

Summary of the 2003 stock assessment

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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, going back to 1974. This year for the first time the same model has been fitted to data from Areas 3B, 4A, and 4B, which go back to 1996. Before that there were no surveys conducted in those areas and catch limits were mostly much lower than they have been during the last several years. 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 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.

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.

Features of the 2003 assessment

Length-specific selectivity

The term “selectivity” means relative vulnerability to capture by setline gear. Older and larger fish are more vulnerable than smaller and younger fish, but until last year it was uncertain whether the most important determinant of selectivity was size or age. In the last several years’ assessments selectivity was treated as a function of age because that approach produced lower estimates and was therefore the conservative choice.

The fit of this model to Area 3A data last year showed very poor year-to-year continuity, symptomatic of a wrong description of selectivity in the model. Treating setline survey selectivity as length-specific rather than age-specific largely eliminated the problem. 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).

In this year’s assessment selectivity is treated as an empirical function of observed mean length at age in survey catches. Separate schedules are estimated for commercial and survey catches, but

the same length-specific schedules are used for females and males. Because they differ in mean length at age, the derived age-specific selectivities of females and males are different.

Separate accounting of females and males

In previous years, the assessment model was a standard age-structured model of the stock, with the estimated number at each age in each year being the combined number of females and males. This was adequate when selectivity was treated as a function of age, but not now when selectivity is treated as a function of length, because females are larger at each age. More importantly, estimating abundance by sex provides estimates of the higher fishing mortality rates sustained by females and estimates of female spawning biomass. The staff was particularly concerned that size-selective fishing combined with the decline in size at age over the last several years could have resulted in a decrease in fishing mortality on males at the expense of females, and therefore a drop in female spawning biomass. As reported below, the sex-specific assessment shows that female spawning biomass is still well above the historical minimum that last occurred in the mid-1970s.

We have sampling data on the sex composition of survey catches but not commercial landings. The latter could be estimated internally by fitting the model to survey catch at age/sex and commercial catch at age only, but the survey sex ratio at age is in fact quite variable, so it was decided to estimate commercial sex composition external to the model and use the external estimates of commercial catch at age/sex as model data. It turned out to be quite feasible to use smoothed functional estimates of sex ratio at length within age in survey catches to key out the commercial length distributions at age to sex (Clark 2004a).

Explicit allowance for the bias and variance of age readings

For many years, the ages of halibut (and other species) were determined by counting the annuli seen when viewing the surface of the whole otolith. This method is reliable through about age 15 but thereafter underestimates the true age by an increasing margin. The true age can be determined by breaking and burning the otolith and counting rings as viewed on a cross section. The bias of surface readings can be corrected in the assessment by doing all the calculations with fish grouped by true age and then predicting and fitting the observed distribution of surface readings. The variance of both surface and break-and-burn readings can be handled the same way (Clark 2004b). Figure 1 shows how the same age composition would appear in the model calculations, as an observed surface age reading distribution, and as an observed break-and-burn age reading distribution.

Analytical (model-based) estimates of abundance in Areas 3B, 4A, and 4B

Estimating abundance by fitting an age-structured model requires a sufficiently long series of survey data that the decline of several year-classes can be tracked as they pass through the fishery, and sufficiently large catches that fishing mortality is a substantial fraction of total mortality. Lacking that kind of data, abundance in Areas 3B and 4 has been estimated with a survey-based method, wherein an index of abundance in all areas was computed by multiplying average survey CPUE by total bottom area, and the biomass in, for example, Area 3B was estimated by multiplying the model-based estimate of Area 3A biomass by the ratio of the Area 3B and Area 3A survey-based index values.

Surveys began in 1996 in Area 3B, and in 1997 in Areas 4A and 4B. Catch limits were raised substantially in 1997 and have remained at that higher level since. So we now have 7-8 years of

survey data and higher catches, which in conjunction with this year's very simple length-based assessment model makes it possible to fit the model and obtain analytical estimates in those areas. In Areas 2A and 4CDE the survey-based method is still used.

Quality of model fits

The fitted model uses the same parameter values (natural mortality, survey and commercial catchabilities, and length-specific selectivities) for females and males. It is therefore very parsimonious, but it nonetheless predicts the catch at age of females and males very well (Fig. 2). This is remarkable because mean size at age differs greatly between the sexes and has declined substantially for both during the period covered by the model fit (Fig. 3). The derived age-specific selectivities therefore vary tremendously by sex and among years, but the model predictions still do a very good job of tracking not only the age composition of the catch of each sex but also the relative magnitudes of the catches of females and males, which are quite different (Fig. 4). The ability of this simple model to predict the catches by age and sex over such a wide range of observed and predicted values leaves little doubt that variation in size at age accounts for the bulk of variation in selectivity at age.

Effects of model changes on abundance estimates

The 2003 model can be fitted in various ways to show the incremental effect of the new features. Figure 5 shows the effects step by step in Area 2C, where they were largest. Fits are shown with data through 2001 (abundance estimates through 2002) to avoid confusing the effects of model changes with the effects of the change from surface to break-and-burn readings. The quantity plotted is estimated recruitment, which is the fundamental abundance estimate in any assessment.

The baseline at the bottom of Figure 5 shows the series of recruitment estimates from last year's assessment model, which had fixed age-specific survey selectivities and drifting age-specific commercial selectivities. The line above that shows the effect of switching to fixed length-specific survey and commercial selectivities but not treating females and males separately. (In this fit the calculations are actually performed separately for each sex, but age-specific selectivity is determined by the overall mean length at age rather than the mean length at age for each sex, so fishing mortality at age is the same for females and males. This model is basically the same as earlier length-specific models used by the staff, and it produces almost the same estimates as the alternative length-specific model reported in last year's assessment.) The next line up shows the added effect of treating females and males separately (i.e., having age- and sex-specific selectivities determined by sex-specific mean length at age). The topmost (black) line shows the added effect of correcting for the bias and variance of surface ages; it is the 2003 assessment model fit. At the left of the graph are the mean 1974-2001 recruitment levels for each model fit. In Area 2C the cumulative change in the mean is a 50% increase. The overall increases in other areas are smaller but still substantial: 20% in Area 2B and 35% in Area 3A.

Length-specific fits have always produced substantially higher estimates of abundance than age-specific fits in Alaska. (The effect has always been much less in British Columbia because the change in size at age was smaller there.) That component of the increase is therefore as expected, and it makes sense that treating the sexes separately would compound the effect, because it intro-

duces a larger variation in length at age. It is somewhat surprising that correcting the ages not only redistributes but also increases the recruitment estimates. That feature must result from an increase in the number of natural deaths that occurs when lifespans are increased by allowing for greater ages and the same natural mortality rate is used.

Estimates of length- and age-specific selectivities

As in previous length-specific model fits, commercial selectivity is estimated to be higher in Area 2B than in Area 3A, with Area 2C intermediate (Fig. 6). The estimates for Areas 3B, 4A, and 4B are similar to the Area 2C estimates.

Because length-specific commercial selectivity appears to have been the same for the last thirty years while mean length at age has declined greatly over the last fifteen years, age-specific commercial selectivity has also declined greatly over the last fifteen years (Fig. 7). Because males in the modal age range (10-15) were less vulnerable to begin with, the relative decline in age-specific selectivity of males has been greater than that of females. In Area 3A, males reached full vulnerability by age 15 in the 1970s and 1980s; now even the oldest males are only about 20% vulnerable, while the oldest females are still fully vulnerable. The same sort of change has occurred elsewhere. Females always sustained higher fishing mortality rates than males because they were larger, but twenty years ago females and males both reached the size of full vulnerability at some point. Males no longer reach that point, so an even larger share of fishing mortality is falling on the females.

Calculation of exploitable biomass

Exploitable biomass is calculated as the fully selected equivalent of all the fully and partially selected age groups (really age/sex groups) in the stock, so it depends on the commercial selectivities that are used to scale the biomass of each group. The 1999-2002 assessments used a set of age-specific selectivities from the 1999 assessment averaged over regulatory areas, called the “fixed coastwide selectivities”. Using a fixed set provided a common measure among areas and years. As shown in Figure 7, these fixed selectivities were a good compromise among areas and between the sexes a few years ago.

They are no longer appropriate, first because they are age-specific rather than length-specific as we now believe to be correct, and second because size at age has declined further since 1999 and the present selectivities are lower than the fixed ones. We therefore need to adopt a new set of length-specific selectivities to calculate exploitable biomass, and it will be lower than the old exploitable biomass, partly because of the decline in size at age since 1999 but mostly because the calculation will be done separately for females and males and the males will contribute less.

It is still desirable to adopt a single coastwide set of selectivities to provide a common measure among areas. Except for Area 3A, all of the regulatory areas in Alaska have selectivity schedules that are close to a line that increases linearly from zero at 80 cm to 1 at 120 cm, so that is a good fixed schedule for those areas. The Area 3A schedule is much lower, but through 120 cm it is a constant fraction (about 70%) of the fixed schedule, so for the great bulk of the stock the relative selectivities of all the age/sex groups are the same. This means that using the fixed schedule in Area 3A and applying a given full-recruitment harvest rate to that biomass will result in the same

level of fishing mortality on the same age/sex groups as in the other Alaska areas. It will also provide a common measure of biomass.

The Area 2B schedule is substantially higher than the fixed schedule, and rather than being proportional it is shifted to the left. Using the same fixed selectivity schedule and the same harvest rate in Area 2B as in Alaska would result in a significant reduction in CEY in Area 2B at a time when the stock is clearly doing well at present harvest levels and we have not yet done the new harvest rate evaluation that the new assessment requires. At least for 2004, therefore, we have decided to use the locally estimated selectivity schedule to estimate exploitable biomass in Area 2B. This means that given the same nominal harvest rate, some age-specific fishing mortality rates will be higher in Canada than in Alaska, and that the exploitable biomass figures are not comparable between Canada and Alaska as they are among Alaska areas.

Estimates of historical and present biomass in Areas 2B, 2C, and 3A

The Commission's paramount management objective is to maintain a healthy level of spawning biomass, meaning a level above the historical minimum that last occurred in the mid-1970s. Although low, this spawning stock nevertheless produced average or better year-classes. In the past we always calculated spawning biomass by applying the female maturity schedule to estimated total biomass at age (including males) because we did not have sex-specific estimates of abundance. One of the main reasons for implementing a sex-specific assessment was to obtain direct estimates of female mortality rates and female spawning biomass. We now have those estimates, and fortunately they show that female spawning biomass is 3-4 times what it was in the mid-1970s (Table 1). So on that score the stock is in good shape.

The numbers of fish aged 8 and older are now 5-10 times what they were in 1974, but their total biomass is only 3-5 times the 1974 level, and exploitable biomass (computed with the new length-specific commercial selectivities) only 2-3 times. The difference between the large increase in numbers and the more modest increase in biomass results from the dramatic decline in size at age and therefore selectivity that has occurred over the last fifteen years. A significant part of the age 8+ biomass now consists of males that never get large enough to be caught in any numbers, as shown by their near disappearance from commercial catches in Area 3A (Fig. 4b). Looked at another way, in 1974 a large fraction of the total age 8+ biomass was exploitable; now that fraction is much smaller (Figs. 8a-c).

Estimates of present biomass in Area 3B, 4A, and 4B

In these areas the model is fitted to data from 1996-2003 only (Figs. 8d-f). Before that exploitation rates were low and there were no surveys, which among other things means that there is no way to estimate the sex composition of commercial landings. Although less data goes into the assessment in these areas, the model is simple enough that the abundance and selectivity estimates are very well determined; the coefficients of variation are less than 5%.

The survey-based method that we used for the last several years assumes that survey catchability and selectivity are the same throughout Areas 3 and 4. The model fits indicate that survey catchability in Areas 4A and 4B is about the same as in Area 3A, but that it is higher in Area 3B. The model fits also show that selectivity is lower in Area 3A than in Area 3B and 4. Using the fixed selectivities to

calculate exploitable biomass increases the 3A value by about 40%, which has the effect of shrinking the other areas' estimates relative to the Area 3A estimate on the standardized scale, as shown in the table below. In short, the analytical estimates in all three areas are lower than the survey-based estimates relative to Area 3A mainly because selectivity is lower in Area 3A than in those areas. Another factor in the case of Area 3B is higher estimated survey catchability than in Area 3A.

	Area 3B	Area 4A	Area 4B
Survey index as a fraction of 3A	0.71	0.26	0.16
Exploitable biomass calculated with fixed selectivities as a fraction of 3A	0.45	0.14	0.10

Estimates of present biomass in Areas 2A and 4CDE

For these areas we cannot do an analytical assessment so we continue to use the survey-based estimate scaled to an adjoining area. For Area 2B this is 13% of the Area 2B estimate. For Area 4CDE we have been scaling to Area 3A because that was the nearest area with an analytical estimate. We now have an estimate for Area 4A, and by the same procedure can estimate the Area 4CDE biomass as 142% of the Area 4A biomass.

Estimated CEY in 2004

A major change in this year's assessment is the adoption of a new set of length-specific commercial selectivities, which produce much lower estimates of exploitable biomass than the old fixed age-specific selectivities. (Table 1). In the past we calculated CEY by applying the established 20% harvest rate to exploitable biomass, but we cannot do the same thing now because the 20% harvest rate was chosen on the basis of simulations that used the old fixed age-specific selectivities. A new set of simulations with the new, lower selectivities can be expected to lead to a higher target harvest rate, but that work has not yet been done. For this year's CEY calculations, we have adopted a provisional target harvest rate of 25% for Areas 2 and 3. For Area 4, we have stuck with 20% because of uncertainty about the long-term productivity of the Bering Sea/Aleutians region relative to the Gulf of Alaska.

The resulting estimates of setline CEY (Table 2) are considerably higher than last year's in Areas 2A, 2B, and especially 2C, where this year's assessment changes had the largest total effect. In Area 3A setline CEY is a little lower. In Areas 3B and 4 the numbers are much lower—half or less—because of the lowered selectivities and in Area 4 the continued use of a 20% harvest rate.

References

- Clark, W.G. 2004a. A method of estimating the sex composition of commercial landings from setline survey data. Int. Pac. Halibut Comm. Report of Assessment and Research Activities 2003: 111-162.
- Clark, W.G. 2004b. Statistical distribution of IPHC age readings. Int. Pac. Halibut Comm. Report of Assessment and Research Activities 2003: 99-110.
- Clark, W.G., and Hare, S. R.. 2003. Assessment of the Pacific halibut stock at the end of 2002. Int. Pac. Halibut Comm. Report of Assessment and Research Activities 2002:95-120.

Table 1. Various measures of abundance in 2004 compared with 1974. Biomass is in millions of net pounds, numbers in millions. Calculations of spawning and total biomass use mean weight at age/sex in the survey (i.e., including sublegals) while calculations of exploitable biomass use mean weight at age/sex in the commercial landings. This is why exploitable biomass can exceed total biomass. “Old exploitable biomass” is calculated with the fixed coastwide age-specific commercial selectivities used in the 1999-2002 assessments. “New exploitable biomass” is calculated with the length-specific commercial selectivities estimated in the 2003 assessment.

	Area 2B		Area 2C		Area 3A	
	1974	2004	1974	2004	1974	2004
Female spawning biomass	11	35	18	56	40	144
Total biomass age 8+	23	67	42	188	89	429
Total numbers age 8+	1.5	7.5	1.5	9.7	2.5	25.1
Mean weight age 8+	15	9	28	19	36	17
Old exploitable biomass	22	88	30	153	50	360
New exploitable biomass	26	65	30	80	73	146

Table 2. Removals in 2003 and estimates of CEY in 2004 (millions of net pounds).

	2A	2B	2C	3A	3B	4A	4B	4CDE	Total
2003 setline CEY at 20% ^{1,2}	1.29	11.32	9.11	34.22	29.19	11.22	7.76	10.82	114.93
2003 catch limit ²	1.31	11.75	8.50	22.63	17.13	4.97	4.18	4.45	74.92
2003 commercial landings ³	0.82	11.75	8.45	22.68	17.41	4.97	3.87	3.25	73.20
Other removals									
Sport catch	0.40	1.07	2.60	5.00	0.01	0.04	0	0	9.12
Legal-sized bycatch	0.29	0.15	0.17	1.36	0.58	0.50	0.18	2.56	5.79
Personal use	0	0.30	0.17	0.07	0.02	0.17	0	0	0.73
Legal-sized wastage	0.01	0.02	0.03	0.09	0.04	0.02	0.01	0.01	0.23
Total other removals	0.70	1.54	2.97	6.52	0.65	0.73	0.19	2.57	15.87
...excluding sport catch	0.30	0.47	---	---	---	---	---	---	---
Total removals	1.52	13.29	11.42	29.20	18.06	5.70	4.06	5.82	89.07
2004 exploitable biomass ⁴	8.5	65	80	146	65	21	15	30	430.5
2004 total CEY at 25% (20% in Area 4)	2.1	16.3	20.0	36.5	16.3	4.2	3.0	6.0	104.4
2004 setline CEY ⁵	1.8	15.8	17.0	30.0	15.7	3.5	2.8	3.4	90.0

Notes:

1. Estimates of 2003 setline CEY (first row) are the figures reported in the 2002 assessment.
2. In Area 2A the setline CEY and catch limit include sport catch and treaty subsistence catch.
3. Commercial landings include IPHC survey and other research catches, which can result in small overages.
4. 2004 exploitable biomass is computed with a new set of length-specific selectivities that are lower than the age-specific selectivities used in the 1999-2002 assessments, so these figures are not comparable with last year's exploitable biomass estimates.
5. In Area 2B the setline CEY for 2004 includes sport catch for the first time.

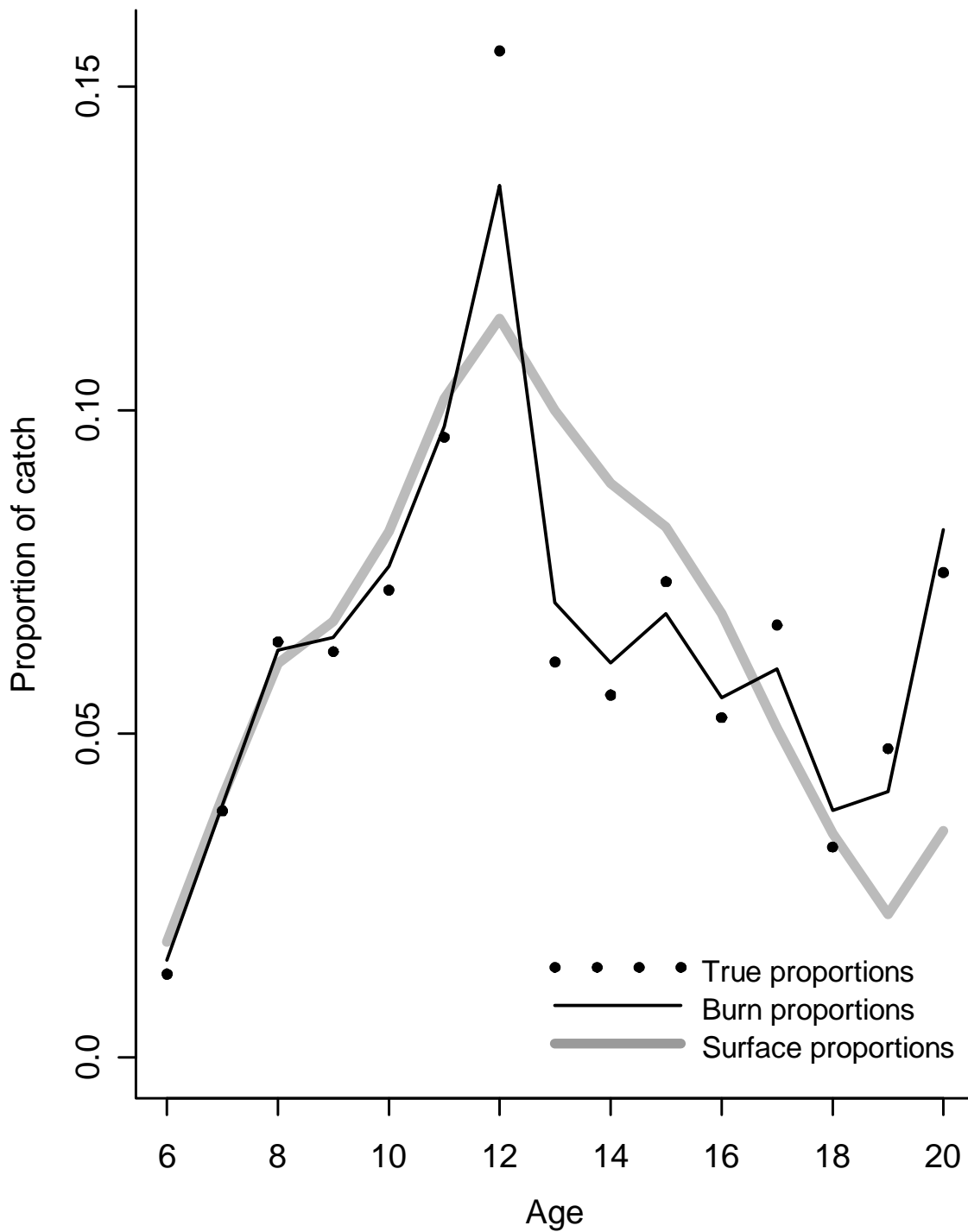


Figure 1. An example of true age proportions in the catch and the corresponding observed distributions of surface and break-and-burn age readings. At ages beyond about 15 surface ages are biased and quite variable; break-and-burn ages are unbiased and less variable.

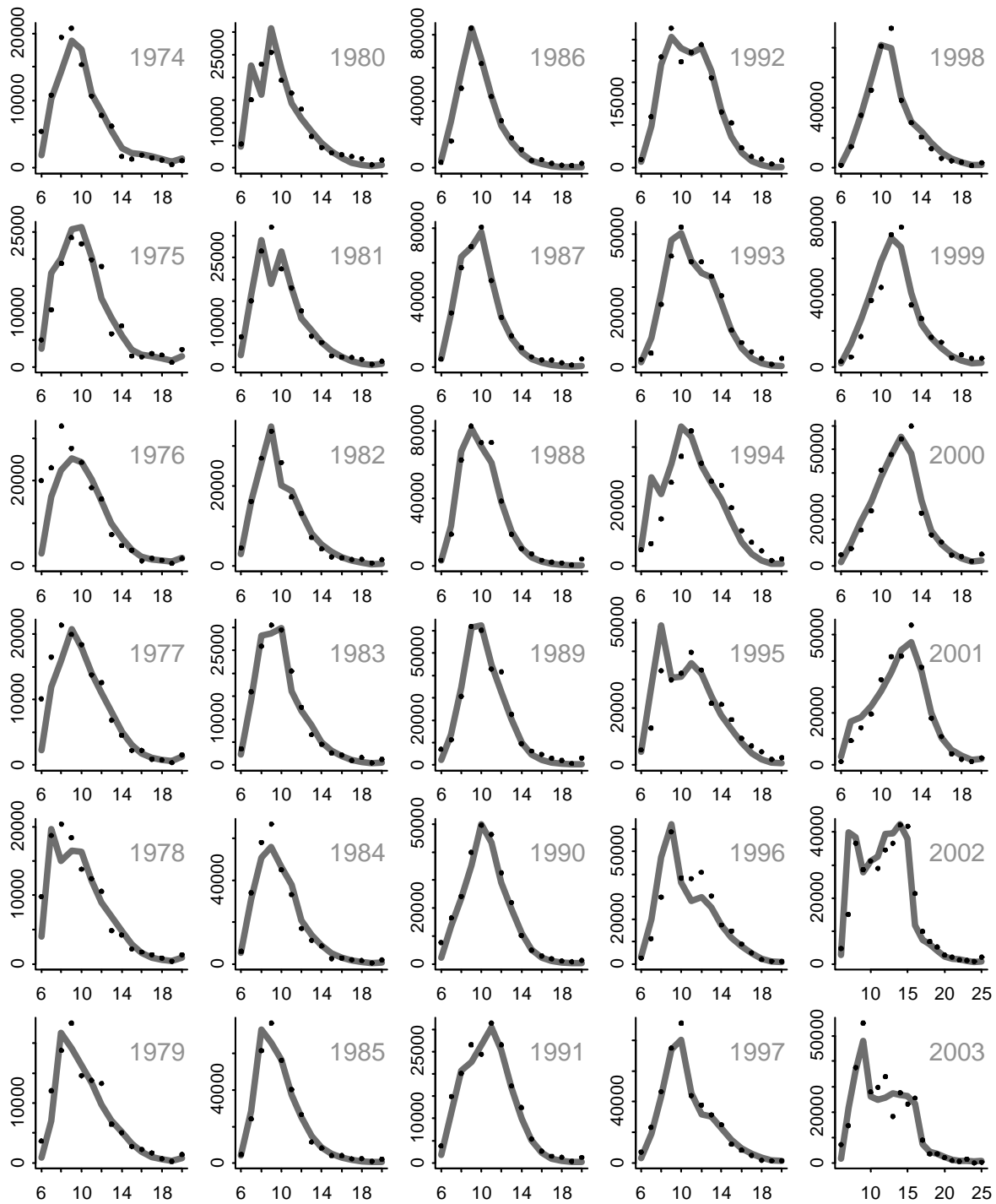


Figure 2a. Observed catch at age of females in Area 2B (points) and model predictions (lines).

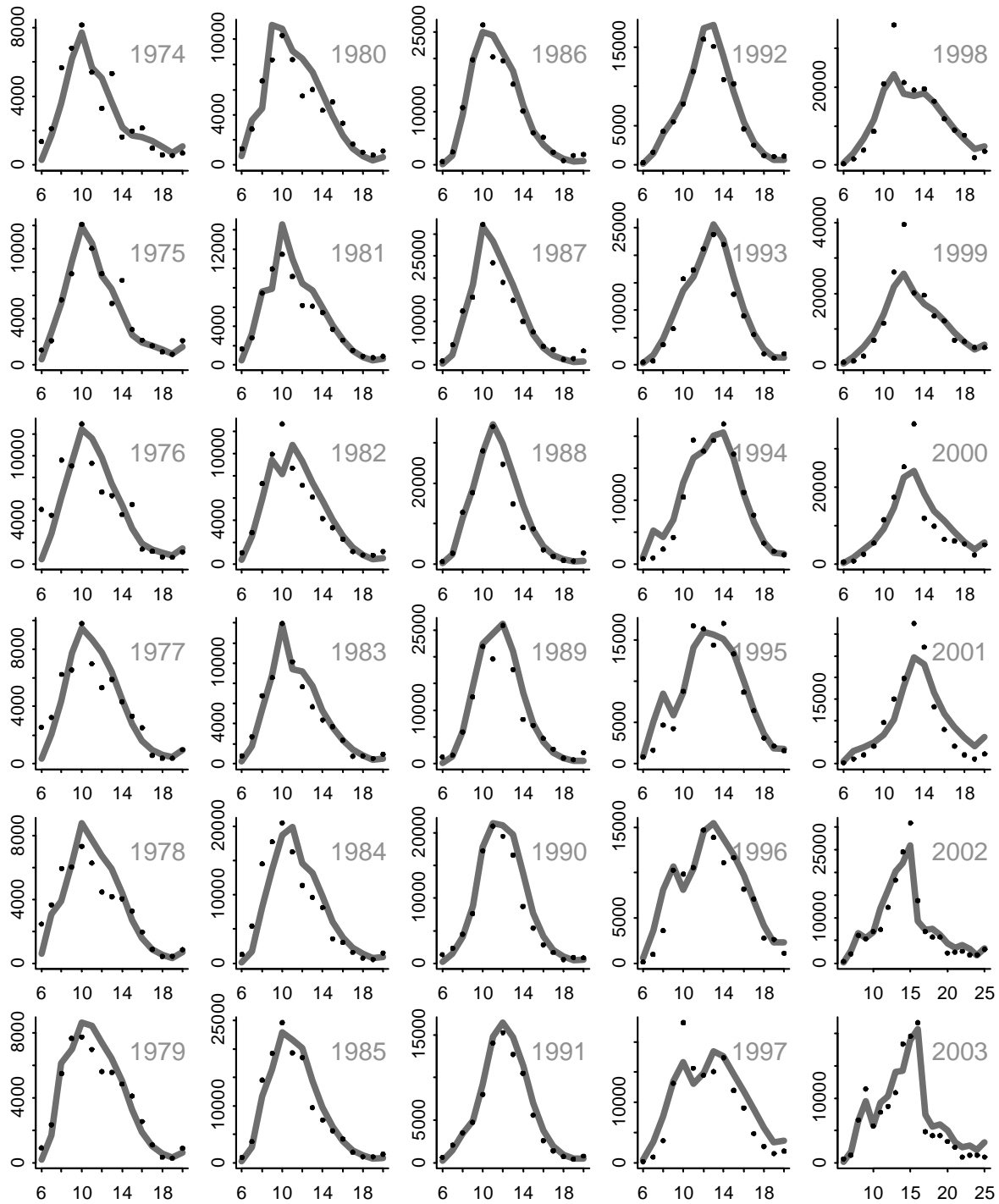


Figure 2b. Observed catch at age of males in Area 2B (points) and model predictions (lines).

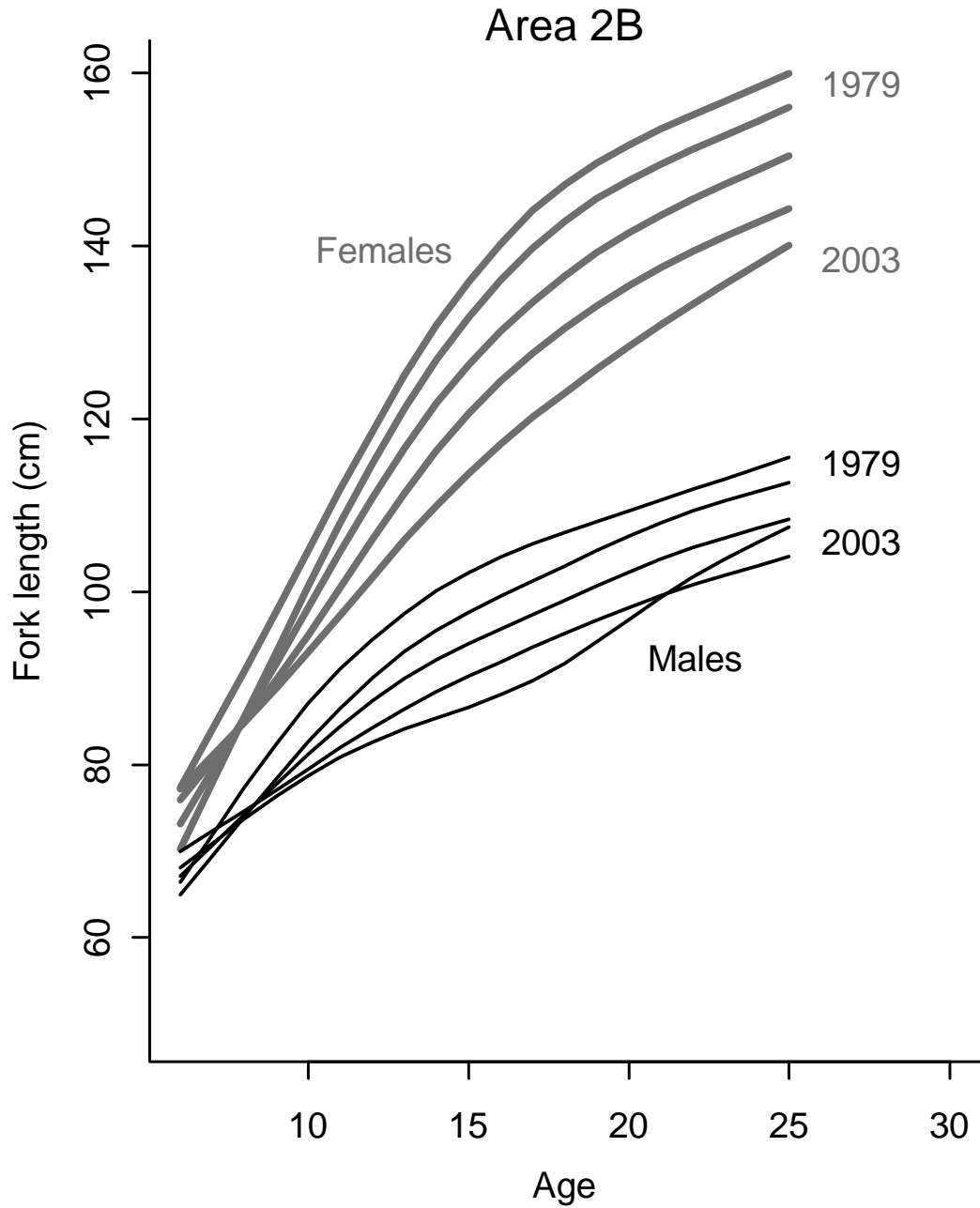


Figure 3. Mean length at age of females and males in setline survey catches in Area 2B. For each sex, the graphs show the observed growth schedules in a sequence of years at intervals between 1979 and 2003. The upturn in the male growth schedule in 2003 is an artifact of the conversion from surface to break-and-burn readings.

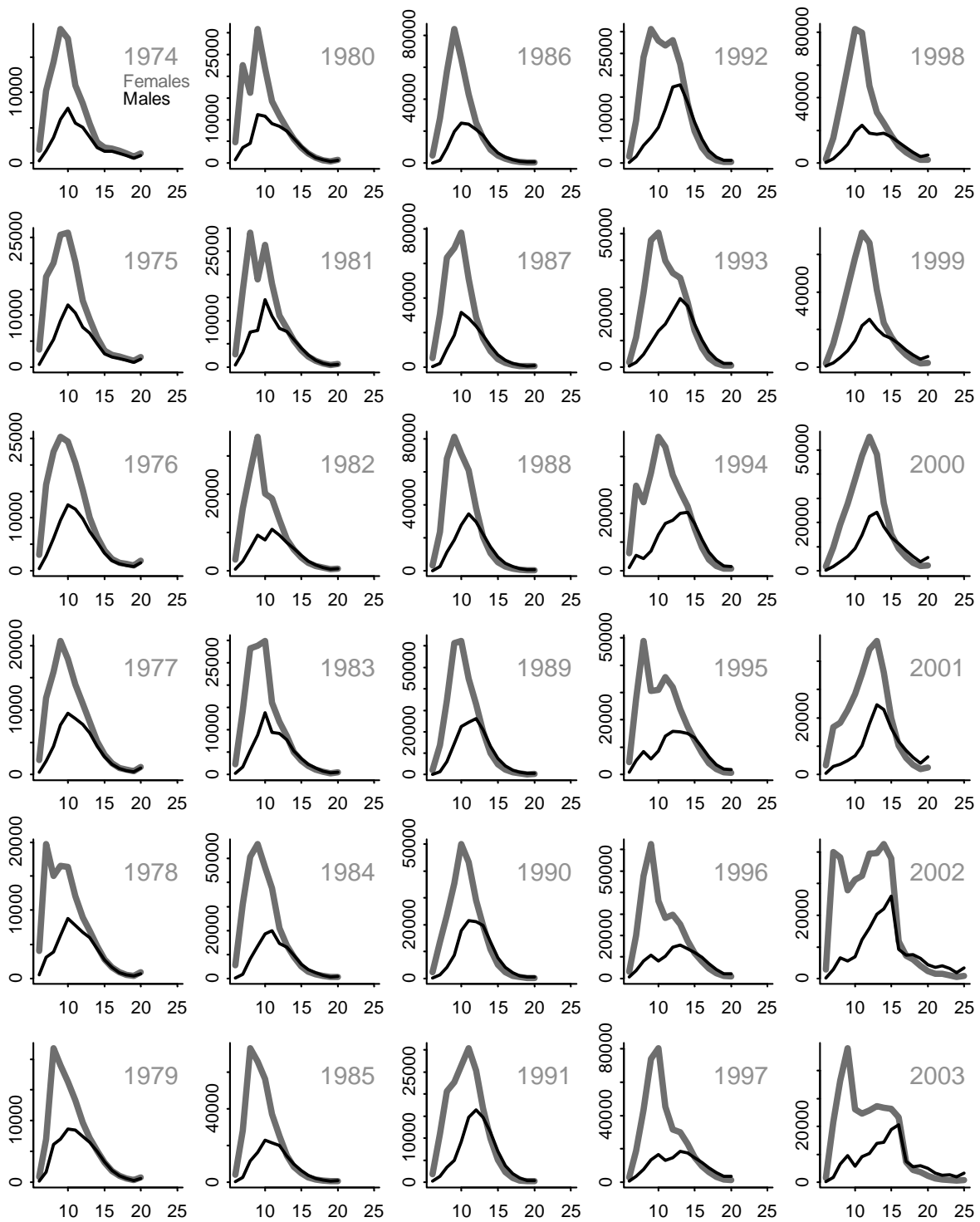


Figure 4a. Catch at age of females and males in Area 2B, by year.

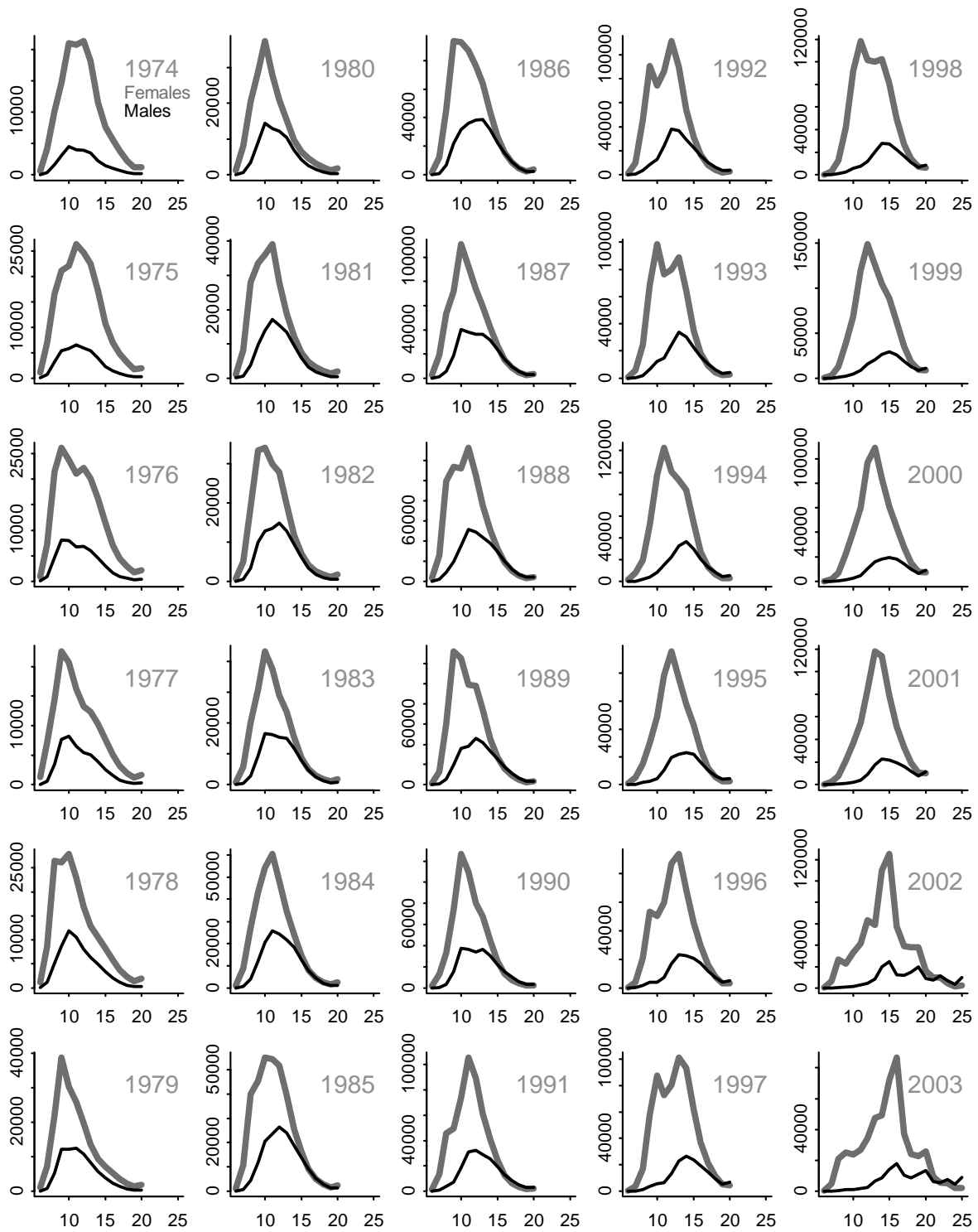


Figure 4b. Catch at age of females and males in Area 3A, by year.

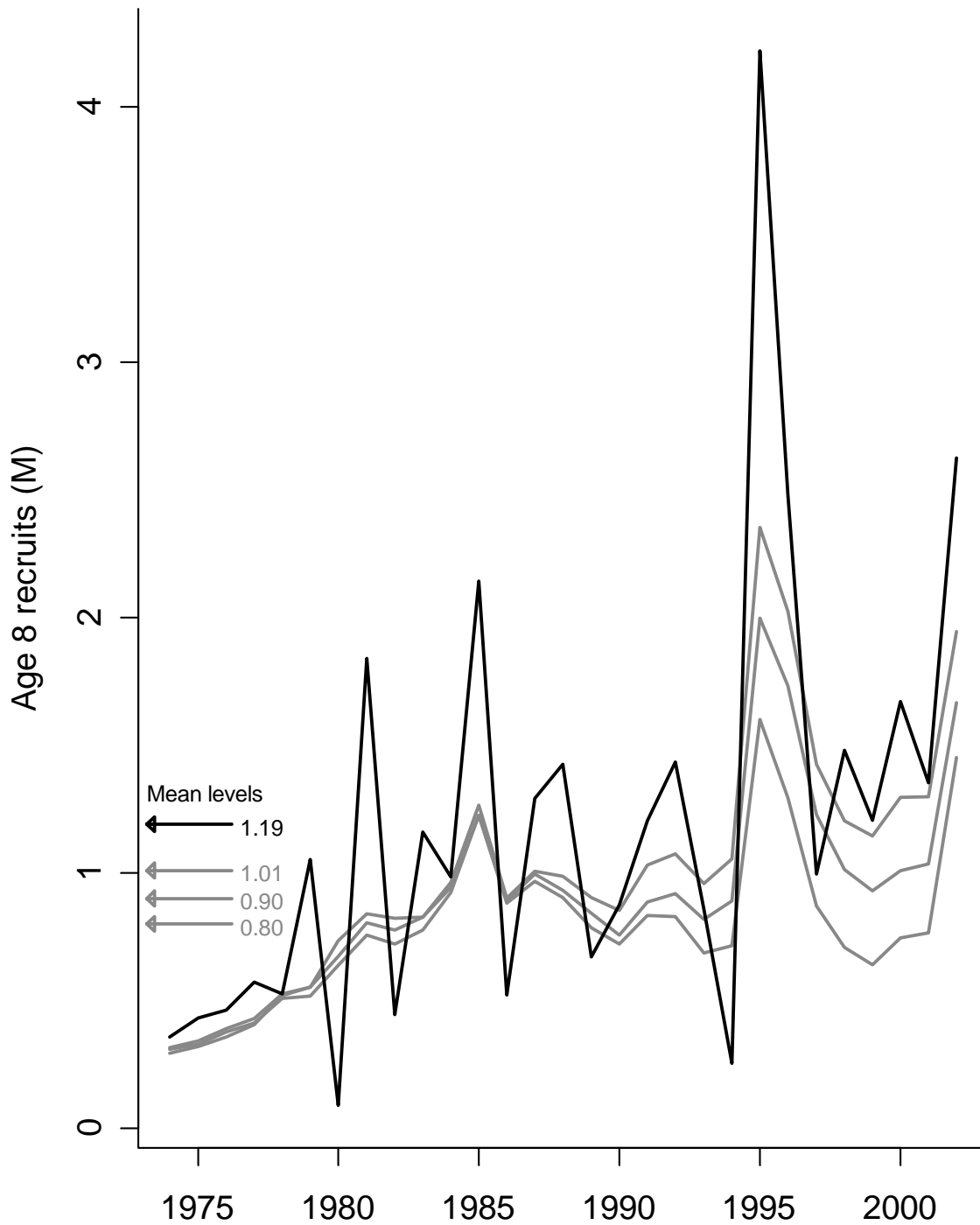


Figure 5. Estimates of recruitment in Area 2C from fits of old and new models. Bottom line shows the 2002 assessment with fixed age-specific survey selectivities; next line up shows the effect of switching to length-specific selectivities; next line up the added effect of treating females and males separately; topmost (black) line the added effect of correcting for surface age bias and variance.

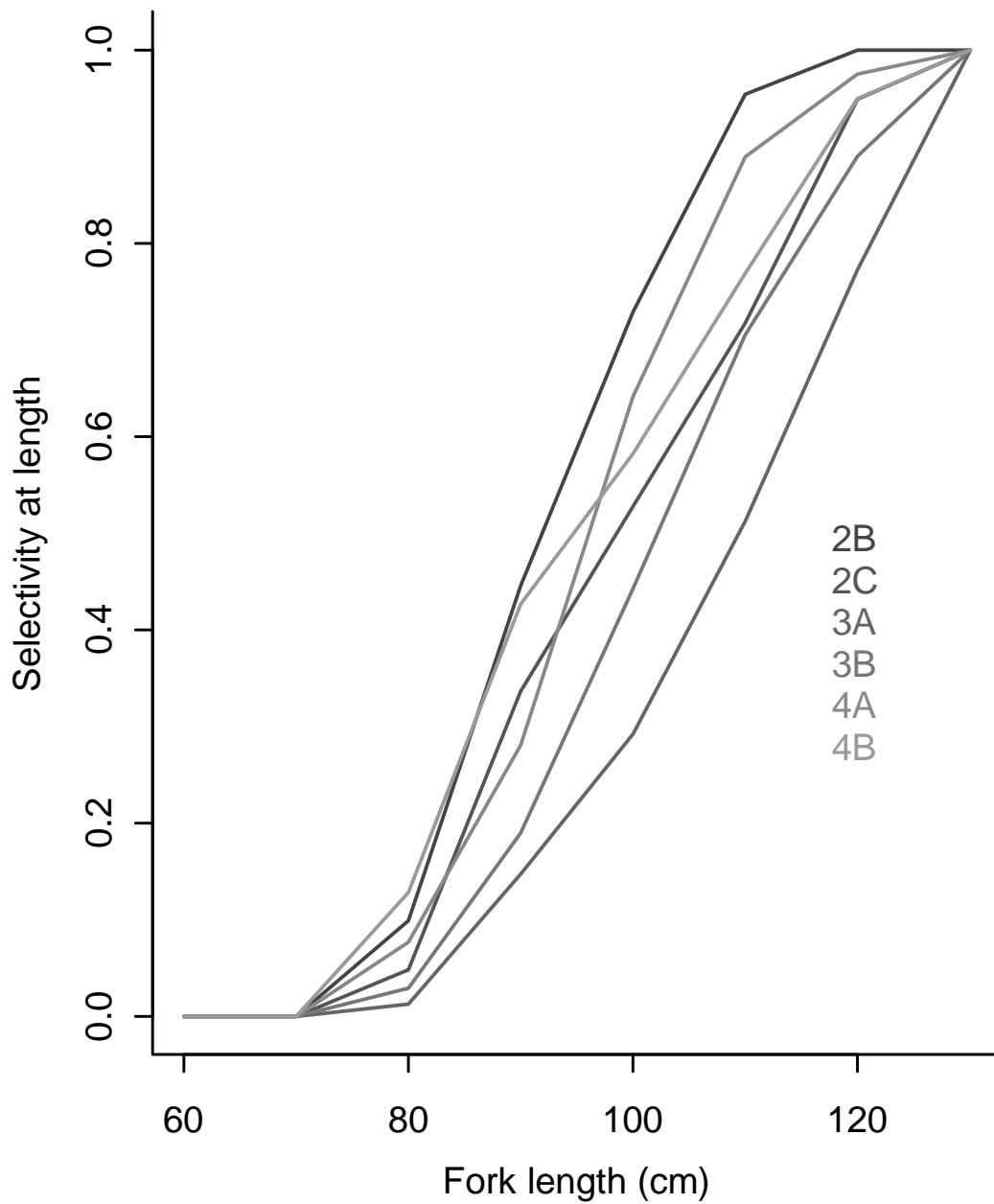


Figure 6. Estimated length-specific commercial selectivity. The topmost line is Area 2B. The bottom line is Area 3A, and the other Alaska areas are clustered in the middle.

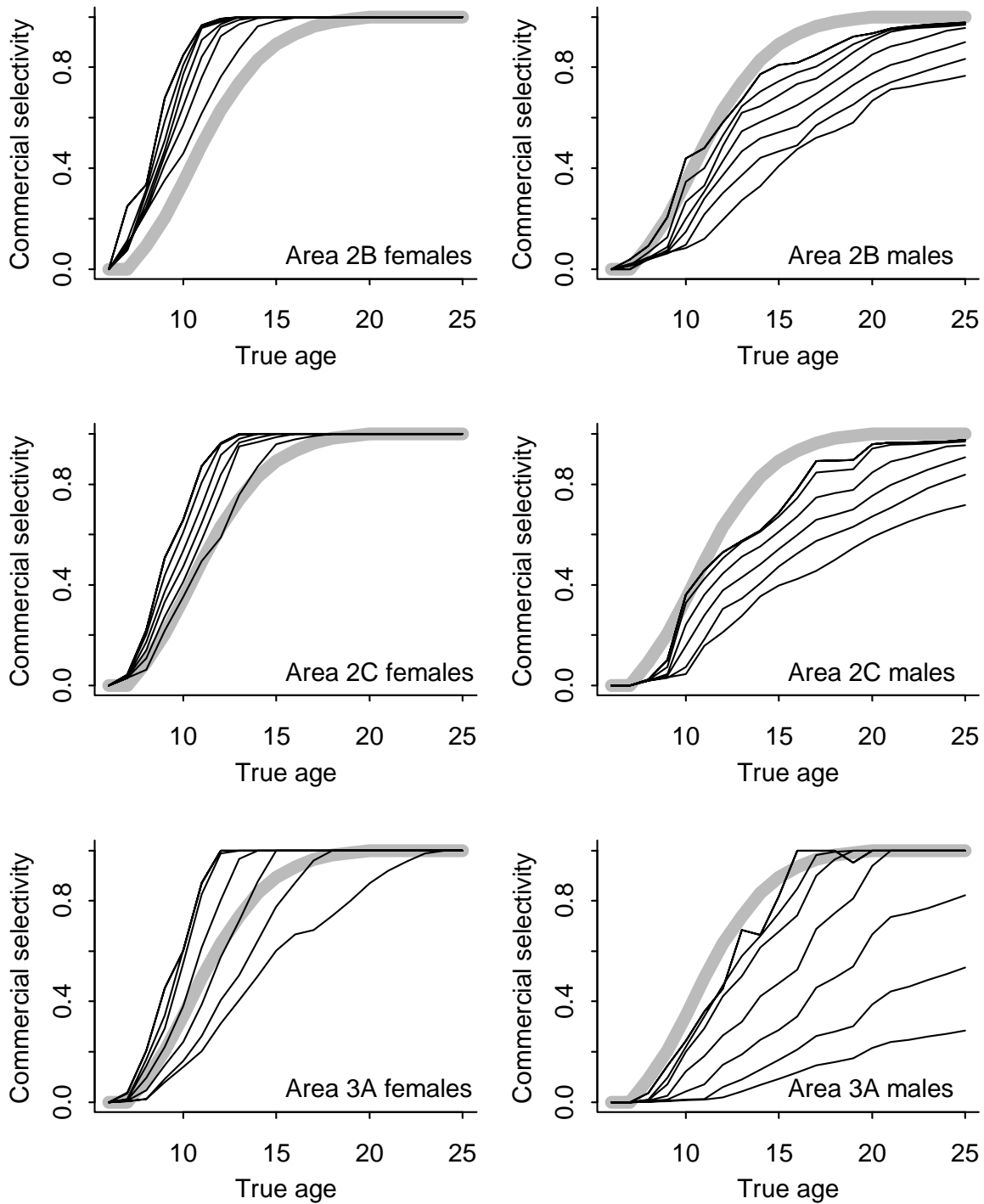


Figure 7. The downward drift of age-specific commercial selectivities over time due to constant length-specific selectivity and declining size at age, plotted by area and sex. The thin black lines in each graph are the selectivities estimated for a particular year; the thick gray line is the set of fixed coastwide selectivities that were used to compute exploitable biomass in the 1999-2002 assessments.

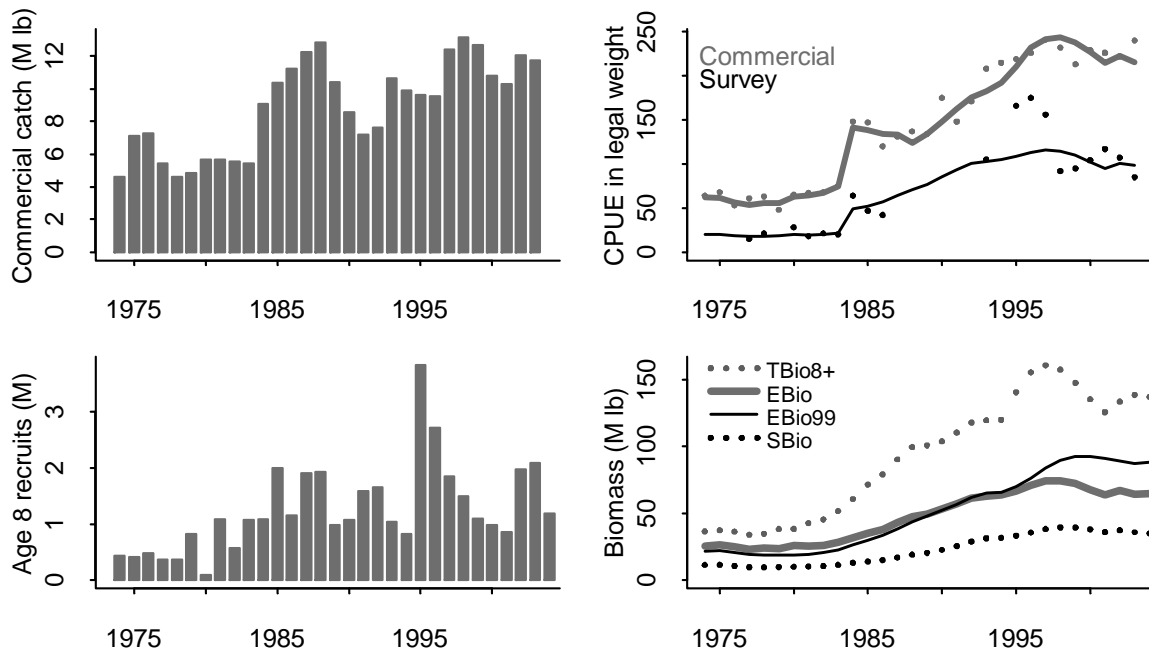


Figure 8a. Features of the Area 2B assessment. In the upper right graph, the points are the observed CPUE values and the lines are the model predictions. In the lower right graph, “TBio8+” is total biomass of fish aged 8 and older, “EBio” is exploitable biomass as calculated this year, “EBio99” is exploitable biomass as calculated last year, and “SBio” is female spawning biomass.

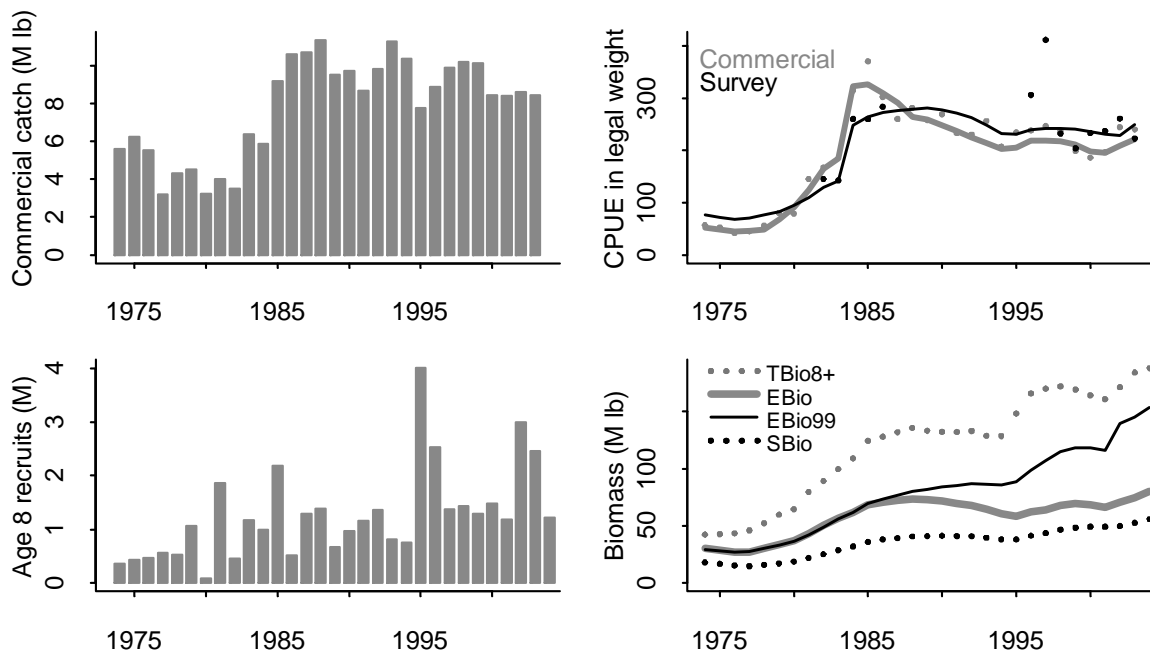


Figure 8b. Features of the Area 2C assessment.

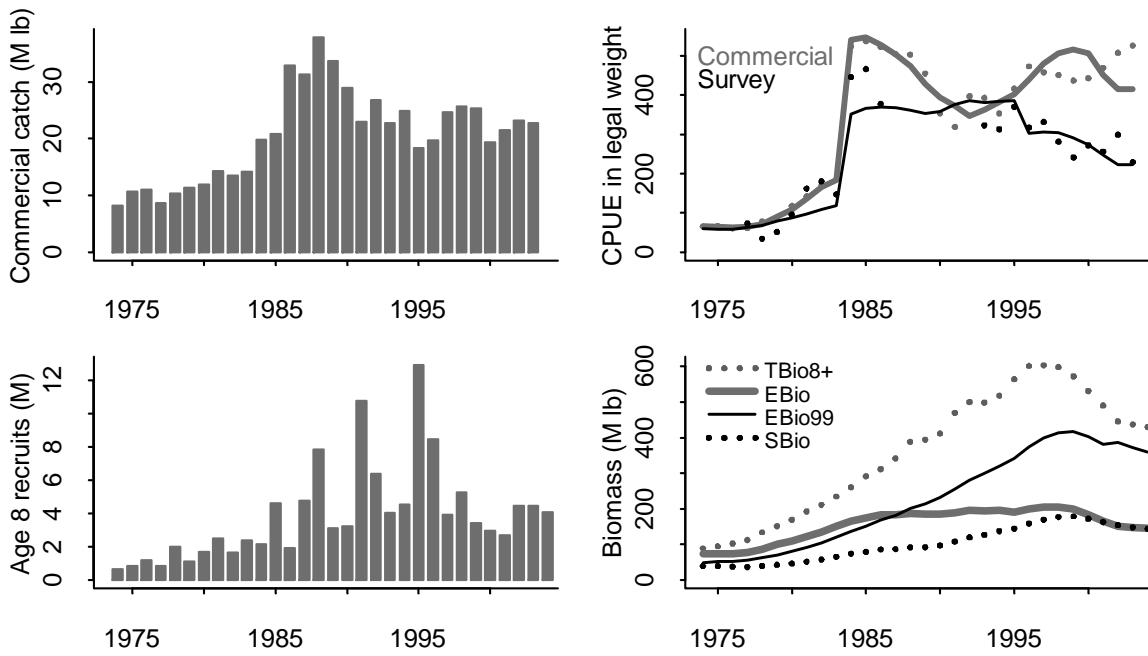


Figure 8c. Features of the Area 3A assessment. (See Figure 10a legend for details.)

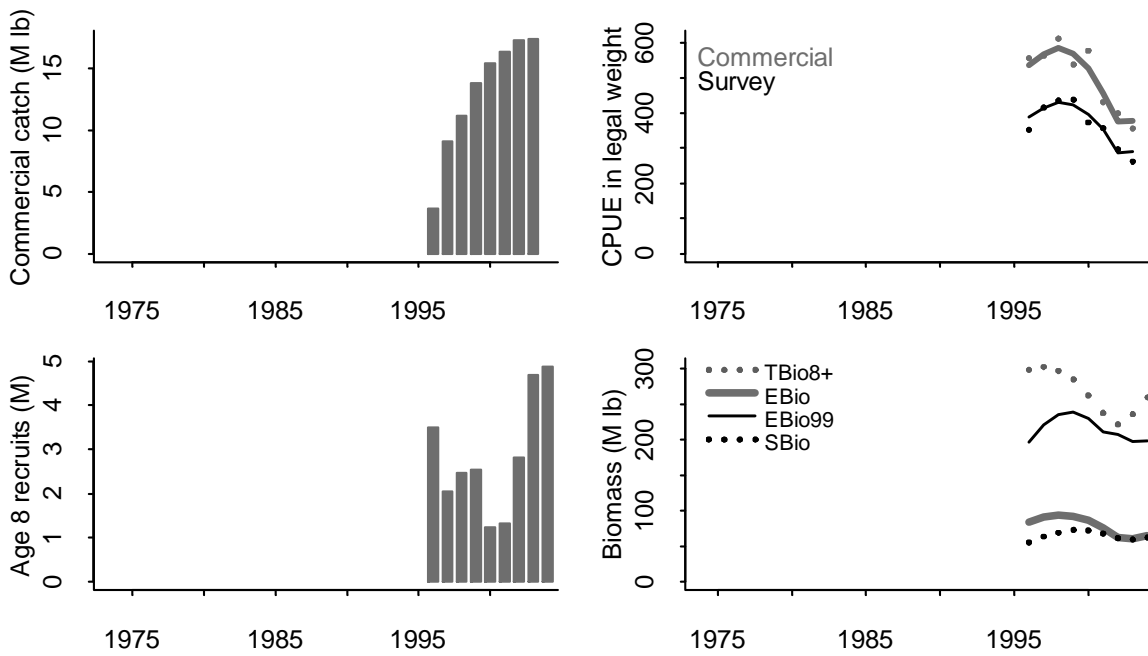


Figure 8d. Features of the Area 3B assessment.

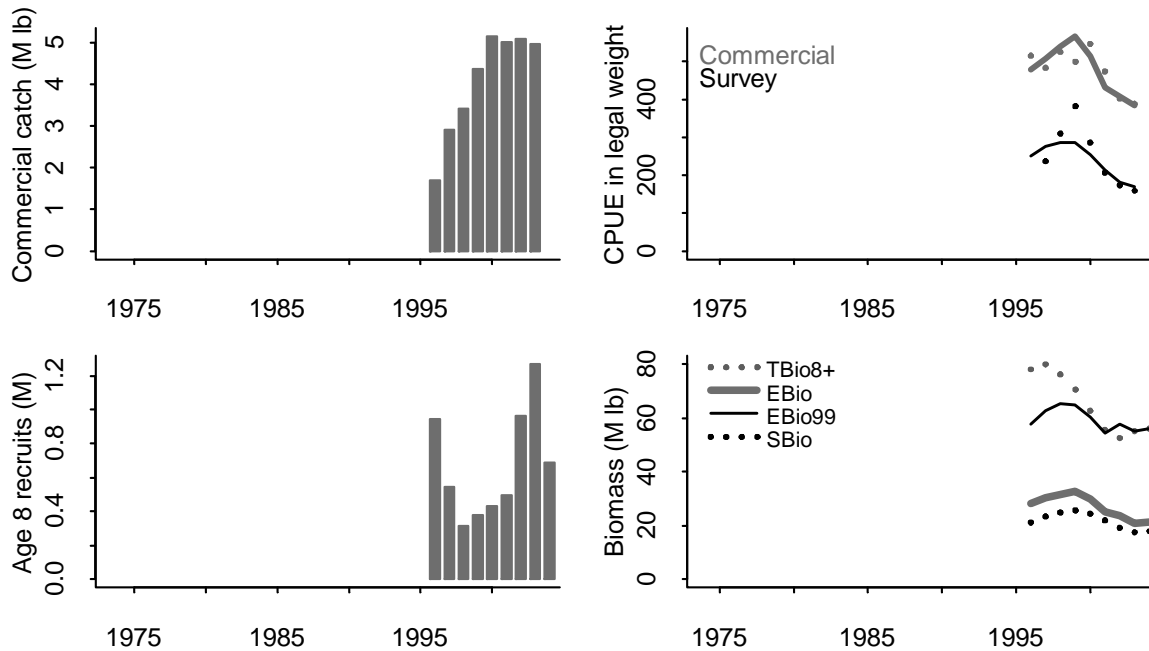


Figure 8e. Features of the Area 4A assessment. (See Figure 10a legend for details.)

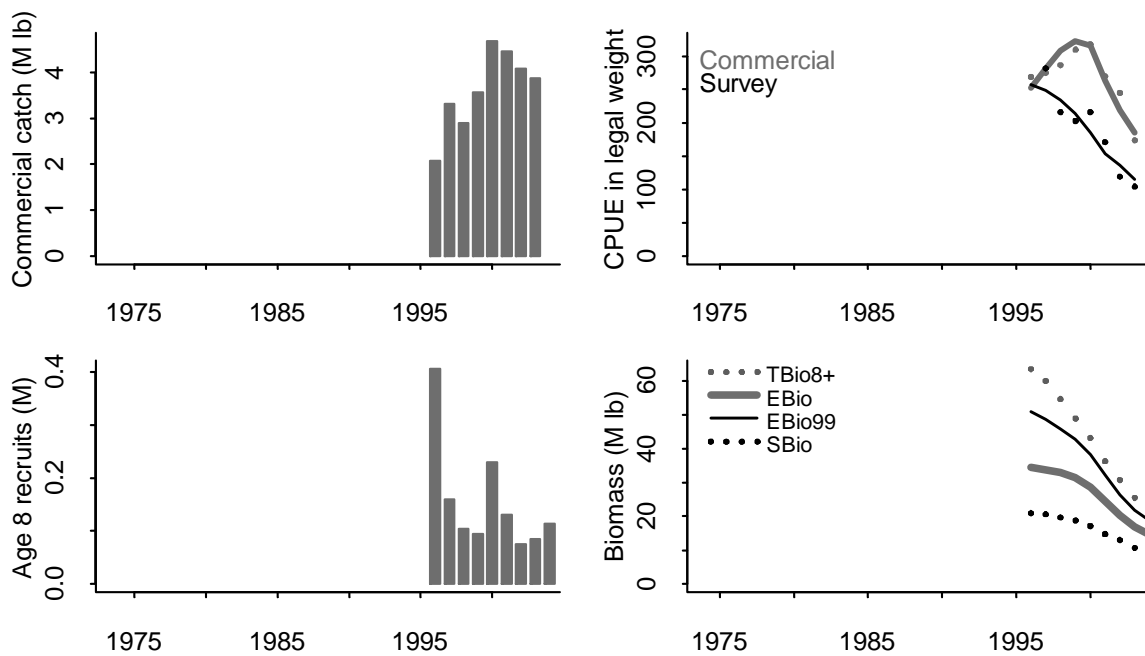


Figure 8f. Features of the Area 4B assessment.

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	11.74	8.45	22.68	17.41	---	4.97	3.87	0.93	1.91	0.41	73.19

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	0.286	0.154	0.167	1.364	0.584	---	0.499	0.184	2.558	5.796

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	183	240	240	526	356	388	174	100	443	---

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	85	223	229	262	159	104	---	195	---

