APPENDIX A

PACIFIC HALIBUT STOCK ASSESSMENT AND FISHERY EVALUATION

by
Staff of the International Pacific Halibut Commission
November 6, 2000

Relative to the November, 1999 SAFE Report, new information in this document includes:

1. Updated catch statistics for 1999 and preliminary catches for 2000;
2. Estimates of removals from other sources in 1999;
3. Age composition data for the 1999 commercial fishery;
4. Updated assessments for all areas conducted in November, 1999; and
5. Results of 1999 IPHC standardized setline assessment surveys.

NOTE: The assessment reported in this document was conducted by IPHC in October-November, 1999 for the 2000 fishery. A newer assessment, conducted for the 2001 fishery, can be found on the IPHC web site, http://www.iphc.washington.edu by December 2000.

Note: Halibut data are traditionally reported in pounds, net weight, i.e., with the head removed and the body eviscerated. For this document, information is presented in metric units (kg or metric tons), round weight, which represents a "head-on" fish that is not eviscerated. For those desiring, the conversion from round weight to net weight is 0.75.

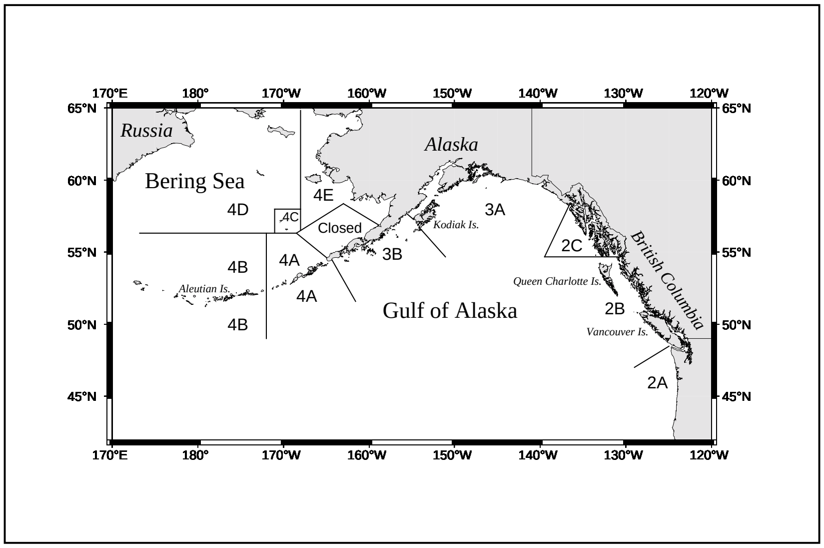
INTRODUCTION

Halibut belong to a family of flounders called Pleuronectidae. The scientific name is *Hippoglossus stenolepis*, a name derived from the Greek *hippos* (horse), *glossa* (tongue), *steno* (narrow), and *lepis* (scale). Halibut are found on the continental shelf of the North Pacific Ocean and have been recorded from Santa Barbara, California to Nome, Alaska. Halibut also occur along the Asiatic coast from the Gulf of Anadyr, Russia to Hokkaido, Japan. Halibut are demersal, living on or near the bottom, and prefer water temperatures ranging from 3 degrees to 8 degrees C. Although halibut have been taken as deep as 300 fathoms (1,100 m), most are caught when they are at depths from 15 fathoms (27 m) to 150 fathoms (275 m).

The resource and fishery is managed by the International Pacific Halibut Commission (IPHC or Commission), which was established in 1923 by a Convention between Canada and the United States. The Convention has been revised several times to extend the Commission's authority and to meet new conditions in the fishery. The most recent amendment, termed a Protocol, was signed in 1979 (McCaughran and Hoag 1992). Among other issues, the Protocol altered the Commission's mandate such that management was to be based on optimum yield, rather than the previously prescribed maximum sustainable yield.

In the United States, the Protocol was put into effect by enabling legislation called the Northern Pacific Halibut Act of 1982. Among the many measures addressed, one of the most significant was the provision that provided authority to the regional fishery management councils to develop regulations for the halibut fishery which are not in conflict with IPHC regulations (McCaughran and Hoag 1992). The councils did not become involved in halibut management until a decision was made by NOAA in 1987 that the Commission should no longer consider regulations that relate to domestic allocation. That task would be undertaken by the appropriate regional fishery council.

In 1932, the Convention waters were divided into four large regulatory areas, which have subsequently been subdivided and regrouped. The regulatory areas, depicted in the figure on the right, have remained unchanged since 1992. The separation of Convention waters at Cape Spencer, Alaska was, in part, arrived at from biological data obtained from early tagging experiments which suggested, according to Kask (1937) that "…the halibut on banks south of Cape Spencer and the halibut on banks north and west of Cape Spencer form separate and distinct stocks." Presently, the Commission considers the halibut resource in the Convention waters to form one homogenous population.



CATCH HISTORY

Halibut are the target of a commercial fishery that has been in existence for over 100 years. The sport fishery has grown in importance in more recent years. Catch limits have been in place for the commercial fishery since the 1930s. The sport fishery is regulated by daily bag and possession limits on individual fishermen. Catches by both fisheries are managed by IPHC regulatory area.

The 1990s have seen a dramatic change in the management regime employed by the U.S. and Canada in managing their commercial halibut fleets. In 1991, Canada instituted an Individual Vessel Quota (IVQ) system, whereby the annual catch limit for Area 2B was allocated among the licensed vessels in relation to the vessels' past production and vessel size. In 1995, the U.S. followed with a similar system termed Individual Fishing Quota (IFQ), in which each licensed fisherman was given a share of the annual catch limit based on the individual's past production. Both systems have resulted in much longer seasons, currently March 15 through November 15, and have also kept catches within the prescribed limits. The quota systems used by each country will not be reviewed in this document, but further information can be found in documents produced by the respective federal agencies.

Bycatch mortality, i.e., the catch of halibut in other fisheries, is the second largest source of removals from the stock. Bycatch is managed by the U.S. and Canadian governments in their respective zones.

Catch Limits (Quotas)

Catch limits have been used by the Commission to control fishing mortality since 1932. The basis for determining appropriate catch limits has changed considerably over the years. From the 1930s through the 1970s, catch limits were adjusted up or down as the catch per unit of effort (CPUE) in the fishery either increased or decreased. The management system at the time assumed that CPUE reflected abundance and that abundance was primarily influenced by removals (Southward 1968). Further, several studies were conducted during the 1950s and 1960s to estimate maximum sustainable yield (Chapman et al. 1962). The management system changed during the 1980s, when the Commission began estimating biomass from the analysis of catch and age data in the commercial fishery (Quinn II et al. 1985). Catch limits during the early 1980s were based on keeping removals below the surplus production of stock, i.e., the excess of what is required to replenish the population biomass each year due to removals from fishing and other causes. This strategy was designed to rebuild stocks and partly resulted in a sharp increase in biomass during the early 1980s. By 1985, stocks were considered healthy and the management strategy shifted to setting catch limits as a fixed proportion of the estimated biomass, referred to as constant exploitation yield. Table 1 shows the catch limits by area for 1977 through 2000 in metric tons, round weight.

Among areas, catch limits have historically been highest in Area 3A and lowest in the areas at the ends of the range: Area 2A and 4. Since 1981, catch limits for Areas 2B and 2C have been quite similar, although Area 2B has usually received slightly higher catch limits than Area 2C.

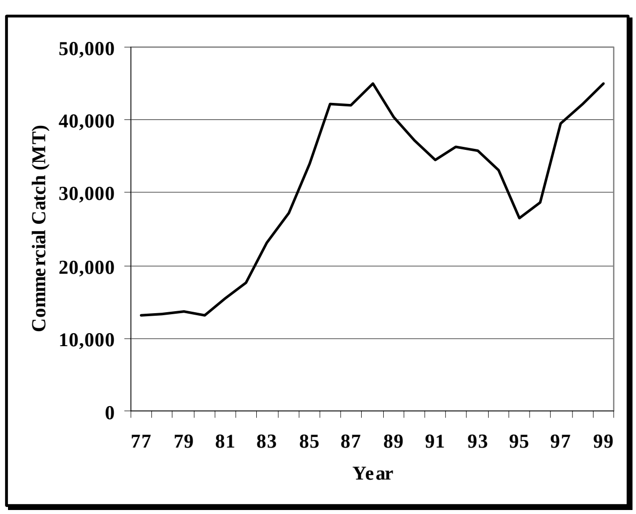
The coast-wide catch limit for 1999 of 44,459 mt represented a 3% increase from the limit set for 1998. Historically, the highest coastwide catch limits occurred in 1988, corresponding to historically high levels of abundance. Catch limits declined to a 36,200 mt level during 1992-1996 in response to declining biomass. Revisions to the stock assessment model in 1997 indicated that abundance was higher than previously thought, and catch limits since 1997 have increased accordingly.

In general, catch limits apply only to the commercial setline (longline) fishery. The sport fishery is managed with daily bag and possession limits which are outside of the catch limits. The lone exception is Area 2A, where the treaty and non-treaty commercial fisheries and the sport fishery are managed within the catch limit.

Commercial Fishery Catches

Retained Catch

Since 1977, the total commercial fishery catch has ranged from 13,200 mt to almost 45,000 mt (Table 2), with peak catches during 1987-1989 and 1997-1999. In the late 1970s, catches were somewhat stable and averaged 13,300 mt through 1980. In 1981, catches began to increase annually and were highest in 1988. Largest catches by area were 6,859 mt in Area 2C (1988); 22,840 mt in Area 3A (1988); 8,389 mt in Area 3B (1999); and 7,182 mt in Area 4 (1999). Catches declined during the 1990s, reaching a low of 26,500 mt in 1995, then rebounded upwards. The catch in 1999 (45,000 mt) represents a 6.7% increase over 1998.



As indicated in the following table, almost half of the total coastwide catch was taken in Area 3A during 1977-1999. The Gulf of Alaska (GOA) areas (2C, 3A, and 3B) accounted for 72% of the coastwide catch and 88% of the total catch taken from Alaskan waters. The contribution from the GOA has declined in more recent years, with only 66% of the coastwide catch and 80% of the Alaska catch for 1999. These declines have occurred in part because of greater stock declines in the GOA areas relative to other areas, but also higher estimates of abundance (and therefore catch) in the more western areas.

Long-term average and 1999 catches (mt) of Pacific halibut and proportion caught by area.

	Area 2A	Area 2B	Area 2C	Area 3A	Area 3B	Area 4	Total
1977-1999 Average	210	5,384	4,819	13,155	3,915	2,907	30,390
Percent By Area							
(a) Coast-wide	0.7%	17.7%	15.9%	43.3%	12.9%	9.6%	100.0%
(b) Alaska areas only	-	-	19.4%	53.1%	15.8%	11.7%	100.0%
1999 Catch	270	7,699	6,169	15,291	8,389	7,182	45,000
Percent By Area							
(a) Coast-wide	0.6%	17.1%	13.7%	34.0%	18.6%	16.0%	100.0%
(b) Alaska areas only	-	-	16.7%	41.3%	22.7%	19.4%	100.0%

Catch Per Unit Effort

IPHC measures CPUE in units per standard skate, the latter being 100 hooks at 18-foot spacing. Analysis by Hamley and Skud (1978) provides factors to standardize different spacings to the 18-foot measure.

Although CPUE has varied widely over the years, it has shown a general increase from the levels observed in the late 1970s. Advances in fishing technology and fishing gear during the 1980's reduced the utility of CPUE as a primary indicator of stock abundance, causing IPHC to develop catch-age and, more recently catch-length, methods of estimating biomass. Consequently, CPUE is now used primarily as an index of abundance and to examine the relative distributions of biomass among regulatory areas and to help partition catch limits between subareas.

CPUE remains highest in the areas comprising the GOA, where it has usually been greater than 200 kg per skate since 1981, and occasionally exceeding 300 kg per skate (Table 3). CPUE in Area 2B has increased since the introduction of the IVQ program in 1991, but only a small part of this is likely due to the program (Sullivan and Rebert 1996). One result of the program has been a longer fishing season, which has enabled fishermen to take their time in locating productive grounds and resulted in some grounds having been fished with far less gear than during the short, open-access fishing periods. Since 1995, CPUE estimates for the Alaskan areas also show increases, probably for similar reasons.

Discards

Halibut discards in the commercial halibut fishery come in the form of (1) sublegal halibut (halibut <82 cm) which cannot be retained and are therefore released and (2) halibut of all sizes which are killed when the gear is lost or abandoned. IPHC has been estimating these removals since 1993 and the results for 1993-1999 are summarized in Table 4. Total coastwide discards averaged 1,500 mt during 1993-1994 then dropped due to substantial reductions in the Alaskan areas. The reduction was likely the result of a change in fishing practices due to the new IFQ program in that area. Fishermen no longer had to race to catch fish during a short 24 hour fishing period, but could fish more slowly and carefully. Discards have increased since 1996, reflecting the increases in overall catches and a slightly higher catch of smaller fish.

During the open access fishery prior to 1995, it was not uncommon for fishermen to set more gear than could be hauled back during the short fishing periods. This practice led to the excess gear being cut and discarded when the period closed, despite having fish on the hooks, and was termed abandoned gear. Additionally, setline gear often becomes snagged or caught on the ocean bottom and breaks, and is lost, despite having fish on the hooks. IPHC staff estimate the amount of mortality due to lost and abandoned gear from effort data in fishermen's logbooks. The results showed that the waste from lost and abandoned halibut gear was 500 mt in 1993 and increased to 777 mt in 1994, primarily due to increases in Area 2C and 3A. Since the inception of the IFQ fishery in 1995, discards from lost and abandoned gear have averaged approximately 200 mt annually, probably in response to the slower fishing possible under IFQs and the opportunity to recover any gear which might become lost.

Discard mortality of sublegals was estimated from sublegal catch rates on research surveys which were applied to effort data from fishermen's logbooks. The results indicate that sublegal mortality averaged roughly 850 mt during 1993-1994. It was highest in Area 3A, averaging approximately 460 mt annually during 1993-1994. With the advent of the IFQ program in 1995, sublegal discards declined as overall catch was reduced. With higher catch limits since 1997, estimates of sublegal discards have increased.

High-grading

In the U.S. IFQ program, it is illegal for fishermen to discard legal-sized fish from a vessel if the fisherman has available IFQ within the area. However, there have been many anecdotal remarks suggesting high-grading of either small or large halibut to meet price and demand. IPHC does not have estimates of how frequently this occurs. Information on the amount of reported legal-sized halibut discarded once an IFQ has been reached is recorded by IPHC samplers during logbook interviews. This type of discard mortality is reflected as part of the wastage component.

The Canadian IVQ program has no provisions regarding legal-sized discards when IVQ is still available, but, as with the U.S. IFQ program, reported discards after IVQ is reached are recorded and estimated through the wastage component.

Sport Fishery Catches

Recreational fishing for halibut was nonexistent in the 1920s but has grown into a major industry. The first IPHC regulations on sport fishing were instituted in 1973 and included an 8-month season with limitations on the individual's daily catch and the gear. Since that time, sport regulations have grown in complexity and have seen increased involvement by state, provincial and federal agencies.

Sport fishery catches are provided to IPHC by state and federal agencies. Estimates for the Area 2A harvest are provided by the Oregon Department of Fish and Wildlife (ODF&W) and Washington Department of Fish and Wildlife (WDF&W) from creel census and telephone surveys. Area 2B estimates continue to be under review by IPHC and Canada Department of Fisheries and Oceans (DFO), but IPHC uses estimates currently based on the DFO Tidal Diary Program. The Alaska Department of Fish and Game (ADF&G) provides harvest estimates from Areas 2C, 3 and 4 using a postal survey and port sampling. The 1999 coast-wide sport fishery harvest is estimated at 5,503 mt (Table 5).

Personal Use

Personal use includes a variety of removals for which little documented data are available: sources include (1) a sanctioned Indian food fish fishery off Canada; (2) a program allowing the retention of sublegal halibut in the Area 4E Community Development Quota (CDQ) program; and (3) unreported harvests landed in rural Alaska. Both the IFQ program off Alaska and the Canadian IVQ program account for any personal use take-home fish as part of the person's quota.

In Canada (Area 2B), DFO estimates the annual Indian food fish catch at 180 mt. The Area 4E program began in 1998 and participants reported to IPHC a total of 2.17 mt (3,590 lbs. net) of retained sublegal halibut in 1998 and 4.78 mt (7,901 lbs. net) in 1999. Estimates for other areas and years have been made by Trumble (1999), based on ADF&G household and postal surveys (Table 6). These results show that coastwide personal use has ranged form 328 to 660 mt. Personal use in the Alaskan areas has averaged 200 mt since 1995.

In Area 2A, state regulations require that any take-home poundage be recorded on the fish ticket. Thus, this type of removal in Area 2A is accounted for in the commercial catches.

Bycatch Mortality

Bycatch mortality is the second largest source of halibut removals and most recently documented by Williams et al. (1989). Halibut bycatch mortality was relatively small until the 1960s, when it increased rapidly due to the sudden development of the foreign trawl fisheries off the North American coast. The total bycatch mortality (excluding the Japanese directed fishery) peaked in 1965 at about 12,900 mt. Bycatch mortality declined during the 1960s, but increased to about 12,000 mt in the early 1970s. During the late 1970s and early 1980s, it dropped to roughly 10,000 mt. By 1985, bycatch mortality had declined to 4,603 mt, the lowest level since the IPHC began its monitoring nearly 25 years earlier. The late 1980s saw an unexpected increase in bycatch mortality, as the foreign fleets off Alaska were replaced by a growing and unregulated U.S. groundfish fishery. Bycatch mortality peaked during this period at 12,240 mt in 1992. For 1999, bycatch mortality is estimated at 7,779 mt (Table 7), only a slight decrease from 1998 and a 36% decrease since 1992. Bycatch in 1999 declined in Area 4 and increased in Area 3.

ASSESSMENT METHODS

The Pacific halibut assessment is based on fitting an age- and length-structured model to data from the fishery and IPHC setline surveys. The only major change in the 1999 assessment was a lowering of setline survey catch rates from the 1990s to account for a bait change, which reduced the population estimates by 20-30% in the eastern and central Gulf of Alaska (Areas 2 and 3A). A continuing decline in size at age also affected the estimates in Area 2C and Area 3A. Very low estimated recruitment in Area 3A in recent years implies a rapidly declining biomass in that area, but trawl surveys indicate continuing high abundance of 60-80 cm fish in that area, so this may be a false alarm. However, it does now appear that recruitment has declined from the high levels of 1985-1995. Farther west (Areas 3B and 4), biomass is estimated by extrapolating the Area 3A estimate on the basis of setline survey results. Total setline CEY (available yield at a harvest rate of 20%) is estimated to be 63 million pounds, down from almost 100 million last year. Most of the decrease in Areas 2AB and 2C is due to the bait correction, while lower weight at age and recruitment are equally influential in Area 3A.

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. Exploitable biomass in each IPHC regulatory area is estimated by fitting a detailed population model to the data from that area. A biological target level for total removals is then calculated by applying a fixed harvest rate—presently 20%—to the estimate of exploitable biomass. This target level is called the "constant exploitation yield" or CEY for that area in the coming year. The corresponding target level for directed setline catches, called the setline

CEY, is calculated by subtracting from the total CEY an estimate of all other removals—sport catches, bycatch of legal sized fish, wastage in the halibut fishery, and fish taken for personal use.

Staff recommendations for quotas 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.

The Assessment Model

From 1982 through 1994, stock size was estimated by fitting an age-structured model (CAGEAN) to commercial catch-at-age and catch-per effort data. In the early 1990s it became apparent that age-specific selectivity in the commercial fishery had shifted as a result of a decline in halibut growth rates, which was more dramatic in Alaska than in Canada. An age- and length-structured model was developed and implemented in 1995 that accounted for the change in growth. It also incorporated survey (as well as commercial) catch-at-age and catch-per effort data. The survey data contain much more information on younger fish, many of which are now smaller than the commercial size limit, and are standardized to provide a consistent index of relative abundance over time and among areas.

At first the model was fitted on the assumption that survey catchability and length-specific survey selectivity were constant, while commercial catchability and selectivity were allowed to vary over time (subject to some restraints). The resulting fits showed quite different length-specific survey selectivities in Area 2B and 3A, however, which suggested that age could still be influencing selectivity. To reflect that possibility, the new model has been fitted in two ways since 1996: by requiring constant length-specific survey selectivity (as in 1995), and by requiring constant age-specific survey selectivity. The age-specific fits generally produce lower estimates of recent recruitment and therefore present abundance, and to be conservative the staff has used those estimates to calculate CEY's.

With either fitting criterion, the abundance estimates depend strongly on the natural mortality rate M used in the population model. Until 1998 the estimate $M = 0.20$ had been used in all assessments. This estimate is quite imprecise, and an analysis done by the staff suggested that a lower working value would be appropriate. The value $M = 0.15$ was chosen and used as a standard, which lowered abundance estimates in the 1998 assessment by about 30%.

The only significant change to the assessment in 1999 was introducing an increase in setline survey catchability, beginning with the 1993 survey data, to account for a change in bait between the 1980s and the 1990s. When setline surveys resumed in 1993 (after being suspended since 1986), chum salmon was adopted as the standard bait, whereas in the 1980s the bait was herring and salmon on alternate hooks. Experiments done in 1999 showed that salmon bait catches 50-150% more halibut than herring. Further experiments were conducted in 2000 in which mixed bait will be compared directly with salmon, but the results are not yet available. In the meantime, a working value of 100% was used in the assessment. This translates to a 33% increase in overall survey catchability after the 1980s. (For every two hooks, in terms of hooks baited with salmon, the survey switched from the equivalent of 1½ hooks to 2 hooks, an increase of one third.)

Stock Size Estimates in Areas 3B and 4

Until 1997 the analytical model was used to estimate halibut abundance for the entire Commission area, including lightly fished regions in the western Gulf of Alaska (Area 3B) and the Bering Sea/Aleutians region (Area 4). Because there is no historical survey data for western Alaska, the assessment relied entirely on commercial data for those areas. In 1997 the Commission first did setline surveys of the entire

Commission area, and they showed substantially more halibut to be available in western Alaska (relative to other areas) than the analytical model had estimated. The reason for the discrepancy is almost certainly that the analytical model, when fitted to commercial data alone, only estimates the size of the *exploited population*, and in western Alaska fishing intensity is very low or nil over large areas, so a substantial part of the stock is effectively unexploited and therefore invisible to the model but not to the surveys.

In light of the survey results, analytical estimates of stock size in Areas 3B and 4 were suspended in 1997. The procedure now is to calculate analytical estimates for Areas 2A, 2B, 2C, and 3A, and then to scale those absolute estimates by survey estimates of relative abundance in Area 3B and 4 to obtain absolute estimates for the western areas. In 1997 the sum of the abundance estimates for Areas 2A through 3A was used as the reference point. Since then the absolute estimate for Area 3A only has been used as the reference point, on the grounds that survey catch rates there are more comparable to survey catch rates farther west.

Analytical Estimates of Abundance in 1998

A stepwise summary of the 1999 assessment is shown in Table 8. The "housekeeping update" of the 1998 assessment (Step 2 in the table) consisted of a number of small items, none of which had an important effect on the estimates except as noted:

(i) Adding the 1998 survey ages, which increased the 3A estimate by about 5 M lb. and reduced the 2C estimate by 2.5 M lb.;

(ii) Recomputing some of the early commercial size-at-age estimates and correcting some of the survey CPUE estimates. The latter increased the 2AB estimate by about 5 M lb.;

(iii) Smoothing the commercial mean weight-at-age over ages within years rather than over years within ages, as was done in the past. The old procedure did not accurately track year-to-year changes in mean weight in the catch. The new procedure reduced the 2C estimate by about 5 M lb as a result of a drop in mean weight between 1998 and 1999 that had been ignored by the old smoother; and

(iv) Slightly altering the growth equations, which raised the 3A estimate by about 5 M lb.

Increasing survey catchability by 35% in the 1990s (Step 3) to account for the bait change has the effect of reducing the apparent increase in halibut abundance since the 1980s by 25% (to 1/1.35 of the former value), but it does not reduce the estimates of 1999 biomass by the same amount because other things play a role, including commercial catch per effort. As it turned out, the 2AB and 2C estimates for 1999 decreased by about 20% and the 3A estimate by almost 30%.

The addition of the 1999 commercial data (Step 4) can affect the 1999 estimates through the commercial CPUE, the age composition of the catch, and the mean weight at age in the catch. The only sizable effect was a large decrease in the 3A estimate caused almost entirely by a decline in the mean weights. This trend has been going on for some time (Table 9. It appeared to have leveled off in the mid-1990s, but in 2C and 3A it has resumed since 1997, reducing biomass estimates in Alaska by a full 20% over the last two years.

The addition of the 1999 survey data (Step 5) had little effect in Area 2AB and a positive effect on estimated 1999 abundance in Alaska, despite the low survey catch rates. This can happen when the survey catch at age increases the estimated abundance of some year-classes.

When the estimated numbers at age are projected forward to 2000 (using the 1999 mean weights to calculate biomass), the change in the biomass estimate depends on the estimated abundance of all the year-classes in the stock, which at ages 8 to, say, 20 in 2000 will be the 1980 through 1992 year-classes. Generally the year-classes coming into the stock are now weaker than the ones passing out of it, so the projections for 2000 are lower than the 1999 estimates (Table 10). The drop is bigger in 3A (20%) than in 2AB and 2C (10%) because the assessment shows that recruitment to 3A peaked in 1980 and has been declining steeply since, to levels that are now on a par with the mid-1970s. In 2AB and 2C the 1987 and 1988 year-classes were strong, and the most recent ones appear to be mediocre but not really poor as in 3A.

In summary, this year's estimates are substantially lower than last year's because of the allowance for increased survey catchability, lower mean weights at age, and recent declines in recruitment. In Alaska (2C and 3A) the cumulative effect is a 35-40% reduction; in Area 2AB about 15%.

Plots of fitted values

There is very little difference between the age- and length-specific fits in Area 2, so only the age-specific fits are illustrated for Area 2AB (Fig.1) and Area 2C (Fig.2). In Area 3A there is more of a difference, so both fits are illustrated (Figs. 3 and 4).

Except for the age-specific fit in Area 3A, all of the fits show the 1987 year-class to be strong. All of the fits show a drop in recruitment after the 1987 year-class, which in Area 3A has been steep and sustained, to the point where estimated recruitment at age 8 in 1999 is the lowest in the 1974-1999 series. As explained below, this severe decline in recruitment is likely overstated. The age- and length-specific fits in 3A show very similar recruitment trends. The length-specific estimates are slightly higher from 1980 on, with the cumulative result that the length-specific estimate of exploitable biomass in 2000 is 121.4 M lb compared with the age-specific value of 94.9.

In the plot of survey catch rates (center left panel), the broad shaded line is a data smoother that shows the general trend of the survey data points. The thin black line is the model predictions of survey catch rates. There is quite a wide scatter of the data points around the general trend, which means that the survey data are quite variable from year to year. Thus while the surveys are an essential index of the general level of stock abundance, the year-to-year changes are not very meaningful.

In the center right panel, commercial catch per effort is plotted as points and the model estimates of exploitable biomass as a dotted line. Predicted commercial CPUE is plotted as a solid line; it reflects estimated changes in commercial catchability ("q") as well as the trend in exploitable biomass. The values of exploitable biomass in this graph are calculated with the model estimates of commercial selectivity in each area in each year, and are not the same as the estimates of exploitable biomass that appear below in the calculation of setline CEY. Those are calculated with a fixed coastwide selectivity.

The estimated selectivities in the lower panels are unremarkable except for the very steep length-specific survey selectivities in recent years estimated with the age-specific model. In light of other evidence of length-specific vulnerability to hooking (from marking and video observations), these curves are probably too steep and shifted too far to the left.

Estimates of Exploitable Biomass and CEY

As explained above, exploitable biomass in 3B and 4 is estimated by scaling the analytical estimate for 3A by survey estimates of relative abundance. For that purpose, average survey catch rates in 3B and 4 relative to 3A were calculated by a procedure that uses all available 1996-1999 data but places more weight on the more recent values. These relative catch rates are then scaled by relative total bottom areas (0-500 fathoms) to estimate relative total biomass levels in 3B, 4A, and 4B. There are no recent survey data for 4CDE, so last year's estimate is carried over. Estimated abundance in Area 3B and 4 relative to

3A is higher this year than last because of lower survey catch rates in 3A in 1999 and continued good catch rates farther west. The full set of exploitable biomass estimates is:

	2AB	2C	3A	3B	4A	4B	4CDE	Total
Exploitable biomass (ebio) relative to 3A	---	---	1.00	1.02	0.38	0.37	0.37	---
Ebio (M lb)	55.5	42.2	94.9	96.8	36.1	35.1	35.1	395.7

The target harvest rate of 20% was chosen on the basis of calculations of stock productivity that used a coastwide average of the estimates of commercial selectivity from the age-specific fit of the model, so the biomass estimates from the age-specific fits are used to calculate exploitable biomass and CEY (Table 11).

Some ad hoc procedures were required to estimate non-commercial removals and setline CEY by subarea within Area 4. Wastage was distributed among subareas in proportion to commercial catch. Sport catch and personal use were allocated 90% to 4A and 10% to 4CDE. Legal sized bycatch mortality was distributed in proportion to total (legal + sublegal) bycatch mortality recorded by NMFS observers. This procedure requires two assumptions. First, the distribution of observer coverage by IPHC regulatory area should be proportional to total fishing effort. Second, the size distribution within each regulatory area should be equal (since we subtract out just the legal portion of the bycatch). It is likely that both of these assumptions are roughly met and this procedure is almost certainly more accurate than other alternatives such as distributing mortality in proportion to biomass. In 1998, observed mortality of halibut was distributed among regulatory areas as follows: 4A 16%, 4B 6%, 4CDE 24%, Closed Area 54%. As the Closed Area is on the eastern Bering shelf, it is treated as part of Area 4CDE.

Outlook

It now appears likely that coastwide recruitment has declined from the high levels of the 1985-1995 period, and size at age is still going down. Thus while abundance in number is still quite high relative to the levels of 1975 or 1980 (Table 10), biomass levels are not as good and the prospect is for a continuing decline as relatively strong year-classes pass out of the stock and relatively weak ones enter (and grow more slowly).

The prospect is worst in 3A, but the apparent near-failure of recruitment there may not be real. NMFS trawl surveys indicate a much higher abundance of 8-year-old halibut in Area 3A than our analytical assessment based on setline data. This is a puzzle, because for legal-sized halibut trawl and setline surveys agree reasonably well on trends in relative abundance, but since 1990 trawl survey catch rates of sublegal halibut have greatly outpaced setline survey catch rates (Fig. 5).

Another cause for suspicion is the re-emergence of a retrospective pattern in the 3A estimates (and only there), with the estimate of exploitable biomass in a given year increasing in each succeeding assessment (Table 12). This is consistent with an over-estimate of the selectivity of young fish, whose abundance is consequently underestimated initially. The estimate is then corrected in later assessments as the year-class moves through the fishery. In the past this pattern was caused by declining size at age, but size at ages 8 and below has changed very little, so some other factor must be at work.

It therefore seems very possible that exploitable biomass in 3A is underestimated and that incoming recruitment will turn out to be no worse in 3A than in 2AB and 2C. But even that would be low by recent standards.

ASSESSMENT PARAMETERS

Natural Mortality, Age and Size of Recruitment, and Maximum Age

Estimates of the natural mortality rate of halibut have varied somewhat over the years. IPHC has used a value of 0.2, but recently revised this downward to 0.15. See the Assessment section for more details.

The age and size of recruitment are under review. However, analyses commonly use age 8 as a measure of recruitment to the fishery.

Regarding age, traditional surface reading of otoliths has provided a maximum age is 42 for female and 27 for male halibut. Recent attempts with otolith break-and-burn aging techniques have indicated that male halibut are much older than previously thought, as a new maximum age for males of 55 has been noted.

Length at Age

IPHC field work includes sampling of the commercial landings in most major ports. Part of the sampling includes length measurements, along with otolith collection. Information on the 1999 age composition by regulatory area is shown in Table 13. Summaries of the average length, and age by regulatory area for 1999 are shown in the following table:

Variable	Area 2A	Area 2B	Area 2C	Area 3A	Area 3B	Area 4A	Area 4B	Area 4C	Area 4D	All Areas
Avg. Length (cm)	97.1	100.4	106.0	102.5	105.7	108.0	111.7	114.0	101.4	104.6
Avg. Age (yrs)	11.3	12.6	12.8	14.1	14.2	12.9	15.7	12.0	12.3	13.3

Halibut weight in kg, round weight can be derived from the length using the following equation:

$$W = (4.175 \times 10^{-6})\, L^{3.24}$$

where L is fork length in cm. Weight in pounds, net weight (head off and eviscerated) can be derived using the following equation:

$$W = (6.9205392 \times 10^{-6})\, L^{3.24}$$

where L is fork length in cm.

Maturity and Length at Age

Maturity at age and length was examined by Parma (1993). All commercial landings of halibut are eviscerated, so research survey data collected during March through September were used to estimate the maturity schedules by age for female halibut only. Data have been collected since the early 1960s, so the data were pooled by regulatory area and three multi-year time periods (1960-1969, 1970-1979, and 1980-1984) were analyzed. The results for maturity at age were as follows:

	Age at 50% Maturity by decade (Parma 1993)		
Reg. Area	**1960s**	**1970s**	**1980s**
2B	11.77	10.49	10.97
2C	12.22	-	11.60
3A	10.53	10.55	11.50
3B	11.32	11.39	11.82
4	13.71	12.24	12.14

Parma (1993) also estimated $L_{0.5}$, but these values will be revised in light of the changes in growth trends. The schedule of maturity at age has been relatively stable in spite of dramatic changes in growth, although data collected in the 1990s show indications that fish are now maturing at least one year earlier.

ABUNDANCE AND EXPLOITATION TRENDS

Trends in Abundance

<u>Relative Abundance: Longline Surveys</u>

IPHC has conducted standardized longline surveys since the 1960s. The surveys were intended to provide information which was not available from sampling of the commercial landings, such as information on sex composition, maturity, and spatial distribution of the resource. The surveys were not designed to provide estimates of absolute abundance.

The survey design has been changed several times (Hoag et al. 1980, Randolph and Larsen 1996), but principally consists of fishing 3-4 predetermined locations each day following a specific setting and hauling schedule. All halibut are measured, sexed, gonad maturity is determined, and otoliths are collected from a randomly determined subsample of the catch. Other variables that are standardized include bait type and size, hook size and spacing.

Average CPUE (kg, rd. wt.) per standard skate (i.e., 100 hooks at 18-foot spacing) for longline surveys in Areas 2B, 2C, 3A, and 3B is shown in Table 14. The increase in the number of stations fished in 1996 corresponds to expanded survey coverage. The 1997 survey incorporated several minor design changes. Additional modifications were made to the survey design for 1998. For stock assessment purposes, only the stations fished on the same grounds are used to compute CPUE indices.

In general, results from the 1999 surveys showed a drop in CPUE (kg per standard skate) in the eastern Gulf areas (Areas 2B, 2C, and eastern 3A) and an increase in Area 3B and Area 4.

<u>Relative Abundance: Commercial Fishery CPUE</u>

Commercial fishery CPUE, in kg (round weight) per standard skate, declined in the eastern areas and increased in the western areas in 1998, with a drop in the overall coastwide CPUE of 4% (Table 3). On an area-by-area basis, CPUE decreased 43% to 77 kg/sk in Area 2A, 15% to 123 kg/sk in Area 2B, 12% to 124 kg/sk in Area 2C, and 9% to 327 kg/sk in Area 3B. CPUE increased 3% to 270 kg/sk in Area 3A and 7% to 254 kg/sk in Area 4.

Absolute Abundance: Trawl Surveys

NMFS Bering Sea Survey

In 1975, and annually since 1979, NMFS has conducted a systematic trawl survey of a standard area of the eastern Bering Sea shelf extending northward to about 61°N. This area is a major nursery ground for juvenile halibut in summer, when the survey is carried out. Every third year the northern shelf and the slope are added to the survey area. Stations are located on a 20 nautical mile (37 km) grid in depths from 30 to 200 fm. Since 1981 the survey trawl used on the shelf has been an Eastern flatfish trawl (without roller gear) with a headrope length of 25 m and a footrope length of 34 m. In earlier years a slightly smaller net of the same design was used.

Abundance is estimated by expanding the survey catch from the area swept by the trawl to the total survey area, assuming the trawl catches everything between the wings and nothing outside that path. This estimate may be biased high or low, but over a long period should provide a good index of relative abundance in the survey area during the summer, when both juvenile and adult halibut are mostly within the depth range covered by the survey. In winter halibut move into deeper water, so a series of winter surveys might show quite different trends.

Total survey biomass increased slowly from about 50,000 mt in 1980 to about 100,000 mt in 1992 (Table 15). In 1993 the estimate jumped to 160,000 mt, and has since remained at about that level. This recent increase is not due to sampling variability; the estimate of the total biomass has a coefficient of variation of only about 10%.

Bering Sea Survey Length Frequencies

In some years it is possible to discern the appearance of an above average year-class at age 2 as a distinct mode at about 20 cm in the survey length frequency. In particular, the strong 1977 year-class was a standout at age 2 in 1979, and sustained the overall level of juvenile abundance for the next two or three years (Figures 6 and 7).

The 1987 year-class made a strong showing in 1989, and in 1990 appeared as an enormous spike, head and shoulders above the spike representing the 1977 year-class in 1980. In the following years, through 1994, it appeared stronger in every year than the 1977 year-class did at the same ages. The bulk of them now appear just below the commercial minimum size of 81 cm, which is small for 9-year-olds.

No other strong year-classes have appeared as 2-year-olds in the trawl survey since the 1987 year-class.

Gulf of Alaska Survey

Every third year, NMFS conducts a trawl survey of the Gulf of Alaska from 170^0 West (Islands of Four Mountains) to Dixon Entrance. Figure 8 shows the swept-area estimates of total abundance at length for surveys through 1996. In most years, the bulk of small halibut (fish less than 40 cm) were found in the Gulf, rather than the Bering Sea. The exception was 1990, when the big 1987 year-class was three years old. Fish of this year-class probably account for the dramatic increase of fish 50-60 cm long in the Gulf at the time of the 1993 survey, and the same fish are probably a substantial fraction of the large numbers of the 60-80 cm fish in the 1996 survey. Wherever those fish came from, they indicate strong recruitment for the next few years as they grow past the commercial minimum size limit of 81 cm and into the setline fishery.

SPAWNER/RECRUIT RELATIONSHIP

Parma (1997) most recently estimated spawner/recruit relationships for halibut. Two relationships were fitted to the data to explore a range of exploitation rates:

(1) A Ricker model with correlated environmental effects: number of recruits at age eight is given by

$$R_{t+8} = S_t \ \exp\{a - b\, S_t + \varepsilon_t\}$$

where S_{tt} is reproductive biomass and $\{e_t\}$ represent environmental effects. The latter are modeled as an autoregressive (AR) process of order one,

$$\varepsilon_t = \rho\, \varepsilon_{t\text{-}i} + e_t,$$

where e_t is a normal random variable with mean 0 and variance σ^2 . The parameter ρ corresponds to the correlation between ε_t and ε_{t-1}. Parameters *a, b,* ρ, and σ^2 were fitted by maximum likelihood to stock-recruitment data for 1943-1996, assuming that reproductive biomass was observed without error.

(2) Flat with shifts in carrying capacity: in this scenario expected recruitment increases in proportion to reproductive biomass until carrying capacity (K_i) is reached, and is constant thereafter,

$$R_{t+8} = \min(aS_t, K_i)\, e^{\varepsilon_t}$$

Carrying capacity K_i, the parameter controlling the maximum level of expected recruitment, alternates periodically between two values, K_1 and K_2, and $\{\varepsilon_t\}$is a series of independent and normally distributed random variables with mean 0 and variance σ^2. The slope *a* was set at the maximum estimated value of R_{t+8}/S_t;K_1 and K_2 were set at the exponential of the mean log-recruitment for the periods 1943-1984 and 1985-1996 respectively, and a periodicity of 20 years was used to alternate between K_1 and K_2. This model is a simple prototype of a stock-recruitment relationship affected by major shifts in climatic regime controlling carrying capacity; it is used here just to explore the performance of different harvest rates under such scenario, without any presumption that halibut stocks will indeed behave in this manner.

Parameter values of the different stock-recruitment models used in the simulations are shown in the following table. Values shown correspond to biomass expressed in million pounds (net weight) and recruitment in thousands of 8-year-olds.

Stock-recruitment Model	**Parameters of the stock-recruitment function**	**Parameters controlling environmental variability**
(1) Ricker with AR environmental effects	**A** = 2.8686 **b** = 2.96982×10^{-3}	ρ=0.89; σ=0.184
(2) Flat with shifts in carrying capacity	**a** = 0.784503 K_1 = 5130 K_2 = 10270	σ=0.2

REFERENCE FISHING MORTALITY RATES AND YIELDS

IPHC management policy follows a Constant Exploitation Yield (CEY) strategy, so rates and yields requested in this section are not available.

MAXIMUM SUSTAINABLE YIELD

Optimal yield for halibut is determined on a dynamic basis under a Constant Exploitation Yield (CEY) policy and is believed to be an improvement over earlier sustainable yield approaches.

Maximum sustainable yield (MSY) for halibut was last examined by Quinn II et al. (1985). They used commercial catch and time-lagged bycatch mortality data, and adjusted fishery effort data for 1929-1984. Their resulting MSY estimate of 43,075 mt compared favorably with the 41,000 - 42,000 mt estimate made by Chapman et al. (1962), which did not include the Bering Sea.

They did not assess MSY for each subarea, but did partition the MSY estimate by assuming that the percent of setline catch taken historically from each subarea was a measure of percent MSY in each subarea. The following table provides subarea estimates (metric tons) based on this partitioning approach for two different levels of bycatch mortality:

	2A	2B	2C	3A	3B	4	Combined
All Gear	543	11,523	7,119	16,952	6,093	905	43,075
Setline only with:							
(a) 6,033 mt bycatch	483	9,894	6,154	14,539	5,249	784	37,042
(b) 12,066 mt bycatch	422	8,265	5,128	12,186	4,344	664	31,009

Parma (1997) used an age-structured model with stochastic stock-recruitment relationships as described above to compute optimal (yield-maximizing) harvest rates and associated average yields. Long-term average yields obtained, not including the Bering Sea stocks, ranged from 24 to 36 thousand mt, depending on the stock-recruitment model and harvest rate used. Long-term average biomass ranged from 68 to 165 thousand mt. Harvest rates in the range of 0.20-0.25 may achieve close to maximum yields under different recruitment scenarios while having a high probability that the stock level stays within the range of historical abundance.

PREVENTION OF OVERFISHING

IPHC does not estimate overfishing levels. However, the risk that the spawning biomass could drop below the historical minimum was taken into account when the current harvest rate of 0.20 was chosen.

ACCEPTABLE BIOLOGICAL CATCH

IPHC management policy does not utilize the ABC concept, but instead is based on harvesting a constant proportion of the available biomass each year. This Constant Exploitation Yield (CEY) for 1997 was calculated using an exploitation fraction of 0.20.

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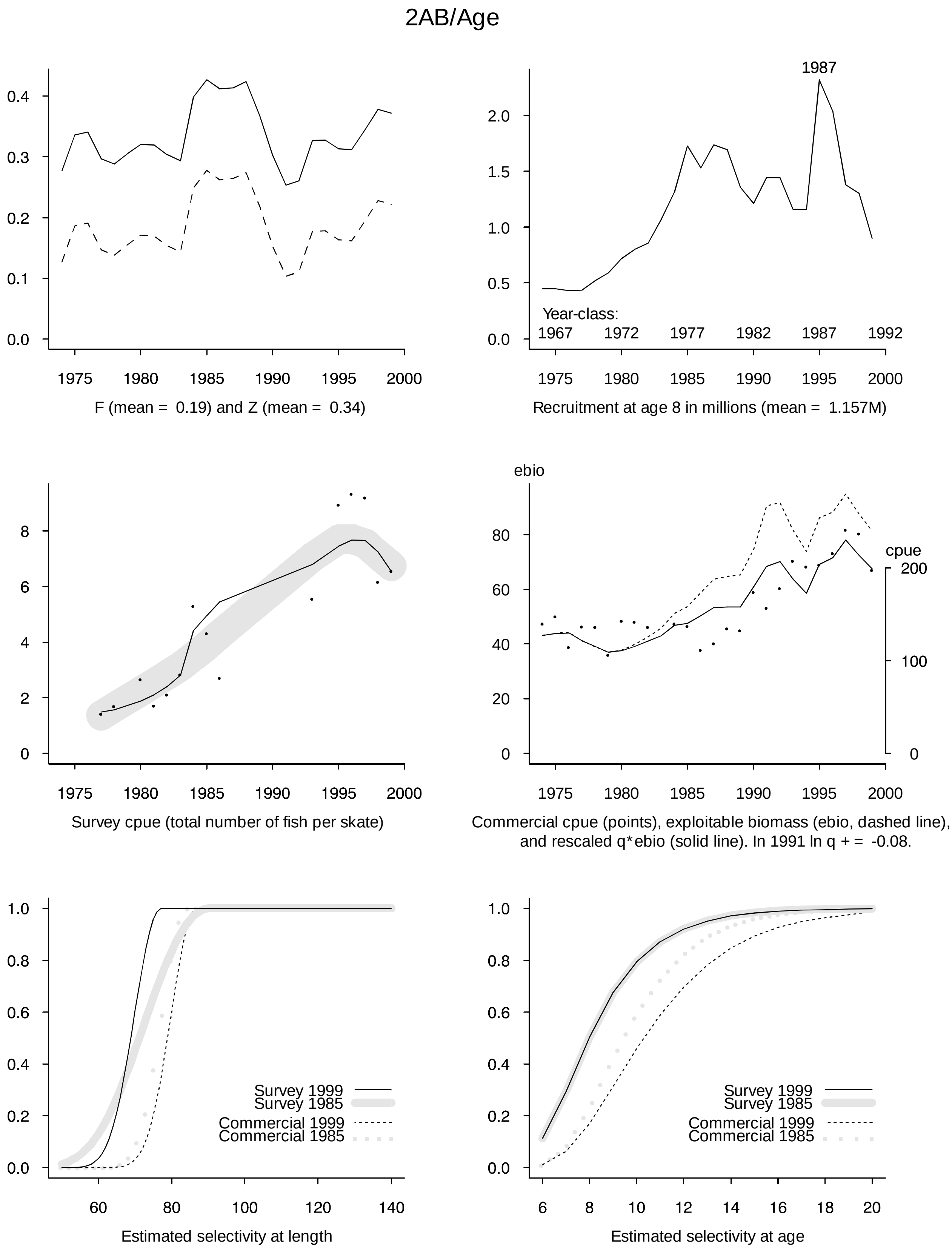

Figure 1. **Features of the age-specific model fit in Area 2AB.**

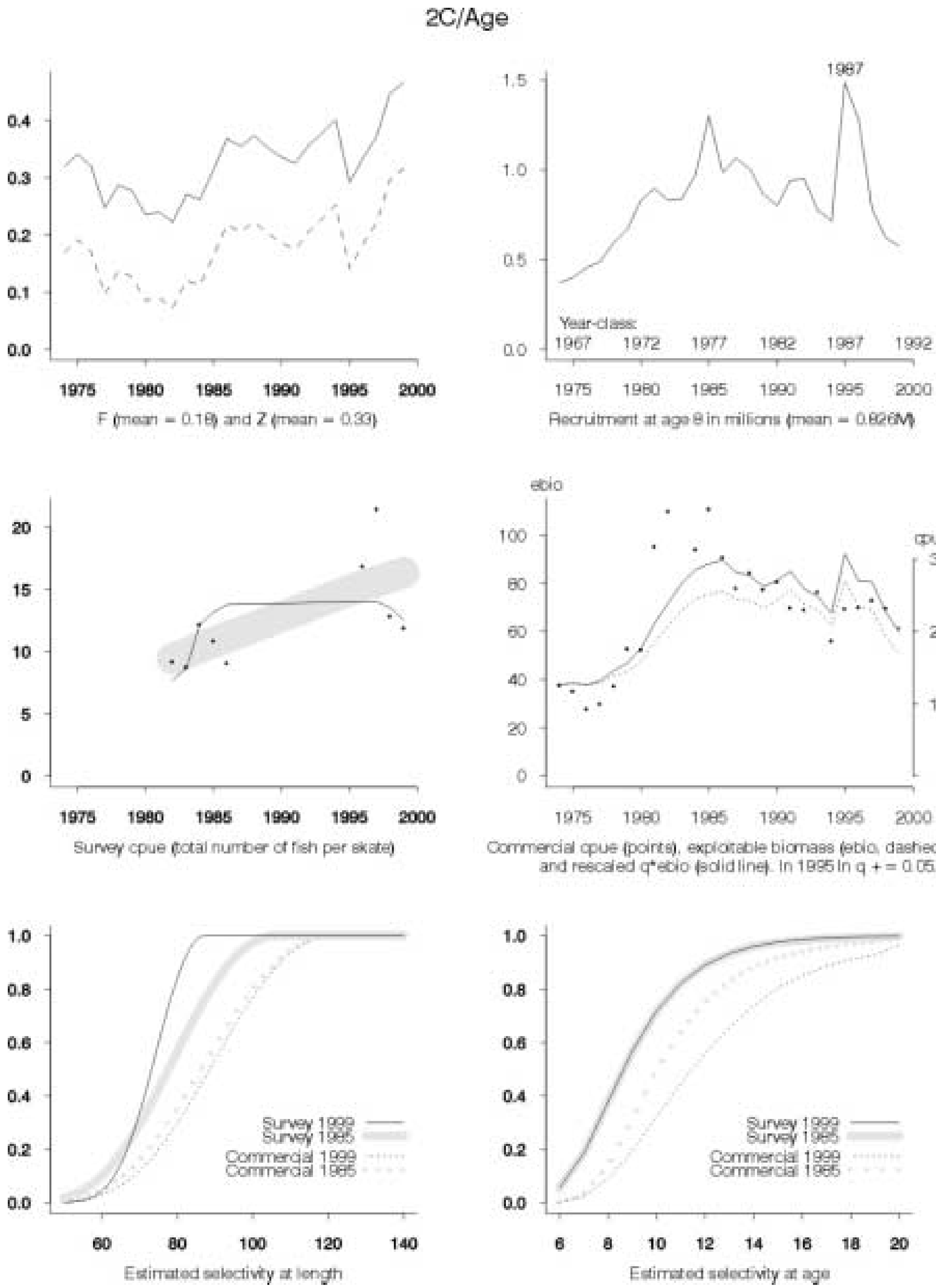

Figure 2. Features of the age-specific model fit in Area 2C.

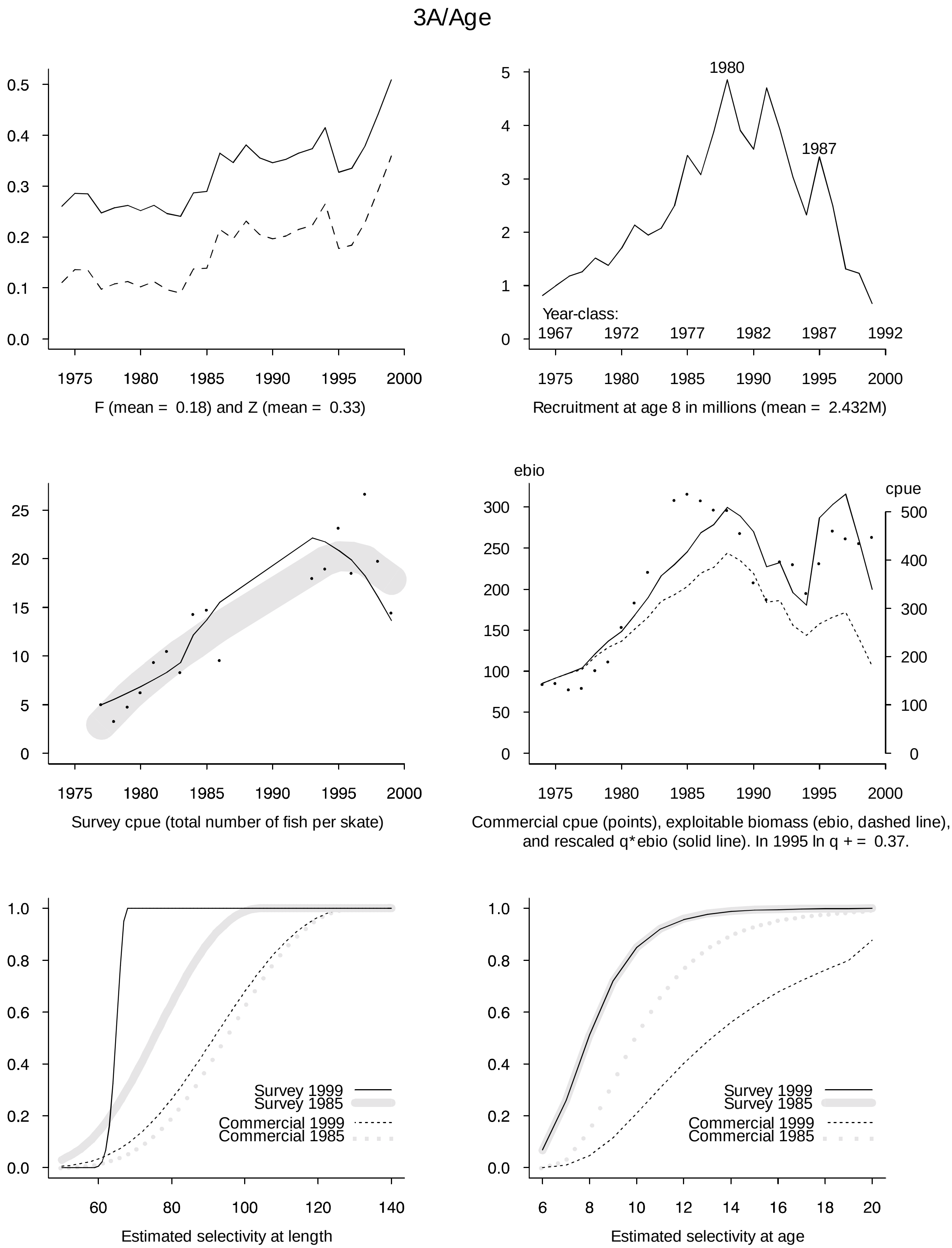

Figure 3. Features of the age-specific model fit in Area 3A.

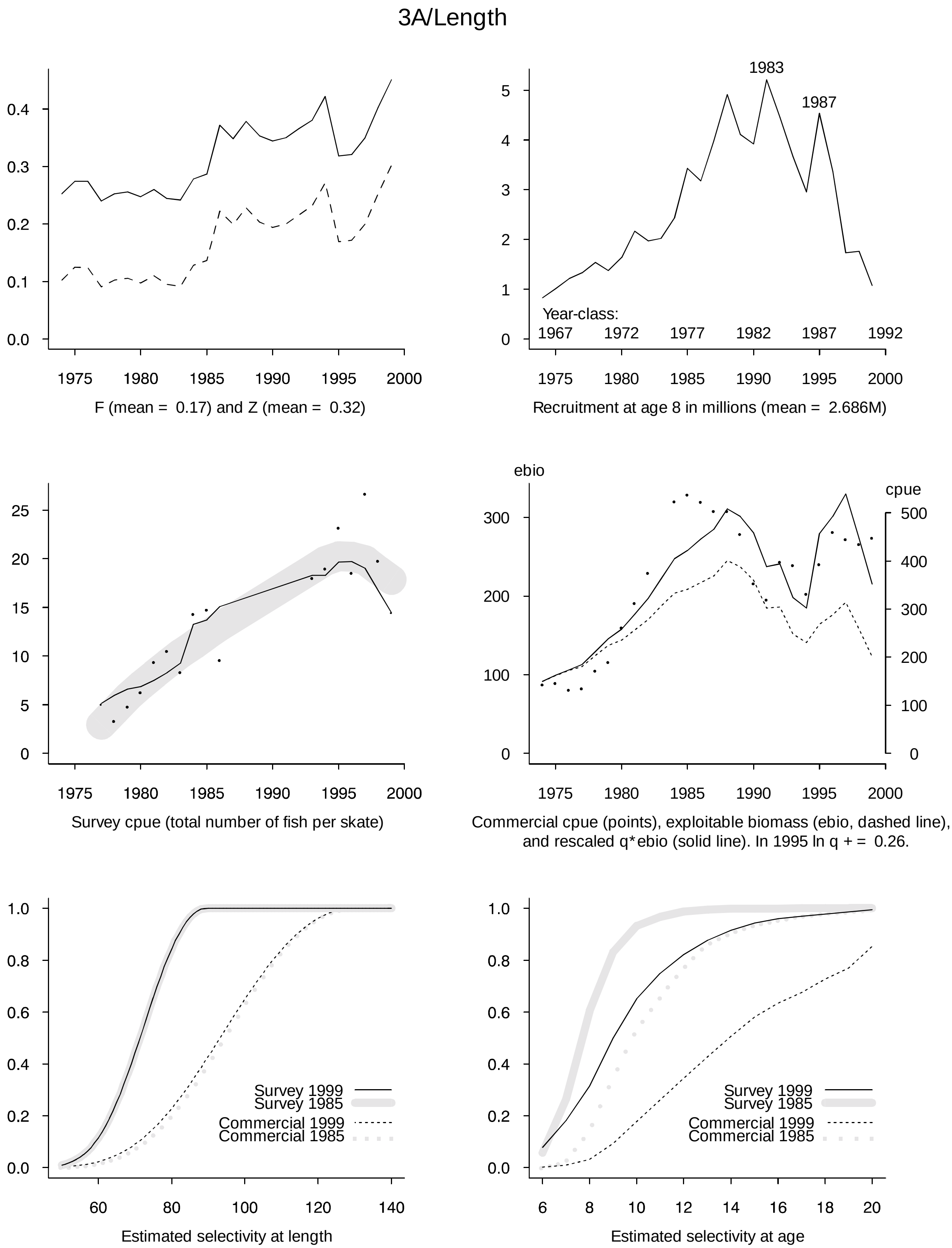

Figure 4. Features of the length-specific model fit in Area 3A.

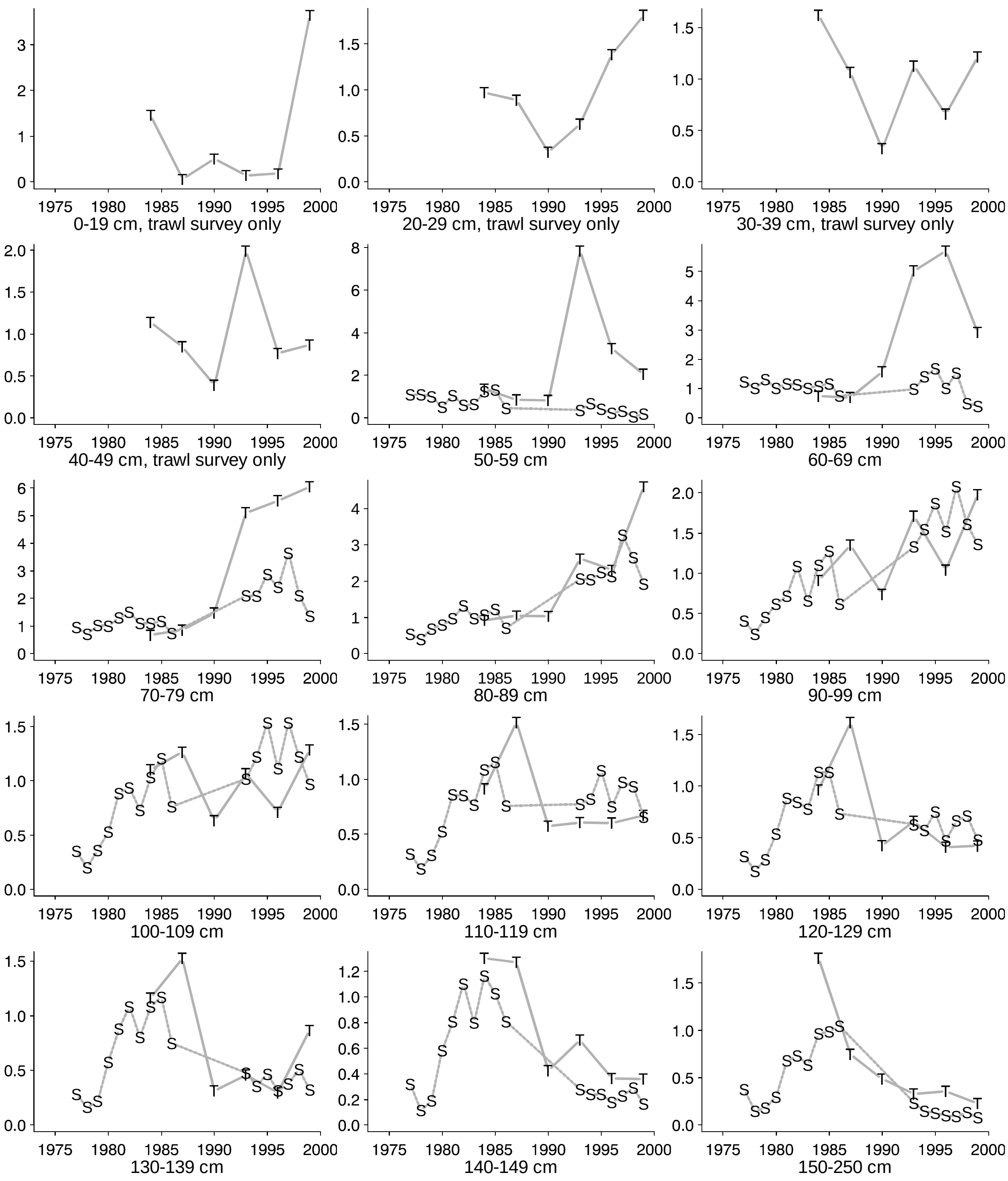

Figure 5. IPHC setline survey (S) and NMFS trawl survey (T) catch rates at length in Area 3A. In each graph, both series are scaled to average 1.0 over the years 1984-1990. Setline catch rates are adjusted for estimated catchability and selectivity.

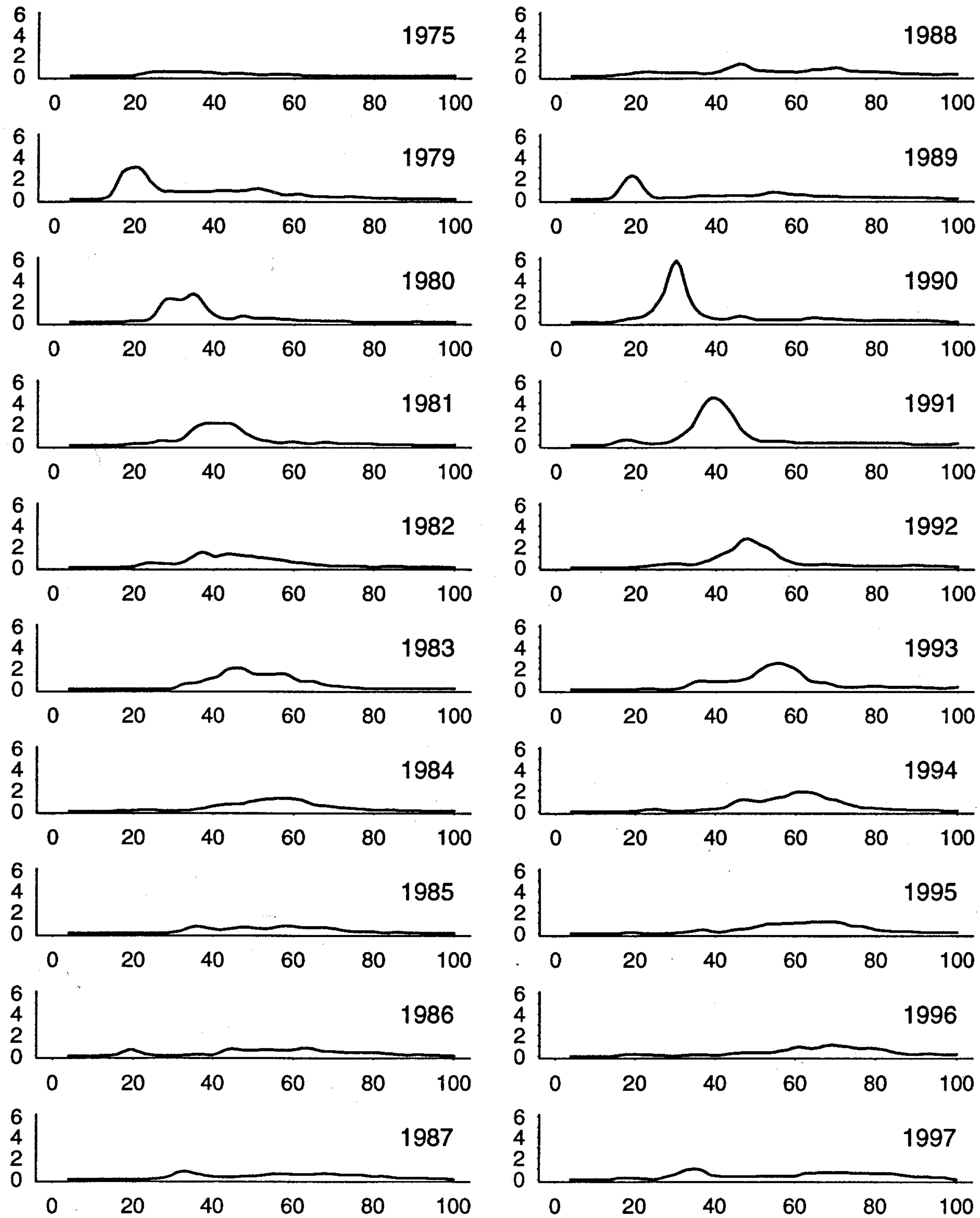

Figure 6. **Smoothed distributions of numbers at length in the 1975-1997 NMFS Bering Sea trawl survey. Horizontal axis is length in cm; vertical axis is absolute frequency in millions/cm.**

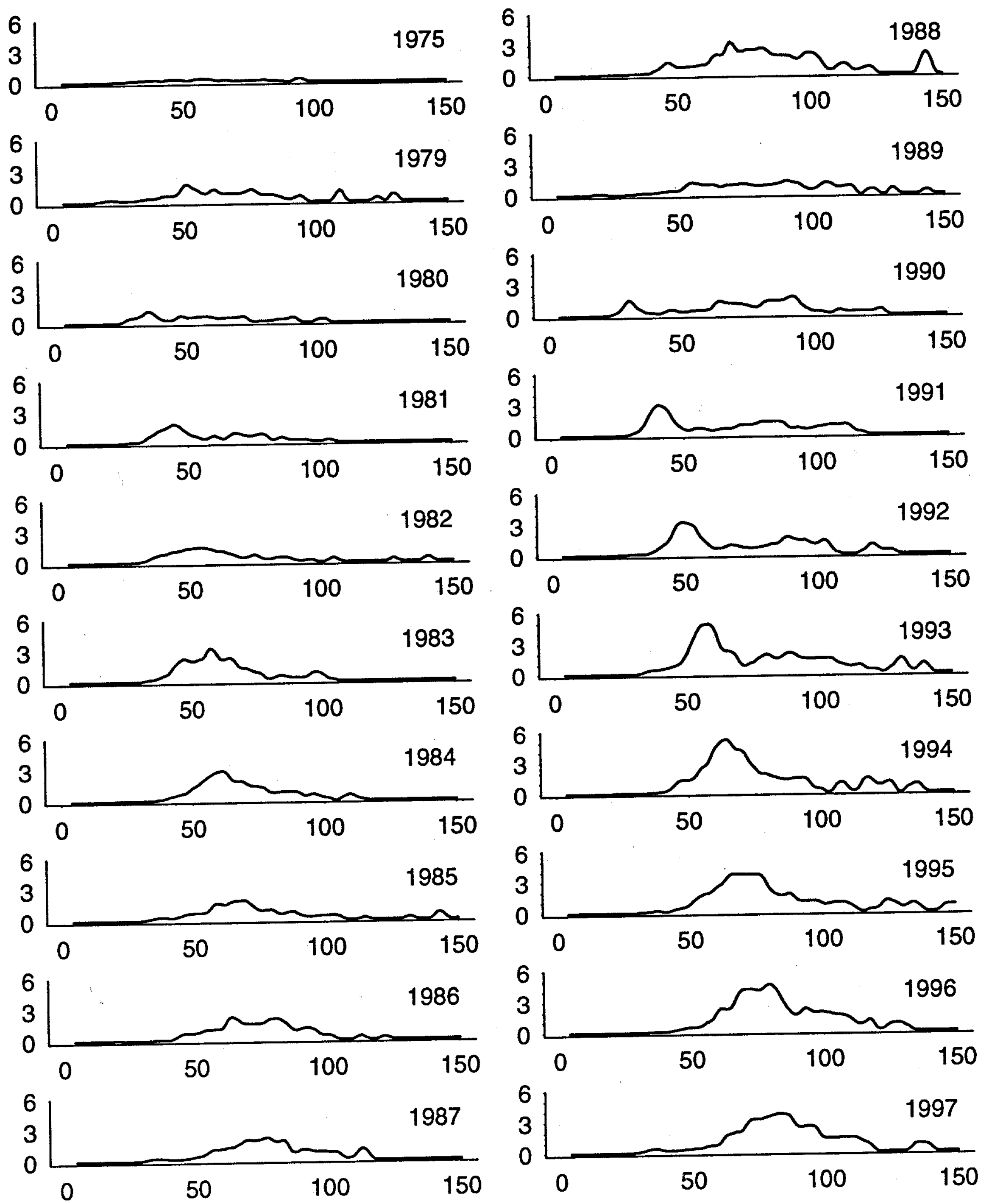

Figure 7. **Smoothed distributions of biomass at length in the 1975-1997 NMFS Bering Sea trawl survey. Horizontal axis is length in cm; vertical axis is absolute biomass in '000 mt/cm.**

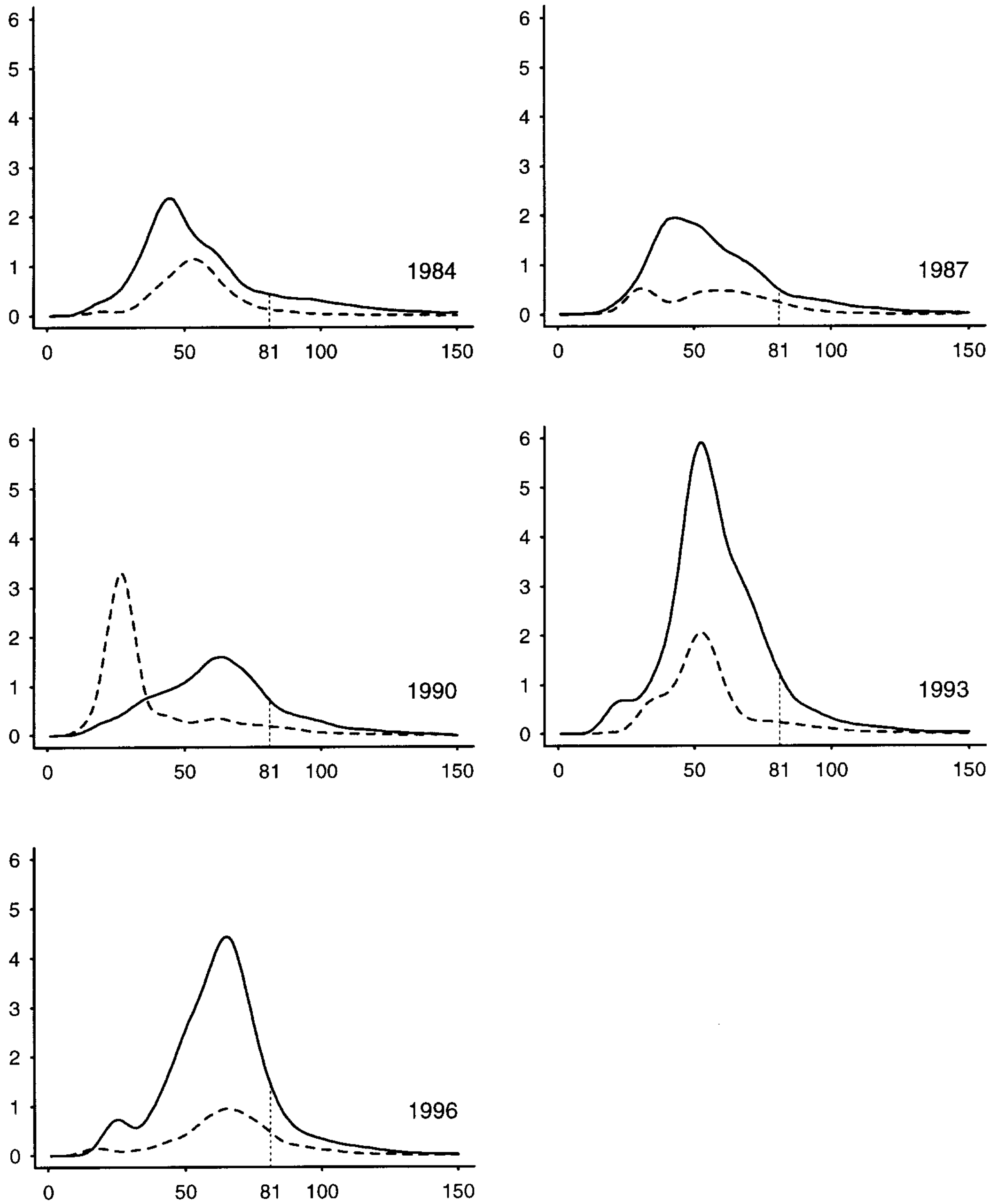

Figure 8. NMFS trawl survey length frequencies (million fish/cm) in the Gulf of Alaska (solid line) and the Bering Sea (dashed line).

Table 1. Catch limits (metric tons, round weight) during 1977-2000 for the commercial fishery for Pacific halibut. Catch limits for Area 2A include both the treaty and non-treaty commercial fisheries, but excludes the ceremonial-&-subsistence fishery.

Year	Area 2			Area 3A & 3B		Area 3C	Area 4					Total
1977		6,636		6,636		no limit			no limit			13,272
1978		5,430		6,636		no limit			no limit			12,066
	Canadian waters		U.S. Waters									
1979	3,620		2,172	6,636		no limit			no limit			12,428
1980	3,680		1,930	6,033					603			12,246
	Area 2A	Area 2B	Area 2C	Area 3A	Area 3B							
1981	121	3,258	2,051	7,843	1,207				603			15,083
1982	121	3,258	2,051	8,446	1,810				905			16,591
							Area 4A	Area 4B	Area 4C	Area 4D	Area 4E	
1983	121	3,258	2,051	8,446	3,016		724	483	241	121	closed	18,361
1984	181	5,430	3,439	10,859	4,223		724	603	241	241	30	25,971
1985	302	6,033	5,430	13,876	5,430		1,026	784	362	362	30	33,635
1986	332	6,757	6,757	16,952	6,214		1,207	1,026	362	422	30	40,059
1987	332	6,938	6,938	18,702	5,731		1,056	1,056	362	362	45	41,522
1988	290	7,541	6,938	21,718	4,826		1,146	1,207	422	422	60	44,570
1989	257	6,033	5,731	18,702	5,128		1,086	1,146	362	362	60	38,867
1990	196	4,706	4,826	18,702	4,344		905	905	302	302	60	35,248
1991	170	4,464	4,464	16,047	5,309		1,026	1,026	362	362	60	33,290
1992	245	4,826	6,033	16,047	5,309		1,388	1,388	483	483	78	36,280
1993	226	6,334	6,033	12,488	3,921		1,219	1,388	483	483	72	36,261
1994	224	6,033	6,636	15,685	2,413		1,086	1,267	422	422	60	36,259
1995	174	5,743	5,430	12,066	2,232		1,176	1,394	465	465	72	36,209
1996	174	5,743	5,430	12,066	2,232		1,176	1,394	465	465	72	36,209
1997	226	7,541	6,032	15,079	5,429		1,773	2,099	700	700	157	39,736
1998	266	7,841	6,333	15,683	6,635		2,111	2,111	959	959	193	43,091
1999	249	7,298	6,327	14,880	8,064		2,557	2,401	1,224	1,224	235	44,459
2000	283	6,410	5,079	11,072	9,088		3,005	2,969	1,228	1,228	235	40,597

Table 2. Commercial catch of Pacific halibut (metric tons, round weight). Catches for Area 2A include both the treaty and non-treaty commercial fisheries, but exclude the treaty ceremonial-&-subsistence fishery.

Year	Area 2A	Area 2B	Area 2C	Area 3A	Area 3B	Area 4	Total
1977	127	3,276	1,924	5,212	1,924	736	13,200
1978	60	2,781	2,606	6,214	796	814	13,272
1979	30	2,932	2,733	6,841	235	826	13,598
1980	12	3,409	1,955	7,221	169	428	13,194
1981	121	3,409	2,419	8,579	271	718	15,516
1982	127	3,342	2,111	8,162	2,896	863	17,501
1983	157	3,282	3,861	8,512	4,675	2,667	23,154
1984	259	5,460	3,529	12,048	3,921	1,906	27,124
1985	296	6,268	5,556	12,578	6,570	2,582	33,850
1986	350	6,769	6,401	19,782	5,327	3,372	42,001
1987	356	7,390	6,443	18,895	4,681	4,151	41,916
1988	296	7,758	6,859	22,840	4,271	2,829	44,854
1989	284	6,292	5,749	20,349	4,730	2,974	40,378
1990	193	5,170	5,870	17,405	5,243	3,276	37,156
1991	217	4,326	5,243	13,791	7,197	3,614	34,387
1992	264	4,611	5,937	16,195	5,212	3,996	36,216
1993	305	6,427	6,827	13,749	4,750	3,782	35,839
1994	224	5,993	6,276	15,023	2,334	3,245	33,094
1995	180	5,820	4,693	11,091	1,888	2,863	26,535
1996	178	5,779	5,358	11,910	2,214	3,188	28,627
1997	250	7,510	5,998	14,892	5,486	5,288	39,424
1998	278	7,952	6,163	15,542	6,748	5,485	42,168
1999	270	7,699	6,169	15,291	8,389	7,182	45,000
2000[1]	283	5,892	4,630	9,705	8,365	7,810	36,685

[1]Catch reported through October 15, 2000.

Table 3. **Catch per unit effort (CPUE) in kg per standard skate (100 hooks at 18-foot spacing) in the commercial fishery for Pacific halibut.**

Year	Area 2A	Area 2B	Area 2C	Area 3A	Area 3B	Area 4
1977	109.9	81.6	60.0	81.2	97.3	106.3
1978	51.6	83.3	74.9	103.7	70.2	100.5
1979	66.4	63.8	106.5	114.0	48.7	88.1
1980	49.5	89.5	110.8	167.9	190.1	107.2
1981	40.8	93.1	189.3	197.7	233.6	150.8
1982	28.5	89.9	193.9	225.1	278.5	132.7
1983	N/A	N/A	N/A	N/A	N/A	N/A
1984	41.6	88.4	169.4	301.8	286.7	142.1
1985	41.7	86.3	205.5	307.6	363.4	183.9
1986	36.7	71.3	177.4	312.4	310.6	166.8
1987	35.4	77.5	157.0	303.8	287.2	179.8
1988	103.2	80.2	169.5	303.5	395.2	178.6
1989	74.8	80.2	155.6	93.5	355.9	184.6
1990	101.4	105.0	162.3	213.0	292.0	204.5
1991	98.9	94.1	140.6	192.4	281.1	220.8
1992	68.8	112.8	138.8	239.5	265.4	188.2
1993	93.5	127.9	153.8	235.9	304.7	203.3
1994	58.5	128.5	112.8	199.7	222.6	149.0
1995	79.0	126.1	140.0	237.1	287.2	164.1
1996	97.1	132.1	140.6	277.5	327.6	214.2
1997	130.3	146.6	146.6	268.5	343.3	219.6
1998	135.1	143.6	140.0	261.8	359.0	237.7
1999	76.6	122.5	123.7	270.3	327.0	254.0

Table 4. **Discards (metric tons, round weight) of Pacific halibut by the directed halibut fishery.**

Year	Area 2A	Area 2B	Area 2C	Area 3A	Area 3B	Area 4	Total
			Discard mortality from lost/abandoned gear				
1993	5.4	57.9	115.8	205.7	38.0	68.2	491.1
1994	0.6	41.6	137.5	509.8	23.5	64.6	777.6
1995	1.8	35.0	38.0	88.1	15.7	25.3	203.9
1996	0.6	17.5	26.5	106.8	13.3	44.6	209.3
1997	3.6	22.3	24.1	44.6	33.2	47.7	175.5
1998	0.6	32.0	24.7	92.9	33.8	32.6	216.5
1999	3.6	22.9	43.4	60.9	41.6	64.5	237.0
			Discard mortality on sublegal halibut				
1993	9.7	143.6	102.0	445.8	118.2	47.1	866.3
1994	4.8	133.9	94.1	486.9	58.5	40.4	818.7
1995	1.8	102.0	45.2	247.9	30.8	22.9	448.8
1996	1.8	129.1	85.7	247.3	53.1	25.3	542.3
1997	2.4	200.3	85.7	404.7	158.0	101.9	953.0
1998	2.4	228.6	108.0	347.4	172.5	105.0	963.9
1999	1.2	199.0	97.7	253.9	152.6	93.5	798.0
			Total from both sources				
1993	15.1	201.5	217.8	651.5	156.3	115.2	1,357.4
1994	5.4	175.6	231.7	996.6	82.0	105.0	1,596.3
1995	3.6	136.9	83.3	336.0	46.5	48.3	652.8
1996	2.4	146.0	111.5	378.2	66.4	83.2	787.7
1997	6.0	222.6	109.8	449.4	191.2	149.6	1,128.5
1998	3.0	260.6	132.7	440.3	206.3	137.5	1,180.4
1999	4.8	222.0	141.1	314.9	194.2	158.0	1,035.0

Table 5. **Sport catches (metric tons, round weight) of Pacific halibut by International Pacific Halibut Commission regulatory area.**

Year	Area 2A	Area 2B	Area 2C	Area 3A	Area 3B	Area 4	Total
1977	8	10	43	118	-	-	180
1978	6	5	49	170	-	-	231
1979	9	11	105	220	-	-	345
1980	11	7	200	294	-	-	513
1981	11	14	192	453	-	7	677
1982	30	40	295	432	-	7	804
1983	38	62	334	570	-	2	1,006
1984	71	75	375	619	-	8	1,147
1985	116	317	411	730	-	5	1,579
1986	201	224	440	1,151	-	12	2,029
1987	269	318	471	1,200	-	18	2,276
1988	150	304	649	1,969	-	22	3,094
1989	197	383	941	1,813	-	14	3,348
1990	119	460	802	2,195	-	24	3,600
1991	95	352	998	2,556	-	45	4,046
1992	151	349	1,006	2,352	-	24	3,883
1993	148	396	1,093	3,176	-	43	4,857
1994	112	396	1,207	2,707	-	31	4,453
1995	142	954	1,061	2,708	12	30	4,908
1996	138	954	925	2,909	13	43	4,983
1997	214	954	1,034	3,401	17	43	5,664
1998	231	954	1,633	3,179	13	69	6,079
1999	204	954	1,104	3,162	13	65	5,503

Table 6. **Estimates (mt) of Pacific halibut used for personal use or as subsistence fish. Area 2A Treaty Indian ceremonial-&-subsistence catch allocated by the PFMC Catch Sharing Plan is not shown here. Retention of sublegal halibut in the Area 4E CDQ program is included.**

Year	Area 2A	Area 2B	Area 2C	Area 3A	Area 3B	Area 4	Total
1991	-	30	434	--------603--------		230	1,297
1992	-	60	-------------------------603------------------------				663
1993	-	181	65	198	36	73	553
1994	-	181	65	198	36	73	553
1995	-	181	n/a	59	22	57	318
1996	-	181	n/a	59	22	57	318
1997	-	181	n/a	59	22	57	318
1998	-	181	103	45	12	100	440
1999	-	181	103	45	12	103	443

Table 7. **Estimates of Pacific halibut bycatch mortality (metric tons, round weight) by International Pacific Halibut Commission regulatory area.**

Year	Area 2	Area 3	Area 4	Total
1977	1,733	3,612	1,758	7,103
1978	1,402	2,952	3,029	7,384
1979	1,899	4,050	3,269	9,218
1980	1,428	4,282	5,570	11,280
1981	1,308	3,789	3,865	8,963
1982	992	3,602	2,869	7,463
1983	1,039	2,951	2,575	6,564
1984	1,116	2,199	2,830	6,146
1985	1,155	952	2,538	4,644
1986	1,170	752	3,363	5,285
1987	1,465	1,878	3,461	6,803
1988	1,441	2,060	5,343	8,844
1989	1,374	2,464	4,393	8,231
1990	1,775	3,715	5,175	10,665
1991	1,890	3,929	6,045	11,864
1992	1,764	4,011	6,465	12,240
1993	1,717	3,229	4,683	9,629
1994	1,322	3,193	5,710	10,224
1995	1,498	2,849	5,263	9,610
1996	759	2,835	5,131	8,725
1997	739	2,659	4,753	8,151
1998	717	2,443	4,660	7,820
1999	706	2,746	4,326	7,779

Table 8. Steps in performing the 1999 assessment and corresponding estimates of exploitable biomass, by area. These estimates are from the model with fixed age-specific survey selectivity; length-specific estimates are about 10% higher in 2AB and 2C, and 25% higher in 3A.

Area 2AB

	1997	1998	1999	2000
1. 1998 assessment	71.9	70.1	**66.8**	---
2. Housekeeping update	76.1	73.3	71.8	---
3. Increase survey catchability in 1990s	80.8	74.5	57.2	---
4. Add 1999 commercial data	67.5	63.6	61.6	57.0
5. Add 1999 survey data	66.4	62.5	60.3	**55.5**

Area2C

	1997	1998	1999	2000
1. 1998 assessment	66.7	64.7	**63.9**	---
2. Housekeeping update	67.1	57.8	54.5	---
3. Increase survey catchability in 1990s	56.5	47.1	42.5	---
4. Add 1999 commercial data	56.6	47.5	41.5	37.4
5. Add 1999 survey data	61.6	52.3	46.4	**42.2**

Area 3A

	1997	1998	1999	2000
1. 1998 assessment	188.5	180.0	**158.8**	---
2. Housekeeping update	224.7	190.2	171.6	---
3. Increase survey catchability in 1990s	178.4	145.8	125.5	---
4. Add 1999 commercial data	172.8	141.0	106.5	85.2
5. Add 1999 survey data	185.4	152.9	117.5	**94.9**

Table 9. Effect of declining weight at age on exploitable biomass (M lbs, net wt.): what estimated ebio would be in 1999 if calculated with estimated numbers at age in 1999 and mean weights at age from previous years. This shows the full effect of smaller sizes across the whole age range, and is larger than the effect on the modal age groups (particularly in Area 2B), which is what is usually shown.

	Area 2AB	Area 2C	Area 3A
Ebio with 1999 nos. and weights from:			
1974	105.4	70.9	278.3
1975	103.6	71.4	283.2
1976	101.6	71.5	286.7
1977	98.7	71.4	288.8
1978	95.0	70.7	289.9
1979	91.8	70.4	289.5
1980	89.4	70.3	288.2
1981	86.8	70.1	286.1
1982	84.7	69.5	283.0
1983	82.8	68.4	278.7
1984	81.4	66.6	273.9
1985	79.7	64.1	267.8
1986	78.0	61.8	261.9
1987	76.3	59.7	254.3
1988	74.5	58.1	245.0
1989	72.6	57.1	233.1
1990	70.7	56.7	218.8
1991	72.4	57.8	180.6
1992	69.8	54.7	179.7
1993	63.6	55.2	157.3
1994	59.9	51.5	141.0
1995	64.0	65.9	144.8
1996	61.1	57.2	144.7
1997	62.3	56.5	149.2
1998	59.3	48.4	133.1
1999	60.3	46.4	117.5

Table 10. Estimated abundance at age in 2000 as a proportion of estimated abundance at the same age in selected earlier years (e.g., in the table below for Area 2AB, the value 6.06 at age 13 in 1975 means that estimated abundance at age 13 in 2000 is 6.06 times the estimated abundance at age 13 in 1975).

Area 2AB. Total estimated age10+ abundance in 2000 = 91% of 1999 level.

Age	8	9	10	11	12	13	14	15	16	17	18	19	20+
1975	1.06	1.74	2.50	2.70	4.41	6.06	2.34	5.19	4.93	3.79	3.23	4.32	4.40
1980	0.67	1.29	2.20	2.98	4.76	5.41	2.72	2.55	3.04	3.23	3.20	2.78	4.45
1985	0.28	0.59	1.06	1.43	2.30	2.98	1.85	2.16	3.33	3.56	2.98	3.39	3.33
1990	0.42	0.58	0.68	0.72	1.27	1.37	0.98	1.30	2.13	2.40	2.39	3.47	4.89
1995	0.23	0.71	1.00	0.84	1.21	1.59	0.68	0.54	0.67	0.79	0.64	1.05	2.05
1999	0.64	0.68	0.93	0.66	0.84	1.89	0.93	0.75	0.92	1.07	0.79	0.73	1.00
2000	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Area 2C. Total estimated age10+ abundance in 2000 = 86% of 1999 level.

Age	8	9	10	11	12	13	14	15	16	17	18	19	20+
1975	1.41	1.31	1.57	2.13	3.29	3.84	1.23	2.23	1.93	1.68	1.51	2.20	3.05
1980	0.68	0.72	0.87	1.33	2.28	3.00	1.52	1.71	2.07	1.84	1.48	1.08	1.79
1985	0.44	0.49	0.61	0.75	1.07	1.24	0.68	0.75	1.01	0.99	0.89	1.03	1.15
1990	0.74	0.57	0.53	0.62	1.10	0.95	0.60	0.72	0.83	0.71	0.58	0.75	1.04
1995	0.43	0.74	0.74	0.77	1.26	1.73	0.73	0.64	0.71	0.75	0.46	0.68	0.93
1999	1.18	0.91	0.78	0.59	0.82	1.98	0.86	0.76	0.91	1.07	0.79	0.72	0.86
2000	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Area 3A. Total estimated age 10+ abundance in 2000 = 79% of 1999 level.

Age	8	9	10	11	12	13	14	15	16	17	18	19	20+
1975	0.65	0.62	1.34	1.38	2.71	3.67	1.95	5.09	5.88	5.35	6.23	8.96	12.46
1980	0.38	0.37	0.64	0.84	1.72	2.79	2.29	3.29	3.83	4.40	3.07	2.42	3.54
1985	0.19	0.21	0.46	0.53	0.91	1.55	1.28	1.47	2.17	2.60	2.17	2.63	1.85
1990	0.20	0.14	0.21	0.29	0.72	0.91	0.87	1.37	1.84	1.93	1.73	2.15	1.59
1995	0.23	0.26	0.36	0.29	0.45	0.81	0.51	0.55	0.95	1.50	1.05	1.57	1.57
1999	1.29	0.53	0.91	0.50	0.68	1.35	0.69	0.69	0.73	1.15	0.80	0.71	1.04
2000	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Table 11. Estimates of Pacific halibut exploitable biomass (millions of pounds, net wt.) and catch limit recommendations.

Area	2A	2B	2C	3A	3B	4A	4B	4CDE	Total
1999 exploitable biomass (from the 1998 assessment)	5.36	61.64	64.00	159.00	138.33	46.11	34.98	58.83	568.25
1999 Setline CEY (from the 1998 assessment)	0.69	11.21	10.49	24.67	26.83	8.42	6.71	9.80	98.82
1999 quota	0.76	12.10	10.49	24.67	13.37	4.24	3.98	4.45	74.06
2000 exploitable biomass (from the 1999 assessment)	4.44	51.06	42.20	94.90	96.80	36.10	35.10	35.10	395.70
Total CEY at 20%	0.89	10.21	8.44	18.98	19.36	7.22	7.02	7.02	79.14
Non-commercial removals:									
(1) Bycatch	0.38	0.11	0.23	1.60	0.88	0.58	0.22	2.83	6.83
(2) Sport catch	0.34	1.58	1.83	5.24	0.02	0.10	0.00	0.01	9.12
(3) Personal use	0.00	0.30	0.00	0.10	0.04	0.08	0.00	0.01	0.53
(4) Wastage	0.01	0.04	0.07	0.10	0.07	0.04	0.04	0.04	0.39
2000 Setline CEY	0.54	8.18	6.31	11.94	18.36	6.42	6.77	4.13	62.65

Table 12. An apparent retrospective pattern in the estimates of exploitable biomass (millions of pounds, net wt.) in Area 3A.

	Year estimated:								
	1991	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**
Last data year:									
1995	173	182	163	148	146				
1996	179	190	172	158	157	154			
1997	185	199	182	170	173	173	172		
1998	185	199	184	172	176	177	178	146	
1999	188	203	187	176	180	183	185	153	118

Table 13. Age distribution (percent of area catch) of the 1999 commercial catch of Pacific halibut by IPHC regulatory area.

	IPHC Regulatory Area									
Age	2A	2B	2C	3A	3B	4A	4B	4C	4D	All Areas
4	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0
5	0.0	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0
6	0.0	0.5	0.4	0.1	0.1	0.0	0.0	0.0	0.0	0.2
7	0.3	1.4	1.7	0.2	0.4	0.3	0.5	0.2	0.3	0.7
8	3.4	3.6	3.5	1.0	1.5	0.2	0.9	0.9	0.7	1.9
9	12.1	7.6	6.7	3.1	3.2	1.6	2.4	2.9	4.0	4.7
10	16.3	9.9	10.1	5.4	4.7	5.8	3.7	8.1	10.5	7.8
11	22.6	18.2	17.6	11.3	11.9	17.3	10.0	32.8	21.3	16.4
12	28.2	20.6	20.6	16.9	18.8	41.1	16.0	37.9	35.2	23.6
13	9.9	9.1	9.2	10.0	10.9	10.0	14.1	7.0	9.7	9.9
14	2.4	7.6	6.9	10.6	9.6	5.0	4.4	2.9	5.5	7.3
15	1.4	5.9	5.8	10.4	9.7	4.0	7.1	2.6	4.5	6.8
16	0.7	3.9	4.9	9.4	7.4	3.5	6.3	0.7	2.0	5.4
17	0.9	2.0	2.9	6.3	4.3	2.5	3.7	0.5	1.2	3.3
18	0.3	2.8	2.7	5.6	3.8	1.8	5.6	0.7	0.8	3.2
19	0.7	1.6	2.6	3.6	4.4	1.4	3.4	0.5	1.3	2.6
20	0.3	1.2	1.3	2.4	2.7	2.0	3.9	1.2	1.2	1.9
21	0.2	1.3	0.8	1.5	2.0	1.2	4.3	0.3	0.7	1.3
22	0.0	0.8	0.5	1.0	2.0	1.3	2.0	0.0	0.4	1.0
23	0.2	0.9	0.8	0.6	0.8	0.3	2.2	0.5	0.0	0.7
24	0.0	0.3	0.2	0.2	0.8	0.2	2.0	0.0	0.4	0.4
25	0.2	0.1	0.2	0.1	0.5	0.0	1.5	0.0	0.0	0.3
26+	0.0	0.6	0.8	0.4	0.6	0.3	5.8	0.3	0.3	0.8

Table 14. Comparisons of standardized stock assessment survey and commercial fishery CPUE (kg per 100 hooks) for Pacific halibut.

Reg. Area	Year	No. of Stations	Survey CPUE	Commercial Fishery CPUE	Survey CPUE/ Comm. CPUE
2A	1995	78	20.4	79.5	0.256
	1997	77	29.9	130.9	0.229
	1999	84	22.3	77.0	0.290
2B	1993	96	71.6	128.1	0.559
	1995	115	100.6	126.2	0.797
	1996	129	103.9	132.3	0.786
	1997	158	79.2	146.7	0.540
	1998	128	56.6	143.7	0.394
	1999	168	53.3	122.9	0.433
2C	1996	83	191.0	141.1	1.353
	1997	86	244.1	147.1	1.660
	1998	109	142.8	140.5	1.016
	1999	111	126.3	123.9	1.020
3A	1993	88	197.6	236.3	0.836
	1994	117	188.6	200.1	0.943
	1995	122	224.3	237.5	0.944
	1996	265	191.9	278.0	0.690
	1997	273	199.9	268.8	0.744
	1998	370	170.0	262.6	0.647
	1999	371	145.6	270.7	0.538
3B	1994	66	167.0	222.9	0.749
	1996	180	213.0	328.6	0.648
	1997	181	250.3	344.3	0.727
	1998	227	263.8	360.0	0.733
	1999	225	266.4	328.6	0.811
4	1997	330	114.6	219.9	0.521
	1998	175	157.8	238.5	0.661
	1999	144	165.0	254.8	0.647

Table 15. Swept-area estimates of Pacific halibut biomass and abundance on the eastern Bering Sea shelf, according to National Marine Fisheries Service (NMFS) trawl surveys.

	Biomass ('000mt)		Numbers (millions)	
Year	**Total**	**<65cm**	**Total**	**<65cm**
1975	20	8	13	11
1979	73	35	62	56
1980	43	24	44	41
1981	57	31	42	38
1982	61	34	36	33
1983	97	55	47	41
1984	90	42	34	26
1985	69	24	24	17
1986	89	24	28	18
1987	87	19	27	16
1988	141	24	37	22
1989	78	20	34	27
1990	88	24	60	52
1991	100	42	65	58
1992	101	46	47	40
1993	161	66	54	42
1994	162	57	50	32
1995	157	35	39	20
1996	172	23	36	14
1997	149	19	37	19