

Assessment of the Pacific halibut stock at the end of 2005

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Abstract

This year's assessment uses the same methods as last year's to estimate exploitable biomass in all areas except Area 4CDE, where an estimate based on the NMFS trawl survey is reported for the first time. The new estimate is the same as what the old estimation method would have produced. Coastwide exploitable biomass is little changed. Fishery CEY in Areas 4B and 4CDE is lower because of the adoption of a lower harvest rate in those areas.

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 Area 2A is estimated by applying a survey-based estimate of relative abundance to the analytical estimate of biomass in Area 2B. In Area 4CDE the estimate of exploitable biomass is based on the NMFS trawl survey of the eastern Bering Sea shelf.

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 2004

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. 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 2003).

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.

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, 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.

Apart from a few minor and inconsequential corrections and alterations, the 2005 analytical assessment is the same as the 2004 assessment. The only important change in procedure is the use of the NMFS trawl survey to estimate biomass in Area 4CDE where an analytical assessment is not done.

Estimates of exploitable biomass and CEY

Like last year, the model fits in Areas 2B-4B are quite satisfactory (Fig. 1), and the estimates of abundance are little changed in most areas (text table below). The Area 2C estimate is down by about 10% because of a lower commercial CPUE in 2005 and another low survey CPUE in 2005 following last year's 20% drop. The continued decline of both commercial and survey CPUE in Area 3B in 2005 resulted in a substantial downward revision of estimated biomass at

the beginning of 2005, from 56 million pounds in last year's assessment to 40 million in this year's. Estimated biomass at the beginning of 2006 in this year's assessment is higher (45 million) because of strong estimated incoming recruitment.

	2005 biomass 2004 assessment	2005 biomass 2005 assessment	2006 biomass 2005 assessment
Area 2A	7.0	7.5	7.6
Area 2B	58	60	61
Area 2C	66	60	61
Area 3A	146	150	143
Area 3B	56	40	45
Area 4A	20	20	19
Area 4B	10	11	9
Area 4CDE			
Analytical	32	---	---
Trawl survey	---	36	36
Total	395	385	382

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:

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

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 calculated value of the scaling proportion has been 12% or 13% for the last three years, with the alternation between the two adding to the variability of the Area 2A estimate. A working value of 12.5% was adopted this year, with the aim of sticking with it unless and until the calculated value moves very far in either direction.

In last year's assessment, the estimate of biomass in Area 4CDE was calculated by scaling the Area 4A analytical estimate by the same procedure. But lacking setline survey data from the large eastern Bering Sea shelf, the calculation used an assumed setline survey CPUE of 40 lb/skate in all of Area 4CDE, based NMFS trawl survey catch rates and a comparison of trawl and setline survey catch rates at a limited number of stations in Areas 4A and 4C in the mid-1990s. Using this procedure, the estimated biomass in Area 4CDE in last year's assessment was 160% of the Area 4A estimate or 32 million pounds. Because survey CPUE in Area 4A continued to decline in 2005, this year's scaling factor would be 190% and the Area 4CDE estimate would be 36 million pounds. The value shown in the table above is the same, but it is based directly on the most recent NMFS trawl survey results as explained below.

Total CEY (Table 1) is calculated by applying a harvest rate of 22.5% in Areas 2A, 2B, 2C, and 3A, 20% in Areas 3B and 4A, and 15% in Areas 4B and 4CDE. These are the same rates used last year except in Areas 4B and 4CDE, where the rate has been reduced from 20% to 15% (Hare 2006).

Estimates of Area 4CDE biomass from the NMFS trawl survey

The National Marine Fisheries Service has conducted an annual trawl survey on the eastern Bering Sea shelf (20-200 m) using the same gear and station pattern since 1982. The survey trawl has no rollers, so it fishes hard on bottom. The vertical opening is 3.5 m. Standard survey stations are placed on a 20 nautical mile grid, and the standard survey area extends northward to about 61° N (Fig. 2). NMFS also carries out trawl surveys in the Gulf of Alaska and Aleutian Islands using a high-rise (7 m) trawl equipped with rollers for fishing rougher bottom. In areas where both the NMFS trawl survey and the IPHC setline survey are conducted, the trends in survey catch rates at length agree quite well (Fig. 3). The trawl survey catch rates are somewhat more variable from year to year, but there is no reason to doubt that they provide a reliable index of halibut abundance in trawlable areas.

In NMFS flatfish assessments, the absolute density of fish is estimated from the survey catches and the area swept by the trawl (measured as the distance between the trawl wings multiplied by the distance towed), and this density is multiplied by the entire survey area to estimate absolute biomass. Swept-area estimates of absolute abundance are accurate if the survey trawl catches all of the fish in the path of the trawl. They can be low if fish avoid capture by outswimming the trawl or by passing over the headrope or under the footrope. On the other hand, they can be high if the trawl bridles herd fish into the path of the net, or if fish are actually attracted to the vessel.

Albert et al. (2003) observed the behavior of Greenland turbot in the path of a trawl with a video camera. They suspected that some larger fish escaped ahead of the trawl, but they did not observe any do so, and all of the fish that they did sight were overtaken by the trawl within seconds. None swam over the headrope. Handegaard and Tjostheim (2005) tracked the movements of cod in the path of an approaching trawl with a split-beam sonar, beginning at a range of 2-4 km. Fish were seen to dive slowly as the ship approached, and were seen to be herded to both sides by the trawl warps, but movement along the line of the ship's travel was slight, indicating that in this case fish did not escape in front of the trawl. Some fish did appear to be attracted by the ship, moving toward the ship's path. The authors speculate that the fish were attracted to the lower levels of propeller noise forward and aft of the ship. Krieger and Sigler (1996) visually determined the density of rockfish in the path of a trawl from a submersible. Even though the vertical distribution of the rockfish extended well above the headrope, the trawl estimate of density exceeded the visual estimate. The authors believed that both diving and herding played some role.

Somerton and Munro (2001) carried out a careful study of the degree of herding by the bridles of the NMFS Bering Sea survey trawl on seven species of flatfish, not including halibut. They found that because of herding, the trawl caught 120-140% of the fish in the path of the net, depending on species. For five of the seven species, herding was independent of fish length. For two it decreased with length. Munro and Somerton (2002) studied escapement under the footrope of the survey trawl and found it to be negligible for all flatfish studied (not including halibut) except for yellowfin sole. In a similar study of escapement under the footrope of the roller trawl used by NMFS for other surveys, no halibut were observed to escape under the footrope (Weinberg et al. 2002).

In nearly all NMFS flatfish assessments, survey trawl selectivity is assumed to be asymptotic, with the lower catchability of smaller fish due mainly to their distribution in shallow

water outside the survey area rather than to lower vulnerability to capture by the trawl (which has a small-mesh liner). For the same sizes of fish, halibut selectivity should be the same, increasing with length and then not decreasing up to the largest sizes observed among other flatfish species, say 100 cm. But it may decrease among the largest fish. Clark (1993) estimated the selectivity of the roller trawl used in other surveys and found that for halibut it peaked at 65 cm and then declined gradually, reaching 50% at 120 cm. But that study assumed asymptotic selectivity in the IPHC setline survey, whereas more recently it has been found that setline survey selectivity continues to increase beyond 120 cm.

Commercial setline selectivity is well determined in the assessment, and we can use that to estimate the true length composition in any area by scaling up the commercial length composition. The survey trawl selectivity can then be calculated from the trawl survey length composition. There is not enough overlap between the commercial fishery and the trawl survey to do that in Area 4CDE, but we can do the calculations for Area 3A, 3B, and 4A which are surveyed by the roller trawl. That yields the trawl selectivity estimates below.

Length	Area 3A	Area 3B	Area 4A	Median
85	0.28	0.89	1.00	0.89
95	0.70	1.00	0.94	0.94
105	0.84	0.90	0.74	0.84
115	1.00	0.74	0.89	0.89
125	0.89	0.47	0.89	0.89
135+	0.56	0.59	1.00	0.59

The numbers are not very consistent among areas but on the whole they suggest little change in selectivity with length up to at least 125 cm, which covers the bulk of fish in the stock nowadays. These numbers do refer to the roller trawl, which has a larger vertical opening, but that should not be an issue because flatfish generally stay near bottom throughout the process of being captured by a trawl (King et al. 2004).

For estimating halibut biomass in Area 4CDE, we assume no decrease in selectivity with length, and we assume that because of herding the trawl catches 130% of the fish in the path of the net, the midpoint of the NMFS estimates for other flatfish. Both assumptions are conservative. With these estimates of total abundance at length, we can calculate exploitable biomass by applying the fixed length-specific commercial setline selectivity schedule used in all Alaska areas.

The estimates for each of the trawl survey strata vary substantially from year to year, but the total for the shelf survey has been quite stable at an average of 40 million pounds over the last five years. Of that total, about 10% is in stratum 5, which is mostly in Area 4A, so the Area 4CDE estimate is 36 million pounds, which by happenstance is exactly the number that we would have calculated with the old estimation procedure. Of the entire shelf biomass, about 50% is in Area 4D, about 30% in Area 4E and the Closed Area, 10% in Area 4C, and 10% in Area 4A.

NMFS also conducts a trawl survey of the eastern Bering Sea slope (Hoff and Britt 2005), but the exploitable biomass estimate for 2004 was less than 5 million pounds, and almost half was in the Area 4A sector. We have chosen to treat this component as negligible, mainly for simplicity.

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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
2005 catch limit ¹	1.33	13.25	10.93	25.47	13.15	3.44	2.26	3.99	73.82
2005 exploitable biomass (2004 assessment)	7.0	58	66	146	56	20	10	32	395
2006 exploitable biomass (2005 assessment)	7.6 ²	61	61	143	45	19	9	36 ³	382
Other removals									
Sport catch	0.49	1.46	2.54	5.44	0.01	0.04	0.00	0.00	9.98
Legal-sized bycatch	0.17	0.19	0.14	1.32	0.36	0.46	0.28	2.21	5.13
Personal use	0.04	0.30	0.68	0.40	0.03	0.03	0.00	0.07	1.55
Legal-sized wastage	0.01	0.04	0.04	0.08	0.03	0.02	0.00	0.01	0.23
Total	0.71	1.99	3.40	7.24	0.43	0.55	0.28	2.29	16.89
...excluding sport catch	0.22	0.53	---	---	---	---	---	---	
Total CEY ⁴	1.71	13.73	13.73	32.18	9.00	3.80	1.35	5.40	80.90
Fishery CEY ¹	1.49	13.20	10.33	24.94	8.57	3.25	1.07	3.11	65.96

Notes:

1. 2005 catch limit and 2006 fishery CEY include sport catch in Areas 2A and 2B.
2. Area 2A exploitable biomass estimated as 12.5% of Area 2B (12% last year).
3. Area 4CDE exploitable biomass estimate based on NMFS trawl survey for the first time.
4. Total CEY is 22.5% of exploitable biomass in Areas 2A, 2B, 2C, and 3A; 20% in Areas 3B and 4A; 15% in Areas 4B and 4CDE.

Features of the 2005 assessment in Area 2B

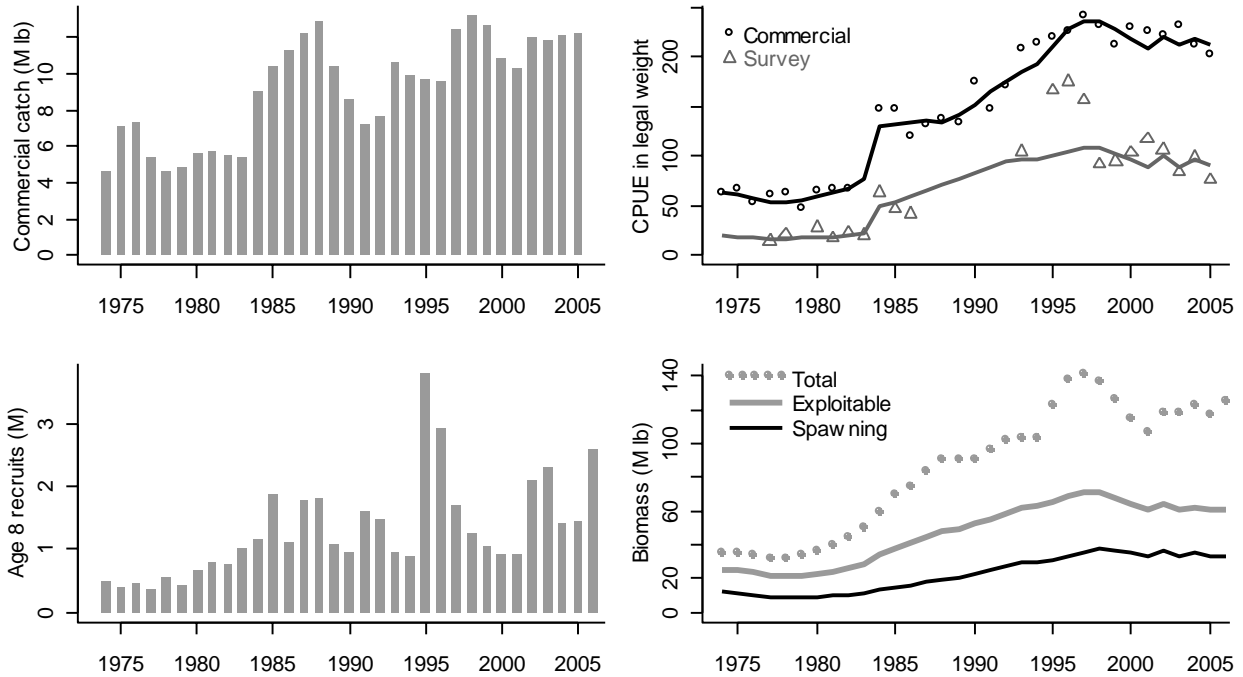


Figure 1a. Features of the 2005 assessment in Area 2B.

Features of the 2005 assessment in Area 2C

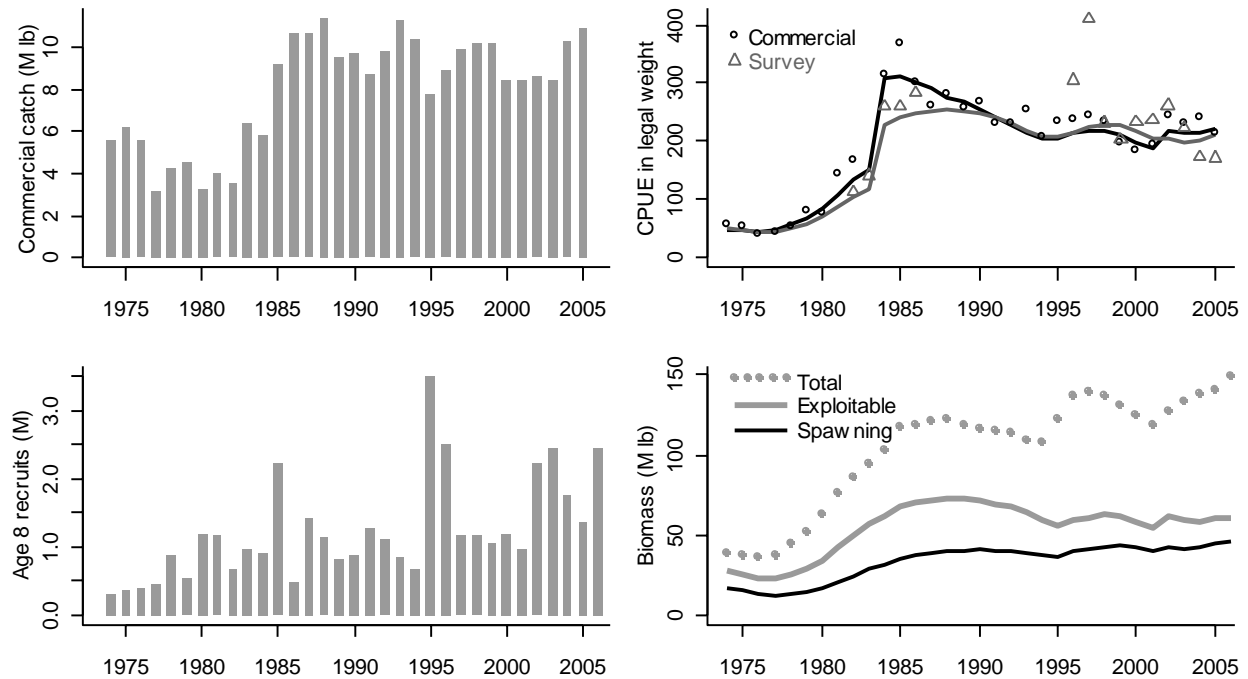


Figure 1b. Features of the 2005 assessment in Area 2C.

Features of the 2005 assessment in Area 3A

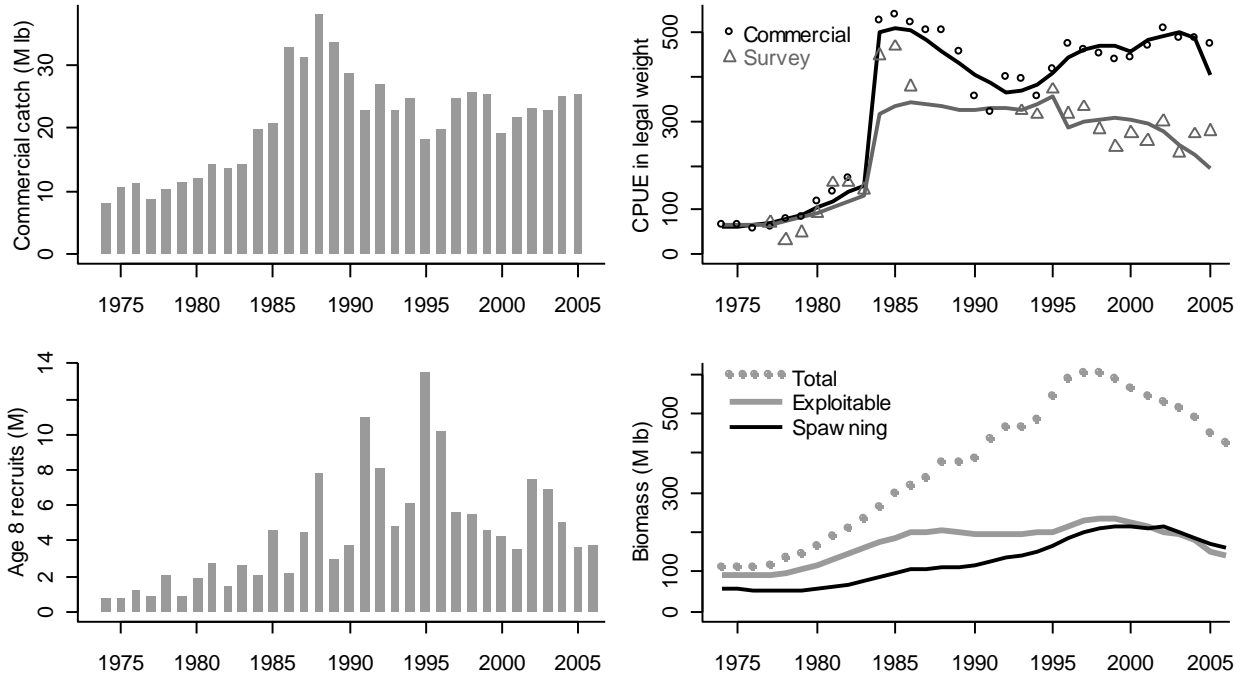


Figure 1c. Features of the 2005 assessment in Area 3A.

Features of the 2005 assessment in Area 3B

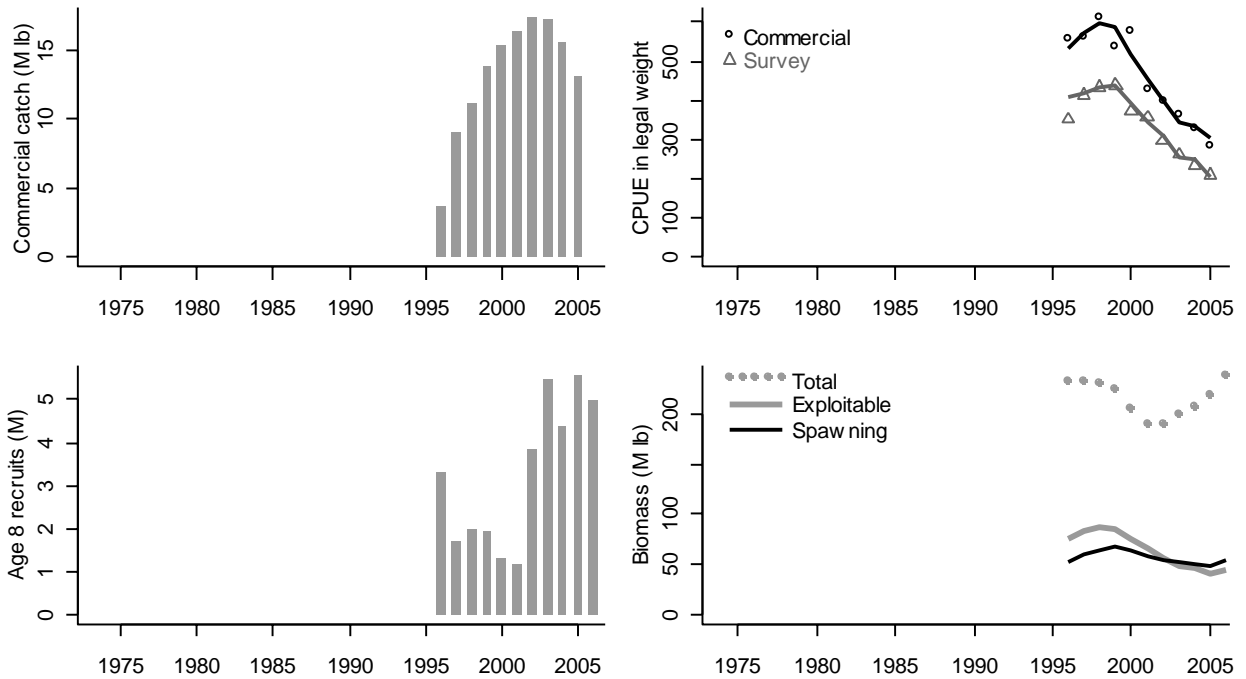


Figure 1d. Features of the 2005 assessment in Area 3B.

Features of the 2005 assessment in Area 4A

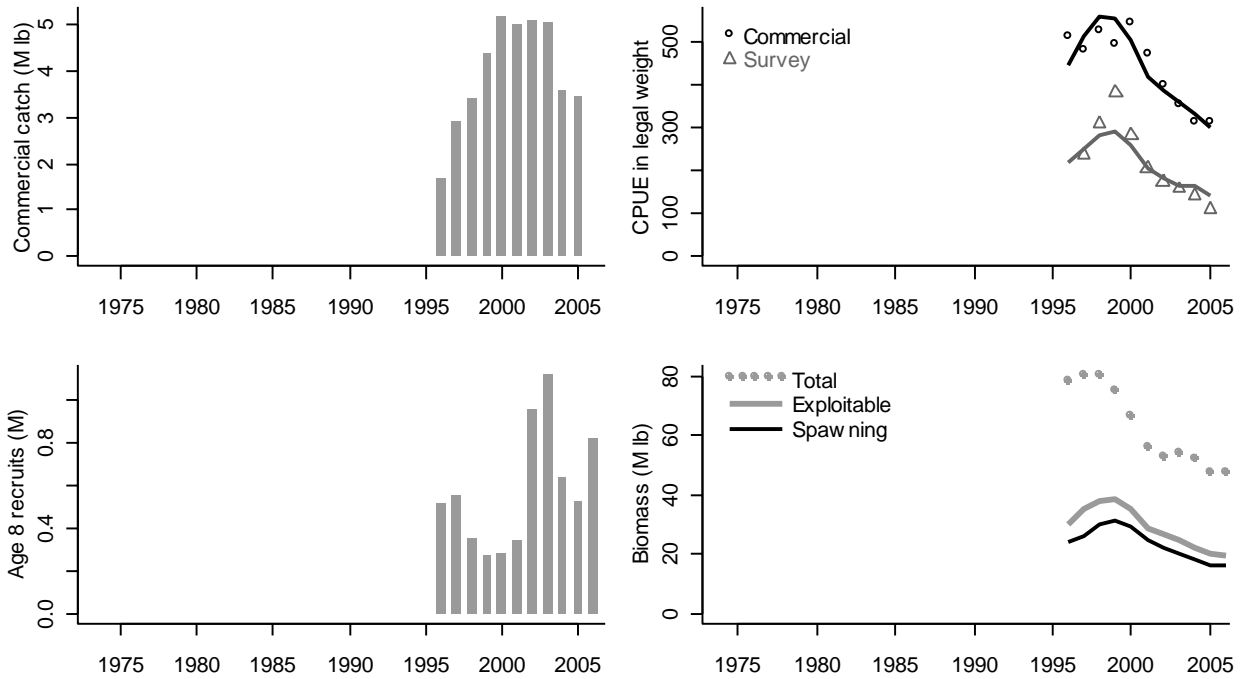


Figure 1e. Features of the 2005 assessment in Area 4A.

Features of the 2005 assessment in Area 4B

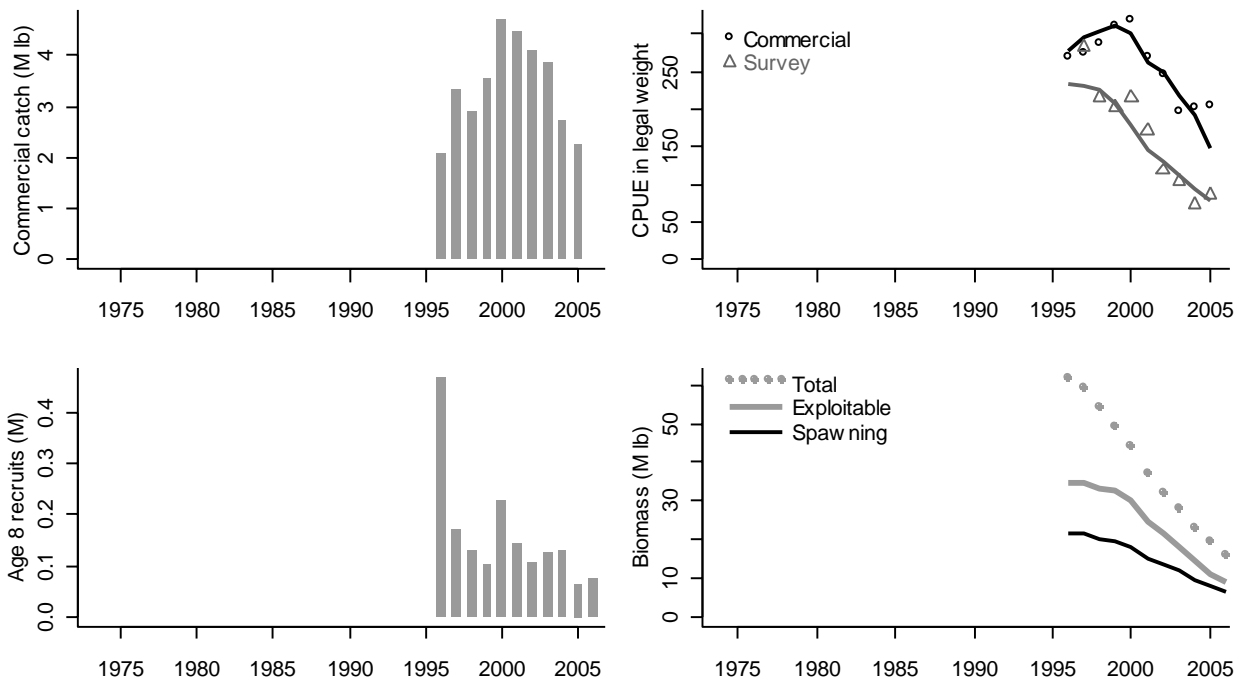


Figure 1f. Features of the 2005 assessment in Area 4B.

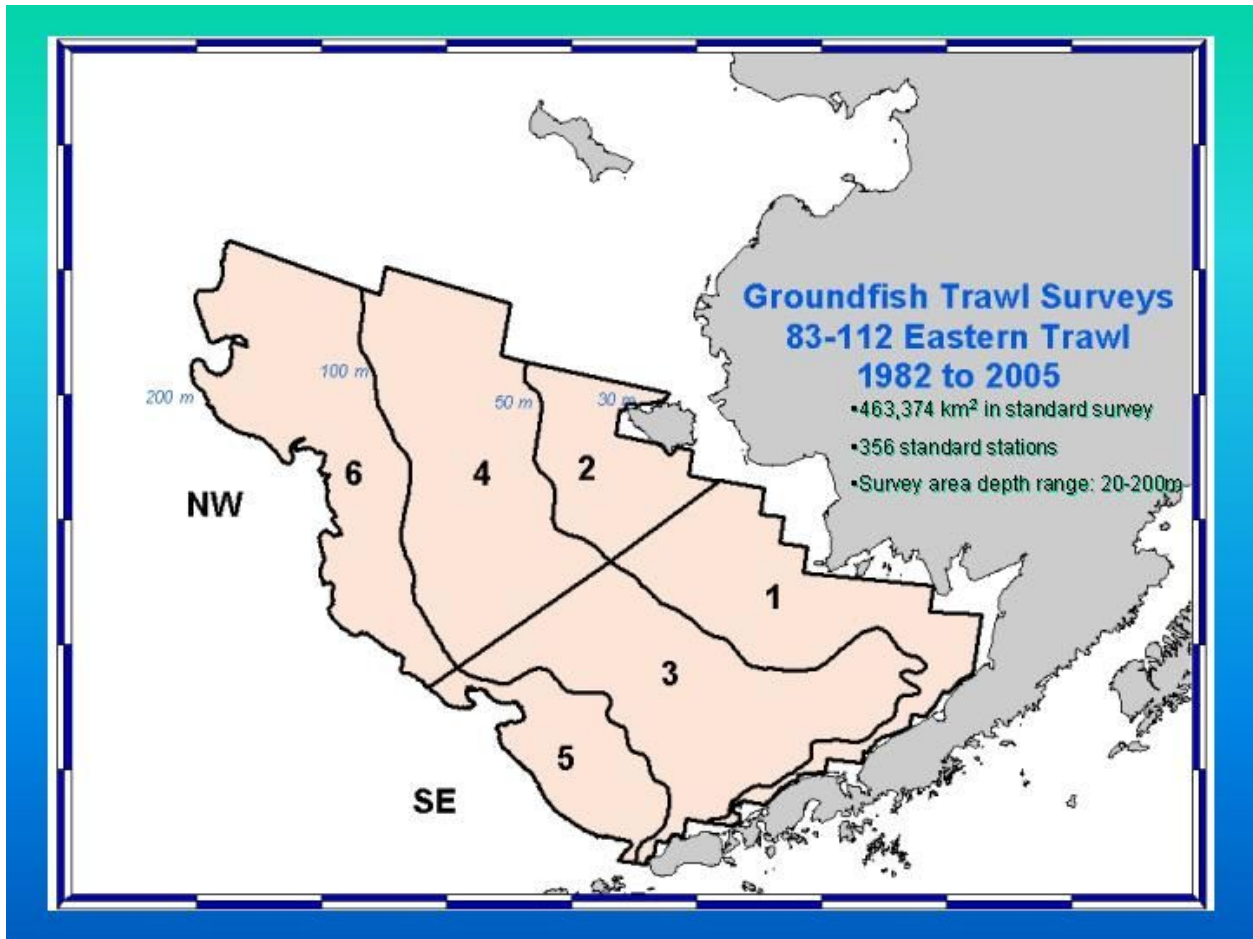


Figure 2. Coverage of the NMFS trawl survey in the eastern Bering Sea.

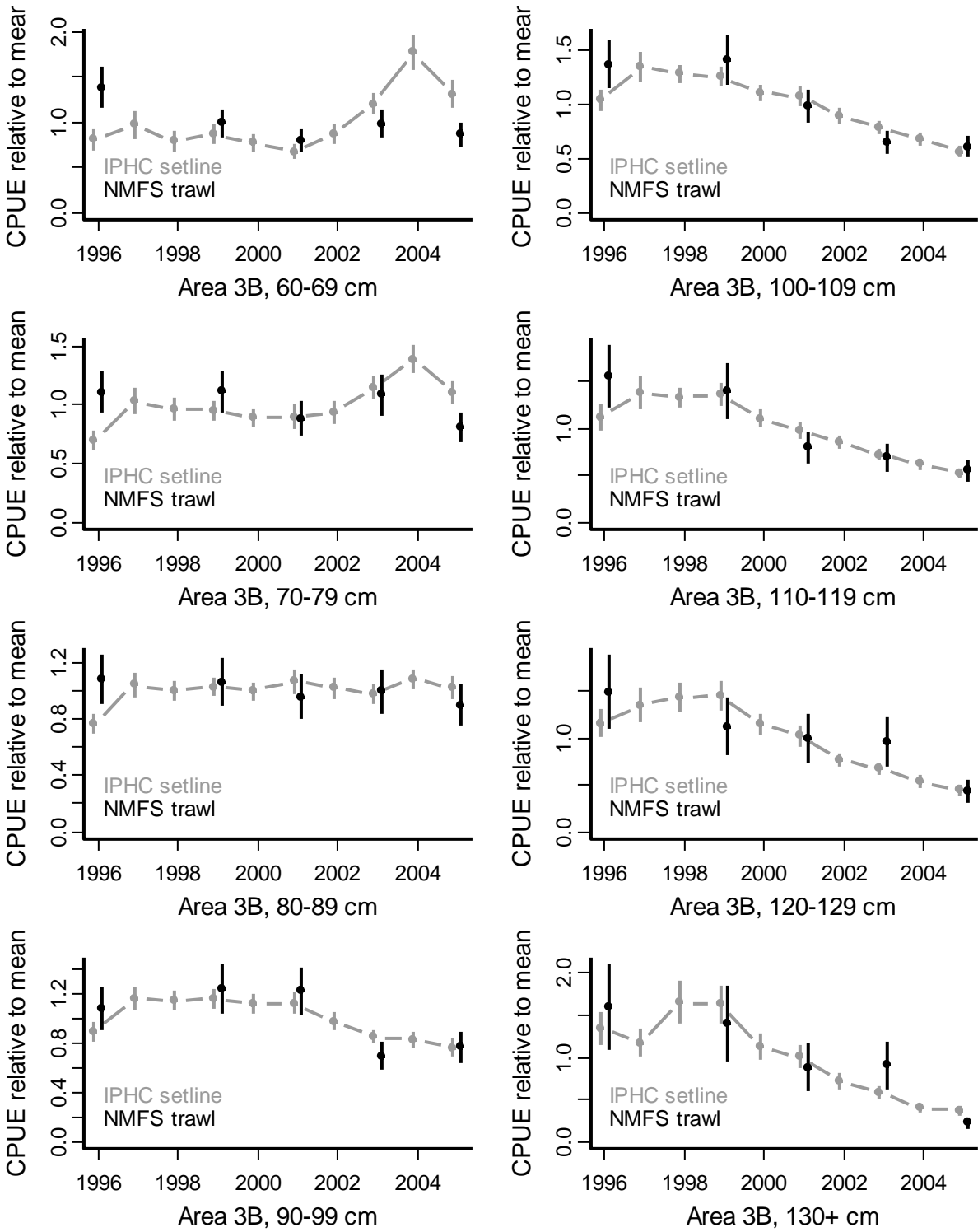


Figure 3. Trends in setline and trawl survey CPUE at length in Area 3B.

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	0.88	12.16	10.23	25.17	15.46	---	3.56	2.72	0.95	1.66	0.31	73.11
2005	0.82	12.33	10.64	25.86	13.29		3.40	1.98	0.54	2.58	0.36	71.81

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
2005	0.172	0.191	0.144	1.321	0.360	---	0.456	0.279	2.206	5.129

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	145	212	240	485	328	315	202	120	444	---
2005	---	203	216	473	285	316	206	105	317	---

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	270	236	142	73	---	132	---
2005	28	76	171	276	211	111	86	---	69	---