

Section 2

**ASSESSMENT OF THE PACIFIC COD STOCK IN THE EASTERN BERING SEA
AND ALEUTIAN ISLANDS AREA** (Partial Chapter)

by

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EXECUTIVE SUMMARY

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

Changes in the Input Data

- 1) Size composition data from the 1999 and January-August 2000 commercial fisheries were incorporated into the model.
- 2) Size composition data from the 2000 EBS bottom trawl survey were incorporated.
- 3) The biomass estimate from the 2000 EBS bottom trawl survey was incorporated (the 2000 estimate of 528,466 t was down about 9% from the 1999 estimate).
- 4) The biomass estimates from the 1991-1997 AI bottom trawl surveys were re-calibrated and the biomass estimate from the 2000 AI bottom trawl survey was incorporated (the 2000 estimate of 136,075 t was up about 63% from the 1997 estimate).

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. To account for the fact that projected spawning biomass is slightly below $B_{40\%}$, this ratio was applied to the maximum permissible value of F_{ABC} rather than to $F_{40\%}$.

Changes in Assessment Results

- 1) The estimated 2001 spawning biomass for the BSAI stock is 369,000 t, up about 3% from last year's estimate for 2000 and up about 10% from last year's F_{ABC} projection for 2001.
- 2) The estimated 2001 total age 3+ biomass for the BSAI stock is 1,320,000 t, up about 2% from last year's estimate for 2000 and up about 10% from last year's $F_{40\%}$ projection for 2001.
- 3) The recommended 2001 ABC for the BSAI stock is 188,000 t, down about 2% from last year's recommendation for 2000 and up about 11% from last year's F_{ABC} projection for 2001.
- 4) The estimated 2001 OFL for the BSAI stock is 248,000 t, up about 3% from last year's estimate for 2000.

SURVEY DATA

EBS Shelf Trawl Survey

Estimates of total abundance (both in biomass and numbers of fish) obtained from the trawl surveys are shown in Table 2.13, together with the standard errors and upper and lower 95% confidence intervals (CI) for the biomass estimates. Survey results indicate that biomass increased steadily from 1978 through 1983, then remained relatively constant from 1983 through 1989. The highest biomass ever observed by the survey was the 1994 estimate of 1,368,109 t. Following the high observation in 1994, the survey biomass estimate declined sharply through 1997, after which the rate of decline lessened considerably. Nevertheless, this year's survey biomass estimate of 528,466 t is the lowest in the entire time series.

In terms of numbers (as opposed to biomass), the record high was observed in 1979, when the population was estimated to include over 1.5 billion fish. The 1994 estimate of population numbers was the second highest on record. After the peak in 1994, a sharp decline was observed through 1997, paralleling the biomass time trend. Numerical abundance has remained approximately constant since 1997, however (the 2000 estimate is approximately 1% less than the 1997 estimate).

Aleutian Trawl Survey

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

Year	Aleutian Management Area	Southern Bering Sea	Aleutian Survey Area
1980	52,070	74,373	126,443
1983	113,148	45,624	158,772
1986	172,625	42,298	214,923
1991	180,904	8,286	189,190
1994	153,026	31,084	184,109
1997	72,674	10,742	83,416
2000	126,918	9,157	136,075

As in previous assessments of Pacific cod in the BSAI, a weighted average formed from EBS and Aleutian survey biomass estimates is used in the present assessment to provide a conversion factor which can be used to translate model projections of EBS catch and biomass into BSAI equivalents. Because the assessment model is configured to represent the portion of the Pacific cod population inhabiting the EBS survey area (as opposed to the more extensive EBS *management* area), it seems appropriate to use the biomass estimates from the entire Aleutian survey area (as opposed to the less extensive Aleutian *management* area) to inflate model projections of EBS catch and biomass. Weighted averages of the biomass estimates from the entire Aleutian survey area and their EBS survey area counterparts indicate that, on average, the ratio of Pacific cod biomass in the combined BS and AI management areas to that in the EBS survey area is about 1.17.

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 (EBS portion only) is shown in Table 2.25, together with estimates provided in last year's final SAFE report (Thompson and Dorn 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, except that the model tended to undershoot the survey substantially (by 24-44%) during the period 1994-1996. The model's estimates of survey biomass for 1997-2000 are within 3-4% of the values observed by the actual survey. The model's estimated age 3+ biomass and spawning biomass levels show continual declines since 1995 and 1987, respectively. The model's estimate of 2000 age 3+ biomass is the lowest in the time series since 1980, and the model's estimate of 2000 spawning biomass is the lowest in the time series since 1981.

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 and Dorn 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 242 million fish. When assessed at age 1, the recruitment time series has an estimated coefficient of variation (assuming an inverse Gaussian distribution) of 62%, and an autocorrelation coefficient of -0.06.

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 1978 1979 1982 1984 1989 1992

Average: 1980 1985 1990 1996

Below average: 1975 1976 1981 1983 1986 1987 1988 1991 1993 1994 1995 1997

Except for changing the 1989 year class from the "average" to "above average" category and the addition of the 1997 year class to the "below average" category, these results are identical to those presented in last year's SAFE report (Thompson and Dorn 1999). Because all year classes since the 1992 have been "below average" except for the "average" 1996 cohort, the stock is likely to continue its downward trend for the near future. Furthermore, the model's present estimates of the age 1 recruitments from the 1998 and 1999 year classes (which are based almost entirely on the size compositions from the 1999 and 2000 trawl surveys) are well below the average for that time series.

Exploitation

Model 1's estimated time series of the ratio between EBS catch and age 3+ biomass is shown in Table 2.27, together with the estimates provided in last year's final SAFE report (Thompson and Dorn 1999). The average value of this ratio over the entire time series is about 0.08. The estimated values exceed the average for every year after 1990 except 1993 and 2000 (it should also be remembered that the estimate of 2000 catch is only partial), whereas none of the estimated values exceed the average in any year prior to 1990 except 1978.

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

Reference point:	$B_{35\%}$	$B_{40\%}$	$B_{100\%}$
EBS:	291,000 t	332,000 t	831,000 t
BSAI:	340,000 t	389,000 t	972,000 t

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

$F_{35\%}$	$F_{40\%}$
0.35	0.29

Specification of OFL and Maximum Permissible ABC

Under Model 1, the EBS spawning biomass for 2001 is estimated at a value of 315,000 t (369,000 t for the BSAI). This is about 5% below the EBS $B_{40\%}$ value of 332,000 t (389,000 t for the BSAI), thereby placing Pacific cod in sub-tier “b” of Tier 3. Given this, Model 1 estimates OFL, maximum permissible ABC, and the associated fishing mortality rates for 2001 as follows:

	Overfishing Level	Maximum Permissible ABC
EBS catch:	212,000 t	183,000 t
BSAI catch:	248,000 t	214,000 t
Fishing mortality rate:	0.32	0.28

For comparison, the age 3+ biomass estimates for 2001 are 1,130,000 t and 1,320,000 t for the EBS and BSAI, respectively.

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. Two circumstances have combined to result in a slightly different approach being recommended for the 2001 ABC: First, insufficient time was available to run the large number of Synthesis models needed to perform the Bayesian meta-analysis for the present assessment. Second, projected 2001 spawning biomass is below $B_{40\%}$, raising the issue of whether a biomass-based adjustment factor should be applied on top of any uncertainty-based adjustment factor that might be applied. These two circumstances are addressed in the present assessment by assuming that the ratio between last year’s recommended F_{ABC} and $F_{40\%}$ (0.87, Thompson and Dorn 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 0.24, a 2001 EBS ABC of 161,000 t, and a 2001 BSAI ABC of 188,000 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 $\frac{1}{2}$ 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 3b: 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 0.20. 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 BSAI 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 $\frac{1}{2} B_{35\%}$, 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 $\frac{1}{2} B_{35\%}$ 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 $\frac{1}{2} B_{35\%}$, 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 $\frac{1}{2} B_{35\%}$ 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 BSAI 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 BSAI Pacific cod stock assessment are summarized in Table 2.43.

REFERENCES

- Thompson, G. G., and M. W. Dorn. 1999. Pacific cod. *In* Plan Team for Groundfish Fisheries of the Bering Sea/Aleutian Islands (editor), Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands regions, p. 151-230. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.

Table 2.2--History of Pacific cod ABC, TAC, total BSAI catch, and type of stock assessment model used to recommend ABC. Catch for 2000 is current through October 28.

Year	ABC	TAC	Catch	Stock Assessment Model
1980	148,000	70,700	45,947	projection of 1979 survey numbers at age
1981	160,000	78,700	63,941	projection of 1979 survey numbers at age
1982	168,000	78,700	69,501	projection of 1979 survey numbers at age
1983	298,200	120,000	103,231	projection of 1979 survey numbers at age
1984	291,300	210,000	133,084	projection of 1979 survey numbers at age
1985	347,400	220,000	150,384	projection of 1979-1985 survey numbers at age
1986	249,300	229,000	142,511	separable age-structured model
1987	400,000	280,000	163,110	separable age-structured model
1988	385,300	200,000	208,236	separable age-structured model
1989	370,600	230,681	182,865	separable age-structured model
1990	417,000	227,000	179,608	separable age-structured model
1991	229,000	229,000	218,053	separable age-structured model
1992	182,000	182,000	205,311	age-structured Synthesis model
1993	164,500	164,500	167,360	length-structured Synthesis model
1994	191,000	191,000	196,664	length-structured Synthesis model
1995	328,000	250,000	245,135	length-structured Synthesis model
1996	305,000	270,000	240,673	length-structured Synthesis model
1997	306,000	270,000	257,762	length-structured Synthesis model
1998	210,000	210,000	195,648	length-structured Synthesis model
1999	177,000	177,000	173,995	length-structured Synthesis model
2000	193,000	193,000	158,607	length-structured Synthesis model

Table 2.13--Biomass, standard error, 95% confidence interval (CI), and population numbers of Pacific cod estimated by NMFS' annual bottom trawl survey of the EBS shelf. All figures except population numbers are expressed in metric tons. Population numbers are expressed in terms of individual fish.

Year	Biomass	Standard Error	Lower 95% CI	Upper 95% CI	Numbers
1979	754,314	97,844	562,539	946,089	1,530,429,650
1980	905,344	87,898	733,063	1,077,624	1,084,147,540
1981	1,034,629	123,849	791,885	1,277,373	794,619,624
1982	1,020,550	73,392	876,701	1,164,399	583,715,089
1983	1,176,305	121,606	937,958	1,414,651	725,351,369
1984	1,001,940	64,127	876,251	1,127,629	636,948,300
1985	961,050	51,453	860,203	1,061,896	800,070,473
1986	1,134,106	71,813	993,353	1,274,858	843,460,794
1987	1,142,450	71,439	1,002,430	1,282,468	754,269,021
1988	959,544	76,284	810,028	1,109,060	509,336,483
1989	960,436	69,157	824,888	1,095,984	339,719,445
1990	708,551	53,728	603,245	813,857	435,856,535
1991	532,590	41,678	450,902	614,279	496,841,261
1992*	546,707	45,754	457,030	636,383	577,416,832
1993	690,524	54,934	582,853	798,196	851,866,426
1994	1,368,109	254,435	869,416	1,866,802	1,237,760,162
1995	1,003,046	92,677	821,400	1,184,692	757,576,445
1996	890,793	120,522	652,160	1,129,426	609,304,214
1997	604,881	69,250	466,382	743,380	487,429,700
1998	534,141	42,942	449,116	619,166	514,321,475
1999	583,259	50,622	483,028	683,490	500,692,872
2000	528,466	43,037	443,253	613,679	481,358,109

*During the 1992 field season, 18 stations were omitted from the standard survey grid due to severe weather and vessel problems. In 1989, 1990, and 1991, these 18 stations represented, on average, 2.2% and 2.8% of the total Pacific cod biomass and numbers, respectively. The 1992 point estimates and confidence interval shown above have been adjusted upward proportionately.

Table 2.25–Time series of EBS 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	
	<u>Last Year</u>	<u>This Year</u>	<u>Last Year</u>	<u>This Year</u>	<u>Last Year</u>	<u>This Year</u>
1978	328	331	48	49	n/a	n/a
1979	474	486	78	80	580	572
1980	1041	1072	133	138	916	923
1981	1524	1584	242	253	1049	1056
1982	1949	2041	406	428	1202	1194
1983	2241	2357	566	600	1134	1118
1984	2252	2381	670	714	1098	1081
1985	2393	2534	704	753	1119	1110
1986	2341	2491	703	754	1105	1099
1987	2403	2566	702	756	1116	1120
1988	2383	2560	694	752	1018	1027
1989	2223	2407	676	738	855	863
1990	1976	2155	645	709	708	712
1991	1714	1882	578	642	650	658
1992	1549	1708	485	544	694	712
1993	1518	1678	420	474	726	750
1994	1501	1666	407	461	750	773
1995	1571	1704	405	450	749	762
1996	1483	1620	389	436	668	679
1997	1358	1494	374	422	572	580
1998	1179	1304	344	392	556	552
1999	1171	1272	333	359	562	560
2000	n/a	1225	n/a	338	n/a	515

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 EBS Pacific cod age 3 recruitment as estimated in last year’s and this year’s assessments.

Year	Recruitment (millions of age 3 fish)	
	<u>Last Year</u>	<u>This Year</u>
1978	91	92
1979	166	177
1980	676	704
1981	300	312
1982	332	354
1983	270	281
1984	85	91
1985	490	517
1986	142	152
1987	392	420
1988	235	255
1989	148	159
1990	85	91
1991	112	122
1992	271	291
1993	259	284
1994	153	165
1995	303	322
1996	147	155
1997	120	129
1998	118	117
1999	256	250
2000	n/a	130

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

Year	EBS Catch Divided by Age 3+ Biomass	
	<u>Last Year</u>	<u>This Year</u>
1978	0.13	0.13
1979	0.07	0.07
1980	0.04	0.04
1981	0.04	0.04
1982	0.03	0.03
1983	0.04	0.04
1984	0.06	0.05
1985	0.06	0.06
1986	0.06	0.05
1987	0.06	0.06
1988	0.09	0.08
1989	0.08	0.07
1990	0.09	0.08
1991	0.12	0.11
1992	0.10	0.10
1993	0.09	0.08
1994	0.12	0.10
1995	0.15	0.13
1996	0.14	0.13
1997	0.17	0.16
1998	0.14	0.12
1999	0.09	0.11
2000	n/a	0.08

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 BSAI 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 1977-1999. See Table 2.28 for symbol definitions.

Equilibrium Reference Points			
SPR	Spawning Biomass	Fishing Mortality	Catch
100%	972	0	0
40%	389	0.29	265
35%	340	0.35	283

Spawning Biomass Projections					
Year	L90%CI	Median	Mean	U90%CI	St. Dev.
2001	369	369	369	369	0.0
2002	330	330	330	330	0.2
2003	297	299	300	307	3.3
2004	278	295	299	333	18.2
2005	271	313	321	399	41.7
2006	274	341	350	456	59.1
2007	282	361	372	494	69.2
2008	291	374	386	511	74.3
2009	296	381	394	530	76.2
2010	300	383	398	545	77.0
2011	303	384	400	543	77.6
2012	303	386	401	541	78.0
2013	304	387	402	556	78.0

Fishing Mortality Projections					
Year	L90%CI	Median	Mean	U90%CI	St. Dev.
2001	0.28	0.28	0.28	0.28	0.000
2002	0.24	0.24	0.24	0.24	0.000
2003	0.22	0.22	0.22	0.23	0.003
2004	0.20	0.22	0.22	0.25	0.014
2005	0.20	0.23	0.24	0.29	0.028
2006	0.20	0.25	0.25	0.29	0.031
2007	0.21	0.27	0.26	0.29	0.029
2008	0.21	0.28	0.27	0.29	0.027
2009	0.22	0.28	0.27	0.29	0.026
2010	0.22	0.29	0.27	0.29	0.025
2011	0.22	0.29	0.27	0.29	0.024
2012	0.22	0.29	0.27	0.29	0.024
2013	0.22	0.29	0.27	0.29	0.024

Catch Projections					
Year	L90%CI	Median	Mean	U90%CI	St. Dev.
2001	214	214	214	214	0.0
2002	166	166	166	167	0.4
2003	135	141	142	155	6.6
2004	121	147	156	217	32.4
2005	118	178	191	308	60.7
2006	125	211	222	349	71.7
2007	134	235	240	362	74.5
2008	143	247	250	371	74.0
2009	144	253	254	381	73.2
2010	148	253	256	384	72.8
2011	150	257	258	377	72.5
2012	150	256	259	381	72.3
2013	150	256	260	386	72.5

Table 2.30—Equilibrium reference points and projections for BSAI 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 1977-1999. See Table 2.28 for symbol definitions.

Equilibrium Reference Points

SPR	Spawning Biomass	Fishing Mortality	Catch
100%	972	0	0
40%	389	0.29	265
35%	340	0.35	283

Spawning Biomass Projections

Year	L90%CI	Median	Mean	U90%CI	St. Dev.
2001	371	371	371	371	0.0
2002	340	340	340	340	0.2
2003	310	313	314	320	3.3
2004	293	310	314	349	18.4
2005	285	328	337	417	42.9
2006	288	357	368	480	62.5
2007	298	381	393	528	74.9
2008	306	396	411	550	81.8
2009	312	406	421	573	84.7
2010	317	411	427	589	86.2
2011	321	415	431	588	87.1
2012	320	419	434	589	87.6
2013	321	422	435	602	87.6

Fishing Mortality Projections

Year	L90%CI	Median	Mean	U90%CI	St. Dev.
2001	0.24	0.24	0.24	0.24	0.000
2002	0.22	0.22	0.22	0.22	0.000
2003	0.20	0.20	0.20	0.21	0.002
2004	0.19	0.20	0.20	0.22	0.012
2005	0.18	0.21	0.21	0.25	0.023
2006	0.18	0.23	0.23	0.25	0.024
2007	0.19	0.25	0.23	0.25	0.022
2008	0.20	0.25	0.24	0.25	0.020
2009	0.20	0.25	0.24	0.25	0.019
2010	0.20	0.25	0.24	0.25	0.018
2011	0.21	0.25	0.24	0.25	0.017
2012	0.21	0.25	0.24	0.25	0.016
2013	0.21	0.25	0.24	0.25	0.016

Catch Projections

Year	L90%CI	Median	Mean	U90%CI	St. Dev.
2001	188	188	188	188	0.0
2002	153	154	154	155	0.4
2003	128	133	135	146	6.0
2004	116	140	148	204	29.6
2005	114	169	180	281	54.1
2006	119	200	207	320	63.5
2007	127	223	225	332	66.1
2008	137	232	235	342	65.8
2009	138	238	239	353	65.1
2010	143	239	242	354	64.8
2011	147	241	244	348	64.5
2012	146	242	245	354	64.1
2013	146	242	246	359	64.2

Table 2.31–Equilibrium reference points and projections for BSAI Pacific cod spawning biomass (1000s of t), fishing mortality, and catch (1000s of t) under the assumption that $F = \frac{1}{2} \max F_{ABC}$ in each year 2001-2013, where future recruitment is drawn from a distribution based on estimated recruitments spawned during the period 1977-1999. See Table 2.28 for symbol definitions.

Equilibrium Reference Points

SPR	Spawning Biomass	Fishing Mortality	Catch
100%	972	0	0
40%	389	0.29	265
35%	340	0.35	283

Spawning Biomass Projections

Year	L90%CI	Median	Mean	U90%CI	St. Dev.
2001	376	376	376	376	0.0
2002	371	371	371	372	0.2
2003	357	360	361	367	3.4
2004	346	363	368	404	19.2
2005	340	386	397	486	47.6
2006	344	423	437	575	75.2
2007	356	459	476	651	95.4
2008	367	493	509	691	107.9
2009	379	517	532	732	114.2
2010	387	531	548	763	117.3
2011	398	546	560	779	118.9
2012	407	554	569	783	119.5
2013	410	559	575	787	119.4

Fishing Mortality Projections

Year	L90%CI	Median	Mean	U90%CI	St. Dev.
2001	0.14	0.14	0.14	0.14	0.000
2002	0.14	0.14	0.14	0.14	0.000
2003	0.13	0.13	0.13	0.13	0.001
2004	0.13	0.13	0.13	0.15	0.006
2005	0.12	0.14	0.14	0.15	0.008
2006	0.13	0.15	0.14	0.15	0.007
2007	0.13	0.15	0.14	0.15	0.006
2008	0.13	0.15	0.14	0.15	0.004
2009	0.14	0.15	0.14	0.15	0.004
2010	0.14	0.15	0.14	0.15	0.003
2011	0.15	0.15	0.14	0.15	0.003
2012	0.15	0.15	0.14	0.15	0.003
2013	0.15	0.15	0.15	0.15	0.002

Catch Projections

Year	L90%CI	Median	Mean	U90%CI	St. Dev.
2001	112	112	112	112	0.0
2002	105	106	106	106	0.2
2003	96	100	101	108	4.0
2004	91	108	112	148	18.4
2005	90	130	132	184	30.5
2006	94	146	148	213	36.8
2007	101	156	160	227	39.8
2008	110	164	168	235	40.8
2009	115	169	173	249	41.0
2010	120	171	177	254	41.1
2011	126	174	179	252	41.0
2012	125	176	181	252	40.9
2013	126	178	183	259	40.9

Table 2.32—Equilibrium reference points and projections for BSAI 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 1977-1999. See Table 2.28 for symbol definitions.

Equilibrium Reference Points

SPR	Spawning Biomass	Fishing Mortality	Catch
100%	972	0	0
40%	389	0.29	265
35%	340	0.35	283

Spawning Biomass Projections

Year	L90%CI	Median	Mean	U90%CI	St. Dev.
2001	373	373	373	373	0.0
2002	351	351	351	352	0.2
2003	323	326	327	333	3.4
2004	302	319	324	361	19.5
2005	288	335	345	434	47.5
2006	286	367	379	512	72.8
2007	294	397	411	573	89.9
2008	303	424	438	601	99.3
2009	316	442	457	634	103.3
2010	322	456	469	659	104.9
2011	333	466	478	669	105.6
2012	342	471	485	668	105.6
2013	345	476	489	677	105.3

Fishing Mortality Projections

Year	L90%CI	Median	Mean	U90%CI	St. Dev.
2001	0.20	0.20	0.20	0.20	0.000
2002	0.20	0.20	0.20	0.20	0.000
2003	0.20	0.20	0.20	0.20	0.000
2004	0.20	0.20	0.20	0.20	0.000
2005	0.20	0.20	0.20	0.20	0.000
2006	0.20	0.20	0.20	0.20	0.000
2007	0.20	0.20	0.20	0.20	0.000
2008	0.20	0.20	0.20	0.20	0.000
2009	0.20	0.20	0.20	0.20	0.000
2010	0.20	0.20	0.20	0.20	0.000
2011	0.20	0.20	0.20	0.20	0.000
2012	0.20	0.20	0.20	0.20	0.000
2013	0.20	0.20	0.20	0.20	0.000

Catch Projections

Year	L90%CI	Median	Mean	U90%CI	St. Dev.
2001	160	160	160	160	0.0
2002	145	146	146	146	0.3
2003	134	137	138	147	4.5
2004	127	145	149	187	19.7
2005	125	162	168	231	34.7
2006	128	178	185	267	43.9
2007	132	191	197	280	48.5
2008	139	199	206	292	50.1
2009	141	205	211	305	50.4
2010	146	207	214	309	50.7
2011	150	210	217	306	50.7
2012	150	213	219	310	50.6
2013	151	213	221	317	50.5

Table 2.33—Equilibrium reference points and projections for BSAI 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 1977-1999. See Table 2.28 for symbol definitions.

Equilibrium Reference Points

SPR	Spawning Biomass	Fishing Mortality	Catch
100%	972	0	0
40%	389	0.29	265
35%	340	0.35	283

Spawning Biomass Projections

Year	L90%CI	Median	Mean	U90%CI	St. Dev.
2001	383	383	383	383	0.0
2002	419	420	420	420	0.2
2003	443	446	446	453	3.5
2004	460	478	483	522	20.5
2005	474	528	540	641	54.9
2006	493	595	611	782	93.8
2007	520	665	685	913	126.8
2008	551	729	753	1011	150.4
2009	578	784	807	1086	165.0
2010	605	828	848	1152	173.5
2011	631	861	882	1200	178.4
2012	661	887	909	1220	180.9
2013	679	906	927	1246	181.5

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 BSAI 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 1977-1999. See Table 2.28 for symbol definitions.

Equilibrium Reference Points

SPR	Spawning Biomass	Fishing Mortality	Catch
100%	972	0	0
40%	389	0.29	265
35%	340	0.35	283

Spawning Biomass Projections

Year	L90%CI	Median	Mean	U90%CI	St. Dev.
2001	367	367	367	367	0.0
2002	316	316	316	317	0.2
2003	279	282	283	289	3.3
2004	260	276	281	315	18.0
2005	253	295	302	377	40.2
2006	256	321	328	428	55.0
2007	264	339	347	456	62.3
2008	274	348	358	465	65.3
2009	277	354	363	482	65.8
2010	280	353	364	491	65.9
2011	283	354	365	488	66.1
2012	280	354	366	482	66.4
2013	282	354	366	499	66.2

Fishing Mortality Projections

Year	L90%CI	Median	Mean	U90%CI	St. Dev.
2001	0.32	0.32	0.32	0.32	0.000
2002	0.28	0.28	0.28	0.28	0.000
2003	0.24	0.25	0.25	0.25	0.003
2004	0.23	0.24	0.24	0.28	0.017
2005	0.22	0.26	0.26	0.33	0.034
2006	0.22	0.28	0.28	0.35	0.040
2007	0.23	0.30	0.30	0.35	0.039
2008	0.24	0.31	0.30	0.35	0.037
2009	0.24	0.31	0.31	0.35	0.037
2010	0.24	0.31	0.31	0.35	0.036
2011	0.25	0.31	0.31	0.35	0.035
2012	0.24	0.31	0.31	0.35	0.035
2013	0.25	0.31	0.31	0.35	0.035

Catch Projections

Year	L90%CI	Median	Mean	U90%CI	St. Dev.
2001	248	248	248	248	0.0
2002	180	180	181	182	0.5
2003	142	148	150	164	7.3
2004	127	155	164	232	35.8
2005	124	189	204	340	68.7
2006	132	223	238	390	81.9
2007	141	245	258	400	85.2
2008	148	255	267	412	84.7
2009	150	261	271	416	83.7
2010	154	260	271	417	83.3
2011	156	264	272	413	83.0
2012	154	261	273	417	83.0
2013	156	261	274	420	83.4

Table 2.35—Equilibrium reference points and projections for BSAI 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 1977-1999. See Table 2.28 for symbol definitions.

Equilibrium Reference Points

SPR	Spawning Biomass	Fishing Mortality	Catch
100%	972	0	0
40%	389	0.29	265
35%	340	0.35	283

Spawning Biomass Projections

Year	L90%CI	Median	Mean	U90%CI	St. Dev.
2001	369	369	369	369	0.0
2002	330	330	330	330	0.2
2003	295	298	299	305	3.3
2004	269	285	289	323	17.9
2005	258	299	307	380	39.9
2006	258	322	330	429	54.8
2007	265	339	347	456	62.2
2008	274	348	358	465	65.2
2009	276	354	363	482	65.8
2010	280	353	364	491	65.9
2011	283	354	365	488	66.1
2012	280	354	366	482	66.4
2013	282	354	366	499	66.2

Fishing Mortality Projections

Year	L90%CI	Median	Mean	U90%CI	St. Dev.
2001	0.28	0.28	0.28	0.28	0.000
2002	0.24	0.24	0.24	0.24	0.000
2003	0.26	0.26	0.26	0.27	0.003
2004	0.23	0.25	0.25	0.28	0.017
2005	0.22	0.26	0.27	0.34	0.034
2006	0.22	0.28	0.29	0.35	0.039
2007	0.23	0.30	0.30	0.35	0.039
2008	0.24	0.31	0.30	0.35	0.037
2009	0.24	0.31	0.31	0.35	0.037
2010	0.24	0.31	0.31	0.35	0.036
2011	0.25	0.31	0.31	0.35	0.035
2012	0.24	0.31	0.31	0.35	0.035
2013	0.25	0.31	0.31	0.35	0.035

Catch Projections

Year	L90%CI	Median	Mean	U90%CI	St. Dev.
2001	214	214	214	214	0.0
2002	166	166	166	167	0.4
2003	157	164	166	181	7.7
2004	134	163	173	242	36.5
2005	127	193	208	343	68.5
2006	133	224	239	389	81.6
2007	141	245	258	400	85.1
2008	148	255	267	412	84.7
2009	150	261	270	415	83.7
2010	154	259	271	417	83.3
2011	156	264	272	413	83.0
2012	154	261	273	417	83.1
2013	156	261	274	420	83.4

Table 2.43--Summary of major results for the stock assessment of Pacific cod in the BSAI region.

Natural mortality rate:		0.37
Reference fishing mortalities:	<u>Rate</u>	<u>Value</u>
	$F_{35\%}$	0.35
	$F_{40\%}$	0.29
	$max F_{ABC}$	0.28
Equilibrium spawning biomass:	<u>Region and type</u>	<u>Value</u>
	EBS $B_{35\%}$	291,000 t
	EBS $B_{40\%}$	332,000 t
	BSAI $B_{35\%}$	340,000 t
	BSAI $B_{40\%}$	389,000 t
Projected biomass for 2001:	<u>Region and type</u>	<u>Value</u>
	EBS Age 3+	1,130,000 t
	EBS Spawning (at $max F_{ABC}$)	315,000 t
	BSAI Age 3+	1,320,000 t
	BSAI Spawning (at $max F_{ABC}$)	369,000 t
Recommended ABC for 2001:	<u>Units</u>	<u>Value</u>
	Fishing Mortality	0.24
	EBS Catch	161,000 t
	BSAI Catch	188,000 t
Overfishing level for 2001:	<u>Units</u>	<u>Value</u>
	Fishing Mortality	0.32
	EBS Catch	212,000 t
	BSAI Catch	248,000 t

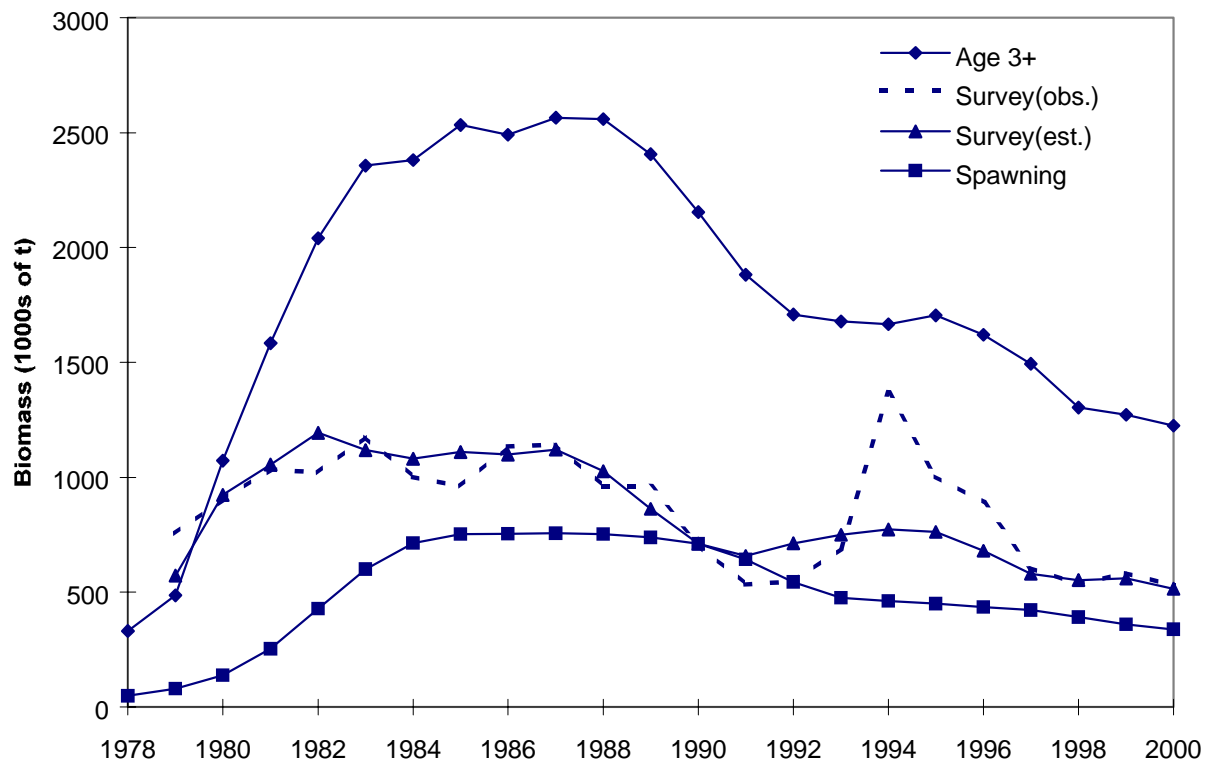


Figure 2.6—Three Pacific cod biomass time series estimated by Model 1, together with the time series of biomass levels observed by the survey.

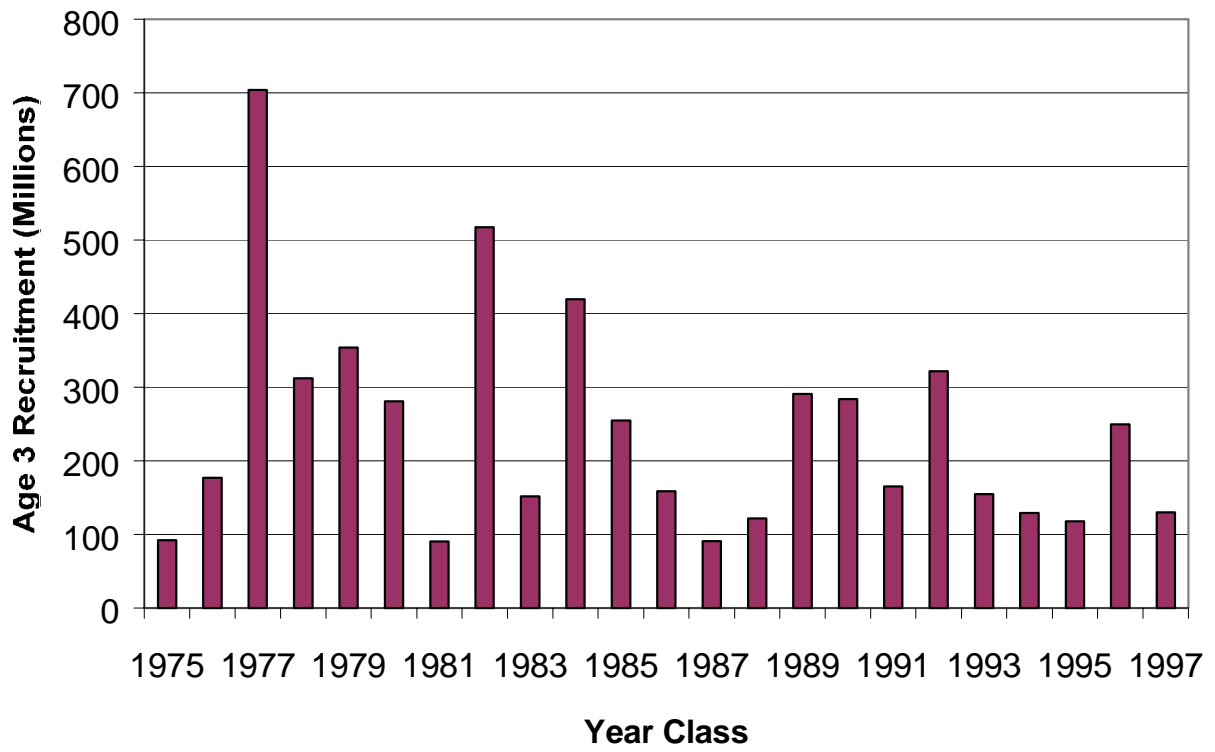


Figure 2.7—Pacific cod recruitment at age 3 as estimated by Model 1.