INTERNATIONAL PACIFIC HALIBUT COMMISSION

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Historical Coastwide IPHC Stock Assessments: 1978 to 1987 – *Compendium of documents*

Seattle, WA, USA

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INTERNATIONAL PACIFIC HALIBUT COMMISSION

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LIST OF DOCUMENTS FOR THE 1978 TO 1987 HISTORICAL COASTWIDE IPHC STOCK ASSESSMENTS

STOCK ASSESSMENT DOCUMENT III

SECTION 1. POPULATION ASSESSMENT, 1987

by

Richard Deriso, Phillip Neal, and Russell Price

Our assessment of the Pacific halibut stock is based on the same three methods of catch-age analysis as used in the previous three years. The information used this year for the assessment is comprised primarily of logbook catch and effort data, port samples of otolith length frequency with age estimates for a subsample, commercial landings, and habitat size estimates. In addition, we employ the results of several years of IPHC sponsored research cruises for standardizing the data which go into our catch-age analysis.

The exploitable biomass of Pacific halibut, combined over all areas, is estimated to be slightly less in 1987 than in 1986, although the decrease is less than 5% overall. The exploitable component of the halibut population still remains near historical high levels, as a whole. Table 1 shows preliminary CPUE (catch per standardized skate of fishing gear) for each regulatory area and span the 1975 through 1987 time period. Notice that area combined CPUE reached a peak of 309.6 lbs/skate in 1985 and then declined to 275.8 lbs/skate in 1987. The changes in CPUE are uneven in the Regulatory Areas with increases in 1987 CPUE (as compared to 1986 values) occurring in Areas 2B, 3A, and 3B, while decreases occurred in Areas 2A, 2C, and 4. Estimates of exploitable biomass for each of the Regulatory Areas generally follow the trends in CPUE but with a smoother pattern of change from year-to-year.

The minor decline of exploitable biomass of Pacific halibut is caused by a drop in abundance of young fish. It is still too early for this to cause serious problems to the fishery. Young halibut are not caught frequently in the commercial fishery. But they are caught in large enough quantities to permit us to estimate abundance of year-classes (roughly) by the time they reach 8 years of age. The recent estimates of biomass of 8 year-olds are not encouraging, but then again year-class abundance has always fluctuated in the past.

Figure 1 shows estimates of the biomass of 8 year-olds, adjusted for incidental catch removals, for every year since 1943. I adjusted upward our estimates of 8 year-olds to include those individuals who were removed in by-catches prior to the age of 8 years. The adjusted estimates give a clearer picture of natural fluctuations in year-class abundance. As suggested in the figure by the dotted sine wave, year-class abundance exhibits an approximate 20 year cycle. Our most recent estimates of 8 year-old abundance suggest the cycle is intact. We have two leading hypotheses about what causes these fluctuations and both hypotheses predict that year-class abundance will continue to decline for the next several years. At this point in time, we do not know whether such declines will occur and, for that matter, we do not place a great deal of confidence in our estimate of 8 year-old abundance in 1987 (these fish have not been in the fishery long enough).

The average size of halibut continues to increase, or at least remain stable. In Figure 2 smoothed estimates of the average weight of 10 year-old halibut is shown by year for each of the Regulatory Areas. There are two distinct sizes of halibut at each given age: smaller halibut in the Regulatory Areas 2C , 2B, and 2A, and larger halibut in the Areas 3A, 3B, and 4. The difference in size of halibut between the major areas 2 and 3 is consistent with historical data, although all halibut are much larger now (50% to 100% larger) than halibut of comparable ages which lived in the 1950's and earlier years. The jump in size of halibut, which began in the early 1960's, remains a feature of the current stock. In particular, there are no signs of depressed growth of halibut through competition for limited prey.

A summary of stock assessment results are given in Table 2. The ranges given for each item correspond to the span of estimates from the three catch-age analyses. ASP (annual surplus production) is a basic measure of stock productivity and it is defined as the excess of biomass above what is needed to replenish the population each year. The range of total ASP for the stock as a whole is 82 to 88 million lbs in 1987. Total removals in 1987 were about 86 million lbs (69 commercial and 17 other sources) which is close to the ASP of the stock. The similarity of catch to ASP indicates that the halibut stock is currently fully utilized.

CEY (constant exploitation yield) estimates have been the preferred numbers to consider for setting catch quotas the last three years. A constant exploitation fraction (0.35) was multiplied by our estimates of exploitable biomass of halibut to get total CEY for the entire stock as a whole. Total CEY for the halibut stock as a whole range from 82 to 94 million lbs. Regulatory Area estimates of CEY are obtained by partitioning the total CEY among Regulatory Areas. Technical details were provided in last years stock assessment document. Setline CEY is calculated by subtracting other removals (item 6 of Table 2) from the total CEY in a Regulatory Area; please note that the amount of by-catch subtracted from each Regulatory Area is the estimated impact of incidental catch losses on future recruitment of fish into that Regulatory Area.

In Figure 3, we show the range of setline CEY estimates for each Regulatory Area, which are based on our "preferred" method (Item 5 of Table 2). The combined area CEY estimates range from 65 to 77 million lbs with about half the CEY occurring in Area 3A. 1987 setline catch quotas fall within the range of CEY estimates for Areas 2B, 2C, and 4. In Area 2A and 3B, the 1987 catches exceeded the CEY ranges, and in Area 3A the 1987 catch is below the CEY range. We should mention that the setline CEY estimate for Area 2A is zero because other removals (sports, incidental, waste) exceed the estimated total CEY for that area; in 2A the CEY estimates should be viewed with caution since very little usable setline logbook data was available in 1987 for stock assessment (most commercial fishermen, particularly off Washington, used black cod fishing gear. At this time, IPHC does not have a conversion factor to convert black cod CPUE to conventional halibut longline CPUE.

Item 6 of Table 2 shows maximum sustainable yield MSY for each Regulatory Area. MSY is a useful long-term reference point, but it should not be used to set current catch quotas since MSY does not reflect current stock conditions.

The last item of Table 2 (item 7) gives our best estimates of other removals of halibut---from sports, wastage, and incidental fishery sources. 1987 sports catch estimates are not available at this time and so we used the 1986 estimates.

Tables 3 through 5 provide a more detailed break-down of the three catch-age analyses. Each of the procedures has its own strengths and weaknesses.

We find it difficult to choose among those three tables for our "best" estimate of exploitable biomass in each of the Areas. We recommend using the mid-point estimate (from the three methods) provided in Table 7, as our current best estimate.

One problem encountered this year in stock assessment is that two new age readers were employed to read most of the otolith ages in the catch. We examined the effect these new readers may have had on our estimates of stock biomass by doing a sensitivity analysis of the results of our closed catch-age method to an alternative set of age estimates. The alternative set of age estimates was obtained by post-multiplying our original age readings by the inverse of a misclassification matrix. The misclassification matrix was constructed by comparing the 10% of the ages read by the new age readers which were also read by our experienced age reader. The results in Table 6 show some differences in the biomass estimates, but nothing substantial. We do not consider the alternative set of age estimates to be as accurate as the original set and thus we did not incorporate those results in the range of CEY estimates given in Table 2.

TECHNICAL MATTERS---INTERNAL DOCUMENTATION

A. To lag or not to lag incidental catches: at present there is no lag placed between the year in which incidental catch occurs and the year in which it is subtracted from total CEY. There are several reasons for this:

1. The extremely large year-classes of recent years are harvested at a higher rate in the setline fishery with the current method. There is little reason to protect these large year-classes from setline exploitation by subtracting the larger incidental catches which occurred a few years ago.

2. Indeed we can argue that this variation on the CEY scheme is desirable. When a series of large year-classes are followed by a series of weak year-classes, then the large incidental catches which come from the large year-classes would be subtracted from the setline catches of the weak year-classes, thus affording more protection for those weak year-classes. Similarly, small incidental catches from weak year-classes would cause smaller quantities to be subtracted from setline catches of the strong year-classes.

3. The age structure of the incidental catch varies from year to year and fishery to fishery. We do not have a reliable scheme for determining exactly how to lag the incidental catch, even if we wanted to.

4. Halibut biomass is transferable among adults in the population in the sense that growth equals natural mortality for adults. Thus whether a pound of 8 year-olds is taken in the catch or a pound of 20 year-olds is taken in the catch makes no difference as far as it affects changes in the adult biomass of the stock. This means that there is not a unique lag between incidental catch and equivalent effect on the adults, again making the choice of a lag to a large extent arbitrary. The main advantage of increasing the lag by 4 years (from say an 8 year-old) to a 12 year-old (mean age in catch) is that it gives some economists another 4 years of discount rates to apply to incidental catch in order to show it doesn't have as much affect on the catch of adults.

One problem with our current method is that we are not really applying a 0.35 exploitation fraction to the "right" exploitable biomass number. The "right" number should be what the exploitable biomass would have been if there had been no incidental catches, but instead an equivalent removal of setline catches. This is a confusing technical issue, but it implies that we are using an effective exploitation fraction of something (slightly) less than 0.35.

B. Some graphs for the closed sub-area catch-age analysis: as part of our analysis of the stocks in 1987 we constructed two graphs which are shown as Figures 4 and Figure 5. We thought they should be included in this document, primarily to show that the 2B stock doesn't look particularly over-exploited in comparison to the 2C stock, with closed sub-area catch-age analysis.

C. No September data: the last opening in 3A and 3B were fraught with problems, including bad weather and trip limits. Because the fishery operated differently during this last opening, we decided not to use either the logbook data or the age readings collected during this opening.

Table 1: Preliminary CPUE estimates. Data are standardized to "C" hook equivalence and adjusted to equal catchablity between Regulatory Areas, as described in IPHC Scientific Report 72, except that Area 2C has a regional adjustment factor of 1.0 based on results in section 5. Area 2A and southern 2B CPUE based in part on conversion of "snap-on" gear to conventional gear, as documented in 1986.

CPUE by Regulatory Area (lbs/skate)

Year	Areas Combined	2A	2B	2C	3A	Chirikof Shumagin	Aleutian Bering S
75	147.5	130.6	148.7	146.8	145.3	149.3	210.7
76	124.8	71.7	116.7	116.0	131.4	142.2	184.2
77	138.5	182.2	135.3	124.3	134.6	161.3	176.2
78	155.1	85.5	138.0	155.1	171.9	116.4	166.6
79	159.7	110.0	105.8	220.8	189.0	80.8	146.1
80	204.0	82.0	143.7	218.4	260.6	249.5	124.2
81	231.5	107.6	175.7	273.6	250.8	294.6	236.8
82	252.5	101.6	176.7	355.9	274.1	300.7	172.5
83	273.7	102.1	180.5	342.9	349.6	335.5	112.1
84	298.4	101.8	188.8	328.5	412.8	353.1	193.6
85	309.6	87.5	176.5	354.1	401.2	420.1	296.4
86	291.7	105.9	154.7	296.4	411.9	322.4	304.6
87	275.8	50.3	157.9	244.5	437.0	329.9	276.4

Catch in million lbs. by subarea

Year	Areas Combined	2A	2B	2C	3A	Chirikof Shumagin	Aleutian Bering S
75	27.616	.460	7.127	6.243	10.601	2.655	.530
76	27.535	.238	7.283	5.527	11.044	2.809	.634
77	21.868	.207	5.427	3.186	8.641	3.323	1.084
78	21.988	.097	4.607	4.316	10.295	1.327	1.346
79	22.527	.046	4.857	4.530	11.335	.390	1.369
80	21.866	.022	5.650	3.238	11.966	.277	.713
81	25.736	.202	5.241	4.495	14.198	.416	1.185
82	29.008	.290	5.538	3.500	13.499	5.766	.416
83	38.384	.363	5.428	6.610	15.580	8.426	1.977
84	44.970	.430	9.054	5.857	19.961	7.545	2.122
85	56.113	.493	10.384	9.211	20.852	12.464	2.709
86	69.576	.549	11.249	10.661	32.738	11.196	3.183
87	69.283	.592	12.218	10.719	31.066	10.224	4.464

Table 2. Summary of 1987 population assessment results. The range of estimates corresponds to maximum and min. of results from three methods of catch-age analysis. Note that range values for Combined is more precise than the sum of ranges from individual Reg. Areas, with the exception of Preferred Setline CEY (#5.)

Reg. Area	2A	2B	2C	3A	3B	4	Combined
1987 Quota	0.55	11.5	11.5	31.0	9.5	4.8	68.8
1987 Catch	0.59	12.2	10.7	31.1	10.2	4.5	69.3
1.							
ASP--total annual surplus production (million lbs)							
Range							
Upper	0.57	14.7	11.5	51.1	11.0	6.5	87.7
Lower	0.54	12.3	6.0	46.2	7.3	4.5	82.1
2.							
Setline ASP--subtract other catches from total ASP							
Range							
Upper	0.24	12.5	8.4	42.3	9.4	5.4	70.7
Lower	0.21	10.1	2.9	37.4	5.7	3.4	65.1
3.							
CEY--total constant exploitation yield (million lbs)							
Range							
Upper	0.32	17.0	17.3	55.6	12.4	7.4	94.3
Lower	0.23	9.8	3.8	43.0	7.2	4.3	82.2
4.							
Setline CEY--subtract other catches from total CEY							
Range							
Upper	-0.01	14.7	14.2	46.9	10.5	6.6	77.2
Lower	-0.10	7.5	0.7	34.3	5.4	3.6	65.1
***********							
5.							
Preferred Setline CEY--proportional allocation, sums to combined CEY							
Range : Note-- maximum relative CEY in 4. is the proportion							
Upper	-0.0	12.2	11.8	39.0	8.7	5.5	77.2
Lower	-0.0	10.3	10.0	32.9	7.4	4.6	65.1
***********							
6.							
MSY--maximum sustainable yield, a long-term reference point							
All gear	0.80	18.6	11.3	29.2	10.0	11.0	80.9
Setline	0.47	16.3	8.2	20.5	8.1	10.2	63.8
7.							
Other catches accounted for in reducing Totals to Setline							
1986 Sport	0.26	0.51	0.73	1.92	0.00	0.01	3.44
1987 Waste	0.03	0.17	0.37	1.58	0.34	0.26	2.74
1987 ByCat	0.04	1.58	2.00	5.22	1.53	0.52	10.87
Total	0.33	2.26	3.09	8.72	1.87	0.79	17.06

Note: By-Catch Mortality is apportioned into areas proportional to biomass estimates from closed subarea catch-age analysis.

Table 7: **Midpoint estimates from the results of the three catch-age analysis methods.**

Setline exploitation fraction (catch lbs / midpt of expl.bio)

4

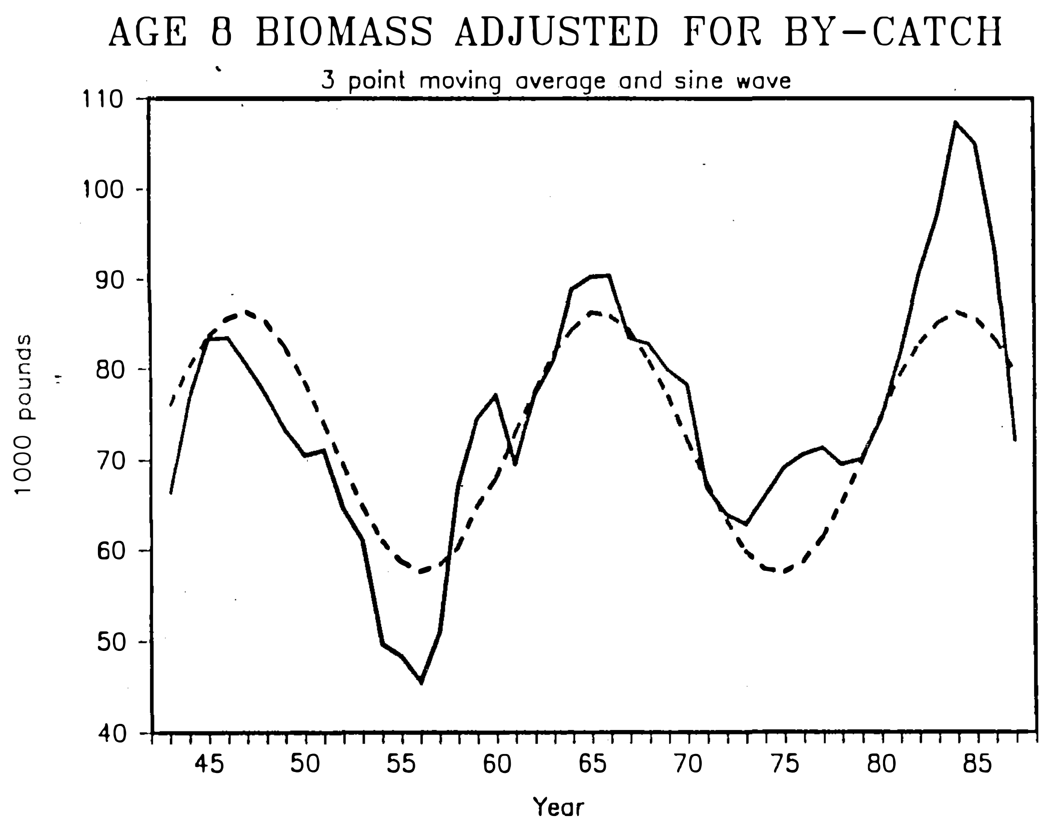
year	combined	'2a	2b	2c	3a	old 3b	old
1975	0.22	0.31	0.26	0.26	0.23	0.19	0.05
1976	0.22	0.18	0.27	0.24	0.23	0.18	0.07
1977	0.17	0.17	0.20	0.14	0.17	0.21	0.14
1978	0.16	0.08	0.17	0.17	0.18	0.08	0.19
1979	0.16	0.04	0.19	0.16	0.18	0.02	0.21
1980	0.14	0.02	0.22	0.10	0.18	0.01	0.12
1981	0.16	0.23	0.20	0.13	0.21	0.01	0.20
1982	0.15	0.32	0.20	0.09	0.18	0.15	0.06
1983	0.18	0.39	0.19	0.15	0.18	0.21	0.23
1984	0.20	0.41	0.29	0.13	0.20	0.19	0.21
1985	0.23	0.52	0.32	0.19	0.19	0.30	0.22
1986	0.27	0.54	0.34	0.22	0.27	0.30	0.26
1987	0.27	0.76	0.36	0.23	0.24	0.29	0.37

9.

Midpoint estimates of exploitable biomass

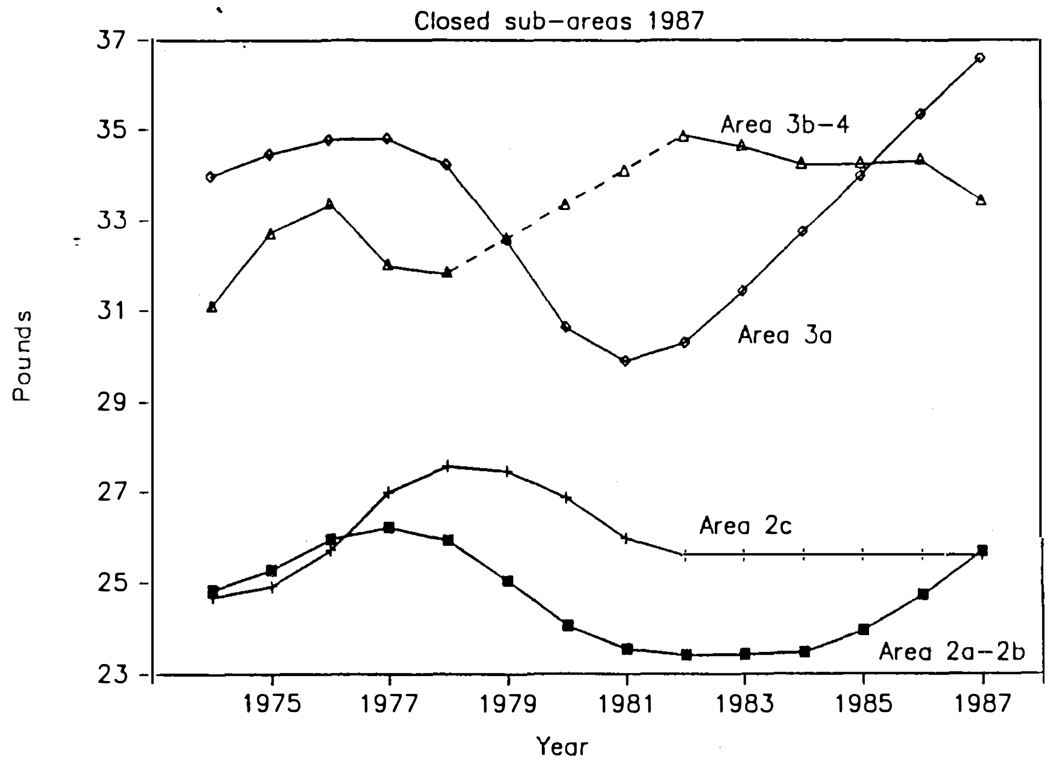
4

year	combined	'2a	2b	2c	3a	old 3b	old
1975	126.21	1.47	27.39	24.46	46.84	14.22	9.95
1976	126.02	1.35	27.06	23.36	48.63	15.20	8.51
1977	128.43	1.20	26.71	23.35	51.22	15.71	7.78
1978	134.81	1.16	26.38	25.80	56.62	16.01	7.12
1979	142.88	1.06	26.21	28.85	61.34	18.81	6.60
1980	152.12	0.99	25.96	31.69	64.81	22.92	6.08
1981	166.03	0.90	25.75	35.57	68.92	28.51	6.05
1982	189.92	0.92	27.30	40.63	77.05	37.87	7.51
1983	210.45	0.94	29.11	44.91	86.90	40.73	8.58
1984	228.04	1.04	30.88	46.41	99.55	40.43	10.11
1985	248.07	0.94	32.90	48.97	112.03	41.81	12.39
1986	254.46	1.01	33.57	48.36	123.16	37.22	12.22
1987	252.11	0.78	33.59	45.66	128.61	35.54	11.96

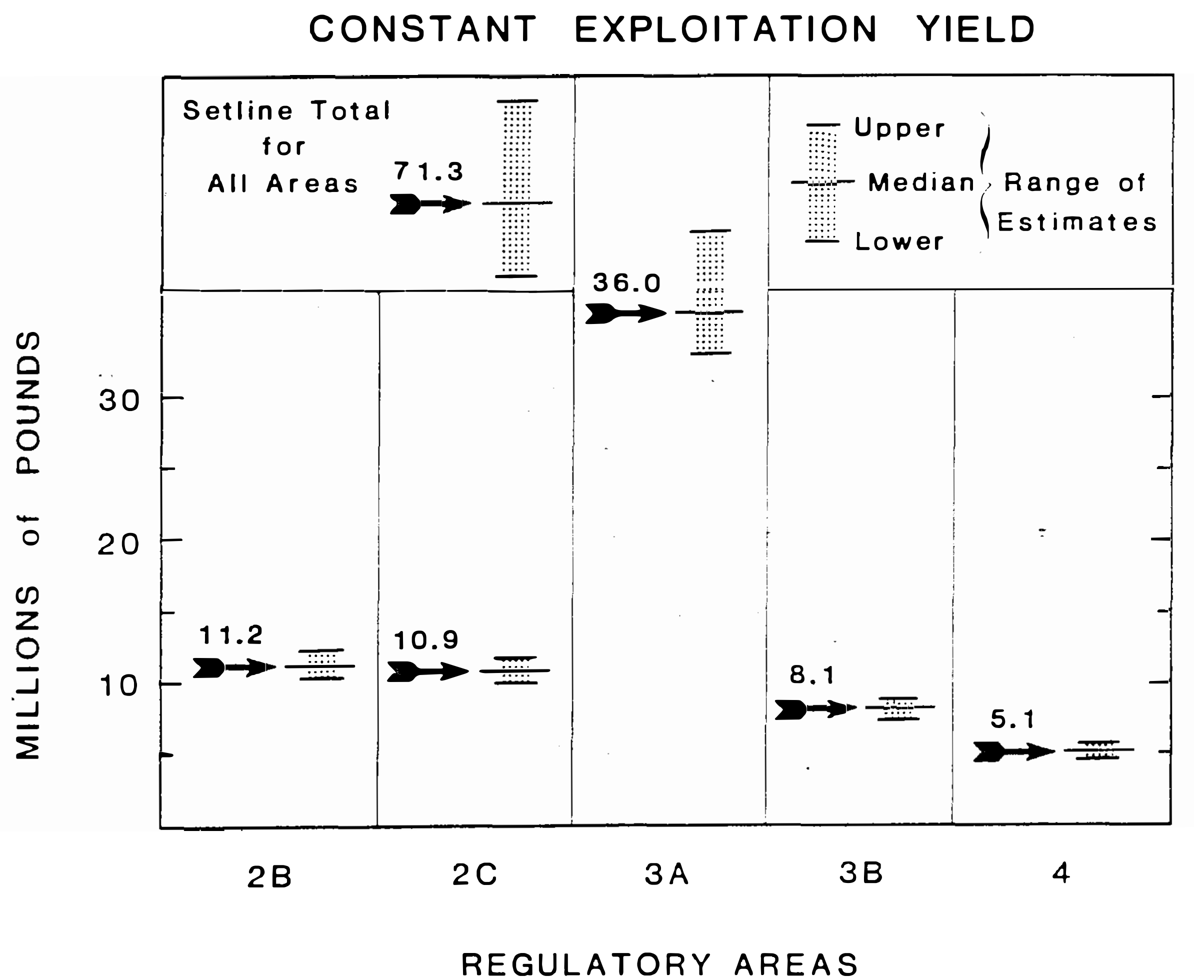

AGE 8 BIOMASS ADJUSTED FOR BY-CATCH
3 point moving average and sine wave
1000 pounds
110
100
90
80
70
60
50
40
45
50
55
60
65
70
75
80
85
Year

19

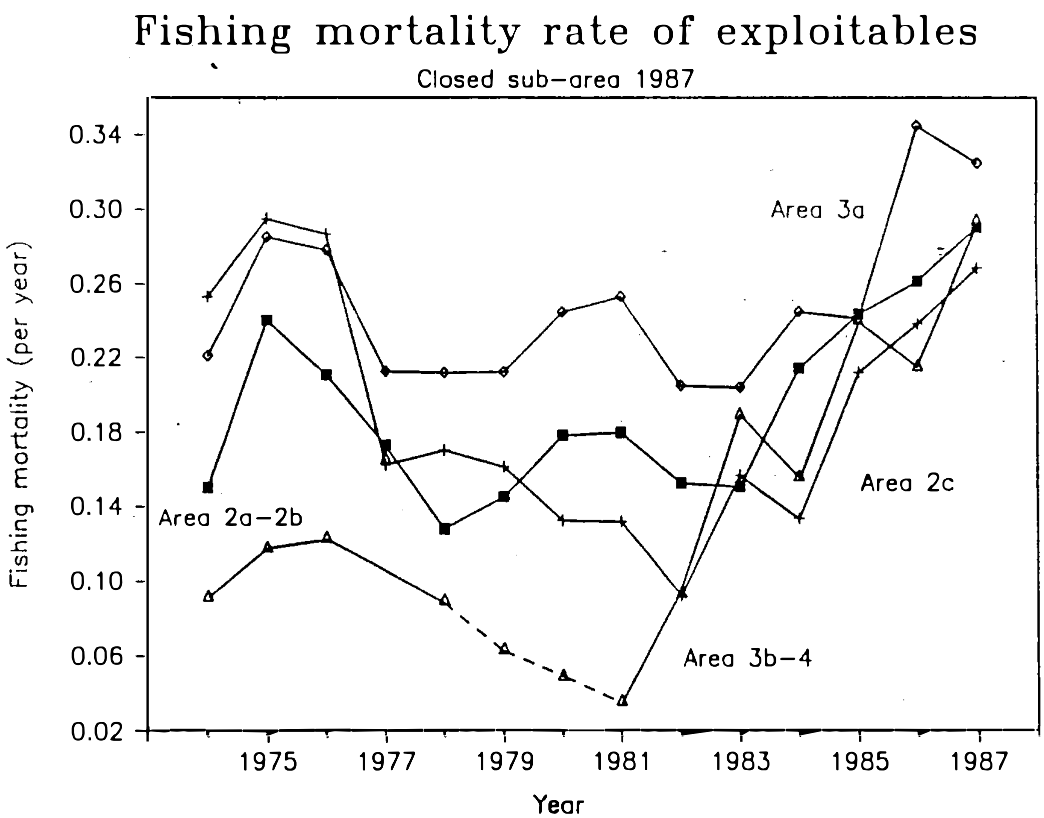
Smoothed weight of 10 year olds



20


CONSTANT EXPLOITATION YIELD
Setline Total for All Areas
71.3
36.0
Upper
Median
Lower
Range of Estimates
MILLIONS of POUNDS
30
20
10
11.2
10.9
8.1
5.1
2B
2C
3A
3B
4
REGULATORY AREAS

21


Fishing mortality rate of exploitables
Closed sub-area 1987
Fishing mortality (per year)
0.34
0.30
0.26
0.22
0.18
0.14
0.10
0.06
0.02
Area 3a
Area 2a-2b
Area 2c
Area 3b-4
1975
1977
1979
1981
1983
1985
1987
Year

23

STOCK ASSESSMENT DOCUMENT III

SECTION 1. POPULATION ASSESSMENT, 1986

by

Richard B. Deriso

Our assessment of the Pacific halibut stock is based primarily on two methods of catch-age analysis, as in the previous two years. IPHC Scientific Report 72 describes the methods in detail. The information used this year for the assessment is comprised primarily of logbook catch and effort data, port samples of otolith length frequency with age estimates for a subsample, commercial landings, habitat size estimates, bottom area estimates, tag return information, and standard stock assessment surveys. Some problems were discovered this year regarding the accuracy of logbook hailed weight estimates used to calculate preliminary CPUE values. As a consequence, we postponed our stock assessment until dealer catch information became available. Results given below use this latest information. Another consequence of inaccuracies in preliminary CPUE estimates, is that the stock abundance in 1985 was biased upward by about 12%, largely due to the use of that preliminary data.

Four improvements were made to our stock assessment methodology. First: better estimates of standardized "J" hook CPUE were derived for IPHC regions 1 & 2 (Columbia, Vancouver), as discussed in another report in this document. Second: maximum sustainable yield estimates were updated for each Area, as discussed in another report in this document. Third: a more precise estimate was made of the amount of incidental, sports, and wastage catches within each regulatory area (given in Table 2). Fourth: better estimates were made of the exploitation fraction to be used in CEY (constant exploitation yield) calculations.

The abundance of Pacific halibut, combined over all areas, was roughly the same as last year. Exploitable biomass of Pacific halibut continued to grow slightly in 1986 by 3.5%, according to migratory catch-age analysis. However, overall CPUE from the fishery dropped by 6% from 1985 levels. Only regulatory area 3A showed an increase in exploitable biomass in 1986, as compared to 1985 levels, according to migratory catch-age estimates. Flat to slightly decreasing biomass estimates were obtained for Areas 2A, 2B, 2C, and 4. Area 3B biomass decreased in 1986 from 1985 levels, according to two of the three catch-age analyses.

Preliminary CPUE and catch estimates are given in Table 1. There's not much to say about this table; it's pretty much self explanatory.

A summary of stock assessment results is given in Table 2.

Deriso, R.B., 1987. Stock Assessment Document III. Section 1. Population assessment, 1986. IPHC Rep., pp. 1–14.

The ranges given for each item correspond to the span of estimates from the three catch-age analyses. ASP (annual surplus production) is the excess of biomass above what is needed to replenish the population each year. The range of total ASP for the stock as a whole is 82 to 85 million lbs . Total removals in 1986 were perhaps as high as 90.5 million lbs (69 commercial, 3.3 sports, 8.2 wastage, 10 incidental) and possibly exceeded ASP in 1986. Setline ASP listed in Table 2 is the amount of production left after subtracting other catches (incidental, sports, wastage). Setline ASP estimates range from 66 to 68 million lbs for the whole population. The setline ASP in Area 2A is probably too high, since 1985 sports catch estimates used in the analysis do not account for likely increases in 1986 sports catch in that area.

CEY (constant exploitation yield) estimates have been the preferred numbers to consider for setting catch quotas the last two years. A constant exploitation fraction (0.35) was multiplied to exploitable biomass to get total CEY for the entire stock. The sub-area CEY estimates were based on two partitioning procedures, applied to total combined area CEY: 1. partition the CEY according to the percentage of exploitable biomass in an area; 2. partition CEY according to the percentage of ASP in an area. The second procedure is our first attempt to account for area-specific productivity. For example, Area 2B historically has higher production (per unit stock biomass) than Areas in Alaska. Setline CEY is found by subtracting other catches (incidental, sports, wastage) from the total CEY numbers. There is quite a bit more uncertainty in the subarea CEY estimates than in the combined area CEY. As a consequence, the range of estimates for the various areas total to CEY's both higher and lower than our range for the total CEY.

Setline CEY was calculated by subtracting other catches from the total CEY; this reduction amounts to about 7% for the entire population biomass, which gives a setline exploitation fraction of about 28%, although it differs by regulatory area.

Included in Table 2 are numbers titled " Preferred Setline CEY ", which is an allocation of the setline CEY estimates for combined areas into the regulatory areas. The allocation procedure is based on the maximum CEY estimate for each area, as described next: first add togeather the maximum setline CEY estimate for each area(this is a total maximum of 102.4 mill.lbs.); divide the max setline CEY for each subarea by the total maximum, 102.4, and product the result with the range estimate for combined area CEY. In essence, this procedure maximizes the allocation of catch to each area subject to the constraint that the total lies within the estimated range.

Revised estimates of MSY are shown towards the bottom of Table 2. After subtracting other catches, the setline MSY figure is seen to lie in the range of the setline CEY estimates for the stock as a whole. There are still major differences between current CEY and MSY for some regulatory areas. CEY is below MSY in areas 2A, 2B, and 4; CEY is near MSY in areas 2C and 3B, while in area 3A it remains appreciably above MSY.

The bottom of Table 2 gives our best estimates of other catches of halibut--from sports, wastage, and incidental fishery sources. We are especially uncertain about the amount of wastage, with some estimates ranging as high as 8.2 million lbs. There has always been some wastage. The effect of such removals, which are not accounted for in historical data, is to lower our estimated target CEY exploitation fraction. Thus such removals are partly compensated for in our estimation procedure. A similiar compensation occurs in our catch-age analysis. We are using an overall wastage estimate of 3.2 million lbs as a ball park estimate of the unaccounted portion of wastage.

A number of things can go wrong in stock assessment. I have tried to use methods as robust as possible, but I can not, yet, develop estimates that are completely free of the CPUE estimates. My concern is that wide-spread cheating and lying about log-book information can severely distort stock assessment. I don't know how much of a problem it is, but I want the reader to be aware of this caveat. Figure 1 shows the importance of high quality fishing effort information in our stock assessment.

Tables 3 through 5 provide a more detailed break-down of the three catch-age analysis procedures followed this year. Each of the procedures has its strengths and weaknesses. I pay a little more attention to the migratory catch-age estimates primarily because that method contains the most biological realism.

Table 6 provides a break-down of the CPUE of sub-legal female halibut from our standardized stock assessment surveys; other CPUE information is given in the report by Kaimmer. I enclose this table because of it is a rough indicator of future recruitment of females, which are the main-stay of the fishery.

PRELIMINARY SURVEY EVALUATION

Are the SSA surveys any good? Table 7 shows R-squares around 0.5 for area 2B and area 2C regressions of sub-legal CPUE versus abundance of 8 year-olds (lagged one year) from catch-age analysis. The area 3A R-square of -0.14 indicates a very poor relationship there. Those regression results are essentially opposite to results we get when legal size CPUE from the surveys are regressed against exploitable biomass estimates for the reg. areas; table 8 shows R-squares of 0.02 for areas 2B and 2C, while 3A is much better with a R-square of 0.7 . Table 9 shows the results in Table 8 hold pretty much the same when commercial CPUE is regressed against survey legal-size CPUE. The biomass and year-class estimates used in this survey evaluation are estimates from an earlier analysis and have been revised in Tables 3-5.These preliminary estimates are highly correlated with the revised ones.

TECHNICAL MATTERS --- internal documentation

CEY and ASP estimates were very sensitive to the choice of the lambda coefficient used to weight fishing effort information in catch-age analysis (see Figures 1 and 2). This year is the first time we've had such high sensitivity. The high sensitivity appears to by due to a conflict of signals in the data: the CPUE trend over the last few years is very upbeat, whereas the age composition of the catch (particularly in 3B) looks depleted in the old age categories---see Cal Blood's report. A lambda value of 0.3 was used in combined area catch-age analysis---the results shown in Figures 1 and 2. Lambda is a constant whose value is the ratio of variance of catch to variance of the fishing effort-fishing mortality relationship (Deriso et al., 1985 CJAFS). A lambda of 0.3 was used since the rss is about 1.2 for this 8-17+(pool older age) analysis, as compared to the 2.1 rss in our earlier 8-20 analysis. The 0.3 is 1.2/2.1 of the 0.5 value of lambda found appropriate in our 1985 publication. The migratory catch-age analysis still uses lambda 2.0 because of higher catch variance. The closed sub-area run uses lambda of 0.5 since the rss for these 8-17+ runs were around 2-3.

Efron's bootstrap method was applied to the migratory catch-age results by Phil Neal. He got the results in Table 10 and Figure 3. Notice that the standard deviations are quite high for the most recent year-classes.

Estimates for area 3B and 4 were partitioned from old area definitions by using bottom area. The old area definitions used in catch-age analysis are old 3B = Chirikof + Shumagin regions ; old 4 = Aleutian + Bering Sea. Our basic data is setup into regions. To get the current 3B find bottom area of stat areas 29-34 (=28132), old 3B is stat areas 29-38 (=33950); thus new 3B is 82.86% of the old 3B. The remaining 17.14% of old 3B is added to 4 to get the new area 4.

I did a monte-carlo study with data in our latest INPFC paper (Deriso, McCaughran and Hoag, 1987?). I used the estimates of survival from birth to age 8. Those were selected randomly and entered into a Leslie type model. The stationary population abundance from this study occurred when the total exploitation fraction was about 0.23 . This also produces approximate equilibrium in a deterministic setting when R/S is 0.556, the average value in the INPFC study. Figure 4 shows the R and S data. The 0.35 exploitation used in our stock assessment is probably not sustainable if survival of the young is density-independent (see our INPFC paper). On the other hand, MSY analysis supports at least a 0.35 exploitation fraction. This year, Gilbert's finding of canabilism among juvenile halibut gives additional support to density-dependence.

Table 1: Preliminary CPUE estimates. Data are standardized to 'J' hook equivalence and adjusted to equal catchability between Reg. Areas, as described in IPHC Sci. Report 72. Area 2A and southern 2B CPUE based on report in this document by Deriso and Price.

CPUE by Regulatory Area (lbs/skate)

Year	2A	2B	2C	3A	Chirikof Shumagin	Aleutian Bering S	Areas Combine
74	59.4	64.1	57.2	64.7	56.7	136.9	62.4
75	59.4	67.6	53.4	66.0	67.9	95.8	63.4
76	32.6	53.0	42.2	59.7	64.6	83.7	53.8
77	82.8	61.5	45.2	61.2	73.3	80.1	60.5
78	38.9	62.7	56.4	78.1	52.9	75.7	67.2
79	50.0	48.1	80.3	85.9	36.7	66.4	70.1
80	37.3	65.3	79.4	118.5	113.4	56.4	89.6
81	48.9	79.9	99.5	114.0	133.9	107.6	101.5
82	46.2	80.3	129.4	124.6	136.7	78.4	112.4
83	46.4	82.0	124.7	158.9	152.5	51.0	120.3
84	46.3	85.8	119.5	187.6	160.5	88.0	131.8
85	39.8	80.2	128.8	182.4	191.0	134.7	135.8
86	48.1	70.3	107.8	187.2	146.5	138.4	127.8

Catch in million lbs. by subarea

YEAR	TOTAL	2A	2B	2C	3A	Chirikof Shumagin	Aleutian Bering S
74	21.306	0.515	4.624	5.605	8.187	1.834	0.541
75	27.616	0.460	7.127	6.243	10.601	2.655	0.530
76	27.535	0.238	7.283	5.527	11.044	2.809	0.634
77	21.868	0.207	5.427	3.186	8.641	3.323	1.084
78	21.988	0.097	4.607	4.316	10.295	1.327	1.346
79	22.527	0.046	4.857	4.530	11.335	0.390	1.369
80	21.866	0.022	5.650	3.238	11.966	0.277	0.713
81	25.736	0.202	5.241	4.495	14.198	0.416	1.185
82	29.008	0.290	5.538	3.500	13.499	5.766	0.416
83	38.384	0.363	5.428	6.610	15.580	8.426	1.977
84	44.970	0.430	9.054	5.857	19.961	7.545	2.122
85	56.113	0.493	10.384	9.211	20.852	12.464	2.709
86	69.576	0.549	11.249	10.661	32.738	11.196	3.183

Table 2. Summary of 1986 population assessment results. The range of estimates corresponds to maximum and min. of results from three methods of catch-age analysis. Note that range values for Combined is more precise than the sum of ranges from individual Reg. Areas, with the exception of Preferred Setline CEY (#5.)

Reg. Area	2A	2B	2C	3A	3B	4	Combined
1986 Quota	0.50	11.2	11.2	28.1	10.3	5.1	66.4
1986 Catch	0.55	11.2	10.6	32.7	9.0	5.6	69.6
1. ASP--total annual surplus production (million lbs)							
Range							
Upper	0.59	14.5	14.1	46.3	13.0	9.5	84.9
Lower	0.52	11.3	13.1	35.1	6.2	4.2	82.1
2. Setline ASP--subtract other catches from total ASP							
Range							
Upper	0.31	12.5	10.1	38.1	11.6	8.7	68.4
Lower	0.25	9.3	9.1	26.9	4.8	3.5	65.6
3. CEY--total constant exploitation yield (million lbs)							
Range							
Upper	0.42	16.9	17.9	51.5	14.4	10.8	92.4
Lower	0.31	10.0	11.3	33.3	6.5	4.2	81.4
4. Setline CEY--subtract other catches from total CEY							
Range							
Upper	0.14	15.0	13.9	43.3	12.7	10.4	75.9
Lower	0.03	8.0	7.4	25.1	4.8	3.8	64.8
***********							
5. Preferred Setline CEY--proportional allocation, sums to combined CEY							
Range							
Upper	0.12	11.9	11.0	34.4	10.1	8.3	75.9
Lower	0.10	10.2	9.4	29.4	8.6	7.1	64.8
***********							
6. MSY--maximum sustainable yield, a long-term reference point							
All gear	0.80	18.6	11.3	29.2	10.0	11.0	80.9
Setline	0.53	16.7	7.3	21.0	8.3	10.6	64.4
6. Other catches		for in reducing Totals to Setline					
1985 Sports	0.228	0.525	1.090	1.492	0.0	0.010	3.345
1986 Wastage	0.0	0.0	0.650	1.997	0.536	0.0	3.183
1986 Incidental	0.047	1.422	2.237	4.704	1.180	0.409	10.000
Total	0.275	1.947	3.977	8.193	1.716	0.419	16.527

Notes: Wastage is half of the 12.3% lost or abandoned gear estimate for August in 3B. Incidental is apportioned into areas proportional to biomass estimates from migratory catch-age analysis.

Table 3. Exploitable biomass, constant exploitation yield (CEY), annual surplus production (ASP) for setline, and commercical catches. Estimates based on migratory catch-age analysis. 3B and 4 are old area definitions.

Biomass in million lbs. by subarea

	TOTAL	2A	2B	2C	3A	3B	4
974	114.221	1.306	23.910	24.693	46.492	10.359	7.461
75	117.901	1.337	24.675	23.581	50.073	11.033	7.202
76	117.514	1.182	23.541	22.733	52.487	11.126	6.445
77	120.212	1.007	23.166	22.931	55.922	11.352	5.834
978	125.833	0.964	22.809	25.293	60.693	11.128	4.946
79	135.158	0.943	22.879	27.497	64.539	13.907	5.393
80	143.919	0.884	22.608	29.933	67.894	17.224	5.376
981	154.444	0.769	22.164	33.690	71.885	20.848	5.088
82	175.220	0.801	22.436	38.059	77.741	29.808	6.375
83	194.167	0.761	24.362	43.531	87.706	31.177	6.630
984	211.120	0.913	26.846	46.545	101.562	28.500	6.754
85	229.430	1.040	28.069	50.129	113.927	28.134	8.131
86	237.304	0.895	28.400	50.909	125.736	23.353	8.011

Setline A.S.P. in million lbs. by subarea

AR	TOTAL	2A	2B	2C	3A	3B	4
74	24.986	0.546	5.389	4.493	11.768	2.508	0.282
975	27.229	0.305	5.993	5.395	13.015	2.748	-0.227
76	30.233	0.063	6.908	5.725	14.479	3.035	0.023
77	27.489	0.164	5.070	5.548	13.412	3.099	0.196
978	31.313	0.076	4.677	6.520	14.141	4.106	1.793
79	31.288	-0.013	4.586	6.966	14.690	3.707	1.352
80	32.391	-0.093	5.206	6.995	15.957	3.901	0.425
81	46.512	0.234	5.513	8.864	20.054	9.376	2.472
982	47.955	0.250	7.464	8.972	23.464	7.135	0.671
83	55.337	0.515	7.912	9.624	29.436	5.749	2.101
84	63.280	0.557	10.277	9.441	32.326	7.179	3.499
985	63.987	0.348	10.715	9.991	32.661	7.683	2.589
86	66.183	0.299	10.841	10.146	36.046	6.378	2.550

CEY in million lbs. by subarea when exploitation is 0.28

AR	TOTAL	2A	2B	2C	3A	3B	4
74	31.982	0.352	6.684	6.908	13.017	2.910	2.079
975	33.012	0.363	6.900	6.602	14.030	3.103	2.014
976	32.904	0.329	6.581	6.350	14.708	3.126	1.810
77	33.659	0.269	6.496	6.429	15.651	3.164	1.649
78	35.233	0.282	6.377	7.082	16.982	3.101	1.374
979	37.844	0.265	6.396	7.682	18.090	3.898	1.514
80	40.297	0.242	6.327	8.382	19.020	4.836	1.491
81	43.244	0.216	6.227	9.427	20.109	5.838	1.427
982	49.061	0.245	6.280	10.646	21.783	8.340	1.766
83	54.367	0.217	6.796	12.178	24.574	8.753	1.848
84	59.114	0.236	7.507	13.005	28.434	7.980	1.892
85	64.240	0.321	7.837	14.004	31.927	7.902	2.248
86	66.445	0.266	7.973	14.286	35.216	6.512	2.259

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CEY in million lbs. by subarea when exploitation is 0.35

YEAR	TOTAL	2A	2B	2C	3A	3B	4
1974	39.978	0.440	8.355	8.635	16.271	3.638	2.599
1975	41.265	0.454	8.624	8.253	17.538	3.879	2.517
1976	41.130	0.411	8.226	7.938	18.385	3.907	2.262
1977	42.074	0.337	8.120	8.036	19.564	3.955	2.062
1978	44.042	0.352	7.972	8.852	21.228	3.876	1.718
1979	47.305	0.331	7.995	9.603	22.612	4.872	1.892
1980	50.372	0.302	7.908	10.477	23.775	6.045	1.864
1981	54.055	0.270	7.784	11.784	25.136	7.297	1.784
1982	61.327	0.307	7.850	13.308	27.229	10.426	2.208
1983	67.958	0.272	8.495	15.223	30.717	10.941	2.311
1984	73.892	0.296	9.384	16.256	35.542	9.975	2.365
1985	80.300	0.402	9.797	17.505	39.909	9.877	2.811
1986	83.056	0.332	9.967	17.857	44.020	8.140	2.824

CEY in million lbs. by subarea when exploitation is 0.35
minus other catches.

EAR	TOTAL	2A	2B	2C	3A	3B	4
986	66.61	0.057	8.020	13.880	35.827	6.424	2.405

CEY in million lbs. by subarea when exploitation is 0.28
where partitioning of total CEY is based on subarea ASP

YEAR	TOTAL	2A	2B	2C	3A	3B	4
1974	31.982	0.704	6.908	5.757	15.064	3.198	0.352
1975	33.012	0.363	7.263	6.536	15.780	3.334	-0.264
1976	32.904	0.066	7.502	6.219	15.761	3.290	0.033
1977	33.659	0.202	6.193	6.799	16.426	3.803	0.236
1978	35.233	0.070	5.250	7.329	15.925	4.616	2.008
1979	37.844	0.000	5.563	8.439	17.787	4.466	1.627
1980	40.297	-0.121	6.488	8.704	19.867	4.836	0.524
1981	43.244	0.216	5.146	8.260	18.638	8.735	2.292
1982	49.061	0.245	7.654	9.174	23.991	7.310	0.687
1983	54.367	0.489	7.774	9.460	28.923	5.654	2.066
1984	59.114	0.532	9.576	8.808	30.207	6.680	3.251
1985	64.240	0.321	10.728	10.021	32.762	7.709	2.570
1986	66.445	0.332	10.897	10.166	36.146	6.379	2.525

CEY in million lbs. by subarea when exploitation is 0.35
where partitioning of total CEY is based on subarea ASP

YEAR	TOTAL	2A	2B	2C	3A	3B	4
1974	39.978	0.880	8.635	7.196	18.830	3.998	0.440
1975	41.265	0.454	9.078	8.170	19.725	4.168	-0.330
1976	41.130	0.082	9.378	7.773	19.701	4.113	0.041
1977	42.074	0.252	7.742	8.499	20.532	4.754	0.295
1978	44.042	0.088	6.562	9.161	19.907	5.769	2.510
1979	47.305	0.000	6.954	10.549	22.233	5.582	2.034
1980	50.372	-0.151	8.110	10.880	24.833	6.045	0.655
1981	54.055	0.270	6.433	10.325	23.298	10.919	2.865
1982	61.327	0.307	9.567	11.468	29.989	9.138	0.859
1983	67.958	0.612	9.718	11.825	36.154	7.068	2.582
1984	73.892	0.665	11.971	11.010	37.759	8.350	4.064
1985	80.300	0.402	13.410	12.527	40.953	9.636	3.212
1986	83.056	0.415	13.621	12.708	45.183	7.973	3.156

CEY in million lbs. by subarea when exploitation is 0.35
minus other catches
where partitioning of total CEY is based on subarea ASP

YEAR	TOTAL	2A	2B	2C	3A	3B	4
1986	66.6	0.140	11.674	8.731	36.990	6.257	2.737

Catch in million lbs. by subarea

YEAR	TOTAL	2A	2B	2C	3A	3B	4
1974	21.306	0.515	4.624	5.605	8.187	1.834	0.541
1975	27.616	0.460	7.127	6.243	10.601	2.655	0.530
1976	27.535	0.238	7.283	5.527	11.044	2.809	0.634
1977	21.868	0.207	5.427	3.186	8.641	3.323	1.084
1978	21.988	0.097	4.607	4.316	10.295	1.327	1.346
1979	22.527	0.046	4.857	4.530	11.335	0.390	1.369
1980	21.866	0.022	5.650	3.238	11.966	0.277	0.713
1981	25.736	0.202	5.241	4.495	14.198	0.416	1.185
1982	29.008	0.290	5.538	3.500	13.499	5.766	0.416
1983	38.384	0.363	5.428	6.610	15.580	8.426	1.977
1984	44.970	0.430	9.054	5.857	19.961	7.545	2.122
1985	56.113	0.493	10.384	9.211	20.852	12.464	2.709
1986	69.576	0.549	11.249	10.661	32.738	11.196	3.183

able 4. Exploitable biomass, constant exploitation yield (CEY), annual surplus production (ASP) for setline, and commerical catches. Estimates ased on closed subarea catch-age analysis with no migration. rea 3B and 4 are old area definitions. 3B is Chirikof and Shumagin.

Biomass in million lbs. by subarea

YEAR	TOTAL	2A	2B	2C	3A	3B	4
1974	122.83	1.43	26.25	26.20	49.29	11.43	8.23
1975	127.55	1.48	27.33	24.92	53.33	12.40	8.10
1976	127.35	1.33	26.47	23.50	56.20	12.57	7.28
1977	129.37	1.12	25.86	23.20	59.85	12.77	6.56
1978	136.64	1.09	25.84	25.36	66.12	12.62	5.61
1979	143.21	1.08	26.06	27.25	70.91	12.91	5.00
1980	152.72	1.01	25.90	29.68	75.22	15.93	4.97
1981	169.07	0.89	25.76	33.20	80.79	22.85	5.58
1982	192.35	0.94	26.39	37.50	88.30	32.31	6.91
1983	214.25	0.90	28.77	43.03	100.41	33.92	7.21
1984	233.52	1.09	32.04	46.02	115.50	31.42	7.45
1985	254.32	1.28	34.44	49.13	129.63	30.91	8.93
1986	264.09	1.13	36.03	49.43	143.24	25.51	8.75

Setline Annual Surplus Production in million lbs

YEAR	TOTAL	2A	2B	2C	3A	3B	4
1974	26.02	0.56	5.70	4.33	12.23	2.80	0.40
1975	27.42	0.31	6.27	4.83	13.47	2.82	-0.28
1976	29.55	0.03	6.67	5.23	14.70	3.01	-0.09
1977	29.15	0.17	5.40	5.34	14.91	3.18	0.13
1978	28.55	0.08	4.83	6.21	15.08	1.61	0.74
1979	32.04	-0.02	4.69	6.97	15.65	3.41	1.34
1980	38.21	-0.10	5.51	6.75	17.54	7.20	1.32
1981	49.02	0.25	5.87	8.80	21.71	9.88	2.52
1982	50.90	0.25	7.93	9.03	25.61	7.38	0.72
1983	57.65	0.55	8.69	9.60	30.67	5.93	2.21
1984	65.77	0.62	11.45	8.97	34.09	7.04	3.61
1985	65.89	0.35	11.98	9.51	34.46	7.06	2.52
1986	68.42	0.31	12.53	9.57	38.08	5.82	2.47

Total CEY in million lbs when exploitation is 0.35

YEAR	TOTAL	2A	2B	2C	3A	3B	4
1974	42.99	0.50	9.19	9.17	17.25	4.00	2.88
1975	44.64	0.52	9.56	8.72	18.66	4.34	2.83
1976	44.57	0.47	9.27	8.23	19.67	4.40	2.55
1977	45.28	0.39	9.05	8.12	20.95	4.47	2.30
1978	47.83	0.38	9.04	8.87	23.14	4.42	1.96

1979	50.12	0.38	9.12	9.54	24.82	4.52	1.75
1980	53.45	0.35	9.06	10.39	26.33	5.58	1.74
1981	59.17	0.31	9.02	11.62	28.28	8.00	1.95
1982	67.32	0.33	9.24	13.13	30.91	11.31	2.42
1983	74.99	0.31	10.07	15.06	35.14	11.87	2.52
1984	81.73	0.38	11.21	16.11	40.42	11.00	2.61
1985	89.01	0.45	12.05	17.20	45.37	10.82	3.13
1986	92.43	0.40	12.61	17.30	50.13	8.93	3.06

Setline CEY after sutracting other catches from total CEY

YEAR	TOTAL	2A	2B	2C	3A	3B	4
1986	75.90	0.12	10.66	13.32	41.94	7.21	2.64

Total CEY when exploitation is 0.35
where partitioning of total CEY is based on subarea ASP

YEAR	TOTAL	2A	2B	2C	3A	3B	4
1974	42.99	0.93	9.41	7.15	20.20	4.63	0.67
1975	44.64	0.50	10.22	7.86	21.94	4.59	-0.46
1976	44.57	0.05	10.06	7.89	22.17	4.54	-0.13
1977	45.28	0.27	8.39	8.29	23.17	4.94	0.21
1978	47.83	0.14	8.10	10.40	25.26	2.70	1.24
1979	50.12	-0.03	7.34	10.90	24.48	5.34	2.09
1980	53.45	-0.14	7.71	9.44	24.53	10.06	1.84
1981	59.17	0.30	7.08	10.62	26.21	11.92	3.04
1982	67.32	0.33	10.48	11.94	33.87	9.76	0.95
1983	74.99	0.72	11.31	12.49	39.89	7.71	2.87
1984	81.73	0.77	14.23	11.14	42.36	8.74	4.48
1985	89.01	0.48	16.18	12.85	46.56	9.53	3.41
1986	92.43	0.42	16.93	12.93	51.45	7.87	3.34

Setline CEY after sutracting other catches from total CEY
where partitioning of total CEY is based on subarea ASP

YEAR	TOTAL	2A	2B	2C	3A	3B	4
1986	75.90	0.15	14.99	8.95	43.25	6.15	2.92

Table 5. Exploitable biomass, constant exploitation yield (CEY), annual surplus production (ASP) for setline, and commerical catches. Estimates based on catch-age analysis for total stock with CPUE subarea partition. Area 3B and 4 are old area definitions. 3B is Chirikof and Shumagin.

Biomass in million lbs. by subarea

YEAR	TOTAL	2A	2B	2C	3A	3B	4
1974	117.51	1.53	27.97	18.92	40.19	16.80	12.10
1975	120.71	1.57	28.97	19.07	42.37	17.38	11.35
1976	120.00	1.44	28.68	18.60	43.80	17.40	10.08
1977	120.83	1.21	27.82	18.51	46.93	17.42	8.95
1978	127.71	1.15	27.20	20.18	52.61	18.39	8.17
1979	135.21	1.08	26.23	23.12	57.19	19.88	7.71
1980	142.76	1.00	25.55	26.55	60.25	22.41	7.00
1981	153.77	0.92	26.60	29.68	64.43	25.83	6.30
1982	174.80	1.05	29.40	33.95	73.67	30.27	6.47
1983	195.66	0.98	31.31	37.18	84.92	34.05	7.24
1984	208.06	1.04	30.59	37.45	94.46	35.99	8.53
1985	225.08	1.12	30.36	38.23	105.23	38.90	11.24
1986	232.48	0.93	29.55	38.16	110.07	40.03	13.73

Setline Annual Surplus Production in million lbs

YEAR	TOTAL	2A	2B	2C	3A	3B	4
1974	24.50	0.56	5.63	5.76	10.37	2.41	-0.22
1975	26.91	0.33	6.84	5.77	12.03	2.67	-0.74
1976	28.36	0.01	6.42	5.43	14.17	2.83	-0.50
1977	28.74	0.15	4.81	4.86	14.33	4.30	0.31
1978	29.49	0.03	3.64	7.26	14.87	2.81	0.88
1979	30.08	-0.04	4.18	7.96	14.39	2.93	0.66
1980	32.87	-0.05	6.70	6.36	16.15	3.70	0.02
1981	46.77	0.33	8.04	8.76	23.44	4.85	1.35
1982	49.87	0.22	7.45	6.73	24.75	9.54	1.18
1983	50.78	0.42	4.71	6.88	25.12	10.37	3.27
1984	61.99	0.51	8.82	6.63	30.73	10.45	4.83
1985	63.50	0.30	9.58	9.15	25.69	13.59	5.20
1986	65.59	0.25	9.33	9.13	26.87	13.98	6.35

Total CEY in million lbs when exploitation is 0.35

YEAR	TOTAL	2A	2B	2C	3A	3B	4
1974	41.13	0.53	9.79	6.62	14.07	5.88	4.24
1975	42.25	0.55	10.14	6.68	14.83	6.08	3.97
1976	42.00	0.50	10.04	6.51	15.33	6.09	3.53
1977	42.29	0.42	9.74	6.48	16.43	6.10	3.13
1978	44.70	0.40	9.52	7.06	18.41	6.44	2.86
1979	47.32	0.38	9.18	8.09	20.02	6.96	2.70
1980	49.97	0.35	8.94	9.29	21.09	7.34	2.45

1981	53.82	0.32	9.31	10.39	22.55	9.04	2.21
1982	61.18	0.37	10.29	11.88	25.78	10.59	2.27
1983	68.48	0.34	10.96	13.01	29.72	11.92	2.53
1984	72.82	0.36	10.70	13.11	33.06	12.60	2.99
1985	78.78	0.39	10.62	13.38	36.83	13.62	3.93
1986	81.37	0.33	10.34	13.36	38.52	14.01	4.81

Setline CEY after sutracting other catches from total CEY

YEAR	TOTAL	2A	2B	2C	3A	3B	4
1986	64.84	0.05	8.40	9.38	30.33	12.29	4.39

Total CEY when exploitation is 0.35
where partitioning of total CEY is based on subarea ASP

YEAR	TOTAL	2A	2B	2C	3A	3B	4
1974	41.13	0.93	9.44	9.66	17.40	4.05	-0.36
1975	42.25	0.52	10.74	9.06	18.89	4.20	-1.16
1976	42.00	0.01	9.51	8.04	20.99	4.18	-0.73
1977	42.29	0.22	7.07	7.15	21.08	6.32	0.45
1978	44.70	0.05	5.51	11.00	22.54	4.26	1.33
1979	47.32	-0.06	6.58	12.53	22.63	4.61	1.04
1980	49.97	-0.08	10.18	9.67	24.55	5.62	0.03
1981	53.82	0.38	9.25	10.08	26.97	5.59	1.56
1982	61.18	0.27	9.14	8.26	30.37	11.71	1.45
1983	68.48	0.57	6.35	9.28	33.88	13.99	4.41
1984	72.82	0.60	10.37	7.79	36.10	12.28	5.68
1985	78.78	0.37	11.89	11.35	31.87	16.86	6.45
1986	81.37	0.31	11.57	11.33	33.33	17.34	7.87

Setline CEY after sutracting other catches from total CEY
where partitioning of total CEY is based on subarea ASP

YEAR	TOTAL	2A	2B	2C	3A	3B	4
1986	64.84	0.03	9.63	7.35	25.14	15.63	7.45

INTERNATIONAL PACIFIC HALIBUT COMMISSION

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POPULATION ASSESSMENT, 1985

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Deriso, R.B., 1986. Population assessment, 1985. IPHC Rep., pp. 1–11.

POPULATION ASSESSMENT, 1985

by

Richard B. Deriso

Ourassessment of the Pacific halibut stock is based primarily on two methods of catch-age analysis, as in 1984. During the last three years, we have described those methods during our staff presentation at the Annual Meetings. The information we've used this year for the assessment is comprised primarily of logbook catch and effort data, commercial landings, port sampling age and length data, and tagreturn information. No new problems were encountered in this year's assessment, although we still observe unusually low catchability of halibut in the southern end of the range (Areas 2A and 2B) and high catchability of halibut in the central range.

Overall, the Pacific halibut stock continued to grow in 1985, increasing coastwide abundance by 8% from 1984. Abundance increases occurred principally in Areas 2C and 3A, with only a minor increase in other areas. Age classes of eight- and nine-year-old halibut are in high abundance, which should add support to the exploitable adult stock over the next three years as they become fully recruited into the fishery.

A summary of results from the analysis is given in Table 1. Results from the first method of assessment, migratory catch-age analysis are given in Table 2. In Table 3, results are shown in the other catch-age method, which uses CPUE partitioning. CPUE estimates, standardized to J hook and constant catchability between areas, are given in Table 4.

Annual surplus production is the excess of biomass above what is needed to replenish the population each year. A range of estimates for each Regulatory Area is shown in Figure 1, along with the mid-point (or median) estimate for each area. The estimated total surplus in 1985 is 75 million pounds with a range of 56 to 93 million pounds. Even if we allow for a rather large incidental catch of 10 million pounds we still have an estimated surplus available to the commercial setline fishery of 65 million pounds.

Estimates of yield are even higher with our preferred method of setting quotas, which is the constant exploitation yield (CEY) concept described last year. That approach is based on taking a fixed percentage of the adult stock each year. A 28% exploitation rate appears reasonable for the halibut stock for a number of reasons, including (1) this is the $F_{0.1}$ rate for halibut, (2) it is within our range of MSY exploitation rates, and (3) it is 90% of our best MSY exploitation estimate for the setline fishery (allows for 10 million pounds incidental catch). A range of estimates of CEY is shown in Figure 2 for each Regulatory Area, along with median estimates for each Area. The estimated total setline CEY is 73 million pounds and ranges from 66 to 80 million pounds.

Table 1. Summary of 1985 population assesment results.

	2A	2B	2C	3A	3B	4	Combined Area
1985 Quota	0.5	10.0	9.0	23.0	9.0	4.25	55.75
1985 Catch	0.5	9.9	8.9	20.4	10.9	4.39	54.97
I.	Annual Surplus Production (10^6 pounds)						
Range of Estimates							
Upper	0.6	10.5	17.6	40.6	14.2	9.4	92.9
Lower	0.3	8.7	7.1	30.7	6.9	2.9	56.6
Median	0.4	9.6	13.0	36.3	11.4	4.9	75.6
II.	Setline Constant Exploitation Yield (10^6 pounds)						
Range of Estimates							
Upper	0.3	9.1	18.5	35.3	13.2	4.4	80.8
Lower	0.3	8.9	12.9	32.2	9.1	3.0	66.4
Median	0.3	9.0	15.7	33.7	11.1	3.6	73.4
III.	Maximum Sustained Yield (10^6 pounds)						
All gear	0.9	19.1	11.8	28.1	10.1	1.5	71.4
(a) 10 million incidental	0.8	16.4	10.2	24.1	8.7	1.3	61.4
(b) 20 million incidental	0.7	13.7	8.5	20.2	7.2	1.1	51.4

Table 2. Exploitable biomass, constant exploitation yield (CEY), annual surplus production (ASP), and commercial catches. Estimates are based on migratory catch-age analysis, as described in IPHC Sci. Rep. No. 72.

Biomass in million lbs. by subarea

YEAR	TOTAL	2A	2B	2C	3A	3B	4
1974	117.425	1.564	28.625	25.257	40.908	12.249	8.822
1975	121.153	1.587	29.296	24.440	44.451	12.935	8.444
1976	121.046	1.385	27.710	24.242	47.052	13.080	7.577
1977	124.022	1.158	26.760	25.142	50.844	13.320	6.798
1978	130.822	1.108	26.222	28.464	56.140	13.048	5.840
1979	143.273	1.112	26.262	31.816	61.129	17.094	5.860
1980	155.841	0.907	26.003	35.786	66.125	21.140	5.880
1981	170.693	0.789	25.725	41.465	71.620	25.186	5.908
1982	197.237	0.685	26.389	48.046	78.709	35.924	7.484
1983	219.787	0.814	28.710	55.675	89.433	36.984	8.171
1984	239.085	0.997	31.911	60.625	103.693	32.997	8.862
1985	258.015	1.088	32.383	66.021	115.120	32.506	10.897

Setline CEY in million lbs. by subarea when exploitation is 0.28

YEAR	TOTAL	2A	2B	2C	3A	3B	4
1974	32.879	0.427	8.022	7.069	11.442	3.419	2.466
1975	33.923	0.441	8.209	6.852	12.450	3.630	2.375
1976	33.893	0.373	7.761	6.779	13.184	3.660	2.135
1977	34.726	0.313	7.501	7.049	14.238	3.716	1.910
1978	36.630	0.293	7.326	7.985	15.714	3.663	1.648
1979	40.116	0.321	7.341	8.906	17.130	4.774	1.645
1980	43.635	0.262	7.287	10.036	18.501	5.934	1.658
1981	47.794	0.239	7.217	11.614	20.073	7.074	1.673
1982	55.226	0.166	7.400	13.475	22.035	10.051	2.099
1983	61.540	0.246	8.062	15.570	25.047	10.339	2.277
1984	66.944	0.268	8.904	17.004	29.054	9.238	2.477
1985	72.244	0.289	9.103	18.495	32.221	9.103	3.034

ASP in million lbs. by subarea (change within area)

YEAR	TOTAL	2A	2B	2C	3A	3B	4
1974	25.034	0.538	5.295	4.788	11.730	2.520	0.163
1975	27.509	0.258	5.541	6.045	13.202	2.800	-0.337
1976	30.511	0.011	6.333	6.427	14.836	3.049	-0.145
1977	28.668	0.157	4.889	6.508	13.937	3.051	0.126
1978	34.439	0.101	4.647	7.668	15.284	5.373	1.366
1979	35.095	-0.159	4.598	8.500	16.331	4.436	1.389
1980	36.718	-0.096	5.372	8.917	17.461	4.323	0.741
1981	52.276	0.098	6.318	10.591	21.314	11.194	2.761
1982	51.268	0.340	7.557	11.114	24.231	6.932	1.094
1983	57.682	0.448	8.637	11.348	28.372	5.821	3.056
1984	63.900	0.522	9.526	11.243	31.398	6.975	4.236
1985	68.959	0.570	9.667	12.244	34.858	6.871	5.209

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Table 2. (cont.) Exploitable biomass, constant exploitation yield (CEY), annual surplus production (ASP), and commercial catches. Estimates are based on migratory catch-age analysis, as described in IPHC Sci. Rep. No. 72.

	ASP in million lbs. by subarea (CPUE partitioned method)						
YEAR	TOTAL	2A	2B	2C	3A	3B	4
1974	25.034	0.325	6.108	5.382	8.712	2.604	1.878
1975	27.509	0.358	6.657	5.557	10.096	2.943	1.926
1976	30.511	0.336	6.987	6.102	11.869	3.295	1.922
1977	28.668	0.258	6.192	5.820	11.754	3.067	1.577
1978	34.439	0.276	6.888	7.508	14.774	3.444	1.550
1979	35.095	0.281	6.422	7.791	14.986	4.176	1.439
1980	36.718	0.220	6.132	8.445	15.568	4.994	1.395
1981	52.276	0.261	7.894	12.703	21.956	7.737	1.830
1982	51.268	0.154	6.870	12.509	20.456	9.331	1.948
1983	57.682	0.231	7.556	14.594	23.477	9.691	2.134
1984	63.900	0.256	8.499	16.231	27.733	8.818	2.364
1985	68.959	0.276	8.689	17.654	30.756	8.689	2.896

	Catch in million lbs. by subarea						
YEAR	TOTAL	2A	2B	2C	3A	3B	4
1974	21.306	0.515	4.624	5.605	8.187	1.834	0.541
1975	27.616	0.460	7.127	6.243	10.601	2.655	0.530
1976	27.535	0.238	7.283	5.527	11.044	2.809	0.634
1977	21.868	0.207	5.427	3.186	8.641	3.323	1.084
1978	21.988	0.097	4.607	4.316	10.295	1.327	1.346
1979	22.527	0.046	4.857	4.530	11.335	0.390	1.369
1980	21.866	0.022	5.650	3.238	11.966	0.277	0.713
1981	25.732	0.202	5.654	4.010	14.225	0.456	1.185
1982	28.718	0.211	5.236	3.485	13.507	5.872	0.407
1983	38.384	0.265	5.436	6.398	14.112	9.808	2.365
1984	44.970	0.431	9.054	5.847	19.971	7.466	2.201
1985	54.853	0.487	9.945	8.903	20.256	10.900	4.362

Table 3. Exploitable biomass, constant exploitation yield (CEY), annual surplus production (ASP), and commercial catches. Estimates are based on catch-age analysis with CPUE partitioning, as described in IPHC Sci. Rep. No. 72.

Biomass in million lbs. by subarea

YEAR	TOTAL	2A	2B	2C	3A	3B	4
1974	121.347	1.578	28.881	19.537	41.501	17.353	12.499
1975	125.294	1.629	30.071	19.796	43.978	18.042	11.778
1976	126.225	1.515	30.294	19.439	46.072	18.303	10.603
1977	129.899	1.299	30.007	19.874	50.271	18.835	9.612
1978	138.665	1.248	29.536	22.048	57.130	19.829	8.875
1979	146.059	1.168	27.605	25.998	62.075	21.179	8.033
1980	156.701	0.940	26.953	31.340	66.598	23.819	7.208
1981	170.632	0.853	27.813	35.662	72.177	27.642	6.484
1982	196.163	0.785	30.209	41.194	84.154	32.955	6.866
1983	222.009	0.888	31.303	45.068	98.350	38.186	8.436
1984	241.106	0.964	30.862	45.087	110.668	42.194	11.332
1985	268.630	1.075	31.967	46.204	126.256	47.279	15.849

Setline CEY in million lbs. by subarea when exploitation is 0.28

YEAR	TOTAL	2A	2B	2C	3A	3B	4
1974	33.977	0.442	8.087	5.470	11.620	4.859	3.500
1975	35.082	0.456	8.420	5.543	12.314	5.052	3.298
1976	35.343	0.424	8.482	5.443	12.900	5.125	2.969
1977	36.372	0.364	8.402	5.565	14.076	5.274	2.692
1978	38.826	0.349	8.270	6.173	15.996	5.552	2.485
1979	40.897	0.327	7.729	7.280	17.381	5.930	2.249
1980	43.876	0.263	7.547	8.775	18.647	6.669	2.018
1981	47.777	0.239	7.788	9.985	20.210	7.740	1.816
1982	54.926	0.220	8.459	11.534	23.563	9.228	1.922
1983	62.163	0.249	8.765	12.619	27.538	10.692	2.362
1984	67.510	0.270	8.641	12.624	30.987	11.814	3.173
1985	75.216	0.301	8.951	12.937	35.352	13.238	4.438

ASP in million lbs. by subarea (change within area method)

YEAR	TOTAL	2A	2B	2C	3A	3B	4
1974	25.252	0.566	5.814	5.865	10.664	2.524	-0.180
1975	28.547	0.346	7.351	5.885	12.695	2.915	-0.645
1976	31.208	0.022	6.996	5.963	15.243	3.342	-0.356
1977	30.635	0.156	4.956	5.359	15.500	4.317	0.346
1978	29.381	0.017	2.676	8.267	15.240	2.676	0.505
1979	33.169	-0.182	4.204	9.872	15.858	3.030	0.544
1980	35.797	-0.065	6.510	7.560	17.545	4.101	-0.011
1981	51.263	0.133	8.050	9.542	26.202	5.769	1.567
1982	54.565	0.314	6.330	7.359	27.703	11.102	1.978
1983	57.481	0.341	4.994	6.417	26.430	13.816	5.261
1984	72.494	0.541	10.159	6.965	35.559	12.551	6.718
1985	80.770	0.603	10.523	7.137	40.568	14.064	9.396

continued----------)

Table 3. (cont.) Exploitable biomass, constant exploitation yield (CEY), annual surplus production (ASP), and commercial catches. Estimates are based on catch-age analysis with CPUE partitioning, as described in IPHC Sci. Rep. No. 72.

	ASP in million lbs. by subarea (CPUE partitioned method)						
YEAR	TOTAL	2A	2B	2C	3A	3B	4
1974	25.252	0.328	6.010	4.066	8.636	3.611	2.601
1975	28.547	0.371	6.851	4.510	10.020	4.111	2.683
1976	31.208	0.374	7.490	4.806	11.391	4.525	2.621
1977	30.635	0.306	7.077	4.687	11.856	4.442	2.267
1978	29.381	0.264	6.258	4.672	12.105	4.201	1.880
1979	33.169	0.265	6.269	5.904	14.097	4.810	1.824
1980	35.797	0.215	6.157	7.159	15.214	5.441	1.647
1981	51.263	0.256	8.356	10.714	21.684	8.305	1.948
1982	54.565	0.218	8.403	11.459	23.408	9.167	1.910
1983	57.481	0.230	8.105	11.669	25.464	9.867	2.184
1984	72.494	0.290	9.279	13.556	33.275	12.686	3.407
1985	80.770	0.323	9.612	13.892	37.962	14.216	4.765

	Catch in million lbs. by subarea						
YEAR	TOTAL	2A	2B	2C	3A	3B	4
1974	21.306	0.515	4.624	5.605	8.187	1.834	0.541
1975	27.616	0.460	7.127	6.243	10.601	2.655	0.530
1976	27.535	0.238	7.283	5.527	11.044	2.809	0.634
1977	21.868	0.207	5.427	3.186	8.641	3.323	1.084
1978	21.988	0.097	4.607	4.316	10.295	1.327	1.346
1979	22.527	0.046	4.857	4.530	11.335	0.390	1.369
1980	21.866	0.022	5.650	3.238	11.966	0.277	0.713
1981	25.732	0.202	5.654	4.010	14.225	0.456	1.185
1982	28.718	0.211	5.236	3.485	13.507	5.872	0.407
1983	38.384	0.265	5.436	6.398	14.112	9.808	2.365
1984	44.970	0.431	9.054	5.847	19.971	7.466	2.201
1985	54.853	0.487	9.945	8.903	20.256	10.900	4.362

Table 4. Catch, standard setline effort, and standard CPUE. Data are standardized to "J" hook equivalence and adjusted to equal catchability between Areas 2B, 2C, 3A, and 3B, as described in IPHC Sci. Rep. No. 72.

CPUE Report for Subareas 1980

Subarea	Catch(lbs.)	Effort(skates)	CPUE(lbs./skate)
2A	22000.	590.	37.3
2B	5650000.	86524.	65.3
2C	3238000.	40776.	79.4
3A	11966000.	101013.	118.5
3B	277000.	2443.	113.4
4	713000.	12633.	56.4
ALL	21866000.	243979.	89.6
2A+2B	5672000.	87114.	65.1
2A+2B+2C	8910000.	127890.	69.7
3A+3B	12243000.	103456.	118.3
3B+4	990000.	15076.	65.7

CPUE Report for Subareas 1981

Subarea	Catch(lbs.)	Effort(skates)	CPUE(lbs./skate)
2A	202000.	6177.	32.7
2B	5654000.	74517.	75.9
2C	4010000.	34309.	116.9
3A	14225000.	129130.	110.2
3B	456000.	3375.	135.1
4	1185000.	11296.	104.9
ALL	25732000.	258804.	99.4
2A+2B	5856000.	80694.	72.6
2A+2B+2C	9866000.	115003.	85.8
3A+3B	14681000.	132505.	110.8
3B+4	1641000.	14671.	111.9

CPUE Report for Subareas 1982

Subarea	Catch(lbs.)	Effort(skates)	CPUE(lbs./skate)
2A	211000.	5369.	39.3
2B	5236000.	69466.	75.4
2C	3485000.	25625.	136.0
3A	13507000.	100738.	134.1
3B	5872000.	44512.	131.9
4	407000.	5968.	68.2
ALL	28718000.	251678.	114.1
2A+2B	5447000.	74835.	72.8
2A+2B+2C	8932000.	100460.	88.9
3A+3B	19379000.	145250.	133.4
3B+4	6279000.	50480.	124.4

continued------>

Table 4. (cont.) Catch, standard setline effort, and standard CPUE. Data are standardized to "J" hook equivalence and adjusted to equal catchability between Areas 2B, 2C, 3A, and 3B, as described in IPHC Sci. Rep. No. 72.

CPUE Report for Subareas 1983

Subarea	Catch(lbs.)	Effort(skates)	CPUE(lbs./skate)
2A	265000.	9464.	28.0
2B	5436000.	76698.	70.9
2C	6398000.	50939.	125.6
3A	14112000.	89001.	158.6
3B	9808000.	67772.	144.7
4	2365000.	29786.	79.4
ALL	38384000.	323660.	118.6
2A+2B	5701000.	86162.	66.2
2A+2B+2C	12099000.	137101.	88.2
3A+3B	23920000.	156773.	152.6
3B+4	12173000.	97558.	124.8

CPUE Report for Subareas 1984

Subarea	Catch(lbs.)	Effort(skates)	CPUE(lbs./skate)
2A	431000.	25964.	16.6
2B	9054000.	136407.	66.4
2C	5847000.	50755.	115.2
3A	19971000.	109155.	183.0
3B	7466000.	47421.	157.4
4	2201000.	24320.	90.5
ALL	44970000.	394022.	114.1
2A+2B	9485000.	162371.	58.4
2A+2B+2C	15332000.	213126.	71.9
3A+3B	27437000.	156576.	175.2
3B+4	9667000.	71741.	134.7

CPUE Report for Subareas 1985

Subarea	Catch(lbs.)	Effort(skates)	CPUE(lbs./skate)
2A	487000.	8240.	59.1
2B	9945000.	132379.	75.1
2C	8903000.	64477.	138.1
3A	20256000.	109991.	184.2
3B	10900000.	58226.	187.2
4	4362000.	23668.	184.3
ALL	54853000.	396981.	138.2
2A+2B	10432000.	140619.	74.2
2A+2B+2C	19335000.	205096.	94.3
3A+3B	31156000.	168217.	185.2
3B+4	15262000.	81894.	186.4

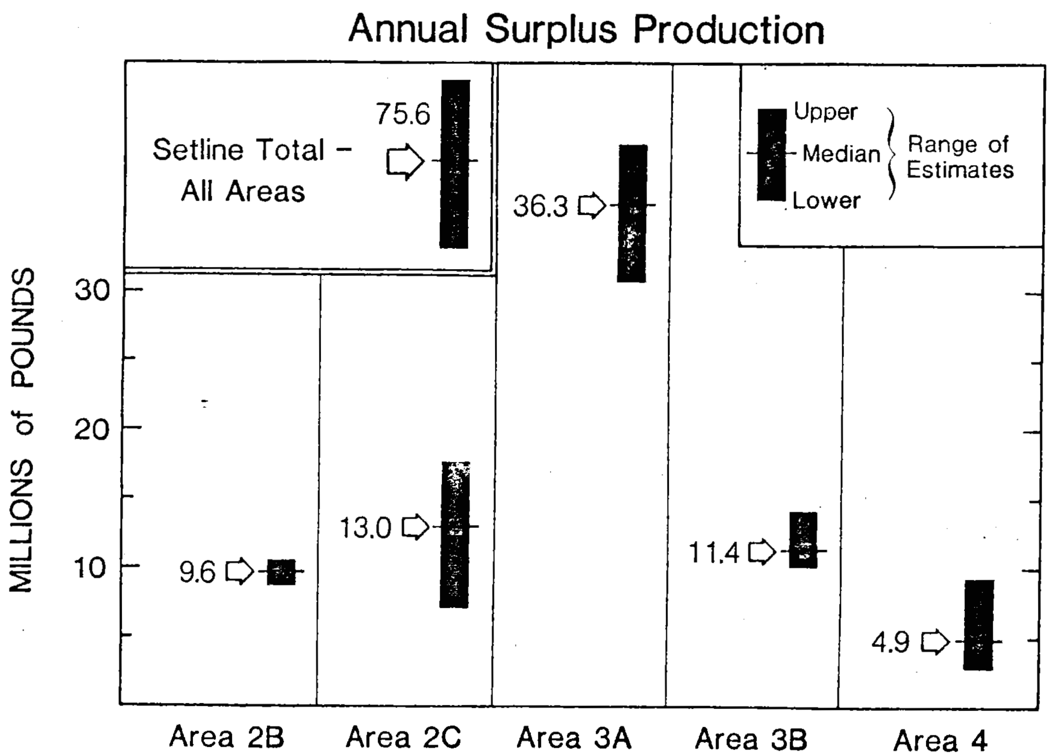

Figure 1. Annual surplus production estimates for 1985 by regulatory area. The upper, lower, and median estimates are based on all analyses made this year.

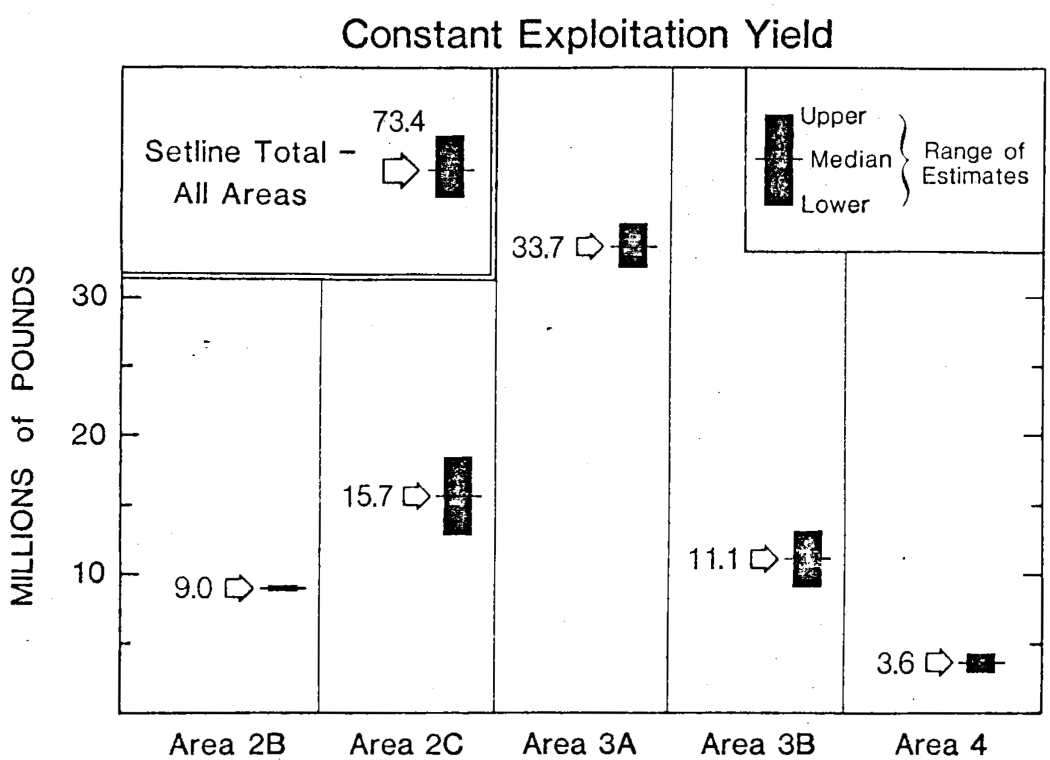

Figure 2. Constant exploitation yield estimates for 1985 by regulatory area. The upper, lower, and median estimates are based on all analyses made this year.

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INTERNATIONAL PACIFIC HALIBUT COMMISSION

January 1985

STOCK ASSESSMENT DOCUMENT III: CONSIDERATIONS FOR DETERMINING CATCH LIMITS

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STOCK ASSESSMENT DOCUMENT III

CONSIDERATIONS FOR DETERMINING CATCH LIMITS

by

Stephen H. Hoag, Richard B. Deriso, and Terrance J. Quinn II

Halibut stocks declined from the early 1960's to the mid-1970's and IPHC responded by reducing catch limits throughout that period. Since then, IPHC has attempted to rebuild stocks by setting catch limits below the annual surplus production (ASP), where ASP is defined as the change in biomass from one year to the next plus the catch. ASP has usually been expressed in terms of setline production, although incidental catches in other fisheries reduce setline ASP and are accounted for in the estimation of setline ASP.

Recommendations by the IPHC staff were aimed at setting catch limits at about 75% of the estimated ASP during 1980-1983. Stocks increased sharply during this period, and catch limit recommendations in 1984 were based on 90% of ASP in areas where stocks appeared to be approaching maximum sustained yield (MSY) levels.

Several factors need to be considered before recommending catch limits for an area. First, estimates of ASP vary depending on the method of estimation. All methods depend to some degree on CPUE data which have been subject to serious problems in recent years. Second, ASP probably is highly variable, particularly among areas, and is dependent on rates of recruitment, mortality, growth, and migration. ASP can be very low or negative, even though stock biomass is large. Therefore, ASP is probably not a good parameter upon which to base catch limits once stocks are at relatively high levels. Third, the catches in an area can affect stocks in another area because of migration. This is particularly true for incidental catches, which tend to consist of smaller fish that tend to have higher rates of migration.

In years like this one, when the halibut stock is at a relatively high abundance level, quotas can be based on MSY estimates rather than being based on ASP estimates. MSY may reliably indicate the long-term goals of management for maximum yield. However, to set annual quotas at a fixed amount corresponding to MSY and leave it there independent of stock abundance changes can easily cause over-exploitation. Catches that rise and fall with the abundance of the stock are better for a long-term management plan. One such policy is to take a fixed percentage of the stock each year: the constant exploitation yield (CEY) is defined as the amount of yield obtained by taking catches proportional to stock abundance where the proportionality constant is determined so that MSY is taken when the stock is at the level of abundance that produces MSY.

Table 1 summarizes estimates of ASP, CEY, and MSY by area. For all areas combined, ASP estimates range from 48.3 to 79.7 million pounds with a median value of 77.3 million pounds. Median CEY estimates range from 66.7 to 86.7 million pounds, depending on the level of incidental catch. The median estimates of ASP and CEY are higher than the estimates of MSY, suggesting that stock productivity in recent years is above the long term average.

Estimates of ASP and CEY by area also vary from area estimates of MSY: MSY estimates in Areas 2A and 2B are higher and the estimate in Area 4 is lower than ASP and CEY estimates. This difference may reflect an atypical distribution of the halibut stocks in recent years. MSY estimates by area, however, are based on the historical

Hoag, S.H., Deriso, R.B., Quinn II, T.J., 1985. Stock Assessment Document III: Considerations for determining catch limits [1984 stock assessment]. IPHC Rep., pp. 1–8.

distribution of catch and this procedure may reflect economic factors as well as the distribution of halibut stocks. The fishery first developed in Areas 2A and 2B and exploitation rates have tended to be higher in these areas. In contrast, the fishery in Area 4 did not develop until the 1960's, and has been impacted to a greater degree by incidental catches.

Setting catch limits requires a clear statement of IPHC objectives. If the objective is to rebuild stocks, then the catch limit should be set below ASP. The probability of rebuilding and the rate of rebuilding increases the farther the catch limit is set below ASP. IPHC's policy of setting catch limits at 75% of ASP during the 1980's appears to have been successful in accomplishing the objective of rebuilding the resource.

CPUE data suggest that stocks are presently near levels that produce MSY and the objective of rebuilding may no longer be appropriate (Areas 2A and 2B may be an exception). Assuming stocks are at MSY levels, ASP is probably not the best parameter upon which to base catch limits. Estimates of ASP will probably vary greatly and could be low or negative, even though stocks are large. CEY or MSY are probably the best parameters upon which to base catch limits. An advantage of CEY is that it is proportional to current estimates of biomass whereas MSY reflects long-term conditions.

Setting catch limits at MSY or CEY may result in achieving maximum yield, but there may be some advantage in keeping catch limits slightly below this level. Stock size will fluctuate over time due to varying environmental conditions, and keeping catch limits below MSY levels may result in more stable yields over time. Stable yields may be advantageous both to the harvesting and the marketing sectors of the industry. As an example, setting catch limits at 90% of the 1984 CEY (assuming 20 million pounds of incidental mortality) would result in the following:

	2A	2B	2C	3A	3B	4	TOTAL
90% CEY	0.3	9.5	10.2	25.4	9.4	5.3	60.0

Because halibut are migratory, the catch limit in one area will affect future yield in other areas. However, most halibut caught in the setline fishery are over 80 cm and migration rates are relatively small. Table 2 shows the estimated effect of 1 million pounds of setline catch in an area on setline yield in other areas based on the distribution of tag recoveries. The results suggest very little impact on yield, e.g., 1 million pounds of catch limit in Area 3A reduces the yield in Area 2B by only 16,000 pounds. The largest effect occurs with catches in Area 4, where almost a third of the yield is potentially lost to other areas.

Incidental catches have a greater impact on yield among areas because incidentally caught halibut tend to be small. Hence, they have a greater tendency to migrate and have greater growth potential. Table 3 illustrates the yield loss that may have occurred as a result of incidental catches during the 1960's and 1970's. For example, a 3 million pound incidental catch in Area 3A causes 0.77 million pounds of yield loss in Area 2B. The analysis assumes constant rates of exploitation and tag reporting among areas. Evidence suggests that rates of exploitation and tag reporting may be higher in Area 2B;

hence, the effect of incidental catch in Area 2B may be exaggerated. Also the effect of incidental catch in the early 1980's may be about 10 million pounds, down substantially from the 20 million pound level of the 1960's and 1970's.

Table 1. Summary of 1984 stock assessment estimates of annual surplus production, optimum exploitation yield, and maximum sustained yield (Quinn II and Deriso, document available upon request).

	2A	2B	2C	3A	3B	4	Combined Areas
	Annual Surplus Production (10^6 pounds)						
Range of Estimates							
Upper	0.5	16.5	20.3	38.9	17.1	6.9	79.7
Lower	0.2	7.3	6.4	19.4	6.4	1.3	48.3
Median	0.3	11.8	11.7	33.0	8.7	4.3	77.3
	Constant Exploitation Yield (10^6 pounds)						
Range of Estimates							
All Gear							
Upper	0.3	14.1	15.6	39.8	14.6	8.3	92.6
Lower	0.2	12.2	13.6	34.4	12.6	7.2	80.3
Median	0.3	13.8	14.7	36.6	13.6	7.7	86.7
Setline only							
(a) 10 million incidental							
Upper	0.3	12.6	13.9	35.5	13.0	7.4	82.6
Lower	0.2	10.7	11.9	30.1	11.0	6.3	70.3
Median	0.3	12.2	13.0	32.4	12.0	6.8	76.7
(b) 20 million incidental							
Upper	0.3	11.1	12.2	31.2	11.4	6.5	72.6
Lower	0.2	9.2	10.2	25.8	9.4	5.4	60.3
Median	0.3	10.6	11.3	28.2	10.4	5.9	66.7
	Maximum Sustained Yield (10^6 pounds)						
All gear	0.9	19.1	11.8	28.1	10.1	1.5	71.4
Setline only:							
(a) 10 million incidental	0.8	16.4	10.2	24.1	8.7	1.3	61.4
(b) 20 million incidental	0.7	13.7	8.5	20.2	7.2	1.1	51.4

Table 2. Effect of 1 million pounds of setline catch in an area on setline yield in other areas, based on tag recoveries (Deriso, unpublished).

One million lbs of setline catch in Area:	Setline Yield Loss (thousands of lbs)					
	2A	2B	2C	3A	3B	4
2A	914	57	29	0		0
2B	2	986	8	4	0	0
2C	0	51	944	5	0	0
3A	3	16	21	947	13	0
3B	5	17	40	190	748	
4	2	33	55	163	62	682

Table 3. Estimated annual yield loss by area from incidental mortality levels of the 1960's and 1970's (millions of lbs).

		Annual Yield Loss*						
Area	Mortality	2A	2B	2C	3A	3B	4	TOTAL
2A	trace	--	--	--	--	--	--	--
2B	2	0.01	2.97	0.02	0.00	0.00	--	3.00
2C	1	--	0.18	1.31	0.01	--	--	1.50
3A	3	0.08	0.77	0.24	3.37	0.04	--	4.50
3B	3	0.03	0.42	0.25	0.68	3.06	0.06	4.50
4	5	--	0.24	0.73	0.65	0.40	5.48	7.50
TOTAL	14	0.12	4.58	2.55	4.71	3.50	5.54	21.00

*Assumes percent recoveries for tagged fish <80 cm is same as relative yield loss; assumes 50% increase in loss due to growth.

INTERNATIONAL PACIFIC HALIBUT COMMISSION

STOCK ASSESSMENT DOCUMENT III: EVALUATION OF POPULATION CONDITION

Seattle, Washington

1984

INTERNATIONAL PACIFIC HALIBUT COMMISSION

January 1984

STOCK ASSESSMENT DOCUMENT III: POPULATION CONDITION

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STOCK ASSESSMENT DOCUMENT III

Section 1. BIOMASS AND ANNUAL SURPLUS PRODUCTION (ASP) ESTIMATES FOR REGULATORY AREAS

by

Terrance J. Quinn II, Richard B. Deriso, and Phillip R. Neal

In 1982, biomass of the total halibut population was obtained from catch-age analysis of age-structured commercial catch data, with catch-effort data used as a stabilizing influence. Biomass and ASP estimates for regulatory areas were obtained by partitioning total biomass and ASP with a combination of CPUE and relative habitat information. This analytical method is called the CPUE-partitioning method. Current investigations suggest that there are substantial problems with CPUE comparisons between areas. A new analytical method, called migratory catch-age analysis, has been developed to provide biomass estimates for regulatory areas that are independent of CPUE partitioning.

Migratory catch-age analysis uses age-structured commercial catch data for 4 regulatory area groups with sufficient data (2A + 2B, 2C, 3A, 3B + 4). Area 3B is defined for historical consistency as the combination of the Chirikof and Shumagin regions and differs somewhat from the Area 3B in the 1983 regulations. Each group is analyzed separately but is linked to other groups with migration rates and population abundance information. CPUE data is used only to stabilize estimates, not to partition biomass. The analysis of groups is iterated until the estimates converge.

The major assumptions of the method are:

1. Catch-at-age can be modelled with a lognormal distribution.

Quinn T.J. II, Deriso R.B., Neal, P.R., 1984. Stock Assessment Document III: Section 1. Biomass and annual surplus production (ASP) estimates for regulatory areas [1983 stock assessment]. IPHC Rep., pp. 1–11.

2. Fishing mortality can be partitioned into yearly full-recruitment fishing mortality and age selectivity factors.

3. Migration rates are constant over time, and the population can be modelled with migration occurring at the start of the year.

4. Natural mortality is equal to 0.2 for all ages and years.

For each regulatory area group, estimates of year-class strength, full-recruitment fishing mortality, and age selectivity are obtained, which result in population abundance estimates.

Exploitable biomass can be expressed as

$$B_t = \sum_a s_a N_{at} W_{at}$$

where B_t is exploitable biomass in year t, s_a is selectivity of age a fish, N_{at} is population abundance, and W_{at} is average fish weight. After this process is completed, the 4 regulatory area groups are partitioned into the 6 main regulatory areas. This requires partitioning 2A + 2B and 3B + 4 into individual areas with CPUE and habitat information.

Finally, ASP for each area is calculated as the sum of catch and change in biomass. ASP in 1983 is then projected from the ratio of ASP to biomass in 1982. ASP is then smoothed to remove extraneous variability.

Three data sets were analyzed using migratory catch-age analysis to examine the sensitivity of the method to CPUE data. For each data set, biomass and ASP estimates are presented for regulatory areas and for the total population. In addition, corresponding ASP estimates from the method of CPUE-partitioning are presented. A preliminary analysis (Table 1) used standard CPUE data. The second analysis (Table 2) used adjusted CPUE data, as described in another document. The third analysis (Table 3) used no CPUE data from 1983.

The preliminary analysis had some convergence problems, probably due to the little fishing in combined area 3B + 4 between 1979 and 1981 and the large change in CPUE in that area in the past five years. Also, the third analysis required more iterations to converge, because there were no CPUE data in 1983 to stabilize the estimates. The overall residual sum of squares was lowest for the second analysis (80.05), followed by the third analysis (80.08), followed by the preliminary analysis (87.62). Thus, the results from the second analysis will be considered as best estimates for populaton parameters excluding annual surplus production, which will be considered separately.

Biomass estimates of the total population and Area 2 among the three analyses are fairly close. For Area 3 and Area 4, biomass estimates from the second and third analyses are similar. Both sets of estimates differ from estimates from the preliminary analysis, presumably due to its convergence problems noted above. Using the estimates from the second analysis, biomass increased in all regulatory areas from 1982 to 1983.

Annual surplus production estimates from migratory catch-age analysis and CPUE-partitioning are shown for the three analyses in Tables 1-3. The range of 1983 surplus production estimates for each regulatory area, shown in Table 4, is not large, indicating reasonable agreement among the partitioning methods and among the data sets used. The mid-range will be used as the best estimate of 1983 surplus production. The 21.4 million pound surplus in Area 2 is partitioned into 400 thousand pounds in Area 2A, 8 million pounds in Area 2B and 13 million pounds in Area 2C. The 28 million pound surplus in Area 3 is

Table 1. PRELIMINARY ESTIMATES

Biomass in million lbs. by subarea

YEAR	TOTAL	2A	2B	2C	3A	3B	4
1967	222.060	3.527	59.084	36.512	52.764	45.861	24.312
1968	202.155	3.636	56.223	34.674	50.418	37.540	19.664
1969	192.869	4.062	54.970	35.751	53.559	29.221	15.306
1970	171.850	3.724	48.406	31.989	52.485	22.987	12.259
1971	157.672	3.415	46.740	28.615	49.720	18.862	10.320
1972	153.101	3.059	47.106	27.168	49.454	16.695	9.619
1973	121.019	1.720	29.363	22.168	47.693	12.579	7.496
1974	119.631	1.534	28.560	22.474	47.086	12.453	7.524
1975	127.536	1.569	29.321	22.998	52.231	13.328	8.089
1976	131.164	1.273	27.783	23.665	56.777	13.483	8.183
1977	135.256	1.161	26.594	25.432	61.694	12.668	7.707
1978	146.351	1.147	26.630	29.710	70.655	11.261	6.948
1979	158.268	1.054	27.093	34.400	80.120	9.712	5.909
1980	175.531	0.939	27.600	40.305	90.542	10.341	5.804
1981	195.751	1.152	27.647	47.811	99.725	12.919	6.497
1982	219.221	1.396	28.751	56.211	108.736	16.350	7.777
1983	242.399	1.660	31.537	65.925	117.792	17.418	8.067

A.S.P. in million lbs. by subarea ASP = C + ΔB

YEAR	TOTAL	2A	2B	2C	3A	3B	4
1967	37.312	0.531	8.408	7.29[illegible]	17.648	6.060	-2.844
1968	37.957	0.241	8.411	6.722	17.648	7.353	-2.233
1969	38.639	-0.008	8.436	5.960	17.622	8.390	-1.532
1970	38.791	-0.121	8.318	5.387	17.330	8.753	-0.937
1971	37.029	-0.121	7.724	5.222	16.195	8.198	-0.400
1972	33.451	-0.057	6.730	5.325	14.699	6.573	0.145
1973	31.063	0.047	5.929	5.692	14.071	4.688	0.48[illegible]
1974	30.621	0.123	5.647	6.247	14.133	3.360	0.53[illegible]
1975	30.808	0.144	5.591	6.781	14.672	2.538	0.463
1976	31.434	0.132	5.504	7.265	15.994	1.977	0.397
1977	32.750	0.104	5.397	7.937	17.747	1.567	0.389
1978	35.191	0.083	5.313	8.950	19.494	1.397	0.583
1979	38.857	0.109	5.385	10.060	20.913	1.623	1.015
1980	43.437	0.222	5.860	11.109	21.902	2.552	1.422
1981	48.473	0.383	6.838	12.317	22.672	4.103	1.651
1982	52.891	0.494	7.933	13.647	23.292	5.543	1.753
1983	55.969	0.542	8.738	14.800	23.700	6.494	1.778

A.S.P. in million lbs. by subarea, partitioned with CPUE data

YEAR	TOTAL	2A	2B	2C	3A	3B	4
67	37.312	0.448	7.500	5.933	13.917	6.194	3.283
68	37.957	0.493	7.629	6.073	14.044	6.377	3.340
69	38.639	0.580	7.844	6.182	14.181	6.491	3.400
70	38.791	0.621	8.069	6.245	14.081	6.401	3.414
71	37.029	0.592	8.109	6.036	13.219	5.888	3.222
72	33.451	0.502	7.727	5.553	11.708	5.051	2.910
73	31.063	0.435	7.424	5.188	10.779	4.535	2.702
74	30.621	0.398	7.410	5.022	10.687	4.409	2.664
75	30.808	0.401	7.486	4.868	10.906	4.467	2.711
76	31.434	0.346	7.544	4.778	11.411	4.558	2.766
77	32.750	0.327	7.467	4.912	12.510	4.683	2.849
78	35.191	0.317	7.285	5.419	14.147	4.962	3.06[illegible]
79	38.857	0.272	7.033	6.606	15.970	5.557	3.381
80	43.437	0.217	6.993	8.296	17.549	6.646	3.779
81	48.473	0.194	7.271	9.985	18.759	8.047	4.217
82	52.891	0.212	7.563	11.424	19.728	9.309	4.654
83	55.969	0.224	7.612	12.425	20.653	10.074	4.925

Quinn T.J. II, Deriso R.B., Neal, P.R., 1984. Stock Assessment Document III: Section 1. Biomass and annual surplus production (ASP) estimates for regulatory areas [1983 stock assessment]. IPHC Rep., pp. 1–11.

Table 2. ADJUSTED CPUE

Biomass in million lbs. by subarea

YEAR	TOTAL	2A	2B	2C	3A	3B	4
1967	217.160	3.514	58.858	36.260	52.561	43.112	22.855
1968	200.618	3.629	56.105	34.626	50.000	36.919	19.339
1969	194.347	4.058	54.914	35.853	52.895	30.599	16.028
1970	174.499	3.720	48.364	32.139	51.194	25.488	13.594
1971	160.453	3.413	46.717	28.766	47.436	22.054	12.067
1972	156.320	3.055	47.048	27.326	45.968	20.888	12.035
1973	130.651	1.712	29.222	22.218	44.118	20.917	12.464
1974	129.492	1.526	28.406	22.579	42.138	21.720	13.123
1975	139.090	1.561	29.174	23.206	45.774	24.504	14.871
1976	143.802	1.270	27.706	24.022	48.957	26.042	15.805
1977	147.770	1.167	26.612	25.950	52.070	26.095	15.876
1978	157.118	1.164	26.772	30.420	58.553	24.866	15.343
1979	164.141	1.058	27.367	35.238	65.028	22.041	13.409
1980	178.121	0.870	28.018	41.168	71.234	23.480	13.351
1981	195.685	0.757	28.393	48.546	74.933	28.250	14.806
1982	217.724	0.832	29.730	56.751	77.902	35.006	17.503
1983	239.834	0.963	32.747	66.293	81.681	39.056	19.094

A.S.P. in million lbs. by subarea   asp = ASP = C + ΔB

YEAR	TOTAL	2A	2B	2C	3A	3B	4
1967	40.501	0.536	8.493	7.498	17.408	8.220	-1.678
1968	40.501	0.245	8.493	6.855	17.378	9.116	-1.409
1969	40.378	-0.006	8.502	6.019	17.173	9.903	-0.951
1970	39.513	-0.120	8.343	5.402	16.643	10.196	-0.226
1971	36.988	-0.121	7.703	5.229	15.549	9.928	0.565
1972	33.546	-0.058	6.707	5.345	14.066	8.725	1.098
1973	31.399	0.048	5.944	5.749	13.101	6.659	1.304
1974	30.966	0.127	5.676	6.353	12.883	4.819	1.322
1975	31.098	0.150	5.624	6.923	13.224	3.606	1.156
1976	31.193	0.140	5.582	7.430	14.210	2.681	0.879
1977	31.502	0.083	5.523	8.098	15.357	2.097	0.738
1978	32.906	-0.003	5.464	9.059	16.185	1.935	0.850
1979	36.065	-0.041	5.573	10.069	16.753	2.604	1.322
1980	40.933	0.015	6.090	11.013	17.138	4.636	2.101
1981	46.739	0.173	7.079	12.150	17.372	7.128	2.795
1982	51.676	0.329	8.178	13.443	17.579	8.875	3.134
1983	54.792	0.397	9.004	14.573	17.812	9.859	3.206

ASP - CPUE PARTITIONING [ASP = (% biomass) x ASP total]

67	40.501	0.486	8.141	6.440	15.107	6.723	3.564
68	40.501	0.527	8.141	6.480	14.985	6.804	3.564
69	40.378	0.606	8.197	6.460	14.819	6.784	3.553
70	39.513	0.632	8.219	6.362	14.343	6.520	3.477
71	36.988	0.592	8.100	6.029	13.205	5.881	3.218
72	33.546	0.503	7.749	5.569	11.741	5.065	2.919
73	31.399	0.440	7.504	5.244	10.895	4.584	2.732
74	30.966	0.403	7.494	5.078	10.807	4.459	2.694
75	31.098	0.404	7.557	4.913	11.009	4.509	2.737
76	31.193	0.343	7.486	4.741	11.323	4.523	2.745
77	31.502	0.315	7.182	4.725	12.034	4.505	2.741
78	32.906	0.296	6.812	5.068	13.228	4.640	2.863
79	36.065	0.252	6.528	6.131	14.823	5.157	3.138
80	40.933	0.205	6.590	7.818	16.537	6.263	3.561
81	46.739	0.187	7.011	9.628	18.088	7.759	4.066
82	51.676	0.207	7.390	11.162	19.275	9.095	4.547
83	54.792	0.219	7.452	12.164	20.218	9.863	4.8[illegible]

Quinn T.J. II, Deriso R.B., Neal, P.R., 1984. Stock Assessment Document III: Section 1. Biomass and annual surplus production (ASP) estimates for regulatory areas [1983 stock assessment]. IPHC Rep., pp. 1–11.

Table 3. NO 1983 CPUE

Biomass in million lbs. by subarea

YEAR	TOTAL	2A	2B	2C	3A	3B	4
1967	217.160	3.507	58.748	36.253	52.558	43.195	22.899
1968	200.342	3.621	55.981	34.600	49.888	36.915	19.337
1969	193.731	4.048	54.778	35.807	52.656	30.478	15.964
1970	173.556	3.710	48.224	32.082	50.811	25.258	13.471
1971	159.191	3.401	46.551	28.699	46.891	21.749	11.900
1972	154.654	3.041	46.835	27.246	45.246	20.484	11.802
1973	128.528	1.708	29.160	22.155	42.958	20.394	12.153
1974	127.000	1.520	28.298	22.497	40.749	21.155	12.781
1975	135.937	1.552	29.003	23.100	43.967	23.844	14.471
1976	139.886	1.258	27.455	23.885	46.635	25.299	15.354
1977	142.896	1.152	26.265	25.769	49.043	25.284	15.383
1978	151.040	1.144	26.301	30.169	54.609	24.005	14.812
1979	156.812	1.034	26.737	34.900	60.041	21.201	12.899
1980	169.073	0.844	27.181	40.727	65.024	22.502	12.795
1981	184.469	0.727	27.253	47.980	67.337	27.014	14.158
1982	203.825	0.787	28.147	56.021	68.726	33.429	16.715
1983	223.145	0.901	30.634	65.333	70.677	37.343	18.257

A.S.P. in million lbs. by subarea ASP = C + ΔB

YEAR	TOTAL	2A	2B	2C	3A	3B	4
1967	40.193	0.534	8.481	7.477	17.292	8.120	-1.732
1968	40.193	0.244	8.480	6.838	17.255	9.008	-1.463
1969	40.090	-0.007	8.488	6.005	17.029	9.791	-1.005
1970	39.263	-0.121	8.324	5.390	16.459	10.083	-0.284
1971	36.774	-0.123	7.676	5.217	15.293	9.822	0.503
1972	33.256	-0.060	6.661	5.331	13.696	8.633	1.034
1973	30.887	0.046	5.878	5.732	12.630	6.575	1.243
1974	30.228	0.125	5.609	6.330	12.375	4.737	1.267
1975	30.163	0.147	5.556	6.892	12.668	3.536	1.10[illegible]
1976	30.151	0.137	5.482	7.384	13.514	2.617	0.835
1977	30.408	0.079	5.385	8.033	14.474	2.016	0.695
1978	31.603	-0.007	5.303	8.975	15.116	1.841	0.803
1979	34.368	-0.046	5.368	9.964	15.485	2.464	1.263
1980	38.787	0.009	5.788	10.881	15.655	4.396	2.028
1981	44.169	0.161	6.647	11.975	15.681	6.858	2.726
1982	48.744	0.311	7.624	13.212	15.674	8.679	3.080
1983	51.589	0.375	8.359	14.292	15.680	9.750	3.159

ASP - CPUE PARTITIONING [ASP = (% biomass) x ASP total]

67	40.193	0.482	8.079	6.391	14.992	6.672	3.537
68	40.193	0.523	8.079	6.431	14.871	6.752	3.537
69	40.090	0.601	8.138	6.414	14.713	6.735	3.528
70	39.263	0.628	8.167	6.321	14.252	6.478	3.455
71	36.774	0.588	8.054	5.994	13.128	5.847	3.199
72	33.256	0.499	7.682	5.520	11.640	5.022	2.893
73	30.887	0.432	7.382	5.158	10.718	4.510	2.687
74	30.228	0.393	7.315	4.957	10.550	4.353	2.630
75	30.163	0.392	7.330	4.766	10.678	4.374	2.654
76	30.151	0.332	7.236	4.583	10.945	4.372	2.653
77	30.408	0.304	6.933	4.561	11.616	4.348	2.645
78	31.603	0.284	6.542	4.867	12.704	4.456	2.7[illegible]
79	34.368	0.241	6.221	5.843	14.125	4.915	2.990
80	38.787	0.194	6.245	7.408	15.670	5.934	3.374
81	44.169	0.177	6.625	9.099	17.093	7.332	3.843
82	48.744	0.195	6.970	10.529	18.182	8.579	4.289
83	51.589	0.206	7.016	11.453	19.036	9.286	4.540

Table 4. Range, midrange, standard error, and approximate 95% confidence interval for the 1983 estimate of annual surplus production by regulatory area.

Area	Range	Midrange	Standard Error	Confidence Interval	75% of ASP	90% of ASP
2A	.2 - .6	0.4	0.60	(-0.8,1.6)	0.3	0.4
2B	7 - 9	8.0	1.35	(5.3,10.7)	6.0	7.2
2C	11 - 15	13.0	2.85	(7.3,18.7)	9.8	11.7
2[a]	18 - 24	21.4	3.20	(15.0,27.8)	16.1	19.3
3A	16 - 24	20.0	2.45	(15.1,24.9)	15.0	18.0
3B	6 - 10	8.0	2.15	(3.7,12.3)	6.0	7.2
3[a]	25 - 31	28.0	3.25	(21.5,34.5)	21.0	25.2
4	1.8 - 4.9	3.4	1.20	(1.0,5.8)	2.6	3.1
TOTAL[a]	51 - 56	52.8	4.75	(43.3,62.3)	39.7	47.6

[a]Except for the range, estimates are calculated from individual areas.

partitioned into 20.0 million pounds in Area 3A and 8 million pounds in Area 3B. The Area 4 surplus is 3.4 million pounds. This results in a total surplus production available to the commercial fishery of 52.8 million pounds. Incidental mortality in 1983 was about 12 million pounds. Because of evidence supporting density-dependence, the current adjustment to the commercial fishery is a factor of 1. Thus, our estimated total production, including adjusted incidental mortality, is 64.8 million pounds.

Preliminary estimates of the standard error of surplus production estimates were obtained for the method of CPUE partitioning. These error estimates included intermediate amounts of variability in estimates of relative habitat and CPUE. These error estimates were applied to 1983 estimates of surplus production and approximate 95% confidence limits were constructed (Table 4). These estimates show the uncertainty of estimation for regulatory areas. Also shown in Table 4 are values of 75% and 90% of 1983 surplus production, which will be used in another document to construct estimates of total allowable catch (TAC).

Other pertinent information about halibut population parameters is also of interest. The catch by regulatory area, shown in Table 5, was used to calculate ASP. In Table 6, the estimated abundance of fish in the population is shown for each regulatory area. All areas have had increases in the number of fish over the last five years. In Table 7, estimates of year-class strength parameters are shown for combined areas 2A + 2B, 3A, and 3B + 4. Age 8 fish is defined as the index of year-class strength, and population parameters presented are average weight, abundance, biomass, selectivity, and catch. The most recent

Table 5. Catch in million lbs. by subarea.

YEAR	TOTAL	2A	2B	2C	3A	3B	4
1967	55.222	0.199	10.352	9.168	19.657	13.436	2.410
1968	48.594	0.138	10.579	5.677	14.774	16.096	1.330
1969	58.275	0.230	13.162	8.985	20.081	14.495	1.322
1970	54.938	0.159	10.639	9.087	19.906	13.906	1.241
1971	46.654	0.318	10.002	6.453	17.761	11.252	0.868
1972	42.884	0.369	10.280	5.634	16.299	9.538	0.764
1973	31.740	0.225	6.974	5.730	13.498	4.980	0.333
1974	21.306	0.515	4.624	5.605	8.187	1.834	0.541
1975	27.616	0.460	7.127	6.243	10.601	2.655	0.530
1976	27.535	0.238	7.283	5.527	11.044	2.809	0.634
1977	21.868	0.207	5.427	3.186	8.641	3.323	1.084
1978	21.988	0.097	4.607	4.316	10.295	1.327	1.346
1979	22.527	0.046	4.857	4.530	11.335	0.390	1.369
1980	21.866	0.022	5.650	3.238	11.966	0.277	0.713
1981	25.732	0.202	5.654	4.010	14.225	0.456	1.185
1982	28.718	0.211	5.236	3.485	13.507	4.837	1.442
1983	37.420	0.207	5.400	6.200	14.000	9.482	2.131

Table 6. Abundance (millions of fish) by subarea from migratory catch-age analysis.

Year	2A	2B	2C	3A	3B	4	Total
1967	0.123	2.059	2.156	4.301	2.046	1.085	11.770
1968	0.116	1.792	1.903	3.863	1.525	0.799	9.997
1969	0.132	1.780	1.983	4.286	1.399	0.733	10.312
1970	0.119	1.543	1.680	3.831	1.074	0.573	8.821
1971	0.115	1.569	1.496	3.309	0.905	0.495	7.889
1972	0.103	1.585	1.397	3.021	0.847	0.488	7.441
1973	0.085	1.443	1.400	2.724	0.725	0.432	6.809
1974	0.073	1.355	1.419	2.778	0.627	0.379	6.632
1975	0.069	1.293	1.501	3.230	0.632	0.383	7.108
1976	0.055	1.206	1.573	3.823	0.617	0.374	7.649
1977	0.051	1.166	1.689	4.174	0.579	0.352	8.011
1978	0.052	1.199	2.083	5.512	0.501	0.309	9.657
1979	0.049	1.[illegible]	2.375	6.009	0.447	0.272	10.430
1980	0.043	1.[illegible]	3.250	6.405	0.398	0.226	11.695
1981	0.040	1.510	3.896	6.578	0.626	0.328	12.978
1982	0.046	1.635	4.043	6.292	0.722	0.361	13.099
1983	0.053	1.291	4.153	6.441	0.726	0.355	13.518

Table 7. Year-class strength (Age 8) Parameters by area from migratory catch-age analysis (analysis with adjusted CPUE data).

AREA 2A+2B

AGE	YEAR	WEIGHT	ABUNDANCE	BIOMASS	SELECTIVITY	CATCH
8	1967	16.120	363009	5851704.916	1.077026	59864.
8	1968	16.660	347007	5781130.990	1.077026	48302
8	1969	16.840	574555	9675509.007	1.077026	108334.
8	1970	16.950	379371	6430346.595	1.077026	36877.
8	1971	17.110	552226	9448588.672	1.077026	110760.
8	1972	17.340	484090	8394120.084	1.077026	90102
8	1973	17.920	405861	7273088.572	0.382866	42121
8	1974	18.670	323198	6034103.828	0.382866	18799
8	1975	19.150	285167	5460938.533	0.382866	20478
8	1976	19.300	306493	5915313.821	0.382866	33839
8	1977	19.320	311551	6019156.572	0.382866	25207
8	1978	19.030	343467	6536170.719	0.382866	19917.
8	1979	18.050	369243	6664837.617	0.382866	22339
8	1980	16.870	399295	6736113.519	0.382866	24493
8	1981	16.280	486333	7917508.698	0.382866	31406
8	1982	16.150	502255	8111415.834	0.382866	28999.
8	1983	16.180	533110	8625718.185	0.382866	30332

AREA 2C

AGE	YEAR	WEIGHT	ABUNDANCE	BIOMASS	SELECTIVITY	CATCH
8	1967	15.330	422572	6478036.412	0.419831	50624
8	1968	16.240	361822	5875992.464	0.419831	25640
8	1969	16.480	550221	9067637.888	0.419831	59959
8	1970	16.250	308753	5017230.578	0.419831	32005.
8	1971	15.980	366130	5850753.009	0.419831	32905
8	1972	15.900	363941	5786657.046	0.419831	29768
8	1973	16.330	369514	6039061.024	0.132843	12737.
8	1974	17.260	366114	6319135.041	0.132843	11506.
8	1975	18.090	431451	7804951.988	0.132843	16746
8	1976	18.610	455311	8473345.446	0.132843	14204
8	1977	18.950	499928	9473635.516	0.132843	7130.
8	1978	19.000	752949	14306037.000	0.132843	12409
8	1979	18.140	721335	13085022.103	0.132843	9605
8	1980	16.530	1374528	22720942.365	0.132843	17347
8	1981	15.660	1316365	20614275.143	0.132843	15418
8	1982	15.610	951108	14846797.769	0.132843	6574
8	1983	15.610	927445	14477417.070	0.132843	10642

AREA 3A

AGE	YEAR	WEIGHT	ABUNDANCE	BIOMASS	SELECTIVITY	CATCH
8	1967	19.070	831575	15855134.427	0.202552	61051
8	1968	19.570	754175	147[illegible]9213.363	0.202552	45522
8	1969	19.930	1289540	25701329.541	0.202552	101757
8	1970	20.110	741611	14792006.464	0.202552	66697
8	1971	20.780	601102	12490904.322	0.202552	47035
8	1972	21.640	525[illegible]	11373516.723	0.202552	42097
8	1973	22.820	44[illegible]	10107451.706	0.124436	21301
8	1974	23.530	584193	13749825.396	0.124436	13746
8	1975	24.010	781912	18773839.344	0.124436	23030
8	1976	24.030	955[illegible]	22954993.298	0.124436	28674
8	1977	22.930	860916	19740849.279	0.124436	15415
8	1978	20.710	1550773	37116501.512	0.124436	32368
8	1979	19.230	1157802	22264536.211	0.124436	26790
8	1980	18.970	1136555	21560451.691	0.124436	27239
8	1981	19.290	1042349	20106914.074	0.124436	27524
8	1982	19.870	794781	15792292.100	0.124436	14534
8	1983	20.240	1191326	24112438.794	0.124436	23916

AREA 3B+4

AGE	YEAR	WEIGHT	ABUNDANCE	BIOMASS	SELECTIVITY	CATCH
8	1967	17.690	596117	10545309.253	0.270374	39474
8	1968	18.820	511408	9624702.620	0.270374	50157
8	1969	18.640	958319	17863666.566	0.270374	75220
8	1970	18.810	534732	10058313.301	0.270374	52041
8	1971	18.970	637095	12085700.051	0.270374	46620
8	1972	20.290	802991	16292677.258	0.270374	44391
8	1973	21.750	653004	14202836.568	0.210069	15858
8	1974	22.640	504809	11428874.354	0.210069	5965
8	1975	23.2[illegible]	712897	16596248.399	0.210069	9812
8	1976	23.760	665297	15833600.793	0.210069	10822
8	1977	22.260	580322	12917970.2[illegible]	0.210069	11783
8	1978	20.460	440823	9020055.452	0.210069	6403
8	1979	19.680	324945	6374930.649	0.210069	3624
8	1980	19.[illegible]	196407	3875498.7[illegible]	0.210069	937
8	1981	1[illegible]	1[illegible]	22414011.[illegible]	0.210069	7181
8	1982	20.[illegible]	[illegible]	17138484.274	0.210069	13208
8	1983	20.[illegible]	[illegible]	17[illegible]556.737	0.210069	25664

Quinn T.J. II, Deriso R.B., Neal, P.R., 1984. Stock Assessment Document III: Section 1. Biomass and annual surplus production (ASP) estimates for regulatory areas [1983 stock assessment]. IPHC Rep., pp. 1–11.

estimates of year-class strength are generally higher than those in the early 1970's, but recent estimates are based on limited observations in the fishery. If Area 2A + 2B needs to be partitioned, 5% and 95% can be allocated to 2A and 2B, respectively, based on 17-year average relative biomass. Similarly, Area 3B + 4 may be partitioned with 64% to Area 3B and 36% to Area 4.

STOCK ASSESSMENT DOCUMENT III

Section 2: EVIDENCE OF DENSITY-DEPENDENCE IN SURVIVAL AND GROWTH OF PACIFIC HALIBUT*

by

Richard B. Deriso

ABSTRACT

Previous management goals at IPHC to rebuild stock sizes are examined in light of new evidence presented on density-dependence in the production of halibut. Results are interpreted to suggest that there is little advantage to any additional rebuilding of halibut stocks. Higher levels of production of recruits appear to come from low mature stock sizes, as indicated by both the age-structured and the CPUE methods.

INTRODUCTION

Management goals to increase stock size could actually decrease the productivity of the resource if density-dependent mechanisms act to decrease recruitment or growth when stock sizes increase. In this paper I present some of the data available on density-dependence in the population dynamics of halibut and examine what consequences this has on current catch quotas.

RESULTS AND DISCUSSION OF ESTIMATES FROM CATCH-AT-AGE ANALYSIS

Commercial catch, annual surplus production, and incidental catch (largely by-catch from trawlers) are shown in Figure 1 for the years 1929 through 1982. Historical changes in stock biomass (Figure 2) can

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*Based on a 1983 Sea Grant Lecture Series manuscript (in press).

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STOCK ASSESSMENT DOCUMENT III:

BIOMASS AND ANNUAL SURPLUS PRODUCTION 1982

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STOCK ASSESSMENT DOCUMENT III:
BIOMASS AND ANNUAL SURPLUS PRODUCTION 1982

by

Terrance J. Quinn II and Richard B. Deriso

SYNOPSIS

Biomass of the total halibut population was estimated by two different methods, one using catch-age data and the other using catch-per-unit-effort (CPUE) data. Analysis of catch-age data is a combination of cohort analysis for historical estimates of population abundance and an updating procedure for recent years. Analysis of CPUE data involves the use of a population model to relate CPUE as an index of biomass to survival, growth, catchability, and recruitment.

Both methods show the same trends in biomass estimates: an increase in the population from 1930 to 1960, a decrease in the population until 1975, and an increase in the population since 1975 (Figure 1). The current population size is similar to those of the early 1940's, which was also a time of population rebuilding, but below the peak population size reached in 1960. Biomass estimates from analysis of CPUE data are uniformly higher than those from analysis of catch-age data. The reasons for this, though not completely understood, involve the definition of the population. For CPUE analysis, the population is made up of all fish between ages 6 and 20. For catch-age analysis, the population is the exploitable component of ages 8 to 20. Nevertheless, yearly changes in biomass used to

calculate surplus production are similar for both methods.

These biomass estimates, along with the amount of commercial setline catch, are used to estimate annual surplus production (ASP), which is the excess over what is required to replenish the population each year. If other conditions in the population and the fishery remain constant, the population increases when catch is held below ASP, and vice versa.

Both methods produce the same long-term estimates of ASP available to the commercial setline fishery (Figure 2). Catch was below ASP from 1930-1960 when the population was rebuilding. Catch greatly exceeded ASP during the population decline in the 1960's. As a result, ASP decreased from 65 million pounds in 1960 to 30 million pounds in 1973. Since 1973, catch has been below ASP and the population has increased. Current ASP is about 40 million pounds. Both methods show short-term oscillations in surplus production. It is not known if these are due to limitations in the data and method, or a phenomenon with some biological explanation.

The decline in setline surplus production can be explained in large part by the removal of millions of pounds of small fish annually as incidental catch in trawl and pot fisheries since the late 1950's. Although information on incidental catch is limited except for recent data from National Marine Fisheries Service observer trips, it is possible to estimate the effect of incidental catch on the surplus available to the setline fishery. With the use of the model used in the analysis of CPUE data, each pound of incidental catch loss contributes an estimated loss of 1.58 pounds to the setline fishery. The total ASP made up of the setline ASP plus this adjusted loss, is reflective of the productivity of the halibut resource. This total ASP is indicative of what would be available to the setline fishery if no incidental catch was taken. Total ASP has ranged between 60 and 80 million pounds since 1929 (Figure 3). The total catch exceeded total ASP in the 1960's when incidental catches became prominent Total catch has been held below ASP since 1973 because of restrictions on the commercial setline fishery. The current total surplus production of 62 million pounds is made up of 40 million pounds available to the setline fishery and 22 million pounds of adjusted losses due to incidental catch. Although these estimates of incidental catch are subject to revision, they show the major impact of incidental catch in reducing setline surplus production.

In order to set catch limits by IPHC regulatory areas, estimates of biomass and surplus production for the total population are partitioned into regulatory areas using a combination of CPUE data and the amount of halibut habitat, which is the bottom area occupied by the halibut population. Estimated habitat expressed as a percentage is 1% for Area 2A, 24% for Area 2B, 20% for Area 2C, 35% for Area 3A, 14% for Area 3B, and 6% for Area 4 (Figure 4a). Relative biomass is estimated annually using CPUE data to adjust the habitat values up or down. Data are meager in Areas 2A and 4 for the breakdown and should be viewed with caution. Relative biomass in 1970 was similar to habitat for each subarea (Figure 4b). Since then, there has been a gradual shift in the population away from Area 2B, with increasing pecentages in Area 2C, 3A, and 3B (Figure 4c). Reasons for the Area 2 shift will be discussed in another document.

These annual percentages of biomass are multiplied by total biomass and surplus production to get biomass and surplus production by regulatory area. These results are more reliable by Areas 2, 3, and 4 rather than their finer subdivisions, which stretch the accuracy of the data. Since 1974, when biomass was at its lowest point in at least 35 years, biomass has increased 26% in Area 2, 91% in Area 3, and between 0 and 57% in Area 4. The best estimates of surplus production are 13 million pounds in Area 2, 24 million pounds in Area 3 and 2 to 3 million pounds in Area 4 (Figure 5). The IPHC staff has recommended that catch limits be near 75% of surplus production to provide for population rebuilding, as in previous years. Recommended catch limits are 9 million pounds in Area 2, 19 million pounds in Area 3, and 2.2 million pounds in Area 4, with 10 million pounds set aside for stock rebuilding (Figure 5) The catch limit in Area 2 is the same as last year because Areas 2A and 2B have shown no improvement, and is slightly below 75% of surplus production. The catch limit in Area 3 is slightly larger than 75% because the population appears to be growing rapidly. The catch limit in Area 4 is designed to spread effort in the Bering Sea to provide better information on relative abundance.

ESTIMATION OF BIOMASS AND SURPLUS PRODUCTION

Estimation of biomass and surplus production is a two-part operation. First, estimates for the entire North American Pacific halibut population are obtained. Two independent methods are used analysis of catch-age data and analysis of CPUE data. Secondly, the total population estimates are partitioned into regulatory areas using estimates of relative halibut habitat and relative density.

Total Population Density

Analysis of Catch-age Data

This method is a combination of cohort analysis for historical estimates of population abundance (Hoag and MacNaughton 1978) and an application of non-linear least squares to catch-age data with the use of catch-effort data as a mild stabilizing influence. A more detailed description of this method and its assumptions will be published in the near future (Proceedings of the INPFC Special Scientific Sessions, 1981).

Substantial research efforts in 1982 were dedicated to the updating procedure, resulting in increased confidence in the most recent estimates. This new method is based on regression of a two-part sum of squares criteria: the first part contains observed and predicted catch-at-age; the second part uses observed fishing effort and predicted fishing mortality. The relative importance of the second component of this sum of squares to the first part is controlled by a parameter L. As seen in Figure 6, similar predictions are obtained for L values away from the extreme assumptions of either no relation between observed fishing effort and fishing mortality (L=0), or that the two are exactly related (L=100) Results presented in this section use L=0.5 in the estimation procedure. Further refinements under investigation include the incorporation of a spawner-recruit relationship and a method of determining variance estimates for surplus production estimates, details of which will be submitted for publication in 1983.

Updated cohort analysis produces estimates of population numbers by age from 1935 to the most recent year. Exploitable biomass of fish is estimated by multiplying population number, average weight by age, and gear selectivity in order to adjust for fish not yet recruited to the fishery. Estimates of gear selectivity, average weight, and biomass are smoothed over time using a procedure of Velleman (1981) to prevent extraneous fluctuations from affecting the analysis. Catch numbers and average weight at age for the years 1978-1982 were adjusted to correct for a preliminary indication that average weight of sampled fish is underestimated by 10% (McGregor and Quinn, in prep.).

Annual surplus production (ASP) is estimated by the sum of catch and change in exploitable biomass. The most recent year's ASP is projected from the previous year's by the change in biomass. The estimates of ASP are then smoothed, which tends to reduce surplus estimates when the population is increasing and increase surplus estimates when the population is declining, thus reducing wild fluctuations in catch. If factors affecting the population and the fishery are constant, then biomass increases when catch is below ASP, and vice versa.

Two types of surplus production are of interest. First, the ASP available to the commercial setline fishery is calculated. Secondly, the total ASP adjusted for incidental halibut loss by other fisheries is calculated. The incidental catch is primarily small fish not yet recruited to the fishery. Each pound of halibut killed incidentally contributes an estimated loss of 1.58 pounds to the commercial fishery. The total ASP, including this adjusted loss, is reflective of the productivity of the halibut resource.

Estimates of exploitable biomass, setline catch and ASP, and total catch and ASP adjusted for incidental catch are shown in Table 1. Biomass of the population has increased at a rate of 5 to 10% each year for the last five years because catches from the setline fishery and total removals including incidental catch have been below surplus production. The current setline surplus production is estimated at 40 million pounds, up from 36 million pounds last year. The total surplus production is estimated at 62 million pounds, with 22 million pounds lost to the setline fishery due to incidental catch.

Analysis of CPUE Data

This method is an application of a delay-difference population model to setline CPUE data from Areas 2 and 3, details of which are summarized in Deriso (1981) and compared to catch-age analysis in Quinn, Deriso, Hoag, and Myhre (Proceedings of INPFC Special Scientific Sessions, 1981). The model incorporates survival, growth, catchability, and a time-lag for recruitment and assumes explicitly that catchability is a random variable. The model that fit the CPUE data best has average catchability parameters for three time periods: 1929-1972, 1973-1979, and 1980-1982. Application of the model produces estimates of yearly exploitable biomass and the setline yield under conditions of equilibrium exploitation. The biomass estimates are used to produce estimates of annual surplus production using the method outlined in the analysis of catch-age data. Biomass estimates are adjusted upward by 8.8% to include the Area 4 population.

Estimates of exploitable biomass, setline catch, equilibrium yield, and ASP, and total catch and ASP are shown in Table 2. The results indicate a larger total biomass and lower exploitation rate compared to catch-age analysis. However, the estimated change in biomass is similar for both methods, resulting in similar estimates of ASP. Biomass of the population has increased at a rate of 3 to 5% each year for the last five years, because total removals have been below surplus production. The current setline surplus production is estimated at 41 million pounds, up from 36 million pounds last year. The total surplus production is estimated at 63 million pounds, with 22 million pounds lost to the setline fishery due to incidental catches. The current estimate of equilibrium yield from the setline fishery is 48 million pounds. Equilibrium yield is higher than ASP, because current survival of recruits is high. Furthermore, surplus production tends to lag behind equilibrium yield when the population is increasing, and vice versa.

Estimates by Regulatory Area

The biomass and ASP estimates for the total halibut population are partitioned into regulatory areas with information about the relative habitat and density of halibut among the areas The habitat information comes from a procedure that incorporates catch-age data, migration estimates and CPUE data, described in detail in last year's stock assessment documents. Although the habitat estimates are variable over time, the variability may be induced by the procedure rather than showing a true phenomenon. The average of the 1935-1970 estimates is used for all years as an index of relative halibut habitat: 1% for Area 2A, 24% for Area 2B, 20% for Area 2C, 35% for Area 3A, 14% for Area 3B, and 6% for Area 4. These values are similar to the average relative catch over the last 25 years (1% for Area 2A, 22% for Area 2B, 17% for Area 2C, 37% for Area 3A, 19% for Area 3B, 5% for Area 4), lending credence to their use.

Relative habitat estimates are multiplied by yearly CPUE estimates, assumed indicative of halibut density, and expressed as percentages to produce estimates of yearly relative biomass. The estimates are smoothed over time by Velleman's procedure, because regulatory area CPUE is quite variable on a yearly basis. Area 4 CPUE data is only available since 1954 consistently, because there was little fishing before then. Average relative biomass in Area 4 between 1954 and 1970 is estimated at 8.8% and is used for all years to overcome the data limitations.

The basis of this method of partitioning is that relative differences in CPUE between areas are more accurate than yearly differences in CPUE within an area. Thus, the method is not sensitive to yearly changes in catchability of fish but is sensitive to changes in catchability between areas. The smoothing of the data is designed to reduce the sensitivity of changes between areas.

Biomass estimates by area are obtained by multiplying yearly estimates of total population biomass and relative biomass by area. Annual surplus production estimates are obtained by multiplying yearly estimates of ASP of the total population and relative biomass by area, assuming that the population is fluid enough that the same proportion of surplus production can be taken from all areas without changing biomass by area. This estimation of surplus production differs from the procedure of adding catch to change in biomass. Although the latter approach is the correct definition of surplus production, its estimates are more variable than the former and even negative sometimes. These problems are due to poor information in some regulatory areas in certain periods when either no fishing occurs, or when catchability appears to change. Thus, estimating surplus production as a proportion of biomass is a more stable approach.

Biomass estimates for Areas 2A, 2B, 2C, 3A, 3B, and 4 are given using total population estimates from catch-age analysis in Table 3 and from catch-effort analysis in Table 4. Changes is biomass are similar for both methods, because the same partitioning procedure is used. Recent estimates of biomass in Areas 2A and 2B have decreased from earlier years. Although CPUE in those areas has not changed, the CPUE in other areas has increased greatly, causing a shift in relative biomass. Recent estimates in Areas 2C, 3A, and 3B have increased because of increasing total population biomass and high CPUE's. Recent estimates in Area 4 have also increased, because biomass in Area 4 is estimated as a constant percentage of currently increasing total biomass. These results are summarized by principal Areas 2, 3, and 4 in Table 5 for catch-age analysis and Table 6 for catch-effort analysis. Since 1974, estimated biomass has increased 30% in Area 2, 90% in Area 3, and 60% in Area 4. The results by principal area are more likely to be accurate than estimates by subarea, because smaller areas are more likely to be affected by changes in catchability.

Corresponding annual surplus production estimates are shown in Table 7 (catch-age by subarea), Table 8 (catch-effort by subarea), Table 9 (catch-age by principal area), and Table 10 (catch-effort by principal area). Recent estimates from catch-age and catch-effort analysis are nearly identical, both being partitioned by the same method. Recent estimates of surplus production by subarea are 0.2 million pounds (Area 2A), 4.0 million pounds (Area 2B), 9.0 million pounds (Area 2C), 15.5 million pounds (Area 3A), 8.0 million pounds (Area 3B), and 3.5 million pounds (Area 4). Grouped by areas, the estimates are 13.2 million pounds (Area 2), 23.5 million pounds (Area 3), and 3.5 million pounds (Area 4), for a total of 40.2 million pounds. If 25% of the surplus is used for population rebuilding as in the past few years, then the total allowable catch (TAC) would be 10 million pounds in Area 2, 17.5 million pounds in Area 3, and 2.5 million pounds in Area 4.

To explore the sensitivity of this method of partitioning biomass, an alternate method of projecting current biomass and surplus production is examined. Generally, CPUE statistics between areas are highly correlated, but recently differences in CPUE have been quite large between areas. For example, CPUE in Areas 2A and 2B have changed little in the past five years, while CPUE in Area 2C has doubled. Also, CPUE in Area 3B has increased dramatically in the last two years.

The alternate method projects 1982 biomass from 1974 biomass by area (Table 3) using the ratio of smoothed CPUE data in 1982 to that in 1974 (Table 11) For example, 1974 biomass in Area 2C was 25.5 million pounds, and the ratio of smoothed CPUE in 1982 to CPUE in 1974 is 3.0, resulting in a projected biomass of 76.5 million pounds. The resulting biomass projections (Table 11) sum to a total of 334 million pounds, 32% higher than the estimated 254 million pounds from catch-age analysis. Thus, changes in CPUE have been greater than changes in biomass, suggesting increased catchability in recent years. The projections show declines in biomass in Areas 2A, 2B, and 4, and substantial increases in other areas. Correcting these projections to the 1982 estimated total biomass of 254 million pounds (Table 11) gives remarkably similar results to the previous partitioning procedure, with one exception: Area 4 biomass is 50% less than previously, because the previous method used 8.8% for Area 4 biomass for all years. The ASP projections, which are based on a rate of 15.8% of the corrected biomass projections, are 0.1 million pounds in Area 2A, 4.0 million pounds in Area 2B, 9.0 million pounds in Area 2C, 16.5 million pounds in Area 3A, 9.0 million pounds in Area 3B, and 1.5 million pounds in Area 4. By principal area, the estimates are 13.1 million pounds in Area 2, 25.5 million pounds in Area 3, and 1.5 million pounds in Area 4, for a total of 40.1 million pounds. These results suggest that the partitioning procedure is not sensitive to relative changes in catchability between areas, as long as the biomass and production estimates for the entire population are obtained independently. Specifically, the results suggest that the Area 4 estimate is not known with confidence, and part of its large surplus may actually belong in Area 3. The recent estimates of production in other areas are considered stable, insofar as CPUE data are used for partitioning.

In summary, the best estimates of surplus production are about 13 million pounds in Area 2, 24 million pounds in Area 3, and 3 million pounds in Area 4. The Area 4 estimate should be used with caution because of data limitations. The IPHC staff recommends a catch limit of 9 million pounds for Area 2, slightly below 75% of surplus production, because the populations in Areas 2A and 2B have not shown any increase. It recommends 19 million pounds in Area 3, slightly above 75% of surplus production, because of rapidly increasing population. A split of 14 million pounds for Area 3A and 5 million pounds for Area 3B is recommended based on last year's catch split. The split provides more catch for Area 3A and less for Area 3B than provided from estimates of surplus production, because the fishery in Area 3B has been prominent for only the last two years in recent times and more fishing information would be desirable to determine the split. The catch limit for Area 4 is recommended to be 2.2 million pounds, with some mechanisms for spreading the effort across the area to obtain more precise information on relative density within Area 4.

INTERNATIONAL PACIFIC HALIBUT COMMISSION

STOCK ASSESSMENT DATA AND ANALYSIS 1981

Seattle, Washington

January, 1982

INTERNATIONAL PACIFIC HALIBUT COMMISSION

January 1982

STOCK ASSESSMENT DATA AND ANALYSIS 1981

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Table 4 (cont'd)

	Area 2			Area 3		
Year	<10	≥10	Total	<10	≥10	Total
1970	16.6	13.8	30.4	14.2	19.9	34.1
1971	27.3	14.2	41.5	8.4	19.4	27.8
1972	19.5	13.4	32.9	8.5	15.6	24.1
		Size limit increased to 32 inches				
1973	8.4	12.8	21.2	4.0	11.7	15.7
1974	5.4	11.5	16.9	3.1	11.3	14.4
1975	4.8	11.7	16.5	4.3	10.7	15.0
1976	5.6	9.6	15.2	4.4	9.8	14.2
1977	4.9	10.4	15.3	3.9	10.9	14.8
1978	6.9	10.7	17.6	5.6	12.9	18.5
1979	7.8	12.3	20.1	6.1	15.9	22.0
1980	9.9	16.4	26.3	7.2	26.1	33.3
1981	14.6	19.3	33.9	8.6	27.1	35.7

1981 STOCK ASSESSMENT Doc. No. 8*

ANALYSIS OF CATCH-AGE DATA

This document provides biomass and annual surplus production estimates from catch-age data for the entire North American Pacific halibut population. A summary of the method used for analyzing catch-age data is given in the recent paper presented at the INPFC Special Scientific Sessions (Quinn et al. 1981). Briefly, the method involves the use of non-linear least squares for catch-age data to obtain estimates of fishing mortality and gear selectivity for recent year-classes. These estimates are used with cohort analysis to obtain estimates of population numbers by age. Finally, population numbers are multiplied by average weight for ages 8 to 20 to obtain biomass. Also, the exploitable biomass is estimated by the multiplication of population numbers, gear selectivity, and average weight, in order to adjust for fish not yet recruited to the fishery.

A summary of year class indicators since 1973 from the method is shown in Table 1. Effort and fishing mortality have been cut in half over the period. The number of fish per skate of ages 8, 9, and 10 has doubled since 1973, but some of the increase may be an increase in catchability. Correspondingly, the estimated number of fish in the population of ages 8, 9, and 10 has increased. It will be interesting to see if in the next few years the pulses of young fish continue to show strength in the fishery or are just an aberration of catchability factors.

*Prepared by Terrance J. Quinn, II

Current biomass is estimated to be between 400 to 460 million pounds (Figure 1) which is a large increase due to the presence of a large number of 8- to 10-year-olds. The exploitable biomass does not show nearly so large an increase because thse ages are not fully recruited to the fishery. Current exploitable biomass is about 250 million pounds, which is about 60% of the maximum exploitable biomass observed in the early 1960's.

Annual surplus production (ASP), formerly called equilibrium yield (EY), is estimated by the smoothed sum of catch and change in exploitable biomass. If catch is below ASP, the biomass should increase, and vice versa. Details of this procedure are given in Quinn et al. (1981). Exploitable biomass, catch, ASP, and the ratios of ASP and catch to biomass are shown in Table 2 for 1935-1981. Catch was generally below ASP between 1935 and 1960, above ASP between 1960 and 1972, and below ASP after 1972. Current ASP is 14.6% of current biomass, or about 36 million pounds.

Part of the reason for the decline in halibut abundance is the level of incidental catch. It is estimated that each pound of incidental catch contribute a loss of 1.58 pounds to the commercial fishery. This loss is added to the commercial catch and ASP's are recalculated to show the amount of commercial catch that could be taken in the future if incidental catches are removed (Table 3). Annual surplus production including the effect of incidental catches has been between 60 and 80 million pounds and is currently near 60 million pounds. Of this value, about 25 million pounds is deleted by fisheries with incidental catches, leaving about 35 million pounds for the commercial fishery.

Table 1. Fishing effort, fishing mortality of older fish, and estimates of number of fish/skate and abundance for ages 8, 9, and 10.

YEAR-CLASS STRENGTH

			Age 8		Age 9		Age 10	
Year	Effort/10^4 Skates	Fishing mortality of older fish	Millions of fish	# per Skate	Millions of fish	# per Skate	Millions of fish	# per Skate
1973	49	.13	2.2	.19	1.8	.24	1.5	.26
1974	34	.10	2.2	.16	1.7	.21	1.4	.23
1975	44	.11	2.7	.16	1.8	.21	1.4	.22
1976	51	.10	3.2	.17	2.2	.21	1.4	.19
1977	36	.08	3.4	.16	2.5	.22	1.7	.25
1978	33	.07	4.5	.24	2.8	.25	2.0	.27
1979	32	.07	4.0	.21	3.6	.31	2.2	.30
1980	24	.07	5.4	.32	3.2	.36	2.9	.45
1981	22	.07	5.2	.38	4.3	.55	2.6	.48

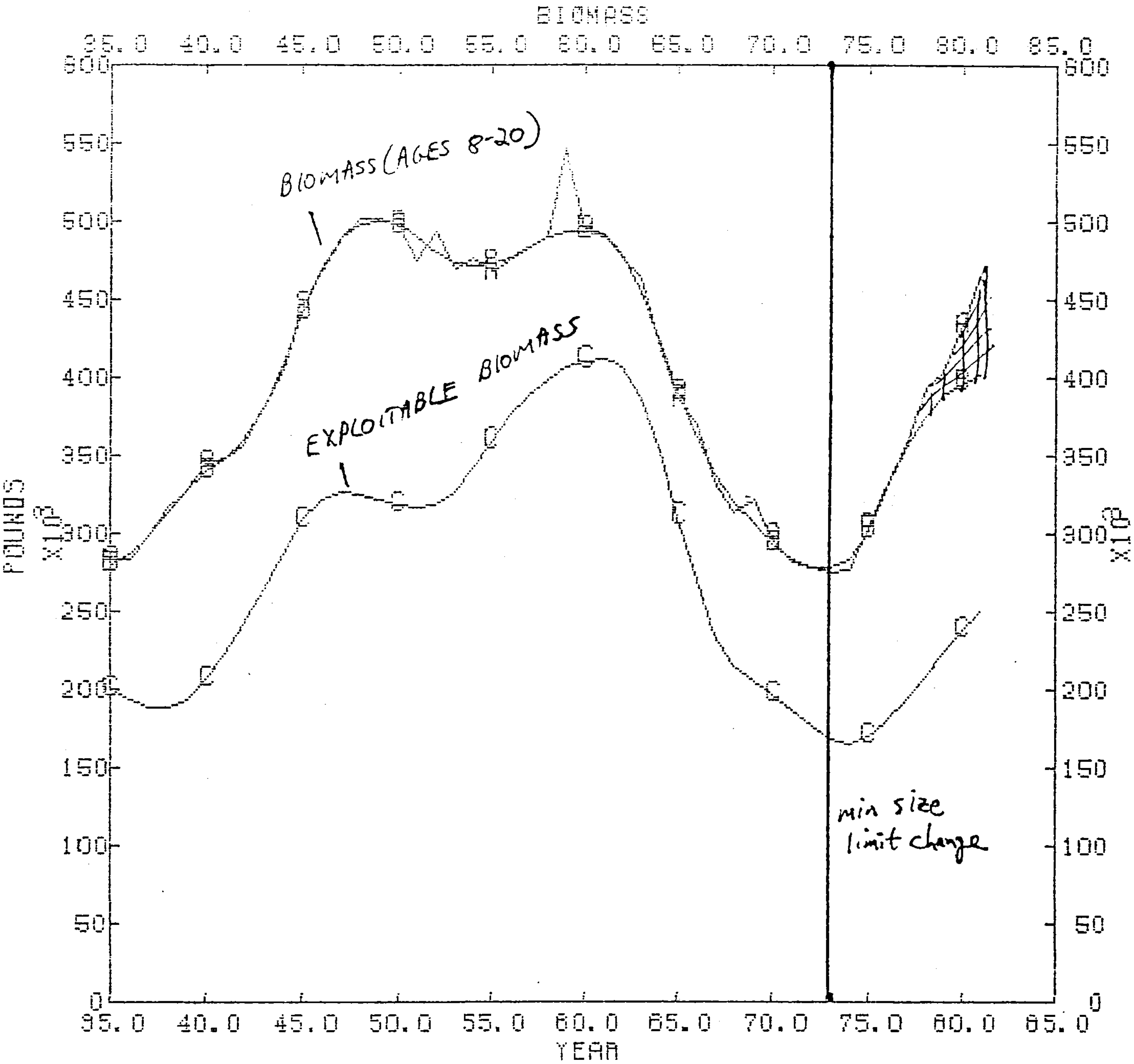

Figure 1. Estimates of biomass and exploitable biomass, 1935-1981.

Table 2. Estimates of exploitable biomass, catch, annual surplus production (ASP), and ratios of ASP and catch to exploitable biomass for the commercial fishery using catch-age analysis, 1935-1981.

	EXPLOITABLE BIOMASS (B)	CATCH	ASP	ASP / B	CATCH / B
35	199669	47343.	41567	0.2082	0.2371
36	193409.	48923.	44153.	0.2283	0.2530
37	189039.	49539.	48715.	0.2577	0.2621
38	188048.	49553.	55611.	0.2957	0.2635
39	193228.	50903.	63178.	0.3270	0.2634
40	206691.	53381.	68734.	0.3325	0.2583
41	224074.	52231.	71701.	0.3200	0.2331
42	242310.	50388.	73233.	0.3022	0.2079
43	262929.	53699.	73750.	0.2805	0.2042
44	286311.	53435.	72842.	0.2544	0.1866
45	308368.	53395.	68965.	0.2236	0.1732
46	321929.	60266.	62027.	0.1927	0.1872
47	325929.	55700.	55752.	0.1711	0.1709
48	325302.	55564.	53075.	0.1632	0.1708
49	322059.	55025.	52698.	0.1636	0.1709
50	318106.	57234.	54470.	0.1712	0.1799
51	316552.	56045.	60568.	0.1913	0.1770
52	318488.	62262.	68933.	0.2164	0.1955
53	326606.	59837.	74798.	0.2290	0.1832
54	341628.	70583.	76968.	0.2253	0.2066
55	359099.	57521.	77026.	0.2145	0.1602
56	375105.	66588.	76144.	0.2030	0.1775
57	388137.	60854.	75174.	0.1937	0.1568
58	398341.	64508.	74631.	0.1874	0.1619
59	406280.	71204.	73811.	0.1817	0.1753
60	410820.	71605.	70953.	0.1727	0.1743
61	411712.	69274.	64040.	0.1555	0.1683
62	406116.	74862.	51768.	0.1275	0.1843
63	385998.	71237.	37351.	0.0968	0.1846
64	351317.	59784.	28162.	0.0802	0.1702
65	310599.	63176.	25853.	0.0832	0.2034
66	269714.	62016.	27937.	0.1036	0.2299
67	235511.	55222.	33867.	0.1438	0.2345
68	215129.	48594.	39586.	0.1840	0.2259
69	205004.	58275.	41432.	0.2021	0.2843
70	196573.	54938.	40911.	0.2081	0.2795
71	186825.	46654.	38100.	0.2039	0.2497
72	176187.	42884.	34040.	0.1932	0.2434
73	168289.	31740.	32271.	0.1918	0.1886
74	165830.	21306.	33101.	0.1996	0.1285
75	169454.	27616.	35238.	0.2079	0.1630
76	180091.	27535.	37022.	0.2056	0.1529
77	194128.	21868.	37500.	0.1932	0.1126
78	208563.	21988.	37058.	0.1777	0.1054
79	224042.	22527.	35924.	0.1603	0.1005
80	238722.	21866.	34734.	0.1455	0.0916
81	249983.	24825.	0.	0.0000	0.0993

Table 3. Estimates of exploitable biomass, annual surplus production (ASP), and ratios of ASP and catch to exploitable biomass for the commercial fishery plus adjusted incidental catch using catch-age analysis, 1935-1981.

	B	CATCH + INC	ASP	ASP / BIO	CATCH / B
35	199669.	47343.	41567.	0.2082	0.2371
36	193409.	48923.	44153.	0.2283	0.2530
37	189039.	49539.	48715.	0.2577	0.2621
38	188048.	49553.	55611.	0.2957	0.2635
39	193228.	50903.	63178.	0.3270	0.2634
40	206691.	53381.	68734.	0.3325	0.2583
41	224074.	52231.	71701.	0.3200	0.2331
42	242310.	50388.	73233.	0.3022	0.2079
43	262929.	53699.	73750.	0.2805	0.2042
44	286311.	53435.	72842.	0.2544	0.1866
45	308368.	53395.	68965.	0.2236	0.1732
46	321929.	60266.	62027.	0.1927	0.1872
47	325929.	55700.	55752.	0.1711	0.1709
48	325302.	55564.	53075.	0.1632	0.1708
49	322059.	55025.	52698.	0.1636	0.1709
50	318106.	57234.	54427.	0.1711	0.1799
51	316552.	56045.	60391.	0.1908	0.1770
52	318488.	62262.	68716.	0.2158	0.1955
53	326606.	59837.	75091.	0.2299	0.1832
54	341628.	72321.	78074.	0.2285	0.2117
55	359099.	59259.	78261.	0.2179	0.1650
56	375105.	68484.	77331.	0.2062	0.1826
57	388137.	62750.	77005.	0.1984	0.1617
58	398341.	66562.	77420.	0.1944	0.1671
59	406280.	75154.	78065.	0.1921	0.1850
60	410820.	81243.	78279.	0.1905	0.1978
61	411712.	83494.	76411.	0.1856	0.2028
62	406116.	91294.	71113.	0.1751	0.2248
63	385998.	98097.	64480.	0.1670	0.2541
64	351317.	89962.	60175.	0.1713	0.2561
65	310599.	101096.	58966.	0.1898	0.3255
66	269714.	91562.	59748.	0.2215	0.3395
67	235511.	83346.	62500.	0.2654	0.3539
68	215129.	75454.	66900.	0.3110	0.3507
69	205004.	84977.	70573.	0.3443	0.4145
70	196573.	82746.	71816.	0.3653	0.4209
71	186825.	81256.	71204.	0.3811	0.4349
72	176187.	80646.	68151.	0.3868	0.4577
73	168289.	64446.	63052.	0.3747	0.3829
74	165830.	54644.	59561.	0.3592	0.3295
75	169454.	48156.	58729.	0.3466	0.2842
76	180091.	51077.	59169.	0.3286	0.2836
77	194128.	43514.	60095.	0.3096	0.2242
78	208563.	44424.	60662.	0.2909	0.2130
79	224042.	49071.	60852.	0.2716	0.2190
80	238722.	48410.	61105.	0.2560	0.2028
81	249983.	53265.	0.	0.0000	0.2131

1981 STOCK ASSESSMENT Doc. No. 9*

METHOD OF ESTIMATING SUBAREA BIOMASS

A new method of estimating biomass by regulatory subareas was developed this year. First, biomass of the entire population is estimated by two methods, delay-difference CPUE analysis (Doc. No. 6) and catch-age analysis (Doc. No. 8). Secondly, total biomass is partitioned into subareas with CPUE data using a method which is now derived.

RELATIVE HABITAT

The estimation of subarea biomass from CPUE data requires additional information about halibut habitat or bottom area. From Gulland (1969), the relationship between abundance N and catch-per-unit-effort CPUE is

$$E(CPUE_r) = q_r N_r / A_r, \qquad (1)$$

where q is fishing effectiveness for an area (related to catchability), A is population area, and subscript r is geographic unit (such as regulatory subarea). CPUE and N may be in either numbers or biomass of fish. From Quinn et al. (1981), the theoretically proper way to combine CPUE data over geographic units assuming fishing effectiveness is constant is to weight by bottom area, i.e.

$$CPUE = \Sigma\, a_r\, CPUE_r,$$

where $a_r = A_r/A$ is relative bottom area and the lack of a subscript implies summation over the subscript. Then, relative abundance is estimated by

$$P_r = a_r\, CPUE_r/CPUE = a_r\, CPUE_r / \Sigma\, a_r\, CPUE_r. \qquad (2)$$

*Prepared by Terrance J. Quinn, II

Bottom area estimates from planimeter tracings of the area between 0 and 150 fathoms have been made by IPHC and are shown in Table 1. These areas define the range where halibut could conceivably occur. Bottom areas in Areas 2A and 3B are much larger than would be expected from where the fishing takes place.

Recently a different measure called habitat was defined by Gilbert St-Pierre to be areas where halibut fishing has occurred historically and is shown in Table 1 for Area 2. Area 2 bottom areas were also recalculated. The differences are prominent, especially in Area 2A which has a lot of bottom area but little habitat. Habitat estimates are not yet available for Areas 3A, 3B, or 4.

An alternative indirect means of determining halibut habitat can be developed from abundance and CPUE data. The concept is to determine coefficients Q_r for each regulatory area r, such that

$$Q_r CPUE_r / \Sigma Q_r CPUE_r$$

is equal to estimated relative abundance N_r/N. The choice of Q_r to be

$$Q_r = \frac{N_r}{CPUE_r}$$

satisfies this concept. From (1), Q_r may be written approximately as

$$Q_r \cong \frac{N_r}{E(CPUE_r)} = \frac{A_r}{q_r} .$$

Thus Q_r is a measure of habitat that refers to bottom area corrected for fishing effectiveness. The estimated relative habitat expressed as a percentage of the total is then

$$Q_r^* = \frac{Q_r}{Q} = \frac{N_r/CPUE_r}{\Sigma N_r/CPUE_r} . \quad (3)$$

Relative habitat for halibut regulatory areas is estimated as follows. Abundance N_r of 8- to 20-year-olds from open-population cohort analysis (Deriso and Quinn 1981), catch C_r in numbers of 8- to 20-year-olds, and effort E_r were compiled from regulatory subarea. CPUE is then calculated as C_r/E_r. The age range 8 to 20 years was used to remove chicken halibut, which are no longer a component of the fishery. For each year and regulatory subarea, Q_r^* was estimated from equation (3). A plot of Q_r^* in Figure 1 for each regulatory subarea illustrates the changes over time between subareas. The mean and median habitat percentages over the years 1935-1970 in each subarea (Table 1) were calculated adjusting for the Bering Sea, which only had catches since 1952. The means and medians are close; however, the median is considered more reliable because of skewness in the distributions.

Complimentary analyses were made with catch and abundance in weight (Table 1). The major differences from values obtained from catch in numbers are that Area 2B is higher and Area 3B is lower. The median values from catch in weight will be used to partition total habitat biomass into regulatory subareas in subsequent sections.

RELATIVE BIOMASS

The estimated relative biomass of each subarea is

$$P_r = Q_r^* \, CPUE_r / \sum_r Q_r^* \, CPUE_r . \qquad (4)$$

The median values of Q_r^* from catch in weight were combined with CPUE data each year using equation (4) to estimate relative biomass. Because few landings have occurred in Area 4, the median relative biomass, .088, was used for all years, and other values were adjusted accordingly. The estimates are plotted in Figure 2 for each subarea and are highly variable. The estimates were smoothed with a robust non-linear procedure and are plotted in Figure 3.

Relative biomass in Area 2A is generally 1% or less of the total population. Relative biomasses in Areas 2B and 2C are fairly close and oscillate between 10 and 20% of the total population. Relative biomasses in Areas 3A and 3B are somewhat variable but are near 40% and 20%, respectively.

TOTAL BIOMASS

Delay-Difference CPUE Analysis

Biomass estimates for the total population for 1929-1981 from the delay-difference analysis (Document No. 6) were used to project relative subarea biomass to total subarea biomass. These estimates account for Area 2 and Area 3 combined biomass; these estimates were adjusted upward by the proportion of Area 4 biomass to obtain total population biomass. The resultant subarea estimates are given in Table 2 and show similar trends to overall biomass.

Catch-age Analysis

Biomass estimates for the total population for 1935-1981 from catch-age analysis (Document No. 8) were also used to project relative subarea biomass to total subarea biomass. The resultant subarea estimates are given in Table 3.

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INTERNATIONAL PACIFIC HALIBUT COMMISSION

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STOCK ASSESSMENT DATA AND ANALYSIS 1981

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STOCK ASSESSMENT Coc. No. 1*

SYNOPSIS

Assessment of halibut stocks in 1980 was based on a variety of techniques and relied on several sources of data. The analyses were based on CPUE, catch, and age composition data from the setline fishery, as well as results from IPHC surveys and estimates of incidental catches from other fisheries. A wide range of results were obtained regarding the condition of halibut stocks. Although some of the methods produces results which contradicted previous conclusions or appeared to be unrealistic, they are included in the documents to indicate the uncertainties associated with the assessment of stocks.

In general, the results indicate an increase in Area 3 stocks and little change in Area 2 stocks. Information on Bering Sea stocks is limited, but does not indicate any major improvement.

Abundance of Adult Halibut

In Area 2, abundance has been relatively stable since the early 1970's. The estimates of biomass averaged about 100 million pounds in 1980, well below the 200 million pound peak level of the 1950's. CPUE in the commercial fishery increased in 1980, but the increase apparently was the results of higher availability of fish, not greater abundancce. IPHC's adult halibut survey in Hecate Strait indicated a slight increase in abundance in 1980, but overall the trend has been relatively level since the surveys begain in 1976.

*Prepared by S. Hoag

In Area 3, abundance has increased since the early 1970's. The estimates of biomass in 1980 averaged about 250 million, and were generally higher than the biomass estimated for the early and mid-1970's (about 200 million pounds), but well below the peak level of the 1950's and 1960's (350-450 million pounds). CPUE of the commercial fishery increased sharply in 1979 and 1980. However, one analysis suggests that the increase was due to higher availability of fish rather than higher abundance. Conversely, availability may have been below normal during the mid-1970's, making stock abundance appear lower than it was. IPHC's adult halibut survey also indicated an increase in abundance: CPUE averaged 98 pounds per skate in 1980, the highest since the survey began in 1976 and well above the 57 pounds per skate in 1979.

Data from the commercial fishery continues to indicate a low abundance of adult halibut in the Bering Sea.

Juvenile Halibut

Cohort analysis suggests that the abundance of juvenile halibut has been relatively stable in recent years, but CPUE data from IPHC's juvenile surveys and from the commercial fishery indicate that juvenile abundance has increased. In the juvenile survey, the CPUE of juveniles was 50.1 fish per hour in Area 3, the highest in any year since the survey begain in 1963, and well above the low of 18.6 fish per hour in 1976. CPUE in the Bering Sea was 28.8 fish, the highest since 1966 and above the low of 3.1 fish in 1972. In the commercial fishery, the CPUE of fish less than 10 years of age has increased in both Areas 2 and 3 since the mid-1970's, although the increase may be partly due to availability rather than abundance.

Effect of the Setline Fishery

Setline catch and effort has declined steadily in Areas 2 and 3 since the early 1960's. Estimates of fishing mortality by setlines have also declined. In 1980, the setline catch was only 5% to 10% of the estimated biomass of adult halibut in Areas 2 and 3. This exploitation rate is below that which maximizes yield per recruit.

Effect of Incidental Catches

The most recent estimates indicate an incidental catch of about 7.6 million pounds in the Bering Sea and 11.0 million pounds in Areas 2 and 3 combined. The highest catch occurs in the foreign trawl fisheries, followed closely by the domestic crab fisheries. The total incidental catch for all areas is nearly as high as the directed catch by the setline fishery. Although the total incidental catch has declined moderately from the peak level of the 1960's and early 1970's, the proportion of the total removals attributed to incidental catches has increased.

Equilibrium Yield for the Setline Fishery

Estimates of equilibrium yield for the setline fishery are very sensitive to small changes in the biomass of adult fish and, therefore, are not considered precise. Most of the estimates suggest an equilibrium yield of about 10 million pounds in Area 2, 20 million pounds in Area 3 and between 1 and 2 million pounds in the Bering Sea. The estimates for Area 2 and the Bering Sea are similar to those presented last year, but estimates for Area 3 are substantially higher. The increase in Area 3 estimates is primarily due to improved methods of estimating equilibrium yield rather than to an actual increase in yield.

STOCK ASSESSMENT Doc. No. 2*

COHORT ANALYSIS

Cohort analysis is a catch-all term used to describe methods of determining population size from catch data in numbers of fish broken down by age. Two methods have been investigated for this year's stock assessment: (1) a non-linear least squares approach which jointly estimates population size, age-selectivity, and fishing mortality under the assumption that age-selectivity is constant over time, (2) cohort analysis, which in this document refers to a method which performs back-calculation of population size for each year-class from age 20 to age 3 using catches, estimates of terminal fishing mortality (F) from the non-linear approach and an assumed natural mortality (M) of 0.2. The assumptions, advantages, and disadvantages of both methods are elaborated upon later in the document.

The procedure used to obtain estimates of biomass and equilibrium yield from catch by age data is shown schematically in Figure 1. First, the non-linear method is used to obtain estimates of terminal fishing mortality for recent times and ages. Secondly, cohort analysis is used to estimate the numbers of fish and fishing mortality for all ages over the time period 1935-1980. Thirdly, estimates of abundance are multiplied by average weight of fish by age to obtain biomass estimates and finally equilibrium yield estimates.

In order to use this procedure, the total catch by age of all fisheries affecting halibut must be determined, because the value for natural mortality is defined only for causes other than fishing. This total catch is made up of the commercial setline catch and incidental catches from

*Prepared by T. Quinn

domestic and foreign trawl fisheries. In addition, preliminary estimates of incidental catch from the crab pot fishery are available this year. The main approach does not use these estimates for Area 3 because they include catches from the Aleutian region, which is no longer a part of Area 3, but they are included in an analysis later in the document to provide an upper bound for the equilibrium yield for Area 3.

Non-linear least-squares approach

The Method

This method uses the basic catch equation with fishing mortality and population size as functions of age and time. Natural mortality is assumed equal to 0.2 for all ages and years. Fishing mortality is partitioned into full-recruitment fishing mortality (ages 17-20) for each year and selectivity as a function of age. Because age-selectivity is assumed independent of time, only data between 1967 and 1980 are used, when the representative proportions of the setline and incidental catches are similar over time.

Advantages

The number of parameters is 59; the number of observations is 252 (18 ages x 14 years), so that the estimate of variability about the parameter estimates can be obtained. The method does not require the assumption of constant catchability over time. The method provides estimates of terminal fishing mortality that can be used for cohort analysis. The method estimates population size, age selectivity, and fishing mortality jointly rather than in piecemeal fashion.

Disadvantages

The assumption of constant age selectivity may not be satisfied when incidental catches go up and setline catches go down, and vice versa. The use of many parameters in a single model may lead to distorted estimates when correlations between the parameter estimates are high. Estimates for recent years are highly variable.

Area 2 Estimates

The estimates of full-recruitment fishing mortality, assumed to be at ages 17-20, are shown in Table 1 for all years. In addition, fishing mortality estimates for all ages in 1979 and 1980 are shown. The Area 2 catch estimates include crab pot catch, which is an insignificant portion of the total catch. The estimates for this year's analysis are similar to last year's. The estimate for 1980 is .117 and is higher than .099 in 1979. As effort was similar for the two years the increase is attributed to an increase in catchability. The relation between fishing mortality and effort is linear (Figure 2), with some tendency for catchability to be higher than expected in the period 1969-1974 and year 1980 and lower in the period 1975-1979.

The estimated number in the population is shown in Table 2, broken down by ages under 10, greater or equal to 10, and total. The table shows the decline in both younger and older fish from 1967 to 1977 and a modest increase since 1977.

Area 3 Estimates

The estimates of full-recruitment fishing mortality are shown in Table 3 for all years. In addition, fishing mortality estimates for all ages in 1979 and 1980 are shown. Two sets of estimates are presented. The first set assumes full-recruitment fishing mortality between ages 17 and 20, the second between ages 16 and 19 with a separate parameter for age 20. Although the second set fits the data better, the jump in mortality from age 19 to 20 is unrealistic. The estimates are similar to those obtained in the 1979 analysis, except they are lower for recent times. The discrepancy in last year's analysis is due to the extrapolation of fishing mortality using effort. This assumes constant catchability, which is apparently not a reasonable assumption. Also last year's analysis used data between 1963 and 1976, where there were more changes in the amount of trawl catch. This year's estimates do not involve the constant catchability assumption and are better correlated with effort (Figure 3). The figure shows some tendency for catchability to be higher than expected in 1967-1968, 1974, and 1980, and lower in 1973 and 1975-1977.

The estimated numbers in the population are shown in Table 8 for two cases of full recruitment in Table 3. The number of young fish is fairly stable with some declines in 1979 and 1980, which are subject to high variability however. The number of older fish showed a large decline between 1967 and 1975 but also a rapid increase since then.

Cohort Analysis

The Method

This method has an equal number of parameters and observations in the catch equation relating catch to fishing mortality and population size for each year-class, because fishing mortality and population size are both functions of age and time. Natural mortality is assumed to be 0.2 for all ages and times. This method requires values of fishing mortality in all years for age 20 and in 1980 for all ages. These values, called terminal F's, are obtained from Tables 1 and 3 using the results of the non-linear least-squares procedure.

Advantages

This method can be carried out easily and inexpensively over a long time period. The estimates make no assumption about catchability or selectivity. After a year-class has experienced a cumulative mortality of 1.0 to 2.0 the choice of terminal F becomes insignificant.

Disadvantages

Because the number of parameters and observations are equal, there is no measure of variability for parameter estimates. Individual estimates are unstable due to oscillations in catch. Estimates of the oldest ages for all years and all ages of the latest years (5 years, say) are highly sensitive to the choice of terminal F. The method is based on an approximation to the catch equation which assumes all fishing is done in the middle of the year.

Results

The estimated values of total fishing mortality are shown in Tables 1 and 3 for 1979, the first year where values are not identical to the terminal F values. The values are quite similar to the non-linear estimates.

Abundance of Adults (Ages 8 to 20)

The estimated numbers of adults for each of the years 1935 to 1980 are obtained by summing the individual estimates. The biomass of adults is obtained by multiplying the individual estimates by the average net weight by age and year obtained from ageing samples from the commercial setline fishery. The resultant estimates of number and biomass of adults for the years 1935 to 1980 are shown in Table 5 for Area 2 and Table 6 for Area 3. Only the first set of non-linear terminal F's is used. The decline in biomass in both areas in the period 1978 to 1980 is due to declines in the average weight by age. This decline may be due to sampling variability, a change in the sex composition, or differences in ageing.

Abundance of Juveniles

The estimated numbers of juveniles (ages 3 to 7) and the numbers at age 3 are shown in Table 7 for Area 2, Table 8 for Area 3, and Table 9 for the combined areas. The combined estimates are more reliable than the individual estimates because not all juveniles stay in the same regulatory area. Estimates since 1975 are unreliable because the year classes have been present in the trawl, crab, or setline fisheries only a short time. Recent estimates of juvenile abundance remain at low levels.

Equilibrium Yield

The equilibrium yield calculations for the setline fishery are shown in Table 10 for Area 2 and Table 11 for Area 3. The change in biomass ("bio-change") from one year to the next is added to the year's catch to estimate equilibrium yield. Three- and five-year moving averages of equilibrium yield are necessary to smooth out variability in average weight.

The five-year averages of equilibrium yield for Area 2 have ranged from 6.3 to 15.6 million pounds over the period 1967-1977. The drop in average weight in 1980 creates a negative equilibrium yield of -11.3. Assuming this is a spurious value, the three-year average equilibrium yield is 10.1 and the five-year average is 9.0.

The five-year averages of equilibrium yield for Area 3 have ranged from 13 to 30 million over the period 1967-1977. Recent equilibrium yields in Area 3 have been quite variable. The drop in average weight in 1980 creates a negative equilibrium yield of -22.4 million. Assuming this is a spurious value, the three-year average is 15.4 million and the five-year average is 24.1 million.

Setline, Trawl, and Full-Recruitment Fishing Mortality

The mean setline mortality and mean trawl mortality for ages 8-15 are shown in Table 12 for Area 2 and Table 13 for Area 3. For both areas there has been a substantial reduction in fishing mortality in recent times due to lower quotas and a larger minimum size limit. The fishing mortality due to the incidental crab pot catch in Area 2 is very small. Crab pot catch for Area 3 is discussed later.

Spawning Stock Size

Estimates of the number and biomass of spawners, number of resultant three-year-olds and production are shown in Table 14 for Area 2, Table 15 for Area 3, and Table 16 for combined areas. The combined estimates are obtained by pooling the estimates for each area. The spawning stock is defined as ages 12 to 20 for Area 2 and Area 3 before 1960, and ages 11 to 20 in Area 3 for 1960 and later. The change in Area 3 is due to a change in maturity. The production is defined as the number of three-year-olds divided by spawning stock biomass. If it is assumed that fecundity is proportional to fish weight, the sex composition in the population has not changed, and the defined spawning stock accounts for most of the eggs produced, then the production values are proportional to early life survival. The combined values are more reliable than the individual values because of juvenile migration. Production has decreased substantially since the late 1930's, but has been fairly stable in recent times. The decline represents a change in the mode of recruitment independent of both the fishery and population size. The decline in production is responsible for the continued low levels of juveniles.

Sensitivity Analysis

The use of cohort analysis in either of its two versions requires an accurate accounting of the total catch broken down by age for each year. All other losses such as death or emigration make up the category of natural mortality. This requires estimation of the total natural mortality for each year and age which is beyond the range of current estimation methods. Thus to use cohort analysis effectively, it is desirable to accumulate as much of the incidental catches as possible into the total catch matrix, so as to minimize the error associated with using a constant value for natural mortality. This year IPHC has attempted to estimate halibut incidental catch of the crab pot fishery. Although these estimates are preliminary, they serve to show the impact of underestimating the catch on fishing mortality, population size and equilibrium yield estimates.

The total catch in numbers of fish by each of the gear types is shown in Table 17 for Area 2 and Table 18 for Area 3. In Area 2, the combined foreign and domestic trawl catches have been at most 50% of the setline catch, while the crab pot catch is insignificant. In Area 3, the trawl catches alone have occasionally exceeded the setline catch and the crab pot numbers are as large as the trawl catches in recent times. The average age of catch by each gear type is shown in Table 19 for Area 2 and Table 20 for Area 3. For both areas the average age of the trawl catch is smaller than that of the crab pot catch, which is smaller than that of the setline. The inclusion of crab pot catch is likely to have a large impact on adult biomass, because of the relatively high average age. However, the estimated crab pot catch should be considered an upper bound, because a large part of the catch is taken in the Aleutians, which is no longer a part of Area 3.

This section repeats the analysis of the previous sections with the inclusion of crab pot catches. The analysis is done only on Area 3, because there is no significant crab pot fishery in Area 2. Both the non-linear and the cohort analysis approaches are used. This analysis is termed a sensitivity analysis, because parameters and data are altered to explore the effects on estimates of fishing mortality and abundance.

Estimates of Fishing Mortality

The first set of fishing mortality estimates involves the non-linear approach with the assumption that full-recruitment fishing mortality occurs between 17 and 20. These estimates are similar to those obtained in the previous section, which is surprising considering the 10 to 50% increase in total catch each year. However, the full-recruitment fishing mortality estimates should be less affected by incidental catches than for lower ages, and this is indeed the case in 1979. The estimates of fishing mortality from cohort analysis in 1979 are similar to these values.

The second set of estimates uses the same data as before but treats age 20 as a separate parameter. These estimates are slightly higher for early years but are quite similar for recent times (Table 21). The cohort analysis for 1979 based on these non-linear estimates are also quite similar.

The third set of estimates are developed to explore the variability of the incidental catches at later ages. The crab pot data catch for age 20 was much higher than for ages 15-19, due to variability in the age composition estimates based on a small sample size. Similar variability is observed in the trawl catch. In this set all incidental catches past the age of 15 are truncated (i.e. set to 0). The estimates of fishing mortality are slightly higher but the effect is minor for recent years (Table 21). Finally, all data from the year 1980 were excluded to see if a given year has any effect on the estimates. The estimates of fishing mortality are virtually identical to the previous estimates (Table 21), suggesting that the results are independent of any change in catchability or selectivity in 1980.

These results suggest that the crab pot catches have little effect on the full-recruitment fishing mortality estimates in Area 3. The estimates for younger ages are slightly larger since the crab pot catch is selective for younger ages. The impact of crab pot catch in recent times is less, because of the overall reduction in mortality from setline, trawl, and crab pot catches.

Estimates of Abundance

The estimates of terminal fishing mortality from the first set of the non-linear least-squares procedure (Table 21) are used in cohort analysis to estimate abundance for all ages between 3 and 20 and all years between 1935 and 1980. The estimates of adult abundance (Table 22) and juvenile abundance (Table 23) may be compared to estimates in Tables 6 and 8, respectively, to show the impact of the crab pot fishery catches on abundance. The estimates of the adult-numbers are one to two million fish higher and the estimates of adult biomass are from 30 to 60 million pounds higher for all years since 1958 with crab pot catch included. The estimated number of 3-year-olds is 1 to 2.5 million fish greater and the estimated number of juveniles is 4 to 8 million fish greater. The resultant equilibrium yield is shown in Table 24. The five-year averages range from 13 to 33 million pounds over the last 14 years. The negative equilibrium yield of -28.7 million pounds in 1979 is due to the drop in average weight by age in 1980. Assuming this is a spurious value, the three-year average is 16.9 million pounds and the five-year average is 27.4 million pounds.

Thus, the effect of crab pot catch is to have little effect on terminal fishing mortality but a large effect on numbers of fish. The increase in numbers also creates an increase in equilibrium yield. These estimates must be regarded with caution because the catches are probably overestimates and are based on a limited data set. They are useful in providing an upper bound on the numbers of fish and equilibrium yield in the Area 3 population.

Effect of Average Weight

As mentioned previously, there has been a decline in average weight by age in the past two years that affect biomass estimates substantially, which in turn affect estimates of equilibrium yield. By examining average weight by age for the last 14 years (Table 25) for both areas, it is clear that there has been an overall increase since 1967 with the decrease coming in only the last two years. The average weight of fish in the setline catch since 1964 has increased markedly in both areas (Table 26), with a major decline only in the last two years. Average weight in the stock assessment surveys since 1976 mimic the decline in average weight by age but are far more variable (Table 27). The average weight of fish in the surveys appears poorly correlated with that in the setline catch, but average weight of older ages, which influences average fish weight, is quite variable.

There are many possible explanations for changes in average weight. Other than random variation in catch statistics, there are three major hypotheses that deserve attention. The first is that the sex composition of the catch changed which would affect average weight by age, since females weigh more than males at the same age. This hypothesis does not explain the decline since 1978, because the proportion of females in the stock assessment survey increased, while the average weight decreased (Table 27).

The second hypothesis is that there are differences in ageing by different readers. Among IPHC staff, there does appear to be consistent differences in ageing, especially for older ages: Examination of average weight by age (Table 25) suggests that in 1980, average weight is shifted by exactly one year older for older ages than in 1979 for both areas. The effect of ageing differences on equilibrium yield is probably minor in the long run, since most of the IPHC ageing has been done by one or two people. Discrepancies in average weight by age do not affect the total number in the catch, since average weight is calculated from all otoliths, not just those aged. The age composition would shift somewhat, which would have some influence on estimate of abundance and mortality. However, the major effect would be on biomass estimates, where average weight by age is multiplied by estimated abundance of fish. Year-to-year fluctuations are balanced out in three- and five-year-averages of equilibrium yield. For Area 3, the median weight by age for the period 1970-1980 was calculated and biomass estimates of equilibrium yield were recalculated. This procedure forced biomass to mimic changes in abundance and made the equilibrium yield estimates smoother. The three- and five-year average equilibrium yields were 22 and 26 million pounds, respectively, slightly higher than before. This modification, however, assumes no change in average weight by age over the last 11 years, which is probably not accurate.

The third hypothesis is that changes in average weight are due to changes in the method of calculating average weight from otoliths. It is intriguing that 1978 was the first year that otolith weight rather than otolith length or radius was used to predict fish length, which corresponds to the period of decline in average weight. This hypothesis is likely to have greatest impact on stock assessment estimates, as it affects both the estimated number of fish in the catch and the average weight of fish. If the average weight of fish in the catch is underestimated, then the number of fish in the catch is overestimated, which creates overestimates of abundance and fishing mortality. The average weight by age, however, is underestimated, creating a compensatory mechanism in biomass estimates.

To determine the amount of compensation, the following procedure was constructed to explore the effect of errors in average weight. Multi-year averages of average weight of fish in the catch (Table 26) were used to re-estimate the number of fish in the catch. Five-year averages were used in the period 1935-1964 and four-year averages were used in the period 1965-1980. The same age-composition was applied to the total catch in numbers. Average weights by age were adjusted by the ratio of the multi-year average of average weight and the year's average weight, as shown in Table 28. This procedure accounts for the change in the minimum size limit in 1973, which may account for the increase in average weight since 1973. For Area 2, the non-linear least-squares procedure failed to converge to reasonable values for the revised data set. Alternatively, the non-linear least-squares estimates from the previous section, used in the cohort analysis the abundance of adults (Table 29), juveniles (Table 30), and equilibrium yield (Table 31) were calculated and are similar to previous estimates. The biomass of adults stabilizes at 110 million pounds for the last 8 years, rather than 125 million pounds in the previous section, and shows no substantial drop in 1980. The latest equilibrium yield is 8.7 to 9.4 million pounds, similar to the unsmoothed estimates with 1980 deleted.

For Area 3, the non-linear procedure converged to reasonable estimates and the fishing mortality estimates were used in cohort analysis to produce estimates of adult abundance (Table 32), juvenile abundance (Table 33), and equilibrium yield (Table 34). This procedure creates slightly higher adult and juvenile abundances than previously. The latest equilibrium yield is 13.7 to 18.5 which is more stable than the unsmoothed estimates with 1980 deleted. Although changes in biomass have been erratic, the values have stabilized near 225 million, which makes the 3-year average equilibrium yield close to the catch. When crab pot catches are included and the entire procedure repeated the equilibrium yield ranges from 19.9 to 25.1.

In summary, the smoothed data base has little effect on the stock assessment estimates. The major change was for recent estimates of biomass, which were smoother than previously. The equilibrium yield estimates for both areas are in accord with previous estimates where 1980 was not included in averaging.

SUMMARY

A summary of estimates of key population parameters for the various catch by age approaches used in this document is shown in Table 35 for Area 2 and Table 36 for Area 3. For Area 2, the estimates are in accord with last year's results. Best estimates are considered to be the average of the main and the smoothed approach. Best estimates of the number of adults, number of juveniles, and number at age three are 4 million, 9 million and 3 million, respectively. The best estimate of adult biomass is 115 million pounds, far less than the maximum of 230 million pounds in 1950. There has been little change in biomass over the last five years, which means that recent catch limits have been close to the equilibrium yield. Thus, the best estimate of equilibrium yield for Area 2 is 9 million pounds.

For Area 3, several approaches were used to provide estimates of population parameters. The major differences between analyses from this year and last year are that this year the assumption of constant catchability was not made and this year crab pot catches were examined for the first time. Analyses were made with and without the inclusion of incidental catches from the crab pot fishery to provide a range of possible estimates and to show the sensitivity of the method to the data set used. Two methods of smoothing out variability were attempted: the first used median weight-by-age for the period 1970-1980; the second used the average weight of the catch smoothed by five-year averages to reconstruct the data base. Because the unsmoothed approach and the two smoothed approach each have limitations, no single approach is preferred and the average of the estimates is considered the best estimate.

With the crab pot incidental catch excluded, the estimates from the three approaches are similar. The estimated number of adults, number of juveniles and number of three-year-olds are 7 million, 14 million, and 4 million, respectively. The current biomass is about 235 million pounds, less than the maximum 375 million pounds in 1949, and has increased over the past few years. The equilibrium yield is 23 million pounds.

With the crab pot incidental catch included, the estimates are higher than before, because the population is back-calculated from the catches which are discounted for natural mortality. The estimated number of adults, number of juveniles, and number of three-year-olds are 9 million, 23 million and 7 million, respectively. The current biomass estimate is 300 million, less than 420 million in 1949, and has increased over the past few years. The average equilibrium yield from these 3 approaches is 27 million.

These two sets of estimates with and without crab pot incidental catch show the range of estimates of population parameters. The best estimates lie within this range, and until the magnitude of crab pot catch is determined more precisely, is taken as the average of the two. Thus the best estimates of number of adults, number of juveniles, and number of 3-year-olds is 8.2 million, 18.5 million, and 5.4 million, respectively. The current biomass estimate is 270 million with an equilibrium yield of 25 million. These values must be treated with caution, however, because the most recent estimates are the most variable. Only when the increasing trend is evident over many years can these estimates be accepted with total confidence.

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STOCK ASSESSMENT DATA AND ANALYSIS 1979

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1979 STOCK ASSESSMENT Doc. No. 1

SYNOPSIS

Stock assessment indicators provide conflicting interpretations of stock condition in 1979. CPUE data from the 1979 fishery suggested an overall increase in stocks, but conclusions were complicated by a sharp reduction in CPUE in the western Gulf of Alaska and in British Columbia. Analysis of catch and age data (cohort analysis) indicated a slight increase in Area 2 stocks, but a major decline in Area 3. Cohort analysis indicated a continuing decline in juvenile abundance in both areas, whereas CPUE and IPHC survey data suggest that juvenile abundance has been stable or even increasing slightly in recent years.

Estimates of equilibrium yield varied substantially, depending on the the source of data used. Again, cohort analysis predicted poorer stock conditions than did CPUE data. All of the estimates showed that recent catches in Area 2 were at or below equilibrium values. Some of the estimates in Area 3, however, indicated that the catch was above the equilibrium and that the stocks will decline unless catches are reduced. Explanations for these conflicting results are not available at this time.

Abundance of Adult Halibut

Information on adult abundance was available from cohort analysis (Doc. No. 2), commercial CPUE data (Doc. No. 3), and stock assessment survey data (Doc. No. 6). The stock assessment survey data, however, was discounted because the survey has only been conducted since 1976 and stock trends are not yet evident.

but appears to be independent of the fishery. The biomass of spawners declined steadily from the 1950's to the early 1970's, and then remained relatively stable.

Other indicators provide a more optimistic picture of juvenile abundance. In the fishery, the CPUE of halibut less than 10 years of age has increased since 1975 by about 80% in Area 2 and about 60% in Area 3 (Doc. No. 4). The CPUE of 9-year-olds, which provides an index of recruitment to the fishery, was higher in 1979 than in any year since 1972 (Doc. No. 3). IPHC juvenile surveys indicate that abundance has declined slightly since the late 1960's; the abundance index in 1979 declined in both the Bering Sea and the Gulf of Alaska but this followed a general increase since about 1975 (Doc. No. 5).

Fishing Mortality

Both cohort analysis and setline fishing effort data show a major reduction in mortality by setlines since the 1960's (Doc. No's. 2 and 3). Estimates of setline mortality in 1979 ranged from .07 to .09 in Area 2 and from .09 to .12 in Area 3.

The decline in fishing mortality is a direct result of reduced catches in recent years. The 1979 catch was about 9.3 million pounds in Area 2, 12.2 million pounds in Area 3 and 0.9 million pounds in the Bering Sea. The 1979 total catch (22.4 million pounds) is less than half of that taken in 1971 (46.7 million pounds).

Incidental Catches by Other Fisheries

Estimates of incidental catch for all relevent fisheries are given in Doc. No. 8. Estimates are only available through 1978.

1979 STOCK ASSESSMENT Doc. No. 2*

COHORT ANALYSIS

The successful utilization of cohort analysis for the estimation of numbers of fish by age depends on the choice of values for natural mortality for all ages, and values for fishing mortality at the terminal age (age 20 for halibut) for all years and for all ages at the last year. Natural mortality is assumed constant at 0.20 for all ages and all years. The effect of the choice of fishing mortality values decreases as the year-class passes through the fishery. Thus, the estimates of fishing mortality and population abundance are likely to be less reliable for the recent past years and the latest year-classes.

The use of cohort analysis in past years was based on the choice of 0.20 for terminal fishing mortality for all years and for all ages at the last year (Hoag and McNaughton 1978). The overestimate of terminal fishing mortality created underestimates of abundance and the cohort estimates since 1971 were deemed unreliable. The estimates since 1971 were projected with CPUE data. However, CPUE is variable in time and space, which causes the projected abundance estimates to be quite variable in recent times. A similar argument applies to the corrections for juveniles from trawl surveys. Thus, it is desirable to have an alternative procedure.

This year, a new method has been developed to allow the cohort estimates to be computed up to and including the year of assessment. The principle shortcoming of the present method is that the estimates have a high variability for the last 3 years, which means that the recent estimates are very sensitive to changes in the choice of terminal fishing mortality values.

*Prepared by T. Quinn

However, the catch in numbers is estimated from the average weight, so that an underestimate of average weight may be compensated by an overestimate of the number of adults.

Abundance of Juveniles

The estimated number of juveniles (ages 3 to 7) and the number at age three are shown for Area 2 (Table 3), Area 3 (Table 4) and the combined areas (Table 5). The combined estimates are more reliable than the individual estimates because it is unlikely that all juveniles grow up in their regulatory area of origin. Not much weight can be placed on recent years because these values represent a very small amount of time in either the trawl or setline fisheries. Irregardless, both areas have been subjected to a long-term decline in the production of young and there is no indication of recovery at the present.

Equilibrium Yield

The equilibrium yield calculations are shown for Area 2 (Table 6) and Area 3 (Table 7). The change in biomass ("biochange") from one year to the next is added to the year's catch as an estimate of equilibrium yield. Three- and five-year moving averages of equilibrium yield are also presented to smooth out variability.

In Area 2, the equilibrium yields in the last 15 years have been between 10 and 20 million pounds, while the catches have been about 5 million pounds larger on the average. The recent equilibrium yield estimates are between 9 and 12 million pounds, which would be the yield that would keep the biomass constant. A conservative policy would set the quota at least one or two million pounds below equilibrium yield.

biomass of spawners has declined steadily since the 1950's but appears to have either leveled off or increased slightly in the last seven years (Table 12). The corresponding number of three-year-olds produced three years later has declined steadily since 1961. Of major interest is a drop in production per pound of spawners from around .14 in the period 1935-1945 to about 0.04 in the past twenty years (Table 12). This drop may represent a change in the mode of recruitment independent of the fishery that has been partially responsible for the decline in the number of juveniles.

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STOCK ASSESSMENT DATA 1978

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ABUNDANCE OF ADULT HALIBUT

IPHC traditionally has relied on CPUE in the setline fishery as an abundance index of adult halibut. Recently, absolute abundance has been estimated using cohort analysis (Hoag and McNaughton, 1978). Estimates of abundance and CPUE show similar trends, suggesting that both provide a similar indication of changes in halibut stocks (r = 0.80 in Area 2 and 0.71 in Area 3). However, there is an advantage in using absolute abundance rather than relative abundance because the effect of catch on stock size can be evaluated more directly. This document presents estimates of both abundance and CPUE. However, CPUE is considered as auxiliary information except that CPUE during 1965-1971 was used to determine a constant of proportionality between CPUE and number of fish. This factor was used to project abundance from CPUE after 1971. Abundance estimates from cohort analysis since 1971 were not used because each year class must be observed in the fishery for several years before the estimates are reliable.

The estimated abundance of adults since 1935 is shown in Table 1. Adults are defined as 8- to 20-year-olds, the dominant ages in the setline catch. Abundance was expressed in terms of both numbers and biomass. Biomass was estimated by multiplying the number of fish at each age by the corresponding average weight (heads off - dressed) of fish in the setline catch. The estimated abundance at each age in 1977 and 1978 is given in Table 2. As previously mentioned, CPUE was used to project abundance after 1971. Changes in biomass after 1971 do not correspond exactly to changes in CPUE for all ages in the fishery. This is because biomass was first estimated for each age and then summed. Ages that are not fully recruited to the setline fishery contribute more to the biomass estimates than to CPUE. This accounts for much of the difference between changes in biomass and CPUE. Table 3 shows CPUE for 8- to 20-year-olds and for all ages in the setline fishery.

*Prepared by S. Hoag and C. Schmitt

ESTIMATES OF EQUILIBRIUM YIELD, AREAS 2 AND 3

The annual equilibrium yield was estimated for Areas 2 and 3 from 1935 to 1978. The estimates were obtained by adding the annual change in biomass (from one year to the next) to the annual setline catch. The biomass from Doc. No. 1 was smoothed by using moving 5-year-averages before calculating the annual change. The results are given in Table 1. The estimated equilibrium yield is for the setline fishery only; the incidental catch by other fisheries was treated as part of the natural mortality.

*Prepared by S. Hoag and C. Schmitt

SPAWNING STOCK SIZE

Estimates of the biomass of spawners and resulting number of progeny are presented by area and year in Table 1 and in Figure 1. The biomass of spawners indicates potential egg production by the population (Schmitt and Skud 1978) and the resulting progeny are represented by the number of 3-year-olds in the population, three years later. The number of 3-year-olds indicates year-class strength before the juveniles enter the trawl and setline fisheries and the appropriate adjustment in time to year of birth has been made. For example, the total biomass of spawners in 1935 was 132,078,800 pounds, which gave rise to the 1935 year class of juveniles, 18,726,000 three-year-olds.

The estimates of biomass of spawners since 1935 are based on three assumptions: (1) the sex composition of the adult population has not changed significantly since 1935; (2) spawners are 12- to 20-year-old halibut but include 11-year-olds in Area 3 after 1959; and (3) fecundity is proportional to fish weight. Until 1972, numbers of halibut by age were estimated by cohort analysis (Hoag and McNaughton 1978) and represent the numbers in the population at the beginning of the year. Thus, it is assumed that the mature fish in a given year spawned early in the same year to produce that year's complement of young. After 1971, the numbers of 3-year-olds were projected from the index of abundance in the juvenile surveys in the Gulf of Alaska (See 1978 Stock Assessment Doc. No. 2). Numbers of spawners after 1971 were projected from CPUE as described in 1978 Stock Assessment Doc. No. 1. To estimate biomass, the numbers of spawners by age were multiplied by the corresponding mean weights (heads-off, dressed) from commercial samples.

*Prepared by C. Schmitt