Assessment of the Pacific halibut stock at the end of 2001

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Abstract

This paper reports estimates of halibut abundance and available setline yield in 2002 at a harvest rate of 20%—about 105 million pounds coastwide, up from 95 million pounds last year. In the past, Areas 2A and 2B were combined for assessment purposes; this year they are treated separately. The analytical assessment in Areas 2C and 3A this year uses all setline survey stations rather than just a standard subarea, resulting in a small decrease in estimated abundance in 2C and a small increase in 3A. An update of survey-based estimates of relative abundance in Area 4 has resulted in a reduction of estimated abundance in Area 4B and an increase in 4CDE.

Introduction

Each year the IPHC staff assesses the abundance and potential yield of Pacific halibut using all available data from the commercial fishery and scientific surveys (Appendix A). Exploitable biomass in each of IPHC regulatory areas 2B, 2C, and 3A is estimated by fitting a detailed population model to the data from that area.

A biological target level for total removals is then calculated by applying a fixed harvest rate—presently 20%—to the estimate of exploitable biomass. This target level is called the "constant exploitation yield" or CEY for that area in the coming year. The corresponding target level for directed setline catches, called the setline CEY, is calculated by subtracting from the total CEY an estimate of all other removals—sport catches, bycatch of legal-sized fish, wastage of legal-sized fish in the halibut fishery, and fish taken for personal use.

In Areas 3B and 4 exploitation rates were low until very recently and no surveys were done before 1996. For both reasons an analytical assessment is not feasible. Instead, exploitable biomass in those areas relative to that in Area 3A is estimated from recent surveys and the analytical estimate of abundance in Area 3A is scaled accordingly to estimate exploitable biomass in Areas 3B and 4. Total and setline CEY for those areas are then calculated as explained above. A similar procedure is used to estimate exploitable biomass in Area 2A on the basis of the 2B assessment and survey results.

Staff recommendations for catch limits in each area are based on the estimates of setline CEY but may be higher or lower depending on a number of statistical, biological, and policy considerations. Similarly, the Commission's final quota decisions are based on the staff's recommendations but may be higher or lower.

This paper reports the staff's estimates of total abundance, recruitment trends, exploitable biomass, and total and setline CEY by area, as calculated at the end of 2001 for the 2002 fishery.

Evolution of assessment methods

From 1982 through 1994, the halibut stock assessment relied on CAGEAN, a simple age-structured model fitted to commercial catch-at-age and catch-per-effort data. The constant age-specific commercial selectivities used in the model were fundamental model parameters, estimated directly.

Beginning in the late 1980s, halibut growth rates in Alaska declined dramatically. As a result, age-specific selectivity decreased, particularly for younger fish near the minimum size limit. CAGEAN did not allow for that, and by the mid-1990s was seriously underestimating the strength of incoming year-classes. In effect, it interpreted lower catches of young fish as an indication of lower abundance, whereas the real cause was lower selectivity.

The staff sought to remedy that problem by making selectivity a function of length in a successor model developed in 1995. It accounted not only for the age structure of the population, but also for the size distribution of each age group and the variations in growth schedule that had been observed. The fundamental selectivity parameters in this model were the two parameters of a function (the left limb of a normal density) by which the selectivity of an individual fish was determined from its length. The age-specific selectivity of an entire age group was calculated by integrating length-specific selectivity over the estimated length distribution of the age group, and that age-specific selectivity was used to calculate predicted catches. The new model was fitted to both commercial data and IPHC setline survey data, with separate length-specific selectivity functions. Commercial catchability and selectivity were allowed to drift slowly over time, while survey catchability and selectivity were held constant.

While appropriate in principle, this age-structured model with length-based selectivities resulted in some puzzling fits and poor estimates of historical abundance (Clark and Hare 2001). As a result the staff in the 2000 assessment reverted to a simpler model (the "2000 model") that really is quite similar to CAGEAN. No attempt is made to predict or fit the distribution of size at age, and age-specific selectivities are fundamental model parameters, estimated directly. Commercial catchability and selectivities are allowed to drift slowly. The model structure provides for the possibility of breaks and/or drift in the survey parameters as well, but the staff catch limit recommendations are based on the most parsimonious form of the model, in which survey catchability and selectivity are held constant (except for breaks at the time of conversion from J-hooks to C-hooks).

Changes in the analytical assessment between 2000 and 2001

The 2000 model was used unchanged in this year's assessment (except for the break in survey catchability in Area 3A, explained below). There were three changes in the input data that resulted in changes in the estimates, and for the first time Area 2B was assessed separately rather than being combined with Area 2A.

Correction of Area 2AB input data error

In the 2000 assessment the combined Area 2AB assessment model fit was inadvertently run with the Area 2B data file, meaning that the reported Area 2AB abundance estimates in fact reflected only the abundance in Area 2B. The reported (incorrect) estimates were:

Reported (incorrect) values	**Area 2A**	**Area 2B**	**2A+2B**
2001 exploitable biomass	7.34	59.36	66.71
2001 total CEY	1.47	11.87	13.34
2001 setline CEY	1.12	10.51	11.63

These are the estimates calculated with the lower of two alternative series of Canadian sport catch estimates, which were the ones that the Commission based its quota decision on. Slightly

different values (based on a higher series of sport catch estimates) were reported in last year's assessment tables. The corrected estimates (i.e., the values obtained when the 2000 model is fitted to last year's combined Area 2AB data file with the lower sport catch series) are:

Corrected values	**Area 2A**	**Area 2B**	**2A+2B**
2001 exploitable biomass	7.72	62.68	70.14
2001 total CEY	1.54	12.54	14.08
2001 setline CEY	1.19	11.18	12.37

As a result of the data error, the 2AB abundance estimate was low by about 5% last year. The setline CEY estimate was low by about 70,000 pounds in 2A and 700,00 pounds in 2B. Using the correct data file naturally results in an increase of about 5% in the 2A and 2B estimates.

Separate treatment of Areas 2A and 2B

Areas 2A and 2B have been combined for assessment purposes since the beginning of model-based analytical assessments in the early 1980s. There is some biological rationale for doing so: clearly there is a seasonal migration of 2A fish between 2B and 2A, and there is some indication from tagging of greater mixing between 2A and 2B than elsewhere. Equally important, though, were the obstacles to performing a standalone 2A assessment: no survey data before 1995, spotty age composition data, uncertainty about the level of bycatch, and sparse and highly variable commercial CPUE data. Combining 2A with 2B effectively swamped these defects in the 2A data.

There is no serious obstacle to doing a standalone 2B assessment. The data for 2B are the best on the coast: a long history of full commercial utilization, good commercial and survey data series, and less change in growth than in Alaska. While there may be some migration of older fish from 2A into 2B, the numbers cannot be large enough to have any practical effect on the analytical estimate of 2B abundance.

Recent surveys have provided a direct measure of the present distribution of biomass between 2A and 2B. The 2B biomass amounted to about 92% of the total in the 1995 and 1997 surveys, and 85% in the 1999 and 2001 surveys.

The analytical estimate of exploitable biomass in 2B is 95% of the analytical estimate for 2A and 2B combined. It is clear from the difference between the analytical estimates and the survey results that the analytical assessment is underestimating abundance in 2A. For management purposes, therefore, it makes most sense to do a standalone assessment of abundance in 2B, and to use that value along with the survey results to estimate present biomass in 2A.

The values that would have appeared in the 2000 assessment following this procedure (when 2A biomass was estimated to be 11% of the 2AB total, equivalent to 12% of the 2B value alone) are:

2A and 2B separated	**Area 2A**	**Area 2B**	**2A+2B**
2001 exploitable biomass	8.01	66.71	74.72
2001 total CEY	1.60	13.34	14.94
2001 setline CEY	1.25	11.98	13.23

Treating 2A and 2B separately increases the biomass estimates for the two areas by about 7%, this on top of the 5% resulting from correcting the data error.

Use of all survey stations in Area 2C and 3A

Before 1996, the setline survey in Area 3A only covered the shelf west of 148º W. The eastern part of the shelf was added in 1996, and stations in Shelikof Strait, Cook Inlet, and Prince William Sound in 1998. Until this year, only stations in the western part of 3A surveyed in all years were used in the assessment.

Similarly in Area 2C, only outside stations were used in the assessment even though inside stations were fished in all surveys, because before 1996 the inside stations were distributed purposively on known commercial grounds rather than being placed systematically.

In Area 2B only the northern part has been surveyed consistently. The Vancouver region was surveyed in 1997, 1999, and 2001, but there is no plan to survey it on a regular basis as it accounts for only about 10% of 2B biomass (Clark 2002a).

Using all the survey stations in 3A and 2C provides a more representative and less variable survey index of abundance in those areas. In Area 2C there is no difference between the survey CPUE series based on all stations and the one based on just the outside stations, but in 3A it appears that the stations added in the east generally have a lower CPUE than the stations in the west, so the survey CPUE series based on all stations shows a drop that does not appear in the series based on just the western stations. That feature of the 3A survey data can be accounted for in the assessment by allowing survey catchability to decrease in 1996. The size of the decrease in CPUE due to the survey expansion is estimated to be 22% when the model is fitted.

Using all survey stations in the assessment increases the 2001 biomass estimate by about 7% in 3A (where a catchability change is allowed) but decreases the estimate in 2C (where catchability does not change) by a surprising 15% (Table 1). The reason for this large effect is that in 2C the survey data (either series) while quite noisy show an increase in CPUE between the mid-1980s and the mid-1990s, while the commercial data show a decrease. The trends in the two 2C survey series are the same, but on average the series based on all stations shows only about a 25% increase in abundance between the mid-1980s and the mid-1990s, whereas the series based on just the outside stations shows a 50% increase. Using all stations therefore allows the model fit to agree better with the commercial data and therefore show a larger decrease since the mid-1980s.

In 2C there were fewer surveys than in 2B and 3A, and the survey data are quite variable whereas the commercial CPUE series is complete and very consistent from year to year. Model fits that essentially ignore the survey data produce estimates very close to the value obtained with the survey CPUE series based on all stations, so the lower estimate in 2C appears to be the right one.

Reweighting of fixed-hook and snap CPUE in Areas 2A and 2B

In Alaska a substantial part of the catch is still taken with fixed-hook gear, and only fixed-hook CPUE has ever been used in the assessment. In 2A and 2B only about 10% of the catch is taken with fixed-hook gear, and snap CPUE has been used in the assessment for several years. In those areas fixed-hook CPUE has consistently been about a third higher than snap

CPUE, and the practice in the assessment has been to compute an average fixed-hook CPUE and an average snap CPUE multiplied by 1.34, and then to use the simple average of those two as the overall commercial CPUE.

The weakness in this method is that it gives equal weight to the two gears even though fixed-hook effort is only a small part of the total. This year the gear-specific CPUE values were weighted in proportion to the gear-specific effort, which should provide a less variable estimate and a consistent CPUE series even if fixed-hook gear continues to fade (Clark 2002c). This change in the CPUE computation has very little effect on the CPUE series or the biomass estimates: the estimate of 2B biomass in 2001 is increased by 1.5% (Table 1).

Explanation of assessment terms and figures

Fits of the 2001 model in Areas 2B, 2C, and 3A are shown in Figure 1. Estimates of biomass and CEY are in Table 2. These figures are projected forward to the beginning of 2002. Abundance at age 8 in 2002 can be estimated (roughly) because that year-class has been observed in setline survey catches at ages 6 and 7.

The top panels in Figure 1 show historical landings and mean weight at age in the catch. The center left panel shows recruitment at age 8 by year. The center upper right panel shows four measures of biomass: legal-sized (LBio), spawning (SBio), exploitable biomass calculated with internally estimated commercial selectivities that drift over years (EBio or variable ebio), and exploitable biomass calculated with an externally fixed set of selectivities (EBioFX or fixed ebio) that are intermediate between the higher 2AB and lower 3A selectivities. Commercial CPUE should be proportional to EBio; allowable removals are calculated by applying the 20% harvest rate to EBioFX, because the fixed selectivities were the ones used in the simulations that led to the choice of the 20% harvest rate.

The bottom panels show the series of survey and commercial CPUE values, the general trend of the data (a data smoother), and the model predictions. The break in both graphs occurs at the time of conversion from J-hooks to C-hooks. In the standard model survey catchability and selectivity are held constant after 1984 (except for the 1996 break in 3A), but commercial catchability and selectivity are allowed to drift.

Assessment results for Area 2B

The 2B assessment is quite stable from year to year. As explained above, the estimated biomass in 2B has increased in this year's assessment not because the 2B assessment itself has changed but because a data error was corrected and 2B was assessed separately rather than in combination with 2A.

In last year's assessment the estimates of recent year-class strength in 2B were dismal. Those estimates have now increased; recent year-classes (at age 8) appear to be near average.

Extrapolation of the Area 2B estimate to Area 2A

Setline surveys were conducted in all of Area 2A and 2B in 1995, 1997, 1999 and 2001. Average CPUE values for all of 2A and all of 2B are shown below. The 2B values are different from those that appear in the assessment tables because they include the Vancouver Island shelf. The proportion of biomass in 2A was calculated from the relative areas: 28.1 thousand square nautical miles in 2B and 12.1 in 2A.

	CPUE in 2A	CPUE in 2B	Proportion of 2AB biomass in 2A
1995	29	144	0.08
1997	35	158	0.09
1999	37	88	0.15
2001	41	102	0.15

Using the average CPUE from the last three surveys in each area as an estimate of density gives a present estimate of relative abundance in 2A as 12% of the total or equivalently 14% of the 2B biomass.

Comparison of combined and separate estimates of 2A and 2B biomass

Under the procedure used before this year, abundance in 2A and 2B was estimated by fitting the assessment model to the pooled data and then dividing the estimated total between the two. If that procedure were applied this year, Area 2A would be estimated as 12% of the 2AB total estimate and the results would be as follows:

Old method: *2A = 12% of 2AB estimate*	Area 2A	Area 2B	Area 2AB
2002 ebio	8.62	63.24	71.86
Total CEY at 20%	1.72	12.65	14.37
Setline CEY	1.18	11.18	12.36

Under the procedure actually used, the assessment model was fitted to just the Area 2B data to obtain an estimate of 2B abundance, and that was extrapolated to 2A by calculating the 2A estimate as 14% of the 2B estimate. The results (from Table 2) are:

New method: *2A = 14% of 2B estimate*	Area2A	Area 2B	Area 2AB
2002 ebio	9.25	66.10	75.35
Total CEY at 20%	1.85	13.22	15.07
Setline CEY	1.31	11.75	13.06

Similar to the comparison reported above for the 2000 assessment, the new procedure results in about a 5% increase in the biomass estimate.

Assessment results for Area 2C

In 2C the survey and commercial CPUE series are still somewhat discordant, mostly because of the very high survey values in 1996 and 1997. As explained above, the fit agrees with the more consistent commercial series. While the addition of inside survey stations to the assessment this year reduced the biomass estimate, the addition of 2001 commercial and survey data increased the estimate, so that estimated CEY is only slightly lower than last year.

The 1994 year-class is estimated to be very strong in 2C but this is probably an overestimate. Eventually that year-class is likely to be above average but not greatly so, as in 2B and 3A.

Assessment results for Area 3A

Estimated abundance in 3A increased as a result of the change in survey data (and the associated change in survey catchability in 1996), and the addition of the 2001 data. This estimate has tended to be more variable from year to year than either the 2B or 2C estimate.

The stock in 3A is declining slowly as a series of weak year-classes replaces strong ones. At age 8 all of the year-classes spawned from 1977 through 1988 were above the 1974-1994 mean (by 50% on average), and all of the year-classes spawned between 1989 and 1993 were below the mean. The 1994 year-class, which last year appeared to be as strong as 1988, now appears to be above average but not by a great deal.

Extrapolation of the Area 3A estimate to Areas 3B and 4

In Areas 3B and 4, exploitation rates were very low until recently and there are no survey data before 1996. Exploitable biomass in those areas is estimated by extrapolating the analytical estimate of abundance in Area 3A to each area on the basis of total bottom area and the average of the last three survey catch rates. Specifically, an index of total biomass in each area (including 3A) is computed as the product of setline survey CPUE and total bottom area. Absolute biomass is then obtained by scaling the absolute 3A estimate by the ratio of the indices. For example, 4A biomass is estimated as the absolute 3A estimate multiplied by the ratio of the 4A to the 3A survey index.

In recent years "total bottom area" was defined as the area between 0 and 500 fm, but in fact the survey only goes down to 275 fm and halibut densities below 300 fm are probably very low in the summer when the surveys are conducted. This year the total bottom area used for calculating the survey-based index was redefined as the area between 0 and 300 fm. In most places the change is inconsequential because there is little bottom area between 300 and 500 fm, but 4B is reduced by about 30% (Table 3, reproduced from Clark 2002b).

Various methods of estimating present density from the time series of survey catch rates were examined, and the average of the last three was found to be best. This is a filtering problem, and the two principal candidate procedures are locally-weighted regression smoothers that attempt to follow the trend of the last few points, and moving averages. The former do not work well on short and noisy series like the setline survey data. The latter do not attempt to determine the local trend and are biased if a trend is present, but up to a certain sample size the reduction in variance outweighs the bias. That optimal sample size depends on the steepness of the trend in the series and the variance of the observations. With trends of 5-10% per year and a coefficient of variation of 10-20% in the survey results, the optimal sample size was about 5, but a sample of 3 performed nearly as well and would perform better in the event of a large real change in the survey index, so that was adopted.

A setline survey index cannot be computed directly for the eastern Bering Sea shelf (4CDE) because no setline survey is done there. NMFS conducts a trawl survey there every year, and a setline survey CPUE is predicted from the average trawl CPUE and the ratio of setline to trawl CPUE in areas of overlap in 4A and 4D. For the last few years the predicted value was 30 lb/skate (Clark 1998). An update this year (Clark 2002) produced a prediction of 40 lb/skate, which has the effect of increasing the 4CDE scaling factor.

The scaling factors (abundance relative to 3A) used last year and this year are:

	3B	4A	4B	4CDE
Factor used in 2000	94%	38%	37%	37%
Factor used in 2001	94%	41%	25%	47%

Recent trends in weight at age

Between the late 1970s and the late 1990s there was a dramatic decrease in the average weight of halibut in commercial landings. At the modal age of 12 years, average weight declined by about 50% in Area 3A and 40% in Area 2B. In recent years weight at age has leveled off in Area 2 and Area 3A, but is still declining farther west (Figure 2).

References

Clark, W.G. 1998. Coastwide distribution of exploitable biomass according to 1997 setline surveys. Int. Pac. Halibut Comm. Report of Assessment and Research Activities 1997:161-166.

Clark, W.G. 2002a. Comparison of setline survey CPUE in standard survey subareas and entire regulatory areas. Int. Pac. Halibut Comm. Report of Assessment and Research Activities 2001 (this volume).

Clark, W.G. 2002b. Density of legal-sized halibut in the eastern Bering Sea and coastwide distribution of exploitable biomass. Int. Pac. Halibut Comm. Report of Assessment and Research Activities 2001 (this volume).

Clark, W.G. 2002c. Comparison of fixed-hook and snap-hook CPUE. Int. Pac. Halibut Comm. Report of Assessment and Research Activities 2001 (this volume).

Clark, W.G., and S.R. Hare. 2001. Assessment of the Pacific halibut stock in 2000. Int. Pac. Halibut Comm. Report of Assessment and Research Activities 2000:85-118.

Table 1. Changes in analytical biomass estimates due to various changes in assessment data and methods between the 2000 and 2001 assessments. All of the 2000 assessment figures for Area 2AB and 2B are the ones calculated with the higher of two Canadian sport catch series as shown in last year's report. The value shown is exploitable biomass ("ebio") in millions of net pounds.

	Area 2AB	Area 2B	Area 2C	Area 3A
2000 assessment estimates of 2001 ebio with preliminary 2000 data: Estimates of ebio in 2001 as reported in late 2000. *Area 2B estimates were erroneously reported as estimates of abundance in Areas 2A and 2B combined.*	73.3	67.6	56.4	138.7
2000 assessment estimates of 2001 ebio with final 2000 data: The same values computed with final 2000 data.	72.2	66.7	56.7	140.3
2000 assessment estimates of 2001 ebio using all 2C and 3A survey stations rather than only standard subareas: Add 2C inside stations, available in all years, and eastern and northern 3A stations added in 1996. Allow a change in survey catchability in 3A in 1996 but not in 2C.	No effect	No effect	48.3	150.4
2000 assessment estimates of 2001 ebio with 2AB CPUE reweighted: Give equal weight to fixed-hook and scaled snap-hook effort. Continue to use only fixed-hook effort in Alaska.	73.5	67.7	No effect	No effect
2001 assessment estimates of 2001 ebio: Estimates of ebio in 2001 with 2001 commercial and survey data added to the fit.	74.3	69.0	52.3	166.3
2001 assessment estimates of 2002 ebio: Estimates of ebio in 2002 from the same fits, still using the higher (mail survey) estimates of B.C. sport catches.	72.4	67.9	53.3	154.8
2001 assessment estimates of 2002 ebio using the lower B.C. sport catch series: Estimates of ebio in 2002 using the lower estimates of B.C. sport catch.	70.5	66.1	No effect	No effect

Table 2. Removals in 2001 and estimates of CEY in 2002 (millions of net pounds).

	2A	2B	2C	3A	3B	4A	4B	4CDE	Total
2001 setline CEY at 20% [1]	1.14	10.51	8.78	21.89	25.46	9.82	10.06	7.63	95.29
2001 catch limit	1.14	10.51	8.78	21.89	16.53	4.97	4.91	4.45	73.18
2001 commercial landings [2]	1.15	10.10	8.40	21.94	16.55	4.98	4.48	4.07	71.67
Other removals									
Sport catch (except 2A) [3]	---	1.02	1.73	5.02	0.01	0.08	0.00	0.00	7.86
Legal-sized bycatch	0.54	0.11	0.22	1.70	0.48	0.54	0.20	2.64	6.43
Personal use	0.00	0.30	0.17	0.07	0.02	0.09	0.00	0.08	0.73
Legal-sized wastage	0.00	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.23
Total other removals	0.54	1.47	2.16	6.82	0.54	0.74	0.23	2.75	15.25
Total removals	1.69	11.57	10.56	28.76	17.09	5.72	4.71	6.82	86.92
2002 exploitable biomass [4]	9.25	66.10	53.30	154.80	145.50	63.50	38.70	72.80	603.95
2002 total CEY at 20%	1.85	13.22	10.66	30.96	29.10	12.70	7.74	14.56	120.79
2002 setline CEY at 20% [5]	1.31	11.75	8.50	24.14	28.56	11.96	7.51	11.81	105.54

Notes:

1. Estimates of 2001 setline CEY (first row) are the figures reported in the 2000 assessment. The value shown for Area 2B is the one calculated with the lower estimates of Canadian sport catch.

2. Figures for commercial landings in the second row include research catches, which are the reason for the small overages in some areas.

3. In Area 2A only, the 2001 catch limit, 2001 commercial landings, and 2002 setline CEY include sport catch and treaty subsistence catch. The figure for "total other removals" does not include sport catch. The breakdown of commercial and sport catches in 2A in 2001 was: treaty commercial 0.412 million pounds, non-treaty commercial 0.264, research 0.017, sport 0.441, treaty subsistence 0.02.

4. Area 2A ebio is calculated as 14% of the 2B ebio.

5. In Area 2B, the results are based on the lower of two alternative series of sport catch estimates. The higher sport catch estimates produce an estimate of exploitable biomass in 2B in 2002 of 67.9 M lb (vs 66.1). At a 20% harvest rate, setline CEY is 11.55 M lb in 2B (vs 11.75).

Table 3. Bottom areas (thousand square nautical miles), recent setline survey CPUE (pounds/skate), and relative exploitable biomass by regulatory area. Area 2A does not include California. The Closed Area is included in Area 4CDE.

.Area	Bottom area 0-500 fm	Bottom area 0-300 fm	Setline CPUE (average of last 3 survey years)	Exploitable biomass relative to Area 3A	Proportion of coastwide biomass
2A	14.1	12.1	38	0.04	0.01
2B	29.7	28.1	117	0.26	0.07
2C	16.1	15.0	225	0.27	0.07
3A	51.2	49.5	256	1.00	0.28
3B	31.8	30.2	395	0.94	0.26
4A	21.6	18.5	339	0.41	0.11
4B	23.2	16.2	197	0.25	0.07
4D edge	5.0	5.0	175	0.07	0.02
4CDE shelf	120.0	120.0	42	0.40	0.11

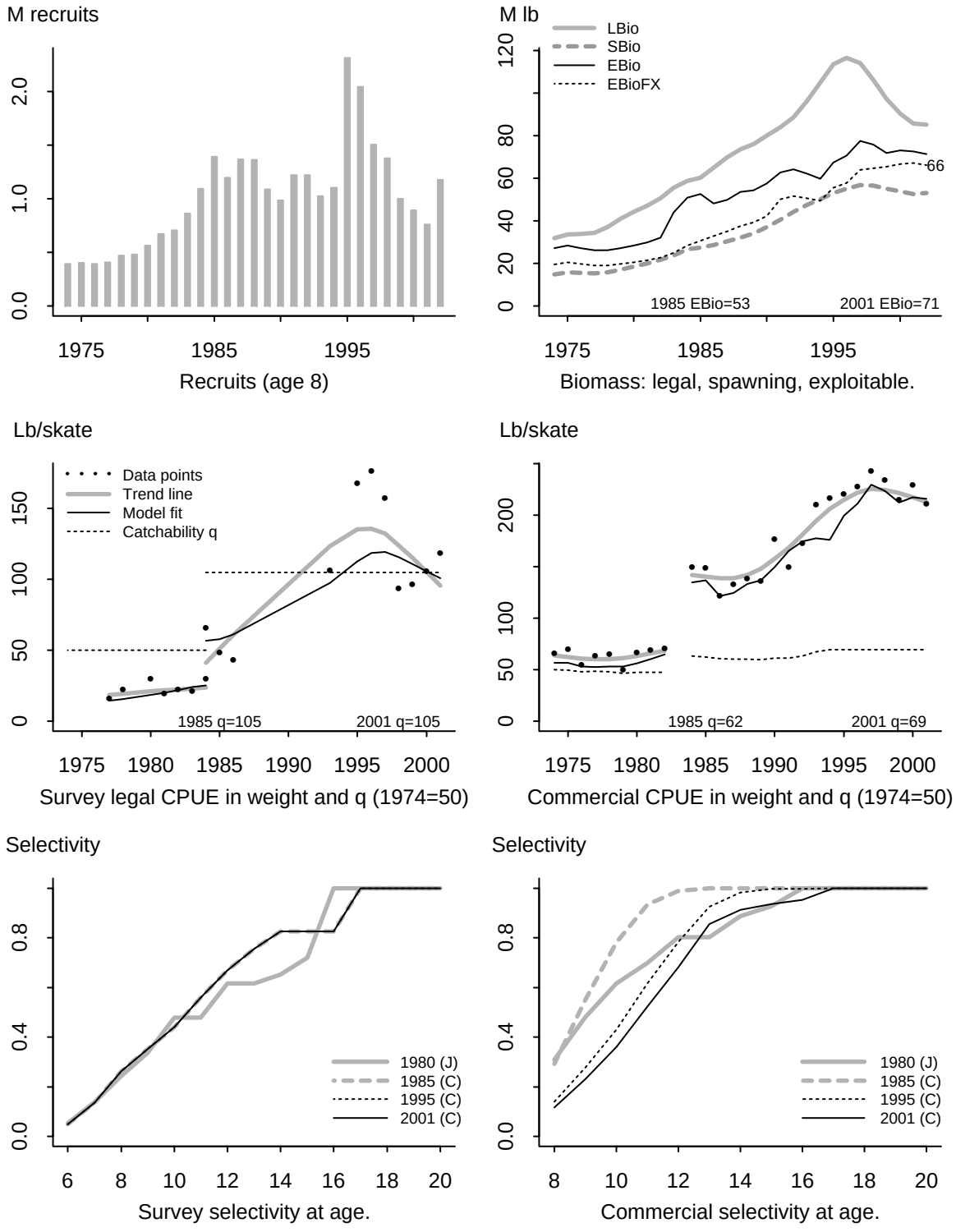

Figure 1a. Features of the assessment data and standard model fit in Area 2B.

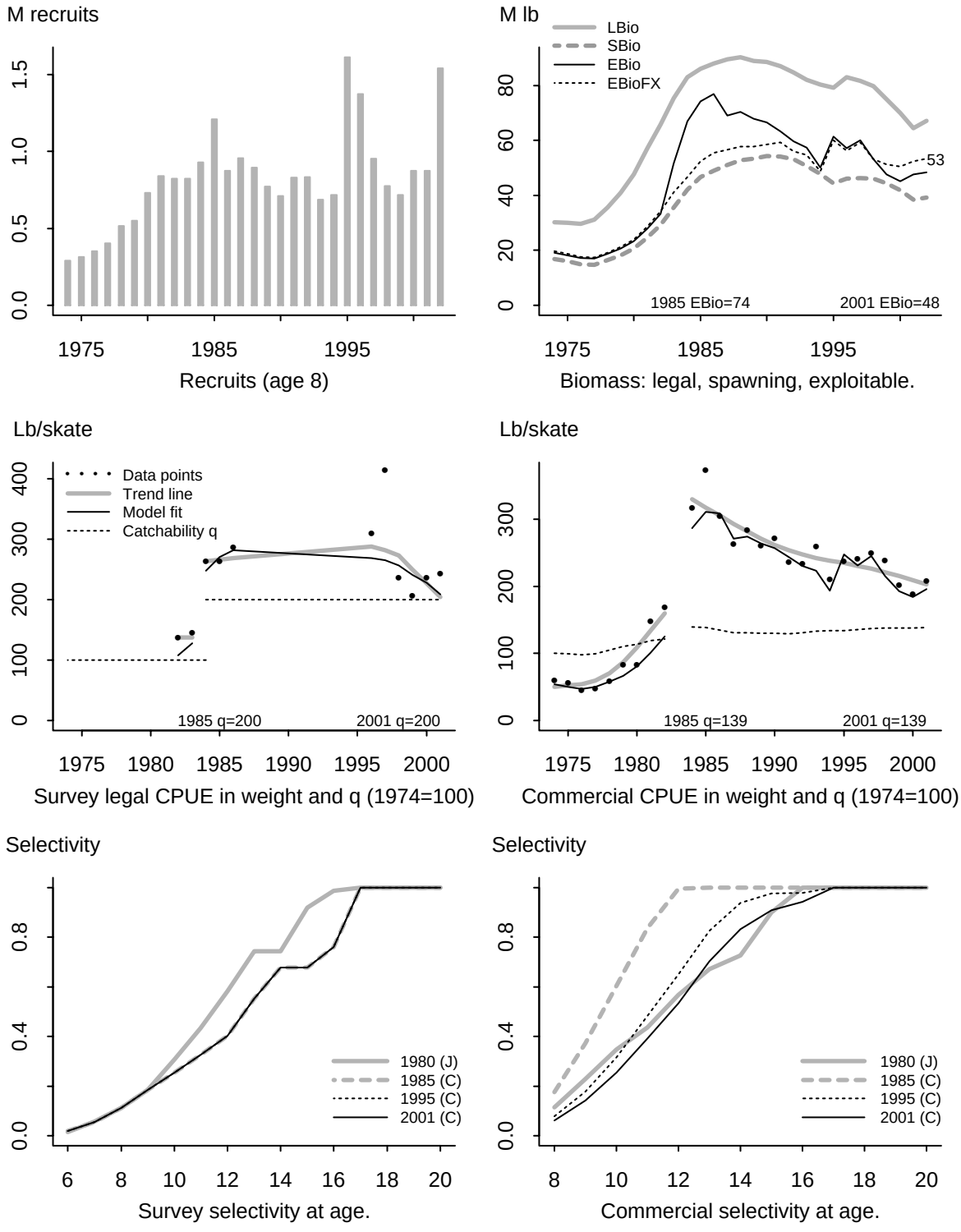

Figure 1b. Features of the assessment data and standard model fit in Area 2C.

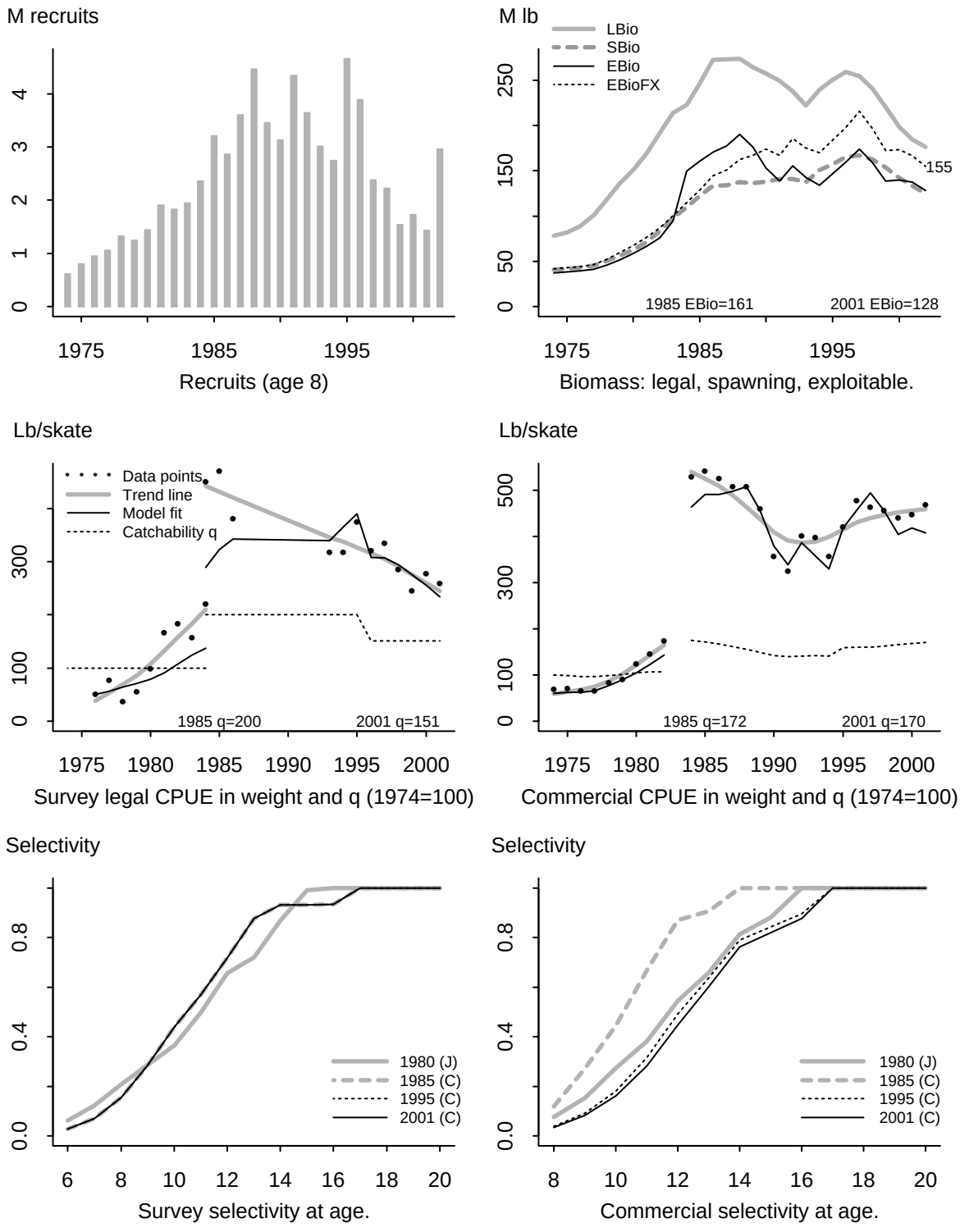

Figure 1c. Features of the assessment data and standard model fit in Area 3A.

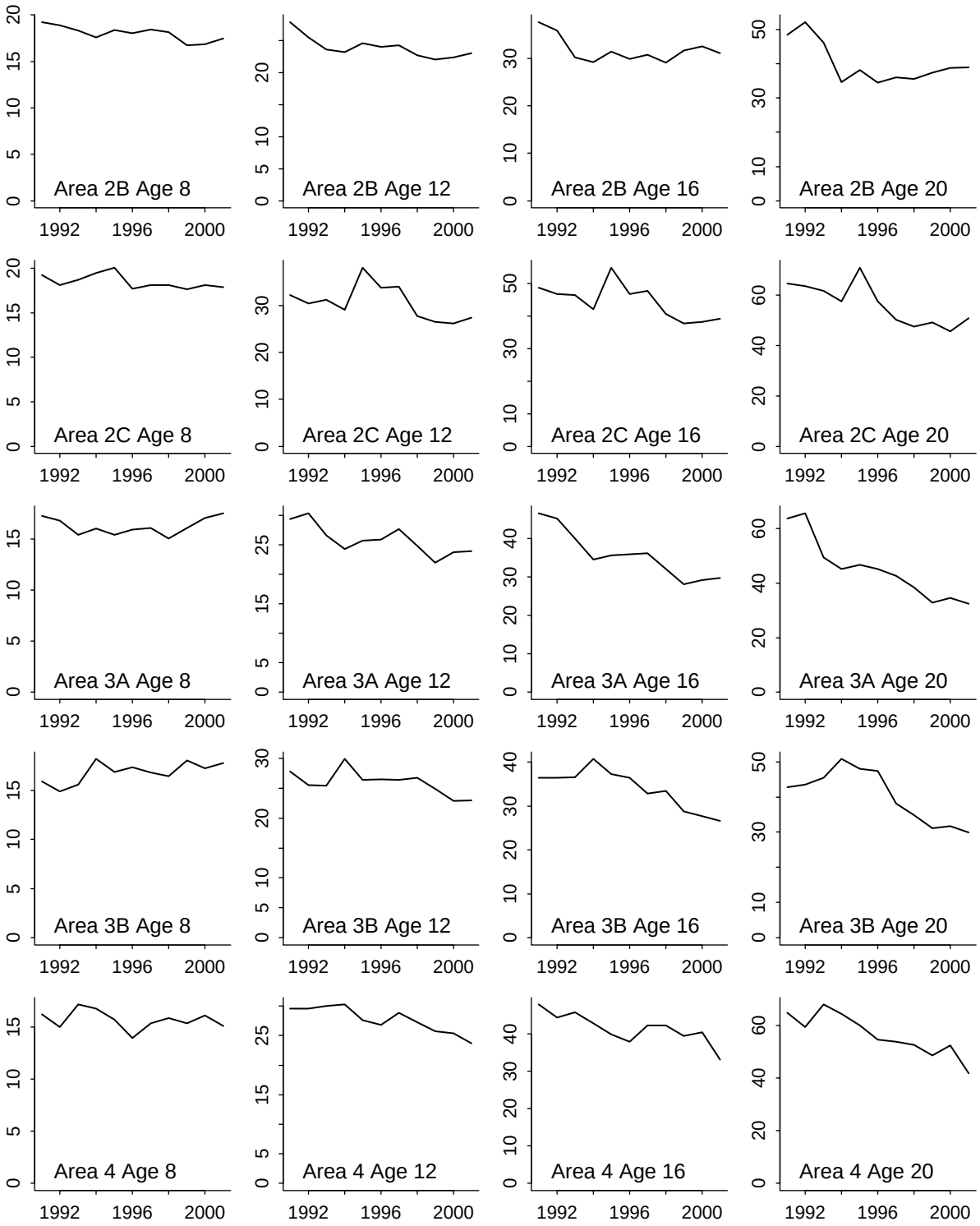

Figure 2. Trends in mean weight at age in the commercial catch, 1991-2001.

Appendix A. Selected fishery and survey data summaries.

Table A1. Commercial catch (million pounds, net weight).

	2A	2B	2C	3A	3B	4	Total
1974	0.52	4.62	5.60	8.19	1.67	0.71	21.31
1975	0.46	7.13	6.24	10.60	2.56	0.63	27.62
1976	0.24	7.28	5.53	11.04	2.73	0.72	27.54
1977	0.21	5.43	3.19	8.64	3.19	1.22	21.88
1978	0.10	4.61	4.32	10.30	1.32	1.35	22.00
1979	0.05	4.86	4.53	11.34	0.39	1.37	22.54
1980	0.02	5.65	3.24	11.97	0.28	0.71	21.87

	2A	2B	2C	3A	3B	4A	4B	4C	4D	4E	Total
1981	0.20	5.66	4.01	14.23	0.45	0.49	0.39	0.30	0.01	0.00	25.74
1982	0.21	5.54	3.50	13.52	4.80	1.17	0.01	0.24	0.00	0.01	29.01
1983	0.27	5.44	6.38	14.13	7.75	2.50	1.34	0.42	0.15	0.01	38.39
1984	0.43	9.05	5.87	19.77	6.69	1.05	1.10	0.58	0.39	0.04	44.97
1985	0.49	10.39	9.21	20.84	10.89	1.72	1.24	0.62	0.67	0.04	56.10
1986	0.58	11.23	10.61	32.80	8.82	3.38	0.26	0.69	1.22	0.04	69.63
1987	0.59	12.25	10.68	31.31	7.76	3.69	1.50	0.88	0.70	0.09	69.45
1988	0.49	12.86	11.36	37.86	7.08	1.93	1.59	0.71	0.45	0.01	74.34
1989	0.47	10.43	9.53	33.73	7.84	1.02	2.65	0.57	0.67	0.01	66.95
1990	0.33	8.57	9.73	28.85	8.69	2.50	1.33	0.53	1.01	0.06	61.60
1991	0.35	7.19	8.69	22.93	11.93	2.25	1.51	0.68	1.44	0.10	57.08
1992	0.43	7.63	9.82	26.78	8.62	2.70	2.32	0.79	0.73	0.07	59.89
1993	0.50	10.63	11.29	22.74	7.86	2.56	1.96	0.83	0.84	0.06	59.27
1994	0.37	9.91	10.38	24.84	3.86	1.80	2.02	0.71	0.71	0.12	54.73
1995	0.30	9.62	7.77	18.34	3.12	1.62	1.68	0.67	0.64	0.13	43.88
1996	0.30	9.55	8.87	19.69	3.66	1.70	2.07	0.68	0.71	0.12	47.34
1997	0.41	12.42	9.92	24.63	9.07	2.91	3.32	1.12	1.15	0.25	65.20
1998	0.46	13.17	10.20	25.70	11.16	3.42	2.90	1.26	1.31	0.19	69.76
1999	0.45	12.70	10.14	25.32	13.83	4.37	3.57	1.76	1.89	0.26	74.31
2000	0.48	10.81	8.44	19.29	15.41	5.15	4.69	1.74	1.93	0.35	68.30
2001	0.69	10.10	8.40	21.94	16.55	4.98	4.48	1.74	1.87	0.46	71.20

Table A2. Bycatch mortality of legal-sized halibut (80+ cm; in million pounds net weight).

	2A	2B	2C	3A	3B	4	Total
1974	0.25	0.90	0.37	4.48	2.82	1.89	10.71
1975	0.25	0.90	0.45	2.61	1.66	1.10	6.97
1976	0.25	0.94	0.50	2.74	1.94	1.18	7.56
1977	0.25	0.72	0.41	3.37	1.54	1.98	8.27
1978	0.25	0.55	0.21	2.44	1.31	3.40	8.17
1979	0.25	0.69	0.64	4.49	0.69	3.45	10.21
1980	0.25	0.51	0.42	4.93	0.87	5.71	12.69
1981	0.25	0.53	0.40	3.99	1.10	4.37	10.64
1982	0.25	0.30	0.20	3.20	1.68	2.94	8.57
1983	0.25	0.29	0.20	2.08	1.22	2.47	6.52
1984	0.25	0.52	0.21	1.51	0.92	2.29	5.70
1985	0.25	0.55	0.20	0.80	0.34	2.25	4.38
1986	0.25	0.56	0.20	0.67	0.20	2.62	4.50
1987	0.25	0.79	0.20	1.59	0.40	2.67	5.91
1988	0.25	0.77	0.20	2.13	0.04	3.27	6.67
1989	0.25	0.72	0.20	1.80	0.44	1.94	5.36
1990	0.25	1.03	0.67	2.63	1.21	4.15	9.96
1991	0.25	1.22	0.55	3.13	1.04	2.92	9.10
1992	0.28	1.02	0.57	2.64	1.12	3.35	8.97
1993	0.28	0.65	0.33	1.92	0.47	2.01	5.66
1994	0.28	0.57	0.40	2.35	0.85	3.48	7.93
1995	0.38	0.71	0.22	1.46	0.83	3.21	6.80
1996	0.47	0.17	0.23	1.40	0.96	3.57	6.80
1997	0.47	0.11	0.24	1.55	0.73	3.80	6.90
1998	0.81	0.12	0.24	1.47	0.73	3.72	7.09
1999	0.66	0.11	0.23	1.28	0.74	3.34	6.36
2000	0.54	0.13	0.25	1.29	0.65	3.23	6.09
2001	0.54	0.11	0.22	1.70	0.48	3.39	6.44

Table A3. Total removals: commercial catch + sport catch + legal-sized wastage + legal-sized bycatch + personal use (millions of pounds net weight).

	2A	2B	2C	3A	3B	4	Total
1974	0.77	5.52	5.97	12.67	4.49	2.60	32.02
1975	0.71	8.03	6.69	13.21	4.22	1.73	34.59
1976	0.49	8.22	6.03	13.78	4.67	1.90	35.10
1977	0.48	6.16	3.67	12.20	4.73	3.20	30.44
1978	0.36	5.17	4.62	13.02	2.63	4.75	30.54
1979	0.32	5.56	5.34	16.19	1.08	4.82	33.31
1980	0.29	6.17	3.99	17.38	1.15	6.42	35.41
1981	0.47	6.20	4.73	18.96	1.55	5.57	37.47
1982	0.51	5.87	4.19	17.44	6.48	4.38	38.88
1983	0.58	5.78	7.15	17.14	8.97	6.89	46.51
1984	0.80	9.63	6.68	22.50	7.42	5.46	52.50
1985	0.94	11.30	10.31	23.79	11.43	6.69	64.45
1986	1.17	12.17	11.97	37.23	9.43	8.53	80.50
1987	1.29	13.48	12.03	36.48	8.50	9.84	81.62
1988	0.99	13.93	12.85	44.76	7.24	8.07	87.85
1989	1.05	11.51	11.48	40.00	8.47	7.03	79.55
1990	0.78	10.06	11.98	36.02	10.12	9.84	78.79
1991	0.77	8.83	11.95	32.42	13.46	9.49	76.92
1992	0.97	9.09	12.68	34.46	9.98	10.23	77.40
1993	1.04	12.00	13.74	30.59	8.46	8.56	74.39
1994	0.83	11.18	13.11	32.86	4.83	9.12	71.93
1995	0.92	11.55	9.80	24.51	4.02	8.11	58.91
1996	1.00	10.93	11.28	26.11	4.70	9.09	63.10
1997	1.25	13.75	12.37	31.86	9.92	12.79	81.94
1998	1.66	14.53	12.98	32.12	12.00	13.03	86.32
1999	1.45	14.01	12.45	31.02	14.69	15.55	89.17
2000	1.38	12.29	11.17	25.98	16.14	17.41	84.37
2001	1.68	11.58	10.56	28.76	17.10	17.25	86.92

Table A4. Commercial CPUE (net pounds per skate).

Values before 1984 are multiplied by the J-C hook correction for catch in weight of legal-sized fish (2.2). 1983 is excluded because it consists of a mixture of J- and C-hook data. No value is shown for area/years after 1980 with fewer than 500 skates of reported catch/effort data. Values for Areas 2A and 2B are slightly different from past years because of the reweighting of fixed-hook and snap CPUE described in the text.

	2A	2B	2C	3A	3B	4
1974	131	141	126	142	125	301
1975	131	149	117	145	149	211
1976	72	117	93	131	142	184
1977	182	135	99	135	161	176
1978	86	138	124	172	116	167
1979	110	106	177	189	81	146
1980	82	144	175	261	249	124

	2A	2B	2C	3A	3B	4A	4B	4C	4D	4E
1981	---	147	318	312	---	---	217	243	---	---
1982	47	151	366	375	478	226	---	199	---	---
1983	---	---	---	---	---	---	---	---	---	---
1984	63	148	314	524	475	366	161	---	197	---
1985	62	147	370	536	602	333	234	---	330	---
1986	60	120	302	522	515	265	---	427	238	---
1987	57	131	260	504	476	341	220	384	---	---
1988	134	137	281	503	655	453	224	---	201	---
1989	124	134	258	455	590	409	268	331	384	---
1990	168	175	269	353	484	434	208	288	381	---
1991	158	148	233	319	466	471	329	223	398	---
1992	115	171	230	397	440	372	278	249	412	---
1993	147	208	256	393	514	463	218	256	851	---
1994	93	215	207	354	377	463	198	167	480	---
1995	116	219	234	416	476	349	189	---	475	---
1996	159	226	238	473	556	515	269	---	---	---
1997	226	241	246	458	562	482	275	335	671	---
1998	194	232	236	451	611	525	287	287	627	---
1999	342	213	199	437	538	498	310	270	535	---
2000	263	227	186	443	577	548	318	223	556	---
2001	142	209	205	465	405	459	284	197	517	---

Table A5. IPHC setline survey CPUE of legal sized fish in weight (net pounds per skate). Figures for Area 2B refer to the Charlotte region only. Figures for all other areas refer to all stations fished. This is a change from previous years and the series for Areas 2C, 3A, and 4A have changed as a result. The eastward expansion of the 3A survey in 1996 lowered average CPUE by around 25%; the raw values in the table should not be taken at face value. Similarly the 4A value for 1999 is elevated because the Bering Sea edge in 4A was not fished that year. *No corrections* are applied; values before 1984 are raw J-hook catch rates.

J-hook surveys

	2A	2B	2C	3A
1974	---	---	---	---
1975	---	---	---	---
1976	---	---	---	---
1977	---	15	---	73
1978	---	21	---	34
1979	---	---	---	51
1980	---	28	---	95
1981	---	18	---	162
1982	---	21	133	180
1983	---	20	142	153

C-hook surveys

	2A	2B	2C	3A	3B	4A	4B	4C	4D
1984	---	64	260	446	---	---	---	---	---
1985	---	47	260	466	---	---	---	---	---
1986	---	42	283	377	---	---	---	---	---
1987	---	---	---	---	---	---	---	---	---
1988	---	---	---	---	---	---	---	---	---
1989	---	---	---	---	---	---	---	---	---
1990	---	---	---	---	---	---	---	---	---
1991	---	---	---	---	---	---	---	---	---
1992	---	---	---	---	---	---	---	---	---
1993	---	105	---	313	---	---	---	---	---
1994	---	---	---	313	---	---	---	---	---
1995	29	166	---	370	---	---	---	---	---
1996	---	175	306	317	352	---	---	---	---
1997	35	156	411	331	415	237	282	71	111
1998	---	92	232	281	436	304	216	---	---
1999	37	95	204	241	441	367	204	---	---
2000	---	104	232	273	378	286	216	---	213
2001	41	117	239	255	365	209	171	---	201

Appendix B. Recent changes in assessment methods and harvest policy.

1982-1994: stock size was estimated with CAGEAN, a strictly age-structured model fitted to commercial catch-at-age and catch-per-effort data. Because of a decrease in growth rates between the late 1970s and early 1990s, there were persistent underestimates of incoming recruitment and total stock size in the assessments done in the early 1990s.

Until 1985, allowable removals were calculated as a proportion of estimated annual surplus production (ASP), the remaining production being allocated to stock rebuilding. In 1985 the Commission adopted a constant harvest rate policy, meaning that allowable removals are determined by applying a fixed harvest rate to estimated exploitable biomass. This harvest level is called the Constant Exploitation Yield, or CEY. The fixed harvest rate was set at 28% in 1985, increased to 35% in 1987, and lowered to 30% in 1993.

1995: a new age- and length-structured model was implemented that accounted for the change in growth and was fitted to survey as well as commercial catch-at-age and catch-per-effort data. The new model produced substantially higher biomass estimates. In Area 3A this resulted from accounting for the change in growth schedule. In Area 2B, where the change in growth had been much less than in Alaska, it resulted from fitting the model to survey catch-per-effort, which showed a larger stock increase since the mid-1980s than commercial catch-per-effort. Quotas were held at the 1995 level to allow time for a complete study of the new model and results,

1996: differences in estimated selectivity between British Columbia and Alaska led to the consideration of two alternatives for fitting the model, one in which survey selectivity was a fixed function of age and the other in which it was a function of length. Spawner-recruit estimates from the new model resulted in a lowering of the target harvest rate to 20%. Quotas were increased somewhat, but not to the level indicated by the new biomass estimates.

1997: setline surveys of the entire Commission area indicated substantially more halibut in western Alaska (IPHC Areas 3B and 4) than the analytical assessment. Biomass in those areas was estimated by scaling the analytical estimates of absolute abundance in Areas 2 and 3A by the survey estimate of relative abundance in western Alaska. CEY estimates increased again, and quotas were increased again, but still to a level well below the CEY's.

1998: the working value of natural mortality was lowered from 0.20 to 0.15, reducing analytical estimates of biomass in Areas 2 and 3A by about 30%. At the same time setline survey estimates of abundance in Areas 3B and 4 relative to Areas 2 and 3A increased, so biomass estimates in the western area decreased by a smaller amount.

1999: setline survey catch rates in the 1990s were adjusted downward to account for the effect of changing to all-salmon bait when the surveys resumed in 1993. This reduced biomass estimates by 20-30%.

2000: the bait adjustment applied in 1999 was removed, which increased biomass estimates by 30-40%, approximately back to the level in the 1998 assessment. In addition, a purely age-

structured model was adopted in place of the age- and size-structured model used in 1999. The 2000 model produced similar estimates of present biomass but lower estimates of historical biomass.

2001: instead of a combined Area 2AB assessment, a standalone assessment of Area 2B was done and the biomass estimate extrapolated to 2A on the basis of survey results, which increased the abundance estimate by 7%. Also in 2A and 2B, snap CPUE (scaled up by 1.35) was given the same weight as fixed-hook CPUE; negligible effect. All survey stations in 2C and 3A were used in the assessment rather than just the standard survey areas, which increased the biomass estimate by 7% in 3A and lowered it by 15% in 2C.

Appendix C. Selected historical estimates from the 2001 assessment.

The following tables show trends in recruitment, stock size, and exploitation rate estimated with the model used in 2000. Except for the catches, all of these estimates are liable to change in later years, sometimes dramatically, as new data and methods are used in the assessment.

The columns in the tables are:

R = age 8 recruits (millions)
N = total abundance of age 8+ fish (millions)
C = total catch in number of age 8+ fish (million net lb)
C/N = exploitation rate in number of age 8+ fish
B = total biomass of legal-sized fish (million net lb)
Y = total catch in weight of age 8+ fish (million net lb)
Y/B = exploitation rate in weight

The "catches" are actually total removals except for bycatch. Total biomass is calculated using estimated mean size at age in the sea rather than in the catch, and is not directly comparable with estimates of exploitable biomass.

Table C1. Historical estimates for Area 2B

	R	N	C	C/N	B	Y	Y/B
1974	0.39	1.42	0.13	0.09	31.76	4.27	0.13
1975	0.40	1.47	0.19	0.13	33.61	6.77	0.20
1976	0.39	1.45	0.20	0.14	33.84	6.34	0.19
1977	0.41	1.45	0.16	0.11	34.29	4.91	0.14
1978	0.47	1.55	0.14	0.09	37.08	4.05	0.11
1979	0.48	1.67	0.16	0.09	41.04	4.57	0.11
1980	0.57	1.83	0.18	0.10	44.18	5.29	0.12
1981	0.67	2.05	0.20	0.10	47.24	5.27	0.11
1982	0.70	2.26	0.20	0.09	50.50	5.22	0.10
1983	0.86	2.61	0.21	0.08	55.61	5.16	0.09
1984	1.09	3.13	0.36	0.12	58.83	8.44	0.14
1985	1.39	3.73	0.44	0.12	60.33	10.27	0.17
1986	1.20	3.97	0.47	0.12	64.91	11.28	0.17
1987	1.37	4.33	0.50	0.12	69.80	12.08	0.17
1988	1.36	4.60	0.55	0.12	73.61	12.78	0.17
1989	1.09	4.51	0.43	0.10	76.04	10.45	0.14
1990	0.99	4.44	0.36	0.08	79.92	8.54	0.11
1991	1.22	4.68	0.27	0.06	83.97	7.21	0.09
1992	1.22	4.96	0.30	0.06	88.66	7.75	0.09
1993	1.02	4.98	0.46	0.09	96.04	11.15	0.12
1994	1.10	4.94	0.43	0.09	104.83	10.33	0.10
1995	2.31	6.16	0.42	0.07	113.51	10.43	0.09
1996	2.04	6.92	0.44	0.06	116.61	10.45	0.09
1997	1.50	7.04	0.56	0.08	114.12	13.06	0.11
1998	1.38	6.90	0.62	0.09	106.06	14.08	0.13
1999	1.00	6.34	0.58	0.09	97.16	13.71	0.14
2000	0.89	5.81	0.49	0.08	90.33	11.88	0.13
2001	0.76	5.30	0.45	0.09	85.64	11.24	0.13

Table C2. Historical estimates for Area 2C.

	R	N	C	C/N	B	Y	Y/B
1974	0.29	1.15	0.13	0.12	30.20	5.50	0.18
1975	0.32	1.17	0.15	0.13	29.98	6.13	0.20
1976	0.35	1.20	0.13	0.11	29.59	5.45	0.18
1977	0.40	1.30	0.08	0.06	31.08	3.17	0.10
1978	0.52	1.54	0.12	0.08	35.60	4.21	0.12
1979	0.55	1.76	0.13	0.07	40.87	4.58	0.11
1980	0.73	2.12	0.10	0.05	47.50	3.49	0.07
1981	0.84	2.56	0.13	0.05	57.12	4.25	0.07
1982	0.82	2.90	0.11	0.04	65.69	3.91	0.06
1983	0.82	3.21	0.19	0.06	75.37	6.82	0.09
1984	0.93	3.51	0.19	0.05	83.02	6.32	0.08
1985	1.21	4.05	0.29	0.07	86.07	10.03	0.12
1986	0.87	4.08	0.37	0.09	87.98	11.63	0.13
1987	0.96	4.10	0.35	0.09	89.40	11.75	0.13
1988	0.89	4.09	0.39	0.10	90.30	12.49	0.14
1989	0.77	3.92	0.34	0.09	88.90	11.15	0.13
1990	0.71	3.77	0.33	0.09	88.42	11.19	0.13
1991	0.83	3.74	0.31	0.08	87.04	11.14	0.13
1992	0.83	3.75	0.36	0.10	84.66	11.99	0.14
1993	0.69	3.57	0.37	0.10	82.01	13.33	0.16
1994	0.72	3.44	0.38	0.11	80.36	12.57	0.16
1995	1.62	4.21	0.23	0.06	79.09	9.47	0.12
1996	1.38	4.77	0.33	0.07	82.99	10.95	0.13
1997	0.95	4.75	0.37	0.08	81.71	12.03	0.15
1998	0.78	4.51	0.44	0.10	79.71	12.64	0.16
1999	0.72	4.18	0.42	0.10	74.88	12.09	0.16
2000	0.87	4.08	0.37	0.09	70.02	10.77	0.15
2001	0.88	4.04	0.34	0.08	64.44	10.23	0.16

Table C3. Historical estimates for Area 3A.

	R	N	C	C/N	B	Y	Y/B
1974	0.61	2.30	0.17	0.07	78.44	8.10	0.10
1975	0.80	2.54	0.22	0.09	82.00	10.43	0.13
1976	0.95	2.86	0.23	0.08	88.75	10.92	0.12
1977	1.06	3.24	0.18	0.06	101.15	8.73	0.09
1978	1.32	3.86	0.24	0.06	118.12	10.35	0.09
1979	1.24	4.27	0.27	0.06	136.19	11.33	0.08
1980	1.44	4.78	0.27	0.06	150.89	12.28	0.08
1981	1.91	5.65	0.33	0.06	169.20	14.75	0.09
1982	1.83	6.28	0.30	0.05	192.29	14.10	0.07
1983	1.94	6.98	0.35	0.05	214.15	14.91	0.07
1984	2.36	7.97	0.51	0.06	222.68	20.56	0.09
1985	3.21	9.52	0.57	0.06	246.72	22.77	0.09
1986	2.86	10.48	0.92	0.09	272.58	36.21	0.13
1987	3.60	11.68	0.93	0.08	273.31	34.41	0.13
1988	4.45	13.56	1.22	0.09	274.12	41.93	0.15
1989	3.45	13.87	1.11	0.08	264.52	37.88	0.14
1990	3.13	13.96	0.98	0.07	257.72	33.08	0.13
1991	4.34	15.37	0.95	0.06	249.78	28.93	0.12
1992	3.64	15.89	1.02	0.06	238.03	31.71	0.13
1993	3.01	15.66	0.98	0.06	222.51	28.62	0.13
1994	2.74	15.26	1.10	0.07	239.96	30.38	0.13
1995	4.66	16.73	0.82	0.05	250.93	22.95	0.09
1996	3.89	17.48	0.87	0.05	259.21	24.65	0.10
1997	2.38	16.58	1.02	0.06	254.88	30.22	0.12
1998	2.22	15.53	1.12	0.07	240.90	30.59	0.13
1999	1.54	13.86	1.19	0.09	220.67	29.65	0.13
2000	1.72	12.55	0.92	0.07	198.22	24.58	0.12
2001	1.43	11.38	0.99	0.09	184.48	26.99	0.15