Section 2

ASSESSMENT OF THE PACIFIC COD STOCK IN THE GULF OF ALASKA
(Partial Chapter)

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EXECUTIVE SUMMARY

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

Changes in the Input Data

Size composition and total catch data from the 1999 and January-August 2000 commercial fisheries (both federally managed and state-managed) were incorporated into the model.

Changes in the Assessment Model

The Bayesian meta-analysis which has formed the basis for a risk-averse ABC recommendation in each of the last four years was not performed for the present assessment. Instead, the ratio between last year's recommended F_{ABC} and $F_{40\%}$ (0.87) was assumed to apply this year as well.

Changes in Assessment Results

1) The estimated 2001 spawning biomass for the GOA stock is 93,800 t, down about 15% from last year's estimate for 2000 and down about 7% from last year's F_{ABC} projection for 2001.
2) The estimated 2001 total age 3+ biomass for the GOA stock is 526,000 t, down about 7% from last year's estimate for 2000 and down about 5% from last year's $F_{40\%}$ projection for 2001.
3) The recommended 2001 ABC for the GOA stock is 67,800 t, down about 11% from last year's recommendation for 2000 and down about 5% from last year's F_{ABC} projection for 2001.
4) The estimated 2001 OFL for the GOA stock is 91,200 t, down about 11% from last year's estimate for 2000.

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 March of 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 3 fish in January of a given year.

Biomass

Model 1's description of the recent history of the stock is shown in Table 2.25, together with estimates provided in last year's final SAFE report (Thompson et al. 1999). The biomass trends estimated in the present assessment are also shown in Figure 2.6. The model's estimated time series of "survey" biomass parallels the biomass trend from the actual survey fairly closely. The model's estimate of survey biomass for 1999 is within 7% of the value observed by the actual survey. The model's estimated age 3+ biomass and spawning biomass levels show continual (or near-continual) declines since 1989 and 1987, respectively. The model's estimates of 2000 age 3+ and spawning biomasses are the lowest in their respective time series.

Recruitment

Model 1's estimated time series of age 3 recruitments is shown in Table 2.26, together with the estimates provided in last year's final SAFE report (Thompson et al. 1999). Model 1's recruitment estimates are also plotted in Figure 2.7. The current time series of age 3 recruitment has a mean value of 134 million fish. When assessed at age 1, the recruitment time series has an estimated coefficient of variation (assuming an inverse Gaussian distribution) of 36%, and an autocorrelation coefficient of 0.11.

One possible means of assigning a qualitative ranking to each year class within this time series is as follows: an "above average" year class can be defined as one in which numbers at age 3 are at least 120% of the mean, an "average" year class can be defined as one in which numbers at age 3 are less than 120% of the mean but at least 80% of the mean, and a "below average" year class can be defined as one in which numbers at age 3 are less than 80% of the mean. These criteria give the following classification of year class strengths:

Above average:	1977	1979	1984	1987	1989						
Average:	1976	1980	1981	1982	1983	1985	1986	1988	1990	1991	1995
Below average:	1975	1978	1992	1993	1994	1996	1997				

These results compare to those presented in last year's SAFE report as follows: The 1978 cohort was changed from "average" to "below average," the 1980 cohort was changed from "above average" to "average," the 1986 cohort was changed from "below average" to "average," and the 1997 cohort was added to the "below average" category. Because all year classes since the 1991 have been "below average" except for the "average" 1995 cohort, the stock is likely to continue its downward trend for the near future. Furthermore, the model's present estimates of age 1 recruitment from the 1998 year class (which is based almost entirely on the size composition from the 1999 trawl survey) is well below the average for that time series.

Exploitation

Model 1's estimated time series of the ratio between catch and age 3+ biomass is shown in Table 2.27, together with the estimates provided in last year's final SAFE report (Thompson et al. 1999). The average value of this ratio over the entire time series is about 0.06. The estimated values exceed the average for every year after 1989 except 1994, whereas none of the estimated values exceed the average in any year prior to 1990.

PROJECTIONS AND HARVEST ALTERNATIVES

Amendment 56 Reference Points

Amendment 56 to the GOA 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 GOA 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:* $1/20 < B/B_{40\%} \leq 1$
$F_{OFL} = F_{35\%} \times (B/B_{40\%} - 1/20) \times 20/19$
$F_{ABC} \leq F_{40\%} \times (B/B_{40\%} - 1/20) \times 20/19$

3c) *Stock status:* $B/B_{40\%} \leq 1/20$
$F_{OFL} = 0$
$F_{ABC} = 0$

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:

$B_{35\%}$	$B_{40\%}$	$B_{100\%}$
78,400 t	89,600 t	224,000 t

The fishing mortality rates corresponding to $B_{35\%}$ and $B_{40\%}$ area as follow:

$F_{35\%}$	$F_{40\%}$
0.46	0.37

Specification of OFL and Maximum Permissible ABC

Under Model 1, spawning biomass for 2001 is estimated at a value of 93,800 t. This is about 5% above the $B_{40\%}$ value of 89,600 t, thereby placing Pacific cod in sub-tier "a" of Tier 3. Given this, Model 1 estimates OFL, maximum permissible ABC, and the associated fishing mortality rates for 2001 as follows:

	Overfishing Level	Maximum Permissible ABC
Catch:	91,200 t	76,700 t
Fishing mortality rate:	0.46	0.37

For comparison, the age 3+ biomass estimate for 2001 is 554,000 t.

ABC Recommendation

For the past four years, the BSAI and GOA Pacific cod assessments have advocated a harvest strategy that formally addresses the uncertainty surrounding the natural mortality rate M and the survey catchability coefficient Q. This strategy relied on a Bayesian meta-analysis, which involved running thousands of individual Synthesis models, each based on a unique pair of M and Q values and each resulting in a conditional maximum log-likelihood and a conditional projected catch. In past years, the conditional projected catch was computed assuming an $F_{40\%}$ harvest strategy. However, insufficient time was available to run the large number of Synthesis models needed to perform the Bayesian meta-analysis for the present assessment. This circumstance is addressed in the present assessment by assuming that the ratio between last year's recommended F_{ABC} and $F_{40\%}$ (0.87, Thompson et al. 1999) can also serve as a ratio between this year's recommended F_{ABC} and the maximum permissible value of F_{ABC}. Applying this ratio to the 2001 maximum permissible value of F_{ABC} gives a recommended 2001 F_{ABC} value of 0.33 and a 2001 ABC of 67,800 t.

Standard Harvest Scenarios and Projection Methodology

As in last year's assessments, a standard set of projections is required in this year's assessments 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 2000 numbers at age estimated in the assessment. This vector is then projected forward to the beginning of 2001 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2000. 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 2001, 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 2001 recommended in the assessment to the *max* F_{ABC} for 2000. (Rationale: When F_{ABC} is set at a value below *max* F_{ABC}, it is often set at the value recommended in the stock assessment.)

Scenario 3: In all future years, F is set equal to 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 1995-1999 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 above ½ of its MSY level in 2001 and above its MSY level in 2011 under this scenario, then the stock is not overfished.)

Scenario 7: In 2001 and 2002, 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 2013 under this scenario, then the stock is not approaching an overfished condition.)

Projections and Status Determination

In addition to the reference points used in Amendment 56, projection of future harvests using the seven standard harvest scenarios requires two more reference points for a stock managed under Tier 3: First, for harvest scenario #2, the ratio of the recommended F_{ABC} to *max* F_{ABC} is 0.87. Second, for harvest scenario #4, the average fishing mortality rate from the period 1995-1999 is 0.23. Table 2.28 defines symbols used to describe projections of spawning biomass, fishing mortality rate, and catch corresponding to the seven standard harvest scenarios. These projections are shown in Tables 2.29-35. Overall, these projections indicate that further declines in the GOA Pacific cod stock can be expected for the next few years, even under conservative exploitation strategies.

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 2001:

a) If spawning biomass for 2001 is estimated to be below ½ $B_{35\%}$, the stock is below its MSST.

b) If spawning biomass for 2001 is estimated to be above $B_{35\%}$, the stock is above its MSST.

c) If spawning biomass for 2001 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 2.34). If the mean spawning biomass for 2011 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 2.35):

a) If the mean spawning biomass for 2003 is below ½ $B_{35\%}$, the stock is approaching an overfished condition.

b) If the mean spawning biomass for 2003 is above $B_{35\%}$, the stock is not approaching an overfished condition.

c) If the mean spawning biomass for 2003 is above ½ $B_{35\%}$ but below $B_{35\%}$, the determination depends on the mean spawning biomass for 2013. If the mean spawning biomass for 2013 is below $B_{35\%}$, the stock is approaching an overfished condition. Otherwise, the stock is not approaching an overfished condition.

In the case of GOA Pacific cod, spawning biomass for 2001 is estimated to be above $B_{35\%}$. Therefore, the stock is above its MSST and is not overfished. Although mean spawning biomass for 2003 in Table 2.35 is below $B_{35\%}$, it is above $B_{35\%}$ in 2013. Therefore, the stock is not approaching an overfished condition.

SUMMARY

The major results of the GOA Pacific cod stock assessment are summarized in Table 2.45.

REFERENCES

Thompson, G. G., H. H. Zenger, and M. W. Dorn. 1999. Pacific cod. *In* Plan Team for Groundfish Fisheries of the Gulf of Alaska (editor), Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska, p. 105-184. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.

Table 2.25–Time series of Pacific cod age 3+ biomass, spawning biomass, and survey biomass as estimated in last year's and this year's assessments.

Year	Age 3+ Biomass		Spawning Biomass		Survey Biomass	
	Last Year	This Year	Last Year	This Year	Last Year	This Year
1978	610	653	123	116		
1979	653	725	140	132		
1980	799	799	151	141		
1981	840	853	158	147		
1982	888	887	170	157		
1983	929	907	184	169		
1984	940	911	200	182	543	521
1985	938	912	210	191		
1986	929	928	218	197		
1987	958	932	220	198	504	488
1988	955	934	218	195		
1989	931	941	216	194		
1990	938	935	207	186	489	488
1991	894	913	192	173		
1992	883	888	179	163		
1993	854	853	172	156	474	473
1994	830	830	172	157		
1995	795	805	171	158		
1996	734	760	164	152	381	394
1997	675	719	151	142		
1998	645	671	134	128		
1999	611	621	128	116	318	326
2000	n/a	560	n/a	104		

Notes: Spawning biomass is computed as the sum of March female numbers at age times population weight at age times fraction mature at age.

"Survey biomass" is the model's estimate of what the actual survey should have observed.

All biomass figures are in 1000s of t.

Table 2.26–Time series of Pacific cod age 3 recruitment as estimated in last year's and this year's assessments.

Year	Recruitment (millions of age 3 fish)	
	Last Year	This Year
1978	60	56
1979	154	150
1980	311	287
1981	116	106
1982	176	164
1983	174	159
1984	133	121
1985	130	119
1986	122	115
1987	210	200
1988	138	131
1989	109	117
1990	200	187
1991	127	127
1992	187	180
1993	141	138
1994	116	116
1995	97	100
1996	95	105
1997	97	106
1998	150	136
1999	101	86
2000	n/a	66

Table 2.27–Time series of Pacific cod catch divided by age 3+ biomass as estimated in last year's and this year's assessments.

Year	Catch Divided by Age 3+ Biomass	
	Last Year	This Year
1978	0.02	0.02
1979	0.02	0.02
1980	0.04	0.05
1981	0.04	0.05
1982	0.03	0.04
1983	0.04	0.04
1984	0.03	0.03
1985	0.02	0.02
1986	0.03	0.03
1987	0.03	0.04
1988	0.04	0.04
1989	0.05	0.05
1990	0.08	0.08
1991	0.09	0.09
1992	0.09	0.10
1993	0.07	0.07
1994	0.06	0.06
1995	0.09	0.09
1996	0.09	0.10
1997	0.11	0.11
1998	0.11	0.11
1999	0.12	0.14
2000	n/a	0.13

Table 2.28–Definitions of symbols and terms used in the Pacific cod projection tables.

Symbol	Definition
SPR	Equilibrium spawning per recruit, expressed as a percentage of the maximum level
L90%CI	Lower bound of the 90% confidence interval
Median	Point that divides projection outputs into two groups of equal size (50% higher, 50%
Mean	Average value of the projection outputs
U90%CI	Upper bound of the 90% confidence interval
St. Dev.	Standard deviation of the projection outputs

Table 2.29–Equilibrium reference points and projections for GOA Pacific cod spawning biomass (1000s of t), fishing mortality, and catch (1000s of t) under the assumption that $F = max\ F_{ABC}$ in each year 2001-2013, where future recruitment is drawn from a distribution based on estimated recruitments spawned during the period 1977-1998. See Table 2.28 for symbol definitions.

Equilibrium Reference Points

SPR	Spawning Biomass	Fishing Mortality	Catch
100%	224.1	0	0
40%	89.6	0.37	78.7
35%	78.4	0.46	84.8

Spawning Biomass Projections

Year	L90%CI	Median	Mean	U90%CI	St. Dev.
2001	93.8	93.8	93.8	93.8	0.00
2002	81.1	81.1	81.2	81.2	0.05
2003	72.8	73.2	73.3	74.1	0.40
2004	69.9	71.8	72.0	74.9	1.58
2005	70.9	75.6	76.1	83.1	3.97
2006	72.7	80.9	81.9	92.6	6.58
2007	74.8	85.3	86.4	101.2	8.45
2008	75.9	87.7	88.9	105.9	9.58
2009	76.6	88.4	90.1	108.3	10.13
2010	76.8	89.3	90.7	108.9	10.32
2011	77.4	89.2	91.0	109.6	10.27
2012	77.5	89.3	91.0	109.3	10.20
2013	77.7	89.3	91.1	109.9	10.21

Fishing Mortality Projections

Year	L90%CI	Median	Mean	U90%CI	St. Dev.
2001	0.37	0.37	0.37	0.37	0.000
2002	0.34	0.34	0.34	0.34	0.000
2003	0.30	0.30	0.30	0.31	0.002
2004	0.29	0.30	0.30	0.31	0.007
2005	0.29	0.31	0.31	0.35	0.017
2006	0.30	0.34	0.34	0.37	0.024
2007	0.31	0.36	0.35	0.37	0.023
2008	0.31	0.37	0.36	0.37	0.021
2009	0.32	0.37	0.36	0.37	0.020
2010	0.32	0.37	0.36	0.37	0.020
2011	0.32	0.37	0.36	0.37	0.019
2012	0.32	0.37	0.36	0.37	0.019
2013	0.32	0.37	0.36	0.37	0.019

Catch Projections

Year	L90%CI	Median	Mean	U90%CI	St. Dev.
2001	76.7	76.7	76.7	76.7	0.00
2002	59.9	60.0	60.0	60.1	0.06
2003	48.1	48.7	48.8	49.7	0.51
2004	45.6	48.2	48.6	52.9	2.33
2005	48.2	55.7	56.9	69.4	6.94
2006	50.8	65.2	66.8	85.2	11.10
2007	53.7	72.1	72.9	92.6	12.42
2008	55.3	75.9	75.6	95.8	12.85
2009	56.3	76.8	76.6	97.7	12.99
2010	56.0	78.2	77.0	97.6	12.97
2011	57.4	77.5	77.1	97.9	12.66
2012	57.1	77.3	77.2	97.5	12.51
2013	57.7	77.2	77.2	97.7	12.58

Table 2.30–Equilibrium reference points and projections for GOA Pacific cod spawning biomass (1000s of t), fishing mortality, and catch (1000s of t) under the assumption that the ratio of F to $max\ F_{ABC}$ in each year 2001-2013 is fixed at a value of 0.87, where future recruitment is drawn from a distribution based on estimated recruitments spawned during the period 1977-1998. See Table 2.28 for symbol definitions.

Equilibrium Reference Points

SPR	Spawning Biomass	Fishing Mortality	Catch
100%	224.1	0	0
40%	89.6	0.37	78.7
35%	78.4	0.46	84.8

Spawning Biomass Projections

Year	L90%CI	Median	Mean	U90%CI	St. Dev.
2001	94.4	94.4	94.4	94.4	0.00
2002	84.0	84.0	84.0	84.1	0.05
2003	76.5	76.9	77.0	77.8	0.40
2004	73.7	75.6	75.8	78.7	1.60
2005	74.6	79.3	79.9	86.9	4.02
2006	76.4	84.9	85.8	97.0	6.81
2007	78.5	89.5	90.9	106.9	9.06
2008	79.9	92.5	94.0	112.5	10.55
2009	80.7	93.9	95.9	115.2	11.34
2010	81.1	95.3	96.9	117.4	11.66
2011	82.0	96.1	97.5	118.5	11.68
2012	81.8	96.1	97.8	118.2	11.62
2013	82.4	96.1	97.9	117.9	11.63

Fishing Mortality Projections

Year	L90%CI	Median	Mean	U90%CI	St. Dev.
2001	0.33	0.33	0.33	0.33	0.000
2002	0.30	0.30	0.30	0.30	0.000
2003	0.27	0.28	0.28	0.28	0.002
2004	0.26	0.27	0.27	0.28	0.006
2005	0.27	0.28	0.29	0.31	0.015
2006	0.27	0.31	0.30	0.33	0.018
2007	0.28	0.32	0.31	0.33	0.015
2008	0.29	0.33	0.32	0.33	0.014
2009	0.29	0.33	0.32	0.33	0.013
2010	0.29	0.33	0.32	0.33	0.012
2011	0.30	0.33	0.32	0.33	0.011
2012	0.29	0.33	0.32	0.33	0.011
2013	0.30	0.33	0.32	0.33	0.011

Catch Projections

Year	L90%CI	Median	Mean	U90%CI	St. Dev.
2001	67.8	67.8	67.8	67.8	0.00
2002	55.9	56.0	56.0	56.1	0.05
2003	46.1	46.6	46.7	47.6	0.47
2004	43.8	46.2	46.6	50.6	2.14
2005	46.1	53.0	54.1	65.7	6.27
2006	48.6	61.9	62.9	77.6	9.51
2007	51.3	68.8	68.4	85.2	10.60
2008	53.2	71.3	71.0	89.0	11.07
2009	54.0	71.9	72.2	90.8	11.28
2010	54.3	73.0	72.7	90.9	11.29
2011	55.5	72.7	73.1	91.3	11.03
2012	55.2	72.8	73.2	91.4	10.87
2013	56.0	72.9	73.3	91.3	10.88

Table 2.31–Equilibrium reference points and projections for GOA Pacific cod spawning biomass (1000s of t), fishing mortality, and catch (1000s of t) under the assumption that F = ½ $max\ F_{ABC}$ in each year 2001-2013, where future recruitment is drawn from a distribution based on estimated recruitments spawned during the period 1977-1998. See Table 2.28 for symbol definitions.

Equilibrium Reference Points

SPR	Spawning Biomass	Fishing Mortality	Catch
100%	224.1	0	0
40%	89.6	0.37	78.7
35%	78.4	0.46	84.8

Spawning Biomass Projections

Year	L90%CI	Median	Mean	U90%CI	St. Dev.
2001	96.0	96.0	96.0	96.0	0.00
2002	93.1	93.1	93.2	93.3	0.05
2003	89.5	90.0	90.1	90.8	0.42
2004	88.0	89.9	90.2	93.2	1.65
2005	89.3	94.2	94.9	102.6	4.36
2006	91.5	101.1	102.3	116.0	8.00
2007	94.3	108.6	110.1	129.7	11.33
2008	96.8	114.6	116.2	139.8	13.63
2009	99.4	119.4	120.7	146.9	14.93
2010	101.6	122.5	123.9	149.7	15.52
2011	103.7	125.4	126.4	153.4	15.64
2012	105.3	126.7	127.9	155.7	15.58
2013	106.0	127.4	128.8	155.8	15.52

Fishing Mortality Projections

Year	L90%CI	Median	Mean	U90%CI	St. Dev.
2001	0.19	0.19	0.19	0.19	0.000
2002	0.19	0.19	0.19	0.19	0.000
2003	0.18	0.18	0.18	0.19	0.001
2004	0.18	0.18	0.18	0.19	0.003
2005	0.18	0.19	0.19	0.19	0.002
2006	0.19	0.19	0.19	0.19	0.001
2007	0.19	0.19	0.19	0.19	0.001
2008	0.19	0.19	0.19	0.19	0.001
2009	0.19	0.19	0.19	0.19	0.000
2010	0.19	0.19	0.19	0.19	0.000
2011	0.19	0.19	0.19	0.19	0.000
2012	0.19	0.19	0.19	0.19	0.000
2013	0.19	0.19	0.19	0.19	0.000

Catch Projections

Year	L90%CI	Median	Mean	U90%CI	St. Dev.
2001	40.7	40.7	40.7	40.7	0.00
2002	39.0	39.0	39.0	39.1	0.01
2003	36.1	36.4	36.5	37.1	0.32
2004	35.3	37.0	37.1	39.3	1.27
2005	37.1	40.8	41.1	45.7	2.71
2006	39.1	44.6	45.3	52.9	4.56
2007	40.5	47.9	48.7	59.2	5.98
2008	41.6	50.3	51.0	62.7	6.76
2009	42.4	51.8	52.6	64.5	7.11
2010	43.2	53.0	53.6	66.0	7.22
2011	44.1	53.7	54.2	66.7	7.14
2012	44.5	53.9	54.6	67.2	7.06
2013	44.6	54.1	54.9	67.2	7.05

Table 2.32–Equilibrium reference points and projections for GOA Pacific cod spawning biomass (1000s of t), fishing mortality, and catch (1000s of t) under the assumption that F = the 1995-1999 average in each year 2001-2013, where future recruitment is drawn from a distribution based on estimated recruitments spawned during the period 1977-1998. See Table 2.28 for symbol definitions.

Equilibrium Reference Points

SPR	Spawning Biomass	Fishing Mortality	Catch
100%	224.1	0	0
40%	89.6	0.37	78.7
35%	78.4	0.46	84.8

Spawning Biomass Projections

Year	L90%CI	Median	Mean	U90%CI	St. Dev.
2001	95.5	95.5	95.5	95.5	0.00
2002	90.1	90.1	90.1	90.3	0.05
2003	84.6	85.1	85.2	86.0	0.43
2004	81.7	83.7	83.9	87.1	1.73
2005	81.9	87.1	87.8	95.7	4.50
2006	83.5	93.4	94.5	108.2	8.03
2007	86.0	100.1	101.5	120.9	11.10
2008	88.3	105.5	106.9	129.1	13.09
2009	90.7	109.5	110.7	135.2	14.14
2010	92.4	112.1	113.3	137.7	14.56
2011	94.4	114.4	115.3	140.5	14.58
2012	95.4	115.2	116.4	141.9	14.46
2013	95.7	115.7	117.1	142.1	14.39

Fishing Mortality Projections

Year	L90%CI	Median	Mean	U90%CI	St. Dev.
2001	0.23	0.23	0.23	0.23	0.000
2002	0.23	0.23	0.23	0.23	0.000
2003	0.23	0.23	0.23	0.23	0.000
2004	0.23	0.23	0.23	0.23	0.000
2005	0.23	0.23	0.23	0.23	0.000
2006	0.23	0.23	0.23	0.23	0.000
2007	0.23	0.23	0.23	0.23	0.000
2008	0.23	0.23	0.23	0.23	0.000
2009	0.23	0.23	0.23	0.23	0.000
2010	0.23	0.23	0.23	0.23	0.000
2011	0.23	0.23	0.23	0.23	0.000
2012	0.23	0.23	0.23	0.23	0.000
2013	0.23	0.23	0.23	0.23	0.000

Catch Projections

Year	L90%CI	Median	Mean	U90%CI	St. Dev.
2001	49.3	49.3	49.3	49.3	0.00
2002	46.1	46.1	46.1	46.1	0.02
2003	42.7	43.0	43.0	43.4	0.19
2004	42.0	43.1	43.3	45.2	1.02
2005	43.0	46.7	47.1	52.7	3.10
2006	44.2	51.0	51.7	61.0	5.45
2007	45.7	54.6	55.5	67.9	7.08
2008	46.9	57.2	58.0	71.7	7.91
2009	47.8	58.7	59.6	73.9	8.25
2010	48.6	60.0	60.6	75.2	8.33
2011	49.6	60.5	61.2	75.6	8.23
2012	49.9	60.7	61.6	75.9	8.12
2013	50.1	60.9	61.8	75.9	8.11

Table 2.33–Equilibrium reference points and projections for GOA Pacific cod spawning biomass (1000s of t), fishing mortality, and catch (1000s of t) under the assumption that $F = 0$ in each year 2001-2013, where future recruitment is drawn from a distribution based on estimated recruitments spawned during the period 1977-1998. See Table 2.28 for symbol definitions.

Equilibrium Reference Points

SPR	Spawning Biomass	Fishing Mortality	Catch
100%	224.1	0	0
40%	89.6	0.37	78.7
35%	78.4	0.46	84.8

Spawning Biomass Projections

Year	L90%CI	Median	Mean	U90%CI	St. Dev.
2001	98.2	98.2	98.2	98.2	0.00
2002	107.7	107.7	107.8	107.9	0.05
2003	115.1	115.6	115.6	116.4	0.43
2004	122.0	124.0	124.3	127.5	1.74
2005	129.8	135.1	135.8	144.1	4.69
2006	137.6	148.4	149.8	165.1	8.91
2007	145.7	162.9	164.7	187.3	13.39
2008	153.1	175.0	177.3	206.7	17.22
2009	159.4	185.8	188.0	222.3	20.01
2010	165.3	194.5	196.7	233.7	21.81
2011	171.8	202.7	204.8	243.3	22.79
2012	176.8	208.5	210.3	251.2	23.39
2013	179.3	212.4	214.1	255.2	23.64

Fishing Mortality Projections

Year	L90%CI	Median	Mean	U90%CI	St. Dev.
2001	0	0	0	0	0
2002	0	0	0	0	0
2003	0	0	0	0	0
2004	0	0	0	0	0
2005	0	0	0	0	0
2006	0	0	0	0	0
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

Catch Projections

Year	L90%CI	Median	Mean	U90%CI	St. Dev.
2001	0	0	0	0	0
2002	0	0	0	0	0
2003	0	0	0	0	0
2004	0	0	0	0	0
2005	0	0	0	0	0
2006	0	0	0	0	0
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

Table 2.34–Equilibrium reference points and projections for GOA Pacific cod spawning biomass (1000s of t), fishing mortality, and catch (1000s of t) under the assumption that $F = F_{OFL}$ in each year 2001-2013, where future recruitment is drawn from a distribution based on estimated recruitments spawned during the period 1977-1998. See Table 2.28 for symbol definitions.

Equilibrium Reference Points

SPR	Spawning Biomass	Fishing Mortality	Catch
100%	224.1	0	0
40%	89.6	0.37	78.7
35%	78.4	0.46	84.8

Spawning Biomass Projections

Year	L90%CI	Median	Mean	U90%CI	St. Dev.
2001	92.9	92.9	92.9	92.9	0.00
2002	76.5	76.6	76.6	76.7	0.05
2003	67.5	67.9	68.0	68.7	0.40
2004	64.7	66.6	66.8	69.7	1.57
2005	66.0	70.5	71.1	77.9	3.89
2006	67.8	75.7	76.6	86.8	6.30
2007	69.6	79.6	80.5	93.6	7.72
2008	70.7	81.5	82.3	96.7	8.34
2009	71.2	81.9	82.9	98.3	8.52
2010	71.2	82.3	83.0	98.1	8.51
2011	71.9	82.0	83.0	97.7	8.36
2012	71.6	81.9	82.9	97.6	8.26
2013	71.8	81.7	83.0	97.6	8.26

Fishing Mortality Projections

Year	L90%CI	Median	Mean	U90%CI	St. Dev.
2001	0.46	0.46	0.46	0.46	0.000
2002	0.39	0.39	0.39	0.39	0.000
2003	0.34	0.34	0.34	0.34	0.002
2004	0.32	0.33	0.33	0.35	0.008
2005	0.33	0.35	0.36	0.39	0.021
2006	0.34	0.38	0.39	0.44	0.031
2007	0.35	0.40	0.40	0.46	0.033
2008	0.36	0.41	0.41	0.46	0.033
2009	0.36	0.42	0.41	0.46	0.033
2010	0.36	0.42	0.41	0.46	0.033
2011	0.36	0.42	0.41	0.46	0.032
2012	0.36	0.42	0.41	0.46	0.032
2013	0.36	0.41	0.41	0.46	0.032

Catch Projections

Year	L90%CI	Median	Mean	U90%CI	St. Dev.
2001	91.2	91.2	91.2	91.2	0.00
2002	64.5	64.6	64.6	64.7	0.07
2003	50.2	50.8	50.9	52.0	0.57
2004	47.7	50.6	51.0	55.9	2.60
2005	50.9	59.3	60.6	74.6	7.78
2006	54.0	69.8	71.8	93.8	13.00
2007	56.8	76.8	78.6	104.3	14.95
2008	58.6	80.0	81.2	107.0	15.43
2009	59.0	80.4	81.9	107.9	15.51
2010	59.0	80.8	81.8	107.2	15.37
2011	60.0	80.2	81.7	107.1	15.00
2012	59.5	79.9	81.6	106.7	14.89
2013	59.8	79.6	81.6	107.3	15.03

Table 2.35–Equilibrium reference points and projections for GOA Pacific cod spawning biomass (1000s of t), fishing mortality, and catch (1000s of t) under the assumption that $F = max\ F_{ABC}$ in each year 2001-2002 and $F = F_{OFL}$ thereafter, where future recruitment is drawn from a distribution based on estimated recruitments spawned during the period 1977-1998. See Table 2.28 for symbol definitions.

Equilibrium Reference Points

SPR	Spawning Biomass	Fishing Mortality	Catch
100%	224.1	0	0
40%	89.6	0.37	78.7
35%	78.4	0.46	84.8

Spawning Biomass Projections

Year	L90%CI	Median	Mean	U90%CI	St. Dev.
2001	93.8	93.8	93.8	93.8	0.00
2002	81.1	81.1	81.2	81.2	0.05
2003	72.2	72.7	72.8	73.5	0.40
2004	67.0	68.9	69.1	72.0	1.56
2005	66.9	71.5	72.0	78.8	3.88
2006	68.1	76.0	76.9	87.0	6.27
2007	69.6	79.6	80.6	93.6	7.71
2008	70.6	81.4	82.2	96.6	8.34
2009	71.1	81.8	82.8	98.2	8.52
2010	71.1	82.3	82.9	98.1	8.50
2011	71.8	82.0	83.0	97.7	8.36
2012	71.6	81.9	82.9	97.6	8.26
2013	71.8	81.7	83.0	97.6	8.26

Fishing Mortality Projections

Year	L90%CI	Median	Mean	U90%CI	St. Dev.
2001	0.37	0.37	0.37	0.37	0.000
2002	0.34	0.34	0.34	0.34	0.000
2003	0.36	0.37	0.37	0.37	0.002
2004	0.34	0.35	0.35	0.36	0.008
2005	0.33	0.36	0.36	0.40	0.021
2006	0.34	0.38	0.39	0.44	0.031
2007	0.35	0.40	0.40	0.46	0.033
2008	0.35	0.41	0.41	0.46	0.033
2009	0.36	0.41	0.41	0.46	0.033
2010	0.36	0.42	0.41	0.46	0.033
2011	0.36	0.42	0.41	0.46	0.032
2012	0.36	0.42	0.41	0.46	0.032
2013	0.36	0.41	0.41	0.46	0.032

Catch Projections

Year	L90%CI	Median	Mean	U90%CI	St. Dev.
2001	76.7	76.7	76.7	76.7	0.00
2002	59.9	60.0	60.0	60.1	0.06
2003	57.1	57.7	57.8	59.0	0.60
2004	50.7	53.7	54.1	59.1	2.67
2005	52.2	60.6	61.9	75.9	7.83
2006	54.3	70.1	72.1	94.0	12.96
2007	56.8	76.8	78.5	104.1	14.92
2008	58.5	79.8	81.1	106.9	15.43
2009	59.0	80.3	81.8	107.9	15.52
2010	59.0	80.8	81.8	107.2	15.37
2011	60.0	80.2	81.7	107.1	15.00
2012	59.5	79.9	81.6	106.7	14.89
2013	59.8	79.6	81.6	107.3	15.03

Table 2.45--Summary of major results for the stock assessment of Pacific cod in the GOA region.

Natural mortality rate:		0.37
Reference fishing mortalities:	Rate	Value
	$F_{35\%}$	0.46
	$F_{40\%}$	0.37
	max F_{ABC}	0.37
Reference spawning biomass:	Type	Value
	$B_{35\%}$	78,400 t
	$B_{40\%}$	89,600 t
Projected biomass for 2000:	Type	Value
	Age 3+	526,000 t
	Spawning (at *max* F_{ABC})	93,800 t
Recommended ABC for 2000:	Units	Value
	Fishing Mortality	0.33
	Catch	67,800 t
Overfishing level for 2000:	Units	Value
	Fishing Mortality	0.46
	Catch	91,200 t

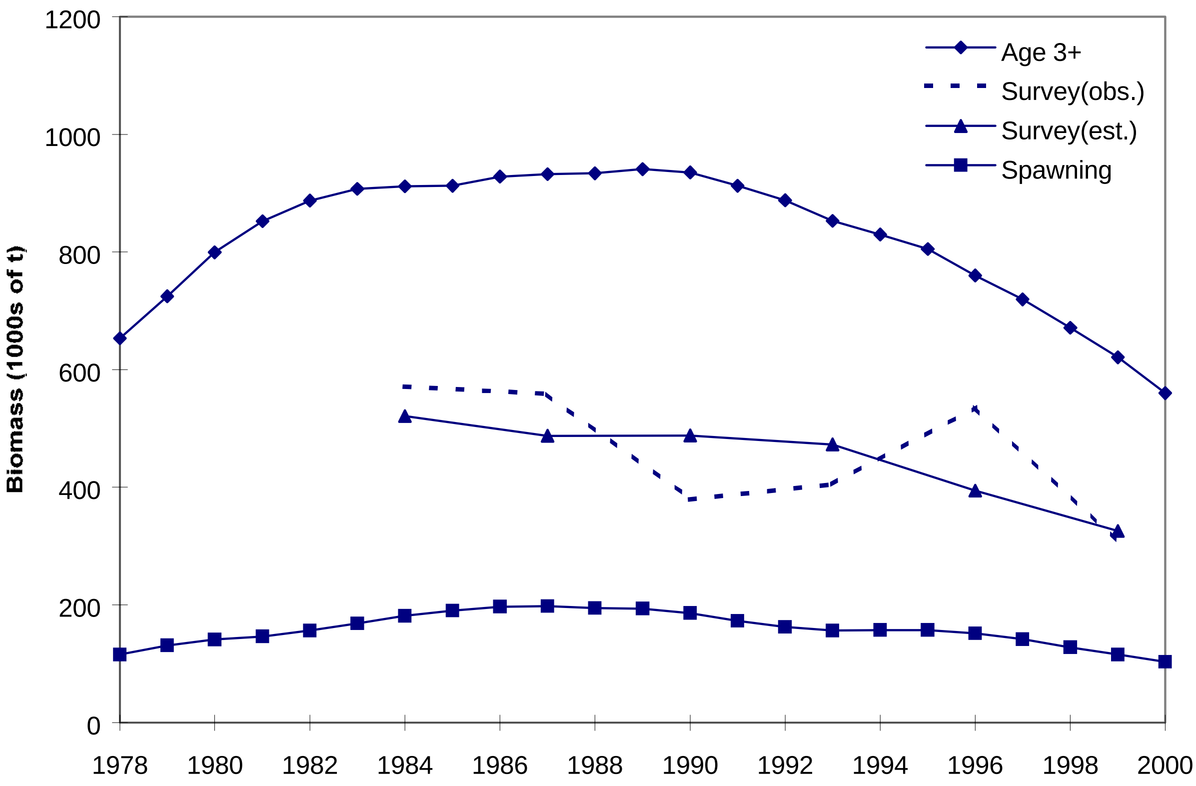

Figure 2.6–Three Pacific cod biomass time series estimated by Model 1, together with the time series of biomass levels observed by the survey.

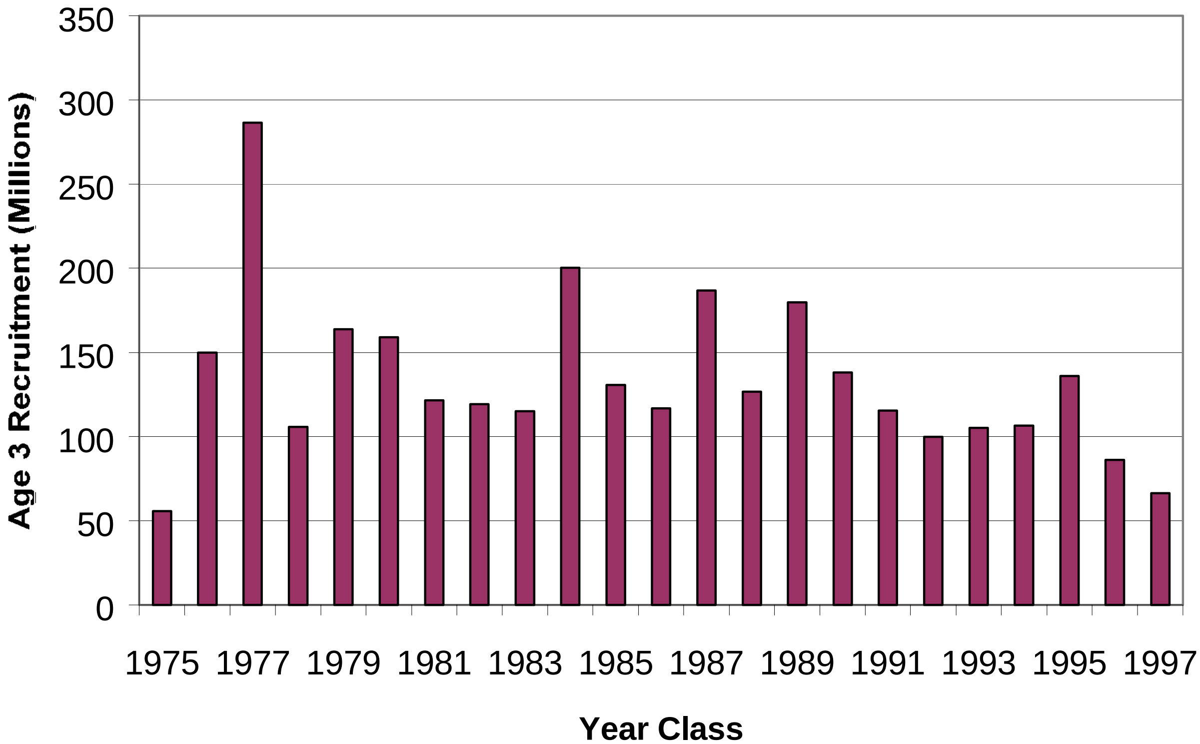

Figure 2.7–Pacific cod recruitment at age 3 as estimated by Model 1.