Assessment of the Pacific halibut stock at the end of 2004

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Abstract

This year's assessment uses the same methods as last year's to estimate exploitable biomass. Estimated coastwide exploitable biomass is 395 million pounds compared with 431 million last year, largely due to downward revisions of last year's estimates rather than a real decline in the stocks. A constant harvest rate of 22.5% rather than last year's 25% is used to calculate total CEY in Areas 2 and 3A. In Area 3B the target harvest rate is 20% this year rather than 25% last year. In Area 4 the target harvest rate remains at 20%. Fishery CEY totals 72.17 million pounds.

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, 3A, 3B, 4A, and 4B is estimated by fitting a detailed population model to the data from that area, going back to 1974 in the eastern areas and to 1996 in Areas 3B and 4. Exploitable biomass in Areas 2A and 4CDE is estimated by applying a survey-based estimate of relative abundance to the analytical estimate of biomass in the adjoining area (2B for 2A, 4A for 4CDE).

A biological target level for total removals is calculated by applying a fixed harvest rate 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 catches in directed fisheries subject to allocation is called the fishery CEY. It comprises the commercial setline catch in all areas plus the sport catch in Areas 2A and 2B. It is calculated by subtracting from the total CEY an estimate of all unallocated removals—bycatch of legal-sized fish, wastage of legal-sized fish in the halibut fishery, fish taken for personal use, and sport catch except in Areas 2A and 2B.

Staff recommendations for catch limits in each area are based on the estimates of fishery 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.

Evolution of assessment methods through 2003

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. CAGEAN did not allow for that, and by the mid-1990s was seriously underestimating abundance. In effect, it interpreted lower catches as an indication of lower abundance, whereas the real cause was lower selectivity. Incoming year classes were initially estimated to be small, but in subsequent years' assessments those estimates would increase when unexpectedly large numbers of fish from those year classes appeared in the catches. The year-to-year changes in the stock trajectory shown by the assessment therefore developed a strong retrospective pattern. Each year's fit showed a steep decline toward the end, but each year the whole trajectory shifted upward.

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 (Sullivan et al. 1999).

When this model was fitted to data from Area 2B and Area 3A, quite different length-specific selectivities were estimated, which suggested that fishery selectivity was not wholly determined by the properties of the gear and the size of the fish but also depended on fish behavior (e.g., migration). These behavioral elements are likely to be more related to age than size. The age of sexual maturity, for example, remained virtually the same in Alaska despite the tremendous decrease in growth, so the size at maturity is now much smaller than it was. While size must affect selectivity, it was thought that age was also influential.

To allow for that, the model was fitted in two ways. The original form was called the "length-specific" fit, because a single set of estimates of the two parameters of the length-based survey selectivity function was used in all years. In a second form, called the "age-specific" fit, the parameters were allowed to drift over time (like the commercial selectivity parameters), but they were required (by a heavy penalty) to vary in such a way that the integrated age-specific selectivities calculated in each year remained constant over time.

The usual diagnostics gave little reason to prefer one fit over the other. Goodness of fit was similar: good for both in 2B, not so good for either in 3A. The retrospective behavior of both fits was dramatically better than that of CAGEAN and quite satisfactory in all cases, although the length-specific fit was more consistent from year to year in 3A and the age-specific fit was more consistent in 2B (Clark and Parma 1999). The two fits produced very similar estimates of abundance in Areas 2B and 2C, but in 3A the length-specific estimates were substantially higher, so out of caution the staff catch limit recommendations were based on the age-specific fit through 1999.

The assessment model was simplified and recoded as a purely age-structured model in 2000 to eliminate some problems associated with the modeling of growth and the distribution of length at age (Clark and Hare 2001). It retained the option of modeling survey selectivity as a function of mean length at age (observed not predicted), but the production fits continued to be based on constant age-specific survey selectivity, estimated directly as a vector of age-specific values rather than as a parametric function of age.

The fit of this model to Area 3A data in 2002 showed a dramatic retrospective pattern, similar to the pattern of successive CAGEAN fits in the mid-1990s. Treating setline survey selectivity as length-specific rather than age-specific largely eliminated the pattern. Accumulated data showing very similar trends in catch at length in IHPC setline surveys and

NMFS trawl surveys provided further evidence that setline selectivity is, after all, determined mainly by size rather than by age (Clark and Hare 2002).

Another anomaly of the 3A model fit in 2002 was the unexpectedly large number of old fish (age 20+) in the last few years' catches. This was found to be the result of an increase in the proportion of otoliths read by the break-and-burn rather than surface method. Surface readings tend to understate the age of older fish, and IPHC age readers had been gradually doing more and more break-and-burn readings as the number of older fish in the catches increased. The poor model fit at these ages indicated a need to deal explicitly with the bias and variance of both kinds of age readings.

An entirely new model was written for the 2003 assessment (Clark and Hare 2004). Both commercial and survey selectivity were parameterized as piecewise linear functions of mean length at age in survey catches, and were required to reach an asymptote of one at or before a length of 130 cm. Because females are larger than males, all of the population accounting and predictions were done separately for each sex. (The age/sex/size composition of the commercial landings was estimated external to the assessment for this purpose.) The observed age compositions (surface or break-and-burn) were predicted by applying estimated misclassification matrices to the age distributions. Even in its most parsimonious form—with just one survey and one commercial selectivity schedule for both sexes in all years—this model achieved very good fits to the sex-specific observations and good retrospective performance. It also produced somewhat higher estimates of average recruitment and recruitment variability. With this simple model it was feasible do standalone analytical assessments of abundance in Areas 3B, 4A, and 4B for the first time, using data from 1996-2003.

Features of the 2004 assessment

Only two minor changes were made for the 2004 assessment, and neither had a significant effect on the estimates of abundance. First, both the 2004 PIT tag recoveries (Clark and Chen 2005) and a reanalysis of earlier wire tag data (Clark 2005) indicated that commercial selectivity is not always asymptotic; it appeared to be more dome-shaped in Area 2B and more ramp-shaped in Area 3A. Fitting the assessment model with free-form selectivity schedules showed much the same thing for commercial selectivity (Fig. 1), namely an assortment of shapes beyond 120 cm. Nevertheless a schedule that reaches an asymptote of one at 120 cm is a good approximation to and compromise among the free estimates, and using an asymptotic commercial schedule is desirable for computing exploitable biomass and reporting harvest rates, so that it what was used in the assessment. All of the freely estimated survey selectivities either level out or increase after 120 cm. Freely estimated survey selectivities present no practical difficulties, so they were estimated that way in the assessment, and most of the estimates were ramp-shaped.

The second minor change was allowing sex-specific values for survey and commercial catchabilities. This was done only in the Area 3A assessment, where the standard model fitted the age composition of male catches well but the numbers of males in the catches were generally in excess of the predictions. In Area 3A males were estimated to be about twice as catchable as females of the same size; in other areas there was no difference. Even with higher catchability, males in Area 3A were estimated have quite low fishing mortality rates because they are so small.

Analytical estimates of abundance and CEY

Like last year's, this year's model fits are generally good (Fig. 2) and recent retrospective performance is satisfactory. Changes in stock biomass from the beginning of 2004 to the beginning of 2005 as estimated within this year's assessment are all 5% or less except in Area 4B, where there was an estimated 20% decrease. Some of the estimates of stock biomass have changed much more than 5% from last year's assessment because the addition of the 2004 data to this year's model fit has revised last year's estimate of biomass at the beginning of 2004, in most cases downward.

	2004 biomass 2003 assessment	2004 biomass 2004 assessment	2005 biomass 2004 assessment
Area 2A	8.5	7.9	7.0
Area 2B	65	61	58
Area 2C	80	65	66
Area 3A	146	154	146
Area 3B	65	54	56
Area 4A	21	20	20
Area 4B	15	12	10
Area 4CDE	30	28	32
Total	431	402	395

It is these downward revisions of last year's estimates that mainly account for the reduction of estimated coastwide exploitable biomass from 431 million pounds to 395. Female spawning biomass remains far above the minimum that occurred in the mid 1970s.

Table 1 shows estimates of exploitable biomass, total CEY, and fishery CEY. Exploitable biomass in Alaska is calculated with a fixed set of length-specific commercial selectivities that increase linearly from zero at 80 cm to one at 120 cm. In Area 2B the locally estimated selectivities are used because they are substantially higher than the values estimated for the Alaska areas.

Exploitable biomass in Area 2A is calculated as a proportion of the Area 2B analytical estimate. The proportion used is the ratio of survey CPUE's (three-year running mean) weighted by bottom areas:

$$\text{proportion} = \frac{(\text{2A CPUE})\times(\text{2A bottom area})}{(\text{2B CPUE})\times(\text{2B bottom area})}$$

The idea here is that survey CPUE is an index of density and multiplying it by the total bottom area gives an index of total biomass. The value of the scaling proportion this year is 12%, down from 13% last year as a result of updating the CPUE values. In the same way, exploitable biomass in Area 4CDE is calculated as 160% of the Area 4A biomass (up from 142% last year).

Total CEY is calculated by applying a harvest rate of 22.5% in Areas 2A, 2B, 2C, and 3A, and 20% in Areas 3B and 4 (Hare and Clark 2005). Last year the target harvest rate for Areas 2 and 3 was 25% pending a reanalysis of harvest policy using the new estimates of length-specific commercial selectivity.

Reliability of model fits to short data series

In Areas 2B, 2C, and 3A the model is fitted to 31 years of data (1974-2004), but in Areas 3B, 4A, and 4B to only 9 years (1996-2004). The performance of fits to short data series can be examined by comparing fits to the full series and fits to shorter subsets in areas with long data series.

Figure 3a shows the Area 3A fit to the first 9 years of data (1974-1982), and on the same graph the estimates from this year's fit to the full series. The 1982 fit agrees quite well with the 2004 fit in respect of selectivities, numbers at age in 1974, and fishing mortality rates. Most of the 1982 estimates of recruitment are a bit high and as a result the estimate of exploitable biomass in 1983 is high by 15% or so, but as explained below that is well within the normal error range of fits based on many years of data.

Similarly Figure 3b compares this year's full Area 2C fit (1974-2004 data) with one that uses data from 1996-2004 only. Again the estimates from the short data series compare quite well with those from the full data set. In this case the exploitable biomass estimate from the short data series is about 10% lower than the full estimate.

Figure 3c shows the same comparison for Area 2B. In this case the 1996-2004 fit is pathological. Estimates of selectivities and numbers at age agree very well with the full assessment, but fishing mortality is greatly overestimated and as a result exploitable biomass is underestimated by more than 30%. This occurs because the survey CPUE series happens to begin with the very high 1996 and 1997 values. The later, lower survey catch rates suggest a substantial total mortality rate, which produces the high estimated fishing mortality rates and low abundance estimates. The commercial CPUE values show quite a different trend, so it is doubtful that this assessment would have been taken at face value even if no more data were available, but this example does show that an assessment based on a short data series can be strongly influenced by a few stray data points.

We do not believe that this year's 3B, 4A, and 4B assessments are suspect for this reason because in every case the survey and commercial CPUE series are very consistent and coherent in showing steady declines over the last 5-6 years. It is conceivable that these downward trends are an artifact of a widespread decline in setline catchability, and the low PIT tag recoveries certainly put the fishing mortality estimates in doubt, but the assessment data by themselves do not raise any suspicions about the fits or the estimates.

Variance estimates

Our estimates are maximum-likelihood estimates, and their variances can be estimated by any of a number of standard methods. In practice all of the methods produce very similar estimates, and the estimates are much too low when the model is misspecified (Punt and Butterworth 1993), which is almost always true of stock assessment models. The usual estimates of standard deviation for our model fits are less than 5%, but this year's estimates of abundance at the beginning of 2004 differ from last year's estimates by up to 20%. Changes of this size do not result from statistical variability but from trends in the stock and the fishery that are not reflected in the necessarily parsimonious parameterization of the model (Clark et al. 2004). These trends cause the model fits to make large excursions and abrupt corrections that appear as year-to-year changes much larger than what would be expected from sampling errors.

Figure 4 illustrates this characteristic with the retrospective behavior of the Area 3A exploitable biomass estimates. The estimate shoots way up in the mid-1980s, drops way down in the early 1990s, and since 1993 tracks reasonably well.

By now we know the actual abundance of the stock in the 1980s and early 1990s because all of the year classes then present have by now passed through, and their abundance in the 2004 model fit is therefore entirely determined by the catch at age. We can configure the 2004 assessment model to calculate the trends in catchability and selectivity that were occurring at that time and see why the current estimates make the observed excursions and corrections. Doing that shows that selectivity has changed little over the years, but that both commercial and especially survey catchability were increasing quite rapidly in the late 1970s and early 1980s. This was a period when people in the industry spoke of a sudden increase in abundance that could only be explained by fish coming out of a “black hole.” In retrospect it is clear that catchability was increasing, perhaps because halibut took up a more demersal habit after the 1977 regime shift. The assessment model fits for that period allow for a slow drift in commercial catchability but no change in survey selectivity, so the increasing catch rates can only be fitted in successive assessments by increasing the abundance estimates. The estimated value of (constant) survey selectivity also increases in successive assessments, but even so the model fits cannot match the observed increase in survey catch rates (Fig. 3a).

In the latter 1980s and early 1990s commercial catchability declined owing to the nature of the derby fishery. There were no surveys between 1986 and 1993, so the assessments of that period rely on commercial CPUE as an index of abundance; hence the downward excursion of the biomass estimate in the early 1990s and the abrupt correction in 1993 when the next survey index of abundance became available. At its worst in 1991 the biomass estimate was low by about 50%, but the model fit to the data was good and the nominal variance was small (Fig. 5). In the 2004 assessment (Fig. 2c) the 1985-1995 period appears as a time when commercial catchability fell (before increasing again after the adoption of individual quotas in 1995) but there was little change in exploitable biomass despite the wide swings in the assessment estimate.

Because the actual abundance is effectively known for the early years of the data series (say eight or more years before the last data year), it is possible to calculate an empirical error variance from the observed deviations between the first assessment estimate for a given year and the converged value that becomes known eight or more years later. The 1982 assessment error, for example, can be calculated as the difference between the estimate made in that year’s assessment and the historical value for 1982 computed in this year’s assessment. Doing that for all possible years and two different models in Areas 2B, 2C, and 3A produces a generic value of the standard deviation of the biomass estimate of about 20%. Most (not all) of the really large deviations occur in the earlier years. More recently the assessment has been tracking somewhat better, so a 10-15% standard deviation seems more reasonable as a working value.

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Table 1. Estimates of exploitable biomass and CEY.

	Area 2A	Area 2B	Area 2C	Area 3A	Area 3B	Area 4A	Area 4B	Area 4CDE	Total
2004 catch limit	1.48	13.80	10.50	25.06	15.60	3.47	2.81	3.79	76.51
2004 exploitable biomass (2003 assessment)	8.5[1]	66	80	146	65	21	15	30[2]	431.5
2005 exploitable biomass (2004 assessment)	7.0[1]	58	66	146	56	20	10	32[2]	395.0
Other removals									
Sport catch	0.51	1.37	2.31	4.74	0.01	0.02	0.00	0.00	8.96
Legal-sized bycatch	0.37	0.14	0.15	1.52	0.39	0.52	0.29	1.92	5.3
Personal use	0.02	0.30	0.63	0.28	0.03	0.02	0.00	0.08	1.36
Legal-sized wastage	0.00	0.02	0.03	0.07	0.03	0.02	0.00	0.01	0.18
Total	0.90	1.83	3.12	6.61	0.46	0.58	0.29	2.01	15.8
…excluding sport catch	0.39[3]	0.44[4]	---	---	---	---	---	---	
Total CEY at 20%	1.40	11.6	13.2	29.2	11.2	4.0	2.0	6.4	79
Fishery CEY at 20%	1.01	11.2	10.1	22.6	**10.7**	**3.4**	**1.7**	**4.4**	**65.11**
Total CEY at 22.5%	1.56	13.1	14.9	32.9	12.6	4.5	2.3	7.2	89.06
Fishery CEY at 22.5%	**1.17**[3]	**12.7**[3,4]	**11.8**	**26.3**	12.2	3.9	2.0	5.2	75.27

Notes:

1. Area 2A exploitable biomass estimated as 13% of Area 2B for 2004 and as 12% for 2005 due to changes in survey catch rates.
2. Area 4CDE exploitable biomass calculated as 142% of Area 4A biomass for 2004 and as 160% for 2005.
3. Fishery CEY includes sport catch in Areas 2A and 2B.
4. Combined sport and commercial CEY for Area 2B includes Area 2B sport catch landed in the U.S. (0.200 million lb) and legal sized wastage (0.02 million lb) to conform with the Canadian allocation program. If sport landings in the U.S. are left out of fishery CEY, they become a subtraction from total CEY and fishery CEY is reduced to 12.5 million lb.

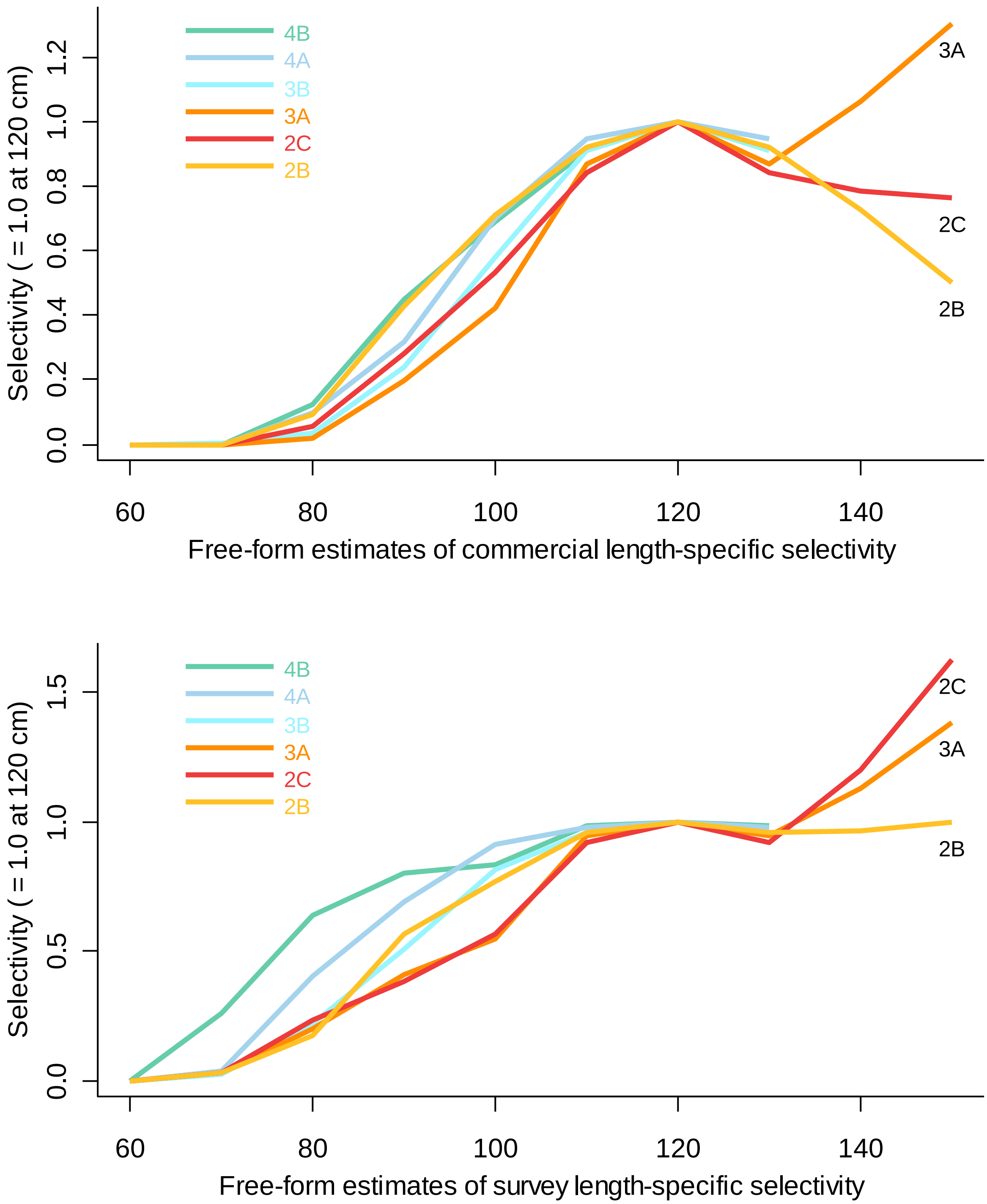

Figure 1. Free-form estimates of length-specific commercial (above) and survey (below) selectivity from assessment model fits. In the production fits commercial selectivity was asymptotic, but not survey selectivity.

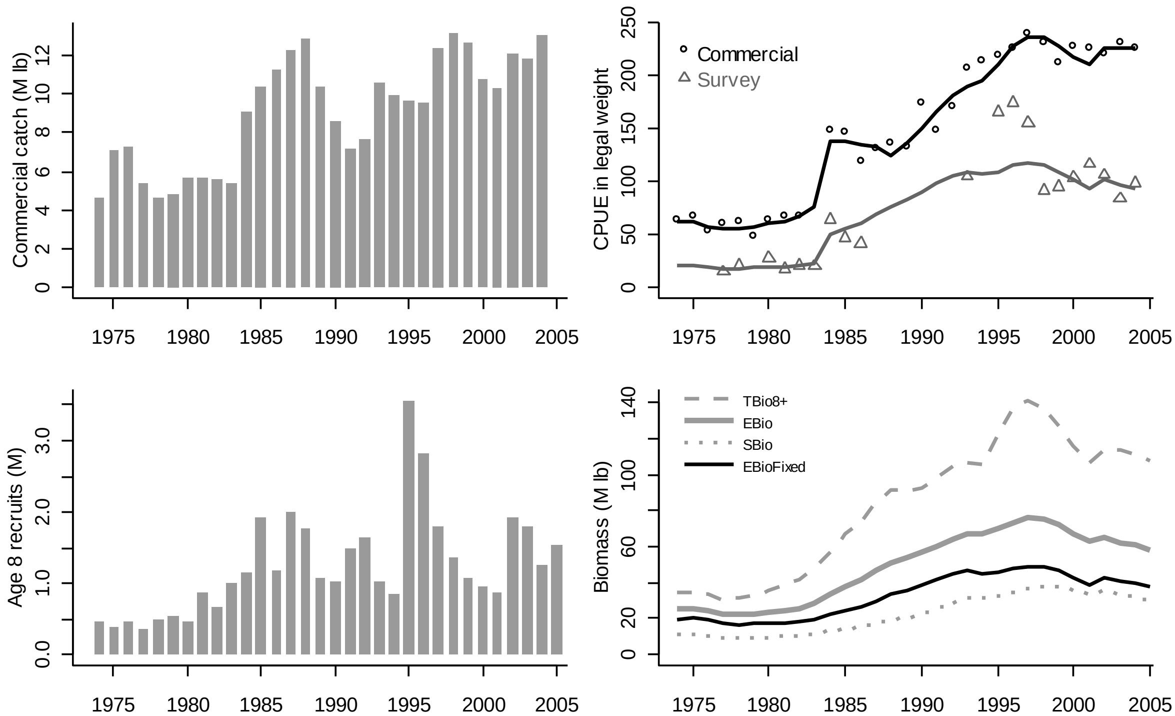

Figure 2a. Features of the 2004 assessment in Area 2B.

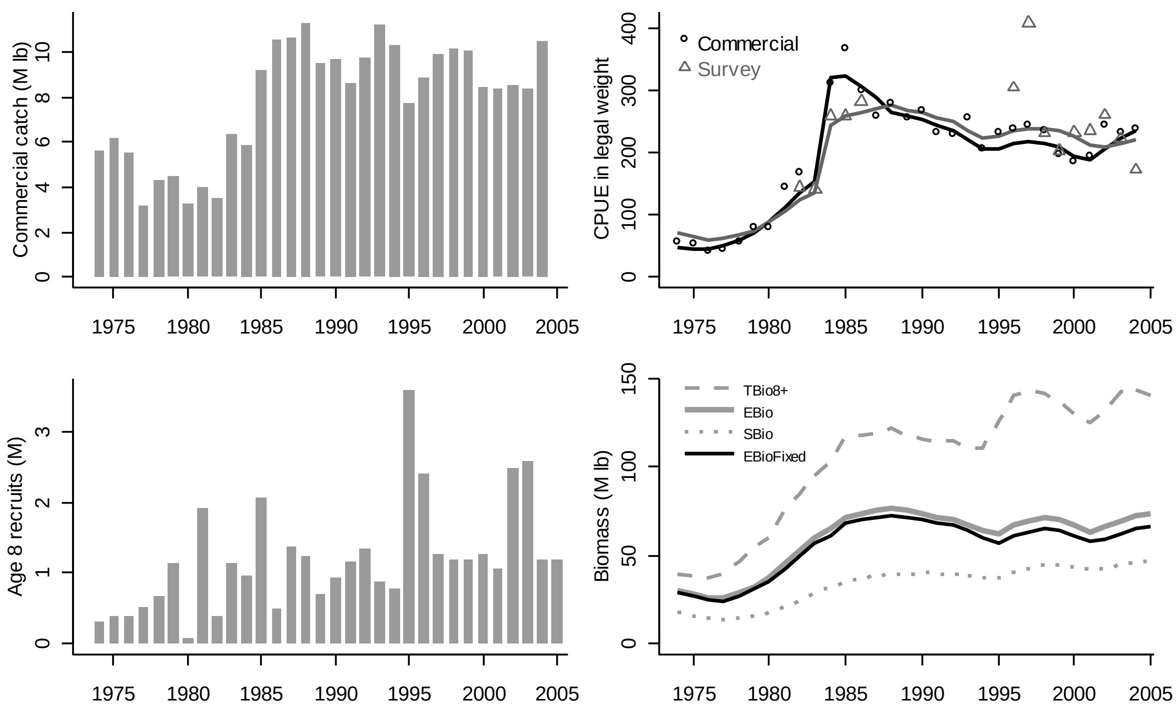

Figure 2b. Features of the 2004 assessment in Area 2C.

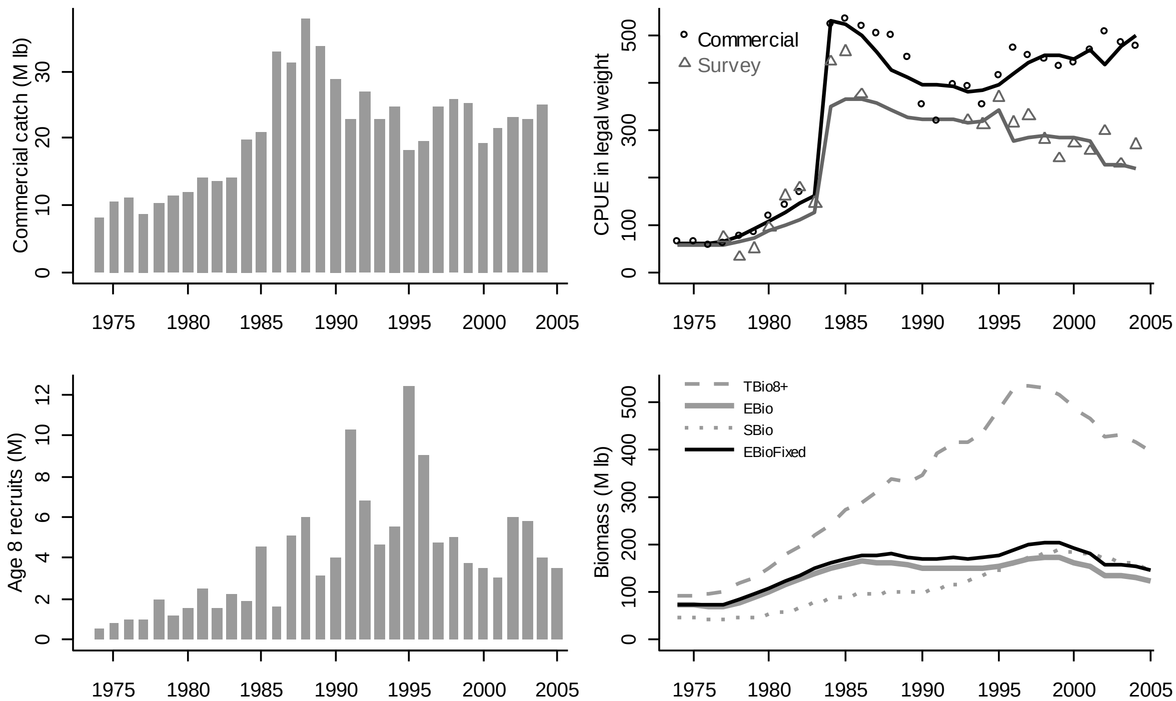

Figure 2c. Features of the 2004 assessment in Area 3A.

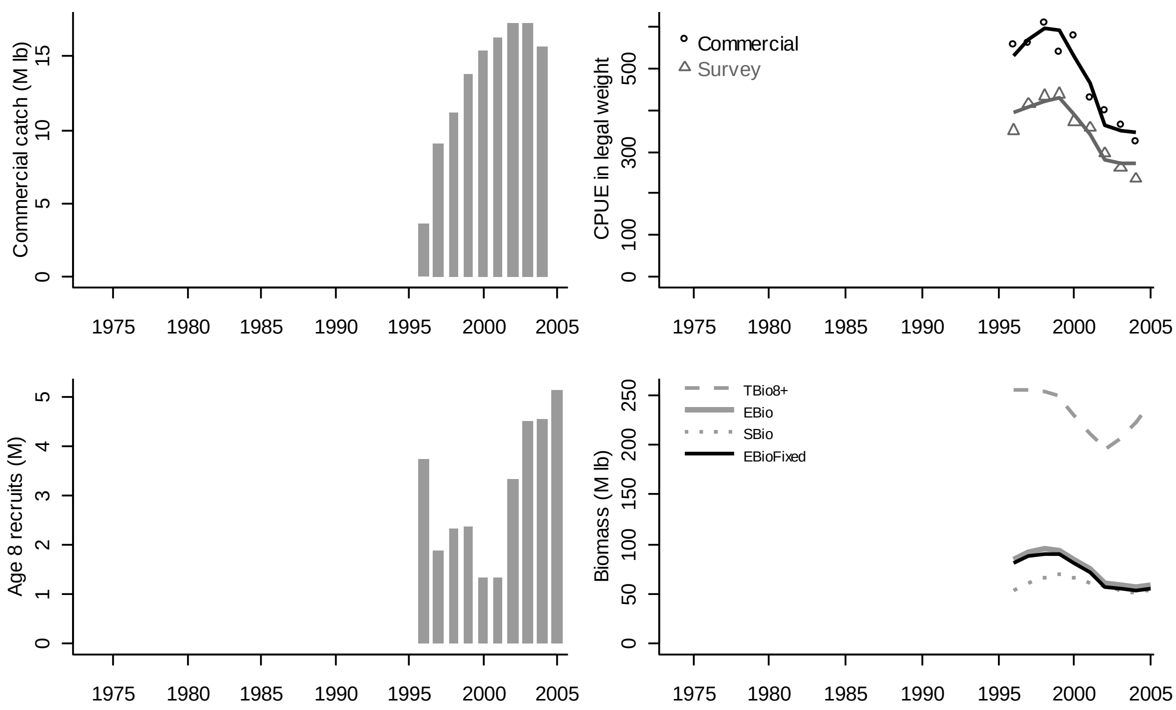

Figure 2d. Features of the 2004 assessment in Area 3B.

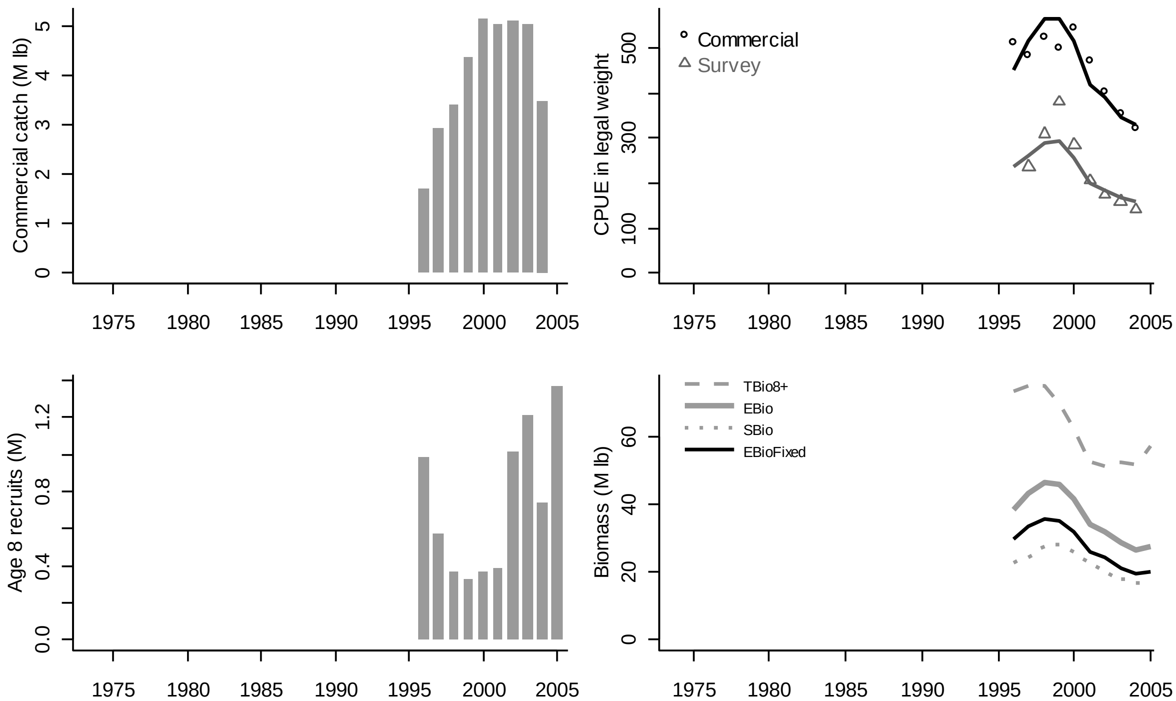

Figure 2e. Features of the 2004 assessment in Area 4A.

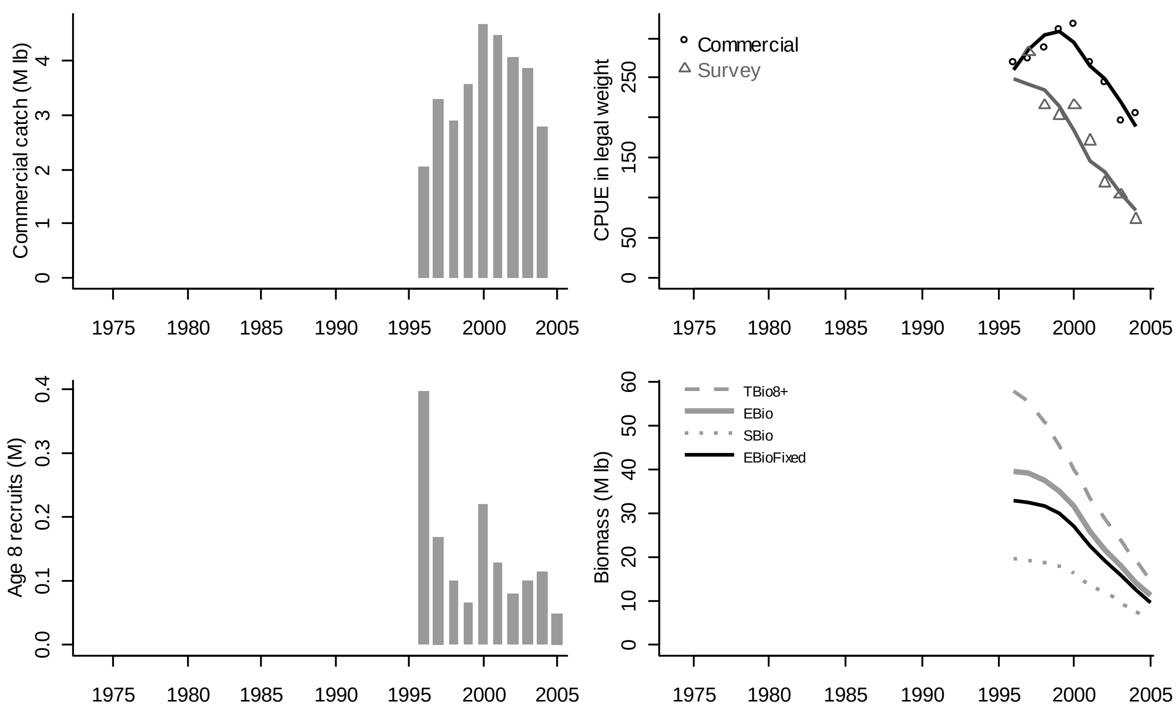

Figure 2f. Features of the 2004 assessment in Area 4B.

Features of the 1982 assessment in Area 3A

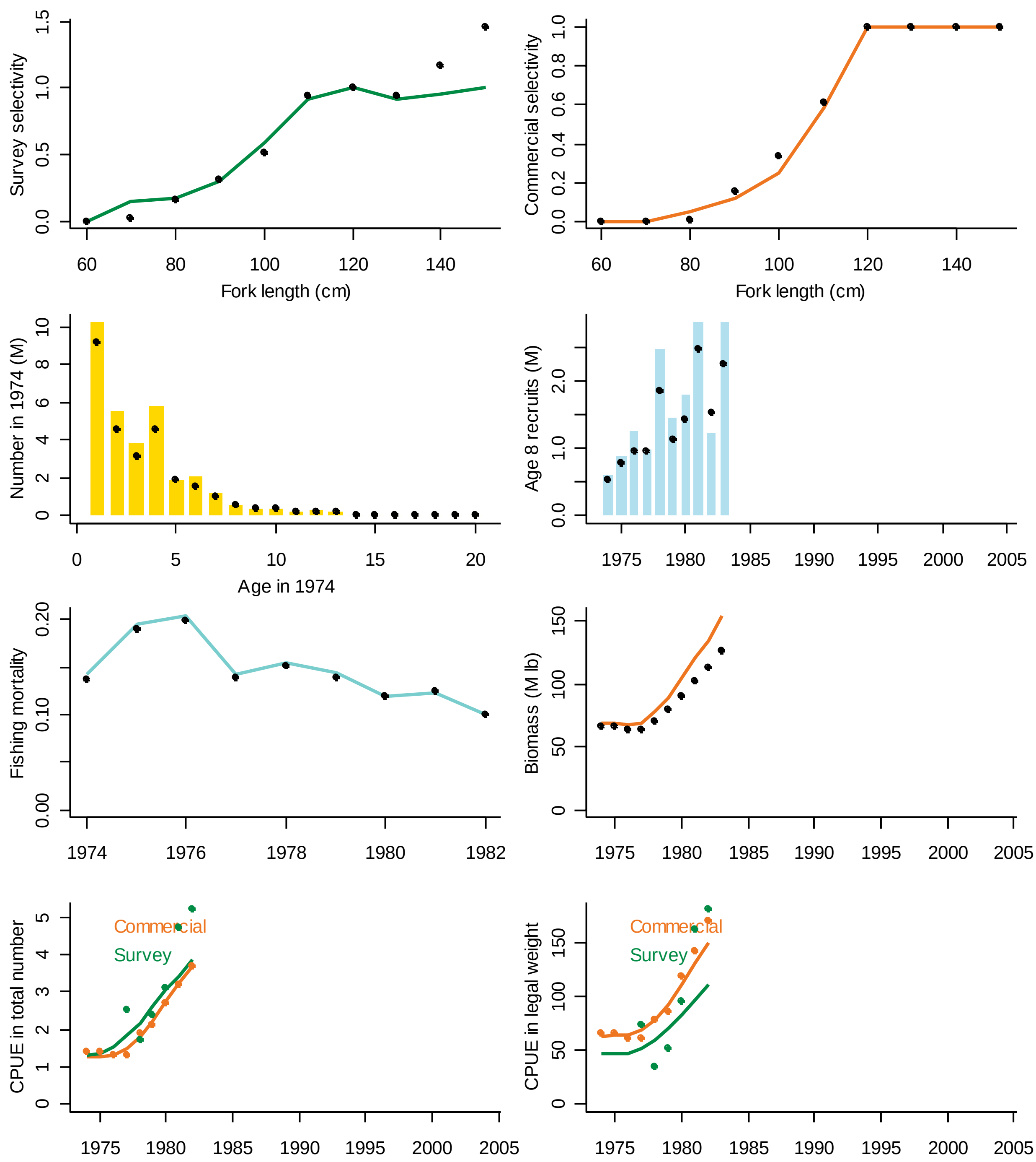

Figure 3a. Estimates of the stock in Area 3A in 1982 from a 1974-1982 fit (lines in upper six panels) and this year's 1974-2004 fit (points in upper six panels). In the bottom two panels the points are observed values and the lines are predictions from the 1974-1982 fit.

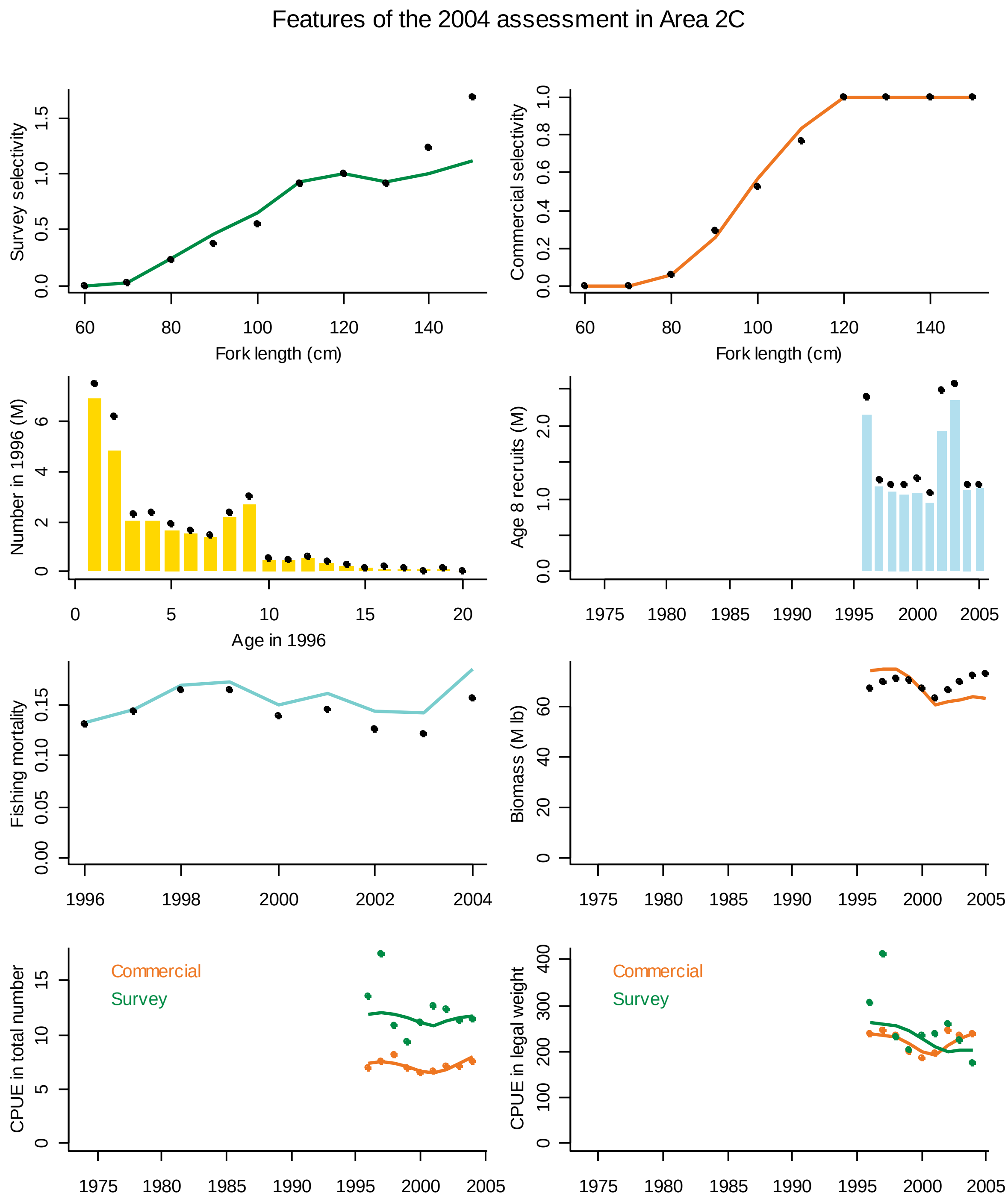

Figure 3b. Estimates of the stock in Area 2C in 2005 from a 1996-2004 fit (lines in upper six panels) and this year's 1974-2004 fit (points in upper six panels). In the bottom two panels the points are observed values and the lines are predictions from the 1996-2004 fit.

Features of the 2004 assessment in Area 2B

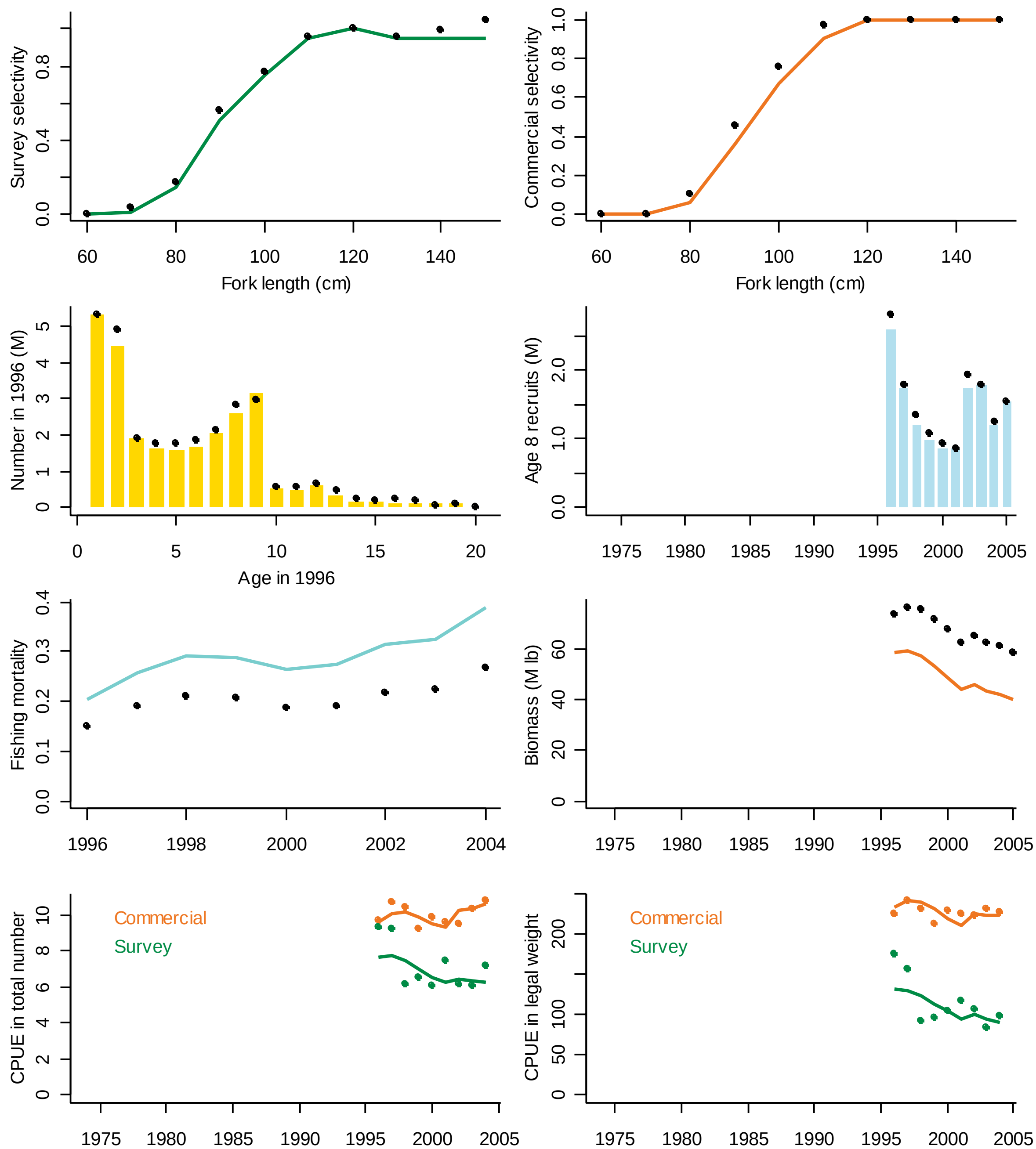

Figure 3c. Estimates of the stock in Area 2B in 2005 from a 1996-2004 fit (lines in upper six panels) and this year's 1974-2004 fit (points in upper six panels). In the bottom two panels the points are observed values and the lines are predictions from the 1996-2004 fit.

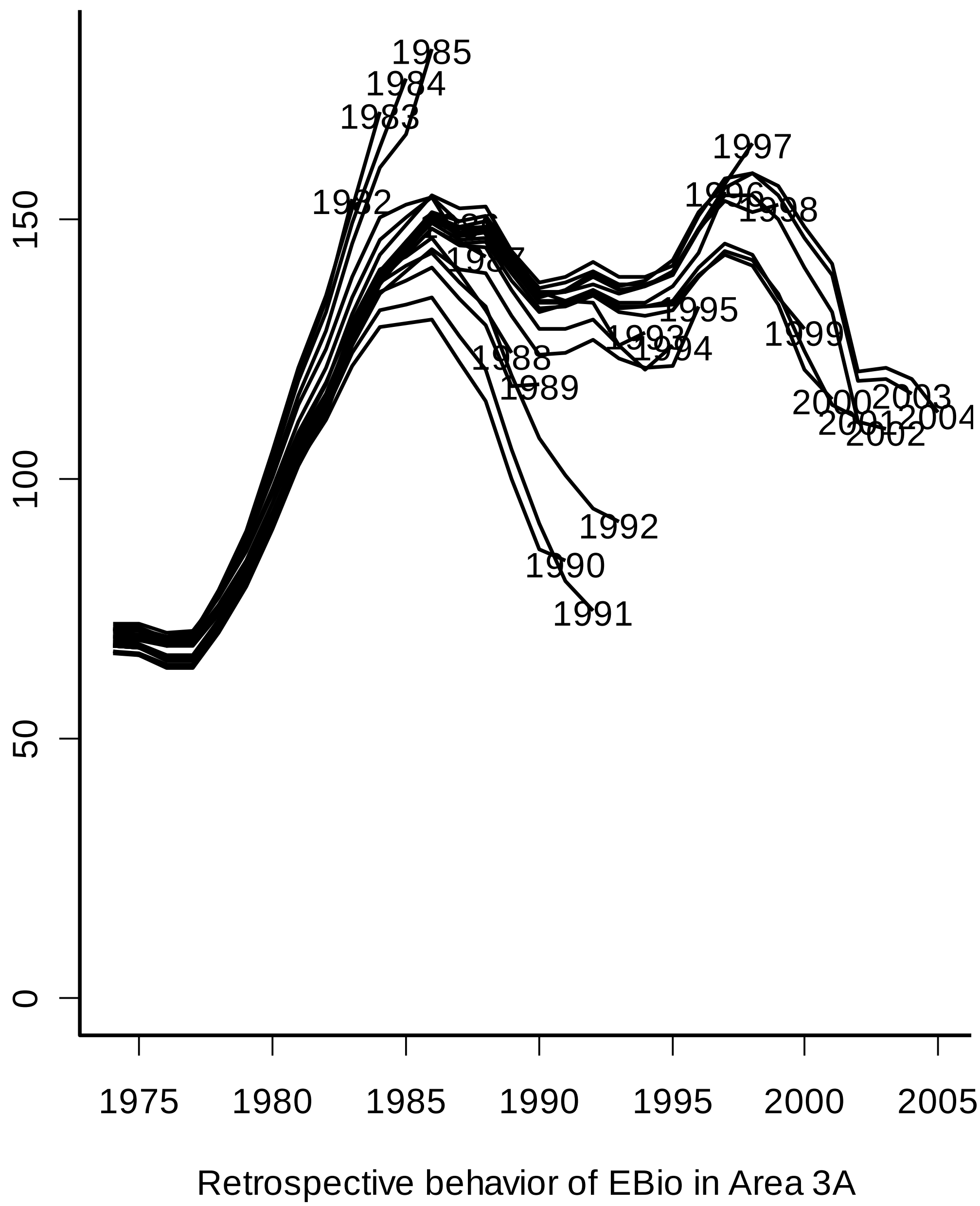

Figure 4. Retrospective behavior of estimates of exploitable biomass by the 2004 assessment model.

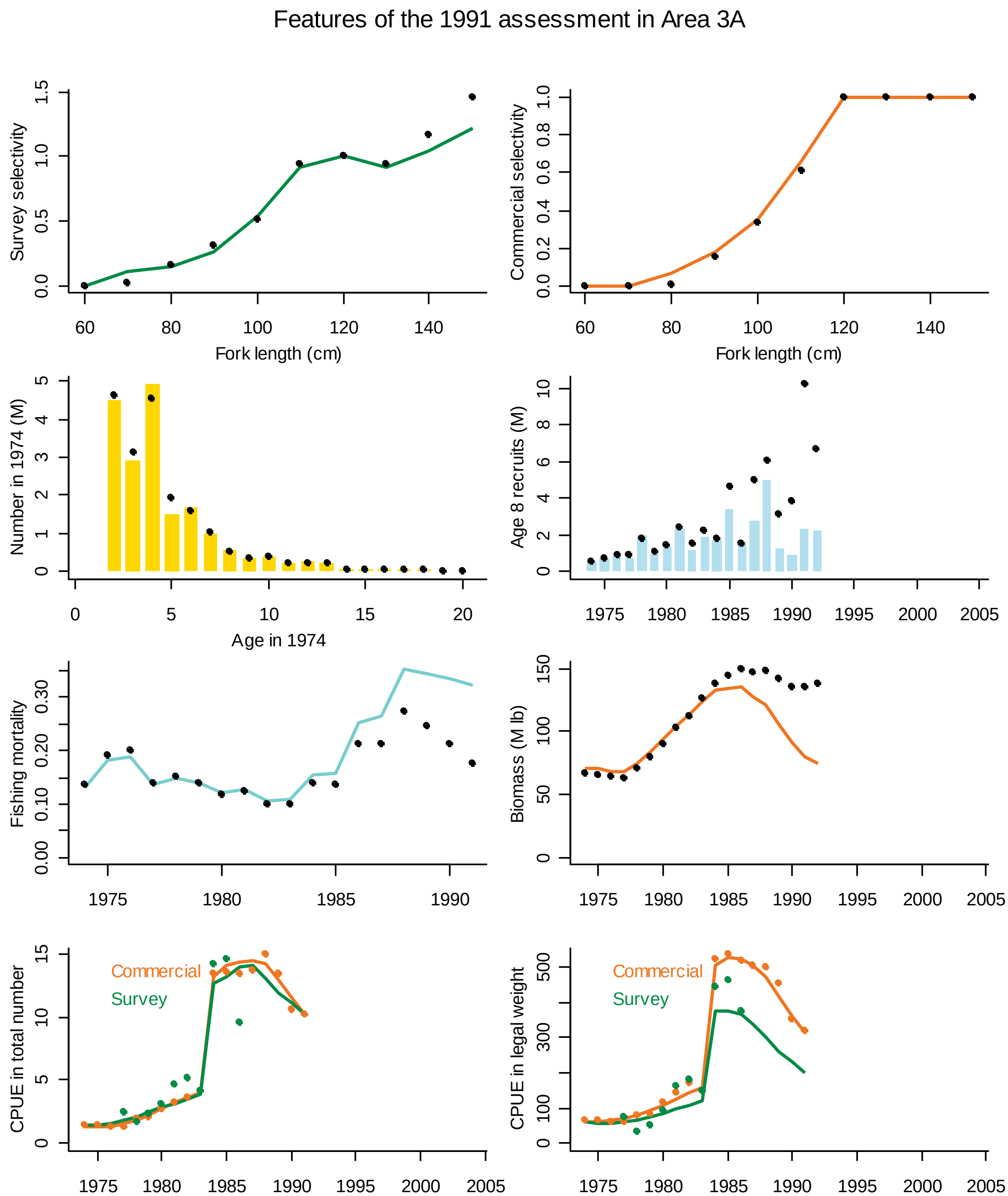

Figure 5. Estimates obtained by fitting the assessment model to data from 1974-1991 (lines in the upper sex panels) and to the full 1974-2004 data set (points in the upper six panels). In the bottom two panels the points are observed CPUE values and the lines are predictions from the 1974-1991 model fit.

Appendix A. Selected fishery and survey data summaries.

Table A1. Commercial catch (million pounds, net weight). Figures include IPHC research catches. Sport catch in Areas 2A and 2B is *not* included in this table.

	2A	2B	2C	3A	3B	4	4A	4B	4C	4D	4E	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
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	0.26	5.44	6.38	14.14	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	11.22	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	0.11	69.47
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	33.74	7.84	---	1.02	2.65	0.57	0.67	0.01	66.95
1990	0.32	8.57	9.73	28.85	8.69	---	2.50	1.33	0.53	1.00	0.06	61.60
1991	0.36	7.19	8.69	22.93	11.93	---	2.26	1.51	0.68	1.44	0.10	57.08
1992	0.44	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	0.72	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	9.54	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	13.84	---	4.37	3.57	1.76	1.89	0.26	74.31
2000	0.48	10.81	8.44	19.27	15.41	---	5.16	4.69	1.74	1.93	0.35	68.29
2001	0.68	10.29	8.40	21.54	16.34	---	5.01	4.47	1.65	1.84	0.48	70.70
2002	0.85	12.07	8.60	23.13	17.31	---	5.09	4.08	1.21	1.75	0.56	74.66
2003	0.82	11.79	8.41	22.75	17.23	---	5.02	3.86	0.89	1.96	0.42	73.19
2004	0.89	12.16	10.30	25.05	15.61	---	3.48	2.71	0.96	1.67	0.31	73.13

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

	2A	2B	2C	3A	3B	4	4A	4B	4CDE	Total
1974	0.252	0.900	0.371	4.477	2.816	1.892	---	---	---	10.708
1975	0.252	0.902	0.451	2.610	1.661	1.097	---	---	---	6.973
1976	0.252	0.941	0.503	2.741	1.944	1.181	---	---	---	7.562
1977	0.254	0.725	0.407	3.366	1.544	1.976	---	---	---	8.272
1978	0.253	0.551	0.213	2.441	1.308	3.400	---	---	---	8.166
1979	0.253	0.694	0.638	4.488	0.688	3.446	---	---	---	10.207
1980	0.253	0.514	0.418	4.927	0.870	5.713	---	---	---	12.695
1981	0.252	0.533	0.403	3.989	1.096	4.369	---	---	---	10.642
1982	0.252	0.299	0.199	3.197	1.683	2.944	---	---	---	8.574
1983	0.253	0.291	0.200	2.083	1.218	2.472	---	---	---	6.517
1984	0.252	0.516	0.211	1.508	0.919	2.291	---	---	---	5.697
1985	0.252	0.548	0.201	0.797	0.341	2.246	---	---	---	4.385
1986	0.253	0.558	0.202	0.674	0.197	2.617	---	---	---	4.501
1987	0.253	0.793	0.202	1.588	0.396	2.674	---	---	---	5.906
1988	0.253	0.773	0.202	2.126	0.042	3.273	---	---	---	6.669
1989	0.253	0.720	0.202	1.805	0.437	1.944	---	---	---	5.361
1990	0.253	1.029	0.674	2.633	1.215	---	0.625	0.335	2.385	9.149
1991	0.253	1.221	0.546	3.126	1.035	---	0.731	0.236	2.237	9.385
1992	0.276	1.017	0.574	2.644	1.116	---	0.724	0.655	1.937	8.943
1993	0.276	0.651	0.333	1.919	0.466	---	0.140	0.479	1.407	5.671
1994	0.276	0.571	0.396	2.352	0.848	---	1.197	0.536	1.820	7.996
1995	0.381	0.705	0.219	1.460	0.825	---	1.087	0.149	2.116	6.942
1996	0.473	0.166	0.233	1.403	0.960	---	0.594	0.459	2.991	7.279
1997	0.473	0.109	0.240	1.549	0.729	---	0.844	0.198	2.964	7.106
1998	0.834	0.117	0.238	1.471	0.731	---	1.193	0.327	2.725	7.636
1999	0.761	0.107	0.230	1.283	0.743	---	0.909	0.336	2.642	7.011
2000	0.634	0.128	0.254	1.286	0.646	---	0.808	0.580	2.279	6.615
2001	0.645	0.149	0.184	1.617	0.632	---	0.574	0.387	2.900	7.088
2002	0.286	0.152	0.166	1.073	0.719	---	0.534	0.196	2.735	5.861
2003	0.355	0.133	0.144	1.177	0.500	---	0.515	0.219	2.105	5.148
2004	0.367	0.140	0.149	1.520	0.393	---	0.516	0.294	1.915	5.294

Table A3. Commercial CPUE (net pounds per skate).

Values before 1984 are raw J-hook catch rates, with no hook correction. 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.

	2A	2B	2C	3A	3B	4A	4B	4C	4D	4E
J-hook CPUE:										
1974	59	64	57	65	57	---	---	---	---	---
1975	59	68	53	66	68	---	---	---	---	---
1976	33	53	42	60	65	---	---	---	---	---
1977	83	61	45	61	73	---	---	---	---	---
1978	39	63	56	78	53	---	---	---	---	---
1979	50	48	80	86	37	---	---	---	---	---
1980	37	65	79	118	113	---	---	---	---	---
1981	33	67	145	142	160	158	99	110	---	---
1982	22	68	167	170	217	103	---	91	---	---
1983	---	---	---	---	---	---	---	---	---	---
C-hook CPUE:										
1984	63	148	314	524	475	366	161	---	197	---
1985	62	147	370	537	602	333	234	---	330	---
1986	60	120	302	522	515	265	---	427	239	---
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	209	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	257	851	---
1994	93	215	207	353	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	483	275	335	671	---
1998	194	232	236	451	611	525	287	287	627	---
1999	---	213	199	437	538	500	310	270	535	---
2000	263	229	186	443	577	547	318	223	556	---
2001	169	226	196	469	431	474	270	203	511	---
2002	181	222	244	507	399	402	245	148	503	---
2003	184	231	233	487	364	355	196	105	389	---
2004	142	227	239	479	326	321	205	124	456	---

Table A4. 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. 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; J-hook values are raw J-hook catch rates.

	2A	2B	2C	3A	3B	4A	4B	4C	4D	4E
J-hook surveys:										
1974	---	---	---	---	---	---	---	---	---	---
1975	---	---	---	---	---	---	---	---	---	---
1976	---	---	---	---	---	---	---	---	---	---
1977	---	15	---	73	---	---	---	---	---	---
1978	---	21	---	34	---	---	---	---	---	---
1979	---	---	---	51	---	---	---	---	---	---
1980	---	28	---	95	---	---	---	---	---	---
1981	---	18	---	162	---	---	---	---	---	---
1982	---	21	145	180	---	---	---	---	---	---
1983	---	20	142	147	---	---	---	---	---	---
1984	---	28	---	217	---	---	---	---	---	---
C-hook surveys:										
1984	---	64	260	446	---	---	---	---	---	---
1985	---	47	260	466	---	---	---	---	---	---
1986	---	42	283	377	---	---	---	---	---	---
1987	---	---	---	---	---	---	---	---	---	---
1988	---	---	---	---	---	---	---	---	---	---
1989	---	---	---	---	---	---	---	---	---	---
1990	---	---	---	---	---	---	---	---	---	---
1991	---	---	---	---	---	---	---	---	---	---
1992	---	---	---	---	---	---	---	---	---	---
1993	---	105	---	323	---	---	---	---	---	---
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	435	310	216	---	---	---
1999	37	95	204	241	438	382	203	---	---	---
2000	---	104	233	272	373	286	216	---	213	---
2001	41	117	237	256	357	207	171	---	197	---
2002	33	107	261	299	297	174	119	---	257	---
2003	22	84	223	229	262	159	104	---	195	---
2004	27	99	173	271	236	142	73	---	132	---