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

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EXECUTIVE SUMMARY

Summary of Major Changes

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

Changes in the Input Data

1) Catch data for 2006 were updated, and preliminary catch data for 2007 were incorporated.
2) Commercial fishery size composition data were recompiled for the years 1990-2006 and incorporated, and preliminary size composition data from the 2007 commercial fisheries were incorporated.
3) Size composition data from the 2007 EBS shelf bottom trawl survey were incorporated.
4) The biomass estimate from the 2007 EBS shelf bottom trawl survey was incorporated into several preliminary models (the 2007 estimate of 423,703 t was down about 18% from the 2006 estimate, and is the all-time low in the time series).
5) The numeric abundance estimates from the 1979-2007 EBS shelf bottom trawl surveys were incorporated into the final models (the 2007 estimate of 713,374,144 fish was up about 86% from the 2006 estimate).
6) Age composition data from the 1995 and 2006 EBS shelf bottom trawl surveys were incorporated into some of the models.
7) Seasonal catch per unit effort (CPUE) data for the trawl, longline, and pot fisheries from 1991-2007 were incorporated.
8) Catch rates of Pacific cod from the 1998-2007 International Pacific Halibut Commission (IPHC) longline surveys were incorporated.
9) Pacific cod size composition data from the 2007 IPHC longline survey were incorporated.

Changes in the Assessment Model

Many changes have been made in the stock assessment model since last year's assessment. Some of these are described in the report of a technical workshop held in April of this year (Thompson and Conners 2007). For example, the base model developed for the technical workshop differed with respect to last year's author-recommended model in the following respects:

Feature	Last year's assessment	Technical workshop base model
Software	SS2 version 1.23d	SS2 verson 2.00c
Natural mortality rate (*M*)	Fixed at 0.37	Estimated internally
Length-at-age parameters	Estimated externally	Estimated internally
Pre-shift median recruitment	Estimated iteratively	Estimated internally
First year included in model	1964	1976
First year of current regime	1977	1976
No. initial year classes estimated	None (all set at equilibrium)	10
Selectivity pattern	4-parameter double normal	6-parameter double normal
Bounds on log catchability	Essentially unbounded	Low=2×ln(0.75), high=0
Bounds on selectivity parameters	Essentially unbounded	Most have low=-10, high=10
Form of prior distributions	All normal	Normal and symmetric beta

Dozens of other models were also considered at the workshop.

Further changes were made between the technical workshop and this year's preliminary SAFE Report (Thompson et al. 2007). The following were among the ways in which Model 1 from the preliminary SAFE Report differed from the base model developed for the technical workshop:

Feature	Technical workshop base model	Model 1 from preliminary SAFE
Software	SS2 version 2.00c	SS2 version 2.00i
Selectivities forced to be asymptotic	None	January-May trawl fishery
Time-varying selectivity	Fishery selectivities constant within blocks, surveys constant	Fishery and survey selectivities variable across years
Time-varying length at age 1	Constant	Variable across years
Std. dev. of log-scale recruitment deviations (σ_R)	σ_R set iteratively	$\sigma_R = 0.6$
No. initial year classes estimated	10	3
Variability in length at age	CV = function of length at age	SD = function of age
Slope trawl survey data	Included	Excluded
Fishery CPUE data	Excluded	Included for comparison only
Form of age data	Marginal age compositions	Age-at-length compositions
Form of prior distributions	Normal and symmetric beta	All uniform
Bounds on log catchability	Low=2×ln(0.75), high=0	Low=-2, high=2
Bound parameters, if any	Parameters did not approach bounds due to priors	Fixed at bound (i.e., taken out of the estimation process)

Three other models were also considered in the preliminary SAFE Report.

Relative to Model 1 from the preliminary SAFE Report, the following changes have been made in the base model presented in this assessment (Model 1):

Feature	Model 1 from preliminary SAFE	New base model (Model 1)
Natural mortality rate	Estimated internally	Fixed at 0.34
Form of age data	Age-at-length compositions	Marginal age compositions
Basis of maturity schedule	Length	Age
Basis of trawl survey selectivity	Length	Age
Seasonal structure	Partially seasonal	Fully seasonal
Selectivities forced to be asymptotic	January-May trawl fishery	Jun-Aug trawl, Sep-Dec trawl, Jun-Aug longline, Sep-Dec pot
Time-varying selectivity; std. dev. of selectivity deviations (σ_S)	Fisheries and surveys variable across years; σ_S =0.4	Fisheries constant, surveys variable across years; σ_S =0.2
Time-varying length at age 1	Variable across years	Constant across years
Variability in length at age	SD = function of age	SD = function of length at age
Survey abundance units	Biomass	Numbers
Multinomial sample size; records with small actual sample sizes	Square root of actual sample size; all records used	Scaled bootstrap harmonic mean; records with small N excluded
Std. dev. of log-scale recruitment deviations (σ_R)	σ_R = 0.6	σ_R set iteratively
First year included in model	1976	1977
Starting year of regime shift	1976	1977
Parameters with large std. dev.	Left free	Fixed at their respective MLEs

The reference to multinomial sample size in the table above refers to the fact that, as in previous assessments, size composition data are assumed to be drawn from a multinomial distribution specific to a particular year, gear/fishery, and season within the year. In an attempt to move toward a more statistically based specification, this year a bootstrap analysis of the available fishery length data from 1990-2006 was undertaken.

Three other models are also presented in this assessment.

Changes in Assessment Results

Under the base model, the following changes in assessment results were obtained:

1) The projected 2008 female spawning biomass for the BSAI stock is 398,000 t, up about 30% from last year's estimate for 2007 and up about 50% from last year's F_{ABC} projection for 2008. However, the 2008 level is estimated to be only 29% of equilibrium unexploited female spawning biomass, compared to 38% estimated last year for 2007 and 33% projected last year for 2008.
2) The projected 2008 age 3+ biomass for the BSAI stock is 1,080,000 t, up about 13% from last year's estimate for 2007.
3) The recommended 2008 ABC for the BSAI stock is 150,000 t, down about 15% from the actual 2007 ABC and up about 15% from last year's F_{ABC} projection for 2008. The recommended preliminary 2009 ABC for the BSAI stock is 162,000 t.
4) The estimated 2008 OFL for the BSAI stock is 176,000 t, down about 15% from the actual 2007 OFL and up about 14% from last year's F_{ABC} projection for 2008. The estimated preliminary 2009 OFL for the BSAI stock is 190,000 t.

Responses to Comments from the SSC

SSC Comments Specific to the Pacific Cod Assessments

From the December, 2006 minutes:

> *"With regard to the longline data, the SSC suggests excluding them from future assessments."*
>
> The above comment refers to use of Pacific cod CPUE data from the NMFS longline survey, which were included in some of the models presented in last year's assessment (though not in the model recommended by the authors and adopted by the Plan Team and SSC). These data have been excluded from this year's assessment.

Also from the December, 2006 minutes:

> *"Following the Plan Team meeting, a potential problem with the model fit was pointed out by an external reviewer and the author provided revised model B1 output on very short notice. The revised model provided a slightly improved fit overall. The largest differences between the revised and original model B1 results were in the fits to trawl survey age composition (worse fit in the revised model) and trawl survey size-at-age data (improved fit). While the differences in model fit are relatively minor, the model resulted in substantially higher estimates of biomass and the implied maximum ABC.*
>
> *"The SSC is concerned that the revised model results did not receive any review by the Plan Team and that the apparent volatility of the model requires further investigation. The large difference in estimated biomass and the pattern of differences in likelihood components between the two model fits suggests that the model may be unstable or that two very different solutions provide very similar overall fits. Potential problems with the model configuration should be fully evaluated. All of the models examined by the author this year, including the revised model, suggest a series of poor recruitments from at least 2000 to 2004, and a decreasing trend in biomass that is projected to continue as these year classes enter the fishery. Therefore, the pattern of decreasing biomass in recent years and into the future appears to be a robust result.*
>
> *"To resolve uncertainties within the assessment model, the SSC recommends that the AFSC conduct a workshop with the authors. In particular, the workshop should explore the following issues with regard to both the GOA and BSAI assessments:*
>
> - *Estimation of growth inside the model versus the use of externally estimated length-at-age and weight-at-length parameters (with variances)*
> - *Model convergence sensitivity to different weights assigned to the log priors and data components*
> - *Model fit to contrasting models that fix Q and estimate M and alternatively fix M and estimate Q.*
> - *To fully explore the parameter space (and model fit), a suite of models incorporating fixed values for M and Q for a matrix of plausible values could also be explored.*
> - *Consider a simpler logistic form for the survey selectivity and estimability of descending parameters for survey and fishery selectivity."*
>
> Following this request, the Alaska Fisheries Science Center convened a public workshop to examine various technical issues pertaining to the assessments for Pacific cod in the Bering Sea, Aleutian Islands, and Gulf of Alaska. The workshop took place at the Seattle lab of the Alaska Fisheries Science Center during the dates of April 24-25, 2007. A total of 44 people participated in the workshop. SSC chair Pat Livingston served as chair of the workshop and Liz Conners served as rapporteur. Many alternative models, for both the Bering Sea and Gulf of Alaska

stocks, were presented at the workshop, and several other models were developed during the workshop. Workshop participants contributed a total of 40 suggestions for the authors to consider in developing this year's stock assessments. A full report of the workshop was provided by Thompson and Conners (2007).

From the June, 2007 minutes:

"The SSC also reviewed the Pacific cod workshop report that evaluated stock assessment models in both the BS and GOA. The SSC received public comment from Kenny Down (Alaska Frontier Company). The SSC commends Dr. Grant Thompson (AFSC) for his excellent work and thanks the AFSC for conducting the workshop. The SSC looks forward to presentation of results of additional model simulations in October, 2007."

A preliminary stock assessment was produced in September of this year (Thompson et al. 2007). It included results of four new models developed in response to suggestions made at the technical workshop.

From the October, 2007 minutes:

"The SSC suggests that the analysts consider the following in some of the models brought forward in December:

i. "One or more model fits in which the value of natural mortality (M) is fixed. We are skeptical of model estimates of M, including the previous fixed value M=0.37. Purely for purposes of comparison we would like to see one fit with M=0.37. We would suggest that the author investigate the possibility of choosing a different fixed value based on life history theory (i.e., the value of M for which the observed growth and maturity schedules are optimal).

ii. "Plots of the empirical length-at-age distributions calculated by keying out the survey length distributions using the length-stratified survey age readings. These empirical length-at-age frequencies must sum to the observed survey length frequencies, including the strong modes that the model fits fail to predict. This exercise may reveal differences between the empirical and estimated length-at-age distributions that will shed some light on the apparent inconsistencies between the age and length data."

Models 1 and 2 in the present assessment address the suggestions made in (i) above. Regarding (ii), none of the models presented in this assessment exhibit significant inconsistencies between the estimated mean lengths at age and the modes from the long-term average survey size compositions.

SSC Comments on Assessments in General

From the December, 2006 minutes:

"The SSC appreciates the addition of phase-plane diagrams to most stock assessments and reiterates interest in these diagrams for all stock assessments in which it is possible to do so using standardized axes (i.e., X axis of B/Btarget; and Y axis of Fcatch/FOFL), formatted relative to harvest control rules. In addition, values from the most recent year should be provided annually by the assessment authors to the plan team."

Recalling that the December, 2005 SSC minutes identified the axes as "$F/F_{35\%}$ *versus* $B/B_{35\%}$," the quantity *Btarget* in the December, 2006 minutes is interpreted here to mean $B_{35\%}$ and the quantity *FOFL* in the December, 2006 minutes is interpreted here to mean $F_{35\%}$. The requested phase-plane diagram appears in Figure 2.9. Values from the most recent year (2007) are: relative biomass = 0.932 and relative fishing mortality = 0.618.

INTRODUCTION

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

FISHERY

Catches of Pacific cod taken in the EBS, AI, and BSAI for the periods 1964-1980 and 1981-2007 are shown in Tables 2.1a and 2.1b, 2.2a and 2.2b, and 2.3a and 2.3b, respectively. The catches in Tables 2.1a, 2.2a, and 2.3a are broken down by year and fleet sector (foreign, joint venture, domestic annual processing), while the catches in Tables 2.1b, 2.2b, and 2.3b are broken down by gear type as well. During the early 1960s, a Japanese longline fishery harvested BSAI Pacific cod for the frozen fish market. Beginning in 1964, the Japanese trawl fishery for walleye pollock (*Theragra chalcogramma*) expanded and cod became an important bycatch species and an occasional target species when high concentrations were detected during pollock operations. By the time that the Magnuson Fishery Conservation and Management Act went into effect in 1977, foreign catches of Pacific cod had consistently been in the 30,000-70,000 t range for a full decade. In 1981, a U.S. domestic trawl fishery and several joint venture fisheries began operations in the BSAI. The foreign and joint venture sectors dominated catches through 1988, but by 1989 the domestic sector was dominant and by 1991 the foreign and joint venture sectors had been displaced entirely. Presently, the Pacific cod stock is exploited by a multiple-gear fishery, including trawl, longline, pot, and jig components. Figures 2.1a-2.1c show areas in which sampled hauls or sets for each of the three main gear types (trawl, longline, and pot) were concentrated during January-May, June-August, and September-December, 2006. Figures 2.1d-2.1e show the corresponding information for January-May and June-August, 2007 (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 more than two hauls/sets containing Pacific cod were sampled in it during the respective season and year.

The history of acceptable biological catch (ABC) and total allowable catch (TAC) levels is summarized and compared with the time series of aggregate (i.e., all-gear, combined area) commercial catches in Table 2.4. From 1980 through 2007, TAC averaged about 79% of ABC, and aggregate commercial catch averaged about 89% of TAC. In 10 of these 28 years (37%), TAC equaled ABC exactly, and in 5 of these 27 years (19%), catch exceeded TAC (by an average of 4%). In 2007, TAC was set at 97% of ABC to account for a small, State-managed fishery inside State of Alaska waters. Changes in ABC over time are typically attributable to three factors: 1) changes in resource abundance, 2) changes in management strategy, and 3) changes in the stock assessment model. For example, in the assessments for fishery years 1980 through 2007, seven different assessment models were used (Table 2.4). All assessments from 1993 through 2004 used the Stock Synthesis 1 modeling software with primarily length-based data, albeit with some changes in model structure from time to time. The assessment was migrated to Stock Synthesis 2 in 2005, and several changes have been made to the model within the SS2 framework 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 (2002-2006), the EBS accounted for an average of about 86% of the BSAI catch.

The catches shown in Tables 2.1b, 2.2b, 2.3b, and 2.4 include estimated discards. Discard rates of Pacific cod in the various EBS and AI target fisheries are shown for each year 1991-2002 in Table 2.5a and for each year 2003-2004 in Table 2.5b. Values for 2005-2007 have not yet been tabulated.

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

> (i) Hook-and-line gear. Subject to other provisions of this part, directed fishing for CDQ and non-CDQ Pacific cod with vessels equal to or greater than 60 ft (18.3 m) LOA using hook-and-line gear is authorized only during the following two seasons:
>
> > (A) A season. From 0001 hours, A.l.t., Jan. 1 through 1200 hours, A.l.t., June 10; and
> >
> > (B) B season. From 1200 hours, A.l.t., June 10 through 2400 hours, A.l.t., Dec. 31.
>
> (ii) Trawl gear. Subject to other provisions of this part, directed fishing for CDQ and non-CDQ Pacific cod with trawl gear in the BSAI is authorized only during the following three seasons:
>
> > (A) A season. From 1200 hours, A.l.t., Jan. 20 through 1200 hours, A.l.t., Apr. 1;
> >
> > (B) B season. From 1200 hours, A.l.t., Apr. 1 through 1200 hours, A.l.t., June 10; and
> >
> > (C) C season. From 1200 hours, A.l.t., June 10 through 1200 hours, A.l.t., Nov. 1.
>
> (iii) Pot gear. Subject to other provisions of this part, non-CDQ directed fishing for Pacific cod with vessels equal to or greater than 60 ft (18.3 m) LOA using pot gear in the BSAI is authorized only during the following two seasons:
>
> > (A) A season. From 0001 hours, A.l.t., January 1 through 1200 hours, A.l.t., June 10; and
> >
> > (B) B season. From 1200 hours, A.l.t., September 1 through 2400 hours, A.l.t., Dec. 31.
>
> (iv) Jig gear. Subject to other provisions of this part, directed fishing for CDQ and non-CDQ Pacific cod with jig gear is authorized only during the following three seasons:
>
> > (A) A season. From 0001 hours, A.l.t., Jan. 1 through 1200 hours, A.l.t., Apr. 30;
> >
> > (B) B season. From 1200 hours, A.l.t., Apr. 30 through 1200 hours, A.l.t., Aug. 31; and
> >
> > (C) C season. From 1200 hours, A.l.t., Aug. 31 through 2400 hours, A.l.t., Dec. 31.

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

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

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

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

DATA

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

Commercial Catch Data

Catch Biomass

Catches taken in the EBS for the period 1977-2007 are shown in Table 2.6. Catches for the years 1977-1980 may not include discards. Catches in these tables are broken down by the three main gear types and intra-annual periods consisting of the months January-May, June-August, and September-December. This particular division, which was suggested by participants in the EBS fishery, is intended to reflect actual intra-annual differences in fleet operation (e.g., fishing operations during the spawning period may be different than at other times of year). In years for which estimates of the distribution by gear or period were not available, proxies based on other years' distributions were used.

Catch Size Composition

Fishery size compositions are presently available, by gear, for at least one gear type in every year from 1977 through the first part of 2007. For ease of representation and analysis, length frequency data for Pacific cod can usefully be grouped according to the following set of 25 intervals or "bins," with the upper and lower boundaries shown in cm:

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

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

Catch Per Unit Effort

Catch per unit effort are available by gear and season for the years 1991-2007 and are shown below (units are kg/hr for trawl gear, kg/hook for longline gear, and kg/pot for pot gear):

	Trawl			Longline			Pot		
Year	Sea. 1	Sea. 2	Sea. 3	Sea. 1	Sea. 2	Sea. 3	Sea. 1	Sea. 2	Sea. 3
1991	58.85	49.23	24.40	1.02	0.71	0.55		68.53	103.16
1992	49.11	104.89	30.40	0.80	0.50	0.49	76.14	49.20	26.94
1993	51.00	50.84	106.54	0.66	0.35		85.53		
1994	51.41	45.97	51.01	0.73		0.58	86.03		97.17
1995	62.04	57.44	62.76	0.86		0.60	85.19	69.59	52.18
1996	35.70	36.59	32.98	0.81		0.54	67.67	53.19	49.54
1997	51.20	32.77	75.73	0.87		0.58	76.71	47.20	46.56
1998	36.26	27.95	43.34	0.74		0.44	63.17	46.65	32.70
1999	37.54	16.67	20.80	0.68	0.46	0.50	53.98	40.13	37.50
2000	32.73	14.17	22.40	0.68	0.49	0.40	51.31		
2001	22.42	45.65	14.42	0.56	0.44	0.41	70.30		46.11
2002	29.70	31.72	16.28	0.68	0.39	0.37	67.55		44.93
2003	26.91	33.46	21.86	0.52	0.35	0.35	73.86		58.16
2004	50.06	29.76	16.12	0.56	0.34	0.36	76.48		51.93
2005	45.06	21.12		0.64	0.36	0.35	86.93		46.12
2006	41.58	25.74		0.76	0.43	0.37	87.16		52.40
2007	37.82	47.98		0.73	0.48		64.63		64.24

Survey Data

EBS Shelf Bottom Trawl Survey

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

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

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

Estimates of total abundance (both in biomass and numbers of fish) obtained from the trawl surveys are shown in Table 2.12a (1979-1981) and 2.12b (1982-2007), together with their respective standard errors. Upper and lower 95% confidence intervals are also shown for the biomass estimates. Survey results indicate that biomass increased steadily from 1978 through 1983, and then remained relatively constant from 1983 through 1988. The highest biomass ever observed by the survey was the 1994 estimate of 1,368,120 t. Following the high observation in 1994, the survey biomass estimate declined steadily through 1998. The survey biomass estimates remained in the 596,000-619,000 t range from 2002 through 2005. The 2006 biomass estimate was 517,698 t, a 14% drop from the 2005 value and the second lowest estimate in the time series. This was followed by another drop in 2007, when the survey produced a biomass estimate of 423,703 t, an 18% drop from the 2006 value. The 2007 value is the lowest estimate in the time series. However, the 2007 estimate of numeric abundance moved in the opposite direction, an 86% increase over the 2006 estimate and the highest numeric abundance since 2001.

EBS Slope Bottom Trawl Survey

The Alaska Fisheries Science Center conducted bottom trawl surveys of the EBS slope in 2002 and 2004. The biomass estimates and standard errors from the 2002 and 2004 surveys are shown below (all figures are in t):

Year	Biomass	Standard Error
2002	7511	1944
2004	5756	968

Because the survey estimates of Pacific cod biomass on the slope are so small (on the order of 1% of the shelf biomass estimates), the slope survey data are not used in the BSAI Pacific cod assessment.

Aleutian Bottom Trawl Survey

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

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

For many years, the assessments of Pacific cod in the BSAI used a weighted average formed from EBS and Aleutian survey biomass estimates to provide a conversion factor which was used to translate model projections of EBS catch and biomass into BSAI equivalents. Prior to the 2004 assessment, the weighted average was based on the sums of the biomass estimates from the EBS shelf and AI survey biomass time series. However, in December of 2003 the SSC requested that alternative methods of estimating relative biomass between the EBS and AI be explored. Following a presentation of some possible alternatives, the SSC recommended that an approach based on a simple Kalman filter be used (SSC Minutes, October, 2004). In the 2006 assessment, the Kalman filter approach was applied to the updated (through 2006) time series, indicating that the best estimate of the current biomass distribution is 84% EBS and 16% AI (the previous proportions were 85% and 15%, respectively).

IPHC Longline Survey

The International Pacific Halibut Commission (IPHC) conducts an annual longline survey designed to estimate the relative abundance of Pacific halibut (*Hippoglossus stenolepis*). The survey also takes Pacific cod incidentally. The CPUE time series (number of Pacific cod per hook) since 1998 is as follows:

1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
0.160	0.104	0.112	0.103	0.076	0.096	0.104	0.101	0.116	0.107

Pacific cod length composition data have not been taken historically in the IPHC survey. However, during this year's survey, IPHC staff made a special effort to collect Pacific cod size composition data. A total of 2785 lengths were collected, distributed among length bins as follows (no Pacific cod were recorded below length bin 12):

Bin:	12	13	14	15	16	17	18	19	20	21	22	23	24	25
No.:	2	11	55	238	599	720	440	240	144	122	99	60	39	16

ANALYTIC APPROACH

Model Structure

History of Model Structures Developed Under Stock Synthesis 1 and 2

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

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

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

In the EBS Pacific cod model, each year has traditionally been partitioned into three seasons: January-May, June-August, and September-December (these seasonal boundaries were suggested by industry participants). Four fisheries have traditionally been defined: The January-May trawl fishery, the June-December trawl fishery, the longline fishery, and the pot fishery.

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

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

A major change took place in the 2005 assessment (Thompson and Dorn 2005), as the model was migrated to the newly developed Stock Synthesis 2 (SS2) program, which makes use of the ADMB modeling architecture (Fournier 2005) currently used in most age-structured assessments of BSAI and GOA groundfish. The move to SS2 facilitated improved estimation of model parameters as well as statistical characterization of the uncertainty associated with parameter estimates and derived quantities such as spawning biomass. 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. After the assessment was completed, an external reviewer discovered that the authors' recommended model, which was also accepted by the Plan Team as the preferred model, had converged at a local rather than global minimum. This led the SSC to request that a technical workshop be held to explore alternative models.

Review of Technical Workshop and Preliminary SAFE Report

Many changes have been made in the stock assessment model since last year's assessment. Some of these are described in the report of the technical workshop requested by the SSC, which was held in April of this year (Thompson and Conners 2007). For example, the base model developed for the technical workshop differed with respect to last year's author-recommended model in the following respects:

Feature	Last year's assessment	Technical workshop base model
Software	SS2 version 1.23d	SS2 verson 2.00c
Natural mortality rate (*M*)	Fixed at 0.37	Estimated internally
Length-at-age parameters	Estimated externally	Estimated internally
Pre-shift median recruitment	Estimated iteratively	Estimated internally
First year included in model	1964	1976
First year of current regime	1977	1976
No. initial year classes estimated	None (all set at equilibrium)	10
Selectivity pattern	4-parameter double normal	6-parameter double normal
Bounds on log catchability	Essentially unbounded	Low=2×ln(0.75), high=0
Bounds on selectivity parameters	Essentially unbounded	Most have low=-10, high=10
Form of prior distributions	All normal	Normal and symmetric beta

Dozens of other models were also considered at the workshop. Most of these were developed in advance of the workshop to address specific requests made by the SSC pertaining to catchability, natural mortality, estimation of growth parameters inside the model, use of asymptotic selectivity, and use of prior distributions. Other models were developed during the workshop itself in response to suggestions made by workshop participants.

Further changes were made between the technical workshop and this year's preliminary SAFE Report (Thompson et al. 2007). Much of the effort in developing these models was directed toward ensuring that the estimation routine had reached the global maximum in the absence of informative prior distributions. Generally, it was necessary to choose starting values for model parameters that were close to the final (estimated) values.

Four models were presented in the preliminary SAFE Report. The following were among the ways in which Model 1 from the preliminary SAFE Report differed from the base model developed for the technical workshop:

Feature	Technical workshop base model	Model 1 from preliminary SAFE
Software	SS2 version 2.00c	SS2 version 2.00i
Selectivities forced to be asymptotic	None	January-May trawl fishery
Time-varying selectivity	Fishery selectivities constant within blocks, surveys constant	Fishery and survey selectivities variable across years
Time-varying length at age 1	Constant	Variable across years
Std. dev. of log-scale recruitment deviations (σ_R)	σ_R set iteratively	$\sigma_R = 0.6$
No. initial year classes estimated	10	3
Variability in length at age	CV = function of length at age	SD = function of age
Slope trawl survey data	Included	Excluded
Fishery CPUE data	Excluded	Included for comparison only
Form of age data	Marginal age compositions	Age-at-length compositions
Form of prior distributions	Normal and symmetric beta	All uniform
Bounds on log catchability	Low=2×ln(0.75), high=0	Low=-2, high=2
Bound parameters, if any	Parameters did not approach bounds due to priors	Fixed at bound (i.e., taken out of the estimation process)

The other three models in the preliminary SAFE Report considered the effects of increasing natural mortality as a function of age, giving a large emphasis to fitting the longline fishery CPUE data, starting the model in 1982 rather than 1976, ignoring the age data, and iteratively adjusting the average input multinomial sample sizes and root-mean-squared-errors of the abundance indices.

The use of age-at-length composition data rather than marginal age compositions in three of the models presented in the preliminary SAFE Report was a response in part to a finding from the technical workshop. In the models presented at the technical workshop (which used marginal age compositions), the mean lengths estimated for the first few ages seemed to be distinctly different from the first few modes in the long-term average size composition from the bottom trawl survey. However, use of age-at-length composition data failed to eliminate this discrepancy.

Model Structures Considered in This Year's Assessment

Four models are presented in this assessment. Relative to Model 1 from the preliminary SAFE Report, the following changes have been made in the base model presented in this assessment (Model 1):

Feature	Model 1 from preliminary SAFE	New base model (Model 1)
Natural mortality rate	Estimated internally	Fixed at 0.34
Form of age data	Age-at-length compositions	Marginal age compositions
Basis of maturity schedule	Length	Age
Basis of trawl survey selectivity	Length	Age
Seasonal structure	Partially seasonal	Fully seasonal
Selectivities forced to be asymptotic	January-May trawl fishery	Jun-Aug trawl, Sep-Dec trawl, Jun-Aug longline, Sep-Dec pot
Time-varying selectivity; std. dev. of selectivity deviations (σ_S)	Fisheries and surveys variable across years; σ_S =0.4	Fisheries constant, surveys variable across years; σ_S =0.2
Time-varying length at age 1	Variable across years	Constant across years
Variability in length at age	SD = function of age	SD = function of length at age
Survey abundance units	Biomass	Numbers
Multinomial sample size; records with small actual sample sizes	Square root of actual sample size; all records used	Scaled bootstrap harmonic mean; records with small N excluded
Std. dev. of log-scale recruitment deviations (σ_R)	σ_R = 0.6	σ_R set iteratively
First year included in model	1976	1977
Starting year of regime shift	1976	1977
Parameters with large std. dev.	Left free	Fixed at their respective MLEs

Model 1 was developed partly in response to requests from the SSC for inclusion of a model in which the natural mortality rate was based on other life history parameters (see below) and for inclusion of a model in which marginal age compositions are used. The decision to set the standard deviation of time-varying selectivity parameters at 0.2 was based on Francis et al. (2003).

Model 2 is the same as Model 1 except that the natural mortality rate is fixed at 0.37. This model is included in response to another SSC request (the SSC asked that this model be included "purely for purposes of comparison").

Model 3 is the same as Model 1 except that the natural mortality rate is estimated internally. This model is included to determine whether the available data are sufficient to permit estimation of this parameter.

Model 4 differs from Model 1 in several respects. It estimates the natural mortality rate internally, constrains survey selectivities to be asymptotic, ignores the age data, ignores the late-1970s regime shift, starts the model in 1982 instead of 1977, bases maturity on length rather than age, bases survey selectivity on length rather than age, allows more survey selectivity parameters to have annual deviations, sets the standard deviation of selectivity parameter deviations at 0.4 rather than 0.2, and ignores the initial catch in estimating the initial fishing mortality rate. This model is included in response to public comment.

Parameters Estimated Independently

Natural Mortality

In the 1993 BSAI Pacific cod assessment (Thompson and Methot 1993), the natural mortality rate M was estimated using SS1 at a value of 0.37. Although attempts have been made to re-estimate M in some years (during the late 1990s and, most recently, in the 2005 assessment (Thompson and Dorn 2005)), all models of the BSAI Pacific cod stock accepted by the Plan Team and SSC since 1993 have ultimately retained a value of 0.37 for *M*, as have all subsequent assessments of the GOA Pacific cod stock (with one exception, in 1995). Other published estimates of *M* for Pacific cod are shown below:

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

As noted above, two of the models in the present assessment estimate *M* independently. Model 1 fixes *M* at a value of 0.34, based on Equation 7 of Jensen (1996) and an age at maturity of 4.9 years (Stark 2007). Model 2 fixes *M* at the traditional value of 0.37. Models 3 and 4 estimate *M* conditionally.

Variability in Estimated Age

Variability in estimated age in SS2 is based on the standard deviation of estimated age. Weighted least squares regression was used in the 2005 and 2006 assessments to estimate a proportional relationship between standard deviation and age. The regression was not recomputed this year, because only two new years' worth of age data were available. The estimated proportionality is 0.103 (i.e, the standard deviation of estimated age was modeled as 0.103 × age).

Weight at Length

Parameters governing the allometric relationship between weight (kg) and length (cm) were re-estimated in the 2006 assessment by log-log regression from the same data used to estimate the parameters of the length-at-age relationship. The parameter values were: multiplicative constant = 3.86×10^{-6}, and exponent = 3.266. These were not re-estimated 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 has been used for many years. The parameter values used for this schedule in the 2005 and 2006 assessments were set on the basis of a study by Stark (2007) at the following values: length at 50% maturity = 58 cm and slope of linearized logistic equation = -0.132. The same parameter values are used for Model 4 in the present assessment. However, recent changes in SS2 allow for use of either a length-based or an age-based maturity schedule. Models 1-3 in the present assessment use an age-based schedule with intercept = 4.9 years and slope = -0.965 (Stark 2007). The use of an age-based rather than a length-based schedule follows a recommendation from the author of the maturity study from which the parameter values were taken (James Stark, Alaska Fisheries Science Center, personal communication).

Parameters Estimated Conditionally

Parameters estimated conditionally (i.e., within individual SS2 runs, based on the data and the parameters estimated independently) include the natural mortality rate (Models 3 and 4), length-at-age parameters, parameters governing variability in length at age, log median recruitment, initial fishing mortality, survey catchability, selectivity parameters, annual recruitment deviations, and annual deviations in one (Models 1-3) or two (Model 4) parameters governing the ascending limb of the trawl survey selectivity schedule.

A new, “recommended” (Methot 2007) selectivity function has been implemented for the present assessment, as it was at the technical workshop and in the preliminary SAFE Report. One of the things that may have led to convergence problems with the 2006 Bering Sea assessment model was that the four-parameter double-normal selectivity function used in that assessment exhibited differentiability problems. The new form of the double-normal selectivity pattern is supposed to exhibit superior performance. As with the double-normal selectivity pattern used in last year’s assessments, the new form is constructed from two underlying and rescaled normal distributions, with a horizontal line segment joining the two peaks. The new form uses the following six parameters:

1. Beginning of peak region (where the curve first reaches a value of 1.0)
2. Width of peak region (where the curve first departs from a value of 1.0)
3. Ascending “width” (equal to twice the variance of the underlying normal distribution)
4. Descending width
5. Initial selectivity (at minimum length/age; not used in old form)
6. Final selectivity (at maximum length/age; not used in old form)

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

For all parameters estimated within individual SS2 runs, the estimator used is the mode of the logarithm of the joint posterior distribution, which is in turn calculated as the sum of the logarithms of the parameter-specific prior distributions (see below) and the logarithm of the likelihood function.

In addition to the above, 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 SS2 assumes that the input total catch data are true values rather than estimates, so the fishing mortality rates can be computed algebraically given the other parameter values and the input catch data.

Uniform prior distributions were used for all parameters.

Likelihood Components

All four models included likelihood components for trawl survey relative abundance, fishery and survey size composition, recruitment, and parameter deviations. In addition, Models 1-3 included likelihood components for age composition and initial catch (Model 4 did not attempt to fit either of these data types).

In SS2, emphasis factors are specified to determine which likelihood components receive the greatest attention during the parameter estimation process. As in previous assessments, each likelihood component in each model was given an emphasis of 1.0 in the present assessment.

Use of Size Composition Data in Parameter Estimation

Size composition data are assumed to be drawn from a multinomial distribution specific to a particular year, gear/fishery, and time period within the year. In the parameter estimation process, SS2 weights a given size composition observation (i.e., the size frequency distribution observed in a given year, gear/fishery, and period) according to the emphasis associated with the respective likelihood component and the sample size specified for the multinomial distribution from which the data are assumed to be drawn. In developing the model upon which SS1 was originally based, Fournier and Archibald (1982) suggested truncating the multinomial sample size at a value of 400 in order to compensate for contingencies which cause the sampling process to depart from the process that gives rise to the multinomial distribution. For many years, previous 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 SS2 with usable information regarding the appropriate effort to devote to fitting individual length samples.

Although the "square root rule" for specifying multinomial sample sizes gives reasonable values, the rule itself is largely *ad hoc*. In an attempt to move toward a more statistically based specification, this year a bootstrap analysis of the available fishery length data from 1990-2006 was undertaken. The actual sample sizes are shown by year, gear, and season in Tabel 2.13a. The average actual sample size across all years, gears, and seasons is 37,375. The harmonic mean sample sizes from the bootstrap analysis are shown in Table 2.13b. The harmonic means are smaller than the actual sample sizes (average = 8,244), but still range well into the thousands. A multinomial sample size in the thousands would likely overemphasize the size composition data. As a compromise, it may be reasonable to scale the harmonic means proportionally. For example, Table 2.13c shows the harmonic means rescaled to achieve an average sample size of 300. For comparison, the square roots of the actual sample sizes are shown in Table 2.13d, and the ratios of the rescaled harmonic means to the square roots are shown in Table 2.13e. In general, the rescaled harmonic means are greater than the square roots for the January-May trawl fishery and the longline fishery (all three seasons). The reverse is true for the June-August trawl fishery, the September-December trawl fishery, the June-August pot fishery, and the September-December pot fishery. The two methods result in fairly similar values for the January-May pot fishery. Overall, the rescaled harmonic means are larger than the square roots by a factor of about 2:1.

If the rescaled harmonic mean approach is adopted, the question remains of what to do about years not covered by the bootstrap analysis (2007 and pre-1990) and what to do about the survey samples. A possible solution is provided by noting the consistency of the ratios between the harmonic means (the raw harmonic means, not the rescaled harmonic means) and the actual sample sizes. These ratios are shown in Table 2.13f. For the years prior to 1999, the ratio is very consistently close to 0.16, and for the years after 1998, the ratio is very consistently close to 0.34. This consistency was used to specify the missing values as follows: For fishery data, the sample sizes for length compositions from years prior to 1999 were tentatively set at 16% of the actual sample size, and the sample sizes for length compositions from 2007 were tentatively set at 34% of the actual sample size. For the pre-1982 trawl survey, length compositions were tentatively set at 16% of an assumed sample size of 10,000. For the post-1981 trawl survey and IPHC survey length compositions, sample sizes were tentatively set at 34% of the actual sample size. Then, with sample sizes for fishery length compositions from 1990-2006 tentatively set at their bootstrap harmonic means (not rescaled), all sample sizes were adjusted proportionally so that the average was 300. The resulted in the set of multinomial sample sizes shown in Table 2.14.

Use of Age Composition Data in Parameter Estimation

Like the size composition data, the age composition data are assumed to be drawn from a multinomial distribution specific to a particular year, gear/fishery (in this case, the EBS shelf bottom trawl survey), and time period within the year (in this case, the June-August period). Input sample sizes for the multinomial distributions were computed by scaling the actual number of otoliths read in each year proportionally such that the average of the input sample sizes was equal to 300.

To avoid double counting of the same data, Models 1-3 ignore length composition data from the EBS shelf bottom trawl surveys in years where age data are available.

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

Fishery CPUE data are included in the models for comparative purposes only. Their respective catchabilities are estimated analytically, not statistically. The same is true for the relative abundance data from the IPHC longline survey.

For the trawl surveys, each year's survey abundance datum is assumed to be drawn from a lognormal distribution specific to that year. The model's estimate of survey abundance in a given year serves as the geometric mean for that year's lognormal distribution, and the ratio of the survey abundance datum's standard error to the survey abundance datum itself serves as the distribution's coefficient of variation.

Use of Recruitment Deviation "Data" in Parameter Estimation

The recruitment deviations likelihood component is different from traditional likelihoods because it does not involve "data" in the same sense that traditional likelihoods do. Instead, the log-scale recruitment deviation plays the role of the datum and the log-scale recruitment mean and σ_R play the role of the parameters in a normal distribution, but, of course, all of these are treated as parameters by SS2 (although σ_R is fixed).

MODEL EVALUATION

As described above, four models are evaluated in the present assessment. Briefly, Model 1 fixes *M* at a value of 0.34 based on life history theory, Model 2 fixes M at the traditional value of 0.37, Model 3 estimates *M* internally, and Model 4 differs with respect to the others in several ways.

All models appeared to converge successfully and the Hessian matrices from all models were positive definite. Once convergence appeared to be achieved, 50-100 additional runs were undertaken for each model with initial parameter values displaced from their converged values to provide additional assurance that another (better) solution did not exist.

Overall Conclusions Common to All Models

Before choosing a preferred model, it is important to note that, in many respects, the descriptions of the stock provided by all of the models are, qualitatively at least, very similar. For example, Figure 2.2 compares the time series of numbers of age 0 fish (on a log scale) as estimated by all four models. The models are mostly in agreement as to the strongest year classes in the time series, particularly the 1977 year class (Model 4, which does not start the time series until 1979, does not estimate the strength of the 1977 year class). Models 1-3 agree that the 2001-2005 year classes currently appear to be weak (Model 4 shows 2001 and 2003-4 to be weak, with 2002 and 2005 just slightly above average). Figure 2.3 compares the time series of female spawning biomass as estimated by all four models. The overall shapes of all the estimated time series are again qualitatively similar, with the main difference being one of scale. All models show spawning biomass to have declined overall since about 1985, with recent short-term decline starting in about 2005.

Comparing and Contrasting the Models

Tables 2.15a-c present summaries of some key results from the four models. In each row of these tables, the cell with the highest value is shaded green (light gray if the document is viewed in grayscale) and the cell with the lowest value is shaded pink (dark gray).

Table 2.15a is structured as follows:

> Section 1: Parameter counts. This section enumerates the number of parameters, both fixed and estimated, by type. The number of free parameters ranges from 112-118, while the number of total (fixed and free) parameters ranges from 145-156.

Section 2: Aggregate likelihood components. In general, lower values are better than higher values. However, note that Model 4 does not use two of the aggregate likelihood components (age compositions and initial catch) and uses a different data set than the other three models, so values are not strictly comparable across models.

Section 3: Relative abundance likelihoods. The only likelihoods that are actually used in this section are the trawl survey likelihoods (pre-1982 and post-1981 in Models 1-3, post-1981 only in Model 4). The others are shown for comparative purposes only.

Section 4: Size composition likelihoods. The aggregate size composition likelihood is broken down by individual fishery/season and gear.

Table 2.15b is structured as follows:

Section 1: Life history and recruitment. This section contains the natural mortality rate, parameters governing the length-at-age relationship and variability in length at age, mean length at age for the trawl survey as measured in July for ages 1-3, median recruitment, and standard deviation of log recruits. The natural mortality rate ranged from 0.22 (Model 3) to 0.46 (Model 4). The mean lengths at ages 1-3 are presented so that they can be compared with the first three modes from the long-term average trawl survey size composition, which occur at 17, 33, and 45 cm. The standard deviation of log recruits was fixed at 0.78 for Models 1-3, which is equal to the standard deviation of the estimated recruitment deviations from Model 1. The standard deviation of log recruits in Model 4 was fixed at 0.6.

Section 2: Catchability and selectivity. This section summarizes the estimated trawl survey catchabilities (on a log scale), the size/age at which selectivity first reaches a value of 1.0 and the selectivity at maximum size/age for each fishery/survey, and the average of the product of trawl survey catchability and trawl survey selectivity within the 60-81 cm range. Nichol et al. (2007) estimated that this quantity had an average value of 0.47 for 11 fish equipped with archival tags. For the four models, this quantity ranged from 0.56 (Model 1) to 1.08 (Model 3). Selectivities are also plotted for each fishery/season and survey for all four models in Figures 2.4a-d.

Table 2.15c is structured as follows:

Section 1: Examples of historical biomass. Because these are estimates rather than projections, and the data used in the model all pertain to the EBS rather than the BSAI, these values are for the EBS only. Total biomass, age 3+ biomass, and female spawning biomass are shown for three example years: 1977 (the starting year of all the models except Model 4), 1985 (the approximate year of peak spawning biomass in all of the models), and 2007 (the most recent year of data). In general, Model 1 tends to give the highest values and Model 3 the lowest.

Section 2: Projected biomass. These are projections for the overall BSAI stock. Total biomass, age 3+ biomass, and female spawning biomass are shown for 2008 and 2009. In general, Model 2 tends to give the highest values and Model 3 the lowest.

Section 3: Spawning biomass reference points. B100%, B40%, and B35% are shown, along with the projected ratios of female spawning biomass to B100% in 2008 and 2009. Model 3 gives the highest estimates of B100%, B40%, and B35% and Model 4 the lowest. Conversely, Model 3 gives the lowest ratios and Model 4 the highest.

Section 4: ABC reference points. F40%, FABC, ABC, and relative changes in ABC are shown for 2008 and 2009. For all of these quantities, Model 3 gives the lowest values and Model 4 the highest.

Section 5: OFL reference points. Analogous to the ABC reference points section.

Tables 2.16a-2.16c show the estimates and standard deviations for every parameter estimated by any of the models. A blank cell indicates that a parameter was fixed a priori, bound or had a high standard deviation (>10). Parameters that were bound or had high standard deviations were fixed and then removed from the estimation process. An entry of "n/a" means that a parameter is not applicable to a particular model.

Tables 2.17a and 2.17b provide alternative measures of how well the models are fitting the fishery CPUE and survey relative abundance data. Table 2.17a shows root mean squared errors (lower values are better) and Table 2.17b shows correlations between observed and estimated values. Generally, Models 1 and 3 give the lowest RMSEs and Model 4 the highest, while Model 3 gives the highest correlations and Models 2 and 4 the lowest. The correlations with the IPHC abundance data were particularly disappointing, with no model being able to achieve a correlation greater than -0.38. Figures 2.5a-d plot observed versus estimated CPUE and relative abundance for all fisheries/seasons and surveys under all four models.

Tables 2.18a and 2.18b provide alternative measures of how well the models are fitting the size composition data (higher values are better). Table 2.18a compares median input sample size to median output sample size ("effective" sample size McAllister and Ianelli 1997), and Table 2.18b shows the same thing, but using means rather than medians. Note that Model 4 uses a different data set than the other three models, so results are not strictly comparable across models. This caveat notwithstanding, Model 4 tended to have the highest effective sample sizes and Model 2 the lowest.

For age composition data, the following table summarizes the input and output sample sizes (Model 4 does not use age composition data):

Source:	Input	Model 1	Model 2	Model 3
Median:	309	123	111	157
Mean:	300	65	50	70

Evaluation Criteria

Because all of the models seem to perform reasonably well in terms of fitting the data, the following criteria are therefore proposed for this year's assessment:

1) The model should assume or estimate a reasonable value for *M*.
2) The model should estimate mean trawl survey lengths for ages 1-3 that are close to the first three modes from the long-term average trawl survey size composition.
3) The model should estimate a reasonable average for the product of trawl survey catchability and trawl survey selectivity for the 60-81 cm size range.

It should be understood that the above criteria are not proposed as absolutes, but rather as useful guidelines for the present assessment while model structure is being refined.

Selection of Final Model

Criterion #1 argues against choosing Models 3 or 4. If the life history theory published by Jensen (1996) and the age of maturity published by Stark (2007) are accurate, *M* should be close to be 0.34. The values of *M* estimated by Models 3 (0.22) and 4 (0.46) are sufficiently different from this value that they should not be adopted without further investigation. It may also be noted that the SSC has recently expressed skepticism about the traditional *M* of 0.37 (Model 2), suggesting that it should be included in the present assessment "purely for purposes of comparison."

Criterion #2 does not rule out any of the four models.

Criterion #3 favors Model 1. The estimate obtained by Nichol et al. (2007) is 0.47, and the value closest to that is obtained by Model 1. A bootstrap analysis of Nichol et al.'s data indicate that Model 1's estimate of 0.56 falls within the 95% confidence interval, but the other models' estimates do not.

By process of elimination, then, Model 1 is recommended as the preferred model.

Final Parameter Estimates and Associated Schedules

Final estimates of all statistically estimated parameters in Model 1 are shown in Tables 2.16a-c.

Estimates of year-, gear-, and season-specific fishing mortality rates from Model 1 are shown in Table 2.19.

Schedules of selectivity at length/age from Model 1 are shown in Table 2.20. As noted previously, these are plotted in Figure 2.4a.

Schedules of length at age and weight at age for the population, each fishery/season, and each survey from Model 1 are shown in Tables 2.21 and 2.22, respectively.

RESULTS

Definitions

The biomass estimates presented here will be defined in two ways: 1) age 3+ biomass, consisting of the biomass of all fish aged three 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. The fishing mortality rates presented here will be defined as full-selection, instantaneous fishing mortality rates expressed on a per annum scale.

Biomass

Table 2.23 shows the time series of EBS (not expanded to BSAI) Pacific cod female spawning biomass for the years 1977-2007 as estimated last year and this year under Model 1. Both estimated time series are accompanied by their respective 95% confidence intervals.

The estimated time series of EBS age 3+ biomass and female spawning biomass from Model 1 are shown, together with the observed time series of trawl survey biomass (assuming a catchability of 1.0), in Figure 2.6. All three biomass trends show a declining trend for at least the last three years.

Recruitment

Table 2.24 shows the time series of EBS (not expanded to BSAI) Pacific cod age 0 recruitment (1000s of fish) for the years 1977-2006 as estimated last year and this year under Model 1. Both estimated time series are accompanied by their respective 95% confidence intervals.

Model 1's recruitment estimates for the entire time series (1977-2006) are shown in Figure 2.7, along with their respective 95% confidence intervals and the average for the current environmental regime. For the time series as a whole, the largest year class appears to have been the 1977 cohort. Other large cohorts include the 1978, 1982, 1984, 1989, 1992, 1996, and 1999 year classes. Of the 2001-2005 year classes, however, none have 95% confidence intervals that extend above the 1977-2006 average. One potential bright spot on the horizon is the 2006 year class, whose point estimate is currently the second highest in the time series. However, its confidence interval is very large, since the only data currently available to estimate its strength is the size composition data from the 2007 shelf trawl survey.

To date, it has not been possible to estimate a reliable stock-recruitment relationship for this stock. With the move to SS2, prospects for future estimation of such a relationship should improve, and one of the models developed for this year's technical workshop (Thompson and Conners 2007) included internal estimation of a stock-recruitment relationship. In the interim, Figure 2.8 is provided to give some indication of the possible relationship between stock and recruitment. The Ricker (1954) curve shown in this figure (fit by maximum likelihood, ignoring process error) is intended to be illustrative only, and is not recommended for management purposes.

Exploitation

Table 2.25 shows the time series of EBS Pacific cod catch divided by age 3+ biomass for the years 1977-2007 as estimated last year and this year under Model 1.

Figure 2.9 plots the trajectory of relative fishing mortality and relative female spawning biomass from 1977 through 2007 based on Model 1, overlaid with the current harvest control rules (fishing mortality rates in the figure are standardized relative to $F_{35\%}$ and biomasses are standardized relative to $B_{35\%}$, per SSC request). The entire trajectory lies underneath the F_{OFL} control rule except for the years 1977-1978. For the period since 1979, the entire trajectory also fell below the $maxF_{ABC}$ control rule, except for 1997, when the fishing mortality rate appears to have exceeded the retroactively calculated $maxF_{ABC}$ by about 4% It should also be noted that the current harvest control rules did not go into effect until 1999.

PROJECTIONS AND HARVEST ALTERNATIVES

Amendment 56 Reference Points

Amendment 56 to the BSAI Groundfish Fishery Management Plan (FMP) defines the "overfishing level" (OFL), the fishing mortality rate used to set OFL (F_{OFL}), the maximum permissible ABC, and the fishing mortality rate used to set the maximum permissible ABC. The fishing mortality rate used to set ABC (F_{ABC}) may be less than this maximum permissible level, but not greater. Because reliable estimates of reference points related to maximum sustainable yield (MSY) are currently not available but reliable estimates of reference points related to spawning per recruit are available, Pacific cod in the BSAI are managed under Tier 3 of Amendment 56. Tier 3 uses the following reference points: $B_{40\%}$, equal to 40% of the equilibrium spawning biomass that would be obtained in the absence of fishing; $F_{35\%}$, equal to the fishing mortality rate that reduces the equilibrium level of spawning per recruit to 35% of the level that would be obtained in the absence of fishing; and $F_{40\%}$, equal to the fishing mortality rate that reduces the equilibrium level of spawning per recruit to 40% of the level that would be obtained in the absence of fishing. The following formulae apply under Tier 3:

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

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

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

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

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

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

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

$F_{OFL} = 0$

$F_{ABC} = 0$

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 1:

Reference point:	$B_{35\%}$	$B_{40\%}$	$B_{100\%}$
BSAI:	473,000 t	540,000 t	1,350,000 t
EBS:	397,000 t	454,000 t	1,130,000 t

For a stock exploited by multiple gear types, estimation of $F_{35\%}$ and $F_{40\%}$ requires an assumption regarding the apportionment of fishing mortality among those gear types. For this assessment, the apportionment was based on Model 1's estimates of fishing mortality by gear for the five most recent complete years of data (2001-2006). 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 28.1%, longline 60.7%, and pot 0.112%. This apportionment results in estimates of $F_{35\%}$ and $F_{40\%}$ equal to 0.37 and 0.31, respectively.

Specification of OFL and Maximum Permissible ABC

BSAI spawning biomass for 2008 is estimated by Model 1 at a value of 398,000 t. This is about 11% below the BSAI $B_{40\%}$ value of 540,000 t, thereby placing Pacific cod in sub-tier "b" of Tier 3. Given this, Model 1 estimates OFL, maximum permissible ABC, and the associated fishing mortality rates for 2007 and 2008 as follows:

Quantity	Overfishing Level	Maximum Permissible ABC
2008 BSAI catch:	176,000 t	150,000 t
2009 BSAI catch	190,000 t	162,000 t
2008 Fishing mortality:	0.26	0.22
2009 Fishing mortality:	0.26	0.22

The age 3+ biomass estimates for 2008 and 2009 from Model 1 are 1,080,000 t and 1,420,000 t.

ABC Recommendation

Review of Past Approaches

BSAI Pacific cod ABCs for the years 1998-2002 were based on a harvest strategy that attempted to address some of the statistical uncertainty in the assessment model, namely the uncertainty surrounding parameters the natural mortality rate M and survey catchability Q (Thompson and Dorn 1997, 1998, 1999). For the 2001-2002 ABCs, the strategy was simplified by assuming that the ratio between the recommended F_{ABC} and $F_{40\%}$ estimate given in the 1999 assessment (0.87) was an appropriate factor by which to multiply the current maximum permissible F_{ABC} to obtain a recommended F_{ABC} (Thompson and Dorn 2001). For the 2003 and 2004 ABCs, concerns regarding the performance of the assessment model led to a decision that kept ABC constant at the 2002 level of 223,000 t, well below the maximum permissible level estimated in the respective assessments (Thompson and Dorn 2002, 2003). In the 2004 assessment (Thompson and Dorn 2004), the maximum permissible value for the 2005 ABC was estimated to be 227,000 t, only slightly higher than the 2003-2004 ABCs of 223,000 t. Because the 2003-2004 "constant catch" ABCs were intended to provide a precautionary alternative to the model's maximum permissible ABCs, it seemed appropriate in the 2004 assessment to consider another method for recommending ABC. This method was based on a consideration of the mean-variance tradeoff associated with future catches predicted by the standard projection model, and resulted in a 2005 ABC of 206,000 t. In the 2005 assessment, the Plan Team and SSC selected a model that resulted in a maximum permissible ABC of 194,000 t, which was adopted as the 2006 ABC. Similarly, the maximum permissible ABC was selected in the 2006 assessment, giving an ABC of 176,000 t.

Recommendation for 2008

Based on Model 1, the maximum permissible ABC (Tier 3b) for 2008 is 150,000 t. This would constitute a 15% decrease from the 2007 value of 176,000, roughly paralleling the decrease in the trawl survey biomass estimate of 18%. Because the stock is in Tier 3b, added precaution is already built into the maximum ABC computation. Therefore, 150,000 t is the recommended ABC for 2008. For comparison, a Tier 5 computation (using a BSAI biomass estimate of 516,000 t based on the most recent EBS and AI bottom trawl surveys) would set the maximum permissible 2008 ABC at 132,000 t if M is assumed to be 0.34 and 143,000 t if M is assumed to be 0.37.

Area Allocation of Harvests

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

Standard Harvest and Recruitment Scenarios and Projection Methodology

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

For each scenario, the projections begin with an estimated vector of 2007 numbers at age. This vector is then projected forward to the beginning of 2008 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2007. In each subsequent year, the fishing mortality rate is prescribed on the basis of the spawning biomass in that year and the respective harvest scenario. In each year, recruitment is drawn from an inverse Gaussian distribution whose parameters consist of maximum likelihood estimates determined from recruitments estimated in the assessment. Spawning biomass is computed in each year based on the time of peak spawning and the maturity and weight schedules described in the assessment. Total catch is assumed to equal the catch associated with the respective harvest scenario in all years. This projection scheme is run 1000 times to obtain distributions of possible future stock sizes, fishing mortality rates, and catches.

Five of the seven standard scenarios will be used in an Environmental Assessment prepared in conjunction with the final SAFE. These five scenarios, which are designed to provide a range of harvest alternatives that are likely to bracket the final TAC for 2008, are as follow ("*max* F_{ABC}" refers to the maximum permissible value of F_{ABC} under Amendment 56):

> *Scenario 1*: In all future years, F is set equal to *max* F_{ABC}. (Rationale: Historically, TAC has been constrained by ABC, so this scenario provides a likely upper limit on future TACs.)
>
> *Scenario 2*: In all future years, F is set equal to a constant fraction of *max* F_{ABC}, where this fraction is equal to the ratio of the F_{ABC} value for 2007 recommended in the assessment to the *max* F_{ABC} for 2007. (Rationale: When F_{ABC} is set at a value below *max* F_{ABC}, it is often set at the value recommended in the stock assessment.)
>
> *Scenario 3*: In all future years, 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 4*: In all future years, F is set equal to the 2002-2006 average F. (Rationale: For some stocks, TAC can be well below ABC, and recent average F may provide a better indicator of F_{TAC} than F_{ABC}.)

Scenario 5: In all future years, F is set equal to zero. (Rationale: In extreme cases, TAC may be set at a level close to zero.)

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

Scenario 6: In all future years, F is set equal to F_{OFL}. (Rationale: This scenario determines whether a stock is overfished. If the stock is expected to be 1) above its MSY level in 2008 or 2) above ½ of its MSY level in 2008 and above its MSY level in 2018 under this scenario, then the stock is not overfished.)

Scenario 7: In 2008 and 2009, 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 2020 under this scenario, then the stock is not approaching an overfished condition.)

Projections and Status Determination

Scenario Projections and Two-Year Ahead Overfishing Level

Projections corresponding to the standard scenarios are shown for Model 1 in Tables 2.26-2.31 (Table 2.26 combines scenarios 1 and 2, which are redundant).

In addition to the seven standard harvest scenarios, Amendments 48/48 to the BSAI and GOA Groundfish Fishery Management Plans require projections of the likely OFL two years into the future. While Scenario 6 gives the best estimate of OFL for 2008, it does not provide the best estimate of OFL for 2009, because the mean 2008 catch under Scenario 6 is predicated on the 2008 catch being equal to the 2008 OFL, whereas the actual 2008 catch will likely be less than the 2008 OFL. Table 2.15c contains the appropriate one- and two-year ahead projections for both ABC and OFL under any of the four models considered in the present assessment.

Status Determination

Harvest Scenarios #6 and #7 are intended to permit determination of the status of a stock with respect to its minimum stock size threshold (MSST). Any stock that is below its MSST is defined to be *overfished*. Any stock that is expected to fall below its MSST in the next two years is defined to be *approaching* an overfished condition. Harvest Scenarios #6 and #7 are used in these determinations as follows:

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

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

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

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

Is the stock approaching an overfished condition? This is determined by referring to harvest Scenario #7 (Table 2.31):

a. If the mean spawning biomass for 2010 is below ½ $B_{35\%}$, the stock is approaching an overfished condition.

b. If the mean spawning biomass for 2010 is above $B_{35\%}$, the stock is not approaching an overfished condition.

c. If the mean spawning biomass for 2010 is above ½ $B_{35\%}$ but below $B_{35\%}$, the determination depends on the mean spawning biomass for 2020. If the mean spawning biomass for 2020 is below $B_{35\%}$, the stock is approaching an overfished condition. Otherwise, the stock is not approaching an overfished condition.

Based on the above criteria and Tables 2.30 and 2.31, the stock is not overfished and is not approaching an overfished condition.

ECOSYSTEM CONSIDERATIONS

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

Ecosystem Effects on the Stock

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

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

Fishery Effects on the Ecosystem

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

Bycatch of Nontarget and "Other" Species

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

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

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

Steller Sea Lions

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

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

Seabirds

The following is a summary of information provided by Livingston (ed., 2002): In both the BSAI and GOA, the northern fulmar (*Fulmarus glacialis*) comprises the majority of seabird bycatch, which occurs primarily in the longline fisheries, including the hook and line fishery for Pacific cod (Tables 2.33b and 2.36b). Shearwater (*Puffinus* spp.) distribution overlaps with the Pacific cod longline fishery in the Bering Sea, and with trawl fisheries in general in both the Bering Sea and GOA. Black-footed albatross

(*Phoebastria nigripes*) is taken in much greater numbers in the GOA longline fisheries than the Bering Sea longline fisheries, but is not taken in the trawl fisheries. The distribution of Laysan albatross (*Phoebastria immutabilis*) appears to overlap with the longline fisheries in the central and western Aleutians. The distribution of short-tailed albatross (*Phoebastria albatrus*) also overlaps with the Pacific cod longline fishery along the Aleutian chain, although the majority of the bycatch has taken place along the northern portion of the Bering Sea shelf edge (in contrast, only two takes have been recorded in the GOA). Some success has been obtained in devising measures to mitigate fishery-seabird interactions. For example, on vessels larger than 60 ft. LOA, paired streamer lines of specified performance and material standards have been found to reduce seabird incidental take significantly.

Fishery Usage of Habitat

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

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

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

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

Data Gaps and Research Priorities

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

SUMMARY

The major results of the Pacific cod stock assessment are summarized in Table 2.38.

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

Eastern Bering Sea only:

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

Table 2.1b—Summary of 1981-2007 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 2007 are through early October.

Eastern Bering Sea only:

	Foreign			Joint Venture		Domestic Annual Processing					
Year	Trawl	LLine	Subt.	Trawl	Subt.	Trawl	LLine	Pot	Other	Subt.	Total
1981	30347	5851	36198	7410	7410	12884	1	0	14	12899	56507
1982	23037	3142	26179	9312	9312	23893	5	0	1715	25613	61104
1983	32790	6445	39235	9662	9662	45310	4	21	569	45904	94801
1984	30592	26642	57234	24382	24382	43274	8	0	205	43487	125103
1985	19596	36742	56338	35634	35634	51425	50	0	0	51475	143447
1986	13292	26563	39855	57827	57827	37646	48	62	167	37923	135605
1987	7718	47028	54746	47722	47722	46039	1395	1	0	47435	149903
1988	0	0	0	106592	106592	93706	2474	299	0	96479	203071
1989	0	0	0	44612	44612	119631	13935	145	0	133711	178323
1990	0	0	0	8078	8078	115493	47114	1382	0	163989	172067
1991	0	0	0	0	0	129392	76734	3343	0	209469	209469
1992	0	0	0	0	0	77259	80174	7512	33	164978	164978
1993	0	0	0	0	0	81790	49295	2098	2	133185	133185
1994	0	0	0	0	0	84931	78566	8037	730	172264	172264
1995	0	0	0	0	0	110956	97665	19275	599	228496	228496
1996	0	0	0	0	0	91910	88882	28006	267	209064	209064
1997	0	0	0	0	0	93924	117008	21493	173	232598	232598
1998	0	0	0	0	0	60780	84323	13232	192	158526	158526
1999	0	0	0	0	0	51902	81463	12399	100	145865	145865
2000	0	0	0	0	0	53815	81640	15849	68	151372	151372
2001	0	0	0	0	0	35655	90360	16385	52	142452	142452
2002	0	0	0	0	0	51065	100269	15051	166	166552	166552
2003	0	0	0	0	0	47580	106967	21957	155	176659	176659
2004	0	0	0	0	0	57784	109692	17238	231	184945	184945
2005	0	0	0	0	0	52604	112994	17104	104	182807	182807
2006	0	0	0	0	0	53202	95485	18957	81	167725	167725
2007	0	0	0	0	0	45107	74338	16903	82	136430	136430

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 1981-2007 catches (t) of Pacific cod in the Aleutian Islands region by fleet sector and gear type. All catches include discards. LLine = longline, Subt. = sector subtotal. Catches for 2007 are through early October.

Aleutian Islands region only:

	Foreign			Joint Venture		Domestic Annual Processing					
Year	Trawl	LLine	Subt.	Trawl	Subt.	Trawl	LLine	Pot	Other	Subt.	Total
1981	2680	235	2915	1749	1749	2744	26	0	0	2770	7434
1982	1520	476	1996	4280	4280	2121	0	0	0	2121	8397
1983	1869	402	2271	4700	4700	1459	0	0	0	1459	8430
1984	473	804	1277	6390	6390	314	0	0	0	314	7981
1985	10	829	839	5638	5638	460	0	0	0	460	6937
1986	5	0	5	6115	6115	784	1	1	0	786	6906
1987	0	0	0	10435	10435	2662	22	88	0	2772	13207
1988	0	0	0	3300	3300	1698	137	30	0	1865	5165
1989	0	0	0	6	6	4233	284	19	0	4536	4542
1990	0	0	0	0	0	6932	602	7	0	7541	7541
1991	0	0	0	0	0	3414	3203	3180	0	9797	9797
1992	0	0	0	0	0	14558	22108	6317	84	43068	43068
1993	0	0	0	0	0	17312	16860	0	33	34204	34204
1994	0	0	0	0	0	14382	7009	147	0	21539	21539
1995	0	0	0	0	0	10574	4935	1024	0	16534	16534
1996	0	0	0	0	0	21179	5819	4611	0	31609	31609
1997	0	0	0	0	0	17349	7151	575	89	25164	25164
1998	0	0	0	0	0	20531	13771	424	0	34726	34726
1999	0	0	0	0	0	16437	7874	3750	69	28130	28130
2000	0	0	0	0	0	20362	16183	3107	33	39684	39684
2001	0	0	0	0	0	15826	17817	544	19	34207	34207
2002	0	0	0	0	0	27929	2865	7	0	30801	30801
2003	0	0	0	0	0	31478	974	2	0	32455	32455
2004	0	0	0	0	0	25766	3099	0	0	28865	28865
2005	0	0	0	0	0	19613	3001	0	13	22627	22627
2006	0	0	0	0	0	20054	3552	567	8	24181	24181
2007	0	0	0	0	0	28456	4635	626	7	33724	33724

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

Eastern Bering Sea and Aleutian Islands region combined:

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

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

Eastern Bering Sea and Aleutian Islands region combined:

	Foreign			Joint Venture		Domestic Annual Processing					
Year	Trawl	LLine	Subt.	Trawl	Subt.	Trawl	LLine	Pot	Other	Subt.	Total
1981	33027	6086	39113	9159	9159	15628	27	0	14	15669	63941
1982	24557	3618	28175	13592	13592	26014	5	0	1715	27734	69501
1983	34659	6847	41506	14362	14362	46769	4	21	569	47363	103231
1984	31065	27446	58511	30772	30772	43588	8	0	205	43801	133084
1985	19606	37571	57177	41272	41272	51885	50	0	0	51935	150384
1986	13297	26563	39860	63942	63942	38430	49	63	167	38709	142511
1987	7718	47028	54746	58157	58157	48701	1417	89	0	50207	163110
1988	0	0	0	109892	109892	95404	2611	329	0	98344	208236
1989	0	0	0	44618	44618	123864	14219	164	0	138247	182865
1990	0	0	0	8078	8078	122425	47716	1389	0	171530	179608
1991	0	0	0	0	0	132806	79937	6523	0	219266	219266
1992	0	0	0	0	0	91818	102282	13829	117	208046	208046
1993	0	0	0	0	0	99102	66155	2098	35	167389	167389
1994	0	0	0	0	0	99313	85575	8184	730	193802	193802
1995	0	0	0	0	0	121530	102600	20299	599	245029	245029
1996	0	0	0	0	0	113089	94701	32617	267	240673	240673
1997	0	0	0	0	0	111273	124159	22068	262	257762	257762
1998	0	0	0	0	0	81310	98094	13657	192	193253	193253
1999	0	0	0	0	0	68339	89337	16150	169	173995	173995
2000	0	0	0	0	0	74177	97823	18956	101	191056	191056
2001	0	0	0	0	0	51482	108177	16929	71	176659	176659
2002	0	0	0	0	0	78994	103134	15058	166	197352	197352
2003	0	0	0	0	0	79059	107941	21959	156	209114	209114
2004	0	0	0	0	0	83550	112790	17239	231	213810	213810
2005	0	0	0	0	0	72217	115995	17104	117	205434	205434
2006	0	0	0	0	0	73256	99037	19524	89	191906	191906
2007	0	0	0	0	0	73564	78973	17529	88	170154	170154

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

Year	ABC	TAC	Catch	Stock assessment model (from previous year)
1980	148,000	70,700	45,947	projection of 1979 survey numbers at age
1981	160,000	78,700	63,941	projection of 1979 survey numbers at age
1982	168,000	78,700	69,501	projection of 1979 survey numbers at age
1983	298,200	120,000	103,231	projection of 1979 survey numbers at age
1984	291,300	210,000	133,084	projection of 1979 survey numbers at age
1985	347,400	220,000	150,384	projection of 1979-1985 survey numbers at age
1986	249,300	229,000	142,511	separable age-structured model
1987	400,000	280,000	163,110	separable age-structured model
1988	385,300	200,000	208,236	separable age-structured model
1989	370,600	230,681	182,865	separable age-structured model
1990	417,000	227,000	179,608	separable age-structured model
1991	229,000	229,000	219,266	separable age-structured model
1992	182,000	182,000	208,046	SS1 model (age-based data)
1993	164,500	164,500	167,389	SS1 model (length-based data)
1994	191,000	191,000	193,802	SS1 model (length-based data)
1995	328,000	250,000	245,029	SS1 model (length-based data)
1996	305,000	270,000	240,673	SS1 model (length-based data)
1997	306,000	270,000	257,762	SS1 model (length-based data)
1998	210,000	210,000	193,253	SS1 model (length-based data)
1999	177,000	177,000	173,995	SS1 model (length-based data)
2000	193,000	193,000	191,056	SS1 model (length-based data)
2001	188,000	188,000	176,659	SS1 model (length-based data)
2002	223,000	200,000	197,352	SS1 model (length-based data)
2003	223,000	207,500	209,114	SS1 model (length-based data)
2004	223,000	215,500	213,810	SS1 model (length-based data)
2005	206,000	206,000	164,404	SS1 model (length- and age-based data)
2006	194,000	194,000	191,906	SS2 model (length- and age-based data)
2007	176,000	170,720	170,154	SS2 model (length- and age-based data)

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

Eastern Bering Sea

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

Aleutian Islands

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

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

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

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

Year	Trawl Fishery			Longline Fishery			Pot Fishery		
	Sea. 1	Sea. 2	Sea. 3	Sea. 1	Sea. 2	Sea. 3	Sea. 1	Sea. 2	Sea. 3
1977	14935	6139	6858	1851	260	3292	0	0	0
1978	19710	8101	9051	2443	343	4344	0	0	0
1979	16131	6630	7407	1999	281	3555	0	0	0
1980	18387	7558	8444	2279	320	4053	0	0	0
1981	15067	14087	21486	1286	624	3942	0	0	0
1982	21742	18151	16348	363	475	2308	0	0	0
1983	40757	24300	22705	2941	748	2756	0	0	0
1984	48237	24964	25045	5012	2128	19508	0	0	0
1985	55673	28673	22310	13703	1710	21379	0	0	0
1986	59786	26598	22382	8895	438	17278	0	0	0
1987	64413	15604	21462	20947	723	26752	0	0	0
1988	127470	25662	47166	444	646	1385	90	51	160
1989	127459	16986	19798	3810	4968	5157	33	63	49
1990	101645	11402	10524	13171	16643	17299	0	986	395
1991	107979	15549	5863	25470	21472	29792	12	1042	2288
1992	59460	11840	5959	49696	24201	6276	2622	4632	258
1993	67148	5362	9280	49244	27	23	2073	24	0
1994	61009	5806	18115	57968	13	20585	4923	0	3113
1995	90366	8543	12047	68458	26	29180	12484	3469	3322
1996	78194	3126	10590	62011	26	26845	18143	6401	3462
1997	81313	3927	8684	70676	43	46290	14584	3576	3333
1998	45008	5603	10169	54234	18	30071	9022	2779	1432
1999	44904	3312	3686	55180	1923	24360	9346	1001	2052
2000	44508	4578	4730	40180	1375	40086	15742	0	107
2001	22849	7025	5781	38368	6700	45291	11645	442	4298
2002	37008	9554	4503	50024	12132	38113	10852	401	3799
2003	34515	9986	3079	53156	11032	42773	15452	74	6586
2004	42181	12407	3197	56050	10459	43183	12560	521	4388
2005	45014	6664	926	53556	12773	46665	12147	0	4957
2006	46045	6124	1033	51079	14598	29808	14265	0	4692
2007	35403	8753	1033	44206	12810	29808	12256	18	4692

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

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1978	0	0	0	1	1	0	1	0	3	16	19	73	220	103	29	19	13	4	5	4	0	1	2	0	0
1979	0	0	0	0	0	0	1	21	45	94	204	315	329	77	122	147	144	37	5	4	3	1	1	0	0
1980	0	0	0	0	0	0	2	36	75	235	635	1014	1560	1038	971	714	497	632	485	197	86	49	17	5	2
1982	0	0	0	0	0	2	1	6	58	113	64	73	294	386	518	729	731	534	241	104	51	41	21	3	3
1983	0	0	0	0	0	1	1	50	154	93	95	176	492	758	1626	2344	2071	1307	644	211	77	36	21	12	6
1984	0	1	2	1	0	15	194	401	367	220	105	223	709	779	1264	2262	3195	2930	2027	1039	434	144	24	13	2
1985	0	0	2	0	4	0	2	39	116	257	720	1752	2234	1079	1388	2440	4999	5563	4288	2630	1385	594	221	67	23
1986	0	4	16	8	34	60	118	249	635	761	683	783	2228	3560	3287	2095	2631	3469	3357	2442	1346	454	168	58	17
1987	0	0	3	13	15	58	192	440	477	592	1161	2054	3898	2890	3326	5470	5461	4306	3650	3106	1953	1076	440	198	63
1988	1	0	1	1	6	29	92	580	1448	1956	2185	4311	11135	10599	10194	9103	10096	12012	10395	5807	3010	1686	814	346	92
1989	0	0	3	3	1	0	28	217	494	795	720	954	3110	4341	4654	5664	7033	8561	8246	6265	3826	1867	919	388	144
1990	0	0	0	0	0	11	93	214	284	269	232	203	416	853	1482	2458	3274	3396	3059	2109	1365	738	424	161	52
1991	0	0	0	0	0	14	128	335	393	367	389	604	2129	2128	1770	2416	3307	3528	3007	2104	1371	761	403	192	66
1992	0	0	0	0	0	9	52	156	323	382	568	1077	2241	1742	1545	1531	1753	1532	1384	1024	682	409	230	102	44
1993	0	0	0	0	0	10	93	428	617	658	1718	2987	4493	3792	3576	2542	1640	1288	1041	759	505	316	182	78	35
1994	0	0	0	0	0	13	136	457	789	664	398	626	2039	2917	2912	2322	2297	1901	1170	699	424	240	140	69	34
1995	0	0	0	0	0	20	71	127	163	303	1181	2663	4198	2714	3176	3669	3894	3045	1763	1022	624	345	175	92	32
1996	0	0	0	0	0	7	76	224	277	232	232	507	1862	3157	2940	2095	2323	2488	1957	1292	733	441	227	116	59
1997	0	0	0	0	0	8	76	296	564	574	439	503	1842	2099	2798	3872	3840	2762	1612	1010	641	342	169	75	31
1998	0	0	0	0	0	11	106	204	191	144	125	191	697	831	920	1389	1982	2110	1283	646	312	183	102	45	20
1999	1	0	0	0	0	1	36	143	134	119	347	847	1669	1011	1038	1292	1673	1697	1218	781	384	190	77	36	17
2000	0	0	0	0	0	1	21	61	54	83	180	336	950	1383	1491	1376	1361	1405	1104	761	466	259	135	63	28
2001	0	0	0	0	0	1	3	10	29	54	37	59	306	487	646	918	972	783	497	358	215	137	61	30	13
2002	0	0	0	0	0	4	34	148	255	253	221	261	749	860	906	1494	1912	1672	959	440	211	97	45	19	10
2003	0	0	0	0	0	0	3	31	95	128	139	246	670	703	760	989	1290	1466	1049	622	308	130	58	27	10
2004	0	0	0	0	0	2	3	32	122	196	194	186	799	1329	1487	1739	1760	1393	946	590	315	190	111	62	26
2005	0	0	0	0	0	2	7	52	120	162	147	140	461	756	1118	1584	1958	1796	1139	728	404	232	108	44	16
2006	0	0	0	0	0	1	5	28	91	147	161	176	582	882	992	1186	1473	1570	1299	952	578	290	133	39	25
2007	0	1	2	8	13	28	56	151	231	283	384	440	1196	1843	2275	3112	3013	2579	2083	1633	1073	655	358	132	55

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

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1977	0	0	0	0	0	0	0	0	6	12	22	39	40	273	331	367	355	188	104	38	12	3	2	0	0
1981	0	0	0	1	2	3	10	71	398	675	423	365	1109	1006	448	152	34	13	1	0	0	0	0	0	0
1983	0	0	0	0	0	1	0	1	4	15	42	71	77	81	200	284	248	186	83	28	6	3	4	0	0
1984	0	1	4	51	201	206	313	556	455	357	339	305	679	695	891	1109	959	817	597	453	312	120	41	8	1
1985	0	0	0	0	0	0	0	3	24	74	68	119	404	256	66	35	39	58	46	23	9	5	7	2	1
1986	0	0	0	0	0	0	7	2	2	3	5	7	15	62	92	72	67	95	98	84	46	30	8	4	0
1987	0	0	0	0	0	1	2	5	9	4	8	22	116	204	333	592	974	1093	720	525	385	248	133	68	25
1991	2	0	0	0	0	2	11	15	24	43	37	54	237	258	411	444	435	467	409	362	252	142	30	6	9
1997	0	0	0	0	0	0	2	0	0	2	5	5	45	167	229	219	283	167	67	27	12	2	0	0	0
1998	0	0	0	0	0	0	0	1	36	70	82	54	127	282	351	324	252	165	110	46	15	12	6	12	8
2001	0	0	0	0	0	0	0	2	11	27	53	65	151	337	356	301	313	226	115	58	61	31	33	15	2
2002	0	0	0	0	0	0	2	2	8	40	155	227	306	505	667	480	356	210	171	128	59	37	18	9	2
2003	0	0	0	0	0	0	1	2	4	19	34	51	141	324	345	361	401	336	267	192	110	45	16	8	3
2004	0	0	0	0	0	1	2	5	5	12	9	27	92	193	291	355	333	289	289	283	215	130	69	25	5
2005	0	0	0	0	0	0	1	0	4	12	38	72	97	124	154	167	173	165	175	150	97	66	37	12	4
2006	0	0	0	0	0	0	4	9	20	44	48	64	129	156	128	126	112	90	89	128	133	101	32	12	2
2007	0	0	0	0	1	4	9	16	83	168	132	118	309	334	386	303	182	95	59	33	23	13	12	2	0

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

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

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

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1978	0	0	0	0	0	0	0	0	1	4	23	124	623	812	435	269	216	160	110	58	36	7	7	0	0
1979	0	0	0	0	0	0	0	8	83	377	683	434	337	1135	2126	2432	1356	465	233	128	56	27	3	6	0
1980	0	0	0	0	0	0	0	0	5	15	66	212	591	604	320	182	199	244	111	36	11	4	0	0	0
1981	0	0	0	0	5	18	7	7	10	0	18	48	285	496	448	335	197	153	89	70	36	9	4	0	0
1982	0	0	0	0	0	0	0	1	0	9	13	18	131	184	266	334	314	211	101	61	44	31	10	1	1
1983	0	0	0	0	0	0	0	0	3	16	48	170	1116	1525	2035	2732	3421	3065	1838	792	334	163	88	36	7
1984	0	0	0	0	0	1	0	6	19	40	41	46	416	800	1323	2414	3163	3015	2012	1015	437	155	70	24	6
1985	0	0	0	0	0	0	0	1	12	34	186	550	1367	958	1828	3877	7018	8009	5977	3362	1591	537	175	44	7
1986	0	0	0	0	0	0	0	8	30	81	121	385	1765	3055	3578	3014	3739	5900	5622	3348	1554	654	237	63	13
1987	0	0	0	0	0	2	0	5	18	88	425	1362	4950	5219	8337	14661	16709	12862	11421	9132	4689	1828	519	180	31
1990	0	0	0	0	0	0	0	0	0	0	1	2	20	100	221	377	480	420	342	230	174	107	67	31	11
1991	0	0	0	0	0	0	0	0	1	3	12	32	109	249	502	912	1150	978	700	406	248	137	84	33	14
1992	0	0	0	0	0	0	0	4	7	24	96	256	869	1282	1329	1601	1886	1639	1158	837	528	307	165	75	25
1993	0	0	0	0	0	0	2	9	21	49	167	369	1080	2056	2763	2413	1688	1280	946	692	425	229	98	49	12
1994	0	0	0	0	0	0	2	3	9	20	54	144	733	1845	3065	3958	3309	1817	850	485	294	186	91	46	15
1995	0	0	0	0	0	0	2	3	8	27	159	456	1231	2085	3529	4520	4244	2616	1121	443	214	111	54	28	13
1996	0	0	0	0	0	0	0	2	6	18	62	181	996	2224	2991	3323	3131	2280	1335	655	297	146	82	36	16
1997	0	0	0	0	0	0	1	2	10	24	62	190	970	2005	3472	4601	4086	2399	1243	658	376	172	71	25	10
1998	0	0	0	0	0	0	0	4	16	34	88	253	843	1395	2048	2946	3141	2307	1196	518	233	125	52	18	8
1999	0	0	0	0	0	0	1	5	12	45	261	775	1824	1807	2111	2533	2483	2089	1308	679	291	139	59	29	18
2000	1	0	0	0	0	0	1	4	12	45	154	364	1510	2476	2555	2115	1736	1219	708	361	176	72	36	14	4
2001	0	0	0	0	0	1	2	6	23	67	98	203	909	1761	2404	2672	2095	1110	545	274	136	73	33	16	7
2002	0	0	0	0	0	2	5	25	57	89	255	641	1465	1704	2443	3386	3031	1836	722	300	133	77	55	12	6
2003	0	0	0	0	0	0	2	8	46	107	290	704	2109	3046	3153	2909	2552	1841	937	414	150	61	24	10	3
2004	0	0	0	0	0	0	7	15	23	45	84	233	1128	2541	3874	4240	2951	1562	801	422	183	76	34	13	4
2005	0	0	0	0	0	0	1	7	21	49	128	274	931	1516	2204	3184	3467	2395	947	380	182	73	28	9	2
2006	0	0	0	0	0	0	0	3	10	31	70	146	750	1880	2391	2453	2317	1988	1335	650	248	101	38	11	4
2007	0	0	0	0	0	1	2	6	16	32	138	372	1824	3744	6435	8854	7325	5413	3711	2466	1323	519	195	79	34

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

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1978	0	0	0	0	0	0	0	0	0	0	3	2	78	444	1093	783	436	328	170	64	30	6	1	1	0
1979	0	0	0	0	0	0	0	0	2	14	49	90	155	93	302	604	628	274	74	33	14	3	3	0	0
1980	0	0	0	0	0	0	0	0	0	0	1	29	169	334	293	185	148	140	67	17	4	2	0	0	0
1981	0	0	0	0	0	0	0	0	2	1	8	29	88	160	265	292	228	108	35	32	24	3	1	0	0
1982	0	0	0	0	0	0	0	0	0	9	42	17	98	190	128	161	130	117	74	38	11	5	3	2	0
1983	0	0	0	0	0	0	0	0	1	2	14	13	91	319	383	504	623	675	505	355	150	50	18	10	0
1984	0	0	0	0	0	2	0	0	2	7	14	17	102	376	750	1602	2167	1873	1405	891	567	203	59	16	3
1985	0	0	0	0	0	0	0	0	0	1	3	28	246	368	206	418	775	1000	823	590	429	245	105	23	2
1986	0	0	0	0	0	0	0	0	0	0	0	1	15	94	247	306	175	162	205	104	60	24	13	0	0
1990	0	0	0	0	0	0	0	0	1	3	6	11	35	106	263	439	574	560	462	332	227	149	97	39	14
1991	0	0	0	0	0	0	0	0	0	1	2	8	43	124	266	466	614	690	629	513	357	191	109	49	18
1992	0	0	0	0	0	0	0	1	5	12	32	63	320	643	671	729	793	685	515	411	317	219	136	74	25
1999	0	0	0	0	0	0	0	0	0	0	2	6	44	88	75	74	76	66	45	32	19	10	4	2	1
2000	0	0	0	0	0	0	0	0	0	0	0	1	9	26	54	85	65	45	31	22	11	7	3	1	0
2001	0	0	0	0	0	0	0	1	2	6	13	27	106	260	374	417	410	285	116	50	23	12	7	2	1
2002	0	0	0	0	0	0	0	4	10	24	42	81	328	578	653	664	646	447	260	115	49	26	13	7	1
2003	0	0	0	0	0	0	0	1	3	9	25	60	248	541	674	636	538	403	219	116	51	21	9	3	1
2004	0	0	0	0	0	0	0	0	1	2	4	17	91	247	457	564	531	399	236	156	80	36	13	5	1
2005	0	0	0	0	0	0	0	0	1	2	9	20	100	208	320	415	507	496	390	257	142	78	29	8	2
2006	0	0	0	0	0	0	0	0	0	1	9	27	106	257	403	419	422	363	329	317	243	150	72	27	7
2007	1	0	0	0	0	0	0	0	0	0	5	25	208	677	954	1229	1183	917	560	557	452	336	177	73	13

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

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

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

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1992	0	0	0	0	0	0	0	0	0	0	1	2	12	33	42	75	121	108	69	42	27	16	9	4	1
1993	0	0	0	0	0	0	0	0	0	0	0	2	14	33	59	86	87	76	53	32	20	12	5	2	1
1994	0	0	0	0	0	0	0	0	0	0	1	7	38	136	216	225	223	175	118	60	34	20	12	5	1
1995	0	0	0	0	0	0	0	0	0	0	4	19	96	224	493	713	642	452	261	150	88	50	19	10	4
1996	0	0	0	0	0	0	0	1	1	4	8	20	145	430	717	818	838	679	408	237	132	81	44	19	7
1997	0	0	0	0	0	0	0	0	1	2	5	10	70	204	450	805	882	551	298	159	88	60	32	14	7
1998	0	0	0	0	0	0	0	0	0	0	1	7	60	126	186	391	506	440	261	114	44	25	11	5	4
1999	0	0	0	0	0	0	0	0	0	1	2	15	126	198	294	442	456	385	240	123	59	33	11	7	3
2000	0	0	0	0	0	0	0	0	0	0	3	27	226	526	774	766	654	613	362	209	94	42	21	8	3
2001	0	0	0	0	0	0	0	0	1	1	4	6	69	218	514	896	840	428	171	72	38	22	9	5	2
2002	0	0	0	0	0	0	0	0	0	0	2	5	45	179	421	785	768	458	187	65	31	17	9	3	3
2003	0	0	0	0	0	0	0	1	1	3	4	23	115	292	498	735	880	732	394	189	78	29	9	4	2
2004	0	0	0	0	0	2	2	5	6	4	5	9	113	368	613	745	684	461	250	142	52	31	14	6	2
2005	0	0	0	0	0	0	0	0	1	0	4	8	51	194	473	725	698	488	238	121	63	47	22	7	1
2006	0	0	0	0	0	0	0	0	0	1	1	2	66	274	577	799	794	562	282	173	85	46	24	10	4
2007	0	0	0	0	0	0	0	0	0	0	7	16	180	489	730	938	982	849	612	430	315	156	97	50	10

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

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1990	0	0	0	0	0	0	0	0	0	0	0	0	1	5	9	17	28	36	27	28	17	10	5	0	0
1991	0	0	0	0	0	0	0	0	0	0	0	0	1	8	18	32	44	45	34	23	11	7	2	1	0
1992	0	0	0	0	0	0	0	0	0	1	5	20	113	201	194	215	211	147	90	62	38	21	11	8	3
1995	0	0	0	0	0	0	0	0	0	0	0	3	31	55	73	125	140	113	89	59	33	27	20	8	5
1996	0	0	0	0	0	0	0	0	0	0	1	4	28	98	202	283	252	179	126	107	75	53	30	16	11
1997	0	0	0	0	0	0	0	0	0	1	1	2	15	51	110	171	235	152	74	37	23	13	9	7	3
1998	0	0	0	0	0	0	0	0	0	0	0	0	8	23	55	99	136	141	84	42	23	16	5	2	1

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

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

Table 2.10a—Length frequencies for the 1979-1981 EBS shelf bottom trawl survey by length bin.

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1979	0	5	44	186	374	457	694	1764	2393	1884	1171	618	202	70	44	51	29	8	0	3	1	1	0	0	0
1980	0	6	85	241	82	42	224	687	929	1320	1542	2062	1364	893	333	100	33	31	19	6	2	0	0	0	0
1981	0	20	156	330	278	32	100	330	653	724	511	1063	1396	1746	1215	812	398	156	39	27	13	1	0	0	0

Table 2.10b—Length frequencies for the 1982-2007 EBS shelf bottom trawl survey by length bin.

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1982	17	97	234	148	37	28	132	403	766	750	416	520	1512	1326	1288	1178	874	474	210	90	29	9	4	0	0
1983	393	1396	1289	622	147	32	135	370	551	380	209	393	1367	1289	1341	1128	921	650	325	151	31	19	4	1	0
1984	70	129	82	142	282	920	1653	1712	1041	485	249	261	536	579	864	961	880	590	381	173	94	38	9	1	0
1985	162	540	964	1537	1761	664	298	595	880	942	1154	1528	1879	678	480	543	687	674	496	253	111	38	17	5	0
1986	154	465	501	154	114	692	1775	1908	1585	1083	553	425	1069	1338	1203	628	416	453	370	264	119	74	21	13	0
1987	18	69	250	398	267	185	440	899	779	606	617	957	1478	827	598	654	632	413	211	166	71	49	16	7	0
1988	8	49	76	88	109	233	279	384	641	625	491	660	1418	1306	1114	849	570	420	293	244	74	32	25	7	4
1989	24	154	298	205	70	34	82	87	139	348	339	366	871	1193	1294	1143	945	858	666	338	247	145	90	62	0
1990	201	488	699	355	133	122	249	292	321	276	175	123	194	223	346	419	283	266	182	128	82	33	26	11	3
1991	131	389	432	369	229	272	620	898	932	631	346	193	301	312	250	215	207	178	110	112	49	20	22	7	2
1992	18	456	517	698	556	435	854	1075	856	542	451	622	915	546	242	222	176	103	97	86	51	37	28	15	3
1993	114	924	1088	981	677	213	247	614	847	666	489	615	1071	665	399	267	230	85	62	48	37	20	23	14	6
1994	19	145	291	363	326	445	956	1922	2081	1121	444	522	1216	961	1059	920	565	288	92	46	34	60	16	22	9
1995	30	73	135	208	77	173	460	691	579	705	1064	1233	1360	616	434	484	326	253	132	84	40	27	19	9	3
1996	14	65	164	198	110	103	357	699	677	526	499	744	1477	1404	908	499	288	237	148	109	71	25	16	7	3
1997	91	473	601	728	507	140	215	481	628	451	407	399	919	809	842	583	436	215	105	60	40	26	10	4	1
1998	30	262	334	74	46	311	1151	1837	1396	655	379	367	659	458	378	391	333	244	132	64	33	29	9	10	1
1999	71	334	286	113	141	415	760	874	667	718	1169	1648	1854	768	493	447	337	252	132	89	62	37	24	7	2
2000	174	917	1308	505	54	141	487	784	604	563	748	957	1718	1417	893	536	266	187	99	79	57	33	19	3	0
2001	95	646	1828	2113	1010	408	903	1990	2543	1613	705	486	1192	1276	1077	818	513	257	123	71	34	22	14	4	5
2002	31	190	374	352	105	209	664	1459	1449	1005	792	1216	1578	878	609	545	367	208	103	49	19	16	15	3	2
2003	19	283	633	774	682	489	182	252	682	837	974	1192	1974	1218	770	516	340	261	142	86	35	14	2	1	0
2004	24	275	483	562	318	218	484	729	930	979	711	578	806	925	844	714	474	283	211	111	82	34	15	5	4
2005	5	153	590	892	1018	1053	484	415	575	726	647	625	855	702	520	527	495	360	292	182	104	46	21	7	0
2006	478	1286	1075	884	317	165	266	604	753	866	706	533	728	855	643	494	395	320	259	238	144	76	35	14	1
2007	488	3110	2018	966	369	118	255	325	301	205	165	176	297	289	203	210	161	115	65	50	53	33	13	13	4

Table 2.11—Age compositions observed by the EBS shelf bottom trawl survey, 1994-2006.

Year	1	2	3	4	5	6	7	8	9	10	11	12+
1994	0.0536	0.4015	0.1844	0.1259	0.1241	0.0837	0.0195	0.0050	0.0020	0.0001	0.0002	0.0000
1995	0.0276	0.2705	0.4401	0.1074	0.0803	0.0536	0.0106	0.0041	0.0042	0.0003	0.0008	0.0006
1996	0.0032	0.2306	0.2469	0.3568	0.0941	0.0541	0.0144	0.0000	0.0000	0.0000	0.0000	0.0000
1997	0.2355	0.1841	0.1737	0.1610	0.1225	0.0898	0.0227	0.0081	0.0009	0.0010	0.0006	0.0000
1998	0.0664	0.4546	0.2020	0.1137	0.0589	0.0596	0.0284	0.0140	0.0022	0.0000	0.0002	0.0000
1999	0.0715	0.1992	0.3090	0.2409	0.0806	0.0575	0.0266	0.0103	0.0036	0.0000	0.0007	0.0000
2000	0.2240	0.1162	0.1675	0.2476	0.1563	0.0595	0.0108	0.0120	0.0028	0.0026	0.0007	0.0000
2001	0.2598	0.2469	0.2052	0.0941	0.0915	0.0703	0.0236	0.0056	0.0014	0.0009	0.0006	0.0001
2002	0.0799	0.1868	0.3104	0.2443	0.0733	0.0575	0.0390	0.0065	0.0018	0.0005	0.0000	0.0001
2003	0.1487	0.1633	0.2546	0.2212	0.1220	0.0412	0.0291	0.0151	0.0033	0.0003	0.0003	0.0007
2004	0.1421	0.1622	0.2805	0.1301	0.1333	0.0908	0.0346	0.0177	0.0062	0.0011	0.0014	0.0000
2005	0.1836	0.2560	0.1868	0.1383	0.0621	0.0843	0.0485	0.0243	0.0106	0.0016	0.0040	0.0000
2006	0.3198	0.1443	0.1703	0.1180	0.0946	0.0632	0.0473	0.0290	0.0097	0.0029	0.0009	0.0002

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

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

Table 2.12b— Abundance measured in units of biomass and numbers, with standard errors, as estimated by EBS shelf bottom trawl surveys, 1982-2007. For biomass, 95% confidence intervals (CI) are also shown. All biomass figures are expressed in metric tons. Population numbers are expressed in terms of individual fish.

	Abundance (biomass)				Abundance (numbers)	
Year	Estimate	Standard Error	Lower 95% CI	Upper 95% CI	Estimate	Standard Error
1982	1,012,856	73,588	867,151	1,158,562	583,715,842	38,040,768
1983	1,185,419	120,868	941,146	1,429,692	751,066,723	80,440,661
1984	1,048,595	63,643	922,583	1,174,608	680,914,697	49,913,926
1985	1,001,108	55,845	890,536	1,111,681	841,108,075	112,271,991
1986	1,117,774	69,604	979,957	1,255,590	838,123,105	83,854,636
1987	1,106,621	68,682	970,630	1,242,612	728,956,963	48,520,099
1988	959,000	76,265	807,996	1,110,004	508,065,276	35,526,047
1989	836,177	62,981	711,475	960,878	292,210,905	19,939,408
1990	691,255	51,455	589,375	793,136	423,835,267	36,466,423
1991	517,209	38,158	441,657	592,761	488,861,768	50,972,542
1992	551,369	45,780	460,725	642,013	601,795,262	70,551,400
1993	690,535	54,380	582,862	798,208	851,863,422	106,911,178
1994	1,368,120	250,044	868,032	1,868,209	1,237,758,281	153,120,867
1995	1,003,096	91,739	821,453	1,184,740	757,657,482	75,485,760
1996	890,793	87,552	717,439	1,064,146	609,304,214	88,330,629
1997	604,881	69,250	466,382	743,380	487,429,700	72,155,388
1998	558,419	45,182	468,960	647,879	537,278,347	48,263,858
1999	583,891	50,621	483,662	684,120	500,915,139	46,536,008
2000	528,466	43,037	443,253	613,679	481,358,109	44,098,753
2001	833,626	76,247	681,133	986,119	985,568,802	94,981,577
2002	618,680	69,082	480,516	756,845	566,471,072	57,675,818
2003	595,826	62,099	471,628	720,024	499,925,561	62,237,449
2004	596,464	35,191	526,787	666,142	424,075,921	36,061,059
2005	603,788	43,150	517,488	690,089	452,075,840	63,294,550
2006	517,698	28,341	461,583	573,813	393,993,981	23,784,449
2007	423,703	34,811	354,080	493,326	733,374,144	195,954,076

Table 2.13a—Actual length sample sizes from at-sea observers by gear and season, 1990-2006.

Year	Twl(1)	Twl(2)	Twl(3)	Lgl(1)	Lgl(2)	Lgl(3)	Pot(1)	Pot(2)	Pot(3)
1990	70,213	326	4,138	22,030	69,835	63,550		1,526	5,107
1991	124,193	1,701		54,119	58,576	85,581		6,388	7,351
1992	70,164	170	476	141,207	75,623	20,926	13,714	15,318	3,282
1993	73,155		354	121,206			7,665		
1994	101,934		547	152,377		41,671	21,544		4,947
1995	65,390		667	138,341		66,596	31,515	5,090	6,036
1996	100,144		3,554	148,856		73,687	48,338	9,057	9,429
1997	96,103	499		173,973		144,358	28,305	5,180	8,992
1998	80,880	1,692	1,303	126,890	64	173,242	21,469	4,498	3,000
1999	36,374	144	761	77,556	7,244	47,216	13,456		2,613
2000	34,153	139	173	52,859	6,285	86,683	12,003		226
2001	18,125	1,922	1,214	64,859	16,300	87,251	9,432		5,113
2002	24,192	3,114	2,437	68,503	30,893	84,876	6,680		5,132
2003	25,989	6,165	1,975	95,501	36,712	102,683	8,931		5,872
2004	21,784	3,359	1,600	79,913	32,196	89,005	6,386		4,257
2005	23,500	1,249	184	67,901	37,570	85,617	5,173		4,516
2006	22,761	804		54,983	30,529	51,831	6,423		5,219

Table 2.13b—Harmonic mean sample sizes from a bootstrap simulation by gear and season, 1990-2006.

Year	Twl(1)	Twl(2)	Twl(3)	Lgl(1)	Lgl(2)	Lgl(3)	Pot(1)	Pot(2)	Pot(3)
1990	10,644	96	877	3,637	10,170	9,922		272	346
1991	12,787	163		8,022	10,080	15,353		1,517	1,375
1992	7,868	3	17	21,882	12,284	3,759	1,848	3,114	574
1993	8,742		27	15,863			1,374		
1994	15,585		21	20,708		7,739	3,577		429
1995	8,777		173	23,094		9,465	5,046	979	708
1996	16,971		497	20,728		10,605	7,757	1,361	1,105
1997	17,763	86		24,208		21,020	4,621	922	1,494
1998	14,414	302	346	22,378	10	29,137	3,259	798	546
1999	11,416	38	245	26,617	2,629	16,268	4,351		826
2000	11,555	28	24	17,284	2,171	28,133	3,750		87
2001	5,947	597	377	21,330	5,591	29,835	3,034		1,464
2002	8,136	1,135	855	23,052	10,850	29,647	2,309		1,553
2003	8,267	2,057	754	31,835	12,208	32,752	3,018		1,829
2004	7,142	1,166	553	27,633	11,600	30,546	2,206		1,414
2005	7,945	379	60	25,101	13,207	29,536	1,813		1,568
2006	8,045	248		20,065	11,217	18,418	2,144		1,848

Table 2.13c—Harmonic means from bootstrap rescaled proportionally to exhibit an average of 300.

Year	Twl(1)	Twl(2)	Twl(3)	Lgl(1)	Lgl(2)	Lgl(3)	Pot(1)	Pot(2)	Pot(3)
1990	387	3	32	132	370	361		10	13
1991	465	6		292	367	559		55	50
1992	286	0	1	796	447	137	67	113	21
1993	318		1	577			50		
1994	567		1	754		282	130		16
1995	319		6	840		344	184	36	26
1996	618		18	754		386	282	50	40
1997	646	3		881		765	168	34	54
1998	525	11	13	814	0	1,060	119	29	20
1999	415	1	9	969	96	592	158		30
2000	420	1	1	629	79	1,024	136		3
2001	216	22	14	776	203	1,086	110		53
2002	296	41	31	839	395	1,079	84		57
2003	301	75	27	1,159	444	1,192	110		67
2004	260	42	20	1,006	422	1,112	80		51
2005	289	14	2	913	481	1,075	66		57
2006	293	9		730	408	670	78		67

Table 2.13d—Square roots of actual sample sizes.

Year	Twl(1)	Twl(2)	Twl(3)	Lgl(1)	Lgl(2)	Lgl(3)	Pot(1)	Pot(2)	Pot(3)
1990	265	18	64	148	264	252		39	71
1991	352	41		233	242	293		80	86
1992	265	13	22	376	275	145	117	124	57
1993	270		19	348			88		
1994	319		23	390		204	147		70
1995	256		26	372		258	178	71	78
1996	316		60	386		271	220	95	97
1997	310	22		417		380	168	72	95
1998	284	41	36	356	8	416	147	67	55
1999	191	12	28	278	85	217	116		51
2000	185	12	13	230	79	294	110		15
2001	135	44	35	255	128	295	97		72
2002	156	56	49	262	176	291	82		72
2003	161	79	44	309	192	320	95		77
2004	148	58	40	283	179	298	80		65
2005	153	35	14	261	194	293	72		67
2006	151	28		234	175	228	80		72

Table 2.13e—Ratio of rescaled bootstrap harmonic means to square roots of actual sample sizes.

Year	Twl(1)	Twl(2)	Twl(3)	Lgl(1)	Lgl(2)	Lgl(3)	Pot(1)	Pot(2)	Pot(3)
1990	1.46	0.19	0.50	0.89	1.40	1.43		0.25	0.18
1991	1.32	0.14		1.25	1.52	1.91		0.69	0.58
1992	1.08	0.01	0.03	2.12	1.63	0.95	0.57	0.92	0.36
1993	1.18		0.05	1.66			0.57		
1994	1.78		0.03	1.93		1.38	0.89		0.22
1995	1.25		0.24	2.26		1.33	1.03	0.50	0.33
1996	1.95		0.30	1.96		1.42	1.28	0.52	0.41
1997	2.09	0.14		2.11		2.01	1.00	0.47	0.57
1998	1.84	0.27	0.35	2.29	0.05	2.55	0.81	0.43	0.36
1999	2.18	0.11	0.32	3.48	1.12	2.72	1.37		0.59
2000	2.28	0.09	0.07	2.74	1.00	3.48	1.25		0.21
2001	1.61	0.50	0.39	3.05	1.59	3.68	1.14		0.75
2002	1.90	0.74	0.63	3.21	2.25	3.70	1.03		0.79
2003	1.87	0.95	0.62	3.75	2.32	3.72	1.16		0.87
2004	1.76	0.73	0.50	3.56	2.35	3.73	1.00		0.79
2005	1.89	0.39	0.16	3.51	2.48	3.67	0.92		0.85
2006	1.94	0.32		3.11	2.34	2.94	0.97		0.93

Table 2.13f—Ratio of rescaled bootstrap harmonic means to actual sample sizes.

Year	Twl(1)	Twl(2)	Twl(3)	Lgl(1)	Lgl(2)	Lgl(3)	Pot(1)	Pot(2)	Pot(3)
1990	0.15	0.29	0.21	0.17	0.15	0.16		0.18	0.07
1991	0.10	0.10		0.15	0.17	0.18		0.24	0.19
1992	0.11	0.02	0.03	0.15	0.16	0.18	0.13	0.20	0.17
1993	0.12		0.08	0.13			0.18		
1994	0.15		0.04	0.14		0.19	0.17		0.09
1995	0.13		0.26	0.17		0.14	0.16	0.19	0.12
1996	0.17		0.14	0.14		0.14	0.16	0.15	0.12
1997	0.18	0.17		0.14		0.15	0.16	0.18	0.17
1998	0.18	0.18	0.27	0.18	0.16	0.17	0.15	0.18	0.18
1999	0.31	0.26	0.32	0.34	0.36	0.34	0.32		0.32
2000	0.34	0.20	0.14	0.33	0.35	0.32	0.31		0.38
2001	0.33	0.31	0.31	0.33	0.34	0.34	0.32		0.29
2002	0.34	0.36	0.35	0.34	0.35	0.35	0.35		0.30
2003	0.32	0.33	0.38	0.33	0.33	0.32	0.34		0.31
2004	0.33	0.35	0.35	0.35	0.36	0.34	0.35		0.33
2005	0.34	0.30	0.32	0.37	0.35	0.34	0.35		0.35
2006	0.35	0.31		0.36	0.37	0.36	0.33		0.35

Table 2.14—Multinomial sample sizes for length compositions.

	Trawl fishery			Longline fishery			Pot fishery			Trawl survey		
Year	Sea. 1	Sea. 2	Sea. 3	Sea. 1	Sea. 2	Sea. 3	Sea. 1	Sea. 2	Sea. 3	Pre82	Post81	IPHC
1977		13										
1978	4		23	21	25	18						
1979	11		6	73	17	21				74		
1980	61			19	10	22				74		
1981		35	11	17	9	10				74		
1982	29		12	13	8	35					166	
1983	75	10	107	129	27	71					207	
1984	121	70	31	111	74	617					191	
1985	221	9	12	263	39	971					266	
1986	211	5	11	246	10	784					242	
1987	302	40	148	685		1304					167	
1988	710		21								157	
1989	431										157	
1990	493		41	168	471	459		13	16		89	
1991	592	8		371	467	711		70	64		114	
1992	364		1	1013	569	174	86	144	27		151	
1993	405			734			64				164	
1994	721		1	958		358	166		20		-219	
1995	406		8	1069		438	234	45	33		-145	
1996	785		23	959		491	359	63	51		-147	
1997	822	4		1120		973	214	43	69		-144	
1998	667	14	16	1036		1349	151	37	25		-151	
1999	528		11	1232	122	753	201		38		-184	
2000	535			800	100	1302	174				-197	
2001	275	28	17	987	259	1381	140		68		-311	
2002	377	53	40	1067	502	1372	107		72		-193	
2003	383	95	35	1473	565	1516	140		85		-194	
2004	331	54	26	1279	537	1414	102		65		-170	
2005	368	18		1162	611	1367	84		73		-178	
2006	372	11		929	519	852	99		86		-191	
2007	340	36		669	116		92				157	44

Table 2.15a—Summary of statistics pertaining to four models.

	Model 1	Model 2	Model 3	Model 4
Parameter counts				
No. fixed mortality/growth parameters	1	1	0	0
No. fixed selectivity parameters	30	32	31	38
Total no. fixed parameters	31	33	31	38
No. free mortality/growth parameters	5	5	6	6
No. stock-recruitment parameters	2	2	2	2
No. recruitment deviations	33	33	33	28
No. initial fishing mortalities	1	1	1	1
No. catchabilities	2	2	2	1
No. free selectivity parameters	42	40	41	28
No. selectivity deviations	29	29	29	52
Total no. free parameters	114	112	114	118
Total no. fixed and free parameters	145	145	145	156
Aggregate likelihood components				
Abundance indices	71.60	71.09	52.57	60.50
Length compositions	1748.40	1775.08	1748.74	1781.17
Age compositions	206.66	176.57	179.87	n/a
Initial catch	0.01	0.01	0.16	n/a
Recruitment	29.66	31.03	45.72	17.17
Annual deviations	9.46	20.74	10.81	18.73
Total	2065.79	2074.52	2037.86	1877.57
Relative abundance likelihoods				
Jan-May trawl fishery CPUE	48.41	50.83	44.16	48.65
Jun-Aug trawl fishery CPUE	29.46	31.47	26.52	31.21
Sep-Dec trawl fishery CPUE	38.99	40.88	34.55	40.38
Jan-May longline fishery CPUE	9.54	10.65	10.09	12.17
Jun-Aug longline fishery CPUE	6.37	7.92	5.95	10.11
Sep-Dec longline fishery CPUE	10.14	13.27	7.38	17.13
Jan-May pot fishery CPUE	3.83	3.10	6.17	3.07
Jun-Aug pot fishery CPUE	0.48	0.48	0.44	0.49
Sep-Dec pot fishery CPUE	11.58	11.37	11.88	10.81
Pre-1982 trawl survey abundance	4.16	5.57	5.47	n/a
Post-1982 trawl survey abundance	67.44	65.52	47.10	60.50
IPHC longline survey CPUE	31.72	33.13	37.01	36.68
Size composition likelihoods				
Jan-May trawl fishery sizecomp	480.73	490.26	494.53	504.15
Jun-Aug trawl fishery sizecomp	103.25	102.82	103.00	77.84
Sep-Dec trawl fishery sizecomp	69.40	68.66	66.24	60.27
Jan-May longline fishery sizecomp	331.07	331.62	323.65	296.77
Jun-Aug longline fishery sizecomp	122.72	120.39	120.55	120.86
Sep-Dec longline fishery sizecomp	377.69	374.26	370.99	364.71
Jan-May pot fishery sizecomp	37.70	38.98	37.04	43.75
Jun-Aug pot fishery sizecomp	22.40	22.29	22.36	24.19
Sep-Dec pot fishery sizecomp	41.57	41.73	41.06	46.25
Pre-1982 trawl survey sizecomp	24.22	25.54	23.41	n/a
Post-1982 trawl survey sizecomp	136.87	157.78	145.16	241.15
IPHC longline survey sizecomp	0.80	0.76	0.75	1.23

Table 2.15b—Summary of key parameters from four models.

	Model 1	Model 2	Model 3	Model 4
Life history and recruitment				
Natural mortality rate M	0.34	0.37	0.22	0.46
Mean Jan. population length at age 1	6.99	7.14	6.83	6.33
Mean Jan. population length at age 20	94.03	96.89	93.47	102.55
Brody growth rate K	0.22	0.21	0.23	0.20
Std. dev. of length at age 1	3.11	3.23	3.05	4.12
Std. dev. of length at age 20	9.26	9.28	9.45	13.76
Mean July survey length at age 1	17.16	17.15	17.10	16.85
Mean July survey length at age 2	32.83	32.69	32.89	34.23
Mean July survey length at age 3	45.48	45.39	45.58	46.21
Post-1976 log median recruits (1000s)	13.59	13.77	12.40	13.84
Pre-1977 log median recruits (1000s)	11.91	11.83	10.85	14.59
Standard deviation of log recruits	0.78	0.78	0.78	0.60
Catchability and selectivity				
Pre-1982 trawl survey log catchability	-0.11	-0.05	0.98	n/a
Post-1981 trawl survey log catchability	-0.33	-0.17	0.42	-0.38
Jan-May trawl fish. begin peak	74.99	76.93	75.06	81.56
Jan-May trawl fish. sel. at max. size	0.71	0.72	0.70	0.57
Jun-Aug trawl fish. begin peak	69.60	73.08	70.24	86.31
Jun-Aug trawl fish. sel. at max. size	1.00	1.00	1.00	1.00
Sep-Dec trawl fish. begin peak	86.66	89.62	88.68	99.75
Sep-Dec trawl fish. sel. at max. size	1.00	1.00	1.00	1.00
Jan-May longl. fish. begin peak	65.20	66.04	65.05	67.66
Jan-May longl. fish. sel. at max. size	0.33	0.35	0.32	0.45
Jun-Aug longl. fish. begin peak	65.35	66.98	65.32	70.76
Jun-Aug longl. fish. sel. at max. size	1.00	1.00	1.00	1.00
Sep-Dec longl. fish. begin peak	66.04	67.24	65.96	70.01
Sep-Dec longl. fish. sel. at max. size	0.70	0.72	0.68	1.00
Jan-May pot fish. begin peak	67.97	68.55	67.97	69.83
Jan-May pot fish. sel. at max. size	0.46	0.50	0.45	0.67
Jun-Aug pot fish. begin peak	67.02	67.79	66.95	67.99
Jun-Aug pot fish. sel. at max. size	0.56	0.61	0.54	1.00
Sep-Dec pot fish. begin peak	64.16	65.50	64.07	68.28
Sep-Dec pot fish. sel. at max. size	1.00	1.00	1.00	1.00
Pre-1982 trawl surv. begin peak	1.22	1.25	1.22	n/a
Pre-1982 trawl surv. sel. at max. size	0.13	0.19	0.14	n/a
Post-1981 trawl surv. begin peak	1.11	3.82	1.09	34.15
Post-1981 trawl surv. sel. at max. size	0.10	0.11	0.04	1.00
IPHC longline surv. begin peak	68.24	68.39	68.28	66.75
IPHC longline surv. sel. at max. size	0.50	0.54	0.51	1.00
Ave. post-82 surv. sel. x Q (60-80 cm)	0.56	0.64	1.08	0.68

Table 2.15c—Summary of key management reference points from four models.

	Model 1	Model 2	Model 3	Model 4
Examples of historical biomass (BS)				
BS total biomass 1977	528	367	126	n/a
BS total biomass 1985	2501	2179	1165	1875
BS total biomass 2007	1051	1074	510	1018
BS age 3+ biomass 1977	487	326	116	n/a
BS age 3+ biomass 1985	2469	2147	1153	1818
BS age 3+ biomass 2007	1000	991	489	917
BS female spawning biomass 1977	128	76	19	n/a
BS female spawning biomass 1985	932	773	440	613
BS female spawning biomass 2007	370	353	181	310
Projected biomass (BSAI)				
BSAI total biomass 2008	1266	1474	584	1465
BSAI total biomass 2009	1513	2006	830	1956
BSAI age 3+ biomass 2008	1080	1137	504	1054
BSAI age 3+ biomass 2009	1423	1904	796	1861
BSAI female spawning biomass 2008	398	396	192	341
BSAI female spawning biomass 2009	395	422	237	357
Spawning biomass reference points				
B100%	1350	1290	1420	748
B40%	540	516	568	299
B35%	473	452	497	262
Proportion of B100% in 2008	0.29	0.31	0.14	0.46
Proportion of B100% in 2009	0.29	0.33	0.17	0.48
ABC reference points				
F40%	0.31	0.32	0.21	0.45
maxFABC 2008	0.22	0.24	0.063	0.45
maxFABC 2009	0.22	0.26	0.080	0.45
BSAI ABC 2007 (Council adopted)	176	176	176	176
BSAI maxABC 2008 (from model)	150	182	22.4	281
BSAI maxABC 2009 (from model)	162	240	38.1	327
rel. change in ABC (2007 to 2008)	-0.15	0.03	-0.87	0.60
rel. change in ABC (2007 to 2009)	-0.08	0.36	-0.78	0.86
OFL reference points				
F35%	0.37	0.39	0.25	0.54
FOFL 2008	0.26	0.29	0.075	0.54
FOFL 2009 (Scenario 6)	0.26	0.30	0.094	0.54
BSAI OFL 2007 (Council adopted)	207	207	207	207
BSAI OFL 2008 (from model)	176	214	26.5	332
BSAI OFL 2009 (from model)	190	283	45.0	389
rel. change in OFL (2007 to 2008)	-0.15	0.03	-0.87	0.60
rel. change in OFL (2007 to 2009)	-0.08	0.37	-0.78	0.88

Table 2.16a—Estimates and standard deviations of parameters (except annual devs) from four models.

	Model 1		Model 2		Model 3		Model 4	
Parameter	Est.	S.D.	Est.	S.D.	Est.	S.D.	Est.	S.D.
Natural mortality					0.216	0.016	0.464	0.018
Mean length at age 1	6.989	0.288	7.138	0.295	6.826	0.290	6.333	0.294
Mean length at age 20	94.025	0.851	96.888	1.086	93.466	0.835	102.550	1.079
Brody growth rate	0.225	0.004	0.213	0.005	0.228	0.004	0.204	0.004
Std. dev. of length at age 1	3.106	0.161	3.227	0.168	3.046	0.164	4.121	0.124
Std. dev. of length at age 20 (offset)	1.093	0.071	1.057	0.078	1.133	0.073	1.206	0.086
Post-1976 log median recruits	13.593	0.068	13.769	0.068	12.403	0.141	13.837	0.159
Pre-1977 log median recruits (offset)	-1.680	0.150	-1.936	0.123	-1.549	0.113	0.749	0.103
Initial fishing mortality	0.162	0.051	0.271	0.094	0.850	0.226	0.728	0.078
Pre-1982 survey catchability (log)	-0.113	0.130	-0.049	0.135	0.984	0.141	n/a	n/a
Post-1981 survey catchability (log)	-0.331	0.071	-0.173	0.081	0.419	0.081	-0.382	0.113
Jan-May trawl beg. peak	74.991	1.001	76.929	0.956	75.055	0.974	81.563	0.893
Jan-May trawl asc. width	6.420	0.041	6.435	0.037	6.495	0.044	6.507	0.035
Jan-May trawl des. width	4.185	0.635	4.228	0.804	4.254	0.623		
Jan-May trawl final sel.	0.907	0.278	0.951	0.372	0.827	0.278	0.299	0.471
Jun-Aug trawl beg. peak	69.601	3.987	73.084	4.308	70.242	4.379	86.314	5.714
Jun-Aug trawl asc. width	6.334	0.222	6.406	0.213	6.434	0.242	6.733	0.203
Sep-Dec trawl beg. peak	86.656	4.563	89.621	4.238	88.682	4.765	99.754	4.663
Sep-Dec trawl asc. width	6.650	0.180	6.675	0.156	6.762	0.182	6.843	0.140
Jan-May longline beg. peak	65.197	0.389	66.043	0.387	65.046	0.372	67.656	0.319
Jan-May longline asc. width	5.292	0.031	5.317	0.029	5.319	0.031	5.365	0.025
Jan-May longline des. width	5.142	0.135	5.189	0.160	5.209	0.135	5.330	0.265
Jan-May longline final sel.	-0.714	0.132	-0.615	0.152	-0.768	0.135	-0.195	0.204
Jun-Aug longline beg. peak	65.347	0.816	66.979	0.775	65.324	0.791	70.762	0.757
Jun-Aug longline asc. width	5.150	0.074	5.235	0.065	5.180	0.074	5.429	0.057
Sep-Dec longline beg. peak	66.042	0.495	67.241	0.488	65.958	0.480	70.006	0.496
Sep-Dec longline peak width	-1.912	0.619	-1.711	0.711	-1.948	0.671		
Sep-Dec longline asc. width	5.232	0.039	5.284	0.035	5.263	0.039	5.414	0.034
Sep-Dec longline des. width	4.799	0.754	5.054	1.345	4.968	0.795		
Sep-Dec longline final sel.	0.852	0.289	0.940	0.550	0.776	0.314		
Jan-May pot beg. peak	67.973	0.684	68.555	0.712	67.966	0.688	69.835	0.793
Jan-May pot asc. width	5.068	0.073	5.081	0.072	5.094	0.074	5.122	0.074
Jan-May pot des. width	4.436	0.413	4.434	0.497	4.503	0.409	3.993	0.915
Jan-May pot final sel.	-0.160	0.225	0.004	0.254	-0.217	0.228	0.716	0.326
Jun-Aug pot beg. peak	67.022	1.758	67.788	1.674	66.954	1.778	67.992	1.545
Jun-Aug pot asc. width	5.072	0.184	5.102	0.170	5.093	0.188	5.084	0.162
Jun-Aug pot des. width	4.247	1.200	4.237	1.424	4.374	1.117		
Jun-Aug pot final sel.	0.259	0.435	0.429	0.505	0.152	0.429		
Sep-Dec pot beg. peak	64.163	1.414	65.500	1.387	64.070	1.436	68.278	1.502
Sep-Dec pot asc. width	4.754	0.182	4.851	0.166	4.773	0.187	5.032	0.157
Pre-1982 survey beg. peak	1.222	0.293	1.247	0.418	1.216	0.338	n/a	n/a
Pre-1982 survey peak width	-2.159	0.165	-2.162	0.236	-2.173	0.188	n/a	n/a
Pre-1982 survey asc. width	-3.968	3.202	-3.834	4.002	-3.992	3.775	n/a	n/a
Pre-1982 survey final sel.	-1.927	1.016	-1.478	1.074	-1.853	0.900	n/a	n/a
Post-1981 survey beg. peak	1.115	0.022	3.823	0.184	1.095	0.018	34.151	0.699
Post-1981 survey peak width	-1.462	0.216			-1.993	0.340		
Post-1981 survey asc. width	-4.432	0.490	2.438	0.236	-4.629	0.489	4.534	0.422
Post-1981 survey des. width	1.893	0.616	2.368	0.295	2.740	0.448		
Post-1981 survey initial sel.							-1.492	0.179
Post-1981 survey final sel.	-2.157	0.617	-2.120	0.714	-3.106	1.334		
IPHC survey beg. peak	68.243	5.603	68.389	0.382	68.284	0.176	66.749	3.781
IPHC survey peak width	-3.315	4.581						
IPHC survey asc. width	4.510	0.777	4.489	0.290	4.510	0.292	4.295	0.657
IPHC survey final sel.	-0.004	0.915	0.144	0.826	0.040	0.779		

Table 2.16b—Estimates and standard deviations of annual recruitment devs estimated by four models.

	Model 1		Model 2		Model 3		Model 4	
Year	Est.	S.D.	Est.	S.D.	Est.	S.D.	Est.	S.D.
1974	1.873	0.208	1.775	0.213	1.502	0.175	n/a	n/a
1975	0.183	0.693	0.389	0.598	-0.411	0.745	n/a	n/a
1976	1.599	0.249	1.580	0.254	1.122	0.269	n/a	n/a
1977	1.456	0.096	1.274	0.098	1.199	0.092	n/a	n/a
1978	0.287	0.178	0.208	0.166	0.032	0.184	n/a	n/a
1979	0.568	0.109	0.483	0.105	0.358	0.114	0.052	0.128
1980	-0.361	0.152	-0.229	0.133	-0.419	0.148	-0.505	0.114
1981	-1.025	0.186	-1.158	0.181	-1.220	0.200	-1.519	0.162
1982	0.830	0.052	0.778	0.050	0.804	0.051	0.930	0.051
1983	-0.865	0.156	-1.029	0.157	-0.919	0.166	-0.424	0.109
1984	0.571	0.058	0.572	0.053	0.612	0.058	0.758	0.051
1985	-0.065	0.084	-0.204	0.083	-0.035	0.087	0.184	0.068
1986	-0.730	0.115	-0.713	0.106	-0.639	0.118	-0.357	0.083
1987	-1.315	0.155	-1.204	0.133	-1.208	0.162	-0.766	0.091
1988	-0.408	0.077	-0.526	0.076	-0.269	0.080	-0.416	0.067
1989	0.306	0.054	0.239	0.052	0.463	0.058	0.335	0.047
1990	0.215	0.057	0.137	0.055	0.387	0.061	0.405	0.047
1991	-0.432	0.075	-0.482	0.071	-0.254	0.079	-0.268	0.063
1992	0.403	0.044	0.353	0.041	0.592	0.051	0.470	0.041
1993	-0.594	0.074	-0.637	0.070	-0.431	0.079	-0.251	0.057
1994	-0.603	0.063	-0.683	0.061	-0.469	0.067	-0.420	0.051
1995	-0.498	0.060	-0.555	0.057	-0.368	0.064	-0.578	0.056
1996	0.413	0.043	0.321	0.041	0.527	0.047	0.356	0.041
1997	-0.272	0.059	-0.280	0.055	-0.162	0.063	0.102	0.042
1998	-0.170	0.055	-0.181	0.051	-0.056	0.058	-0.057	0.047
1999	0.427	0.045	0.372	0.042	0.530	0.048	0.508	0.040
2000	0.055	0.050	0.109	0.047	0.153	0.052	0.538	0.040
2001	-0.594	0.064	-0.579	0.061	-0.525	0.065	-0.440	0.068
2002	-0.393	0.062	-0.338	0.058	-0.353	0.063	0.071	0.055
2003	-0.523	0.074	-0.501	0.070	-0.521	0.077	-0.240	0.075
2004	-1.065	0.098	-0.904	0.096	-0.991	0.099	-0.403	0.099
2005	-0.405	0.131	-0.038	0.112	-0.290	0.115	0.074	0.126
2006	1.134	0.207	1.651	0.176	1.258	0.192	1.861	0.180

Table 2.16c—Estimates and standard deviations of selectivity parameter devs estimated by four models.

			Model 1		Model 2		Model 3		Model 4	
Survey	Parameter	Year	Est.	S.D.	Est.	S.D.	Est.	S.D.	Est.	S.D.
Pre-1982 survey	asc. width	1979	0.033	0.144	0.026	0.144	0.023	0.146	n/a	n/a
Pre-1982 survey	asc. width	1980	0.051	0.137	0.038	0.136	0.047	0.137	n/a	n/a
Pre-1982 survey	asc. width	1981	-0.083	0.139	-0.064	0.137	-0.071	0.139	n/a	n/a
Post-1981 survey	asc. width	1982	0.072	0.090	-0.249	0.150	0.013	0.116	-0.668	0.236
Post-1981 survey	asc. width	1983	0.001	0.058	0.063	0.122	-0.004	0.064	-0.380	0.173
Post-1981 survey	asc. width	1984	0.097	0.090	0.014	0.142	0.078	0.104	0.126	0.111
Post-1981 survey	asc. width	1985	-0.120	0.073	0.299	0.134	-0.138	0.087	0.320	0.123
Post-1981 survey	asc. width	1986	0.072	0.065	0.168	0.140	0.077	0.072	0.021	0.109
Post-1981 survey	asc. width	1987	-0.069	0.102	0.182	0.149	-0.073	0.115	0.206	0.135
Post-1981 survey	asc. width	1988	0.123	0.097	-0.050	0.159	0.142	0.103	-0.014	0.126
Post-1981 survey	asc. width	1989	0.234	0.076	-0.556	0.108	0.269	0.081	-0.824	0.281
Post-1981 survey	asc. width	1990	0.003	0.064	0.031	0.129	0.034	0.067	-0.169	0.185
Post-1981 survey	asc. width	1991	0.049	0.065	0.016	0.134	0.079	0.068	-0.014	0.134
Post-1981 survey	asc. width	1992	-0.246	0.116	0.317	0.142	-0.236	0.123	0.506	0.197
Post-1981 survey	asc. width	1993	-0.232	0.099	0.376	0.134	-0.236	0.110	0.511	0.197
Post-1981 survey	asc. width	1994	0.090	0.070	0.117	0.145	0.104	0.076	0.176	0.122
Post-1981 survey	asc. width	1995	0.221	0.084	0.036	0.150	0.241	0.087	0.094	0.131
Post-1981 survey	asc. width	1996	0.272	0.093	-0.205	0.161	0.283	0.092	-0.010	0.146
Post-1981 survey	asc. width	1997	0.092	0.051	-0.206	0.098	0.101	0.054	0.097	0.129
Post-1981 survey	asc. width	1998	0.172	0.065	-0.199	0.110	0.198	0.070	-0.029	0.108
Post-1981 survey	asc. width	1999	0.191	0.060	-0.484	0.092	0.217	0.065	-0.069	0.110
Post-1981 survey	asc. width	2000	0.072	0.051	-0.317	0.086	0.083	0.053	-0.311	0.138
Post-1981 survey	asc. width	2001	-0.289	0.100	0.327	0.132	-0.328	0.113	0.510	0.182
Post-1981 survey	asc. width	2002	0.052	0.062	-0.351	0.105	0.052	0.069	-0.170	0.158
Post-1981 survey	asc. width	2003	-0.031	0.059	0.061	0.119	-0.067	0.072	0.279	0.130
Post-1981 survey	asc. width	2004	-0.010	0.061	-0.075	0.112	-0.041	0.073	0.125	0.146
Post-1981 survey	asc. width	2005	-0.288	0.117	0.312	0.141	-0.295	0.123	0.529	0.188
Post-1981 survey	asc. width	2006	-0.273	0.117	0.211	0.143	-0.300	0.123	-0.439	0.217
Post-1981 survey	asc. width	2007	-0.256	0.134	0.161	0.164	-0.252	0.136	-0.400	0.181
Post-1981 survey	initial sel.	1982	n/a	n/a	n/a	n/a	n/a	n/a	0.037	0.230
Post-1981 survey	initial sel.	1983	n/a	n/a	n/a	n/a	n/a	n/a	-0.451	0.202
Post-1981 survey	initial sel.	1984	n/a	n/a	n/a	n/a	n/a	n/a	0.210	0.294
Post-1981 survey	initial sel.	1985	n/a	n/a	n/a	n/a	n/a	n/a	0.353	0.241
Post-1981 survey	initial sel.	1986	n/a	n/a	n/a	n/a	n/a	n/a	-0.083	0.237
Post-1981 survey	initial sel.	1987	n/a	n/a	n/a	n/a	n/a	n/a	0.219	0.352
Post-1981 survey	initial sel.	1988	n/a	n/a	n/a	n/a	n/a	n/a	0.324	0.293
Post-1981 survey	initial sel.	1989	n/a	n/a	n/a	n/a	n/a	n/a	0.300	0.176
Post-1981 survey	initial sel.	1990	n/a	n/a	n/a	n/a	n/a	n/a	-0.526	0.239
Post-1981 survey	initial sel.	1991	n/a	n/a	n/a	n/a	n/a	n/a	-0.126	0.251
Post-1981 survey	initial sel.	1992	n/a	n/a	n/a	n/a	n/a	n/a	-0.113	0.348
Post-1981 survey	initial sel.	1993	n/a	n/a	n/a	n/a	n/a	n/a	-0.261	0.311
Post-1981 survey	initial sel.	1994	n/a	n/a	n/a	n/a	n/a	n/a	0.278	0.324
Post-1981 survey	initial sel.	1995	n/a	n/a	n/a	n/a	n/a	n/a	0.157	0.329
Post-1981 survey	initial sel.	1996	n/a	n/a	n/a	n/a	n/a	n/a	0.224	0.301
Post-1981 survey	initial sel.	1997	n/a	n/a	n/a	n/a	n/a	n/a	0.062	0.294
Post-1981 survey	initial sel.	1998	n/a	n/a	n/a	n/a	n/a	n/a	0.207	0.215
Post-1981 survey	initial sel.	1999	n/a	n/a	n/a	n/a	n/a	n/a	0.161	0.206
Post-1981 survey	initial sel.	2000	n/a	n/a	n/a	n/a	n/a	n/a	-0.250	0.186
Post-1981 survey	initial sel.	2001	n/a	n/a	n/a	n/a	n/a	n/a	0.283	0.272
Post-1981 survey	initial sel.	2002	n/a	n/a	n/a	n/a	n/a	n/a	-0.234	0.249
Post-1981 survey	initial sel.	2003	n/a	n/a	n/a	n/a	n/a	n/a	0.402	0.310
Post-1981 survey	initial sel.	2004	n/a	n/a	n/a	n/a	n/a	n/a	0.094	0.366
Post-1981 survey	initial sel.	2005	n/a	n/a	n/a	n/a	n/a	n/a	0.272	0.357
Post-1981 survey	initial sel.	2006	n/a	n/a	n/a	n/a	n/a	n/a	-0.808	0.254
Post-1981 survey	initial sel.	2007	n/a	n/a	n/a	n/a	n/a	n/a	-0.730	0.278

Table 2.17a—Root mean squared errors for fishery CPUE and survey relative abundance time series.

Root Mean Squared Error

Fishery/Survey	1	2	3	4
Jan-May trawl fishery	0.23	0.24	0.22	0.23
Jun-Aug trawl fishery	0.43	0.44	0.41	0.43
Sep-Dec trawl fishery	0.59	0.61	0.56	0.61
Jan-May longline fishery	0.19	0.20	0.20	0.22
Jun-Aug longline fishery	0.23	0.25	0.25	0.28
Sep-Dec longline fishery	0.21	0.24	0.18	0.27
Jan-May pot fishery	0.11	0.10	0.13	0.10
Jun-Aug pot fishery	0.10	0.10	0.09	0.10
Sep-Dec pot fishery	0.30	0.29	0.32	0.28
Pre-1982 trawl survey	0.21	0.24	0.24	n/a
Post-1982 trawl survey	0.23	0.24	0.20	0.24
IPHC longline survey	0.29	0.30	0.30	0.32

Table 2.17b—Correlations between observed data and model estimates for fishery CPUE and survey relative abundance time series.

Correlation (observed:estimated)

Fishery/Survey	1	2	3	4
Jan-May trawl fishery	0.62	0.57	0.66	0.58
Jun-Aug trawl fishery	0.43	0.31	0.48	0.29
Sep-Dec trawl fishery	0.13	0.04	0.31	0.06
Jan-May longline fishery	0.18	0.08	0.34	0.14
Jun-Aug longline fishery	0.25	0.10	0.31	0.04
Sep-Dec longline fishery	0.17	-0.10	0.53	-0.15
Jan-May pot fishery	0.73	0.74	0.63	0.76
Jun-Aug pot fishery	0.87	0.87	0.88	0.86
Sep-Dec pot fishery	0.55	0.55	0.48	0.53
Pre-1982 trawl survey	0.98	1.00	0.77	n/a
Post-1982 trawl survey	0.61	0.59	0.74	0.61
IPHC longline survey	-0.45	-0.46	-0.38	-0.38

Table 2.18a—Median effective multinomial sample size from the data ("input") and estimated for each fishery and survey size composition time series.

Median Effective N

	Models using base data file				Model 4	
Fishery/Survey	Input	1	2	3	Input	Output
Jan-May trawl fishery	372	215	223	205	377	208
Jun-Aug trawl fishery	18	56	52	55	18	64
Sep-Dec trawl fishery	17	62	63	61	17	62
Jan-May longline fishery	734	279	261	281	929	469
Jun-Aug longline fishery	116	231	221	239	259	301
Sep-Dec longline fishery	711	240	220	238	784	301
Jan-May pot fishery	140	223	245	224	140	218
Jun-Aug pot fishery	45	116	129	111	45	141
Sep-Dec pot fishery	64	196	188	191	64	151
Pre-1982 trawl survey	74	62	55	66	n/a	n/a
Post-1982 trawl survey (years without ages)	164	212	141	164	164	216
Post-1982 trawl survey (years with ages)	-184	141	105	133	184	154
IPHC longline survey	44	925	967	968	44	178

Table 2.18b—Mean effective multinomial sample size from the data ("input") and estimated for each fishery and survey size composition time series.

Mean Effective N

	Models using base data file				Model 4	
Fishery/Survey	Input	1	2	3	Input	Output
Jan-May trawl fishery	377	273	274	266	418	315
Jun-Aug trawl fishery	30	66	67	67	30	75
Sep-Dec trawl fishery	29	113	120	113	31	124
Jan-May longline fishery	664	460	458	463	770	612
Jun-Aug longline fishery	241	315	333	336	294	338
Sep-Dec longline fishery	722	482	459	475	850	485
Jan-May pot fishery	151	443	434	452	151	461
Jun-Aug pot fishery	59	170	178	171	59	139
Sep-Dec pot fishery	53	207	195	218	53	171
Pre-1982 trawl survey	35	60	57	62	n/a	n/a
Post-1982 trawl survey (years without ages)	105	243	185	213	171	273
Post-1982 trawl survey (years with ages)	-186	142	105	126	186	200
IPHC longline survey	44	925	967	968	44	178

Table 2.19—Estimates of Pacific cod fishing mortality rates, expressed on an annual time scale (Model 1). Empty cells indicate that recorded catch was negligible or that no catch was recorded.

	Trawl			Longline			Pot		
Year	Sea. 1	Sea. 2	Sea. 3	Sea. 1	Sea. 2	Sea. 3	Sea. 1	Sea. 2	Sea. 3
1977	0.050	0.016	0.026	0.007	0.001	0.010			
1978	0.051	0.016	0.027	0.007	0.001	0.009			
1979	0.032	0.010	0.016	0.004	0.001	0.006			
1980	0.025	0.007	0.012	0.004		0.004			
1981	0.013	0.009	0.020	0.001		0.003			
1982	0.013	0.009	0.012			0.001			
1983	0.021	0.011	0.014	0.002		0.001			
1984	0.024	0.011	0.015	0.003	0.001	0.010			
1985	0.029	0.014	0.013	0.009	0.001	0.012			
1986	0.033	0.013	0.014	0.006		0.010			
1987	0.037	0.008	0.014	0.015		0.016			
1988	0.076	0.014	0.033			0.001			
1989	0.082	0.010	0.015	0.003	0.003	0.004			
1990	0.072	0.008	0.009	0.012	0.011	0.014		0.001	
1991	0.090	0.013	0.006	0.028	0.018	0.030		0.001	0.002
1992	0.060	0.011	0.007	0.067	0.024	0.007	0.004	0.006	
1993	0.072	0.005	0.012	0.066			0.003		
1994	0.062	0.005	0.022	0.069		0.021	0.006		0.003
1995	0.090	0.008	0.015	0.079		0.031	0.015	0.004	0.003
1996	0.080	0.003	0.014	0.073		0.029	0.023	0.008	0.003
1997	0.088	0.004	0.012	0.087		0.055	0.019	0.005	0.004
1998	0.056	0.007	0.016	0.079		0.040	0.014	0.004	0.002
1999	0.059	0.004	0.006	0.088	0.003	0.033	0.016	0.002	0.003
2000	0.057	0.005	0.007	0.059	0.002	0.049	0.026		
2001	0.027	0.007	0.008	0.051	0.008	0.052	0.017	0.001	0.005
2002	0.042	0.009	0.006	0.064	0.013	0.042	0.015	0.001	0.004
2003	0.037	0.009	0.004	0.063	0.011	0.044	0.020		0.006
2004	0.043	0.011	0.004	0.063	0.010	0.044	0.015	0.001	0.004
2005	0.047	0.007	0.001	0.064	0.013	0.052	0.015		0.005
2006	0.053	0.007	0.001	0.069	0.017	0.037	0.020		0.005
2007	0.046	0.011	0.002	0.068	0.016	0.042	0.019		0.006

Table 2.20—Schedules of Pacific cod selectivities at length in the commercial fisheries as defined by final parameter estimates (Model 1). Lengths (cm) correspond to mid-points of size bins. Note that trawl survey selectivities are age-based rather than length-based.

	Trawl fishery			Longline fishery			Pot fishery			
Len.	Sea. 1	Sea. 2	Sea. 3	Sea. 1	Sea. 2	Sea. 3	Sea. 1	Sea. 2	Sea. 3	IPHC
10.5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13.5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16.5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
19.5	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22.5	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
25.5	0.02	0.03	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28.5	0.03	0.05	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
31.5	0.04	0.07	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00
34.5	0.07	0.11	0.03	0.01	0.00	0.00	0.00	0.00	0.00	0.00
37.5	0.10	0.16	0.04	0.02	0.01	0.01	0.00	0.00	0.00	0.00
40.5	0.14	0.22	0.06	0.05	0.03	0.03	0.01	0.01	0.01	0.00
43.5	0.20	0.30	0.09	0.09	0.06	0.07	0.02	0.03	0.03	0.00
47.5	0.29	0.42	0.14	0.21	0.16	0.16	0.07	0.09	0.09	0.01
52.5	0.44	0.59	0.22	0.44	0.38	0.38	0.22	0.27	0.31	0.07
57.5	0.61	0.77	0.33	0.74	0.70	0.68	0.50	0.57	0.68	0.28
62.5	0.78	0.91	0.47	0.96	0.95	0.94	0.83	0.88	0.98	0.70
67.5	0.91	0.99	0.62	1.00	1.00	1.00	1.00	1.00	1.00	0.99
72.5	0.99	1.00	0.77	0.93	1.00	1.00	0.99	0.96	1.00	0.69
77.5	1.00	1.00	0.90	0.73	1.00	0.97	0.79	0.76	1.00	0.50
82.5	0.92	1.00	0.98	0.53	1.00	0.86	0.57	0.61	1.00	0.50
87.5	0.79	1.00	1.00	0.40	1.00	0.77	0.48	0.57	1.00	0.50
92.5	0.72	1.00	1.00	0.35	1.00	0.72	0.46	0.56	1.00	0.50
97.5	0.71	1.00	1.00	0.33	1.00	0.70	0.46	0.56	1.00	0.50
102.5	0.71	1.00	1.00	0.33	1.00	0.70	0.46	0.56	1.00	0.50
107.5	0.71	1.00	1.00	0.33	1.00	0.70	0.46	0.56	1.00	0.50

	Trawl survey	
Age	Pre82	Post81
0	0.00	0.00
1	0.10	0.40
2	1.00	1.00
3	1.00	1.00
4	0.73	1.00
5	0.13	1.00
6	0.13	0.96
7	0.13	0.73
8	0.13	0.44
9	0.13	0.24
10	0.13	0.14
11	0.13	0.11
12	0.13	0.11
13	0.13	0.10
14	0.13	0.10
15	0.13	0.10
16	0.13	0.10
17	0.13	0.10
18	0.13	0.10
19	0.13	0.10
20	0.13	0.10

Table 2.21—Schedules of Pacific cod length (cm) by season and age as estimated by Model 1. Sea1 = Jan-Jun, Sea2 = Jul-Aug, Sea3 = Sep-Dec.

	Population			Trawl fishery			Longline fishery			Pot fishery			Trawl survey		
Age	Sea1	Sea2	Sea3	Sea1	Sea2	Sea3	Sea1	Sea2	Sea3	Sea1	Sea2	Sea3	Pre82	Post81	IPHC
0	8.58	7.91	7.32	13.84	13.76	12.24	11.00	10.82	10.72	10.97	10.82	10.72	10.82	10.82	10.82
1	11.03	17.10	22.06	15.67	20.51	25.25	12.28	18.44	27.62	12.09	17.48	23.52	17.16	17.16	17.16
2	27.97	32.83	36.79	31.20	35.93	40.32	34.60	40.31	43.77	35.60	41.16	45.97	32.83	32.83	42.47
3	41.51	45.39	48.56	44.82	48.18	52.03	47.41	51.24	53.65	49.23	52.08	54.79	45.48	45.48	55.45
4	52.33	55.43	57.95	55.06	57.38	61.08	56.16	58.93	60.85	57.74	59.65	61.21	55.45	55.45	61.74
5	60.97	63.44	65.46	62.94	64.55	68.09	62.69	65.07	66.69	63.89	65.30	66.81	63.44	63.44	66.04
6	67.87	69.84	71.46	69.01	70.38	73.54	67.82	70.50	71.65	68.66	69.91	71.96	69.84	69.84	69.83
7	73.38	74.96	76.25	73.74	75.21	77.84	71.97	75.22	75.80	72.60	73.93	76.44	74.96	74.96	73.78
8	77.78	79.04	80.07	77.52	79.16	81.27	75.45	79.15	79.27	76.05	77.55	80.15	79.04	79.04	77.68
9	81.30	82.31	83.13	80.63	82.37	84.03	78.46	82.36	82.15	79.15	80.74	83.16	82.30	82.30	81.13
10	84.11	84.91	85.57	83.21	84.94	86.26	81.06	84.93	84.52	81.88	83.44	85.58	84.90	84.90	83.98
11	86.35	87.00	87.52	85.35	86.99	88.05	83.28	86.99	86.46	84.20	85.67	87.50	86.97	86.97	86.25
12	88.15	88.66	89.08	87.09	88.62	89.48	85.14	88.62	88.03	86.13	87.46	89.03	88.61	88.61	88.04
13	89.58	89.99	90.32	88.51	89.92	90.63	86.67	89.91	89.28	87.69	88.88	90.24	89.91	89.91	89.44
14	90.72	91.05	91.32	89.64	90.94	91.53	87.91	90.94	90.28	88.94	90.01	91.19	90.93	90.93	90.54
15	91.63	91.90	92.11	90.55	91.75	92.25	88.91	91.75	91.08	89.94	90.90	91.95	91.75	91.75	91.41
16	92.36	92.57	92.74	91.28	92.39	92.83	89.70	92.39	91.71	90.73	91.61	92.55	92.39	92.39	92.09
17	92.95	93.11	93.25	91.85	92.90	93.28	90.34	92.90	92.21	91.36	92.16	93.02	92.89	92.89	92.62
18	93.41	93.55	93.66	92.31	93.30	93.64	90.85	93.30	92.61	91.85	92.61	93.40	93.30	93.30	93.05
19	93.78	93.89	93.98	92.68	93.62	93.93	91.26	93.62	92.92	92.25	92.95	93.70	93.62	93.62	93.38
20	94.08	94.17	94.24	92.97	93.88	94.16	91.58	93.87	93.18	92.56	93.23	93.94	93.87	93.87	93.65

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

	Population			Trawl fishery			Longline fishery			Pot fishery			Trawl survey		
Age	Sea1	Sea2	Sea3	Sea1	Sea2	Sea3	Sea1	Sea2	Sea3	Sea1	Sea2	Sea3	Pre82	Post81	IPHC
0	0.01	0.01	0.01	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
1	0.02	0.05	0.11	0.03	0.08	0.16	0.02	0.07	0.22	0.02	0.05	0.14	0.05	0.05	0.05
2	0.23	0.38	0.54	0.32	0.50	0.72	0.43	0.71	0.92	0.48	0.76	1.07	0.38	0.38	0.88
3	0.80	1.07	1.32	1.01	1.27	1.63	1.19	1.53	1.78	1.34	1.61	1.90	1.07	1.07	1.96
4	1.68	2.02	2.33	1.95	2.23	2.73	2.07	2.41	2.68	2.25	2.50	2.72	2.02	2.02	2.78
5	2.74	3.12	3.45	3.01	3.27	3.89	2.96	3.34	3.62	3.13	3.37	3.64	3.12	3.12	3.47
6	3.88	4.25	4.58	4.06	4.34	4.99	3.82	4.36	4.59	3.97	4.22	4.66	4.25	4.25	4.19
7	4.99	5.34	5.65	5.04	5.39	6.00	4.65	5.39	5.52	4.77	5.08	5.68	5.34	5.34	5.06
8	6.02	6.35	6.62	5.93	6.37	6.91	5.43	6.37	6.39	5.57	5.96	6.63	6.35	6.35	6.01
9	6.95	7.23	7.47	6.75	7.25	7.70	6.19	7.24	7.19	6.37	6.81	7.48	7.23	7.23	6.94
10	7.76	8.00	8.20	7.48	8.01	8.39	6.90	8.00	7.89	7.13	7.59	8.20	8.00	8.00	7.76
11	8.44	8.64	8.81	8.13	8.65	8.97	7.55	8.65	8.49	7.83	8.27	8.81	8.64	8.64	8.45
12	9.01	9.18	9.32	8.69	9.18	9.45	8.12	9.18	9.00	8.43	8.84	9.32	9.18	9.18	9.02
13	9.48	9.62	9.73	9.16	9.62	9.84	8.60	9.62	9.42	8.93	9.31	9.73	9.62	9.62	9.49
14	9.86	9.97	10.06	9.54	9.98	10.17	9.01	9.97	9.77	9.35	9.69	10.06	9.97	9.97	9.86
15	10.17	10.26	10.33	9.86	10.26	10.42	9.34	10.26	10.04	9.68	10.00	10.33	10.26	10.26	10.16
16	10.42	10.49	10.55	10.11	10.49	10.63	9.62	10.49	10.27	9.96	10.25	10.55	10.49	10.49	10.40
17	10.62	10.67	10.72	10.32	10.67	10.80	9.84	10.67	10.45	10.18	10.45	10.72	10.67	10.67	10.59
18	10.78	10.82	10.86	10.48	10.82	10.93	10.01	10.82	10.59	10.35	10.60	10.86	10.82	10.82	10.75
19	10.90	10.94	10.97	10.62	10.94	11.04	10.16	10.94	10.71	10.49	10.73	10.97	10.94	10.94	10.87
20	11.00	11.03	11.05	10.72	11.03	11.12	10.27	11.03	10.80	10.61	10.83	11.06	11.03	11.03	10.97

Table 2.23—Time series of EBS (not expanded to BSAI) Pacific cod female spawning biomass (t) for the years 1977-2006 as estimated last year under the Plan Team's and SSC's preferred model and this year under Model 1, 1977-2007 The columns labeled "L95%CI" and "U95%CI" represent the lower and upper bounds of the 95% confidence interval.

	Last Year's Values			This Year's Values		
Year	Sp. Bio.	L95%CI	U95%CI	Sp. Bio.	L95%CI	U95%CI
1977	56,590	39,103	74,077	127,575	47,260	207,890
1978	78,325	57,381	99,269	155,625	68,818	242,432
1979	114,795	87,281	142,309	202,290	101,556	303,024
1980	181,760	144,358	219,162	283,920	162,116	405,724
1981	290,795	239,529	342,061	425,240	274,389	576,091
1982	424,045	357,133	490,957	625,900	438,524	813,276
1983	544,850	465,244	624,456	819,800	603,485	1,036,115
1984	613,850	527,493	700,207	924,700	701,054	1,148,346
1985	630,500	542,936	718,064	932,450	720,084	1,144,816
1986	622,950	537,388	708,512	888,200	694,836	1,081,564
1987	619,300	537,036	701,564	849,750	674,585	1,024,915
1988	607,300	529,182	685,418	815,200	655,774	974,626
1989	564,850	491,797	637,903	760,400	615,438	905,362
1990	516,550	449,321	583,779	702,300	571,901	832,699
1991	454,815	394,277	515,353	620,050	505,419	734,681
1992	378,065	324,193	431,937	512,550	413,021	612,079
1993	344,165	295,331	392,999	451,425	362,648	540,202
1994	351,985	306,049	397,921	445,295	361,897	528,693
1995	360,540	315,910	405,170	448,745	367,448	530,042
1996	350,860	306,281	395,439	432,445	352,105	512,785
1997	343,040	297,689	388,391	416,680	337,350	496,010
1998	314,645	268,605	360,685	375,345	298,165	452,525
1999	308,685	261,600	355,770	351,455	276,238	426,672
2000	319,535	270,639	368,431	345,010	269,609	420,411
2001	342,440	291,318	393,562	358,985	280,568	437,402
2002	366,965	314,358	419,572	384,300	301,471	467,129
2003	376,425	323,431	429,419	404,030	316,403	491,657
2004	376,585	323,995	429,175	424,690	331,946	517,434
2005	360,260	308,790	411,730	429,370	332,850	525,890
2006	326,400	276,697	376,103	407,020	309,816	504,224
2007	n/a	n/a	n/a	369,640	274,504	464,776

Table 2.24—Time series of EBS (not expanded to BSAI) Pacific cod age 0 recruitment (1000s of fish) as estimated last year under the Plan Team's and SSC's preferred model and this year under Model 1, 1977-2006. The columns labeled "L95%CI" and "U95%CI" represent the lower and upper bounds of the 95% confidence interval for each cohort.

	Last Year's Values			This Year's Values		
Year	Recruits	L95%CI	U95%CI	Recruits	L95%CI	U95%CI
1977	1,611,960	1,292,760	2,009,960	2,533,200	1,869,348	3,197,052
1978	1,014,290	755,490	1,361,690	787,020	486,160	1,087,880
1979	947,821	723,421	1,241,821	1,042,300	796,849	1,287,751
1980	453,442	302,942	678,742	411,490	283,294	539,686
1981	886,610	704,310	1,116,110	211,920	128,575	295,265
1982	1,508,730	1,280,230	1,778,030	1,354,400	1,149,286	1,559,514
1983	383,242	263,542	557,342	248,630	167,343	329,917
1984	1,210,830	1,030,230	1,423,130	1,045,200	892,093	1,198,307
1985	418,040	315,040	554,740	553,370	447,936	658,804
1986	392,177	299,587	513,377	284,700	218,781	350,619
1987	313,653	227,433	432,553	158,470	109,815	207,125
1988	906,898	766,798	1,072,598	392,570	320,744	464,396
1989	1,139,520	975,220	1,331,520	801,750	682,919	920,581
1990	658,085	534,385	810,485	731,990	631,722	832,258
1991	926,882	787,582	1,090,882	383,500	317,436	449,564
1992	1,000,980	858,580	1,166,980	883,170	770,819	995,521
1993	373,064	285,674	487,164	325,880	272,607	379,153
1994	565,069	460,369	693,569	323,260	271,453	375,067
1995	985,921	844,021	1,151,721	359,010	295,639	422,381
1996	1,106,130	960,530	1,273,830	892,480	749,316	1,035,644
1997	600,909	500,609	721,309	449,700	378,282	521,118
1998	830,782	710,482	971,382	497,990	416,483	579,497
1999	1,023,880	890,480	1,177,280	904,670	761,386	1,047,954
2000	528,671	442,611	631,471	623,730	528,149	719,311
2001	462,633	381,223	561,433	325,960	266,200	385,720
2002	429,282	342,522	537,982	398,510	325,433	471,587
2003	394,653	298,673	521,453	350,100	277,070	423,130
2004	303,430	193,130	476,630	203,560	154,074	253,046
2005	675,083	448,783	1,015,383	393,800	273,891	513,709
2006	n/a	n/a	n/a	1,835,100	1,013,252	2,656,948

Table 2.25—Time series of EBS Pacific cod catch divided by age 3+ biomass as estimated last year under the Plan Team's and SSC's preferred model and this year under Model 1, 1977-2007. The last entry in each column is based on partial catches for the respective year, because the year was/is still in progress at the time of the assessment.

Year	Last Year's Values	This Year's Values
1977	0.11	0.07
1978	0.12	0.08
1979	0.05	0.05
1980	0.04	0.03
1981	0.04	0.03
1982	0.04	0.03
1983	0.05	0.04
1984	0.07	0.05
1985	0.08	0.06
1986	0.07	0.06
1987	0.08	0.06
1988	0.12	0.09
1989	0.11	0.09
1990	0.13	0.10
1991	0.17	0.14
1992	0.14	0.12
1993	0.11	0.10
1994	0.14	0.13
1995	0.18	0.16
1996	0.18	0.16
1997	0.21	0.19
1998	0.15	0.15
1999	0.13	0.13
2000	0.13	0.14
2001	0.12	0.12
2002	0.13	0.13
2003	0.14	0.13
2004	0.16	0.14
2005	0.17	0.15
2006	0.19	0.15
2007	n/a	0.15

Table 2.26—Projections for BSAI Pacific cod catch (t), spawning biomass (t), and fishing mortality under the assumption that $F = max\ F_{ABC}$ in 2008-2020 (Scenarios 1 and 2), with random variability in future recruitment.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2008	150,000	150,000	150,000	150,000	0
2009	161,000	161,000	162,000	162,000	111
2010	257,000	258,000	259,000	264,000	2,792
2011	350,000	367,000	369,000	397,000	16,197
2012	325,000	365,000	377,000	468,000	50,648
2013	255,000	347,000	362,000	507,000	83,911
2014	210,000	334,000	346,000	525,000	102,413
2015	182,000	327,000	336,000	525,000	107,342
2016	169,000	321,000	328,000	514,000	106,534
2017	161,000	320,000	324,000	507,000	105,837
2018	166,000	321,000	323,000	512,000	106,547
2019	167,000	316,000	324,000	516,000	107,519
2020	167,000	319,000	325,000	522,000	110,055

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2008	398,000	398,000	398,000	398,000	0
2009	394,000	395,000	395,000	395,000	263
2010	452,000	454,000	455,000	462,000	3,589
2011	529,000	542,000	547,000	579,000	17,567
2012	544,000	584,000	596,000	687,000	50,533
2013	501,000	583,000	603,000	770,000	93,272
2014	457,000	563,000	594,000	820,000	123,433
2015	427,000	555,000	585,000	834,000	134,722
2016	406,000	548,000	577,000	827,000	134,494
2017	397,000	542,000	570,000	830,000	131,220
2018	396,000	542,000	567,000	816,000	130,130
2019	400,000	541,000	567,000	816,000	131,630
2020	403,000	538,000	568,000	823,000	134,414

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2008	0.22	0.22	0.22	0.22	0.00
2009	0.22	0.22	0.22	0.22	0.00
2010	0.25	0.26	0.26	0.26	0.00
2011	0.30	0.31	0.31	0.31	0.00
2012	0.31	0.31	0.31	0.31	0.00
2013	0.28	0.31	0.30	0.31	0.01
2014	0.26	0.31	0.30	0.31	0.02
2015	0.24	0.31	0.29	0.31	0.02
2016	0.23	0.31	0.29	0.31	0.03
2017	0.22	0.31	0.29	0.31	0.03
2018	0.22	0.31	0.29	0.31	0.03
2019	0.22	0.31	0.29	0.31	0.03
2020	0.22	0.31	0.29	0.31	0.03

Table 2.27—Projections for BSAI Pacific cod catch (t), spawning biomass (t), and fishing mortality under the assumption that F = ½ *max* F_{ABC} in 2007-2019 (Scenario 3), with random variability in future recruitment.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2008	136,000	136,000	136,000	136,000	0
2009	149,000	149,000	149,000	149,000	2
2010	208,000	208,000	209,000	210,000	612
2011	251,000	258,000	260,000	278,000	9,997
2012	244,000	271,000	279,000	342,000	34,831
2013	217,000	270,000	282,000	385,000	57,507
2014	199,000	266,000	281,000	409,000	69,408
2015	185,000	266,000	279,000	415,000	72,935
2016	176,000	263,000	275,000	408,000	72,658
2017	169,000	263,000	273,000	404,000	72,158
2018	170,000	262,000	272,000	410,000	72,815
2019	173,000	261,000	272,000	408,000	73,828
2020	175,000	259,000	273,000	424,000	75,780

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2008	399,000	399,000	399,000	399,000	0
2009	401,000	401,000	401,000	402,000	271
2010	464,000	467,000	468,000	474,000	3,738
2011	561,000	575,000	579,000	613,000	18,421
2012	615,000	658,000	671,000	765,000	52,993
2013	601,000	694,000	715,000	896,000	101,334
2014	562,000	699,000	729,000	983,000	142,263
2015	528,000	697,000	731,000	1,020,000	165,097
2016	498,000	698,000	728,000	1,040,000	173,335
2017	478,000	694,000	722,000	1,060,000	174,606
2018	468,000	697,000	717,000	1,040,000	175,177
2019	470,000	694,000	715,000	1,040,000	177,340
2020	468,000	687,000	716,000	1,040,000	180,757

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2008	0.20	0.20	0.20	0.20	0.00
2009	0.20	0.20	0.20	0.20	0.00
2010	0.20	0.20	0.20	0.20	0.00
2011	0.20	0.20	0.20	0.20	0.00
2012	0.20	0.20	0.20	0.20	0.00
2013	0.20	0.20	0.20	0.20	0.00
2014	0.20	0.20	0.20	0.20	0.00
2015	0.20	0.20	0.20	0.20	0.00
2016	0.20	0.20	0.20	0.20	0.00
2017	0.20	0.20	0.20	0.20	0.00
2018	0.20	0.20	0.20	0.20	0.00
2019	0.20	0.20	0.20	0.20	0.00
2020	0.20	0.20	0.20	0.20	0.00

Table 2.28—Projections for BSAI Pacific cod catch (t), spawning biomass (t), and fishing mortality under the assumption that the upper bound on F_{ABC} is set at $F_{60\%}$ (Scenario 4), with random variability in future recruitment.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2008	105,000	105,000	105,000	105,000	0
2009	118,000	118,000	118,000	118,000	2
2010	165,000	165,000	165,000	166,000	462
2011	202,000	207,000	209,000	223,000	7,583
2012	201,000	223,000	229,000	277,000	26,816
2013	183,000	225,000	234,000	314,000	45,214
2014	170,000	223,000	235,000	339,000	55,620
2015	160,000	225,000	235,000	343,000	59,278
2016	152,000	223,000	233,000	343,000	59,562
2017	147,000	223,000	231,000	340,000	59,318
2018	146,000	222,000	231,000	345,000	59,837
2019	150,000	222,000	231,000	345,000	60,660
2020	150,000	220,000	232,000	356,000	62,237

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2008	401,000	401,000	401,000	401,000	0
2009	416,000	416,000	416,000	417,000	271
2010	490,000	492,000	493,000	500,000	3,739
2011	601,000	615,000	619,000	653,000	18,465
2012	673,000	717,000	729,000	825,000	53,657
2013	674,000	769,000	791,000	978,000	104,797
2014	642,000	786,000	818,000	1,090,000	150,814
2015	609,000	791,000	828,000	1,150,000	178,821
2016	579,000	797,000	829,000	1,170,000	190,716
2017	557,000	793,000	826,000	1,190,000	193,876
2018	546,000	798,000	822,000	1,180,000	195,088
2019	548,000	797,000	821,000	1,190,000	197,504
2020	548,000	793,000	822,000	1,180,000	201,226

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2008	0.15	0.15	0.15	0.15	0.00
2009	0.15	0.15	0.15	0.15	0.00
2010	0.15	0.15	0.15	0.15	0.00
2011	0.15	0.15	0.15	0.15	0.00
2012	0.15	0.15	0.15	0.15	0.00
2013	0.15	0.15	0.15	0.15	0.00
2014	0.15	0.15	0.15	0.15	0.00
2015	0.15	0.15	0.15	0.15	0.00
2016	0.15	0.15	0.15	0.15	0.00
2017	0.15	0.15	0.15	0.15	0.00
2018	0.15	0.15	0.15	0.15	0.00
2019	0.15	0.15	0.15	0.15	0.00
2020	0.15	0.15	0.15	0.15	0.00

Table 2.29—Projections for BSAI Pacific cod catch (t), spawning biomass (t), and fishing mortality under the assumption that *F* = 0 in 2007-2019 (Scenario 5), with random variability in future recruitment.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2008	0	0	0	0	0
2009	0	0	0	0	0
2010	0	0	0	0	0
2011	0	0	0	0	0
2012	0	0	0	0	0
2013	0	0	0	0	0
2014	0	0	0	0	0
2015	0	0	0	0	0
2016	0	0	0	0	0
2017	0	0	0	0	0
2018	0	0	0	0	0
2019	0	0	0	0	0
2020	0	0	0	0	0

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2008	409,000	409,000	409,000	409,000	0
2009	467,000	467,000	467,000	468,000	271
2010	582,000	585,000	586,000	592,000	3,741
2011	750,000	764,000	768,000	802,000	18,601
2012	900,000	945,000	959,000	1,060,000	55,758
2013	975,000	1,080,000	1,100,000	1,310,000	116,438
2014	988,000	1,160,000	1,200,000	1,520,000	181,814
2015	984,000	1,210,000	1,260,000	1,670,000	232,320
2016	966,000	1,250,000	1,300,000	1,760,000	262,961
2017	938,000	1,280,000	1,320,000	1,840,000	278,436
2018	924,000	1,290,000	1,330,000	1,870,000	286,143
2019	934,000	1,310,000	1,340,000	1,870,000	291,846
2020	943,000	1,320,000	1,350,000	1,890,000	297,867

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2008	0.00	0.00	0.00	0.00	0.00
2009	0.00	0.00	0.00	0.00	0.00
2010	0.00	0.00	0.00	0.00	0.00
2011	0.00	0.00	0.00	0.00	0.00
2012	0.00	0.00	0.00	0.00	0.00
2013	0.00	0.00	0.00	0.00	0.00
2014	0.00	0.00	0.00	0.00	0.00
2015	0.00	0.00	0.00	0.00	0.00
2016	0.00	0.00	0.00	0.00	0.00
2017	0.00	0.00	0.00	0.00	0.00
2018	0.00	0.00	0.00	0.00	0.00
2019	0.00	0.00	0.00	0.00	0.00
2020	0.00	0.00	0.00	0.00	0.00

Table 2.30—Projections for BSAI Pacific cod catch (t), spawning biomass (t), and fishing mortality under the assumption that $F = F_{OFL}$ in 2007-2019 (Scenario 6), with random variability in future recruitment.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2008	176,000	176,000	176,000	176,000	0
2009	181,000	181,000	181,000	181,000	127
2010	284,000	286,000	287,000	292,000	3,178
2011	378,000	399,000	405,000	452,000	24,872
2012	341,000	407,000	415,000	523,000	62,322
2013	257,000	373,000	386,000	560,000	101,898
2014	212,000	345,000	364,000	568,000	119,982
2015	184,000	333,000	352,000	571,000	123,047
2016	172,000	327,000	344,000	555,000	121,118
2017	165,000	329,000	340,000	553,000	120,121
2018	169,000	327,000	340,000	554,000	121,095
2019	172,000	323,000	341,000	560,000	122,449
2020	171,000	327,000	343,000	565,000	125,284

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2008	396,000	396,000	396,000	396,000	0
2009	383,000	383,000	383,000	383,000	262
2010	434,000	436,000	437,000	444,000	3,569
2011	503,000	516,000	520,000	551,000	17,067
2012	508,000	545,000	556,000	640,000	47,349
2013	459,000	530,000	551,000	705,000	85,769
2014	418,000	509,000	537,000	743,000	109,629
2015	390,000	501,000	527,000	745,000	116,282
2016	375,000	494,000	520,000	736,000	114,049
2017	367,000	493,000	514,000	734,000	110,752
2018	368,000	494,000	512,000	732,000	110,494
2019	370,000	490,000	513,000	726,000	112,356
2020	370,000	493,000	514,000	738,000	114,860

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2008	0.26	0.26	0.26	0.26	0.00
2009	0.25	0.26	0.26	0.26	0.00
2010	0.29	0.29	0.29	0.30	0.00
2011	0.34	0.35	0.35	0.37	0.01
2012	0.34	0.37	0.36	0.37	0.01
2013	0.31	0.36	0.35	0.37	0.02
2014	0.28	0.35	0.34	0.37	0.03
2015	0.26	0.34	0.33	0.37	0.04
2016	0.25	0.33	0.33	0.37	0.04
2017	0.24	0.33	0.33	0.37	0.04
2018	0.24	0.34	0.32	0.37	0.04
2019	0.25	0.33	0.32	0.37	0.04
2020	0.25	0.33	0.32	0.37	0.04

Table 2.31—Projections for BSAI Pacific cod catch (t), spawning biomass (t), and fishing mortality under the assumption that $F = max\ F_{ABC}$ in each year 2007-2008 and $F = F_{OFL}$ thereafter (Scenario 7), with random variability in future recruitment.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2008	150,000	150,000	150,000	150,000	0
2009	161,000	161,000	162,000	162,000	111
2010	301,000	304,000	304,000	310,000	3,258
2011	389,000	409,000	415,000	456,000	23,444
2012	344,000	408,000	417,000	526,000	61,953
2013	257,000	374,000	387,000	561,000	102,040
2014	212,000	345,000	365,000	568,000	120,158
2015	184,000	333,000	352,000	571,000	123,146
2016	172,000	327,000	344,000	555,000	121,163
2017	165,000	329,000	340,000	553,000	120,140
2018	169,000	327,000	340,000	554,000	121,103
2019	172,000	323,000	341,000	560,000	122,452
2020	171,000	327,000	343,000	565,000	125,285

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2008	398,000	398,000	398,000	398,000	0
2009	394,000	395,000	395,000	395,000	263
2010	449,000	452,000	453,000	459,000	3,569
2011	511,000	524,000	528,000	559,000	17,140
2012	511,000	548,000	560,000	645,000	47,884
2013	460,000	531,000	552,000	708,000	86,375
2014	418,000	509,000	538,000	744,000	110,059
2015	389,000	501,000	527,000	746,000	116,519
2016	375,000	494,000	520,000	737,000	114,159
2017	367,000	493,000	514,000	734,000	110,798
2018	368,000	494,000	512,000	732,000	110,512
2019	370,000	490,000	513,000	726,000	112,362
2020	370,000	493,000	514,000	738,000	114,862

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2008	0.22	0.22	0.22	0.22	0.00
2009	0.22	0.22	0.22	0.22	0.00
2010	0.30	0.30	0.31	0.31	0.00
2011	0.35	0.36	0.36	0.37	0.01
2012	0.35	0.37	0.36	0.37	0.01
2013	0.31	0.36	0.35	0.37	0.02
2014	0.28	0.35	0.34	0.37	0.03
2015	0.26	0.34	0.33	0.37	0.04
2016	0.25	0.33	0.33	0.37	0.04
2017	0.24	0.33	0.33	0.37	0.04
2018	0.24	0.34	0.32	0.37	0.04
2019	0.25	0.33	0.32	0.37	0.04
2020	0.25	0.33	0.32	0.37	0.04

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Tier	3b
Reference mortality rates	
M	0.34
$F_{40\%}$	0.31
$F_{35\%}$	0.37
Equilibrium spawning biomass	
$B_{35\%}$	472,000 t
$B_{40\%}$	540,000 t
$B_{100\%}$	1,350,000 t
Projected biomass for 2008	
Spawning (at max FABC)	398,000 t
Age 3+	1,080,000 t
ABC for 2008	
F_{ABC} (maximum permissible)	0.22
F_{ABC} (recommended)	0.22
ABC (maximum permissible)	150,000 t
ABC (recommended)	150,000 t
Overfishing level for 2008	
Fishing Mortality	0.26
Catch	176,000 t

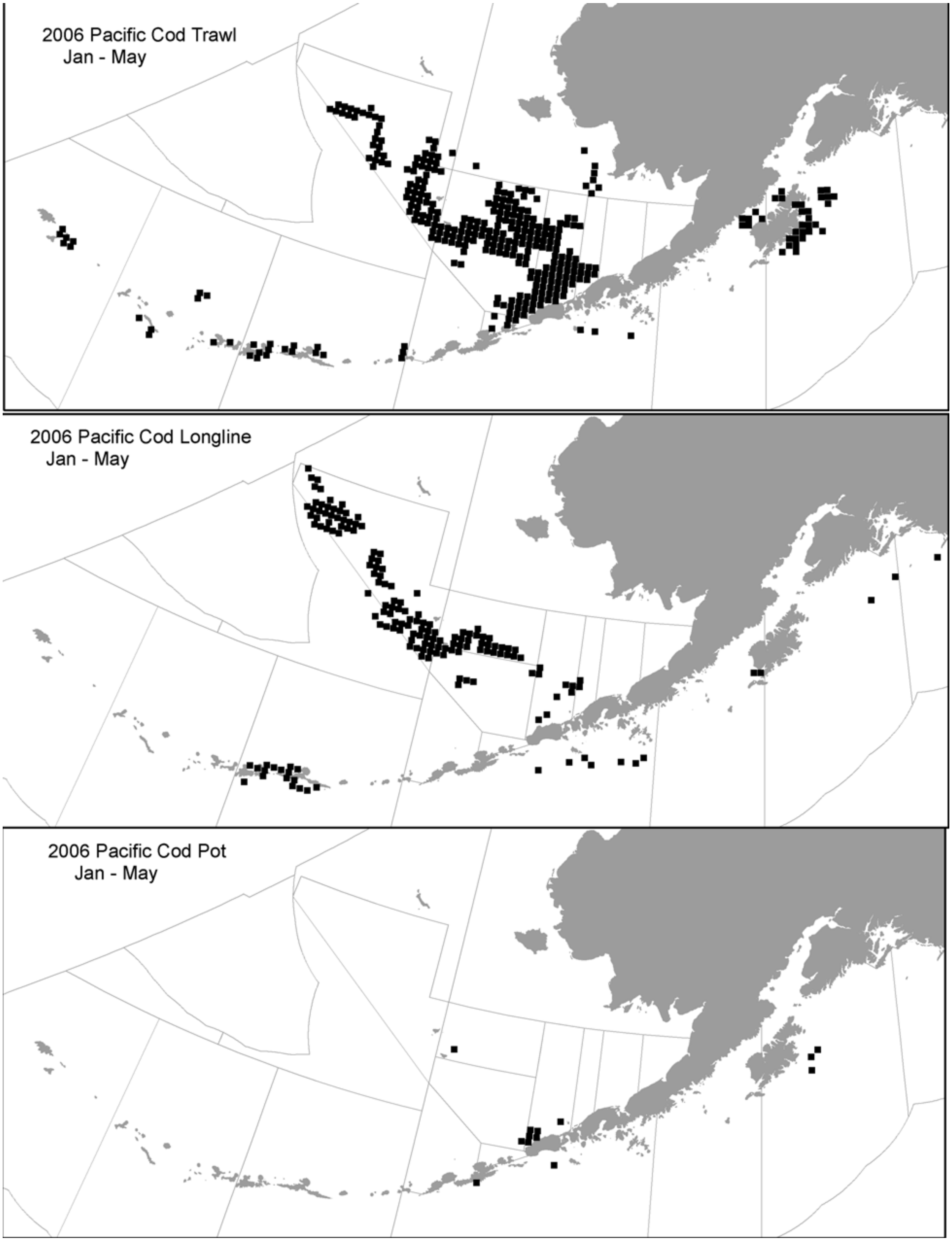


Figure 2.1a—Maps showing each 400 square kilometer cell with at least 3 observed hauls/sets containing Pacific cod in January-May 2006, by gear type, overlaid against NMFS 3-digit statistical areas.

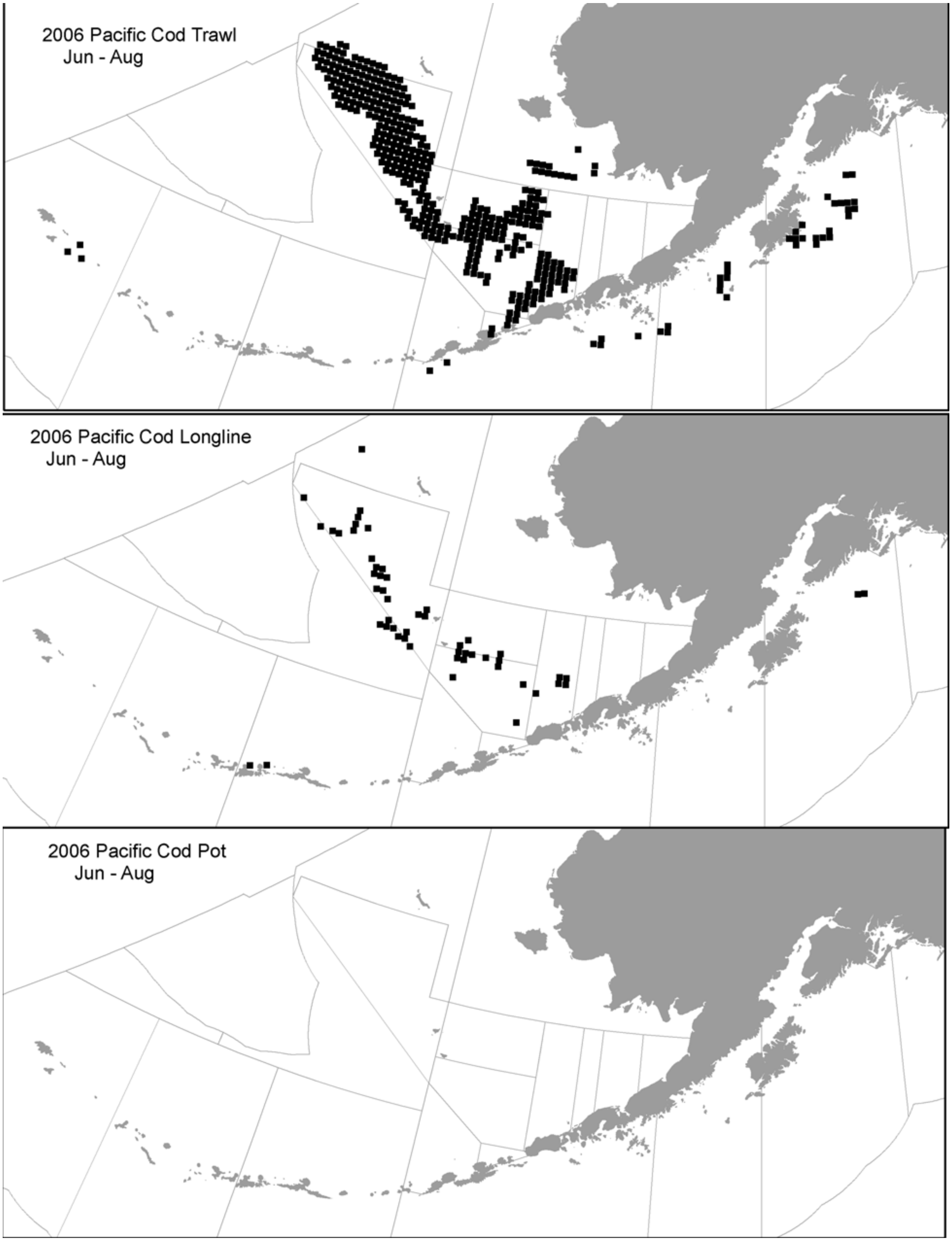


Figure 2.1b—Maps showing each 400 square kilometer cell with at least 3 observed hauls/sets containing Pacific cod in June-August 2006, by gear type, overlaid against NMFS 3-digit statistical areas.

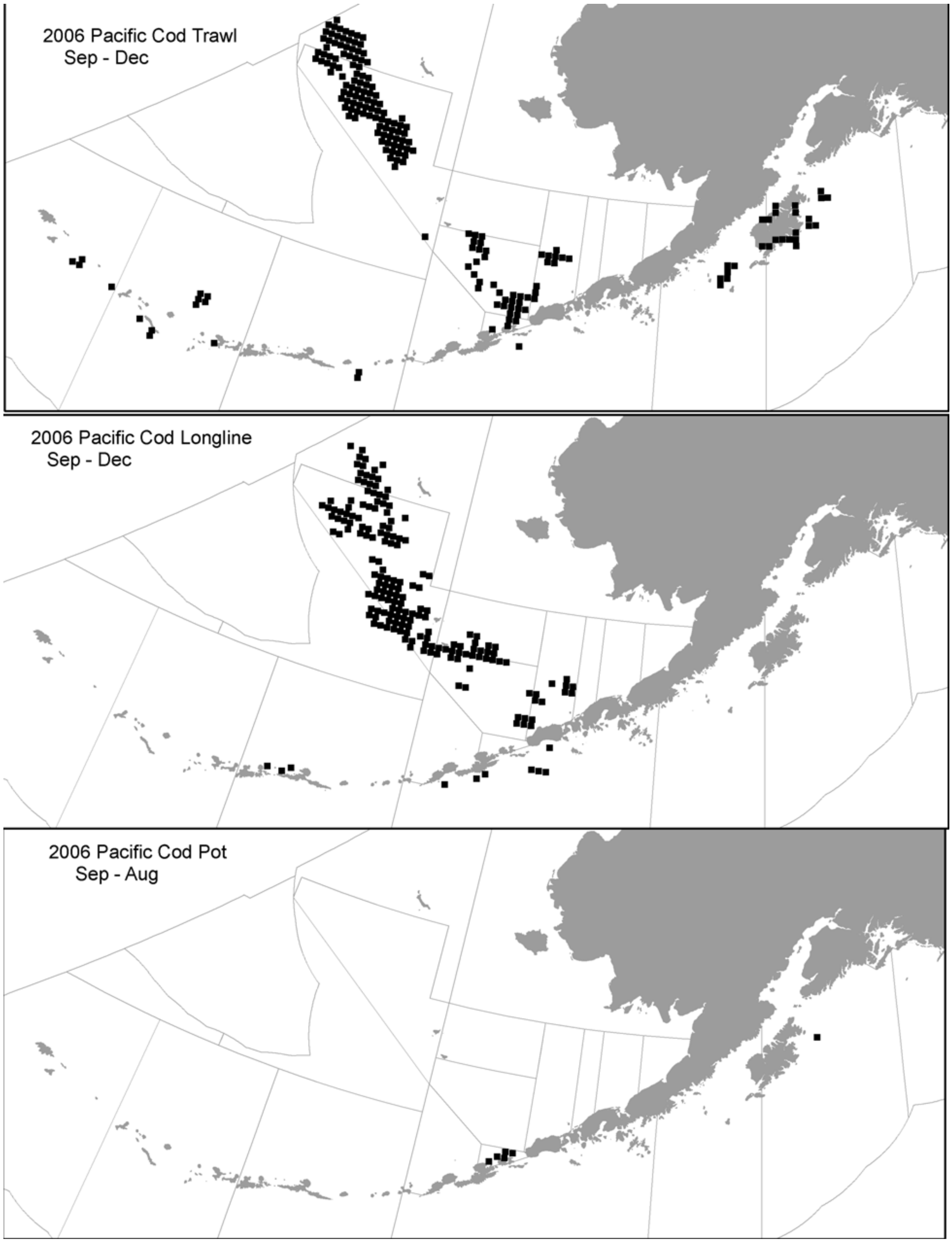


Figure 2.1c—Maps showing each 400 square kilometer cell with at least 3 observed hauls/sets containing Pacific cod in September-December 2006, by gear type, overlaid against NMFS 3-digit statistical areas.

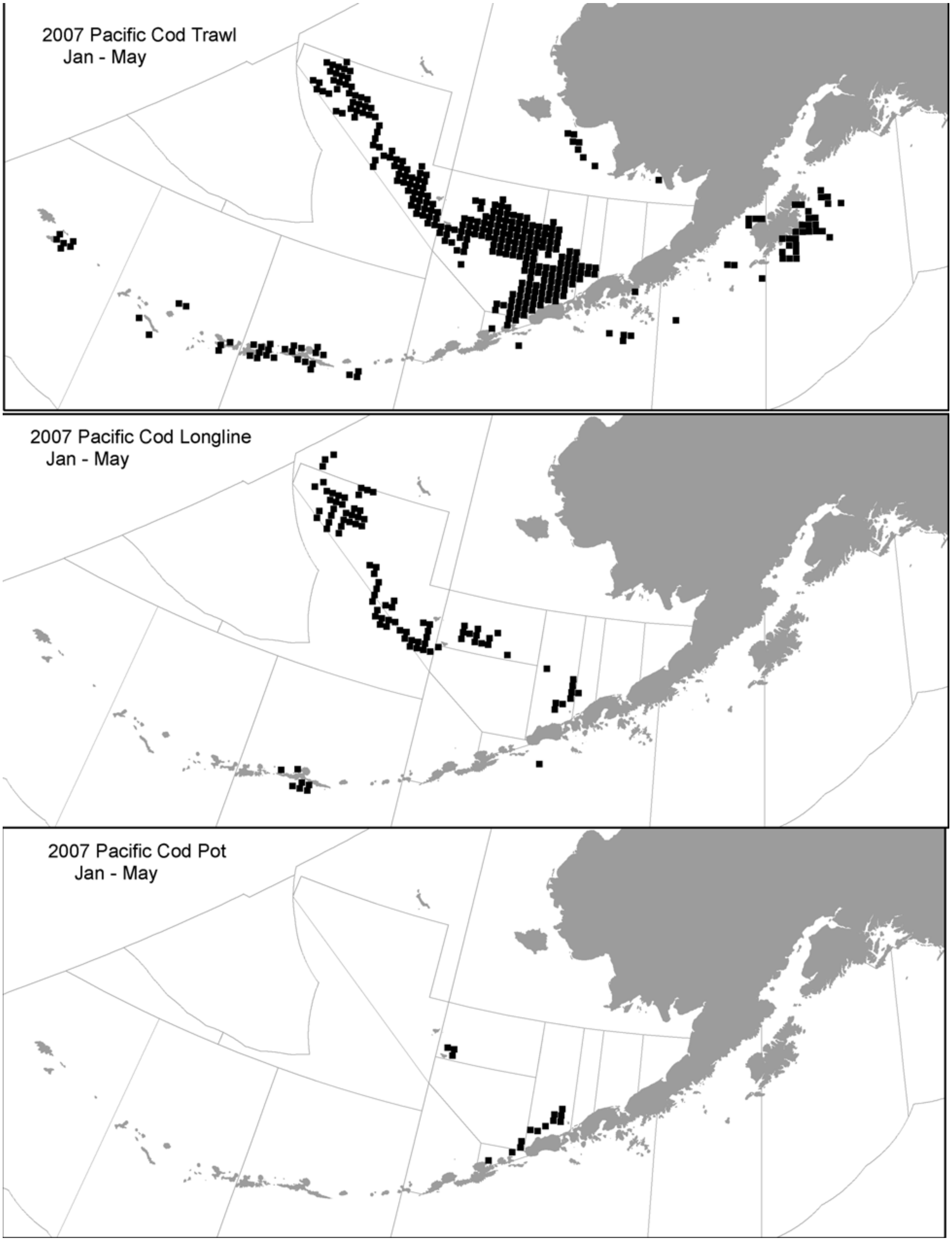


Figure 2.1d—Maps showing each 400 square kilometer cell with at least 3 observed hauls/sets containing Pacific cod in January-May 2007, by gear type, overlaid against NMFS 3-digit statistical areas.

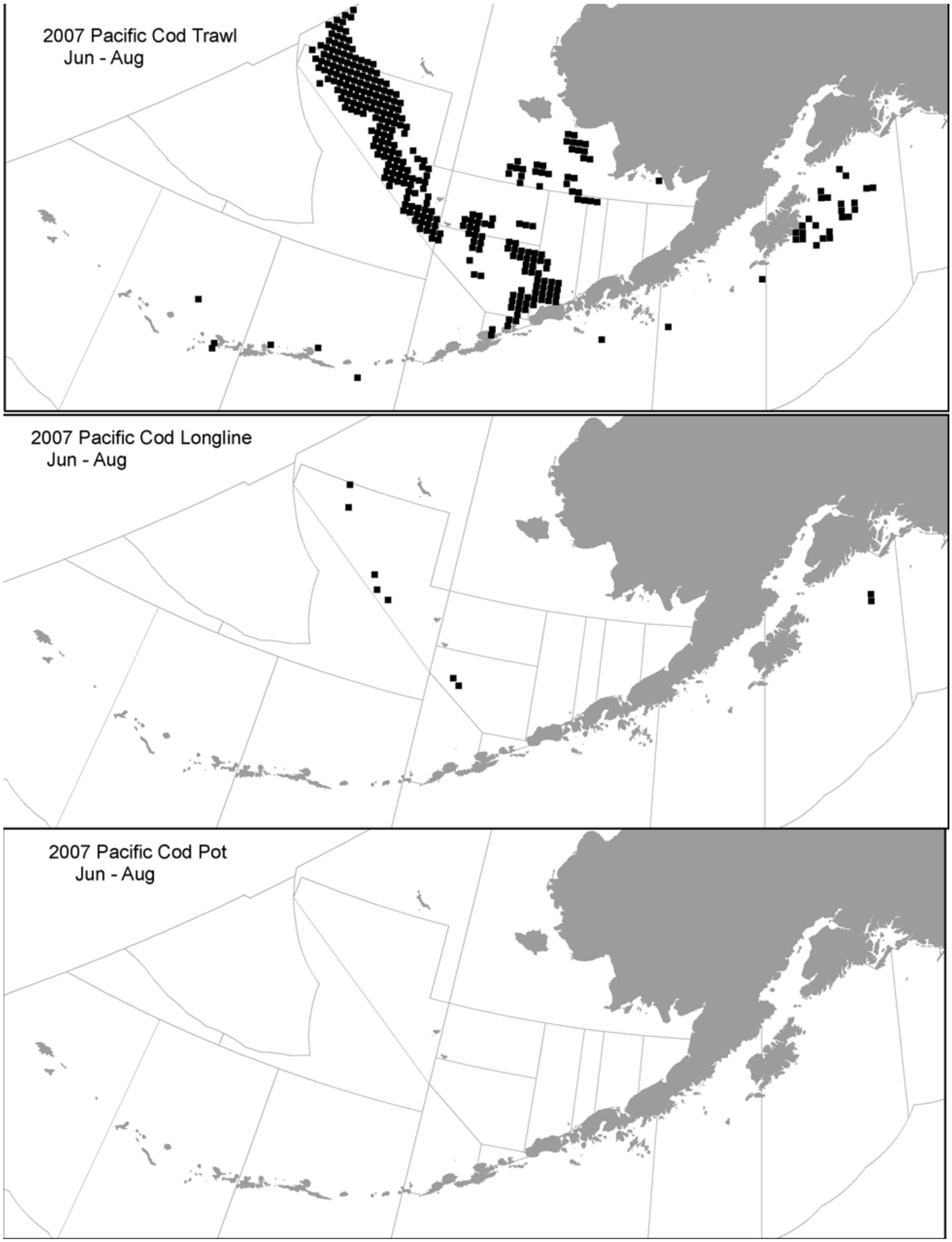


Figure 2.1e—Maps showing each 400 square kilometer cell with at least 3 observed hauls/sets containing Pacific cod in June-August 2007, by gear type, overlaid against NMFS 3-digit statistical areas.

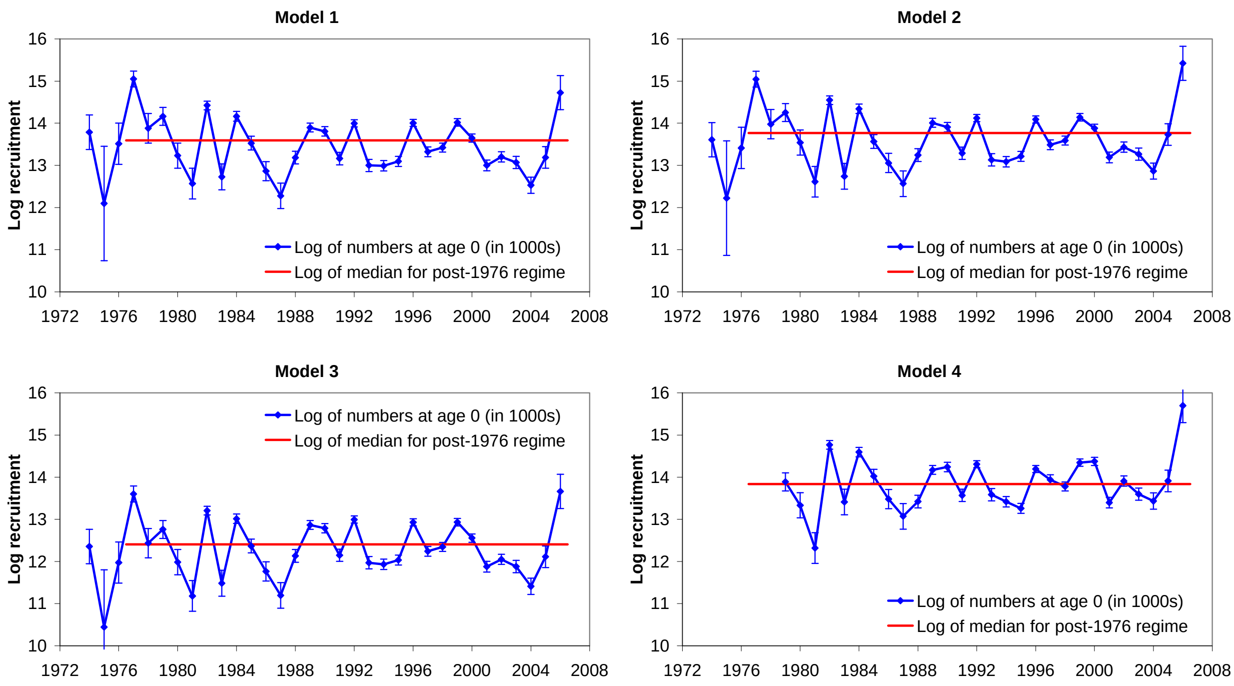


Figure 2.2—Comparison of log numbers (1000s) of age 0 EBS Pacific cod under four alternative models.

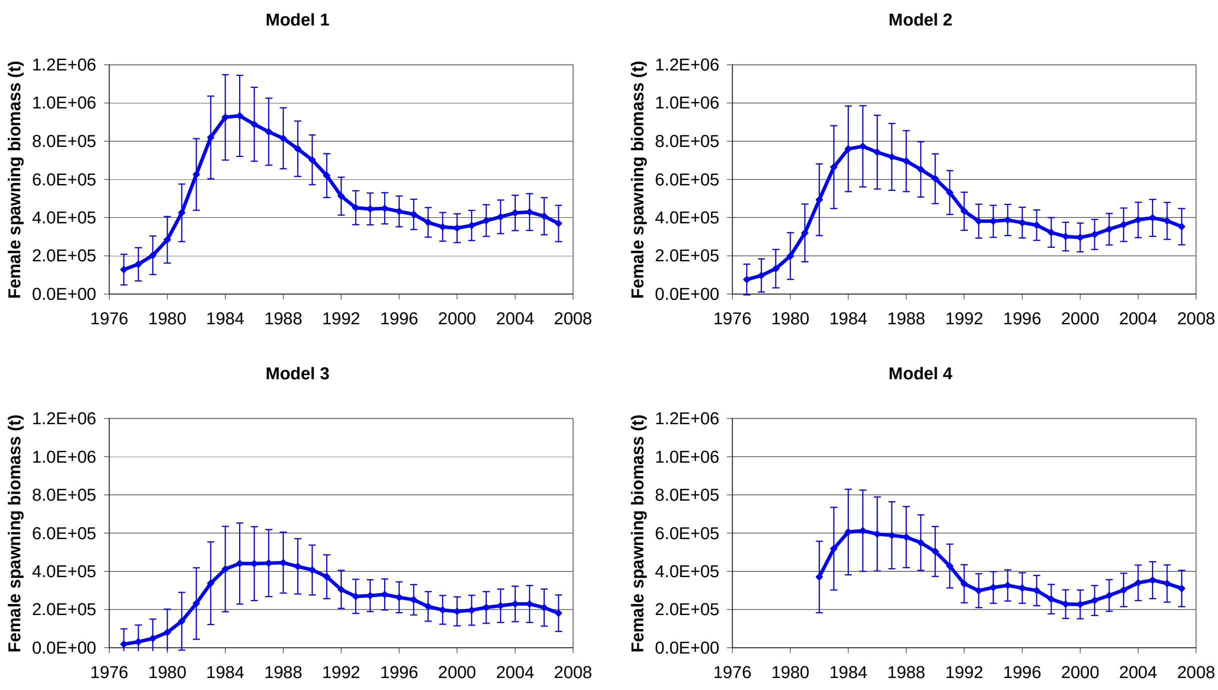


Figure 2.3—Comparison of female spawning biomass of EBS Pacific cod under four alternative models.

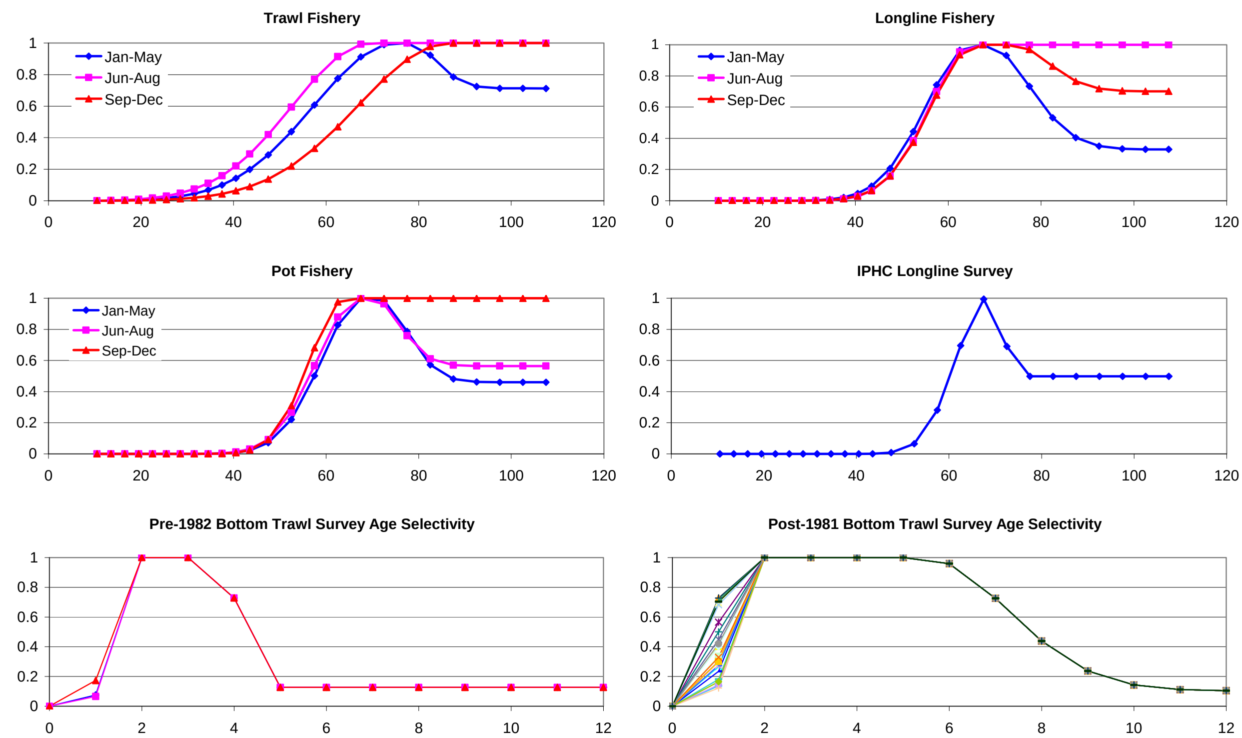


Figure 2.4a. Model 1 selectivity.

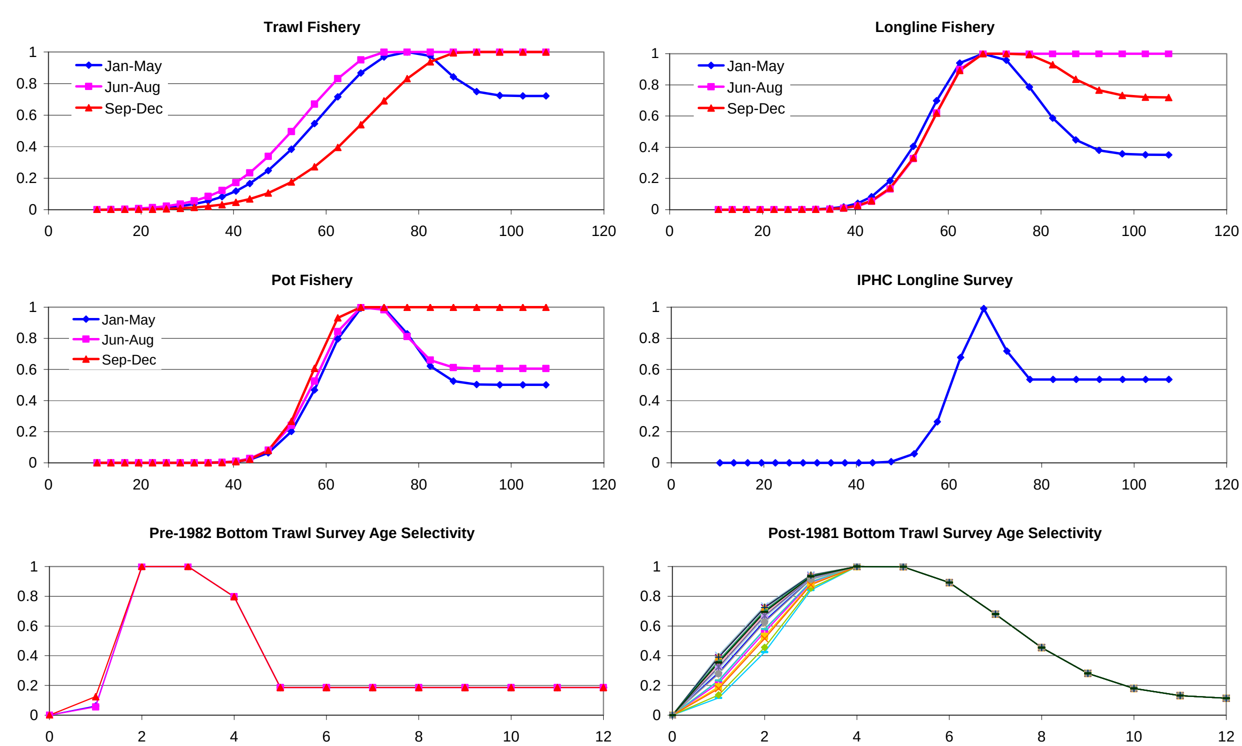


Figure 2.4b. Model 2 selectivity.

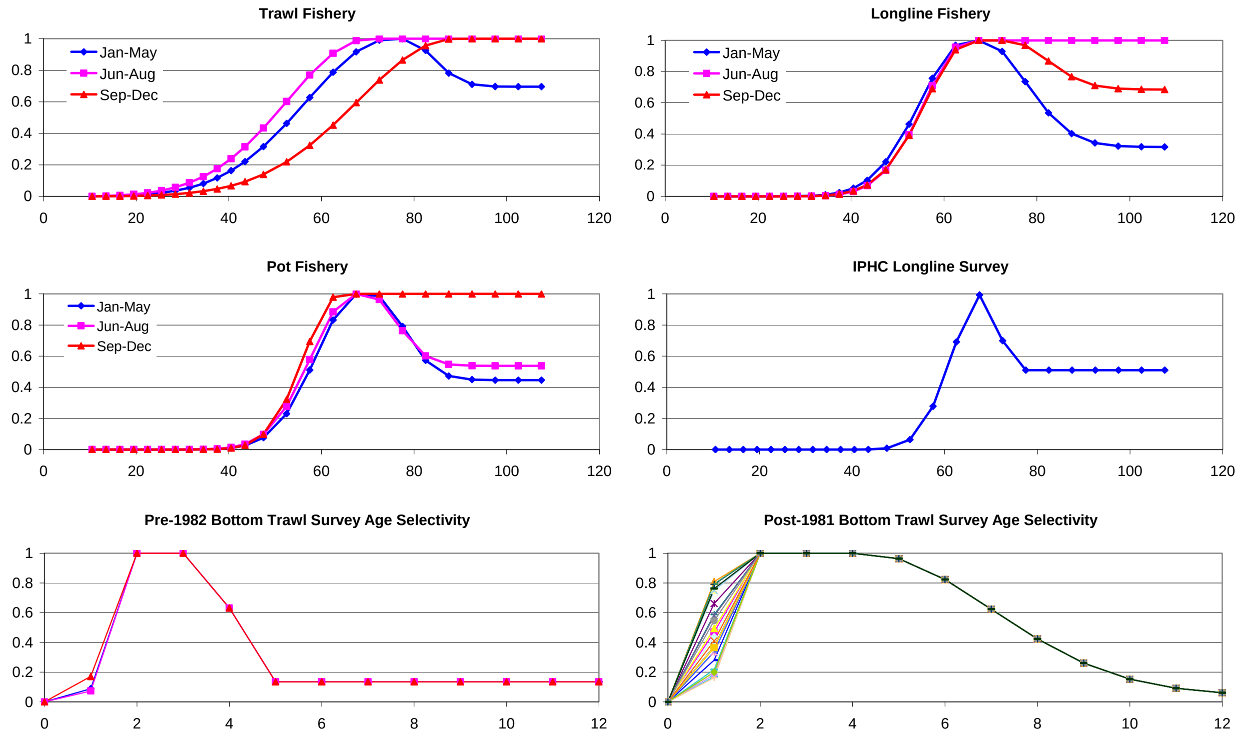


Figure 2.4c. Model 3 selectivity.

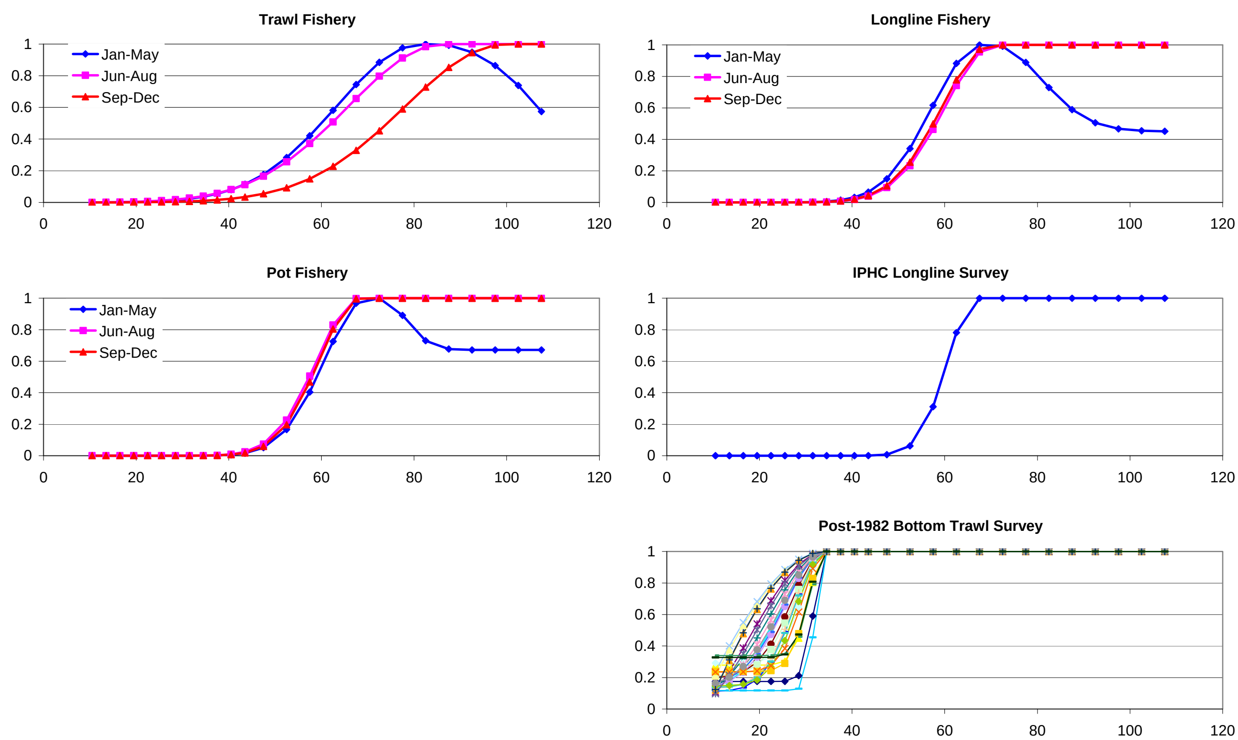


Figure 2.4d. Model 4 selectivity.

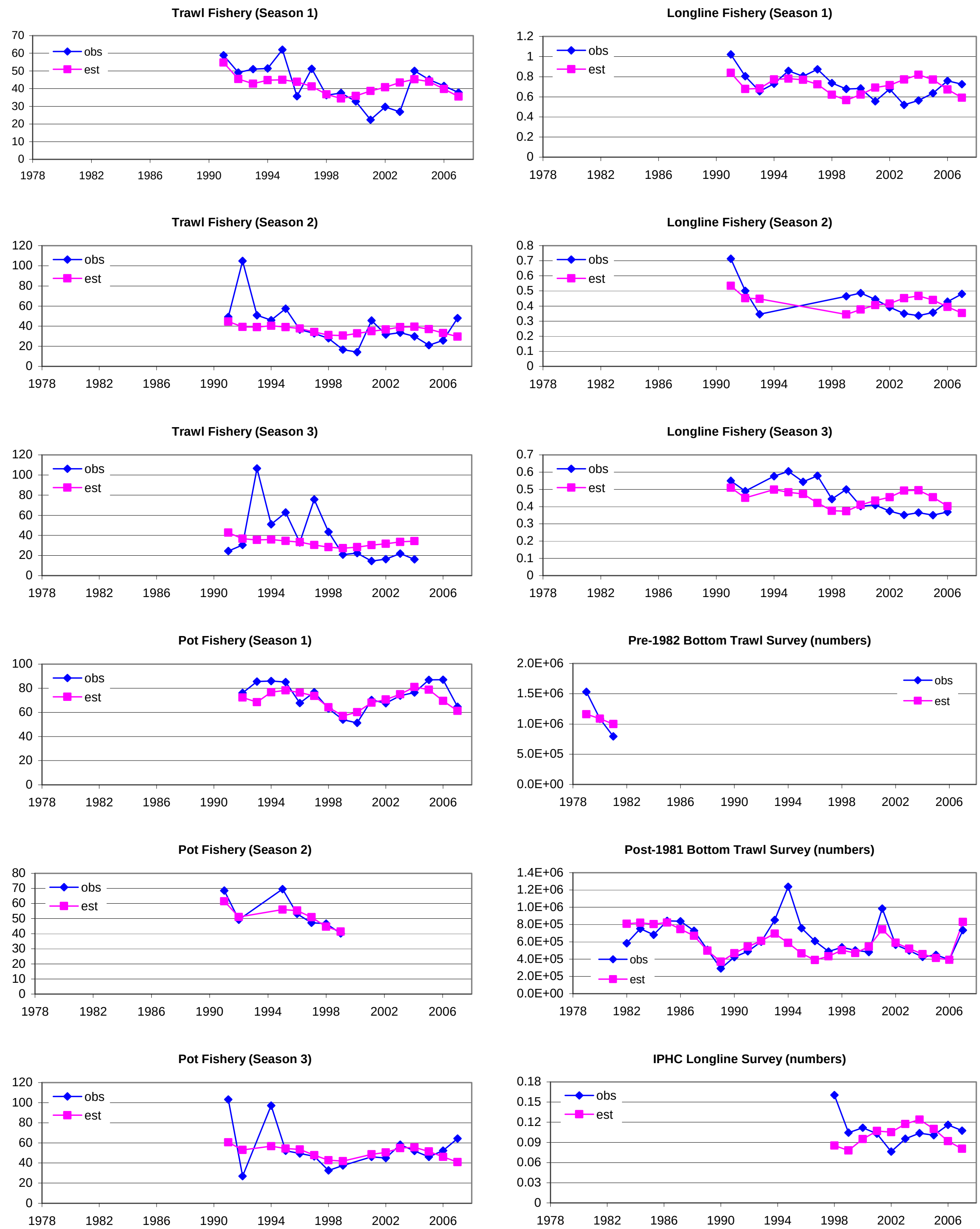


Figure 2.5a. Observed and estimated relative abundance (Model 1).

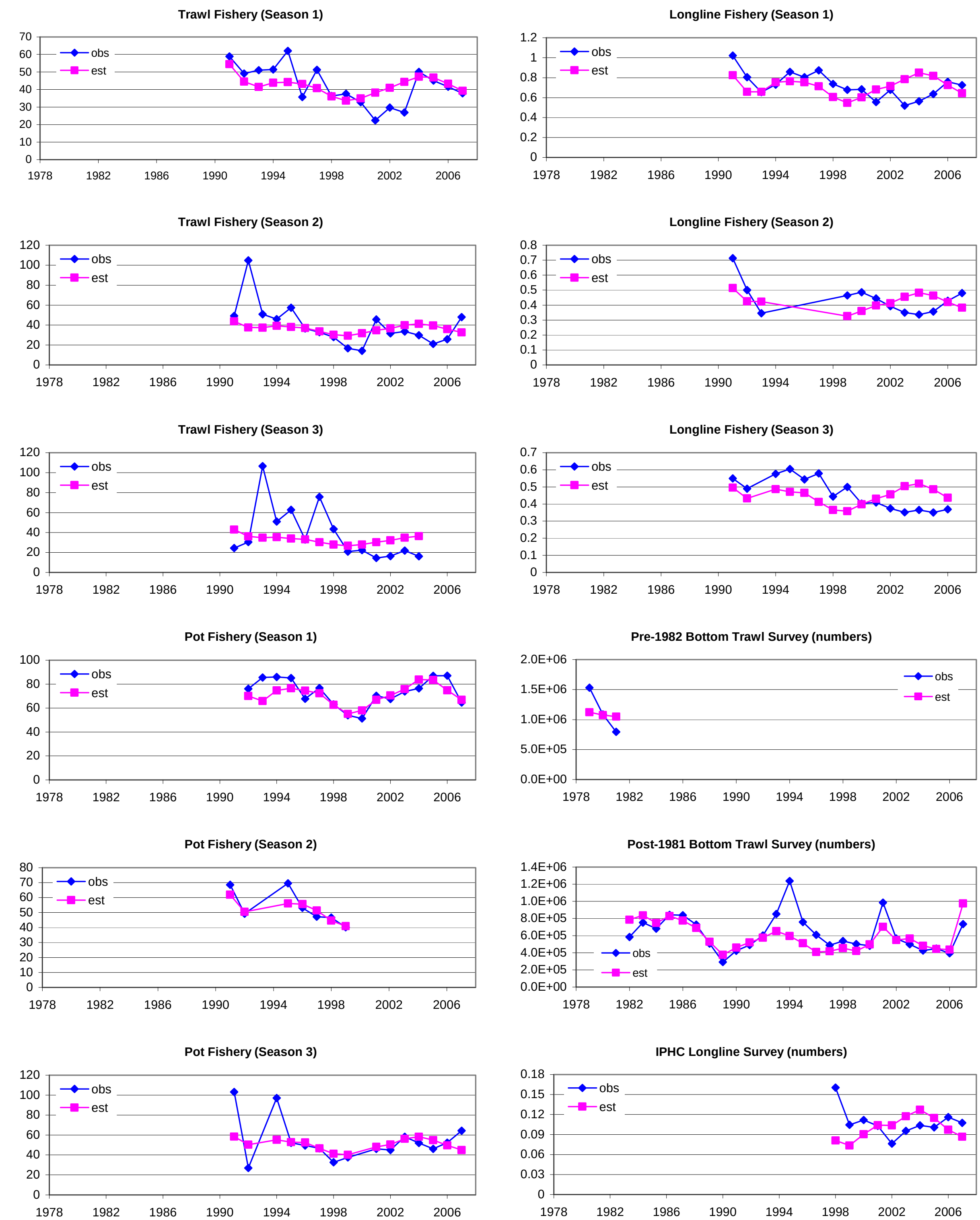


Figure 2.5b. Observed and estimated relative abundance (Model 2).

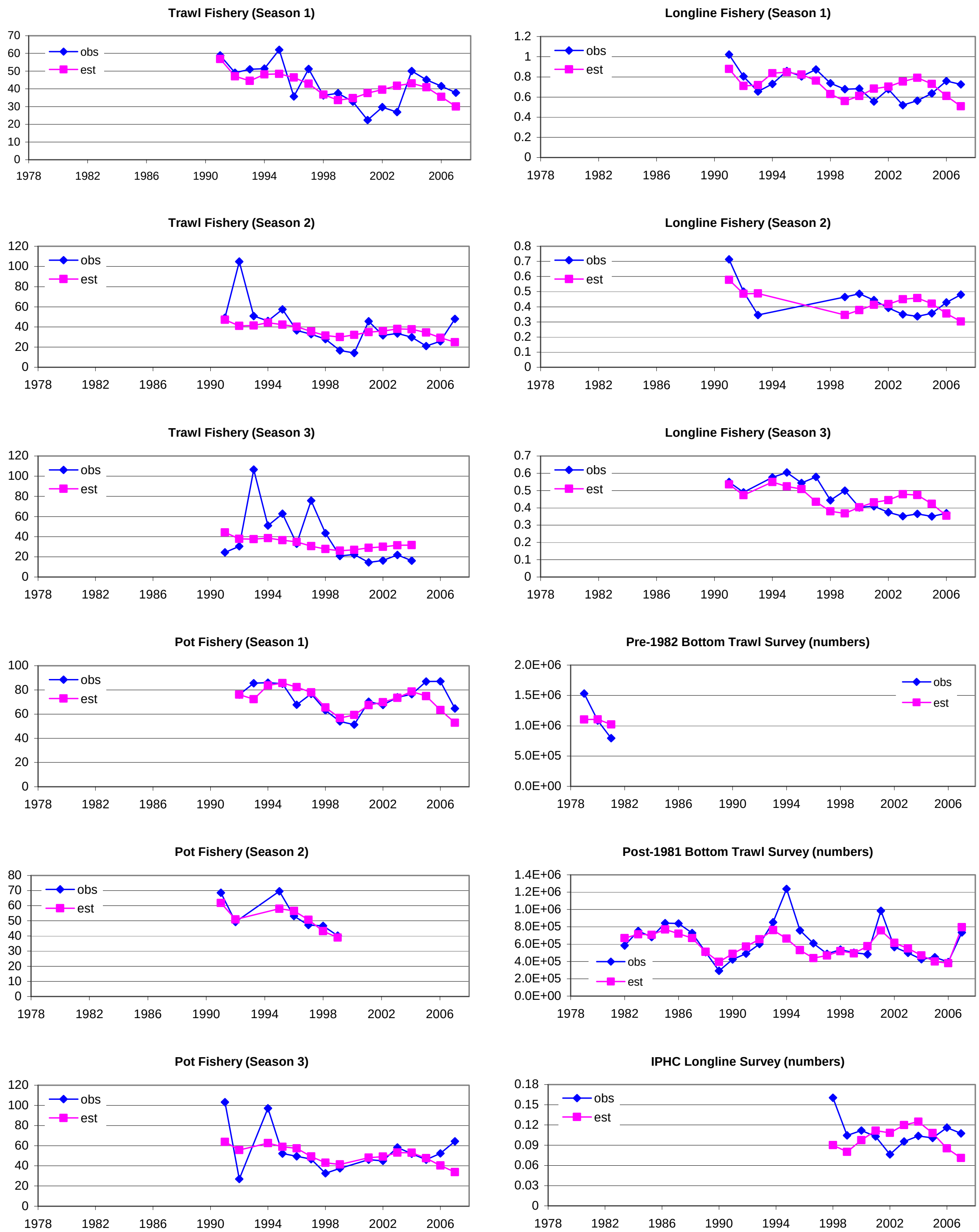


Figure 2.5c. Observed and estimated relative abundance (Model 3).

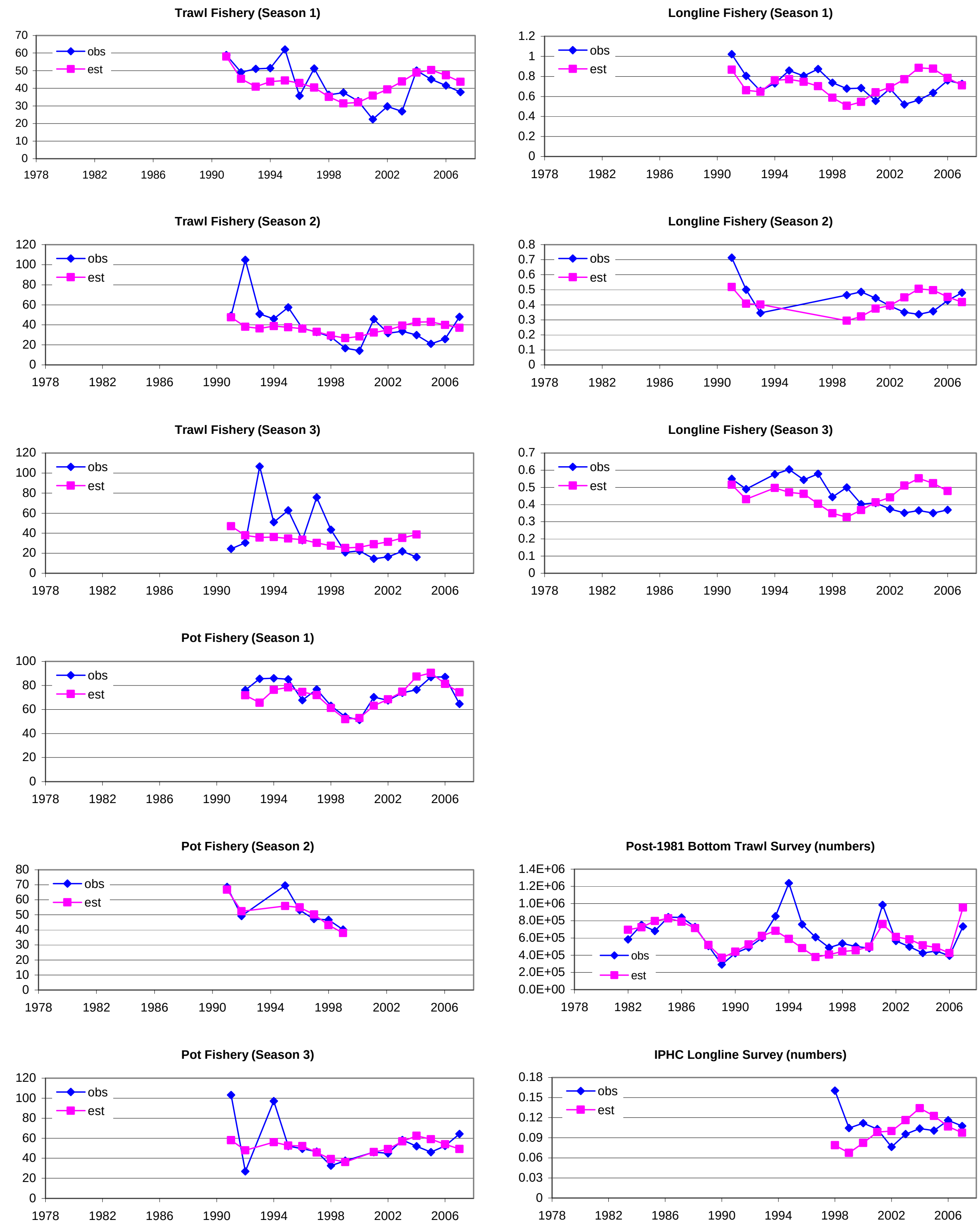


Figure 2.5d. Observed and estimated relative abundance (Model 4).

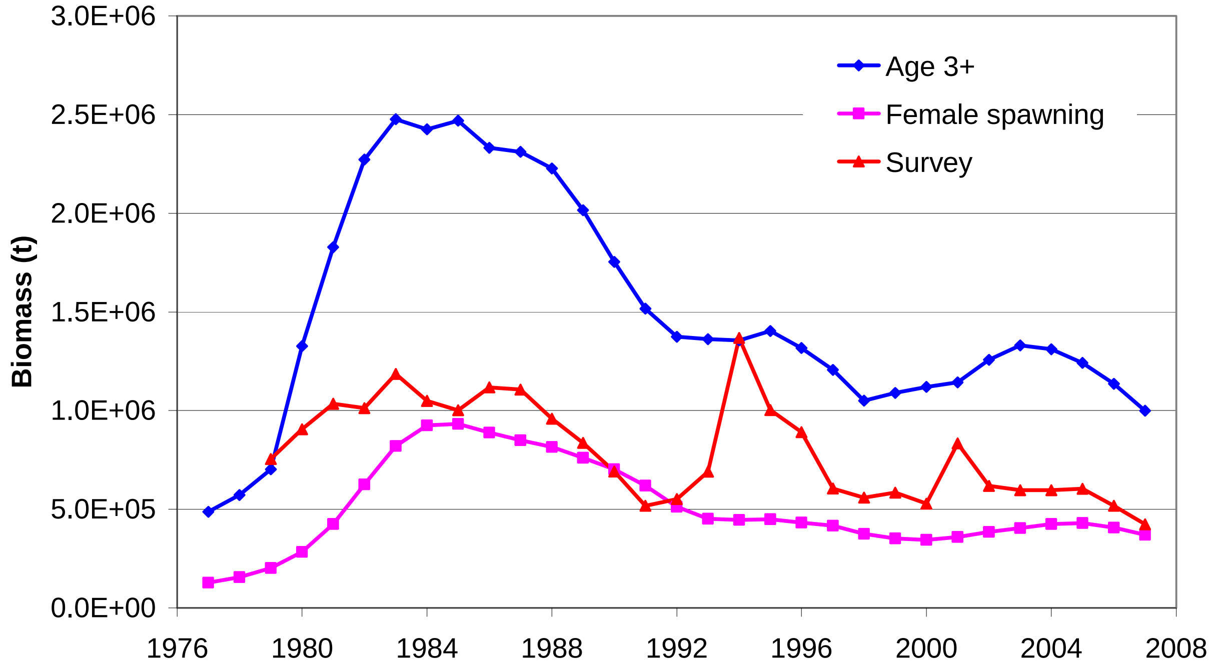


Figure 2.6—Biomass time trends (age 3+ biomass, female spawning biomass, survey biomass) of EBS Pacific cod as estimated by Model 1.

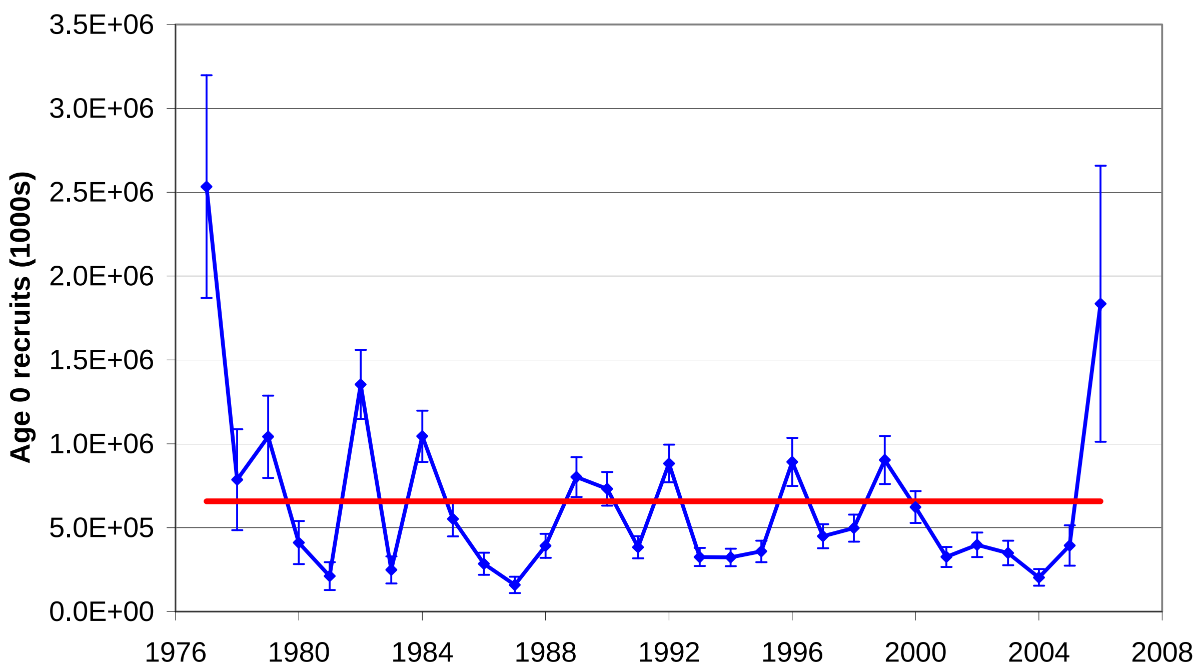


Figure 2.7—Time series of EBS Pacific cod recruitment at age 0, with 95% confidence intervals, as estimated by Model 1. Red line = average.

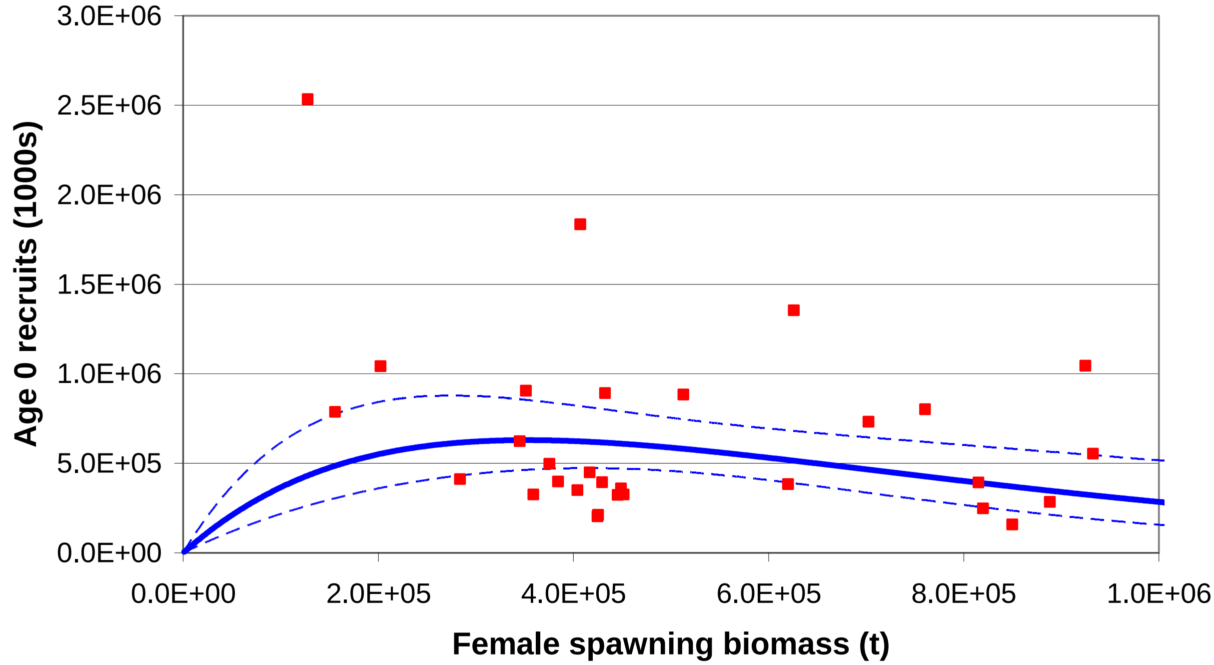


Figure 2.8—Age 0 recruitment versus female spawning biomass for Pacific cod during the years 1977-2006 as estimated by Model 1, with Ricker stock-recruitment curve (for illustrative purposes only).

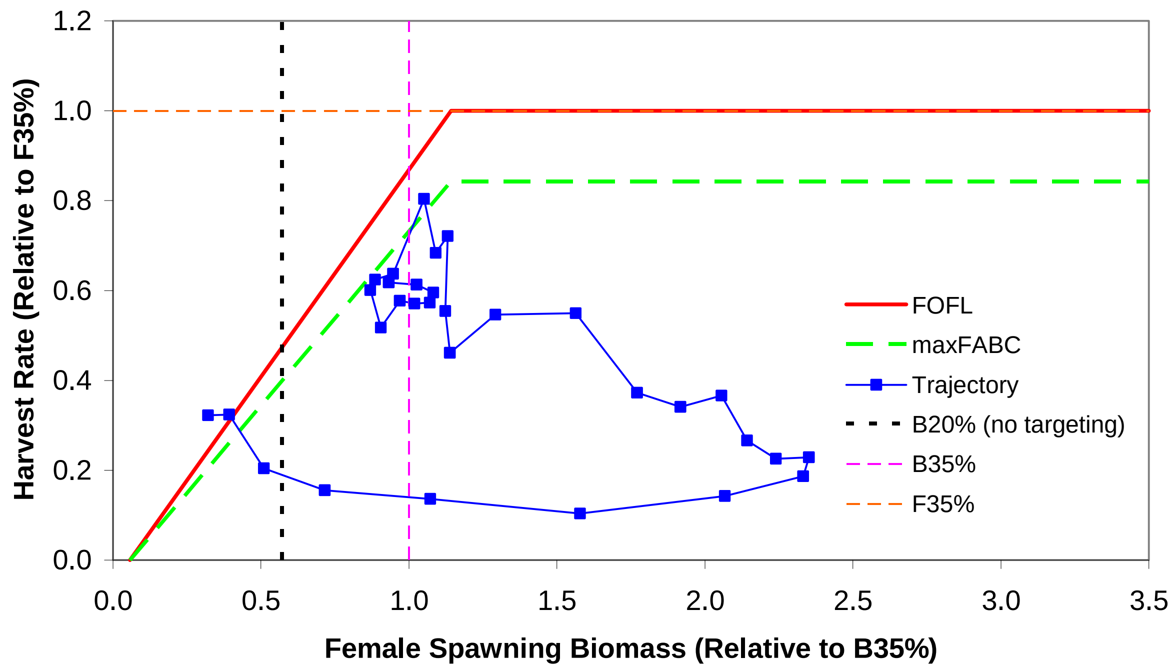


Figure 2.9—Trajectory of Pacific cod fishing mortality and female spawning biomass as estimated by Model 1, 1977-present. Because Pacific cod is a key prey of Steller sea lions, harvests of Pacific cod would be restricted to incidental catch in the event that spawning biomass fell below $B_{20\%}$.

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

Sarah Gaichas and Kerim Aydin

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

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

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

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

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

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

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

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

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

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

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

Reference

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

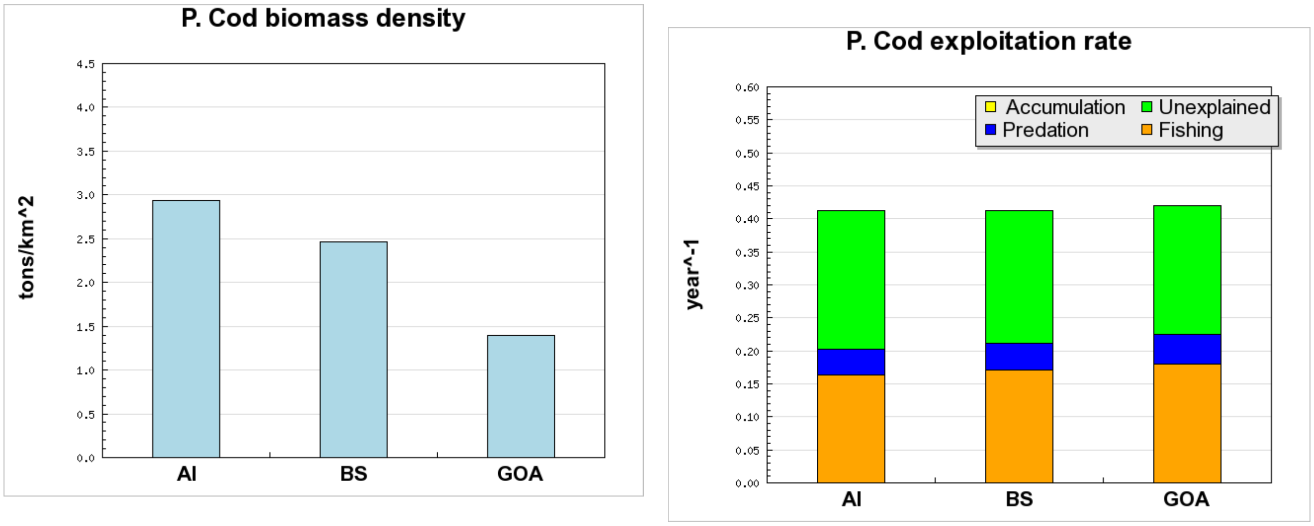
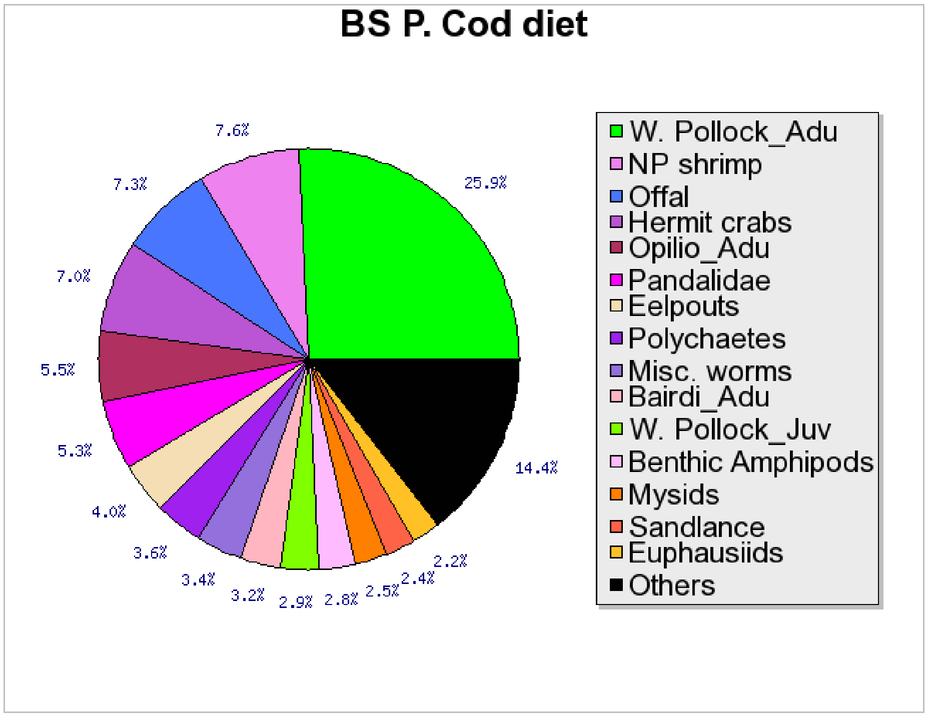


Figure 1. Comparative biomass density (left) and mortality sources (right) for Pacific cod in the AI, EBS, and GOA ecosystems. For the AI and GOA, biomass density (left) is the average biomass from early 1990s NMFS bottom trawl surveys divided by the total area surveyed. For the EBS, biomass density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



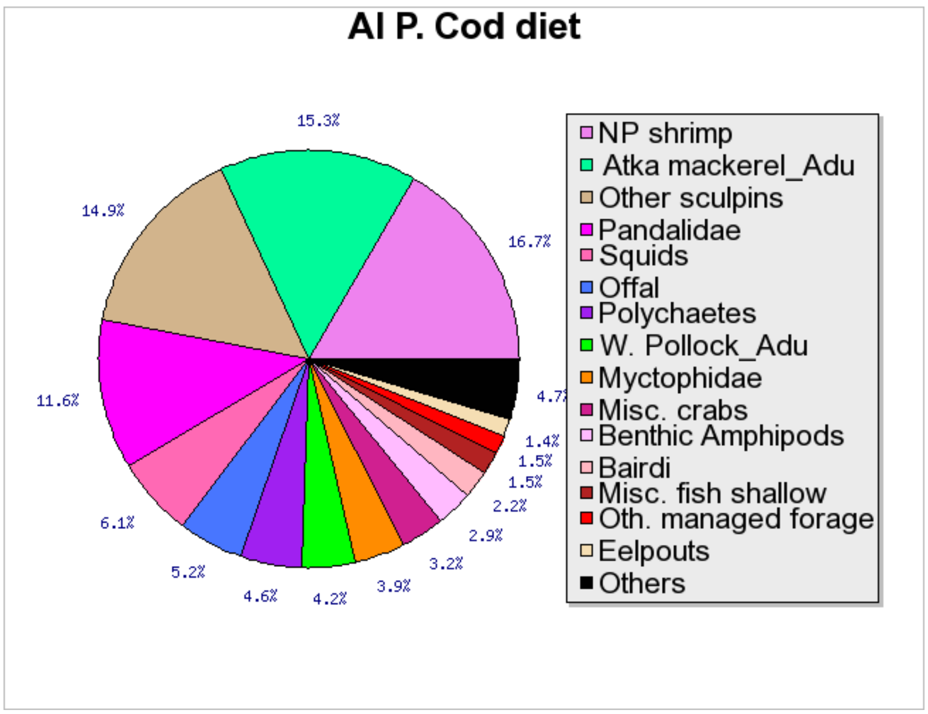


Figure 2. Comparison of Pacific cod diet compositions for the EBS (top) and AI (bottom) ecosystems. Diets are estimated from stomach collections taken aboard NMFS bottom trawl surveys in 1991 (EBS) and in 1991-1994 (AI). See Annex A for detailed methods.

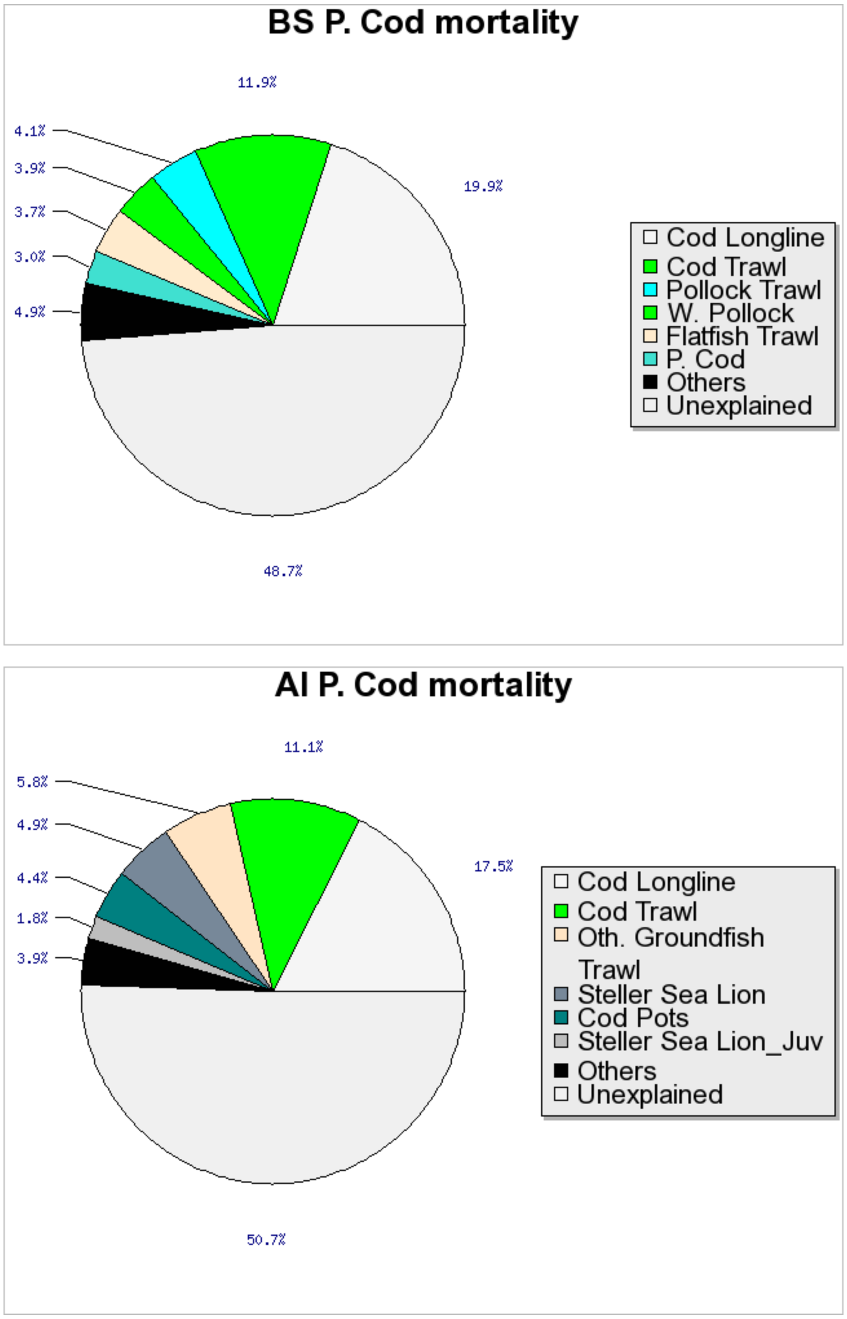


Figure 3. Comparison of Pacific cod mortality sources for the EBS (top) and AI (bottom) ecosystems. Mortality sources reflect cod predator diets estimated from stomach collections taken aboard NMFS bottom trawl surveys in 1991 (EBS) and in 1991-1994 (AI), cod predator consumption rates estimated from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

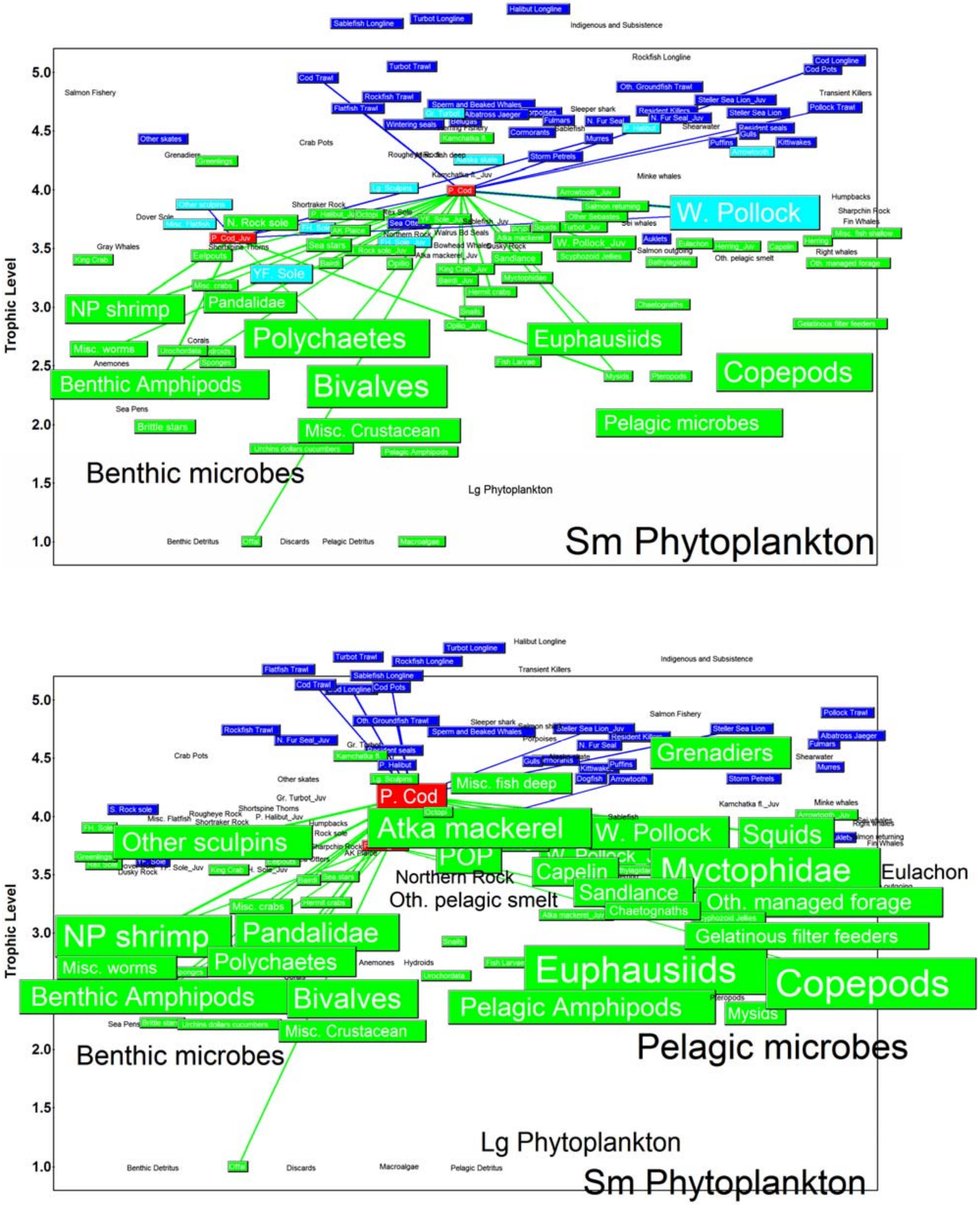
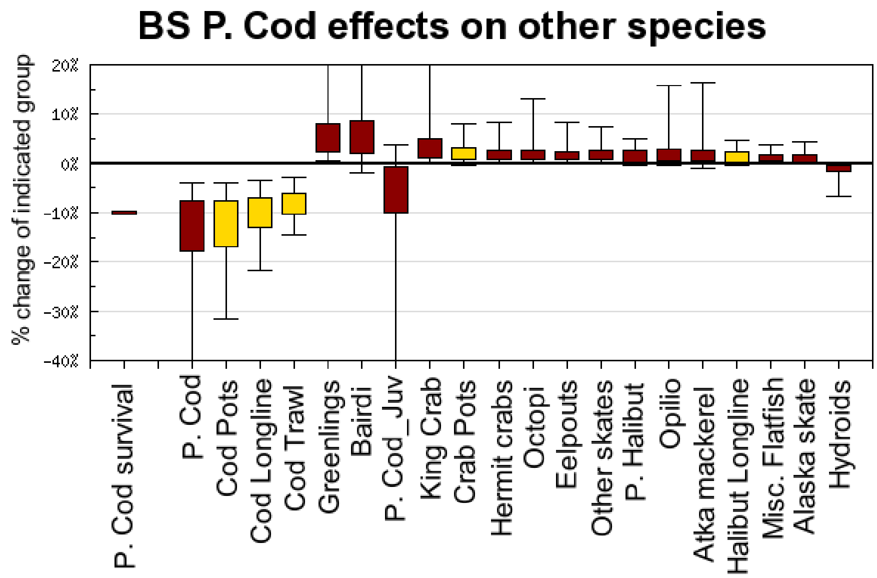


Figure 4. Adult and juvenile cod in the EBS (top) and AI (bottom) food webs. Predators of cod are dark blue, prey of cod are green, and species that are both predators and prey of cod are light blue. Box size is proportional to biomass and lines between boxes represent the most significant energy flows.



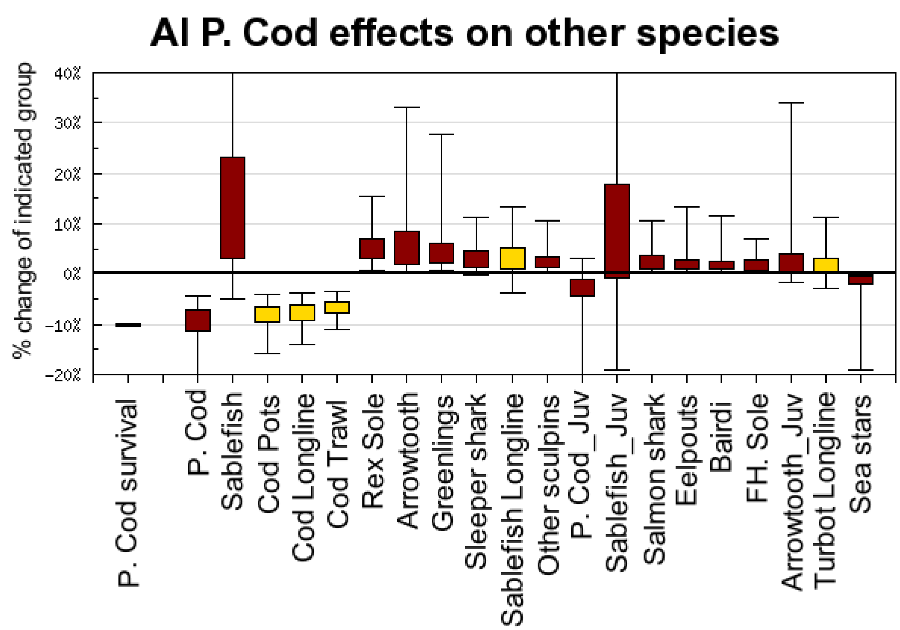
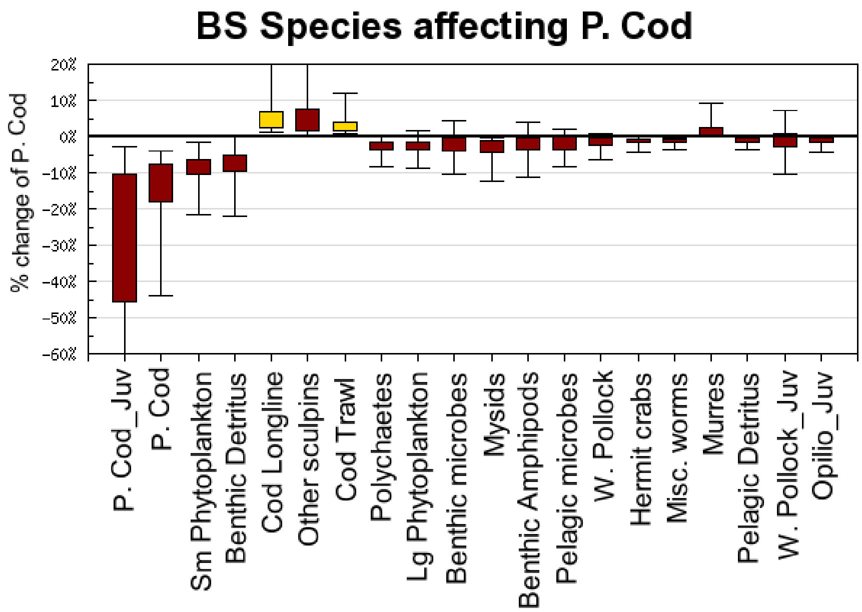


Figure 5. Effect of changing cod survival on fishery catch (yellow) and biomass of other species (dark red): EBS (top) and AI (bottom), from a simulation analysis where cod survival was decreased by 10% and the rest of the ecosystem adjusted to this decrease for 30 years. Boxes show resulting percent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



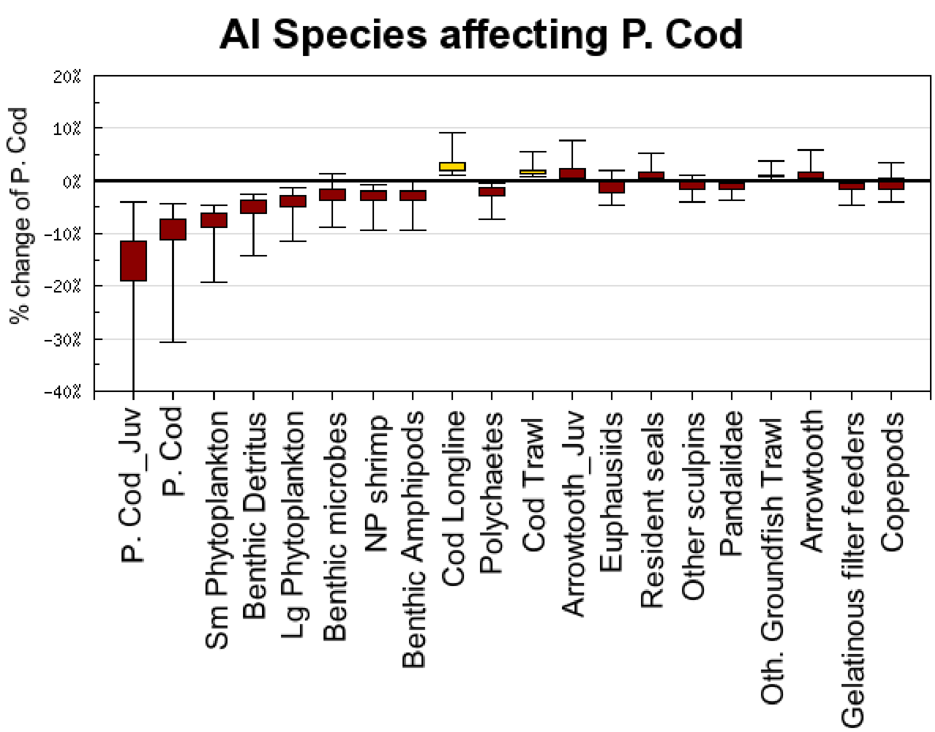
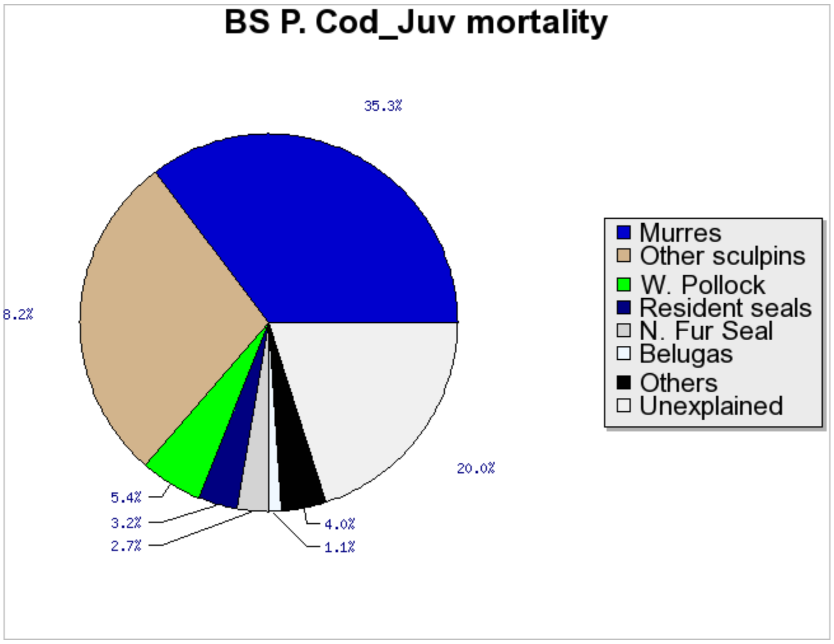


Figure 6. Effect of reducing fisheries catch (yellow) and other species survival (dark red) on cod biomass: EBS (top) and AI (bottom), from a simulation analysis where survival of each X axis species group was decreased by 10% and the rest of the ecosystem adjusted to this decrease for 30 years. Boxes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



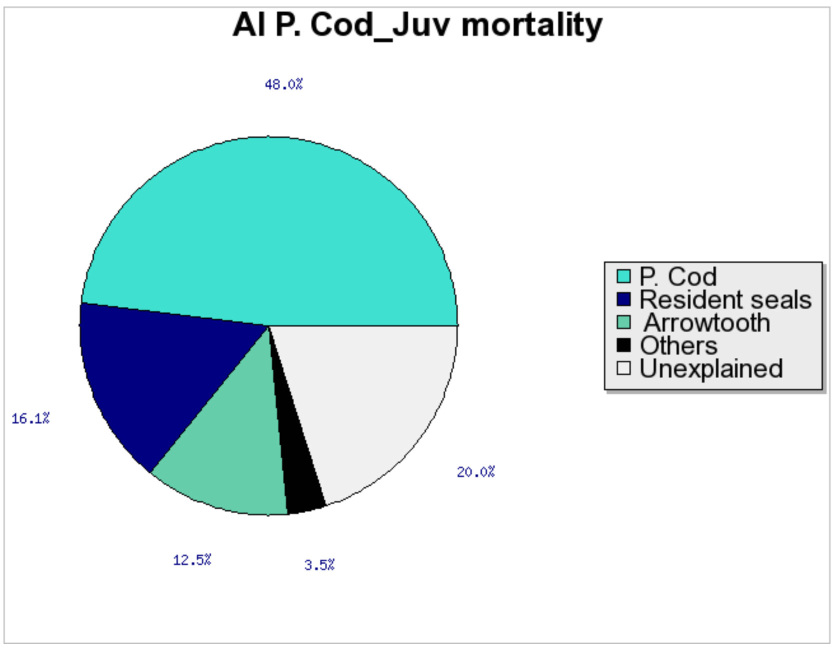


Figure 7. Juvenile cod mortality sources: EBS (top) and AI (bottom). Mortality sources reflect juvenile cod predator diets estimated from stomach collections taken aboard NMFS bottom trawl surveys in 1991 (EBS) and in 1991-1994 (AI), cod predator consumption rates estimated from stock assessments and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

Annex A

Diet composition calculations

Notation:

DC = diet composition

W = weight in stomach

n = prey

p = predator

s = predator size class

h = survey haul

r = survey stratum

B = biomass estimate

v = survey

a = assessment

R = ration estimate

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

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

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

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

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

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

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

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

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

Ration Calculations

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Production rates

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

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

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

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

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