Addendum to Chapter 2:

Revisions to the Assessment of the Pacific Cod Stock in the Eastern Bering Sea and Aleutian Islands Area

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EXECUTIVE SUMMARY

Why is an Addendum Needed?

In the Pacific cod chapter of the 2006 BSAI SAFE report (Thompson et al. 2006), nine models were presented, one of which was similar to the model chosen last year by the Plan Team and SSC and the other eight of which represented a set of alternatives. The authors recommended use of one of the alternative models, specifically Model B1. This model attempted to estimate the catchability coefficient of the EBS shelf bottom trawl survey and used a simpler selectivity function than previous assessments of the Pacific cod stock. The Plan Team concurred with the authors' recommendation and based its ABC and OFL recommendations on Model B1.

After the Plan Team meeting, an external reviewer identified a problem with the parameter estimates obtained by Model B1. In non-technical terms, the problem can be described as follows: The basic goal of stock assessment modeling is to develop a mathematical model of population dynamics that matches the data as closely as possible (i.e., to minimize the "distance" between what the model says the stock is doing and what the data say the stock is doing). Unfortunately, the various data sets used in a stock assessment are typically somewhat inconsistent with one another, and the models developed to represent the population dynamics of the stock and the interaction of the various fishing gears with the stock can be sufficiently complicated that it is sometimes possible to find parameter values that *appear* to give the best possible fit to the data, when in reality other parameter values exist that give an even better fit. This is what happened in the case of Model B1.

Although modern stock assessment models typically contain dozens, or even hundreds, of dimensions (parameters), an analogy can be drawn in terms of topography for the two-dimensional case: The objective is to find the lowest elevation (closest fit to the data) in the topography of some geographic region. While it is usually easy to find the lowest elevation in a particular valley (a "local minimum"), it is harder to prove that no other valley exists somewhere else in the region with an even lower minimum elevation (the "global minimum"). The problem becomes harder as the size of the geographic region increases, and harder still as the dimensionality of the problem increases. Fortunately, the ADMB programming language (Fournier 2005), which is utilized by all age-structured assessments of BSAI and GOA groundfish stocks, contains a number of sophisticated features (e.g., extremely accurate computation of derivatives and "phased" estimation of parameters, so that the most influential parameters are estimated first) that substantially reduce the chances of converging on a local minimum different from the global minimum. In developing the original version of Model B1, appropriate tests were conducted to make sure that the model had truly converged. However, by altering the path by which the minimum is approached, it turns out that a different minimum can be found for Model B1, resulting in a revised version of the model that fits the data better than the original.

What is Included in this Addendum?

This addendum includes substitutes for the “Results” and “Projections and Harvest Alternatives” sections of the Pacific cod chapter of the 2006 SAFE report. To ensure that all revised parameter estimates are made available, substitutes for certain portions of the “Model Evaluation” section are also included.

Because the chapter authors and Plan Team recommended adoption of the original version of Model B1, the substitute sections contained in this addendum are based on the revised version of Model B1. While this seems to be the most straightforward way to address the implications of the revised model, readers should be aware that the authors or Plan Team might have reached different conclusions regarding model choice had the need for a revision been discovered earlier. In order to minimize potential confusion, no model recommendations or ABC recommendations are contained in this addendum. However, several alternative ABC values are presented in the interest of allowing those responsible for final harvest specifications to make a fully informed decision.

To facilitate comparison with the Pacific cod chapter of the SAFE report, table and figure numbers used here are identical with those used in the SAFE report.

It should be noted that Model B2, which is closely related to Model B1, is affected by the problem of incorrect identification of the global minimum in the same way as Model B1. However, because the results from the revised version of Model B2 are so close to the results from the revised version of Model B1 (as was also true in the original versions of those two models), only the results from the revised version of Model B1 are presented here, in the interest of keeping this addendum as concise as possible.

What are the Major Implications?

The major qualitative conclusions from the Pacific cod chapter of the SAFE report are unchanged:

1) All of the models are in basic agreement as to which year classes appear to be strong and which appear to be weak.
2) In particular, all of the models agree that the 2000-2004 year classes currently appear to be weak.
3) From about 1993 to the present, all of the models indicate that female spawning biomass has been fairly stable, although the trend over the last couple of years is downward in all models.
4) All of the models project continued declines in spawning biomass and maximum permissible ABC for the next 2-3 years.

Although the major qualitative conclusions of the assessment are unchanged, if the revised version of Model B1 is accepted as the preferred model, the values of several key outputs change significantly:

1) Projected 2007 female spawning biomass for the BSAI stock is 351,000 t, up about 14% from the original version of Model B1.
2) Projected 2007 total age 3+ biomass for the BSAI stock is 1,080,000 t, up about 13% from the original version of Model B1.
3) The projected maximum permissible 2007 ABC for the BSAI stock is 202,000 t, up about 15% from the original version of Model B1.
4) The projected 2007 OFL for the BSAI stock is 238,000 t, up about 15% from the original version of Model B1.

MODEL EVALUATION

Goodness of Fit

The following table presents values of the various components of the objective function from the original and revised versions of Model B1 (except for the inclusion of the values for the revised version, this is a subset of Table 2.16 in the SAFE report; also, it should be noted that all log likelihood, log prior, and objective function values are multiplied by -1, meaning that a lower value indicates a better fit):

Objective function component	Original	Revised
pre-1982 shelf trawl survey abundance	0.40	0.37
post-1981 shelf trawl survey abundance	45.29	46.26
slope trawl survey abundance	0.22	0.22
Jan-May trawl fishery size composition	266.07	266.62
Jun-Dec trawl fishery size composition	440.95	438.00
longline fishery size composition	489.07	491.40
pot fishery size composition	172.44	171.95
pre-1982 shelf trawl survey size composition	35.18	35.25
post-1981 shelf trawl survey size composition	188.30	189.94
slope trawl survey size composition	1.17	1.17
post-1981 shelf trawl survey age composition	94.91	98.44
post-1981 shelf trawl survey size-at-age	420.83	414.33
recruitment	30.04	29.94
log priors	18.59	17.92
objective function (sum of the above)	2,203.47	2,201.80

It should be noted that the values in the above table are not strictly comparable, because different values of the parameters governing the distribution of recruitments were required for the two versions of Model B1 (see “Parameters Estimated Conditionally” in the Pacific cod chapter of the SAFE report). However, when the recruitment distribution parameters were held constant at the levels obtained in the original version, the results were similar to the above. In particular, it is clear that the revised version provides a better overall fit (lower objective function) than the original version, given that equal weights are assigned to the various components of the objective function.

With the above caveat in mind, the following conclusions emerge: Of the 14 components of the objective function, the revised version of Model B1 fit better than the original version in 7 cases, and the original version fit better than the revised version in the other 7 cases. The biggest single improvement between the two versions was in the post-1981 shelf trawl survey size-at-age component, where the revised version showed an improvement of 6.5 units relative to the original version.

For the length composition and age composition components of the likelihood, another way to assess goodness of fit is by comparing input sample sizes and “effective” output sample sizes (see Pacific cod chapter of the SAFE report). The following table shows the average of the input sample sizes (Input N) for each length or age composition component and the ratio between the average effective sample size and the average input sample size under the original and revised versions of Model B1 (a higher ratio implies a better fit):

Gear	Type	Input N	Original	Revised
Jan-May trawl fishery	Length	169	1.52	1.52
Jun-Dec trawl fishery	Length	42	1.99	2.03
longline fishery	Length	191	1.79	1.80
pot fishery	Length	100	2.44	2.48
pre-82 shelf survey	Length	100	0.64	0.64
post-81 shelf survey	Length	104	0.93	0.92
slope survey	Length	23	10.27	10.02
post-81 shelf survey	Age	94	0.60	0.55

Of the seven length composition components, the revised version of Model B1 had a higher ratio in three cases, the original version had a higher ratio in two cases, and the two versions had virtually identical ratios in two cases. For the age component, the original version had a higher ratio than the revised version. However, it is important to note that for the most recent year of age data (2005), both the original and revised versions gave excellent fits (effective N = 190 and 185 for the original and revised versions, respectively).

Final Parameter Estimates and Associated Schedules

The following table presents estimates of some key parameters from the original and revised versions of Model B1 (except for the last row and the inclusion of values for the revised version, this is a subset of Table 2.16 in the SAFE report):

Parameter	Original	Revised
Sigma(R)	0.62	0.63
ln(post-1976 Rmed)	13.62	13.70
ln(pre-1977 Rmed)-ln(post-1976 Rmed)	-1.18	-1.19
Pre-1982 shelf trawl survey catchability	0.97	0.89
Post-1981 shelf trawl survey catchability	0.57	0.52
Initial fishing mortality rate	0.075	0.069

The first three rows in the above table describe parameters governing the distribution of recruitments. The row labeled “Sigma(R)” shows the standard deviation of the distribution of log-scale recruitment deviations, the row labeled “ln(post-1976 Rmed)” shows the median log-scale recruitment for the post-1976 environmental regime, and the row labeled “ln(pre-1977 Rmed)-ln(post-1976 Rmed)” shows the log of the ratio of median log-scale recruitments between the pre-1977 and post-1976 environmental regimes (i.e., a negative value in this row means that median recruitment was lower in the pre-1977 regime than in the post-1976 regime).

The last three rows in the above table show the estimates of the shelf trawl survey catchability coefficient for the pre-1982 portion and post-1981 portions of the time series and the initial (equilibrium) fishing mortality rate.

Estimates of year-, season-, and gear-specific fishing mortality rates from the revised version of Model B1 are shown in Table 2.18, estimates of regime-specific median recruitments and annual recruitment deviations from the revised version of Model B1 are shown in Table 2.19, and estimates of selectivity parameters from the revised version of Model B1 are shown in Table 2.20.

Schedules of selectivity at length from the revised version of Model B1 are shown for the commercial fisheries in Table 2.21a and for the bottom trawl surveys in Table 2.21b. The schedules in Tables 2.21a and 2.21b are plotted in Figure 2.6.

Schedules of length at age, proportion mature at age, and weight at age from the revised version of Model B1 are shown in Table 2.22.

RESULTS

Definitions

The biomass estimates presented here will be defined in three ways: 1) age 3+ biomass, consisting of the biomass of all fish aged three years or greater in January of a given year; 2) spawning biomass, consisting of the biomass of all spawning females in a given year; and 3) survey biomass, consisting of the biomass of all fish that the model estimates should have been observed by the survey in July of 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. In all comparisons involving last year's results, it is important to note that table entries labeled "Last Year's Values" do not correspond to the values given in last year's SAFE report, because the values given in last year's SAFE report corresponded to the authors' preferred model, not the model chosen by the Plan Team and SSC. Instead, table entries labeled "Last Year's Values" correspond to the results given last year under the model chosen by the Plan Team and SSC.

Biomass

Table 2.23 shows the time series of EBS (not expanded to BSAI) Pacific cod age 3+ and female spawning biomass for the years 1977-2006 as estimated last year under the Plan Team's and SSC's preferred model and this year under the revised version of Model B1. In the case of female spawning biomass, the two estimated time series are accompanied by their respective 95% confidence intervals.

The estimated EBS female spawning biomass time series and confidence intervals from the revised version of Model B1 are shown, together with the revised version of Model B1's estimated time series of EBS age 3+ biomass, in Figure 2.7. Figure 2.7 also compares the observed and model-estimated time series from the EBS shelf bottom trawl survey. All three biomass trends estimated by the revised version of Model B1 are fairly flat from about 1992 through about 2004, but all three show a declining trend for at least the last couple of years.

The biomasses estimated by the revised version of Model B1 are significantly higher than those estimated by the original version. In the Pacific cod chapter of the SAFE report, Model A2 provides the most optimistic estimates of biomass, with the biomass estimates from Model A1 and the original versions of Models B1 and B2 close to one another but significantly below those of Model A2 (see Figure 2.3 of the SAFE report). In contrast, the revised version of Model B1 now provides the most optimistic estimates of biomass, slightly higher than the estimates from Model A2. While the reasons for the increased biomass estimates resulting from the revised version of Model B1 are likely complicated and inter-related, some key factors are likely as follows: There are five internally estimated parameters whose correlations with estimated 2006 female spawning biomass exceed 0.5 in absolute value: 1) the logarithm of the post-1981 shelf trawl survey catchability coefficient (correlation = –0.95), 2) post-1976 median log-scale recruitment (correlation = 0.89), 3) initial equilibrium fishing mortality rate (correlation = –0.75), 4) the logarithm of the pre-1982 shelf trawl survey catchability coefficient (correlation = –0.57), and 5) the width of the longline fishery selectivity peak during the years 1989-1999 (correlation = –0.55). Of these parameters, the estimates of all five changed in the direction that would tend to cause 2006 female spawning biomass to increase. Perhaps most significantly, the estimate of the post-1981 shelf trawl survey catchability coefficient changed from 0.57 to 0.52. Given that the post-1981 shelf trawl survey selectivity schedule was estimated to be approximately asymptotic in both the original and revised versions of Model B1, the change in the estimated value of the catchability coefficient could account for a major portion of the change in estimated biomass.

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 1977-2005 as estimated last year under the Plan Team's and SSC's preferred model and this year under the revised version of Model B1. Both estimated time series are accompanied by their respective 95% confidence intervals.

The revised version of Model B1's recruitment estimates for the entire time series (1964-2005) are shown in Figure 2.8, along with their respective 95% confidence intervals and regime-specific averages. For the time series as a whole, the largest year classes appear to have been the 1976-1977 cohorts. Other large cohorts include the 1978, 1982, 1984, 1989, 1992, 1996, and 1999 year classes. Of the five classes spawned immediately after the strong 1999 year class, however, none have 95% confidence intervals that extend above the 1977-2005 average. One potential bright spot on the horizon is the 2005 year class, whose point estimate is just below the 1977-2005 average. However, its confidence interval is fairly large, since the only data currently available to estimate its strength is the size composition data from the 2006 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. In the interim, Figure 2.9 is provided to give some indication of the relationship between stock and recruitment. The Ricker (1954) curve shown in this figure (fit by maximum likelihood from the outputs of the stock assessment model, 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 1977-2006 as estimated last year under the Plan Team's and SSC's preferred model and this year under the revised version of Model B1.

The average value of this ratio over the entire time series is about 0.11, slightly less than the average value of 0.13 obtained in the model chosen last year by the Plan Team and SSC. The estimated values exceed the average for every year after 1989 except 1993, whereas none of the estimated values exceed the average in any year prior to 1990. This finding is similar to that obtained in past assessments.

Figure 2.10 plots the trajectory of relative fishing mortality and relative female spawning biomass from 1977 through 2006 based on the revised version of Model B1, overlaid with the current harvest control rules (fishing mortality rates in the figure are standardized relative to $F_{35\%}$ and biomasses are standardized relative to $B_{35\%}$, per SSC request). The entire trajectory lies underneath both the F_{OFL} and $maxF_{ABC}$ control rules except for the years 1977 and 1978. It should 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: $B/B_{40\%} > 1$

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

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

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

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

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

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

$F_{OFL} = 0$

$F_{ABC} = 0$

Estimation of the $B_{40\%}$ reference point used in the above formulae requires an assumption regarding the equilibrium level of recruitment. In this assessment, it is assumed that the equilibrium level of recruitment is equal to the post-1976 average (i.e., the arithmetic mean of all estimated recruitments from year classes spawned in 1977 or later). 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 the revised version of Model B1:

Reference point:	$B_{35\%}$	$B_{40\%}$	$B_{100\%}$
BSAI:	300,000 t	343,000 t	858,000 t
EBS:	252,000 t	288,000 t	721,000 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 the revised version of Model B1's estimates of fishing mortality by gear for the three most recent complete years of data (2003-2005). 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 30.1%, longline 59.5%, and pot 10.4%. This apportionment results in estimates of $F_{35\%}$ and $F_{40\%}$ equal to 0.41 and 0.34, respectively.

Short-Term Projections: Specification of OFL and Maximum Permissible ABC

The age 3+ biomass estimates for 2007 from the revised version of Model B1 are 1,080,000 t and 908,000 t for the BSAI and EBS, respectively.

BSAI spawning biomass for 2007 is estimated by the revised version of Model B1 at a value of 351,000 t (EBS value = 295,000 t). This is about 2% above the BSAI $B_{40\%}$ value of 343,000 t (EBS value = 288,000 t), thereby placing Pacific cod in Tier 3a. If the stock were fished at the maximum permissible rate, the model projects that spawning biomass would be about 13% below $B_{40\%}$ in 2008 (Tier 3b). Given this, the revised version of Model B1 estimates maximum permissible BSAI ABC, BSAI OFL, and the associated fishing mortality rates for 2007 and 2008 as follows:

Quantity	2007	2008
BSAI maximum permissible ABC	202,000 t	147,000 t
BSAI OFL	238,000 t	172,000 t
Fishing mortality rate at maximum permissible ABC	0.34	0.30
Fishing mortality rate at OFL	0.41	0.36

In the event that a 2007 ABC lower than the maximum permissible value is deemed advisable, the table below provides some short-term projections associated with a range of alternatives. The table shows projected annual values of ABC and OFL for different fixed levels of ABC in 2007, under the assumption that ABC would be set at the maximum permissible level thereafter. The fixed levels of 2007 ABC range from 200,000 t down to 160,000 t (all ABCs and OFLs are for the entire BSAI stock, and are shown in thousands of t). In all projections, both ABC and OFL are expected to increase after 2009, though it should be noted that these future increases are predicated on the assumption that future recruitments will tend to approximate the long-term (post-1976) average. The last two rows show the average for the years 2006-2009 and the coefficient of variation (ratio of standard deviation to average) for those same years. In general, lowering the 2007 ABC below the maximum permissible value would be expected to decrease both the projected average ABC and the projected coefficient of variation, though only slightly.

	2007 ABC=200		2007 ABC=190		2007 ABC=180		2007 ABC=170		2007 ABC=160	
Year	ABC	OFL	ABC	OFL	ABC	OFL	ABC	OFL	ABC	OFL
2006	194	230	194	230	194	230	194	230	194	230
2007	200	238	190	238	180	238	170	238	160	238
2008	147	173	151	177	154	181	157	185	161	189
2009	123	145	124	147	126	149	128	150	129	152
Ave.	166	196	165	198	164	199	162	201	161	202
CV	0.19	0.20	0.18	0.19	0.16	0.18	0.15	0.18	0.14	0.17

Long-Term Projections

Standard Harvest Scenarios

A standard set of projections is typically produced 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 the vector of 2006 numbers at age estimated in the assessment. This vector is then projected forward to the beginning of 2007 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2006. 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 2007, 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. (Note: Because no ABC recommendation is contained in this addendum, Scenario 2 is not included in the projections.)
>
> *Scenario 3*: In all future years, F is set equal to 50% of *max* F_{ABC}. (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 2007 or 2) above ½ of its MSY level in 2007 and above its MSY level in 2017 under this scenario, then the stock is not overfished.)
>
> *Scenario 7*: In 2007 and 2008, 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 2019 under this scenario, then the stock is not approaching an overfished condition.)

Projections corresponding to the standard scenarios are shown for the revised version of Model B1 in Tables 2.26-2.31.

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 2007:

a. If spawning biomass for 2007 is estimated to be below ½ $B_{35\%}$, the stock is below its MSST.
b. If spawning biomass for 2007 is estimated to be above $B_{35\%}$ the stock is above its MSST.
c. If spawning biomass for 2007 is estimated to be above ½ $B_{35\%}$ but below B35%, the stock's status relative to MSST is determined by referring to harvest Scenario #6 (Table 2.30). If

the mean spawning biomass for 2017 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 2009 is below ½ $B_{35\%}$, the stock is approaching an overfished condition.

b. If the mean spawning biomass for 2009 is above $B_{35\%}$, the stock is not approaching an overfished condition.

c. If the mean spawning biomass for 2009 is above ½ $B_{35\%}$ but below $B_{35\%}$, the determination depends on the mean spawning biomass for 2019. If the mean spawning biomass for 2019 is below $B_{35\%}$, the stock is approaching an overfished condition. Otherwise, the stock is not approaching an overfished condition.

In the case of BSAI Pacific cod, spawning biomass for 2007 is estimated to be above $B_{35\%}$ under the revised version of Model B1. Therefore, the stock is above its MSST and is not overfished. Mean spawning biomass for 2009 in Table 2.31 is above ½ $B_{35\%}$ but below $B_{35\%}$, and mean spawning biomass for 2019 is above $B_{35\%}$. Therefore, the stock is not approaching an overfished condition.

ACKNOWLEDGMENTS

Mark Maunder identified the problem with the local minimum in the objective function for the original version of Model B1 that led to the need for this addendum. Anne Hollowed reviewed an earlier draft of this addendum.

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Table 2.18—Estimates of Pacific cod fishing mortality rates, expressed on an annual time scale (revised version of Model B1). 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
1964	0.017	0.006	0.007	0.002	0.000	0.004			
1965	0.018	0.007	0.008	0.003	0.000	0.005			
1966	0.022	0.008	0.009	0.003	0.000	0.006			
1967	0.039	0.015	0.017	0.006	0.001	0.010			
1968	0.074	0.030	0.034	0.010	0.002	0.020			
1969	0.074	0.029	0.034	0.010	0.002	0.020			
1970	0.120	0.049	0.058	0.017	0.003	0.035			
1971	0.095	0.037	0.043	0.013	0.002	0.027			
1972	0.111	0.044	0.050	0.016	0.002	0.032			
1973	0.157	0.064	0.073	0.023	0.004	0.045			
1974	0.205	0.088	0.100	0.030	0.005	0.059			
1975	0.190	0.082	0.090	0.028	0.004	0.051			
1976	0.187	0.081	0.085	0.028	0.004	0.049			
1977	0.107	0.043	0.042	0.017	0.002	0.024			
1978	0.097	0.039	0.038	0.016	0.002	0.021			
1979	0.053	0.021	0.020	0.008	0.001	0.011			
1980	0.037	0.015	0.014	0.006	0.001	0.008			
1981	0.020	0.018	0.024	0.002	0.001	0.005			
1982	0.020	0.017	0.014	0.000	0.000	0.002			
1983	0.030	0.018	0.017	0.002	0.001	0.002			
1984	0.033	0.017	0.017	0.004	0.002	0.015			
1985	0.039	0.020	0.016	0.011	0.001	0.018			
1986	0.044	0.019	0.016	0.008	0.000	0.015			
1987	0.050	0.012	0.016	0.018	0.001	0.024			
1988	0.102	0.020	0.037	0.000	0.001	0.001			
1989	0.110	0.014	0.016	0.003	0.005	0.005	0.000	0.000	0.000
1990	0.098	0.010	0.010	0.012	0.017	0.018		0.001	0.000
1991	0.119	0.017	0.007	0.028	0.027	0.039	0.000	0.001	0.003
1992	0.079	0.015	0.008	0.067	0.036	0.010	0.004	0.007	0.000
1993	0.097	0.007	0.012	0.072	0.000	0.000	0.003	0.000	
1994	0.084	0.007	0.022	0.079	0.000	0.028	0.007		0.004
1995	0.118	0.011	0.015	0.088	0.000	0.039	0.017	0.005	0.005
1996	0.102	0.004	0.013	0.080	0.000	0.035	0.025	0.010	0.005
1997	0.107	0.005	0.011	0.091	0.000	0.064	0.020	0.006	0.005
1998	0.064	0.008	0.014	0.076	0.000	0.044	0.014	0.005	0.002
1999	0.065	0.005	0.005	0.081	0.003	0.036	0.015	0.002	0.003
2000	0.068	0.006	0.006	0.055	0.002	0.051	0.023		0.000
2001	0.033	0.009	0.007	0.048	0.008	0.054	0.015	0.001	0.005
2002	0.050	0.012	0.005	0.059	0.015	0.045	0.013	0.001	0.005
2003	0.045	0.012	0.004	0.062	0.013	0.051	0.019	0.000	0.008
2004	0.055	0.015	0.004	0.066	0.013	0.054	0.015	0.001	0.006
2005	0.062	0.009	0.001	0.068	0.018	0.065	0.016		0.007
2006	0.070	0.009	0.001	0.075	0.024	0.078	0.021		0.008

Table 2.19—Estimates of Pacific cod regime-specific median recruitments and recruitment deviations (revised version of Model B1). Deviations are expressed as the difference between the logarithm of annual recruitment at age 0 and the logarithm of median recruitment for the respective environmental regime.

Year	ln(Median Recruitment)	Annual Deviation
1964	12.505	-0.400
1965	12.505	-0.484
1966	12.505	-0.549
1967	12.505	-0.554
1968	12.505	-0.438
1969	12.505	-0.182
1970	12.505	-0.236
1971	12.505	-0.300
1972	12.505	-0.137
1973	12.505	0.474
1974	12.505	1.381
1975	12.505	-0.937
1976	12.505	2.337
1977	13.695	0.885
1978	13.695	0.422
1979	13.695	0.356
1980	13.695	-0.378
1981	13.695	0.294
1982	13.695	0.822
1983	13.695	-0.565
1984	13.695	0.574
1985	13.695	-0.500
1986	13.695	-0.560
1987	13.695	-0.779
1988	13.695	0.283
1989	13.695	0.503
1990	13.695	-0.043
1991	13.695	0.300
1992	13.695	0.380
1993	13.695	-0.606
1994	13.695	-0.183
1995	13.695	0.375
1996	13.695	0.483
1997	13.695	-0.131
1998	13.695	0.191
1999	13.695	0.400
2000	13.695	-0.262
2001	13.695	-0.394
2002	13.695	-0.467
2003	13.695	-0.549
2004	13.695	-0.812
2005	13.695	-0.012

Table 2.20—Estimates of Pacific cod selectivity parameters (revised version of Model B1). The first column lists the years defining the era for which the parameter values in that row are applicable. The eras for the commercial fisheries are 1964-1988, 1989-1999, and 2000-2006 (no eras *per se* are defined for the surveys, although separate shelf bottom trawl surveys are defined for the years prior to 1982 and after 1981). The second column lists the particular parameter being described. Four parameters define the shape of the selectivity function: the size at which selectivity first reaches a value of 1.0 ("*peak location*"), the logit transform of the region (within the range from *peak location* to the maximum length in the model) over which selectivity remains at a value of 1.0 ("logit(*peak width*)"), the log of the variance term in the ascending curve ("ln(*asc. variance*)"), and the log of the variance term in the descending curve ("ln(*des. variance*)"). See text for further description of these parameters and how they are used to define the selectivity function. The remaining columns correspond to the fishery or survey to which the values are applicable, using the following notation: TWL1 = January-May trawl fishery, TWL2 = June-December trawl fishery, LGL = longline fishery, POT = pot fishery, SRV1 = pre-1982 shelf trawl survey, SRV2 = post-1981 shelf trawl survey, and SRV3 = slope trawl survey.

Years	Parameter	TWL1	TWL2	LGL	POT
1964-1988	peak location	76.146	79.750	72.678	
1989-1999	peak location	78.018	75.708	69.589	70.632
2000-2006	peak location	80.240	80.629	66.091	65.856
1964-1988	logit(peak width)	-7.881	-0.144	-3.785	
1989-1999	logit(peak width)	-2.152	1.678	-1.271	-1.818
2000-2006	logit(peak width)	-8.250	1.279	-2.873	-8.209
1964-1988	ln(asc. variance)	6.323	6.406	5.523	
1989-1999	ln(asc. variance)	6.340	6.198	5.321	5.141
2000-2006	ln(asc. variance)	6.260	6.486	5.279	4.733
1964-1988	ln(des. variance)	6.308	5.719	6.267	
1989-1999	ln(des. variance)	6.054	4.059	6.423	6.576
2000-2006	ln(des. variance)	6.300	3.888	6.630	7.185

Years	Parameter	SRV1	SRV2	SRV3
n/a	peak location	40.233	44.403	55.756
n/a	logit(peak width)	-8.936	3.685	-1.425
n/a	ln(asc. variance)	5.255	7.083	4.221
n/a	ln(des. variance)	6.987	2.474	5.538

Table 2.21a—Schedules of Pacific cod selectivities at length in the commercial fisheries as defined by final parameter estimates (revised version of Model B1). Lengths (cm) correspond to mid-points of size bins. Len. = length, FOR = 1964-1988, DOM = 1989-1999, NEW = 2000-2006.

	Jan-May Trawl Fishery			Jun-Dec Trawl Fishery			Longline Fishery			Pot Fishery	
Len.	FOR	DOM	NEW	FOR	DOM	NEW	FOR	DOM	NEW	DOM	NEW
10.5	0.00	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	0.00
16.5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
19.5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22.5	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
25.5	0.01	0.01	0.00	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00
28.5	0.02	0.01	0.01	0.01	0.01	0.02	0.00	0.00	0.00	0.00	0.00
31.5	0.03	0.02	0.01	0.02	0.02	0.03	0.00	0.00	0.00	0.00	0.00
34.5	0.04	0.04	0.02	0.03	0.03	0.04	0.00	0.00	0.01	0.00	0.00
37.5	0.07	0.06	0.03	0.05	0.05	0.06	0.01	0.01	0.02	0.00	0.00
40.5	0.10	0.08	0.05	0.08	0.08	0.09	0.02	0.02	0.04	0.00	0.00
43.5	0.15	0.12	0.08	0.11	0.12	0.12	0.03	0.04	0.07	0.01	0.01
47.5	0.23	0.19	0.13	0.18	0.20	0.19	0.08	0.09	0.17	0.04	0.05
52.5	0.37	0.32	0.23	0.29	0.33	0.30	0.20	0.24	0.39	0.15	0.21
57.5	0.54	0.48	0.37	0.44	0.51	0.44	0.40	0.49	0.69	0.36	0.54
62.5	0.72	0.65	0.55	0.61	0.70	0.61	0.66	0.78	0.94	0.68	0.91
67.5	0.87	0.82	0.73	0.78	0.87	0.77	0.90	0.98	1.00	0.94	1.00
72.5	0.98	0.95	0.89	0.92	0.98	0.90	1.00	1.00	0.97	1.00	0.97
77.5	1.00	1.00	0.99	0.99	1.00	0.99	0.97	1.00	0.89	0.99	0.90
82.5	0.93	0.99	0.99	1.00	1.00	1.00	0.85	0.95	0.76	0.93	0.81
87.5	0.79	0.90	0.91	1.00	1.00	1.00	0.68	0.84	0.61	0.81	0.70
92.5	0.61	0.72	0.76	0.99	1.00	1.00	0.50	0.68	0.46	0.66	0.58
97.5	0.44	0.52	0.58	0.87	1.00	1.00	0.33	0.51	0.32	0.50	0.47
102.5	0.28	0.33	0.40	0.65	0.86	0.76	0.20	0.35	0.21	0.36	0.36

Table 2.21b—Schedules of Pacific cod selectivities at length in the bottom trawl surveys as defined by final parameter estimates (revised version of Model B1). Lengths (cm) correspond to mid-points of size bins.

	Shelf Survey		
Length	pre-1982	post-1981	Slope
10.5	0.01	0.38	0.00
13.5	0.02	0.45	0.00
16.5	0.05	0.52	0.00
19.5	0.11	0.59	0.00
22.5	0.19	0.67	0.00
25.5	0.32	0.74	0.00
28.5	0.49	0.81	0.00
31.5	0.67	0.87	0.00
34.5	0.84	0.92	0.00
37.5	0.96	0.96	0.01
40.5	1.00	0.99	0.03
43.5	0.99	1.00	0.11
47.5	0.95	1.00	0.37
52.5	0.87	1.00	0.86
57.5	0.76	1.00	1.00
62.5	0.63	1.00	1.00
67.5	0.50	1.00	0.98
72.5	0.38	1.00	0.81
77.5	0.28	1.00	0.55
82.5	0.19	1.00	0.30
87.5	0.13	1.00	0.14
92.5	0.08	1.00	0.05
97.5	0.05	1.00	0.02
102.5	0.03	1.00	0.00

Table 2.22—Schedules of Pacific cod length (cm), proportion mature, and weight (kg) by season and age as estimated by the revised version of Model B1. Pop. = population, Sea. 1 = Jan-Jun, Sea. 2 = Jul-Aug, Sea. 3 = Sep-Dec, Beg. = beginning of season, Mid. = middle of season, S.Dev. = standard deviation, Mat. = proportion mature, Twl. = trawl fishery, Lgl. = longline fishery, pot = pot fishery, shelf = shelf survey, slope = slope survey.

		Length				Pop. Weight		Fishery Weight			Survey Wt.	
Sea.	Age	Beg.	Mid.	S.Dev.	Mat.	Beg.	Mid.	Twl.	Lgl.	Pot	Shelf	Slope
1	1	11.10	13.79	3.54	0.00	0.01	0.02	0.03	0.04	0.06	0.02	0.07
1	2	23.44	25.85	4.87	0.01	0.13	0.17	0.24	0.31	0.42	0.18	0.45
1	3	34.47	36.61	5.80	0.05	0.43	0.53	0.73	0.87	1.08	0.54	1.00
1	4	44.32	46.23	6.42	0.18	0.98	1.13	1.45	1.55	1.77	1.13	1.52
1	5	53.11	54.82	6.80	0.38	1.75	1.94	2.34	2.31	2.48	1.94	2.13
1	6	60.97	62.50	7.00	0.59	2.72	2.95	3.34	3.16	3.25	2.95	2.93
1	7	67.99	69.35	7.07	0.75	3.86	4.12	4.42	4.12	4.17	4.12	3.82
1	8	74.25	75.47	7.05	0.85	5.12	5.40	5.55	5.21	5.27	5.40	4.73
1	9	79.85	80.94	6.97	0.90	6.47	6.76	6.71	6.37	6.49	6.76	5.63
1	10	84.85	85.82	6.83	0.93	7.86	8.16	7.89	7.57	7.76	8.14	6.55
1	11	89.31	90.18	6.67	0.95	9.27	9.56	9.07	8.78	9.04	9.49	7.48
1	12	93.30	94.08	6.49	0.96	10.65	10.94	10.25	9.99	10.32	10.72	8.42
1	13	96.86	97.55	6.71	0.97	11.98	12.24	11.33	11.08	11.50	11.68	9.13
1	14	100.04	100.66	6.90	0.98	13.16	13.38	12.35	12.12	12.60	12.41	9.79
2	1	16.41	17.96	3.54		0.05	0.05	0.07	0.10	0.15	0.06	0.17
2	2	28.19	29.57	4.87		0.27	0.27	0.36	0.48	0.65	0.28	0.65
2	3	38.71	39.94	5.80		0.71	0.71	0.92	1.11	1.33	0.72	1.19
2	4	48.10	49.21	6.42		1.38	1.38	1.68	1.82	2.04	1.38	1.72
2	5	56.49	57.48	6.80		2.26	2.26	2.61	2.60	2.75	2.26	2.39
2	6	63.99	64.87	7.00		3.33	3.33	3.66	3.48	3.55	3.33	3.22
2	7	70.68	71.47	7.07		4.54	4.54	4.79	4.48	4.53	4.54	4.11
2	8	76.66	77.36	7.05		5.86	5.86	6.00	5.59	5.67	5.86	5.00
2	9	82.00	82.63	6.97		7.23	7.23	7.28	6.76	6.90	7.23	5.90
2	10	86.77	87.33	6.83		8.63	8.63	8.59	7.95	8.17	8.60	6.81
2	11	91.03	91.53	6.67		10.03	10.03	9.85	9.16	9.45	9.91	7.73
2	12	94.83	95.28	6.49		11.39	11.39	10.97	10.36	10.72	11.07	8.66
2	13	98.23	98.63	6.71		12.64	12.64	11.87	11.44	11.88	11.95	9.36
2	14	101.27	101.62	6.90		13.71	13.71	12.63	12.45	12.93	12.61	10.00
3	1	19.48	21.48	3.54		0.10	0.10	0.13	0.19	0.27	0.10	0.30
3	2	30.93	32.72	4.87		0.37	0.37	0.50	0.67	0.87	0.39	0.84
3	3	41.16	42.75	5.80		0.88	0.88	1.14	1.33	1.56	0.89	1.35
3	4	50.29	51.72	6.42		1.62	1.62	1.96	2.06	2.26	1.62	1.91
3	5	58.45	59.72	6.80		2.56	2.56	2.93	2.86	2.99	2.56	2.63
3	6	65.73	66.87	7.00		3.68	3.68	4.00	3.77	3.83	3.68	3.48
3	7	72.24	73.26	7.07		4.93	4.93	5.15	4.80	4.86	4.93	4.36
3	8	78.05	78.96	7.05		6.26	6.26	6.38	5.92	6.02	6.26	5.24
3	9	83.24	84.05	6.97		7.65	7.65	7.67	7.09	7.26	7.64	6.13
3	10	87.88	88.60	6.83		9.05	9.05	8.97	8.29	8.54	9.00	7.03
3	11	92.02	92.67	6.67		10.44	10.44	10.18	9.49	9.81	10.26	7.94
3	12	95.72	96.30	6.49		11.77	11.77	11.25	10.68	11.06	11.35	8.87
3	13	99.02	99.54	6.71		12.98	12.98	12.11	11.74	12.20	12.16	9.55
3	14	101.97	102.43	6.90		13.98	13.98	12.82	12.73	13.22	12.77	10.18

Table 2.23—Time series of EBS (not expanded to BSAI) Pacific cod age 3+ biomass and female spawning biomass for the years 1977-2006 as estimated last year under the Plan Team's and SSC's preferred model and this year under the revised version of Model B1, 1977-2006 (note that the entries labeled "Last Year's Values" do not correspond to the values given in last year's SAFE report, because the values given in last year's SAFE report corresponded to the authors' preferred model, not the model chosen by the Plan Team and SSC). The columns labeled "L95%CI" and "U95%CI" represent the bounds of the 95% confidence intervals of the female spawning biomass point estimates ("Mean").

	Last Year's Values				This Year's Values			
	Age 3+	Female Spawning Biomass			Age 3+	Female Spawning Biomass		
Year	Biomass	Mean	L95%CI	U95%CI	Biomass	Mean	L95%CI	U95%CI
1977	206,295	32,871	23,372	42,369	351,043	63,970	41,324	86,616
1978	249,016	48,058	36,761	59,354	413,578	88,355	60,761	115,949
1979	469,543	76,760	60,268	93,252	748,089	129,390	92,587	166,193
1980	891,564	134,915	109,848	159,982	1,158,690	203,880	152,721	255,039
1981	1,187,170	243,335	205,705	280,965	1,517,400	324,615	252,425	396,805
1982	1,472,030	381,235	330,376	432,094	1,803,040	472,195	375,383	569,007
1983	1,607,040	501,700	441,912	561,488	1,940,570	606,100	488,186	724,014
1984	1,625,670	567,600	504,904	630,296	2,008,660	684,250	553,518	814,982
1985	1,726,130	577,950	516,926	638,974	2,108,490	706,050	570,447	841,653
1986	1,674,350	565,500	508,045	622,955	2,052,550	701,450	565,308	837,592
1987	1,748,410	564,550	510,416	618,684	2,063,370	699,800	564,756	834,844
1988	1,706,510	564,450	513,092	615,808	1,962,320	688,100	555,996	820,204
1989	1,548,160	543,900	495,219	592,582	1,762,380	643,350	516,940	769,760
1990	1,359,840	513,600	468,179	559,021	1,550,070	590,400	472,457	708,343
1991	1,213,970	456,835	415,863	497,807	1,419,360	521,900	414,943	628,857
1992	1,152,860	375,875	339,795	411,955	1,343,810	437,945	342,257	533,633
1993	1,136,790	337,610	305,129	370,091	1,311,710	398,420	311,291	485,549
1994	1,160,790	346,000	315,330	376,670	1,357,450	402,690	320,606	484,774
1995	1,206,320	354,910	325,102	384,718	1,397,110	409,055	329,568	488,542
1996	1,118,340	344,020	314,354	373,686	1,306,820	398,060	319,530	476,590
1997	1,014,240	333,220	303,174	363,266	1,222,930	389,370	310,931	467,809
1998	906,286	296,725	266,672	326,778	1,170,450	359,855	281,849	437,861
1999	915,133	275,280	245,114	305,446	1,238,220	353,235	275,064	431,406
2000	901,674	266,385	235,573	297,197	1,275,970	364,415	284,616	444,214
2001	903,325	268,275	236,733	299,817	1,318,360	388,395	305,981	470,809
2002	962,447	275,295	243,594	306,996	1,390,490	413,955	329,578	498,332
2003	992,856	277,895	246,138	309,652	1,375,020	423,905	338,912	508,898
2004	954,107	284,915	252,345	317,485	1,305,670	423,950	339,499	508,402
2005	886,480	283,075	249,153	316,997	1,194,340	406,580	324,056	489,104
2006	n/a	n/a	n/a	n/a	1,061,930	370,620	291,470	449,770

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 the revised version of Model B1, 1977-2005 (note that the entries labeled "Last Year's Values" do not correspond to the values given in last year's SAFE report, because the values given in last year's SAFE report corresponded to the authors' preferred model, not the model chosen by the Plan Team and SSC). 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	2,087,960	1,727,781	2,523,294	1,761,770	1,387,935	2,236,296
1978	522,535	312,677	873,249	1,109,022	814,494	1,510,054
1979	1,074,910	834,512	1,384,544	1,038,138	780,328	1,381,125
1980	370,327	233,561	587,207	498,211	328,889	754,705
1981	482,648	339,877	685,403	975,982	761,914	1,250,194
1982	1,637,790	1,407,769	1,905,306	1,654,235	1,370,367	1,996,905
1983	315,147	205,383	483,561	413,432	280,562	609,228
1984	1,494,730	1,285,365	1,738,179	1,291,338	1,074,664	1,551,698
1985	428,535	314,820	583,336	441,251	327,515	594,484
1986	286,273	206,672	396,524	415,638	312,832	552,229
1987	200,418	134,291	298,974	333,938	239,140	466,316
1988	658,175	544,584	795,467	965,730	799,657	1,166,293
1989	1,224,710	1,061,143	1,413,498	1,203,482	1,006,723	1,438,697
1990	657,983	532,483	813,062	696,888	555,982	873,505
1991	640,898	524,260	783,476	982,327	816,702	1,181,541
1992	1,031,550	898,553	1,184,225	1,063,770	891,879	1,268,789
1993	280,836	212,685	370,814	396,896	299,301	526,314
1994	351,743	280,394	441,241	605,736	484,720	756,965
1995	627,883	531,606	741,596	1,058,231	885,921	1,264,055
1996	878,950	767,880	1,006,078	1,179,663	1,000,228	1,391,288
1997	411,017	340,031	496,831	638,106	521,369	780,981
1998	631,846	539,514	739,979	880,891	736,783	1,053,186
1999	943,613	820,365	1,085,367	1,084,869	920,607	1,278,440
2000	693,481	586,035	820,616	559,825	459,265	682,403
2001	300,762	234,407	385,904	490,549	396,657	606,667
2002	411,992	323,510	524,669	455,878	357,802	580,837
2003	272,626	193,079	384,942	420,029	313,607	562,565
2004	435,093	279,269	677,917	322,804	203,525	511,987
2005	n/a	n/a	n/a	719,028	473,563	1,091,727

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 the revised version of Model B1, 1977-2006 (note that the entries labeled "Last Year's Values" do not correspond to the values given in last year's SAFE report, because the values given in last year's SAFE report corresponded to the authors' preferred model, not the model chosen by the Plan Team and SSC). 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	0.16	0.09
1978	0.18	0.11
1979	0.08	0.05
1980	0.05	0.04
1981	0.05	0.04
1982	0.04	0.03
1983	0.06	0.05
1984	0.08	0.06
1985	0.08	0.07
1986	0.08	0.07
1987	0.09	0.07
1988	0.12	0.10
1989	0.12	0.10
1990	0.13	0.11
1991	0.17	0.15
1992	0.14	0.12
1993	0.12	0.10
1994	0.15	0.13
1995	0.19	0.16
1996	0.19	0.16
1997	0.23	0.19
1998	0.17	0.14
1999	0.16	0.12
2000	0.17	0.12
2001	0.16	0.11
2002	0.17	0.12
2003	0.18	0.13
2004	0.19	0.14
2005	0.21	0.15
2006	n/a	0.17

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 2007-2019 (Scenario 1, revised version of Model B1), with random variability in future recruitment.

Catch Projections					
Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2007	202177	202177	202177	202177	0
2008	146631	146633	146633	146637	2
2009	122326	122442	122467	122696	123
2010	128134	130089	130500	134291	2062
2011	146015	159532	162265	187917	14275
2012	151208	190743	196680	254813	34570
2013	147045	211637	215344	292153	47496
2014	146719	222306	223346	310663	52716
2015	143933	226555	226422	319649	54141
2016	141309	227757	226885	316573	54654
2017	138005	228242	226612	317181	54440
2018	140107	228010	226382	316044	53670
2019	142048	226096	226467	314680	53266
Spawning Biomass Projections					
Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2007	351030	351030	351030	351030	0
2008	298054	298057	298058	298065	4
2009	270924	271109	271150	271512	196
2010	269045	271193	271603	275663	2206
2011	279805	290702	292563	311675	10805
2012	284561	313179	317666	363014	26812
2013	282161	328721	335565	409764	42465
2014	281106	337205	345952	436202	51748
2015	279528	341082	351228	458079	55536
2016	276984	342811	353371	455675	56893
2017	275273	345934	354065	459002	57012
2018	276606	345196	354379	456690	56534
2019	278536	343963	354786	452836	56323
Fishing Mortality Projections					
Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2007	0.344	0.344	0.344	0.344	0.000
2008	0.296	0.296	0.296	0.296	0.000
2009	0.268	0.268	0.268	0.268	0.000
2010	0.266	0.268	0.268	0.273	0.002
2011	0.277	0.288	0.290	0.311	0.011
2012	0.282	0.312	0.313	0.344	0.020
2013	0.279	0.329	0.322	0.344	0.023
2014	0.278	0.337	0.325	0.344	0.023
2015	0.277	0.342	0.326	0.344	0.024
2016	0.274	0.343	0.326	0.344	0.025
2017	0.272	0.344	0.326	0.344	0.025
2018	0.274	0.344	0.326	0.344	0.025
2019	0.276	0.344	0.327	0.344	0.024

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, revised version of Model B1), with random variability in future recruitment.

Catch Projections					
Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2007	106861	106861	106861	106861	0
2008	94778	94779	94779	94781	1
2009	87552	87623	87639	87778	75
2010	93470	94670	94920	97244	1258
2011	106364	112903	113559	122734	5284
2012	111685	126312	128720	152360	14027
2013	111339	137077	140612	180362	22858
2014	112709	145004	148720	196286	27960
2015	112389	149535	153588	208758	30050
2016	112516	152162	156107	210268	30820
2017	110798	154942	157310	211714	30911
2018	112810	155006	157963	211042	30546
2019	114797	155083	158445	210132	30269
Spawning Biomass Projections					
Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2007	358095	358095	358095	358095	0
2008	337303	337307	337308	337315	4
2009	324776	324964	325004	325371	198
2010	328882	331066	331483	335609	2242
2011	343719	355034	357008	377076	11310
2012	353957	385625	390842	441435	30093
2013	357439	415876	423455	511577	51787
2014	362618	440211	450044	566261	68121
2015	364740	459661	469754	606510	77513
2016	365743	472531	483444	627773	82312
2017	369268	483074	492753	638793	84378
2018	371193	491526	499257	647595	84785
2019	379278	495317	504021	652180	84665
Fishing Mortality Projections					
Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2007	0.172	0.172	0.172	0.172	0.000
2008	0.165	0.165	0.165	0.165	0.000
2009	0.159	0.159	0.159	0.160	0.000
2010	0.161	0.163	0.163	0.165	0.001
2011	0.169	0.172	0.171	0.172	0.001
2012	0.172	0.172	0.172	0.172	0.000
2013	0.172	0.172	0.172	0.172	0.001
2014	0.172	0.172	0.172	0.172	0.001
2015	0.172	0.172	0.172	0.172	0.001
2016	0.172	0.172	0.172	0.172	0.002
2017	0.172	0.172	0.172	0.172	0.002
2018	0.172	0.172	0.172	0.172	0.002
2019	0.172	0.172	0.172	0.172	0.001

Table 2.28—Projections for BSAI Pacific cod catch (t), spawning biomass (t), and fishing mortality under the assumption that *F* = the 2002-2006 average in 2007-2019 (Scenario 4, revised version of Model B1), with random variability in future recruitment.

Catch Projections					
Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2007	145949	145949	145949	145949	0
2008	128747	128747	128747	128747	0
2009	119535	119566	119573	119634	33
2010	124107	124970	125155	126832	907
2011	134297	141060	142393	154874	6938
2012	137439	157678	160982	193226	19187
2013	135834	170429	175070	228002	30337
2014	136789	179232	184109	246393	36090
2015	136509	184389	189143	259319	38074
2016	136271	186220	191483	259589	38645
2017	134709	189046	192455	260973	38536
2018	135863	189120	192918	260073	38087
2019	138538	188667	193326	258133	37848
Spawning Biomass Projections					
Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2007	355276	355276	355276	355276	0
2008	320249	320253	320254	320261	4
2009	296636	296827	296869	297243	202
2010	292508	294748	295176	299410	2300
2011	301424	313020	315026	335464	11518
2012	307067	338961	344072	394224	29905
2013	307036	363805	370993	457406	49993
2014	309674	382477	391657	501585	63826
2015	308570	396276	405952	531814	70845
2016	310210	406483	415128	542257	73987
2017	311682	412665	420915	551201	75058
2018	312799	415582	424797	554755	74950
2019	317988	420855	427673	554323	74638
Fishing Mortality Projections					
Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2007	0.240	0.240	0.240	0.240	0.000
2008	0.240	0.240	0.240	0.240	0.000
2009	0.240	0.240	0.240	0.240	0.000
2010	0.240	0.240	0.240	0.240	0.000
2011	0.240	0.240	0.240	0.240	0.000
2012	0.240	0.240	0.240	0.240	0.000
2013	0.240	0.240	0.240	0.240	0.000
2014	0.240	0.240	0.240	0.240	0.000
2015	0.240	0.240	0.240	0.240	0.000
2016	0.240	0.240	0.240	0.240	0.000
2017	0.240	0.240	0.240	0.240	0.000
2018	0.240	0.240	0.240	0.240	0.000
2019	0.240	0.240	0.240	0.240	0.000

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, revised version of Model B1), with random variability in future recruitment.

Catch Projections					
Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2007	0	0	0	0	0
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
Spawning Biomass Projections					
Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2007	365315	365315	365315	365315	0
2008	384118	384122	384123	384130	4
2009	403483	403675	403716	404091	202
2010	432062	434306	434735	438975	2303
2011	468735	480475	482512	503244	11670
2012	502596	536384	541666	594932	31667
2013	529383	594759	602907	699452	57672
2014	554142	648553	659508	802237	81845
2015	573201	694521	707972	882233	100208
2016	586599	734476	747209	949262	112761
2017	601707	764145	777874	986769	120628
2018	614745	790359	801412	1016610	124915
2019	632262	805159	819277	1040890	126944
Fishing Mortality Projections					
Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2007	0.000	0.000	0.000	0.000	0.000
2008	0.000	0.000	0.000	0.000	0.000
2009	0.000	0.000	0.000	0.000	0.000
2010	0.000	0.000	0.000	0.000	0.000
2011	0.000	0.000	0.000	0.000	0.000
2012	0.000	0.000	0.000	0.000	0.000
2013	0.000	0.000	0.000	0.000	0.000
2014	0.000	0.000	0.000	0.000	0.000
2015	0.000	0.000	0.000	0.000	0.000
2016	0.000	0.000	0.000	0.000	0.000
2017	0.000	0.000	0.000	0.000	0.000
2018	0.000	0.000	0.000	0.000	0.000
2019	0.000	0.000	0.000	0.000	0.000

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, revised version of Model B1), with random variability in future recruitment.

Catch Projections					
Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2007	237943	237943	237943	237943	0
2008	158661	158663	158664	158667	2
2009	129086	129216	129244	129499	138
2010	135751	137944	138404	142656	2313
2011	155620	170748	173846	202604	16173
2012	160321	203792	211879	289181	41371
2013	154658	224246	232854	328183	57225
2014	153890	233188	240288	343610	62128
2015	150139	235450	242069	350339	62991
2016	147449	235214	241321	347722	63314
2017	142721	234217	240313	345219	62969
2018	145246	234747	239540	342364	62146
2019	147202	234462	239503	342474	61916
Spawning Biomass Projections					
Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2007	348202	348202	348202	348202	0
2008	283969	283972	283973	283980	4
2009	254151	254336	254376	254737	195
2010	252015	254153	254562	258602	2195
2011	262579	273383	275227	294160	10703
2012	266378	294460	298791	342310	26072
2013	263122	307967	313850	382038	39652
2014	261756	313808	320814	401197	46222
2015	259380	315955	323187	412561	48078
2016	257126	316138	323297	411441	48441
2017	254626	316079	322751	411523	48118
2018	255968	315596	322390	408955	47483
2019	257507	314780	322499	406323	47236
Fishing Mortality Projections					
Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2007	0.414	0.414	0.414	0.414	0.000
2008	0.339	0.339	0.339	0.339	0.000
2009	0.301	0.301	0.301	0.301	0.000
2010	0.298	0.301	0.301	0.306	0.003
2011	0.311	0.325	0.327	0.351	0.013
2012	0.316	0.352	0.356	0.413	0.027
2013	0.312	0.369	0.369	0.414	0.034
2014	0.310	0.376	0.373	0.414	0.036
2015	0.307	0.379	0.374	0.414	0.037
2016	0.304	0.379	0.374	0.414	0.038
2017	0.301	0.379	0.373	0.414	0.039
2018	0.303	0.379	0.373	0.414	0.038
2019	0.305	0.378	0.373	0.414	0.037

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, revised version of Model B1), with random variability in future recruitment.

Catch Projections					
Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2007	202177	202177	202177	202177	0
2008	146631	146633	146633	146637	2
2009	144062	144198	144228	144495	144
2010	143499	145745	146217	150574	2369
2011	159161	174442	177564	206596	16292
2012	161364	204916	212936	289958	41240
2013	154674	224224	232738	327632	57087
2014	153679	232891	239975	343216	62089
2015	149885	235176	241832	350133	62990
2016	147310	235061	241183	347561	63318
2017	142642	234131	240240	345133	62971
2018	145200	234803	239504	342323	62147
2019	147181	234440	239485	342455	61916
Spawning Biomass Projections					
Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2007	351030	351030	351030	351030	0
2008	298054	298057	298058	298065	4
2009	269414	269598	269639	269999	195
2010	260478	262612	263020	267053	2191
2011	266850	277637	279478	298378	10686
2012	268210	296264	300577	344029	26044
2013	263800	308574	314471	382590	39664
2014	261969	313960	321014	401447	46266
2015	259415	316015	323258	412769	48121
2016	257129	316149	323331	411597	48472
2017	254618	316086	322771	411660	48137
2018	255960	315598	322401	409000	47494
2019	257504	314784	322505	406327	47242
Fishing Mortality Projections					
Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2007	0.344	0.344	0.344	0.344	0.000
2008	0.296	0.296	0.296	0.296	0.000
2009	0.320	0.320	0.320	0.321	0.000
2010	0.309	0.311	0.312	0.317	0.003
2011	0.317	0.330	0.333	0.357	0.013
2012	0.319	0.354	0.358	0.414	0.027
2013	0.313	0.370	0.369	0.414	0.034
2014	0.311	0.377	0.373	0.414	0.036
2015	0.307	0.379	0.374	0.414	0.037
2016	0.304	0.379	0.374	0.414	0.038
2017	0.301	0.379	0.373	0.414	0.039
2018	0.303	0.379	0.373	0.414	0.038
2019	0.305	0.378	0.373	0.414	0.037

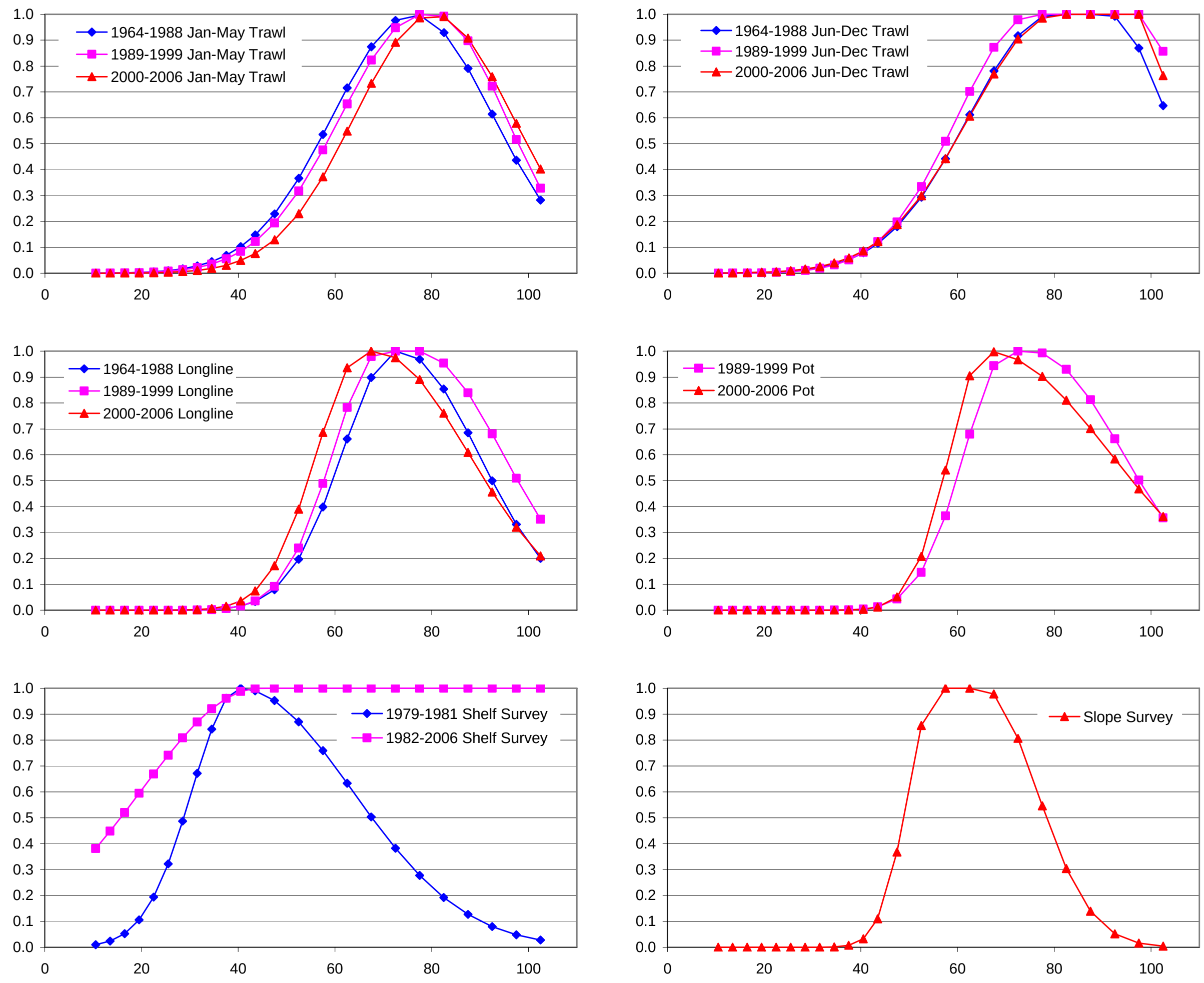

Figure 2.6—Selectivity at length (cm, evaluated at midpoints of length bins) as estimated by the revised version of Model B1.

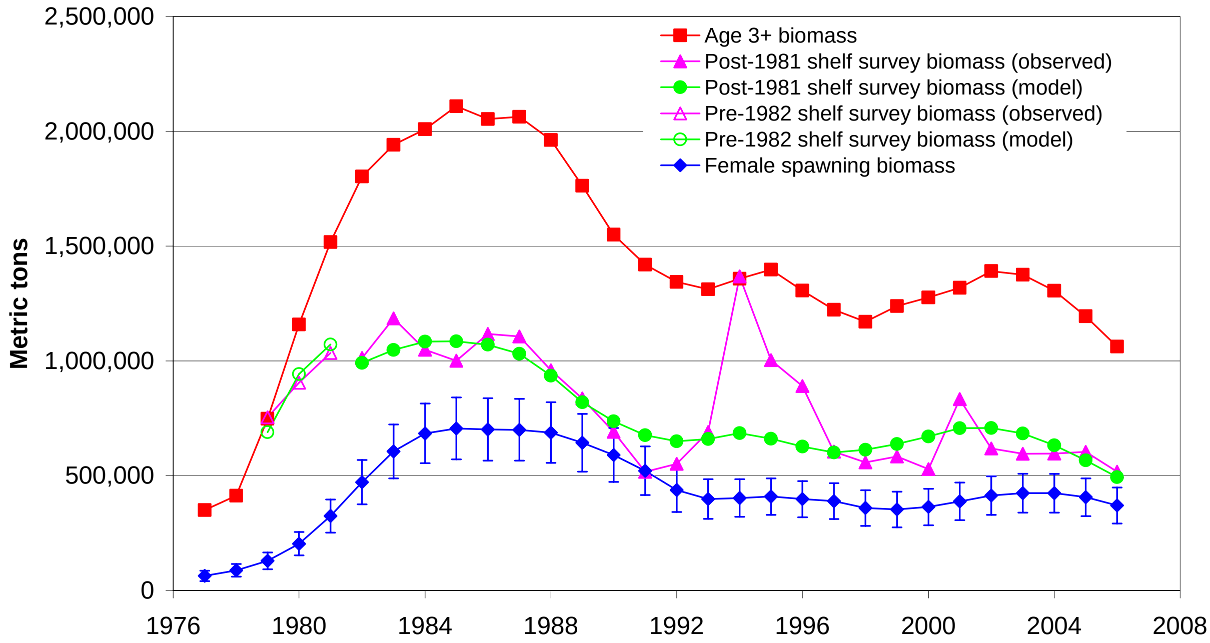

Figure 2.7—Biomass time trends (age 3+ biomass, female spawning biomass, survey biomass) of EBS Pacific cod as estimated by the revised version of Model B1.

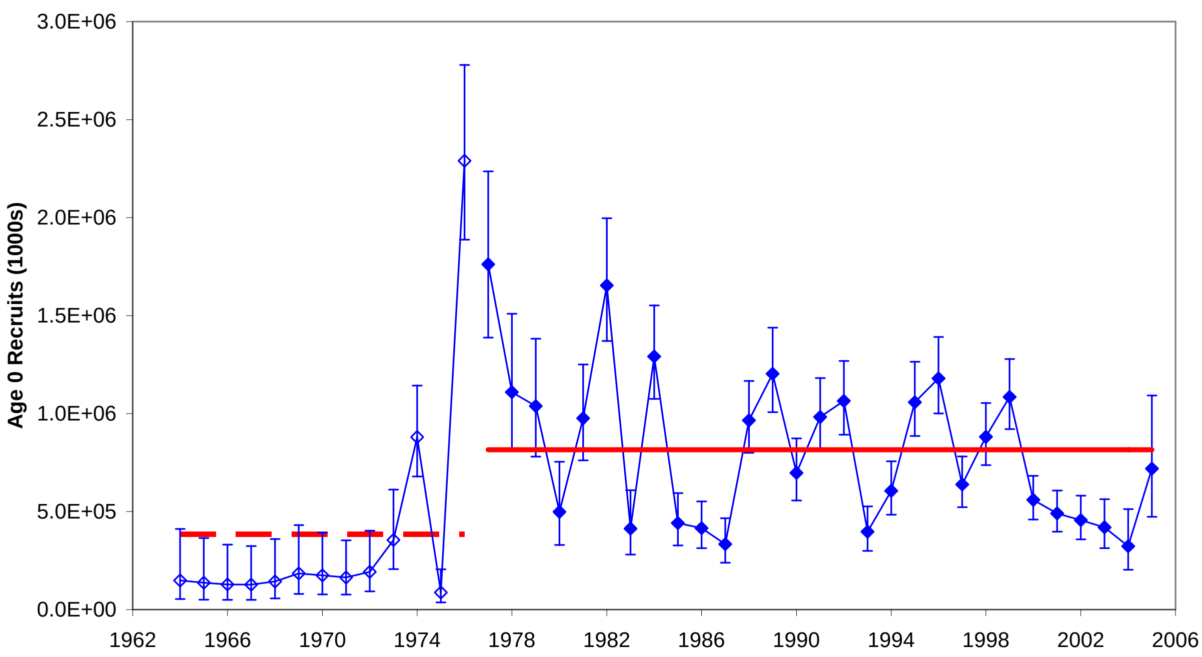

Figure 2.8—Time series of EBS Pacific cod recruitment at age 0, with 95% confidence intervals, as estimated by the revised version of Model B1.

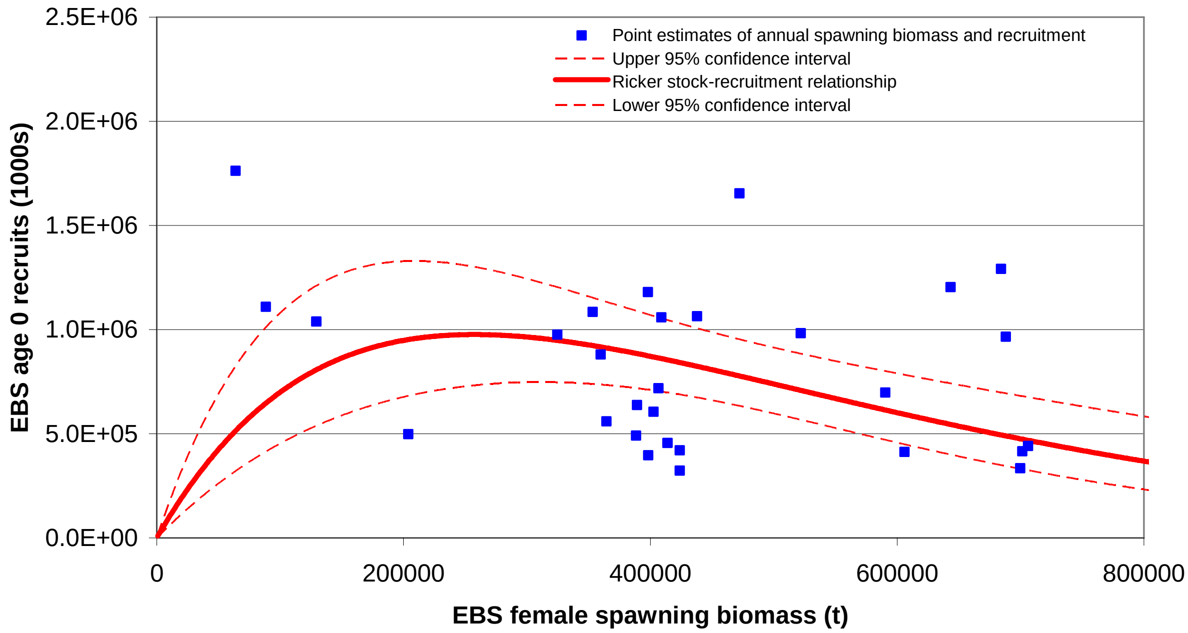

Figure 2.9—Age 0 recruitment versus female spawning biomass for Pacific cod during the years 1977-2005 as estimated by the revised version of Model B1, with Ricker stock-recruitment curve (for illustrative purposes only).

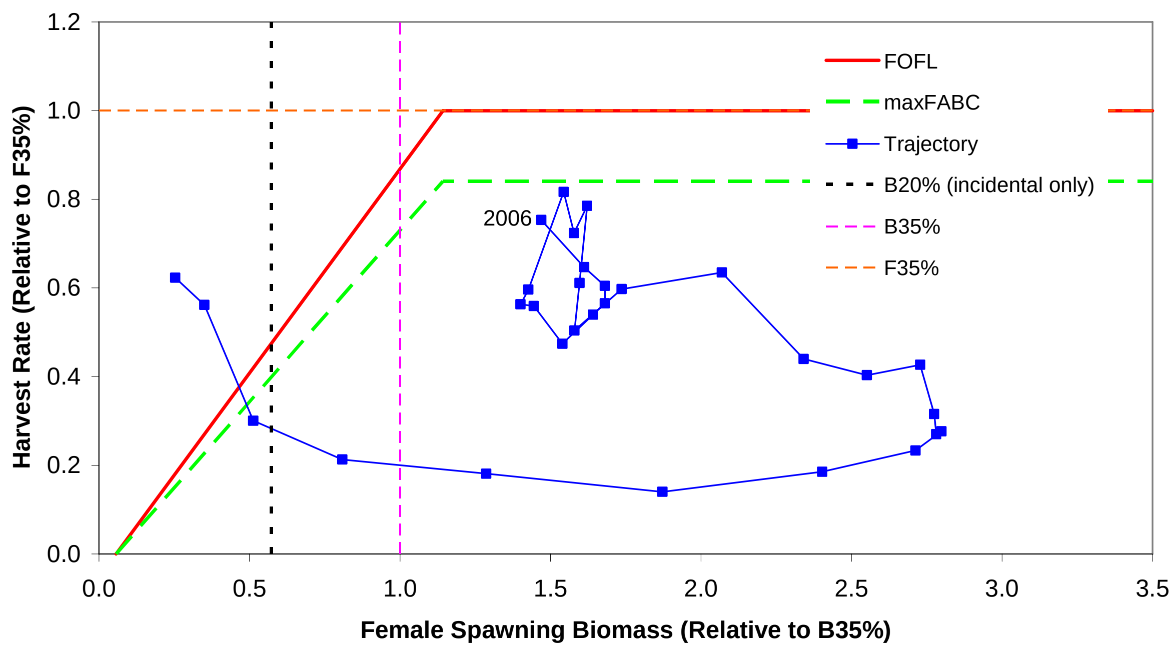

Figure 2.10—Trajectory of Pacific cod fishing mortality and female spawning biomass as estimated by the revised version of Model B1, 1977-present. Because Pacific cod is a key prey of Steller sea lions, harvests would be restricted to incidental catch in the event that spawning biomass fell below $B_{20\%}$.