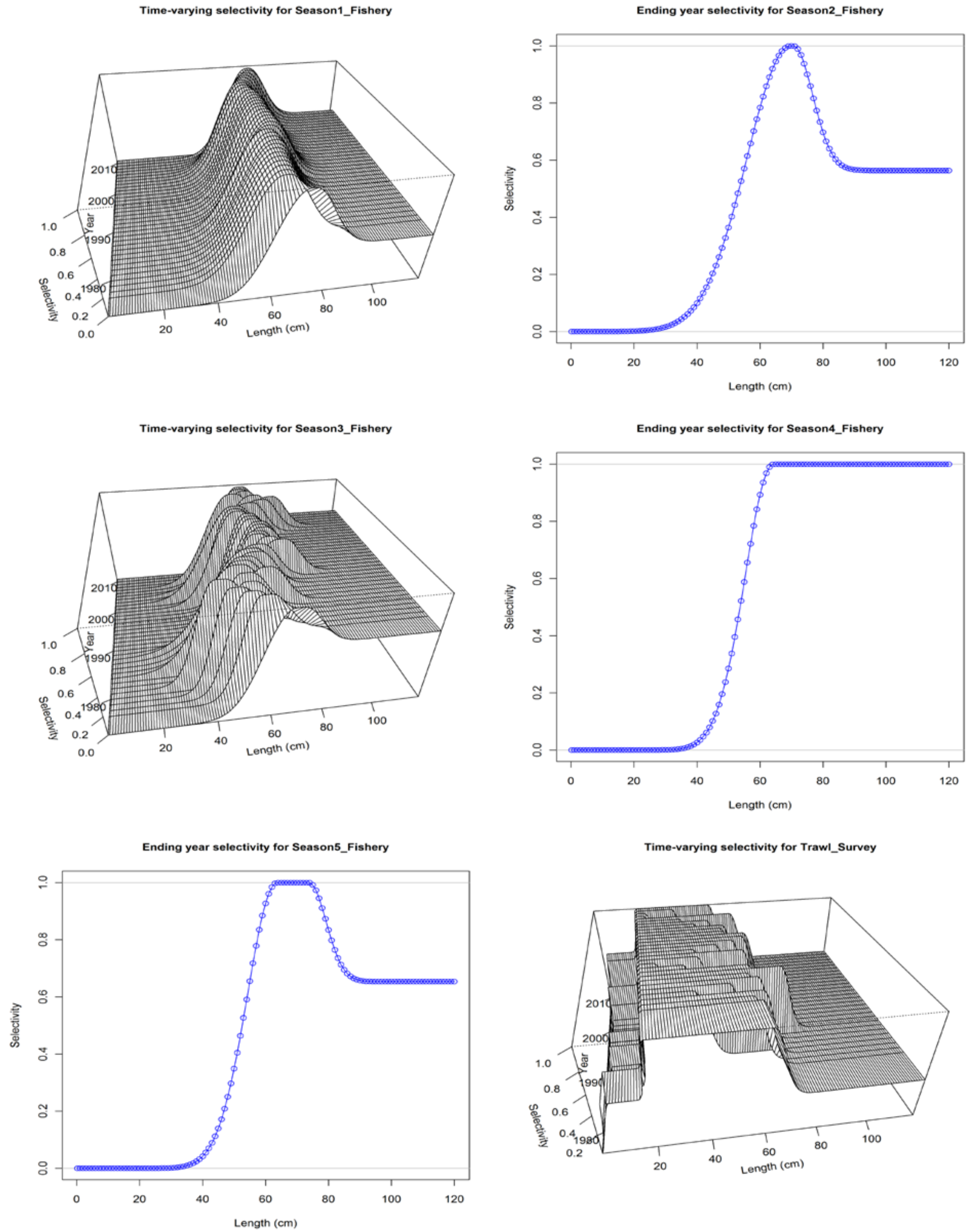

Figure 2.1.10. Fishery and survey selectivity as estimated by Model A.

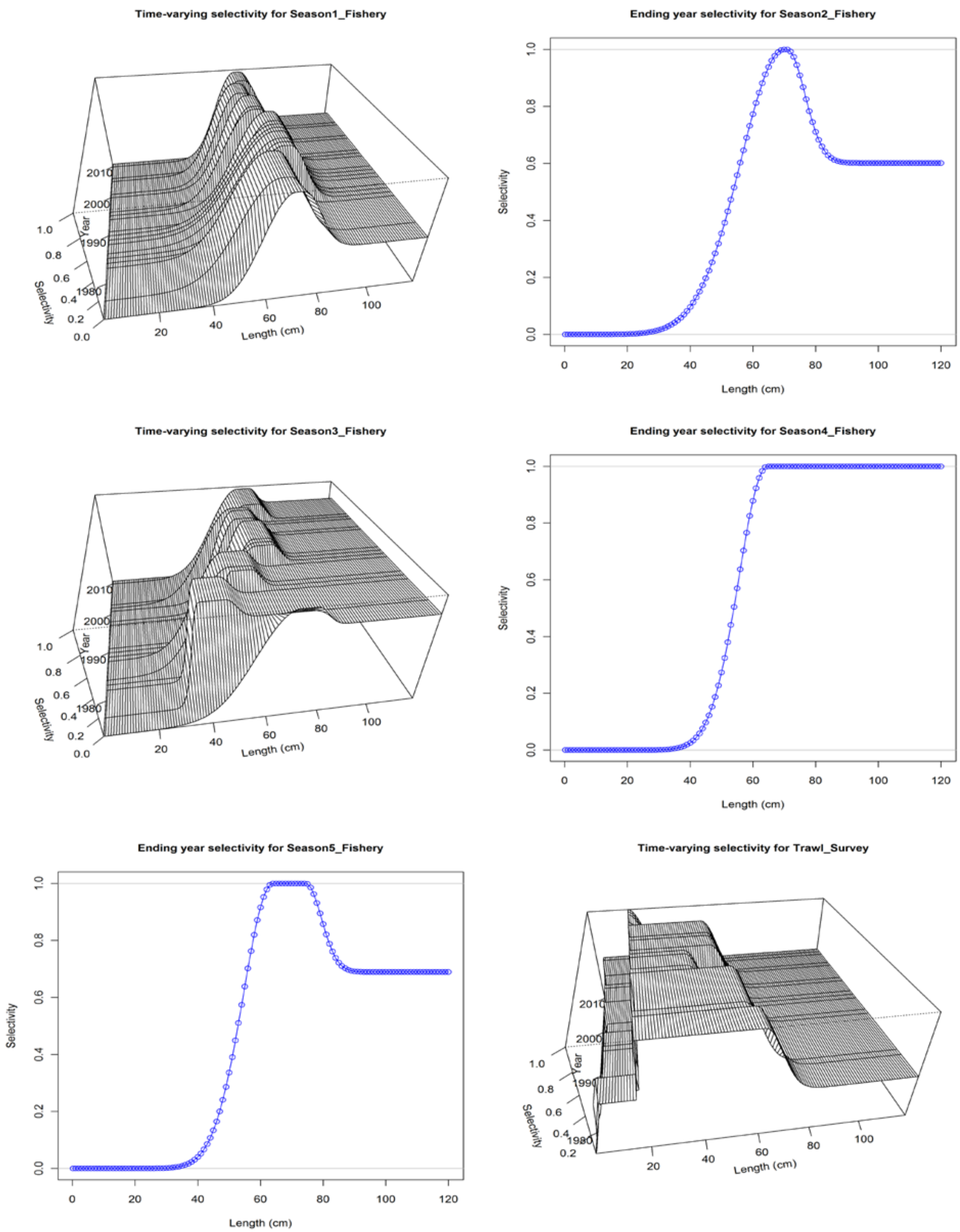

Figure 2.1.11. Fishery and survey selectivity as estimated by Model 5.

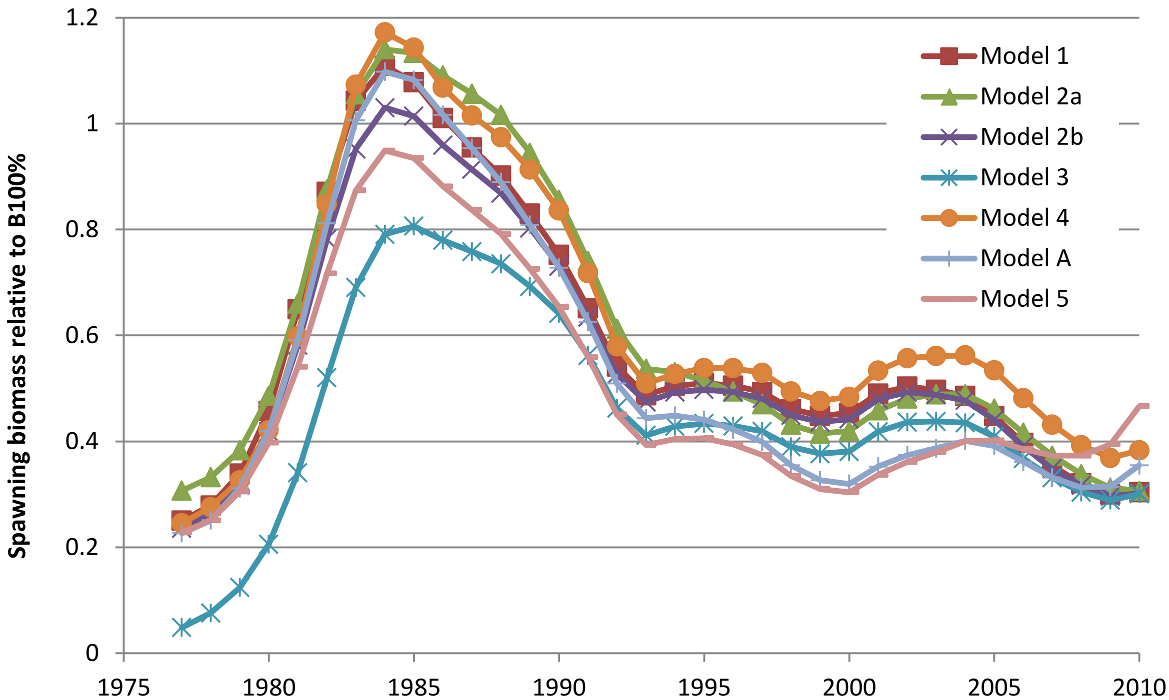

Figure 2.1.12. Time series of spawning biomass relative to $B_{100\%}$ as estimated by each model.

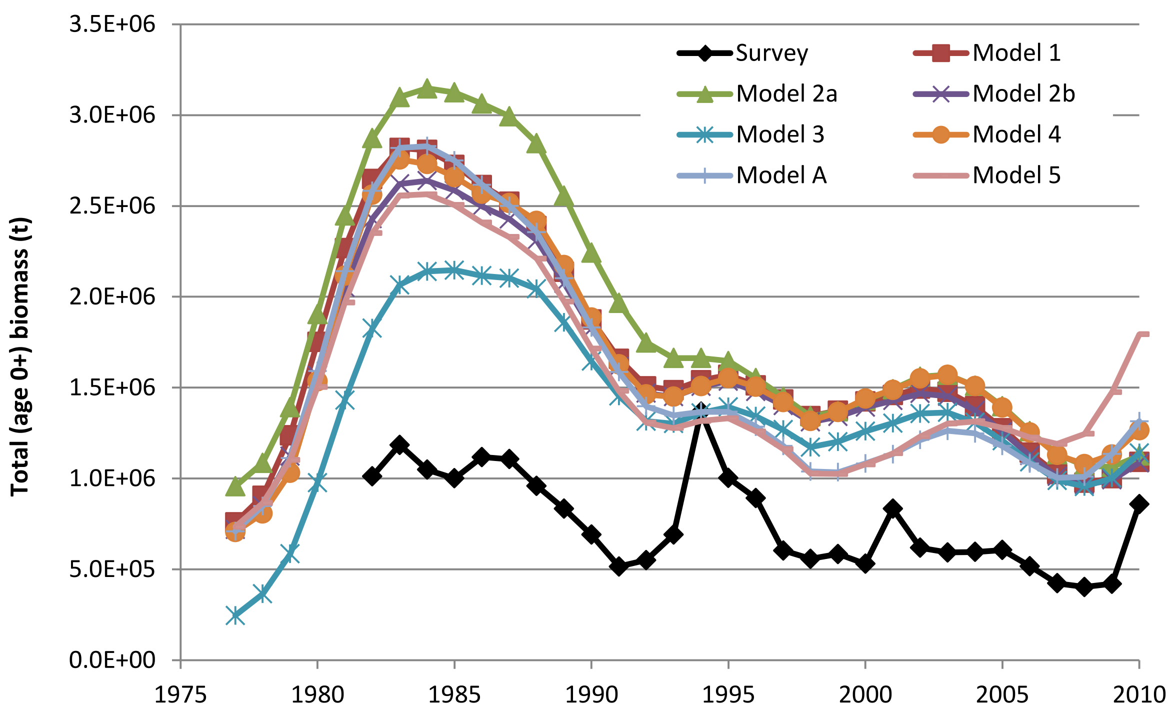

Figure 2.1.13. Time series of total (age 0+) biomass as estimated by each model. The observed survey biomass time series is shown for comparison.

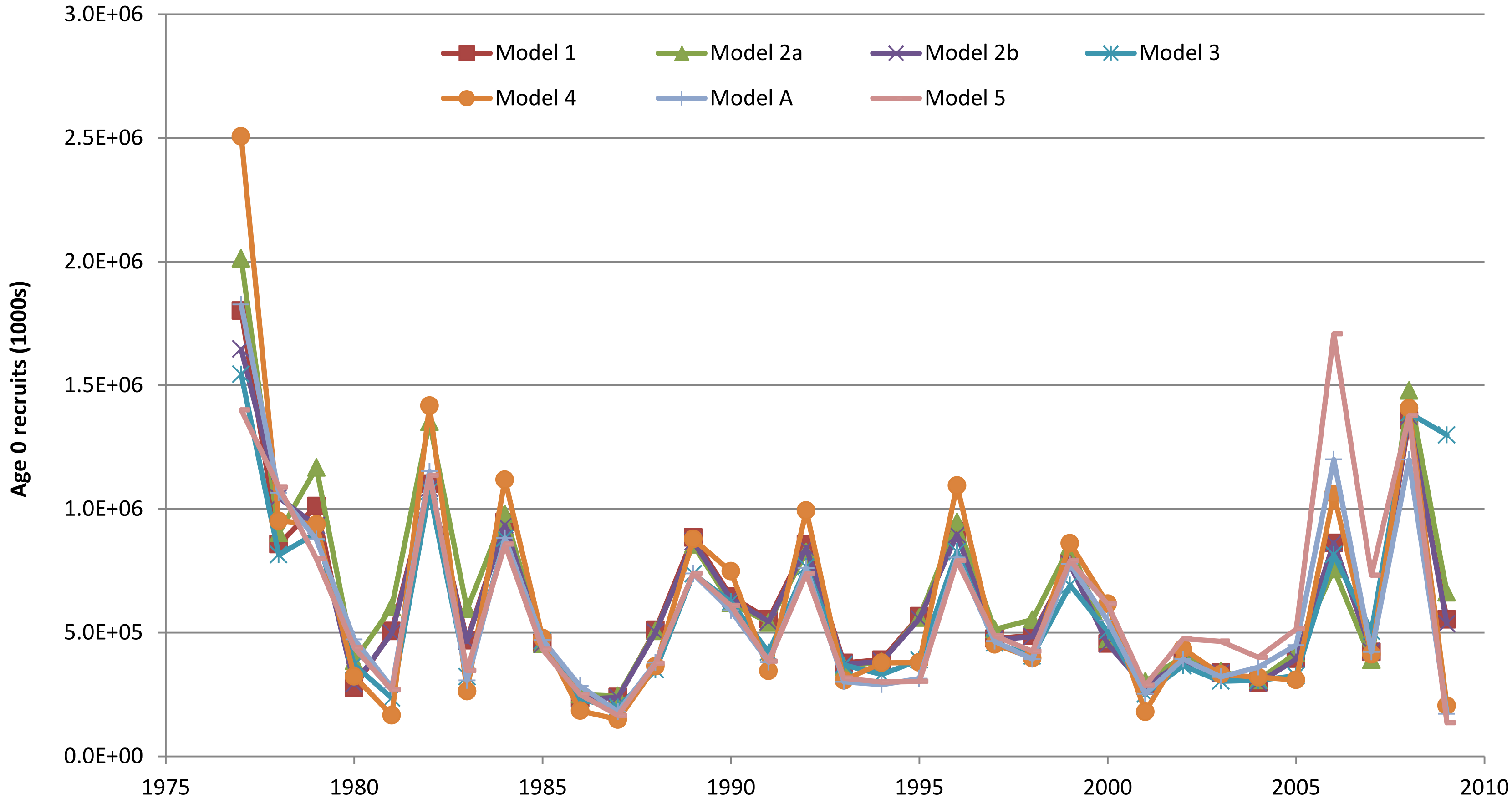

Figure 2.1.14. Time series of age 0 recruitments as estimated by each model.

Attachment 2.2
Preliminary assessment of the Pacific cod stock in the Aleutian Islands Region

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Introduction

Throughout the history of management under the Magnuson-Stevens Fishery Conservation and Management Act, Pacific cod in the Bering Sea and Aleutian Islands (BSAI) have been managed as a single stock. In recent years, however, interest has been shown in managing the eastern Bering Sea (EBS) and Aleutian Islands (AI) portions separately. This document represents a preliminary assessment of the Pacific cod stock in the AI region. Other data and information relevant to this stock can be found in last year's BSAI SAFE report (Thompson et al. 2010).

Comments from the SSC

From the December, 2010 Minutes

SSC1: *"Given the divergence in population abundance between the AI and BS the SSC recommends that an AI assessment be brought forward for evaluation (only) during the next assessment cycle. Biomass distribution is currently estimated at 91% EBS and 9% AI compared to previous proportions of 84% and 16%, respectively."* The present document has been developed in response to this request.

From the February, 2011 Minutes

SSC2: *"The SSC recommends that the stock assessment author and Plan Team develop a plan of action for how the BSAI cod assessment should evolve. The possibilities include maintaining the status quo of a modeling approach in the BS and survey biomass in the AI, having separate models for the BS and AI, or having a single BSAI model (with or without geographic stratification and movement)."* This topic is on the agenda for the August-September Plan Team meeting. Because a long-term plan of action has not been adopted yet, this preliminary assessment has been kept fairly brief, anticipating that initial discussions of separate management for the AI stock will be undertaken in the context of Tier 5 of the BSAI Groundfish Fishery Management Plan.

Data

Catch data for this stock are summarized in Table 2.2.1. Catches since 1991 have averaged about 29,000 t.

The time series of survey biomass estimates is shown with standard errors in Table 2.2.2 and with 95% confidence intervals in Figure 2.2.1. Survey biomass estimates since 1980 have averaged about 143,000 t, with an average coefficient of variation of 18%. The 2010 estimate of 68,200 t is about 52% below the long-term average.

Analytic approach

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 (Thompson and Dorn 2004), the SSC recommended that an approach based on a simple Kalman filter be used. This approach has been used to estimate biomass in the Aleutian Islands ever since, and last year the SSC recommended that its application be extended to the GOA stock as well (SSC minutes, 12/2010). The approach represents a type of trendless random walk, with initial stock size and process error standard deviation estimated by maximum likelihood, after which the smoothed time series of biomass estimates are computed by the Kalman filter recursions. A full discussion of the methodology was given by Thompson and Dorn (2004).

Results

The process error standard deviation was estimated at a value of 20,200 t. The average biomass for the time series was estimated at a value of 132,500, implying a 15% process error coefficient of variation. The time series of biomass estimates resulting from the Kalman filter is shown with standard errors in Table 2.2.2 and with 95% confidence intervals in Figure 2.2.1. The point estimates for 2010 from the survey and from the Kalman filter are extremely close (68,200 t and 69,800 t, respectively).

Example Harvest Specifications

Because no model capable of estimating reference points based on either spawning per recruit or maximum sustainable yield has been approved for this stock, it is anticipated that initial discussions of possible harvest specifications would be undertaken in the context of the Tier 5 control rules. These control rules set the overfishing level (OFL) at the product of the instantaneous natural mortality rate and the best estimate of biomass for the projection year, and they cap the acceptable biological catch (ABC) at 75% of the OFL. The natural mortality rate for the EBS Pacific cod stock has been estimated at a value of 0.34. Assuming that the AI Pacific cod stock has the same natural mortality rate, and given that the best estimate of biomass in 2010 (69,800 t) is also the best estimate of projected biomass under a trendless random walk, the OFL would be 0.34 × 69,800 t = 23,700 t, and the maximum permissible ABC would be 0.75 × OFL = 17,800 t.

It may be noted that the above OFL is lower than the actual catch in 16 out of the last 20 years, and that the maximum permissible ABC is lower than the actual catch in 18 out of the last 20 years.

References

Thompson, G. G., and M. W. Dorn. 2004. Assessment of the Pacific cod stock in the Eastern Bering Sea and Aleutian Islands Area. *In* Plan Team for Groundfish Fisheries of the Bering Sea/Aleutian Islands (compiler), Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands regions, p. 185-302. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.

Thompson, G. G., J. N. Ianelli, and R. R. Lauth. 2010. Assessment of the Pacific cod stock in the eastern Bering Sea and Aleutian Islands area. *In* Plan Team for the Groundfish Fisheries of the Bering Sea and Aleutian Islands (compiler), Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands regions, p. 243-424. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.

Table 2.2.1a—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.

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 2.2.1b—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.

	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 2.2.1c—Summary of 1991-2010 catches (t) of Pacific cod in the Aleutian Islands by jurisdiction and gear. All catches include discards. LLine = longline, Subt. = sector subtotal. Catches since 2006 include those from a State-managed fishery. Catches for 2010 are through October 13. Note that columns for the years 2003-2010 in Table 2.4c of last year's SAFE report chapter were inadvertently transposed.

	Federal					State					
Year	Trawl	Lline	Pot	Other	Subt.	Trawl	Lline	Pot	Other	Subt.	Total
1991	3,414	3,203	3,180		9,798						9,798
1992	14,559	22,108	6,317	84	43,068						43,068
1993	17,312	16,860		33	34,205						34,205
1994	14,383	7,009	147		21,539						21,539
1995	10,574	4,935	1,025		16,534						16,534
1996	21,167	5,819	4,611	13	31,609						31,609
1997	17,336	7,151	575	102	25,164						25,164
1998	20,530	13,771	424	1	34,726						34,726
1999	16,394	7,874	3,750	113	28,130						28,130
2000	20,252	16,183	3,107	142	39,685						39,685
2001	15,362	17,817	544	484	34,207						34,207
2002	27,829	2,865	7	100	30,801						30,801
2003	31,478	978	2	0	32,459						32,459
2004	25,770	3,103	0		28,873						28,873
2005	19,613	3,073	0	13	22,699						22,699
2006	16,956	3,128	401	8	20,493	3,106	455	156		3,717	24,210
2007	25,724	4,182	313	2	30,221	2,907	529	383	6	3,824	34,045
2008	19,291	5,468	1,679	157	26,595	2,540	234	1,634	53	4,462	31,056
2009	20,284	5,469	754	0	26,507	537	279	1,237	20	2,074	28,580
2010	16,713	5,331	481	0	22,525	2,113	32	1,635		3,780	26,306

Table 2.2.2—Time series of biomass estimates (t) observed by the survey and estimated by the Kalman filter.

	Trawl survey observations		Kalman filter estimates	
Year	Mean	St. Error	Mean	St. Error
1980	148,300	29,780	168,600	15,650
1983	215,800	30,990	196,700	22,050
1986	255,100	66,530	200,600	29,210
1991	191,000	25,630	181,700	20,560
1994	184,100	33,700	153,100	21,340
1997	83,420	10,500	90,860	9,889
2000	136,000	23,580	111,600	16,660
2002	82,970	12,170	89,370	10,860
2004	114,200	19,970	102,600	15,160
2006	92,530	24,450	92,080	17,820
2010	68,160	11,010	69,810	10,690

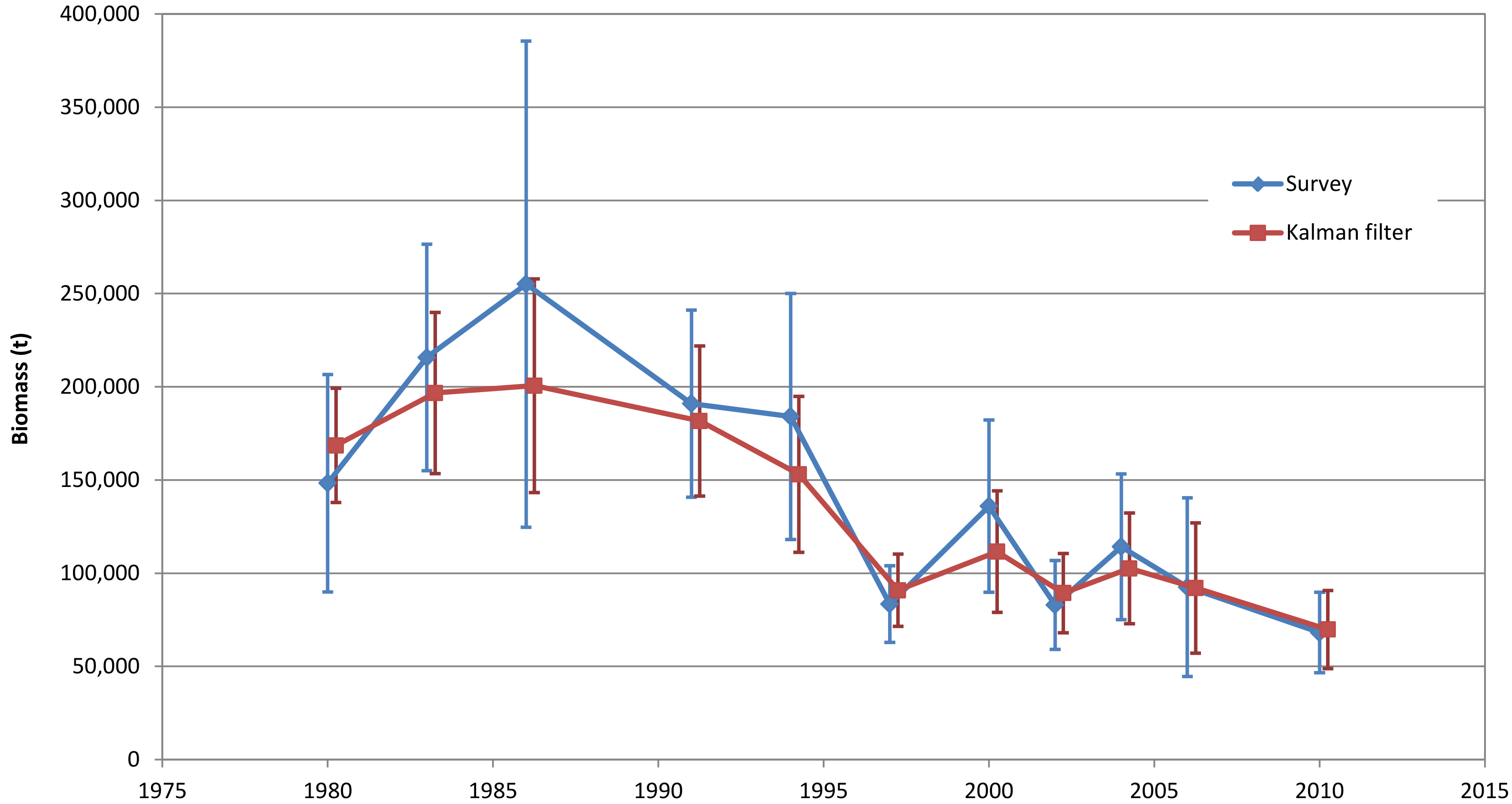

Figure 2.2.1. Time series of biomass as observed by the trawl survey and estimated by the Kalman filter, with 95% confidence intervals. Values along the horizontal axis have been offset slightly for the Kalman filter to make the graph easier to read.

Attachment 2.3:

Supplemental catch data

In order to comply with the Annual Catch Limit (ACL) requirements, two new datasets have been generated to help estimate total catch and removals from NMFS stocks in Alaska.

The first dataset, non-commercial removals, estimates total 2010 removals that do not occur during directed groundfish fishing activities. These include removals incurred during research, subsistence, personal use, recreational, and exempted fishing permit activities, but do not include removals taken in fisheries other than those managed under the groundfish FMP. These estimates represent additional sources of removals to the existing Catch Accounting System estimates. Estimates for Pacific cod from this dataset are shown along with trawl survey removals from 1977-2009 in Table 2.3.1. The research removals are small relative to the fishery catch. Recreational removals are negligible. Removals from activities other than directed fishing totaled 110 t in 2010. This is approximately 0.06% of the 2010 ABC of 174,000 and represents a very low risk to the stock. If these removals were accounted for in the stock assessment model, the recommended ABCs for 2012 and 2013 would likely change very little.

The second dataset, Halibut Fishery Incidental Catch Estimation (HFICE), is an estimate of the incidental catch of groundfish in the halibut IFQ fishery in Alaska, which is currently unobserved. To estimate removals in the halibut fishery, methods were developed by the HFICE working group and approved by the Gulf of Alaska and Bering Sea/Aleutian Islands Groundfish Plan Teams and the Scientific and Statistical Committee of the North Pacific Fishery Management Council. A detailed description of the methods is available in Tribuzio et al. (2011).

These estimates are for total catch of groundfish species in the halibut IFQ fishery and do not distinguish between “retained” and “discarded” catch. These estimates should be considered a separate time series from the current CAS estimates of total catch. Because of potential overlaps, HFICE removals should not be added to the CAS catch estimates. An overlap will exist whenever groundfish are retained or discarded during an IFQ halibut trip. IFQ halibut landings that also include landed groundfish are recorded as retained in eLandings and a discard amount for all groundfish is estimated for such landings in CAS. Discard amounts for groundfish are not currently estimated for IFQ halibut landings that do not also include landed groundfish. For example, catch information for a trip that includes both landed IFQ halibut and Pacific cod would contain the total amount of Pacific cod landed (reported in eLandings) and an estimate of discard based on at-sea observer information. Further, because a groundfish species was landed during the trip, catch accounting would also estimate discard for all groundfish species based on available observer information and following methods described in Cahalan et al. (2010). The HFICE method estimates all groundfish caught during a halibut IFQ trip and thus is an estimate of groundfish caught, whether landed or discarded. This precludes simply adding the HFICE estimate to the CAS total, which would be analogous to counting both retained and discarded groundfish species twice. Further, there are situations where the HFICE estimate includes groundfish caught in State waters, and this would need to be considered with respect to ACLs. Therefore, the HFICE estimates should be considered as preliminary estimates of what is caught in the IFQ halibut fishery. Improved estimates of groundfish catch in the halibut fishery may become available following restructuring of the Observer Program in 2013.

The HFICE estimates of Pacific cod catch by the halibut fishery are small, averaging approximately 0.76% of the annual ABC over the period 2001-2010 (Table 2.3.2). Pacific cod and halibut are often caught and landed in association with each other by the IFQ fishery. It is unknown what level of Pacific cod catch reported here is already accounted for as IFQ harvest in the CAS system because the HFICE estimates do not separate retained and discarded catch. However, even if these were strictly additive removals, 0.76% would represent only a small amount of additional mortality, with little potential risk to the stock. The HFICE estimates may contain useful information on the level of Pacific cod discards in the IFQ fishery, but that level will remain unknown until these estimates are separated from the IFQ landings and CAS system.

References

Cahalan J., J. Mondragon., and J. Gasper. 2010. Catch Sampling and Estimation in the Federal Groundfish Fisheries off Alaska. NOAA Technical Memorandum NMFS-AFSC-205. 42 p.

Tribuzio, CA, S Gaichas, J Gasper, H Gilroy, T Kong, O Ormseth, J Cahalan, J DiCosimo, M Furuness, H Shen, K Green. 2011. Methods for the estimation of non-target species catch in the unobserved halibut IFQ fleet. August Plan Team document. Presented to the Joint Plan Teams of the North Pacific Fishery Management Council.

Table 2.3.1 Total removals of Pacific cod (t) from activities not related to directed fishing, since 1977. "Trawl" refers to a combination of the NMFS echo-integration; small-mesh; large-mesh; and AI and BS (shelf and slope) bottom trawl surveys; and occasional short-term research projects involving trawl gear. "Longline" refers to either the NMFS or IPHC longline survey. "Pot" refers to the blue king crab pot survey. "Other" refers to recreational, personal use, and subsistence harvest.

		Eastern Bering Sea						Aleutian Islands						BSAI
			Longline						Longline					
Year	Source	Trawl	NMFS	IPHC	Pot	Other	Subt.	Trawl	NMFS	IPHC	Pot	Other	Subt.	Total
1977	AFSC	10					10						0	10
1978	AFSC	26					26						0	26
1979	AFSC	61					61						0	61
1980	AFSC	37					37	64					64	101
1981	AFSC	94					94						0	94
1982	AFSC	116					116	153					153	269
1983	AFSC	95					95	102					102	197
1984	AFSC	52					52						0	52
1985	AFSC	100					100						0	100
1986	AFSC	41					41	98					98	139
1987	AFSC	41					41						0	41
1988	AFSC	71					71						0	71
1989	AFSC	56					56						0	56
1990	AFSC	51					51						0	51
1991	AFSC	76					76	37					37	113
1992	AFSC	17					17						0	17
1993	AFSC	25					25						0	25
1994	AFSC	51					51	62					62	113
1995	AFSC	54					54						0	54
1996	AFSC	33					33						0	33
1997	AFSC	26					26	20					20	46
1998	AFSC	21					21						0	21
1999	AFSC	28					28						0	28
2000	AFSC	22					22	24					24	46
2001	AFSC	35					35						0	35
2002	AFSC	24					24	18					18	42
2003	AFSC	26					26						0	26
2004	AFSC	26					26	23					23	49
2005	AFSC	23					23						0	23
2006	AFSC	23					23	15					15	38
2007	AFSC	19					19						0	19
2008	AFSC	18					18						0	18
2009	AFSC	21					21						0	21
2010	AKRO	43		32	4		79	12	10	9			31	110

Table 2.3.2. Estimates of Pacific cod catch (t) from the Halibut Fishery Incidental Catch Estimation (HFICE) working group. Areas 542 and 543 have been combined for 2009 due to confidentiality restrictions.

		Aleutian Islands					
Year	EBS	541	542	543	542/543	Subtotal	Total
2001	570	243	235	350		828	1398
2002	443	186	351	51		587	1030
2003	921	393	80	13		487	1408
2004	378	369	156	133		658	1036
2005	1301	552	142	52		746	2047
2006	1033	956	155	53		1164	2196
2007	1107	184	153	101		437	1544
2008	856	221	339	94		654	1511
2009	832	232	n/a	n/a	298	530	1362
2010	681	320	142	43		505	1186

Attachment 2.4:

Tables and figures for the "Time Series Results" and "Projections and Harvest Alternatives" sections based on the SSC's most recent preferred model (Model 1)

The tables and figures contained in the "Time Series Results" and "Projections and Harvest Alternatives" sections in the main text are based on Model 3b. This attachment reproduces those tables and figures, but based on the SSC's most recent preferred model (Model 1).

Table 2.4.28—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 1. Values for 2012 listed under this year's assessment represent Stock Synthesis projections, and may not correspond exactly 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	834,627	216,589	37,927	686,847	195,750	37,536
1978	968,676	243,639	37,560	793,309	217,856	36,943
1979	1,282,910	290,302	37,886	1,032,530	258,666	36,605
1980	1,767,440	369,757	38,756	1,490,210	337,002	36,981
1981	2,249,760	500,315	39,867	1,997,710	475,069	38,164
1982	2,593,560	670,040	41,598	2,391,600	656,755	40,112
1983	2,738,400	817,145	42,222	2,589,110	814,960	40,925
1984	2,740,820	882,575	39,969	2,601,800	885,860	38,959
1985	2,668,450	867,150	35,638	2,542,640	870,530	34,906
1986	2,574,910	816,915	30,812	2,452,210	820,080	30,277
1987	2,499,160	773,980	26,600	2,383,880	778,995	26,195
1988	2,373,550	733,295	23,292	2,272,060	740,065	22,984
1989	2,130,630	679,105	20,717	2,041,390	684,840	20,448
1990	1,878,370	622,710	18,566	1,792,260	623,970	18,231
1991	1,680,260	545,890	16,396	1,580,890	541,315	15,927
1992	1,547,260	454,646	14,291	1,430,120	447,160	13,709
1993	1,536,830	406,254	12,776	1,409,030	400,011	12,132
1994	1,610,980	419,403	12,255	1,461,640	414,496	11,544
1995	1,651,460	426,772	12,508	1,486,950	417,812	11,639
1996	1,599,380	427,849	13,040	1,426,050	412,041	11,912
1997	1,524,880	423,471	13,384	1,344,350	399,780	11,987
1998	1,451,680	401,978	13,429	1,244,670	370,446	11,812
1999	1,498,780	393,734	13,300	1,266,120	357,095	11,538
2000	1,558,300	400,034	13,278	1,309,990	359,144	11,380
2001	1,602,420	434,215	13,528	1,338,320	388,164	11,383
2002	1,645,100	449,783	13,715	1,369,020	397,009	11,249
2003	1,627,360	448,342	13,756	1,349,140	390,569	11,010
2004	1,547,710	440,618	13,872	1,287,350	384,527	10,899
2005	1,428,430	412,921	14,088	1,172,980	352,702	10,895
2006	1,299,170	373,573	14,168	1,051,890	311,105	10,826
2007	1,189,470	338,856	14,089	954,127	277,699	10,727
2008	1,166,660	313,534	14,152	936,438	256,235	10,873
2009	1,208,150	298,073	14,718	1,002,880	248,388	11,664
2010	1,323,180	303,883	16,280	1,125,170	266,329	13,659
2011	1,517,480	331,545	16,707	1,292,680	314,791	17,148
2012				1,376,790	348,922	19,976

Table 2.4.29—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 1.

	Last year's values		This year's values	
Year	Recruits	Std. dev.	Recruits	Std. dev.
1977	2,173,820	141,849	2,156,140	148,905
1978	701,641	88,122	853,573	94,534
1979	865,775	73,124	879,621	68,296
1980	482,379	43,633	369,786	36,636
1981	187,485	25,641	366,820	31,794
1982	1,098,730	40,442	1,124,690	43,085
1983	345,339	26,643	421,601	29,106
1984	863,779	35,918	938,090	37,907
1985	521,494	28,749	458,257	26,528
1986	273,598	19,196	235,807	17,205
1987	193,316	14,522	210,155	14,446
1988	336,546	16,504	471,870	20,293
1989	751,861	25,314	836,105	28,830
1990	695,184	25,148	640,243	24,776
1991	444,630	18,422	509,156	21,039
1992	834,553	24,219	819,039	23,776
1993	424,298	16,888	359,016	15,411
1994	361,508	14,711	361,842	14,958
1995	402,104	16,543	502,339	19,694
1996	905,191	26,483	854,923	24,513
1997	513,004	18,026	449,847	16,353
1998	416,374	15,675	442,972	15,866
1999	675,222	20,531	719,361	20,223
2000	570,900	18,896	438,710	15,003
2001	271,300	11,762	266,319	11,109
2002	371,140	14,271	379,147	13,955
2003	355,402	15,505	330,055	14,141
2004	311,781	15,238	311,786	14,559
2005	331,043	17,298	445,026	22,163
2006	809,072	41,200	947,211	45,498
2007	425,480	35,511	463,752	30,689
2008	1,040,250	94,823	1,128,900	74,744
2009	789,492	140,368	224,345	32,711
2010			913,889	119,700
Average	592,319		603,530	

Table 2.4.30—Numbers (1000s) at age as estimated by Model 1.

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1977	2156140	724841	39900	248580	49088	32428	21441	14181	9378	6201	4100	2711	1792	1185	783	518	342	226	150	99	193
1978	853573	1524410	506386	27772	170590	33145	21747	14379	9529	6315	4182	2768	1831	1211	801	530	350	232	153	101	197
1979	879621	605030	1067870	353249	19076	115183	22218	14574	9655	6411	4254	2820	1868	1236	818	541	358	237	156	103	202
1980	369786	626087	428088	752790	245946	13096	78563	15142	9943	6595	4383	2911	1930	1279	846	560	371	245	162	107	209
1981	366820	263202	445545	303773	529445	171142	9042	54027	10396	6823	4524	3007	1997	1324	877	581	384	254	168	111	217
1982	1124690	261092	187292	315998	213414	368141	118098	6213	37049	7123	4672	3098	2059	1367	906	600	398	263	174	115	225
1983	421601	800521	185790	132804	221894	148478	254563	81401	4276	25482	4898	3212	2130	1415	940	623	413	273	181	120	234
1984	938090	300083	569608	131580	92832	153184	101656	173541	55387	2907	17319	3328	2183	1447	962	638	423	280	186	123	240
1985	458257	667699	213487	403024	91627	63477	103372	68157	116068	37017	1943	11574	2225	1459	967	643	427	283	188	124	243
1986	235807	326171	475046	151104	280262	62265	42445	68586	45103	76784	24499	1286	7668	1474	967	641	426	283	188	124	243
1987	210155	167839	232050	336087	104934	190130	41549	28093	45267	29756	50678	16179	850	5069	975	640	424	282	187	124	243
1988	471870	149579	119365	163902	232395	70459	125022	27055	18236	29377	19324	32935	10521	553	3299	635	417	276	184	122	240
1989	836105	335855	106360	84008	111933	153740	45537	79679	17124	11506	18509	12167	20731	6621	348	2076	399	262	174	116	228
1990	640243	595113	238945	75017	57524	74145	99641	29201	50886	10922	7337	11803	7760	13223	4224	222	1324	255	167	111	219
1991	509156	455705	423474	169280	51710	37806	47153	62648	18326	31955	6865	4615	7429	4886	8329	2661	140	835	161	105	208
1992	819039	362401	324287	300052	115962	32964	22801	27883	36960	10835	18942	4078	2745	4423	2911	4964	1587	83	498	96	187
1993	359016	582967	257877	229653	205432	73692	19733	13388	16387	21843	6436	11294	2438	1644	2652	1747	2981	953	50	299	170
1994	361842	255536	414884	182971	159020	135597	46838	12392	8426	10369	13887	4106	7222	1561	1054	1702	1122	1915	612	32	302
1995	502339	257547	181826	293683	124712	100826	81187	27497	7284	4985	6171	8301	2462	4339	939	635	1025	676	1155	369	201
1996	854923	357549	183261	128760	201536	79437	59831	46677	15716	4173	2865	3555	4790	1422	2507	543	367	593	391	668	330
1997	449847	608507	254412	129722	88164	127803	46903	34275	26638	9007	2403	1655	2059	2778	825	1457	316	213	345	227	581
1998	442972	320187	433012	180153	88596	55295	74212	26385	19205	14992	5094	1364	942	1173	1585	471	832	180	122	197	462
1999	719361	315293	227837	306631	123562	56740	33415	43849	15558	11366	8905	3034	814	562	701	947	282	498	108	73	394
2000	438710	512019	224379	161330	209790	78778	34190	19781	26034	9306	6841	5383	1839	494	342	427	577	172	303	66	285
2001	266319	312261	364411	159076	111043	137059	49817	21461	12479	16549	5953	4396	3470	1188	320	221	277	374	111	197	228
2002	379147	189558	222232	257946	108065	70089	82779	29923	13045	7691	10311	3737	2773	2196	754	203	141	176	238	71	271
2003	330055	269866	134903	157174	174206	67226	41501	48689	17816	7881	4700	6349	2313	1723	1368	470	127	88	110	149	214
2004	311786	234923	192050	95383	106192	109068	40383	24839	29468	10918	4876	2927	3972	1452	1083	861	296	80	56	70	229
2005	445026	221920	167192	135876	64206	64910	62695	22946	14279	17207	6458	2911	1758	2397	878	657	523	180	49	34	182
2006	947211	316756	157940	118434	91923	39365	37266	35354	12986	8150	9897	3735	1690	1024	1398	513	384	306	106	29	127
2007	463752	674196	225442	111945	80415	56713	22758	21185	20198	7491	4742	5794	2196	997	605	828	304	228	182	63	92
2008	1128900	330085	479836	159729	75928	49728	33000	13038	12191	11725	4382	2789	3422	1301	592	360	492	181	136	108	92
2009	224345	803520	234928	339946	107869	46228	28336	18533	7375	6974	6771	2548	1630	2006	764	348	212	290	107	80	119
2010	913889	159682	571876	166429	229820	66033	26539	16005	10516	4222	4023	3928	1484	952	1174	448	204	124	171	63	117
2011	621823	650479	113648	405457	113842	145749	39852	15797	9543	6302	2542	2430	2378	900	578	713	272	124	76	104	109

Table 2.4.31—Estimates of “effective” fishing mortality (= $-\ln(N_{a+1,t+1}/N_{a,t})-M$) at age and year for Model 1.

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1977	0.015	0.021	0.034	0.051	0.058	0.059	0.057	0.054	0.053	0.052	0.051	0.051	0.050	0.050	0.050	0.050	0.050	0.050	0.050
1978	0.017	0.024	0.039	0.056	0.064	0.065	0.063	0.061	0.059	0.058	0.057	0.057	0.057	0.056	0.056	0.056	0.056	0.056	0.056
1979	0.010	0.014	0.024	0.036	0.042	0.042	0.040	0.039	0.038	0.037	0.037	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036
1980	0.000	0.002	0.011	0.023	0.033	0.038	0.040	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041
1981	0.000	0.003	0.012	0.022	0.030	0.035	0.037	0.038	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039
1982	0.000	0.003	0.011	0.019	0.025	0.029	0.030	0.031	0.031	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032
1983	0.000	0.004	0.015	0.027	0.036	0.041	0.044	0.044	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045
1984	0.000	0.004	0.018	0.035	0.049	0.056	0.058	0.059	0.060	0.060	0.060	0.060	0.060	0.060	0.060	0.060	0.060	0.060	0.060
1985	0.000	0.004	0.019	0.042	0.059	0.069	0.072	0.073	0.072	0.072	0.071	0.071	0.070	0.070	0.070	0.070	0.070	0.069	0.069
1986	0.000	0.004	0.020	0.041	0.058	0.067	0.071	0.072	0.072	0.071	0.071	0.071	0.070	0.070	0.070	0.070	0.070	0.070	0.070
1987	0.000	0.004	0.019	0.046	0.068	0.079	0.083	0.083	0.082	0.081	0.080	0.079	0.079	0.078	0.078	0.078	0.078	0.077	0.077
1988	0.000	0.007	0.033	0.064	0.089	0.105	0.114	0.117	0.119	0.120	0.120	0.120	0.121	0.121	0.121	0.121	0.121	0.121	0.121
1989	0.000	0.007	0.031	0.063	0.087	0.102	0.109	0.111	0.112	0.112	0.112	0.112	0.112	0.112	0.112	0.112	0.112	0.112	0.112
1990	0.000	0.002	0.022	0.066	0.103	0.119	0.122	0.122	0.122	0.121	0.121	0.120	0.120	0.120	0.120	0.120	0.119	0.119	0.119
1991	0.000	0.002	0.028	0.095	0.155	0.181	0.186	0.185	0.183	0.181	0.180	0.179	0.178	0.178	0.178	0.177	0.177	0.177	0.177
1992	0.000	0.001	0.022	0.085	0.149	0.175	0.177	0.173	0.169	0.165	0.163	0.161	0.160	0.159	0.158	0.158	0.158	0.157	0.157
1993	0.000	0.001	0.019	0.067	0.120	0.142	0.143	0.138	0.132	0.128	0.125	0.123	0.121	0.120	0.120	0.119	0.119	0.119	0.118
1994	0.000	0.001	0.024	0.084	0.145	0.171	0.172	0.166	0.160	0.155	0.152	0.150	0.148	0.147	0.147	0.146	0.146	0.145	0.145
1995	0.000	0.002	0.023	0.095	0.179	0.222	0.232	0.230	0.226	0.223	0.221	0.220	0.219	0.219	0.218	0.218	0.218	0.218	0.218
1996	0.000	0.002	0.022	0.089	0.169	0.209	0.216	0.212	0.207	0.203	0.200	0.198	0.197	0.197	0.196	0.196	0.195	0.195	0.195
1997	0.000	0.002	0.027	0.107	0.196	0.240	0.248	0.244	0.239	0.235	0.232	0.230	0.229	0.228	0.227	0.227	0.226	0.226	0.226
1998	0.000	0.002	0.019	0.078	0.146	0.179	0.185	0.182	0.177	0.174	0.172	0.171	0.170	0.169	0.169	0.169	0.168	0.168	0.168
1999	0.000	0.001	0.017	0.074	0.143	0.175	0.178	0.172	0.166	0.161	0.158	0.156	0.154	0.153	0.153	0.152	0.152	0.152	0.151
2000	0.000	0.002	0.025	0.087	0.146	0.169	0.164	0.152	0.142	0.134	0.129	0.126	0.124	0.122	0.121	0.120	0.120	0.119	0.118
2001	0.000	0.002	0.026	0.087	0.137	0.150	0.142	0.130	0.120	0.113	0.108	0.105	0.103	0.102	0.100	0.100	0.099	0.099	0.098
2002	0.000	0.002	0.029	0.099	0.159	0.176	0.168	0.154	0.143	0.134	0.129	0.125	0.123	0.121	0.120	0.119	0.119	0.118	0.118
2003	0.000	0.002	0.027	0.095	0.156	0.175	0.167	0.153	0.141	0.132	0.127	0.123	0.120	0.119	0.118	0.117	0.116	0.116	0.115
2004	0.000	0.003	0.034	0.113	0.180	0.200	0.191	0.176	0.163	0.154	0.148	0.144	0.141	0.139	0.138	0.137	0.136	0.135	0.135
2005	0.000	0.001	0.023	0.096	0.173	0.212	0.219	0.213	0.205	0.198	0.193	0.190	0.188	0.186	0.185	0.184	0.183	0.183	0.182
2006	0.000	0.001	0.022	0.097	0.181	0.226	0.234	0.227	0.217	0.210	0.204	0.200	0.197	0.196	0.194	0.193	0.193	0.192	0.191
2007	0.000	0.001	0.021	0.090	0.169	0.211	0.218	0.210	0.201	0.193	0.188	0.184	0.181	0.180	0.178	0.177	0.177	0.176	0.175
2008	0.000	0.001	0.024	0.102	0.186	0.227	0.233	0.224	0.214	0.205	0.200	0.195	0.192	0.190	0.189	0.188	0.187	0.187	0.186
2009	0.000	0.002	0.026	0.107	0.196	0.240	0.245	0.235	0.224	0.215	0.208	0.203	0.200	0.198	0.196	0.195	0.194	0.194	0.193
2010	0.000	0.001	0.022	0.088	0.161	0.199	0.205	0.198	0.189	0.182	0.176	0.173	0.170	0.168	0.167	0.166	0.165	0.165	0.164
2011	0.000	0.001	0.024	0.102	0.190	0.235	0.242	0.235	0.226	0.218	0.213	0.209	0.207	0.205	0.203	0.202	0.202	0.201	0.201

Table 2.4.32—Projections for BSAI Pacific cod catch (t), spawning biomass (t), and fishing mortality under the assumption that $F = max\ F_{ABC}$ in 2012-2024 (Scenarios 1 and 2), with random variability in future recruitment under Model 1.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2012	275,000	275,000	275,000	275,000	0
2013	275,000	275,000	275,000	275,000	0
2014	274,000	274,000	274,000	274,000	1
2015	270,000	271,000	271,000	271,000	387
2016	258,000	265,000	267,000	281,000	7,652
2017	231,000	256,000	260,000	304,000	23,326
2018	189,000	247,000	250,000	328,000	41,916
2019	161,000	244,000	243,000	337,000	54,290
2020	147,000	241,000	241,000	339,000	59,965
2021	147,000	241,000	241,000	349,000	61,990
2022	145,000	240,000	241,000	343,000	61,970
2023	144,000	240,000	240,000	344,000	60,634
2024	148,000	240,000	239,000	338,000	59,292

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2012	384,000	384,000	384,000	384,000	0
2013	402,000	402,000	402,000	402,000	0
2014	405,000	405,000	405,000	405,000	6
2015	401,000	402,000	402,000	404,000	813
2016	392,000	397,000	399,000	410,000	6,009
2017	367,000	387,000	391,000	428,000	19,901
2018	334,000	374,000	383,000	458,000	39,287
2019	309,000	368,000	377,000	486,000	54,316
2020	294,000	364,000	376,000	493,000	62,532
2021	290,000	364,000	377,000	504,000	66,602
2022	288,000	362,000	377,000	511,000	68,120
2023	288,000	364,000	376,000	500,000	67,148
2024	290,000	365,000	375,000	500,000	64,757

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
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	0.29	0.29	0.29	0.29	0.00
2017	0.29	0.29	0.29	0.29	0.00
2018	0.26	0.29	0.29	0.29	0.01
2019	0.24	0.29	0.28	0.29	0.02
2020	0.23	0.29	0.28	0.29	0.02
2021	0.23	0.29	0.27	0.29	0.02
2022	0.23	0.29	0.27	0.29	0.02
2023	0.22	0.29	0.27	0.29	0.02
2024	0.23	0.29	0.27	0.29	0.02

Table 2.4.33—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 2012-2024 (Scenario 3), with random variability in future recruitment under Model 1.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2012	239,000	239,000	239,000	239,000	0
2013	245,000	245,000	245,000	245,000	0
2014	249,000	249,000	249,000	249,000	1
2015	248,000	249,000	249,000	249,000	332
2016	240,000	246,000	247,000	259,000	6,591
2017	218,000	239,000	243,000	281,000	20,201
2018	196,000	232,000	238,000	303,000	32,966
2019	178,000	230,000	235,000	313,000	41,596
2020	167,000	228,000	234,000	315,000	46,394
2021	165,000	227,000	233,000	326,000	48,814
2022	163,000	226,000	232,000	321,000	49,365
2023	161,000	225,000	231,000	318,000	48,240
2024	163,000	225,000	230,000	313,000	46,925

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2012	386,000	386,000	386,000	386,000	0
2013	417,000	417,000	417,000	417,000	0
2014	429,000	429,000	429,000	429,000	6
2015	433,000	433,000	434,000	435,000	813
2016	428,000	433,000	435,000	446,000	6,023
2017	406,000	426,000	430,000	467,000	20,147
2018	371,000	415,000	423,000	500,000	40,916
2019	339,000	407,000	416,000	533,000	59,296
2020	313,000	403,000	412,000	542,000	71,295
2021	299,000	400,000	410,000	554,000	78,267
2022	293,000	397,000	408,000	562,000	81,580
2023	290,000	397,000	406,000	551,000	81,619
2024	289,000	396,000	404,000	551,000	79,641

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2012	0.25	0.25	0.25	0.25	0.00
2013	0.25	0.25	0.25	0.25	0.00
2014	0.25	0.25	0.25	0.25	0.00
2015	0.25	0.25	0.25	0.25	0.00
2016	0.25	0.25	0.25	0.25	0.00
2017	0.25	0.25	0.25	0.25	0.00
2018	0.25	0.25	0.25	0.25	0.00
2019	0.25	0.25	0.25	0.25	0.00
2020	0.25	0.25	0.25	0.25	0.00
2021	0.25	0.25	0.25	0.25	0.00
2022	0.25	0.25	0.25	0.25	0.00
2023	0.25	0.25	0.25	0.25	0.00
2024	0.25	0.25	0.25	0.25	0.00

Table 2.4.34—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 2012-2024 (Scenario 4), with random variability in future recruitment under Model 1.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2012	142,000	142,000	142,000	142,000	0
2013	156,000	156,000	156,000	156,000	0
2014	166,000	166,000	166,000	166,000	0
2015	172,000	172,000	172,000	173,000	191
2016	171,000	175,000	176,000	183,000	3,828
2017	161,000	173,000	176,000	198,000	12,093
2018	148,000	171,000	175,000	216,000	20,576
2019	137,000	170,000	174,000	225,000	27,003
2020	129,000	169,000	173,000	228,000	30,956
2021	126,000	169,000	173,000	235,000	33,178
2022	124,000	168,000	173,000	237,000	34,055
2023	123,000	168,000	172,000	232,000	33,683
2024	123,000	168,000	171,000	229,000	32,841

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2012	394,000	394,000	394,000	394,000	0
2013	457,000	457,000	457,000	457,000	0
2014	500,000	500,000	500,000	500,000	6
2015	528,000	529,000	529,000	531,000	814
2016	542,000	548,000	549,000	560,000	6,058
2017	532,000	553,000	557,000	596,000	20,758
2018	503,000	550,000	558,000	642,000	44,098
2019	469,000	545,000	555,000	686,000	67,170
2020	436,000	543,000	553,000	710,000	84,118
2021	415,000	540,000	552,000	728,000	95,069
2022	408,000	538,000	551,000	742,000	101,243
2023	401,000	537,000	549,000	732,000	103,117
2024	398,000	536,000	547,000	727,000	101,791

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
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
2023	0.14	0.14	0.14	0.14	0.00
2024	0.14	0.14	0.14	0.14	0.00

Table 2.4.35—Projections for BSAI Pacific cod catch (t), spawning biomass (t), and fishing mortality under the assumption that *F* = 0 in 2012-2024 (Scenario 5), with random variability in future recruitment under Model 1.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
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
2023	0	0	0	0	0
2024	0	0	0	0	0

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2012	404,000	404,000	404,000	404,000	0
2013	517,000	517,000	517,000	517,000	0
2014	619,000	619,000	619,000	619,000	6
2015	702,000	703,000	703,000	704,000	814
2016	764,000	770,000	771,000	782,000	6,107
2017	794,000	815,000	820,000	860,000	21,618
2018	791,000	842,000	851,000	943,000	48,891
2019	768,000	858,000	871,000	1,030,000	80,135
2020	738,000	869,000	884,000	1,090,000	107,122
2021	714,000	876,000	893,000	1,120,000	127,419
2022	700,000	884,000	900,000	1,170,000	141,261
2023	686,000	886,000	903,000	1,180,000	148,894
2024	681,000	890,000	904,000	1,180,000	151,056

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
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
2023	0.00	0.00	0.00	0.00	0.00
2024	0.00	0.00	0.00	0.00	0.00

Table 2.4.36—Projections for BSAI Pacific cod catch (t), spawning biomass (t), and fishing mortality under the assumption that $F = F_{OFL}$ in 2012-2024 (Scenario 6), with random variability in future recruitment under Model 1.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2012	323,000	323,000	323,000	323,000	0
2013	312,000	312,000	312,000	312,000	0
2014	303,000	303,000	303,000	303,000	1
2015	291,000	292,000	292,000	294,000	1,030
2016	266,000	278,000	280,000	304,000	12,173
2017	224,000	261,000	267,000	330,000	34,062
2018	187,000	248,000	257,000	355,000	52,983
2019	161,000	246,000	253,000	364,000	64,052
2020	151,000	245,000	253,000	372,000	69,328
2021	153,000	245,000	254,000	381,000	71,073
2022	149,000	245,000	254,000	371,000	70,790
2023	149,000	246,000	253,000	373,000	69,152
2024	154,000	245,000	252,000	365,000	68,064

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2012	380,000	380,000	380,000	380,000	0
2013	383,000	383,000	383,000	383,000	0
2014	373,000	373,000	373,000	373,000	6
2015	363,000	363,000	364,000	365,000	764
2016	350,000	355,000	357,000	367,000	5,525
2017	328,000	346,000	349,000	382,000	17,735
2018	302,000	337,000	344,000	411,000	33,827
2019	282,000	335,000	341,000	432,000	45,833
2020	269,000	334,000	341,000	435,000	52,384
2021	269,000	333,000	342,000	449,000	55,717
2022	267,000	333,000	343,000	454,000	56,880
2023	267,000	335,000	342,000	441,000	55,745
2024	270,000	334,000	341,000	441,000	53,656

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
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	0.34	0.34	0.34	0.35	0.00
2016	0.33	0.34	0.34	0.35	0.00
2017	0.31	0.33	0.33	0.35	0.01
2018	0.28	0.32	0.32	0.35	0.02
2019	0.26	0.32	0.31	0.35	0.03
2020	0.25	0.31	0.31	0.35	0.03
2021	0.25	0.31	0.31	0.35	0.03
2022	0.25	0.31	0.31	0.35	0.03
2023	0.25	0.32	0.31	0.35	0.03
2024	0.25	0.32	0.31	0.35	0.03

Table 2.4.37—Projections for BSAI Pacific cod catch (t), spawning biomass (t), and fishing mortality under the assumption that $F = max\ F_{ABC}$ in each year 2012-2013 and $F = F_{OFL}$ thereafter (Scenario 7), with random variability in future recruitment under Model 1.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2012	275,000	275,000	275,000	275,000	0
2013	275,000	275,000	275,000	275,000	0
2014	321,000	321,000	321,000	321,000	1
2015	307,000	307,000	307,000	308,000	463
2016	280,000	293,000	294,000	312,000	10,255
2017	229,000	266,000	272,000	334,000	33,953
2018	188,000	249,000	258,000	357,000	53,208
2019	161,000	246,000	253,000	365,000	64,268
2020	150,000	245,000	253,000	371,000	69,456
2021	152,000	245,000	254,000	381,000	71,138
2022	149,000	245,000	254,000	371,000	70,819
2023	149,000	246,000	253,000	373,000	69,164
2024	154,000	245,000	252,000	365,000	68,067

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2012	384,000	384,000	384,000	384,000	0
2013	402,000	402,000	402,000	402,000	0
2014	400,000	400,000	400,000	400,000	6
2015	382,000	383,000	383,000	384,000	813
2016	361,000	367,000	368,000	379,000	5,889
2017	333,000	350,000	354,000	389,000	18,594
2018	303,000	338,000	345,000	415,000	34,606
2019	282,000	335,000	342,000	435,000	46,337
2020	269,000	334,000	341,000	436,000	52,638
2021	269,000	333,000	342,000	448,000	55,825
2022	267,000	333,000	343,000	454,000	56,919
2023	267,000	335,000	342,000	441,000	55,757
2024	270,000	334,000	341,000	441,000	53,658

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2012	0.29	0.29	0.29	0.29	0.00
2013	0.29	0.29	0.29	0.29	0.00
2014	0.35	0.35	0.35	0.35	0.00
2015	0.35	0.35	0.35	0.35	0.00
2016	0.34	0.35	0.35	0.35	0.00
2017	0.31	0.33	0.33	0.35	0.01
2018	0.28	0.32	0.32	0.35	0.02
2019	0.26	0.32	0.31	0.35	0.03
2020	0.25	0.31	0.31	0.35	0.03
2021	0.25	0.31	0.31	0.35	0.03
2022	0.25	0.31	0.31	0.35	0.03
2023	0.25	0.32	0.31	0.35	0.03
2024	0.25	0.31	0.31	0.35	0.03

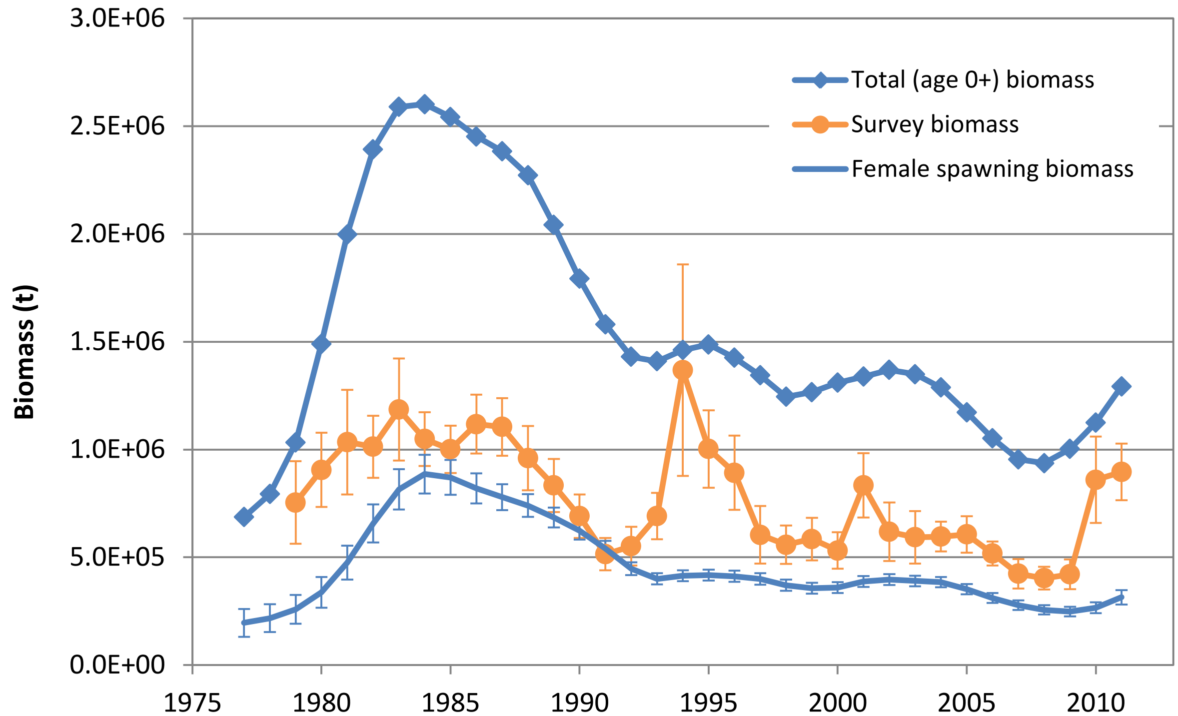

Figure 2.4.16—Biomass time trends (age 0+ biomass, female spawning biomass, survey biomass) of EBS Pacific cod as estimated by Model 1. Spawning survey and survey biomass show 95% CI.

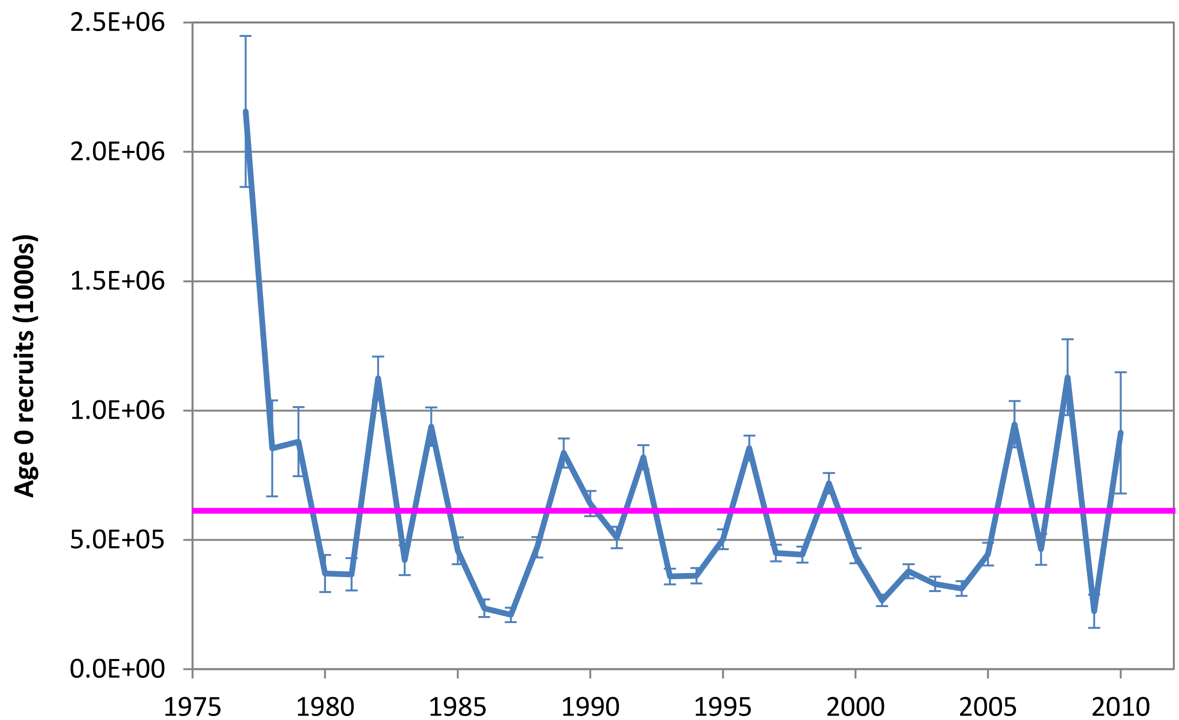

Figure 2.4.17—Time series of EBS Pacific cod recruitment at age 0, with 95% confidence intervals, as estimated by Model 1. Magenta line = 1977-2010 average.

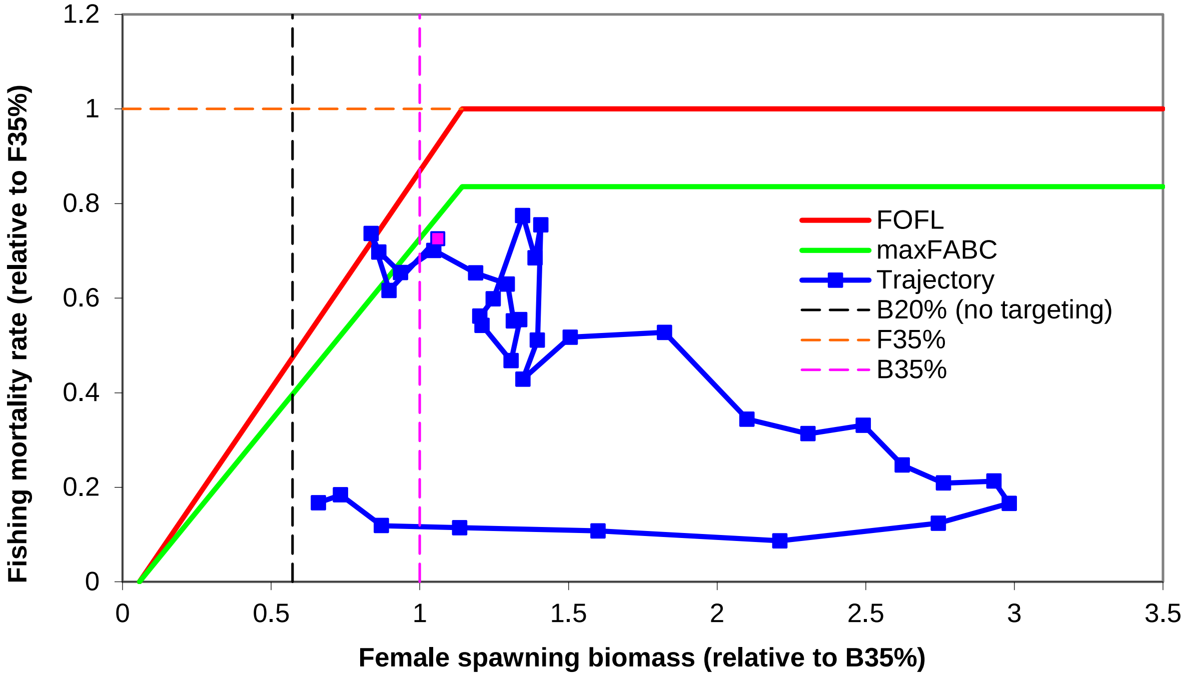

Figure 2.4.18—Trajectory of Pacific cod fishing mortality and female spawning biomass as estimated by Model 1, 1977-present (magenta square = 2011).