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Edited by
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CONDITION OF GROUNDFISH RESOURCES OF THE EASTERN BERING SEA AND ALEUTIAN ISLANDS REGION IN 1982

by

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ABSTRACT

This report contains an assessment of the condition of groundfish and squid in the eastern Bering Sea and Aleutian Islands region through 1982. The assessments are based on species-by-species analyses of the data collected from the commercial fishery and research vessel surveys. Estimates of maximum sustainable yield and equilibrium yields are presented to guide management of the 1983 fishery.

Most of the resources in the Bering Sea-Aleutians management region are in good condition, including walleye pollock, Pacific cod, the flatfishes, and Atka mackerel. Pacific cod and yellowfin sole are in excellent condition and at historic high levels of abundance. Pacific ocean perch and sablefish stocks are in poor condition and remain at low levels of abundance. The equilibrium yield for the groundfish complex as a whole was estimated to be 2.1 million metric tons (t) compared to 2.0 million t in 1981.

CONTENTS

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WALLEYE POLLOCK

by

Richard G. Bakkala and Vidar G. Wespestad

INTRODUCTION

The walleye pollock, *Theragra chalcogramma*, resource in the eastern Bering Sea (Figure 1) supports the largest single species fishery in the North Pacific. Pollock became a highly sought-after species when mechanized processing of minced-meat was successfully implemented on Japanese commercial vessels in the mid-1960's. As a result, pollock catches increased more than 10-fold between 1964 and 1972 (from 175,000 metric tons (t) to nearly 1.9 million t, Table 1). Catches have since declined, due in part to catch restrictions placed on the fishery as a result of declining stock abundance. Catches declined to 914,000 t in 1979 but then increased to 958,300 t in 1980 and 973,500 t in 1981. An additional 58,200 t in 1980 and 55,500 t in 1981 were taken in the Aleutian Islands region (Table 2).

Japanese fisheries have usually accounted for over 80% of total catches since 1970. Most of the remaining catch was taken by the USSR until 1978. The Republic of Korea (ROK) catches in the eastern Bering Sea have exceeded those by the USSR since 1979, reaching 107,600 t in 1980 and 104,900 t in 1981. New fisheries for pollock have developed in recent years--by Poland in 1979 and the Federal Republic of Germany (West Germany) in 1980 and by joint-venture operations between U.S. fishing vessels and processing vessels from Japan, Poland, ROK, West Germany, and the USSR in 1980-81. Of these new fisheries the largest users of the resource in 1981 were Poland (48,400 t) and the joint-venture fisheries (41,900 t).

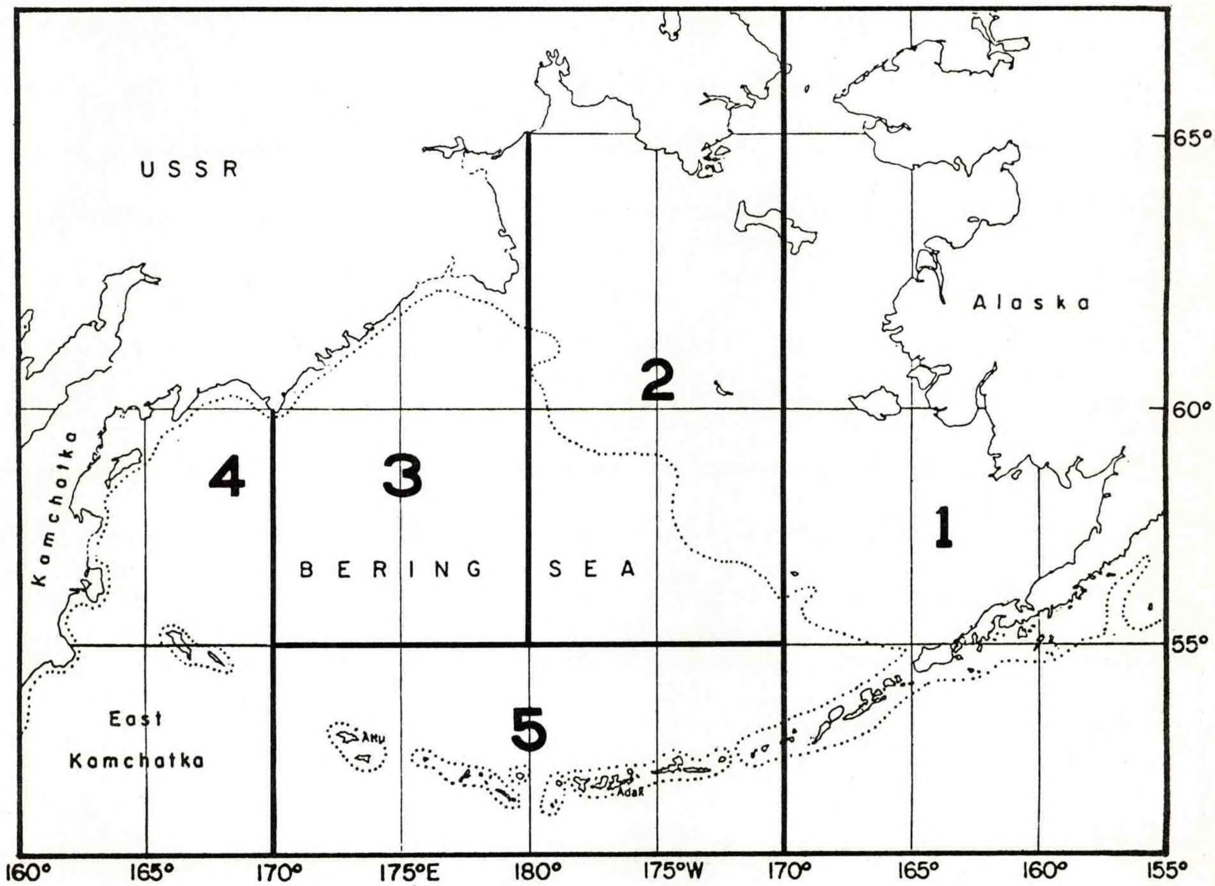

Figure 1.--Bering Sea and Aleutian Islands region showing location of International North Pacific Fisheries Commission statistical areas 1 to 5.

Table 1.--Annual catches of walleye pollock in the eastern Bering Sea in International North Pacific Fisheries Commission statistical areas 1 and 2 (see Figure 1).1/

Year	Japan	USSR	ROK 2/	ROC 3/	Poland	West Germany	Joint ventures 4/	Total
	t							
1964	174,792							174,792
1965	230,551							230,551
1966	261,678							261,678
1967	550,362		1,200					551,562
1968	700,981		1,200					702,181
1969	830,494	27,295	5,000					862,789
1970	1,231,145	20,420	5,000					1,256,565
1971	1,513,923	219,840	10,000					1,743,763
1972	1,651,438	213,896	9,200					1,874,534
1973	1,475,814	280,005	3,100					1,758,919
1974	1,252,777	309,613	26,000					1,588,390
1975	1,136,731	216,567	3,438					1,356,736
1976	913,279	179,212	85,331					1,177,822
1977	868,732	63,467	45,227	944				978,370
1978	821,306	92,714	62,371	3,040				979,431
1979	749,229	58,880	83,658	1,952	20,162			913,881
1980	786,768	2,155	107,608	4,962	40,340	5,967	10,479	958,279
1981	765,287		104,942	3,367	48,391	9,580	41,938	973,505

1/ Catch data for 1964-79 as reported by fishing nation (except 1967-76 ROK catches which were based on U.S. surveillance reports) and for 1980 and 1981 from U.S. observer estimates as reported by French et al. 1981, 1982.

2/ Republic of Korea

3/ Republic of China

4/ Joint ventures between U.S. fishing vessels and ROK, Japanese, Polish, West German, and USSR processors.

Table 2.--Annual catches of walleye pollock in the International North Pacific Fisheries Commission Aleutian Islands statistical area 5 (see Figure 1).1/

Year	Nation					Total
	Japan	USSR	ROK	Poland	Others2/	
	t					
1977	5,667	1,618	325	0	15	7,625
1978	5,025	1,193	64	0	0	6,282
1979	8,047	1,412	45	0	0	9,504
1980	46,052	1	6,256	5,806	41	58,156
1981	37,980	0	11,074	5,593	869	55,516

1/ Catch data for 1977-79 as reported by fishing nations and for 1980 and 1981 from French et al. 1981, 1982.

2/ West Germany and the Republic of China (ROC).

CONDITION OF STOCKS

Relative Abundance

Four procedures, described by Low et al. (1977), have been used to examine trends in abundance of pollock as indicated by catch per unit of effort (CPUE) (Table 3). Results obtained with the International North Pacific Fisheries Commission (INPFC) workshop procedure, which are representative of trends obtained from other procedures, indicated abundance declined rapidly from 1972 to 1975, stabilized at the reduced level through 1978, increased in 1979, declined to the lowest level yet observed in 1980, and then increased some again in 1981. Abundance was essentially the same in 1981 as in base year 1975.

Trends in CPUE from large-scale Northwest and Alaska Fisheries Center (NWAFC) trawl surveys, that have sampled the major part of the eastern Bering Sea continental shelf in 1975 and 1979-82 (see Figure 2), have been relatively stable except in 1980 when CPUE was approximately half that of other years. The sharp decline in 1980 indicated by this method was more severe than the decline suggested by the other methods. The reason for this is unknown but it may have resulted from sampling bias, or because a higher than usual proportion of the population was distributed in waters above those sampled by the trawls. The CPUE data generally suggest that the abundance of pollock remained relatively stable between 1975 and 1981.

An additional source of data for examining the condition of the pollock stock are the surveys by Japanese Danish-seine vessels. These surveys are particularly valuable because they cover a large portion of the eastern Bering Sea continental shelf in the relatively short period of about 2 weeks. Okada et al. (1982) have summarized results from these surveys as follows:

Year	1976	1977	1978	1979	1980	1981
CPUE(t/haul)	4.5	3.7	3.7	2.9	4.2	2.9 1/

1/ Estimated from Figure 3 of Okada et al. (1982).

These data show similar CPUE values in 1976 and 1980 with lower values in other years, particularly in 1979 and 1981.

Biomass Estimates from Cohort Analysis

Methods

A FORTRAN program based on the equations of Pope (1972) was used to estimate the abundance of pollock from commercial fishery data.

Catch Data--Estimates of catches in numbers by age for 1973-78 were taken from Bakkala et al. (1980). For 1979 and 1980 catches in numbers by age were derived from catch data reported by foreign fisheries and from age data collected by U.S. observers from these fisheries. Quarterly catches by nation and vessel class were converted to catches by age using the above age frequency. These catches (by age in weight) were then converted to numbers at age using mean weights at age from U.S. observer age samples. The quarterly elements were then summed to obtain overall annual estimates of catches by age in numbers (Table 4).

Natural and Fishing Mortality--The cohort analysis was initiated using natural mortality (M=0.4) reported by Bakkala et al. (1979). In subsequent trials, values of M and fishing mortality (F) were modified until the age composition from the cohort analysis approximated that from 1979 and 1980 hydroacoustic and demersal trawl surveys (Bakkala et al. 1981). It was assumed that survey data were representative of the age composition of the actual population. F values for the last year of data (1980) were derived by allowing F to vary until the age composition from the cohort analyses was similar to that from the

Table 3.--Relative indices of walleye pollock stock abundance in the eastern Bering Sea, 1964-82.

	Japanese pair trawl data			
Year	U.S. method1/ (t/1,000's of horsepower hours)	Japanese method2/ (t/hour)	INPFC3/ workshop method4/ (% of 1975 value)	U.S. research vessel data (kg/ha)
1964	9.5	--	--	--
1965	18.3	--	--	--
1966	23.6	--	--	--
1967	21.3	--	--	--
1968	23.8	--	194	--
1969	31.5	--	154	--
1970	18.7	--	175	--
1971	14.2	--	172	--
1972	14.2	--	189	--
1973	8.6	12.2	166	--
1974	10.4	10.3	118	--
1975	9.3	9.5	100	66.0
1976	9.4	9.5	103	--
1977	8.6	9.0	98	--
1978	9.4	9.6	105	--
1979	9.4	9.8	110	63.5
1980	6.7	9.3	88	32.2
1981	8.4	9.4	102	57.6
1982	--	--	--	58.7

1/ Alton and Fredin (1974)
2/ Okada et al. (1982)
3/ International North Pacific Fisheries Commission
4/ Low and Ikeda (1980)

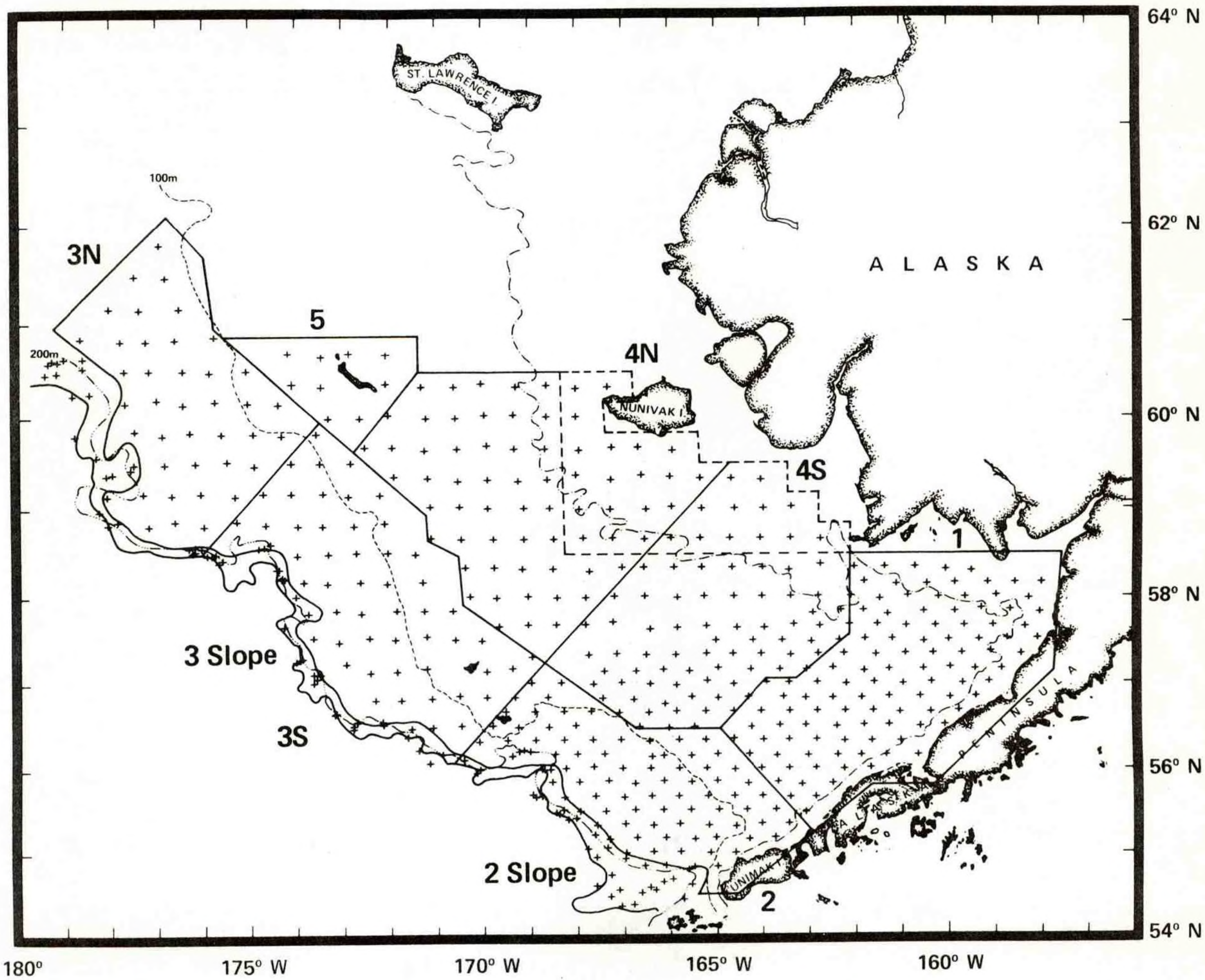

Figure 2.--Area of the eastern Bering Sea generally sampled during large-scale surveys by the Northwest and Alaska Fisheries Center in 1975 and 1979-82. Survey subareas are delineated by the solid lines and subarea numbers are shown adjacent to the subareas. Area within the dashed lines in the vicinity of Nunivak Island was not sampled during the 1981 survey.

Table 4.--Catch of walleye pollock in numbers of fish by age and year of catch, 1973-80.

Age (yr)	1973	1974	1975	1976	1977	1978	1979	1980
1	68476462	143220937	39693663	752524	172223683	36525781	133780134	31679644
2	617408053	3114550193	698186311	451683096	1132241626	565151784	958318125	1120060875
3	747423278	1151068184	3214083261	1708868581	1513617555	934661851	1235419499	1041523325
4	1624812573	327396628	247082252	1150177133	1096730094	792815878	682467001	430156165
5	1243734125	439782621	65733892	113338462	393737717	457077805	540965602	228463365
6	849591719	237407495	123452154	52305660	87584665	123745025	231774924	153058035
7	472714931	152073252	118236434	72467994	32138469	35710834	53803793	75204515
8	342394476	128122712	64431896	84064536	46360235	21534056	22826600	51415520
9	153661400	125754455	37918087	65393224	37081651	24414487	29169814	21146821
10	27680768	52889386	26697169	32224806	29775304	19629510	18240835	22979950
11	3475765	21486785	6597770	14872449	15364550	13827698	10557766	29492772
12	920578	5612968	2607785	10168815	7616694	5277830	9360177	16856047
13	204568	5601836	418458	2619749	5619101	2185261	7387621	4904990
14	847524	999830	538323	0	1120302	671062	383565	4836020
15	0	473044	0	0	308355	202705	187541	845401
16	0	395623	0	0	0	8811	231706	702299

1980 survey. Following the adjustment of 1980 F values, the 1979 cohort age composition was adjusted to that from the 1979 survey by iteratively varying age specific M and F values commencing with ages having the greatest discrepancies. Terminal F values for the oldest age in years prior to 1980 were set equal to the F computed for the next youngest age in that year, based on the assumption of equal catchability for the two ages. The terminal and calculated F values generated by the analyses are given in Table 5. Age specific M values used in the analysis were as follows:

	Age (yr)							
	1	2	3	4	5	6	7	8
M value	0.85	0.45	0.30	0.30	0.30	0.30	0.30	0.30
	Age (yr)							
	9	10	11	12	13	14	15	16
M value	0.30	0.30	0.40	0.40	0.40	0.50	0.50	0.60

RESULTS

The results of the cohort analysis are shown in numbers by age in Table 6 and biomass by age in Table 7. The results show a declining trend in abundance with the sharpest decline occurring between 1973 and 1974 (from 12.8 to 11.0 million t) and then a slower, gradual decline between 1974 and 1980 (from 11.0 to 9.5 million t). The overall trend in abundance from the cohort analysis is generally similar to that from CPUE analysis (Figure 3).

Results of the cohort analysis also indicated that recruitment of the 1972 year-class was higher than any other year-class over the period of the analysis. The 1977 year-class was the second most abundant. The 1968 and 1969 year-classes were also apparently strong based on their abundance at ages 4 and 5 in 1973 and at older ages in later years.

Table 5.--Estimates of fishing mortality (F) for walleye pollock by age of fish and year, 1973-80.

Age (yr)	1973	1974	1975	1976	1977	1978	1979	1980
1	0.0023	0.0074	0.0021	0.0000	0.0125	0.0017	0.0101	0.0000
2	0.0921	0.2192	0.0722	0.0473	0.1321	0.0826	0.0884	0.1770
3	0.1727	0.3035	0.4590	0.3102	0.2692	0.1859	0.3199	0.1580
4	0.3995	0.1182	0.1084	0.3304	0.3785	0.2464	0.2249	0.1950
5	0.4342	0.1978	0.0346	0.0735	0.1995	0.2995	0.2976	0.1210
6	0.6102	0.1509	0.0865	0.0385	0.0829	0.0984	0.2731	0.1420
7	0.5014	0.2271	0.1160	0.0743	0.0331	0.0488	0.0626	0.1480
8	0.5455	0.2720	0.1576	0.1256	0.0689	0.0309	0.0441	0.0870
9	0.4141	0.4457	0.1334	0.2663	0.0831	0.0520	0.0592	0.0580
10	0.2792	0.2723	0.1755	0.1788	0.2077	0.0639	0.0554	0.0670
11	0.1143	0.4381	0.0570	0.1644	0.1421	0.1651	0.0517	0.1400
12	0.0254	0.3450	0.1049	0.1449	0.1468	0.0815	0.2000	0.1350
13	0.0296	0.2654	0.0469	0.1811	0.1375	0.0701	0.1951	0.1900
14	0.0516	0.2620	0.0469	0.0000	0.1429	0.0280	0.0202	0.2500
15	0.0000	0.0500	0.0000	0.0000	0.0960	0.0469	0.0132	0.0770
16	0.0000	0.0500	0.0000	0.0000	0.0000	0.0050	0.1000	0.0900

Table 6.--Estimated numbers of walleye pollock (billions of fish), by age of fish and year, in the eastern Bering Sea from cohort analysis, 1973-80.

Age (yr)	1973	1974	1975	1976	1977	1978	1979	1980
1	46.458	29.579	28.725	26.803	21.158	33.244	20.435	0.000
2	8.786	19.812	12.549	12.252	11.455	8.931	14.185	8.647
3	5.476	5.109	10.146	7.444	7.451	6.400	5.243	8.280
4	5.732	3.413	2.794	4.750	4.044	4.217	3.937	2.821
5	4.102	2.848	2.247	1.857	2.529	2.052	2.442	2.329
6	2.161	1.969	1.731	1.608	1.278	1.534	1.127	1.343
7	1.393	0.870	1.254	1.176	1.146	0.872	1.030	0.635
8	0.946	0.625	0.513	0.827	0.809	0.821	0.615	0.717
9	0.526	0.406	0.353	0.325	0.541	0.559	0.590	0.436
10	0.132	0.258	0.193	0.229	0.184	0.369	0.393	0.412
11	0.039	0.074	0.145	0.120	0.142	0.111	0.256	0.276
12	0.045	0.023	0.032	0.092	0.068	0.082	0.063	0.163
13	0.009	0.029	0.011	0.019	0.053	0.039	0.051	0.035
14	0.022	0.006	0.015	0.007	0.011	0.031	0.025	0.028
15	0.018	0.012	0.000	0.000	0.004	0.006	0.018	0.015
16	0.000	0.011	0.000	0.000	0.000	0.002	0.003	0.011
All ages	75.846	65.046	60.709	57.509	50.874	59.272	50.414	26.147

Table 7.--Estimated biomass (in 1000 t) of walleye pollock, by age of fish and year, in the eastern Bering Sea, based on cohort analysis, 1973-80.

Age (yr)	1973	1974	1975	1976	1977	1978	1979	1980
1	932.	593.	576.	538.	424.	667.	410.	0.
2	991.	2234.	1415.	1382.	1292.	1007.	1600.	975.
3	1431.	1335.	2651.	1945.	1947.	1672.	1370.	2163.
4	2464.	1468.	1201.	2042.	1739.	1813.	1693.	1213.
5	2433.	1689.	1333.	1102.	1500.	1217.	1448.	1382.
6	1594.	1452.	1277.	1186.	943.	1132.	831.	991.
7	1195.	747.	1076.	1010.	984.	748.	884.	545.
8	904.	597.	491.	791.	773.	785.	588.	685.
9	544.	419.	364.	335.	558.	578.	609.	450.
10	144.	281.	210.	250.	201.	402.	430.	450.
11	45.	84.	165.	136.	161.	126.	291.	314.
12	53.	28.	37.	108.	80.	97.	74.	191.
13	10.	35.	13.	23.	64.	47.	61.	41.
14	26.	7.	18.	9.	13.	38.	30.	34.
15	22.	15.	0.	0.	5.	7.	23.	18.
16	0.	14.	0.	0.	0.	3.	4.	14.
All ages	12789.	10999.	10830.	10856.	10685.	10339.	10345.	9466.

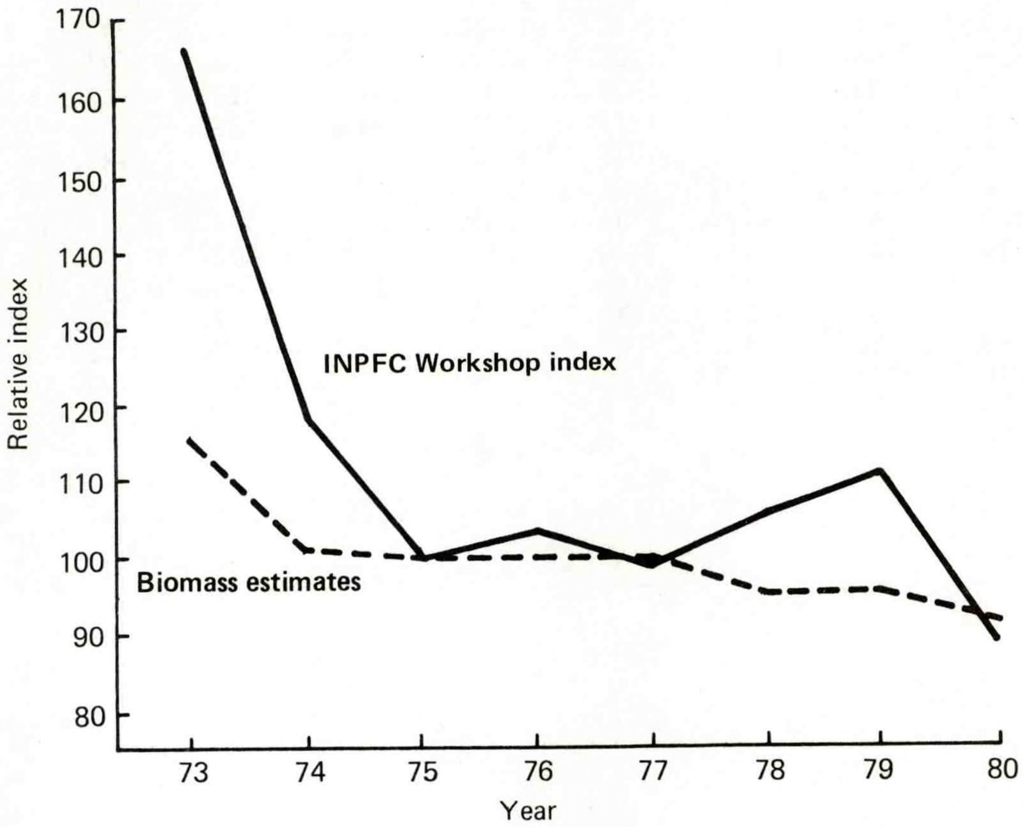

Figure 3.--Trends in abundance of walleye pollock as shown by catch per unit of effort values from the International North Pacific Fisheries Commission (INPFC) workshop procedure and biomass estimates from cohort analysis (expressed as percentages of 1975 values).

Based on the cohort analysis, average F values and exploitation rates ($E = \frac{FA}{Z}$ where F = fishing mortality, A = annual mortality, and Z = total mortality with $\overline{M} = 0.407$, the average of the values used) for 1973-80 were as follows:

	1973	1974	1975	1976	1977	1978	1979	1980
$\overline{F}$ value	.259	.225	.114	.162	.143	.107	.132	.138
E value	.189	.167	.089	.124	.110	.078	.102	.106

Assuming their accuracy, these moderate levels of exploitation would not be expected to inhibit population increases. A more important factor may be the level of recruitment.

Estimated trends in abundance of pollock in immediate future years were examined using a numeric population simulator. The simulation model predicts age-specific abundance through a population decay function:

$$N_{(i+1,\ j+1)} = N_{ij}\, e^{-(M+F)}$$

where N_{ij} = number of age i in year j, and

$N_{(i+1,\ j+1)}$ = number of age i in the following year.

The decay function projects numbers at age from a base year using estimates of natural mortality (M), fishing mortality (F), and recruitment.

The estimate of natural mortality used in the simulator was the age-specific value used in the cohort analysis and the estimate of fishing mortality was the 1980 value (shown above) which was applied to fish age 2 and older in the simulations. Two estimates of recruitment were used; one was the minimum recruitment and the second the average recruitment at age 1--both determined by the cohort analysis (Table 7).

The results (Table 8) indicate that at minimum levels of recruitment abundance will continue a gradual decline while at average levels of recruitment the biomass will slowly increase. The primary importance of the projections is to show that abundance is not likely to undergo any major decline in the immediate future unless recruitment falls substantially below the minimum recruitment used in the simulations.

Biomass Estimates from Research Vessel Surveys

Other estimates of biomass were computed from data obtained from research vessel surveys in the eastern Bering Sea. Mean estimates from large-scale surveys that have sampled the major part of the eastern Bering Sea were as follows:

Year	Type of survey	Mean biomass estimates (t)
1975	U.S. demersal trawl	2,426,000
1979	U.S.-Japan demersal trawl	3,552,000 1/
	U.S. hydroacoustic	7,458,000
1980	U.S. demersal trawl	1,509,000
1981	U.S.-Japan demersal trawl	2,768,500 1/
1982	U.S. demersal trawl	2,666,600

1/ 1979 and 1981 values include estimates from the continental slope while estimates from demersal trawl data in other years are from the continental shelf region only.

Estimates from the demersal trawl surveys are much lower than those from the cohort analysis because of the semidemersal distribution of pollock which places some proportion of the population above the bottom trawls. The combined demersal trawl and hydroacoustic survey estimate in 1979 of 11.0 million t, however, was similar in magnitude to the estimate of 9.9 million t produced by the cohort analysis.

Table 8.--Projection of walleye pollock biomass (million t) using the minimum and average recruitment at age 1 in 1973-79 and fishing mortality in 1980 based on results of the cohort analysis.

Year	Minimum recruitment (410,000 t)	Average recruitment (591,000 t)
1981	10.0	10.6
1982	9.8	11.0
1983	9.6	11.5
1984	9.4	11.8
1985	9.2	12.1

In 1980, a cooperative U.S.-Japan demersal trawl survey was conducted in the Aleutian Islands region. The biomass estimate derived from this survey was 419,900 t in the portion of the Aleutians within INPFC areas 1 and 5 (see Figure 1). Assuming that pollock occupy midwater in the Aleutians as they do in the eastern Bering Sea, this estimate may represent only a portion of the biomass in the region.

Age and Size Composition

Age composition according to NWAFC research vessel surveys and the commercial fishery (sampled by U.S. observers) is illustrated in Figure 4. The fishery shows a consistent pattern from year-to-year with age 3 fish most often predominating, and ages 2 and 4 also contributing substantially. Research vessel catches have consisted primarily of age groups 1-3.

The 1980-82 survey data indicated that recruitment at age 1 from the 1979, 1980, and 1981 year-classes was low compared to the abundance of age 1 fish in 1975 and 1979 (recruitment from the 1974 and 1978 year-classes, respectively). As explained earlier, however, the 1980 survey data may have been less reflective of actual abundance that year than survey data in other years. Nevertheless, the abundance of the 1979 year-class was also relatively low at age 2 based on 1981 survey data and very low in the commercial catches in 1981 according to U.S. observer data (Figure 4).

It should be noted that because aging of 1982 samples had not yet been completed at the time of this writing, age composition of the 1982 population was estimated by applying the 1981 survey age-length key to the 1982 survey length-frequency data. Although growth differences in year-classes between 1981 and 1982 may result in some inaccuracies, the estimates should generally reflect the age composition of the 1982 population. The results thus obtained

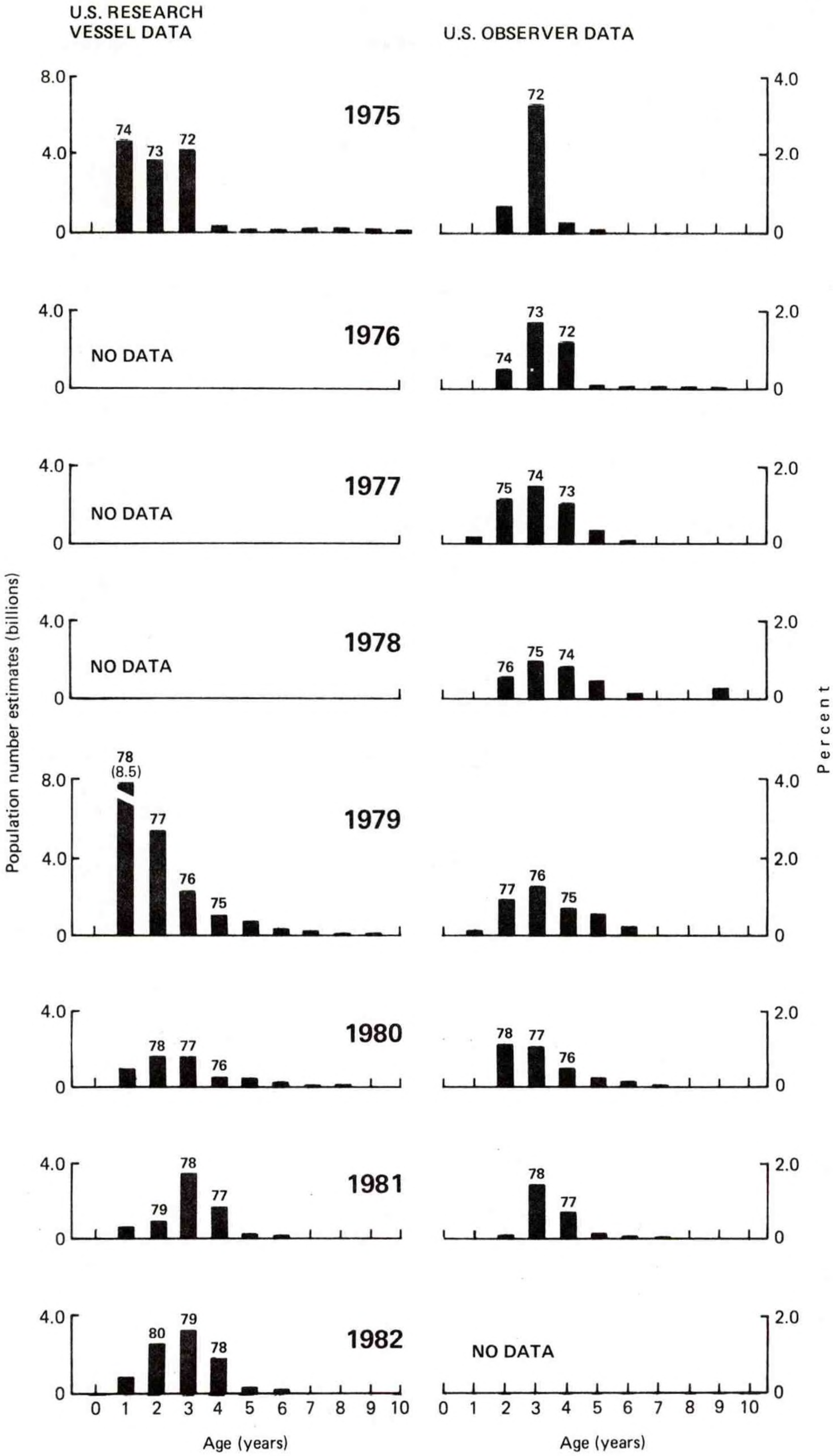

Figure 4.--Age composition of walleye pollock in the eastern Bering Sea as shown by data from Northwest and Alaska Fisheries Center research vessel surveys and by data collected in the commercial fishery by U.S. observers. The numbers above the bars indicate the principal year-classes.

from the 1982 survey further substantiate that the 1980 and 1981 year-classes were weak compared to those of 1974 and 1978.

Length-frequency data from samples obtained during demersal trawl and hydroacoustic surveys in 1979, 1981, and 1982 were used to further examine the low recruitment of the 1979-81 year-classes. Compared to 1979 (1978 year-class), age 1 fish represented by modal peaks at 14 cm in Figure 5 were less abundant in 1981 (1980 year-class) and particularly so in 1982 (1981 year-class). That there was no mode evident at all at 14 cm in 1982 is further evidence that the 1981 year-class may be especially weak. The 1981 length-frequency data also suggests that abundance of age 2 pollock (the 1979 year-class), represented by modes with peaks at 22-24 cm, was also low. Based on the 1982 length data, the strength of the 1979 (mode near 30 cm) and 1980 (mode near 20 cm) year-classes is not clearly evident, but they may be weaker than the 1976 and 1977 year-classes represented by modes in 1979 at similar respective lengths.

Hydroacoustic surveys by the NWAFC were conducted in 1979 and 1982 to assess the abundance of midwater concentrations of pollock in the eastern Bering Sea. Length-frequency distributions from midwater trawl samples taken in conjunction with these surveys were markedly different from one another (Figure 6). The 1979 samples consisted almost entirely of age 1 and age 2 pollock, represented by modal peaks at 15 and 23 cm. In 1982 there was no evidence of a mode representing age 1 pollock and the proportion of age 2 pollock was lower than in 1979. Interestingly, most of the pollock taken in midwater in 1982 were older than age 2 (greater than 30 cm) whereas fish in this category represented only a small proportion of the samples in 1979.

In summary, the age and length-frequency data suggest that the strength of the 1979-81 year-classes are weak--the 1981 year-class especially so. The population should be closely monitored in the years immediately ahead to assess the influence of these weak year-classes on population abundance.

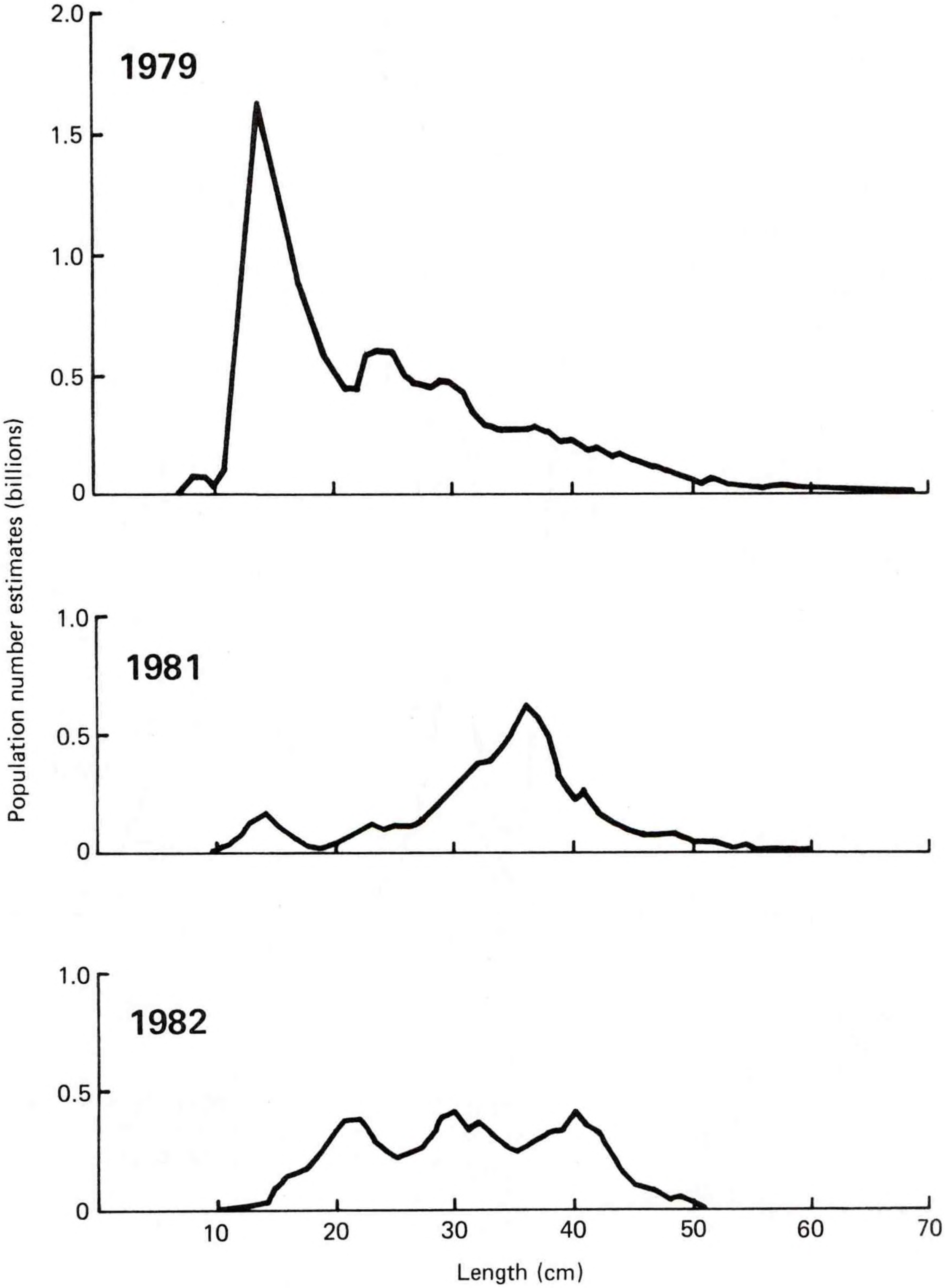

Figure 5.--Population estimates of walleye pollock by centimeter size interval, as shown by Northwest and Alaska Fisheries Center demersal trawl data from the continental shelf of the eastern Bering Sea, 1979-82.

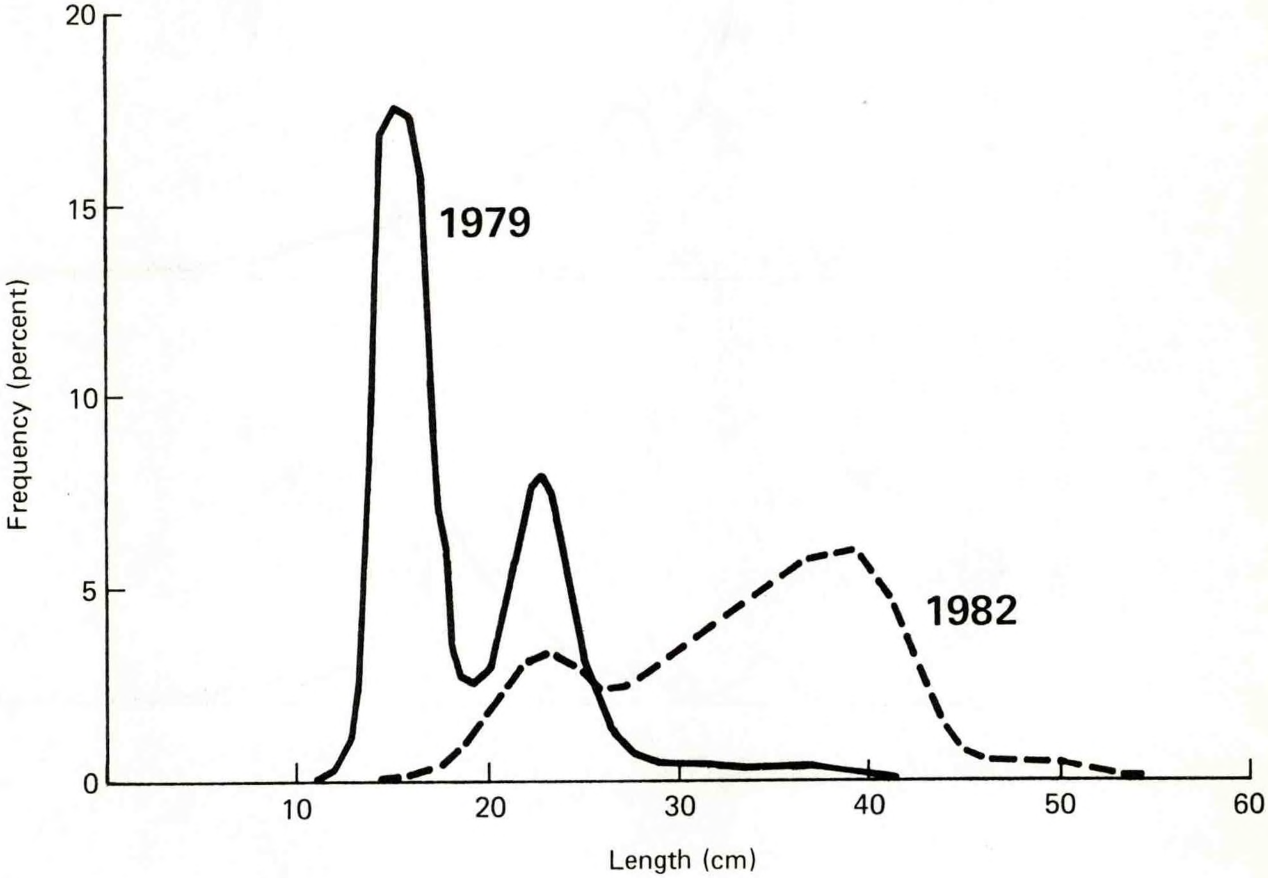

Figure 6.--Length-frequency distribution of walleye pollock taken in midwater over the continental shelf and slope of the eastern Bering Sea during Northwest and Alaska Fisheries Center hydroacoustic surveys in 1979 and 1982.

MAXIMUM SUSTAINABLE YIELD

Maximum sustainable yield (MSY) for eastern Bering Sea pollock has been estimated by two methods: the general production model of Pella and Tomlinson (1969), and the method of Alverson and Pereyra (1969)--the latter for obtaining first approximations of yield per exploitable biomass. Estimates thus derived for the eastern Bering Sea, from data available prior to 1974, ranged from 1.11 to 1.58 million t (Low 1974). The incorporation of 1974-76 data, and the application of the procedure of Rivard and Bledsoe (1977), resulted in an estimated MSY of 1.5 million t (Low et al. 1978).

Based on the premise that the Aleutian Island region stock is independent of that in the eastern Bering Sea, a separate optimum yield has, in the past, been established for this area by the North Pacific Fishery Management Council. The optimum yield there was set at 100,000 t although MSY was not estimated because of lack of data on the Aleutian population.

A biomass estimate for pollock in the Aleutian region can now be computed, however, based on the 1980 U.S.-Japan demersal trawl survey in that region. The estimate thus derived was 419,900 t. Yet the biomass of pollock sampled by demersal trawls may only represent one-half to one-third the total biomass of pollock in the Aleutians, as indicated by a comparison of biomass estimates from demersal trawl surveys and those from cohort analysis and hydroacoustic surveys in the eastern Bering Sea. Assuming a vertical distribution of pollock in the Aleutians similar to that in the eastern Bering Sea, the overall biomass of pollock in the Aleutians may approach or exceed 1.0 million t.

EQUILIBRIUM YIELD

Following the decline in CPUE in the eastern Bering Sea during 1972-75 when catches ranged from 1.4-1.9 million t, CPUE stabilized in 1976-81 when catches ranged from 0.9 to 1.2 million t. The CPUE from the NWAFC demersal trawl survey (Table 3) indicates that abundance in 1982 remained at much the same level as the 1975-81 estimates. This suggests that catches in the range of 0.9-1.2 million t have been close to an equilibrium yield (EY) since 1975.

Evidence was presented to show that year-classes 1979-81 appear to be below average strength with the 1981 year-class being particularly weak. The low production of these year classes may reduce the abundance of the population in the years immediately ahead. There is no evidence from available information that abundance declined markedly in 1982 relative to 1975-81, but the population should be closely monitored in the next few years.

Exploitation rates in 1975-81 have been low (8-12%) for a relatively short-lived species like walleye pollock. Even though abundance of the fishable stock may be reduced by poor recruitment in the next few years, there is no evidence of a decline thus far and the population should be capable of sustaining exploitation rates somewhat higher than it has experienced in recent years. Combined hydroacoustic and demersal trawl survey data indicated that the biomass of pollock in the eastern Bering Sea was 11.0 million t in 1979 while cohort analysis indicated biomass was at least 9.9 million t in 1979 and 9.5 million t in 1980. Based on CPUE data from the fishery and research vessel surveys, which have shown little change or slight increases between 1980 and 1981 or 1982, the biomass in 1982 would be expected to be similar to that in 1980. EY is therefore estimated to be the same as 1981 or 1.2 million t.

For the Aleutian region the EY is estimated to be the same as the approximation of optimum yield or 100,000 t.

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PACIFIC COD

by

Richard G. Bakkala, Vidar G. Wespestad, and Harold H. Zenger, Jr.

INTRODUCTION

The condition of Pacific cod, *Gadus macrocephalus*, in the eastern Bering Sea has been assessed through annual research vessel surveys since 1973. Assessment of the population in the Aleutian Islands region has been achieved only recently. Two groundfish trawl surveys have been conducted in the Aleutian Islands since 1980. The first was an extensive U.S.-Japan cooperative survey during July and August 1980 which covered virtually the entire Aleutian archipelago from Unimak Pass to Attu Island (Figure 1). General results from the U.S. portion of the 1980 survey have been reported by Ronholt et al. (1982), and a joint report is being prepared by U.S. and Japanese scientists. Brown and Wilderbuer (1981) reported on the biological characteristics of Pacific cod captured during the survey.

A second trawl survey, limited to the Aleutian Islands from Unimak Pass to Atka Island, was carried out in February and March 1982 by the Northwest and Alaska Fisheries Center (NWAFC). The principal objective was to assess the abundance of Pacific cod while they were aggregated for spawning in this area. Survey patterns and sampling techniques were similar to those outlined in Ronholt et al. (1982), although particular emphasis was placed on the spawning concentrations on the Cape Sarichef-Akutan Island and Seguam Pass grounds.

CONDITION OF STOCKS

Commercial Catches

Pacific cod are distributed widely over the Bering Sea continental shelf and slope and have a distributional pattern similar to that of walleye pollock,

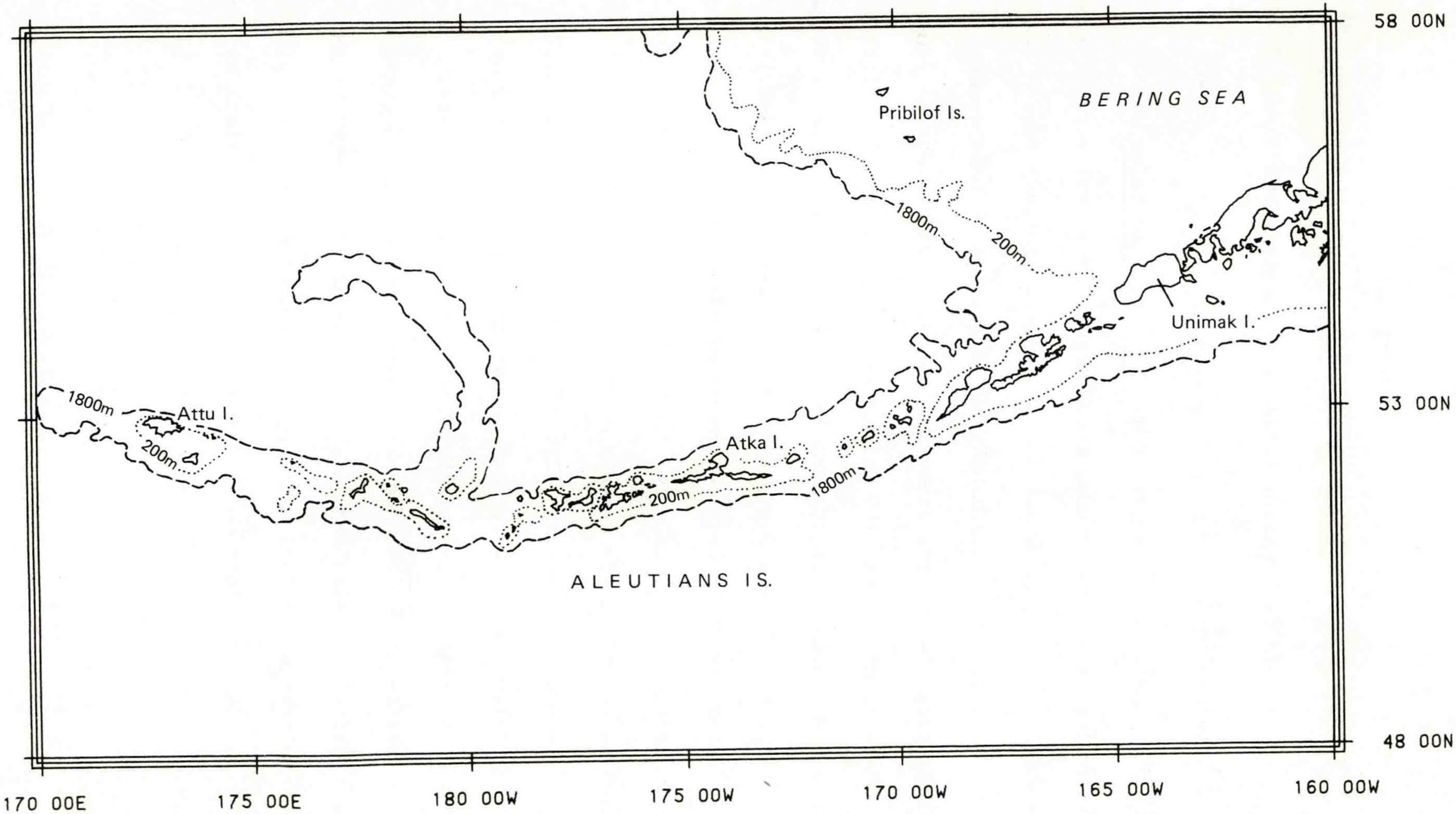

Figure 1.--Aleutian Islands region.

Theragra chalcogramma. During the early 1960s, a fairly large Japanese longline fishery harvested cod for the frozen fish market. Beginning in 1964, the Japanese North Pacific trawl fishery for walleye pollock expanded, and cod became an important incidental catch in the pollock fishery. At present, cod are believed to be an occasional target species of the Japanese trawl fisheries when high concentrations are detected during pollock fishing operations. They also remain a target species of the Japanese longline fishery. Recently a U.S. domestic trawl fishery and U.S.-Republic of Korea (ROK) and U.S.-USSR joint venture fisheries began operations in the eastern Bering Sea and Aleutian Islands areas, taking 14,200 t in 1980 and 23,700 t in 1981.

Annual catches of Pacific cod by all nations in the eastern Bering Sea and Aleutians increased from 13,600 t in 1964 to about 70,400 t in 1970; since then, catches have varied between 36,600 and 64,600 t (Table 1). Catches in 1980 and 1981 increased markedly from the level of the previous 3 years, primarily because of catches from the new joint-venture and U.S. domestic fisheries. Japanese fisheries, however, continue to account for the major portion of the catch as they have since 1964.

Relative Abundance

The abundance of Pacific cod in the eastern Bering Sea has increased substantially since the mid-1970s. The relative abundance of cod increased sixfold between 1976 and 1979 (Figure 2) based on NWAFC research survey data in a comparative fishing area in the southeast Bering Sea (Figure 3). Based on data from large-scale surveys that have sampled major portions of the eastern Bering Sea (see Figure 2 in the article on walleye pollock by Bakkala and Wespestad in this Technical Memorandum), the catch per unit of effort (CPUE) of cod apparently increased approximately 7 times (from 2.7 to 19.8 kg/hectare (ha)) between 1975 and 1979. Data from the large-scale 1980 and 1981 NWAFC surveys

Table 1.--Commercial catches (t) of Pacific cod by area and nation, 1964-81[1/].

Year	Eastern Bering Sea							Aleutian Islands region						E. Bering Sea and Aleutians combined
	Japan	USSR	ROK [2/]	Other nations [3/]	Joint ventures [4/]	U.S. [5/]	Total	Japan	USSR	ROK	Other nations	Joint ventures	Total	
	t							t						
1964	13,408	-	-				13,408	241	-	-			241	13,649
1965	14,719	-					14,719	451	-				451	15,170
1966	18,200	-					18,200	154	-				154	18,354
1967	32,064	-	-				32,064	293	-	-			293	32,357
1968	57,902	-	-				57,902	289	-	-			289	58,191
1969	50,351	-	-				50,351	220	-	-			220	50,571
1970	70,094	-	-				70,094	283	-	-			283	70,377
1971	40,568	2,486	-				43,054	425	1,653	-			2,078	45,132
1972	35,877	7,028	-				42,905	435	-	-			435	43,340
1973	40,817	12,569	-				53,386	566	411	-			977	54,363
1974	45,915	16,547	-	-			62,462	1,334	45	-			1,379	63,841
1975	33,322	18,229	-	-			51,551	2,581	257	-			2,838	54,389
1976	32,009	17,756	716	-			50,481	3,862	312	16			4,190	54,671
1977	33,141	177	-	2			33,320	3,162	100	-			3,262	36,582
1978	41,234	419	859	-			42,512	3,165	120	6			3,291	45,803
1979	28,532	1,956	2,446	47			32,981	5,171	414	6			5,591	38,572
1980	27,334	7	6,346	1,371	8,370	5,858	49,286	2,834	4	58	9	86	2,991	52,277
1981	27,570		6,147	2,481	7,410	16,308	59,916	2,426		476	12	1,749	4,663	64,579

1/ Catch data for 1964-79 as reported by fishing nations and for 1980 and 1981 from French et al., 1981, 1982.

2/ Republic of Korea.

3/ Taiwan, Poland, and Federal Republic of Germany (West Germany).

4/ Joint ventures between U.S. fishing vessels and Japanese, Polish, ROK, West German, and USSR. processing vessels.

5/ U.S. vessels delivering catches to domestic processors.

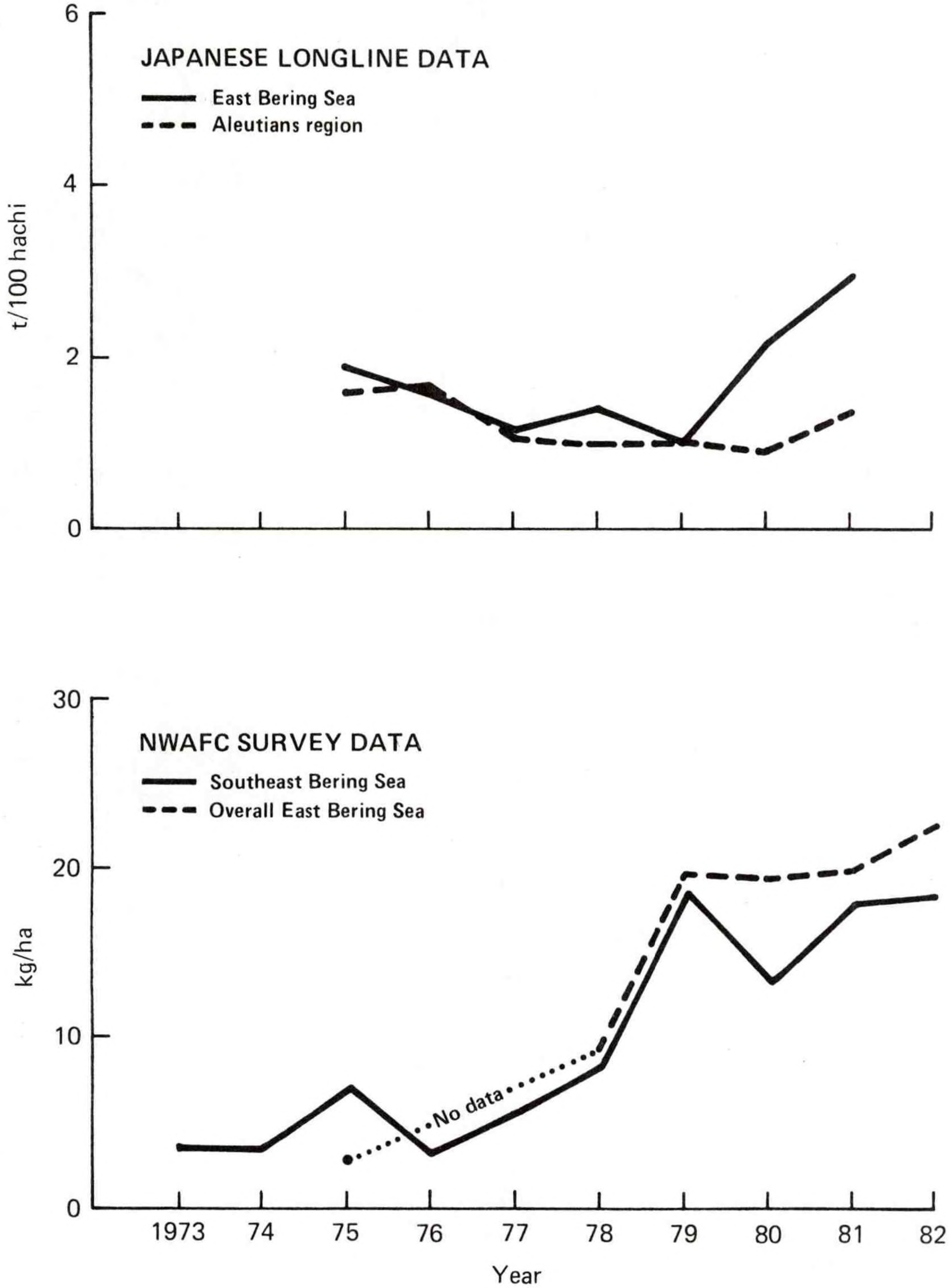

Figure 2.--Relative abundance of Pacific cod as shown by Japanese longline fishery data in the eastern Bering Sea and Aleutian Islands area and by data from Northwest and Alaska Fisheries Center (NWAFC) surveys in the eastern Bering Sea (a hachi is a unit of longline gear 100 m long).

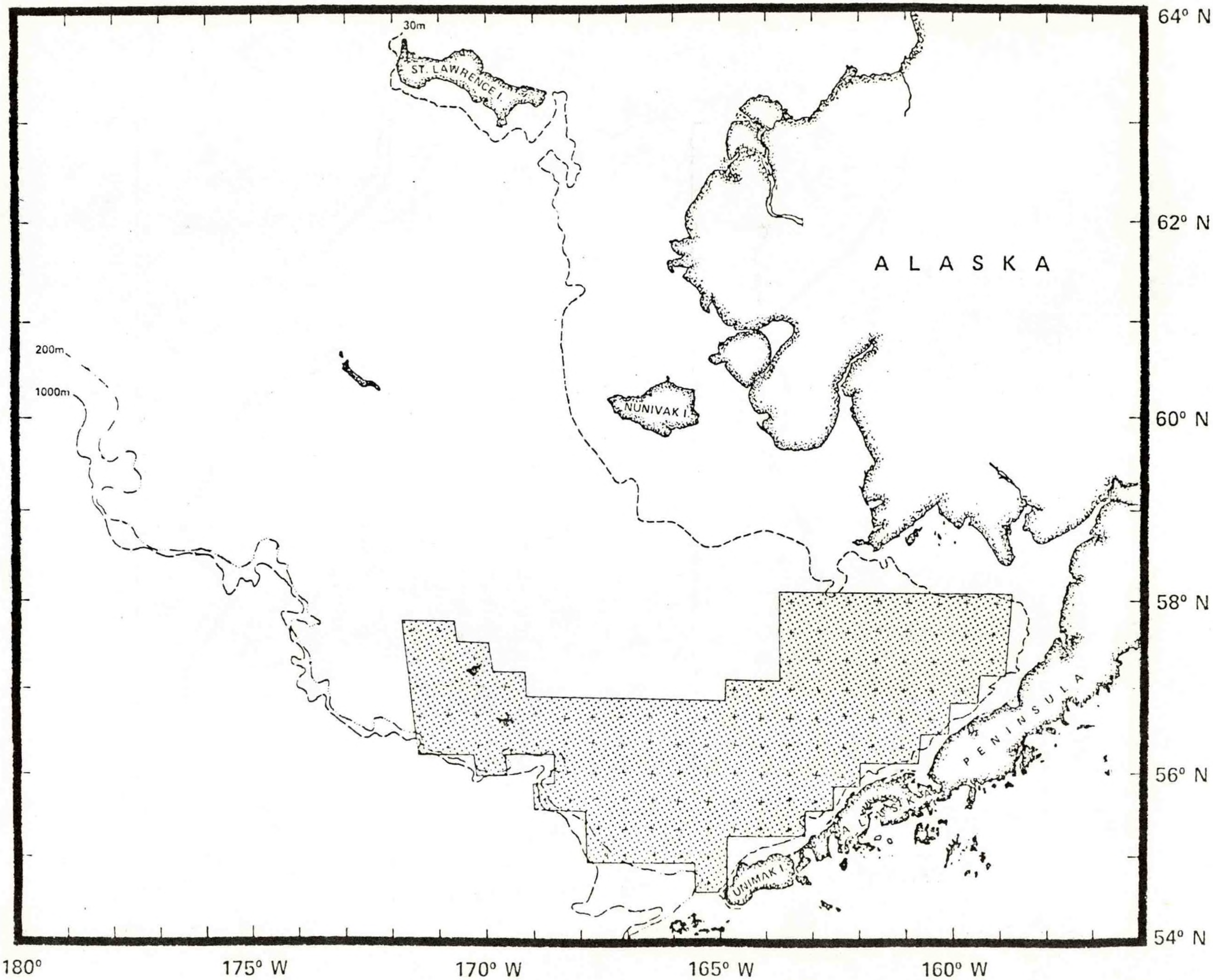

Figure 3.--Comparative fishing area sampled annually during Northwest and Alaska Fisheries Center demersal trawl surveys in 1973-82.

produced CPUE values similar to those in 1979, ranging from 19.5-19.8 kg/ha. The 1982 survey value was somewhat higher at 22.2 kg/ha.

Indices of abundance from Japanese commercial pair trawl and stern trawl vessels do not appear to have accurately reflected trends in abundance of cod (Bakkala et al. 1981). This may have resulted from cod being a nontarget species in these trawl fisheries. Data from the Japanese longline fishery, which targets on Pacific cod at times, may be more representative of stock abundance. Figure 2 illustrates trends in relative abundance from longline catch and effort data from the eastern Bering Sea and Aleutian regions. Only those catches having 50% or more Pacific cod were used in the analysis to identify effort primarily directed toward cod. The trends for the eastern Bering Sea and Aleutians were similar from 1975 to 1979, showing a general decline from more than 1.5 t/100 hachi to about 1.0 t/100 hachi (A hachi is a unit of longline gear 100 m in length.) Relative abundance in the eastern Bering Sea then increased in 1980 and 1981, reaching about 3.0 t/100 hachi in 1981. An increase in the Aleutians was not evident until 1981. The increase in abundance of cod was shown earlier by survey data (1978) than longline fishery data (1980-81) because cod recruit to nearshore waters sampled by research vessels at an earlier age than they recruit to outer shelf and slope waters fished by longline vessels.

Biomass Estimates

Estimates of biomass from large-scale NWAFC demersal trawl surveys in the eastern Bering Sea since 1975 have been as follows:

Year	Biomass mean estimate (t)	95% confidence intervals (t)
1975	64,500	51,500 - 77,500
1978	312,000	87,300 - 536,800
1979	792,300	603,200 - 981,400
1980	913,300	795,700 -1,031,000
1981	840,100	691,700 - 988,400
1982	1,013,900	875,000 -1,152,800

Estimates through 1981 had suggested that the increase in biomass resulting from recruitment of the strong 1977 year-class had peaked in 1980, but the preliminary 1982 estimate was higher than the 1980 and 1981 values. The 95% confidence intervals in these latter 3 years overlapped, however, indicating that these estimates were not significantly different.

Two biomass estimates have been calculated for the overall Aleutian Islands region based on data from the 1980 cooperative U.S.-Japan survey. One estimate was based on data originating from all vessels participating in the survey (two U.S. vessels and one Japanese vessel) and the other from U.S. vessels alone. The estimates from all vessels was 217,300 t (Table 2). However, 52,400 t of the total was located on the Pacific side of the eastern Aleutians (east of 170°W long.) which is part of the Shumagin Island area, an International North Pacific Fisheries Commission (INPFC) statistical area in the Gulf of Alaska. Thus, an estimated 164,900 t of cod was located in Bering Sea INPFC areas based on the catch and effort data from all vessels participating in the survey.

The second biomass estimate, based on catch and effort data from only the U.S. vessels, was 299,300 t, of which 68,200 t was located in the Shumagin INPFC area. Thus, of this second estimate, 231,100 t of biomass was located in Bering Sea INPFC areas. This latter estimate is believed to more accurately reflect the actual biomass of cod in the Aleutian region based on evidence

Table 2.--Biomass and catch per unit of effort (CPUE) estimates for Pacific cod of the Aleutian Islands region by depth and area based on data from the cooperative U.S.-Japan demersal trawl survey during summer 1980.

	Area (long.)							
	170°W - 170°E (Bering Sea and Pacific Ocean sides)		165°W - 170°W (Bering Sea side)		165°W - 170°W (Pacific Ocean side)		Total all areas	
Depth (m)	CPUE (kg/ha)	Biomass (t)	CPUE (kg/ha)	Biomass (t)	CPUE (kg/ha)	Biomass (t)	CPUE (kg/ha)	Biomass (t)
0-100	18	13,004	113	32,456	77	25,195	52	70,655
101-200	61	62,557	204	38,971	76	25,876	82	127,404
201-300	23	13,400	56	3,403	11	1,335	24	18,138
301-400	1	794	4	316	-	-	1	1,110
Total all depths	29	89,755	121	75,146	66	52,406	48	217,307

from comparative trawling experiments which indicated that trawls used by U.S. vessels were more efficient for catching cod than those used by Japanese vessels. Assuming that the catchability coefficient of trawls fished by U.S. vessels did not exceed 1.0, the biomass estimates from these more efficient trawls would more nearly approximate the actual biomass.

Biomass estimates were also derived from the winter 1982 NWAFC survey for cod which sampled the area of the eastern Aleutians from Unimak Pass to Atka Island (Table 3). Only those areas actually sampled were used in deriving these estimates, since poor bottom conditions often precluded trawl operations and the presence of cod could not be verified in the nonsampled areas. The overall biomass estimate for this area was 305,700 t, of which 282,300 t was located in the Bering Sea-Aleutian areas. This estimate exceeds that from the 1980 survey for the entire Aleutian region, suggesting that cod may migrate from other areas in winter to spawn in the eastern Aleutian Islands region.

Size and Age Composition

The increase in abundance of cod in the eastern Bering Sea has primarily been due to the recruitment of the strong 1977 year-class to the population. Population estimates by size group illustrate the recruitment of the strong 1977 year-class to the survey area as age-1 fish in 1978 and the predominance of this year-class in the length-frequency distributions through 1981 (Figure 4). In 1982, for the first time, later year-classes predominated in terms of population numbers. However, the strength of the 1977 year-class is still evident from the relatively high population numbers of fish near 60 cm in length in 1982 (which was the approximate mean length of the 1977 year-class in 1982) compared to earlier year-classes at this size.

The size compositions of cod in the Aleutian region as shown by the summer 1980 and winter 1982 surveys are illustrated in Figure 5. The 1980 distribution

Table 3.--Biomass and catch per unit of effort (CPUE) estimates for Pacific cod in waters of the eastern Aleutian Islands by depth and area based on Northwest and Alaska Fisheries Center survey data during February and March 1982.

	Area (long.)							
	170°W - 174°W (Bering Sea and Pacific Ocean sides)		165°W - 170°W (Bering Sea side)		165°W - 170°W (Pacific Ocean side)		Total all areas	
Depth (m)	CPUE (kg/ha)	Biomass (t)	CPUE (kg/ha)	Biomass (t)	CPUE (kg/ha)	Biomass (t)	CPUE (kg/ha)	Biomass (t)
0-100	-	-	146	28,644	-	-	146	28,644
101-200	1,021	127,188	454	103,929	52	22,342	410	253,459
201-300	118	9,127	364	12,653	-	-	194	21,780
301-400	-	-	100	1,768	-	-	100	1,768
Total all depths	675	136,315	326	146,994	52	22,342	334	305,651

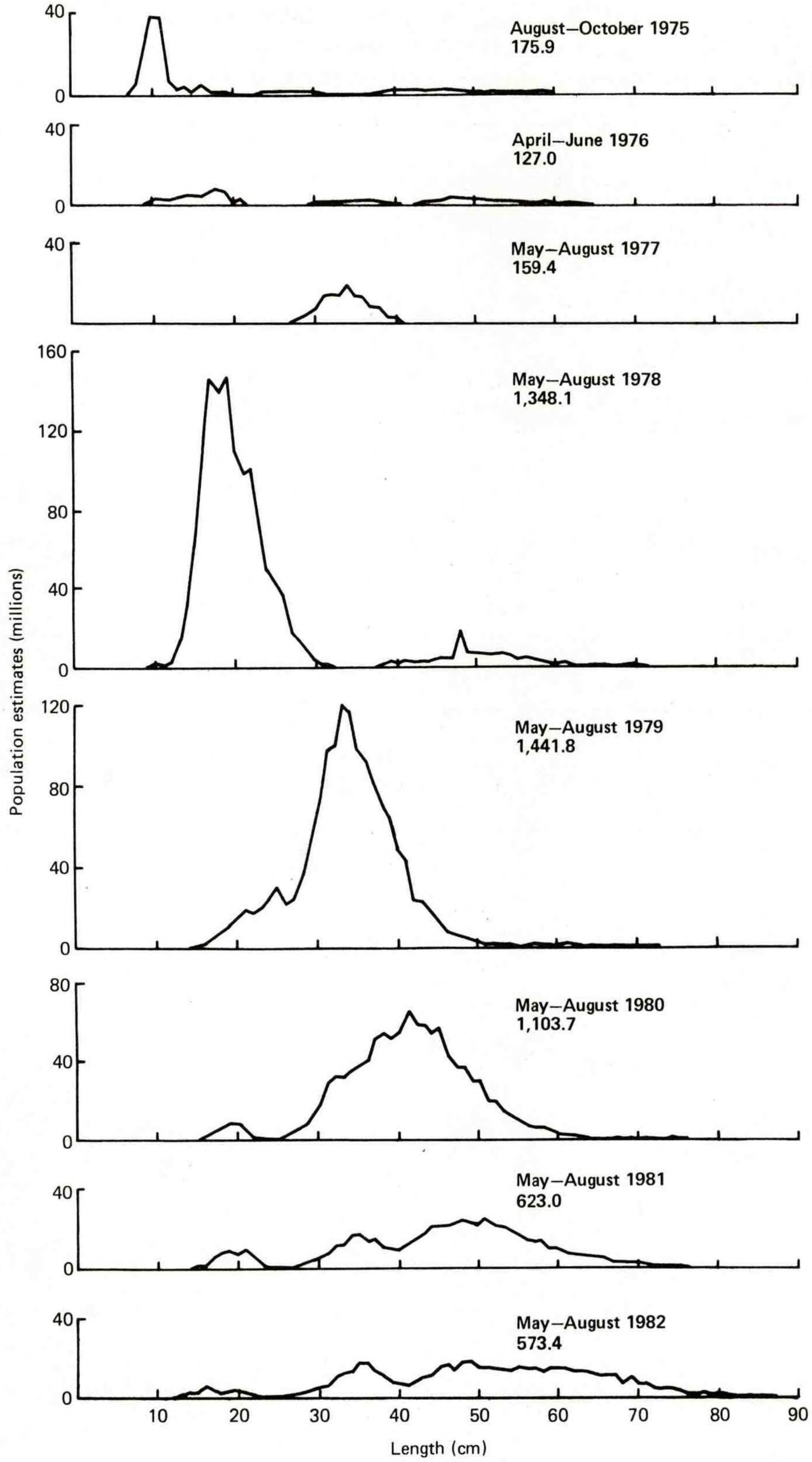

Figure 4 .--Population estimates of Pacific cod by centimeter length interval in the eastern Bering Sea as shown by annual Northwest and Alaska Fisheries Center demersal trawl surveys in 1975-82. Numbers below dates are estimated population numbers within the survey areas.

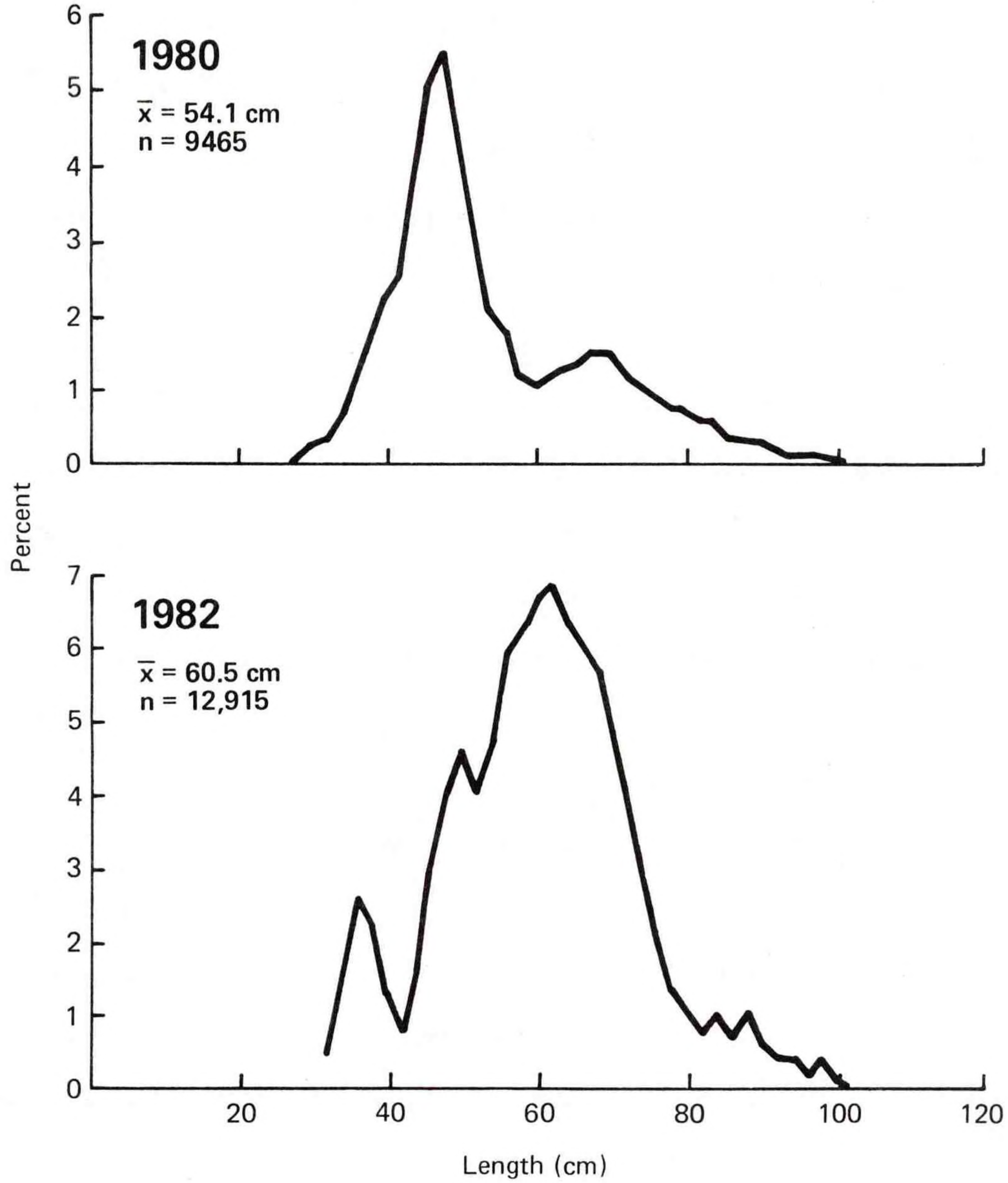

Figure 5.--Length-frequency distributions of Pacific cod sampled throughout the Aleutian Islands region during July-August, 1980 and in the eastern Aleutian Islands during February-March, 1982. Numbers of fish measured are given below mean lengths.

was predominantly fish with a modal length at 47 cm. A second smaller mode was observed at 69 cm. The mode at 47 cm represent age-3 fish of the 1977 year-class based on the mean length of age-3 cod during the 1982 Aleutian survey (Table 4). These data suggest that the 1977 year-class was also relatively strong in the Aleutian Islands region. A major difference between length-frequency distributions of eastern Bering Sea and Aleutian Island cod in 1980 was the much higher proportion of large fish (greater than 60 cm) in the Aleutian Islands population.

The size composition of cod in the eastern Aleutians during the winter 1982 survey was predominated by fish with a modal peak length of 61 cm (Figure 5). This mode primarily represented fish of the 1977 year-class (Table 4).

Unreliable results may be obtained from aging cod by counts of annual rings from scales (Bakkala 1982). A modal analysis of length-frequency data using the methods of MacDonald and Pitcher (1979) was therefore used as an alternate aging method to provide age-specific population estimates from eastern Bering Sea and Aleutian survey data (Tables 4 and 5). The modal analysis may not completely separate population numbers to age groups accurately, especially in the case of age groups adjacent to an abundant age group such as those associated with the 1977 year-class. There is also the obvious problem of some fully recruited year-classes showing higher abundance at an older age, such as shown by the 1980 and 1981 eastern Bering Sea data (Table 5), although this could also result from sampling biases. Regardless of these reservations, the results from the length frequency method appear to reflect observed trends in age and growth of the Bering Sea cod populations.

Samples of cod from the winter 1982 Aleutian survey have been aged using the length-frequency modal analysis, but samples from the summer 1980 Aleutian survey have not been analyzed. Analysis of the winter survey data indicates

Table 4.--Population estimates and mean fork lengths of Pacific cod by age group in the Aleutian Islands from Unimak Pass to Seguam Pass, February-March 1982. Age composition was determined by the method of MacDonald and Pitcher (1979).

		Males			Females			Males and females combined		
Age	Year-class	Percent by age	Population numbers by age	Mean length (cm)	Percent by age	Population numbers by age	Mean length (cm)	Percent by age	Population numbers by age	Mean length (cm)
2	1980	8.6	3,754,300	36.2	7.9	3,313,500	36.1	8.3	7,067,800	36.2
3	1979	9.9	4,321,800	47.5	10.1	4,236,200	48.2	10.0	8,558,000	47.8
4	1978	15.9	6,941,000	55.3	18.4	7,717,400	58.5	17.1	14,658,400	57.0
5	1977	38.7	16,894,300	62.4	34.6	14,512,100	67.9	36.7	31,406,400	64.9
6	1976	10.9	4,758,300	69.3	10.8	4,529,800	74.5	10.9	9,288,100	71.8
7	1975	6.1	2,662,900	73.3	2.6	1,090,500	78.0	4.4	3,753,400	74.7
8	1974	4.0	1,746,200	77.2	5.9	2,474,600	81.2	4.9	4,220,800	79.5
9	1973	2.0	873,100	81.9	3.7	1,551,900	89.3	2.8	2,425,000	86.6
10	1972	1.6	698,500	87.6	3.4	1,426,000	93.5	2.5	2,124,500	91.6
11	1971	2.3	1,004,100	90.8	2.6	1,090,500	97.3	2.4	2,094,600	94.2
		Total	43,654,500			41,942,500			85,597,000	

Table 5.--Estimated population numbers (in millions of fish) for Pacific cod of the eastern Bering Sea as determined by the method of MacDonald and Pitcher (1979). Population numbers for the 1977 year-class are underlined.

Age (yr)	Year 1976	1977[1/]	1978	1979	1980	1981
1	55.4	0	1,268.2	158.4	42.7	62.0
2	23.9	486.9	24.2	1,106.6	442.4	132.3
3	24.5	14.0	32.8	213.5	477.4	145.4
4	11.1	24.4	24.8	12.0	93.6	166.4
5	3.7	8.6	23.1	10.6	30.9	49.9
6	3.6	4.5	9.8	6.4	6.5	32.5
7	2.8	2.8 (ages 7 to > 10)	2.8	6.3	2.1	22.1
8	0.3		4.2	2.4	3.3	9.0
9	1.2		2.1	0.7	3.4	1.1
> 10	0.4		1.8	1.1	1.4	2.1
Total	127.0	541.1	1,393.9	1,518.0	1,103.7	623.0

1/ The 1977 survey was limited to the southeast Bering Sea as shown in Figure 3. Population numbers shown here were expanded to approximate numbers that would have been available if the 1977 survey area was equivalent in area to the 1979 survey area.

that cod sampled in the Unimak Pass to Atka Island area in February and March 1982 consisted of age groups 2-11 years (Table 4). The 1977 year-class at age 5 predominated--representing an estimated 36.7% of the total population numbers. Older age groups (6-11 years) also contributed substantially to catches, representing 28% of the total population numbers.

Results of the analysis for eastern Bering Sea cod illustrate the predominance of the 1977 year-class in the population since 1978 (Table 5).

PROJECTIONS OF ABUNDANCE

Abundance of eastern Bering Sea cod was projected through 1986 by Wespestad et al. (1982) using a numeric population simulator. Projected population numbers were estimated to be 517 million fish and biomass about 600,000 t in 1982.

Estimated population numbers for age 2 and older cod (547 million fish) and biomass (1.0 million t) observed from the 1982 survey data were higher than shown by the simulations. Projected abundance was believed to be lower than observed from 1982 survey data for four principal reasons: 1) the natural mortality coefficient (0.7) used in the simulation may be slightly higher than the actual value; 2) new trawls used by research vessels in 1982 may have been more efficient for cod than trawls used by research vessels in 1979; thus, the 1979 survey population estimates, which were used as base year data for the simulation, may have been underestimated; 3) growth rates in 1982 were different than used in the projections; and 4) weights-at-age used to convert population numbers to biomass were found to be inaccurate and underestimated biomass by 17%.

Projected 1982 population numbers from the numeric population simulator, however, were similar to those estimated from survey data (517 million compared to the observed 547 million from survey data). Based on these results, population numbers and biomass were projected in 1983-86 using 1982 survey population estimates as base year data (Table 6). The projections were made using a natural mortality coefficient of 0.7, and the lower level of average recruitment (221 million fish at age 2) estimated by Wespestad et al. (1982). Exploitation rates on exploitable age groups (ages 3-11) were 0.4 in 1983 and 1984 and 0.2 in 1985 and 1986. The above authors concluded that these exploitation rates would provide the largest cumulative catches in 1983-86 and still maintain the parental stock at a relatively high level. The exploitation rate applied in 1982 was based on a catch of 50,000 t which is an approximation of what the catch might be in the remaining months of 1982 following the late May to early August period of the 1982 survey.

The projections indicate that catches of 228,000 t can be taken from the eastern Bering Sea population in 1983 and 118,000 t in 1984, after which catches may have to be reduced to below 100,000 t.

MAXIMUM SUSTAINABLE YIELD

It is apparent that the eastern Bering Sea cod population is subject to wide fluctuations in abundance. Most data come from a period when the population was undergoing a rapid increase in abundance. Thus, observations of the population over a period of low or stable abundance is not available. In addition, survey data for only one year are available from the Aleutian Islands region, and the abundance estimates from this survey may also represent the Aleutian population at a relatively high level of abundance. It is therefore difficult to derive estimates of maximum sustainable yield (MSY) based on information from only a portion of the abundance cycle of the population. For these reasons, an estimate of MSY with present data is not considered valid.

Table 6.--Estimated population numbers and biomass by age for Pacific cod of the eastern Bering Sea in 1982 and projected population numbers and biomass in 1983-86 (see Wespestad et al. 1982 for methods of projecting population abundance).

Age (yr)	Estimated population abundance in 1982 1/	Projected population abundance 2/			
		1983	1984	1985	1986
Population numbers (millions)					
2	122.8	221.0	221.0	221.0	221.0
3	98.2	61.0	109.7	109.7	109.7
4	137.7	45.0	14.3	25.8	40.0
5	157.9	63.1	10.6	3.4	9.4
6	26.0	72.4	14.8	2.5	1.2
7	1.3	11.9	17.0	3.5	0.9
8	1.3	0.6	2.8	4.0	1.3
9	0.7	0.6	0.1	0.7	1.5
10	0.7	0.3	0.1	0.0	0.2
11	0.3	0.3	0.1	0.0	0.0
All ages combined	546.9	476.2	390.7	370.6	385.2
Population biomass (1,000 t)					
2	68.4	123.1	123.1	123.1	123.1
3	109.8	68.2	122.8	122.8	122.8
4	240.7	78.7	25.1	45.1	69.9
5	377.0	150.7	25.2	8.0	22.4
6	78.5	218.6	44.8	7.5	3.7
7	4.8	43.4	61.9	12.7	3.3
8	5.8	2.6	12.4	17.6	5.6
9	3.5	3.2	0.8	3.5	7.8
10	4.4	2.0	0.9	0.2	1.6
11	2.3	2.4	0.6	0.3	0.1
All ages combined	895.2	692.9	417.6	340.9	360.3
Estimated exploitation rates (E), fishing mortality (F), and potential catches (1,000 t)					
E	0.06	0.40	0.40	0.20	0.20
F	0.080	0.748	0.748	0.310	0.132
Catch	50.0	227.9	117.8	43.6	47.4

1/ Population number and biomass estimates in 1982 from Northwest and Alaska Fisheries Center survey data.

2/ Projections of population numbers and biomass are based on a natural mortality coefficient of 0.7, recruitment at age 2 of 221 million fish and exploitation rates of 0.4 on exploitable ages 3-11 in 1983 and 1984 and 0.2 in 1985 and 1986.

EQUILIBRIUM YIELD

Equilibrium yield (the annual yield which allows the stock to be maintained at approximately the same level of abundance in successive years) is not an appropriate management concept to apply to the cod resource at the present time. The population is at a high point in its natural cycle of abundance due to the strong 1977 year-class, and the abundance of this year-class is expected to decline from natural causes in the next few years. Thus, yields cannot be adjusted to maintain the stock at the present level but should be increased to take advantage of the available surplus before it is lost to natural mortality.

Based on a number of simulations of the eastern Bering Sea cod population using various exploitation rates, Wespestad et al. (1982) concluded that the exploitation strategy that appeared to provide the greatest cumulative catch in 1983-86 was to increase exploitation rates to 0.4, while the strong 1977 year-class remained relatively abundant in the population. Based on these findings and the projections in Table 6, the allowable catch in the eastern Bering Sea in 1983 is estimated to be 228,000 t. Assuming that the change in biomass in the Aleutians between 1980 and 1983 is the same as that estimated in the eastern Bering Sea (913,300 t in 1980 and 692,900 t in 1983), the 1983 biomass in the Aleutians would be estimated as 175,600 t (231,100 t · 0.76). Again using an exploitation rate of 0.4, the Aleutian population would provide another 70,200 t of allowable catch in 1983. Thus, the overall allowable catch in the eastern Bering Sea-Aleutians areas for 1983 is estimated to be approximately 298,200 t from a biomass of approximately 870,000 t.

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YELLOWFIN SOLE

by

Richard G. Bakkala and Vidar G. Wespestad

INTRODUCTION

The yellowfin sole, Limanda aspera, resource of the eastern Bering Sea was substantially reduced in abundance by intense exploitation in the early 1960's. Cohort analyses (Wakabayashi et al. 1977, Bakkala et al. 1982) indicated that this intense exploitation in early years of the fishery and continued exploitation through the 1960's reduced the exploitable biomass to a third or less of pre-1960 levels. The resource began to recover in about 1972 and abundance in 1982 is estimated to be as high or higher than pre-1960 levels.

STOCK STRUCTURE

The possible existence of a southern and northern stock of yellowfin sole in the eastern Bering Sea was discussed by Wakabayashi et al. (1977). The conflicting meristic and morphological information reviewed by the authors prevented any decision with regard to the stock question. Biochemical genetic variations in yellowfin sole from the southern and northern areas of the eastern Bering Sea, as well as from samples of the Gulf of Alaska, were examined by Grant et al. (1981). Results indicated that samples from the two areas of the eastern Bering Sea were not significantly different, but that significant differences were found between the Bering Sea and Gulf of Alaska samples. The biochemical analysis showing a highly significant difference between Gulf of Alaska and eastern Bering Sea samples lends credence to the findings that only one stock exists in the eastern Bering Sea. Based on these findings, assessment of the yellowfin sole population in the eastern Bering Sea will be based on the assumption of a single stock.

CONDITION OF STOCK

Catch Statistics

Variations in annual catches of yellowfin sole (Table 1) can be summarized as follows:

Period	Number of years	Range in annual catches (t)	Average annual catch (t)
1954-58	5	12,562 - 44,153	24,049
1959-62	4	185,321 - 553,742	403,967
1963-68	6	53,810 - 162,228	99,928
1969-71	3	133,079 - 167,134	153,537
1972-77	6	42,235 - 78,240	57,950
1978-81	4	87,391 - 138,433	105,535

Catches in 1972-77 were relatively low due primarily to the absence of a directed fishery for yellowfin sole by the USSR. The USSR reentered the yellowfin sole fishery in 1978-79, and catches nearly doubled over the average annual levels of 1972-77. The USSR was prohibited from fishing in the U.S. 200-mile fishery conservation zone in 1980 and 1981, although they were allowed to process catches taken by U.S. fishermen in joint venture operations. As a result of the absence of the USSR fishery, overall catches of yellowfin sole declined to 87,400 t in 1980 but increased to 97,300 t in 1981. Recent developments in the fishery have been the increased utilization of the resource by

Table 1.--Annual catches of yellowfin sole in the eastern Bering Sea (east of 180° long. and north of 54°N lat.) in metric tons.[1/]

Year	Japan	USSR	ROK	Others	Joint Venture	Total
	-------------------------	-------------------------	------------------------- t	-------------------------	-------------------------	-------------------------
1954	12,562					12,562
1955	14,690					14,690
1956	24,697					24,697
1957	24,145					24,145
1958	39,153	5,000				44,153
1959	123,121	62,200				185,321
1960	360,103	96,000				456,103
1961	399,542	154,200				553,742
1962	281,103	139,600				420,703
1963	20,504	65,306				85,810
1964	48,880	62,297				111,177
1965	26,039	27,771				53,810
1966	45,423	56,930				102,353
1967	60,429	101,799				162,228
1968	40,834	43,355	-			84,189
1969	81,449	85,685	-			167,134
1970	59,851	73,228	-			133,079
1971	82,179	78,220	-			160,399
1972	34,846	13,010	-			47,856
1973	75,724	2,516	-			78,240
1974	37,947	4,288	-			42,235
1975	59,715	4,975	-			64,690
1976	52,688	2,908	625			56,201
1977	58,090	283	-			58,373
1978	62,064	76,300	69			138,433
1979	56,824	40,271	1,919	3		99,017
1980	61,295	6	16,198	269	9,623	87,391
1981	63,961		17,179	115	16,046	97,301

1/ Source of catch data: 1954-76, Wakabayashi and Bakkala 1978; 1977-79, data submitted to the U.S. by fishing nations; 1980-81, French et al. 1981, 1982.

Republic of Korea (ROK) fisheries (16,200 t in 1980 and 17,200 t in 1981) and by joint venture fisheries (9,600 t in 1980 and 16,000 t in 1981).

Relative Abundance

The two sources of information used to examine trends in relative abundance for yellowfin sole are pair trawl data from the Japanese commercial fishery and U.S. research vessel data. The pair trawl catch and effort data used are those from 1° longitude by 1/2° latitude statistical blocks and months in which yellowfin sole made up 50% or more of the total catch. Effort data is adjusted for changes in horsepower.

The Japanese commercial fishery for yellowfin sole mainly operated in the months of October-March from 1969 to 1976 but since then operations have been shifting to summer and fall months. Catch per unit of effort (CPUE) values were originally calculated for the October-March period but, because of the seasonal changes in the fishery, have recently also been calculated for the September-December and July-October periods. The trends shown by the October-March and September-December data are similar (Table 2; Figure 1).

The CPUE trend lines from the September-March and September-December pair trawl data have shown a substantial increase in the relative abundance of yellowfin sole between the 1972-73 and the 1977-78 fishing seasons (Figure 1). Changes in fishing strategy between the 1973-74 and 1974-75 fishing seasons which increased the efficiency of the fleet (Bakkala et al. 1979) may have accounted for part of this increase. Based on the September-December trend line there was a decrease in CPUE in 1978, but the 1979 and 1980 values were the highest observed in the fishery. In 1981 there was a sharp decrease in CPUE. The 1979-81 values, however, may not be comparable to those in earlier years because fishing was not conducted in December in 1979 and 1981 and in November and December of 1980. The CPUE trend for the July-October period was

Table 2.--Catch, effort, and catch per unit of effort (CPUE) for yellowfin sole by Japanese pair trawlers in 1/2 degree by 1 degree statistical blocks and months in which yellowfin sole made up 50% or more of the total catch of groundfish.

Period	Fishing year	Catch (t)	Hours	Average hp	Thousands of hp hours	CPUE (t/thousand hp-hours)
Oct.-March	1969-70	14,250	1,925	1,200	2,310	6.17
	1970-71	26,766	1,762	1,200	2,114	12.66
	1971-72	25,873	2,937	1,400	4,112	6.29
	1972-73	32,354	2,788	1,400	3,903	8.29
	1973-74	27,234	1,853	1,400	2,594	10.50
	1974-75	32,456	833	1,400	1,166	27.84
	1975-76	40,126	988	1,400	1,383	29.01
	1976-77	28,792	641	1,400	897	32.10
	1977-78	28,243	503	1,400	704	40.12
Sept.-Dec.	1969	7,009	1,051	1,200	1,261	5.56
	1970	11,768	1,052	1,200	1,262	9.32
	1971	23,447	2,546	1,400	3,564	6.58
	1972	15,978	1,666	1,400	2,332	6.85
	1973	19,291	1,059	1,400	1,483	13.01
	1974	20,911	563	1,400	788	26.54
	1975	25,825	566	1,400	792	32.61
	1976	22,243	517	1,400	724	30.72
	1977	26,407	476	1,400	666	39.65
	1978	21,692	458	1,400	641	33.84
	1979	16,088	238	1,400	333	48.31
	1980	13,231	174	1,400	244	54.23
	1981	19,658	440	1,400	616	31.91
July-Oct.	1978	22,373	631	1,400	883	25.34
	1979	30,619	826	1,400	1,156	26.49
	1980	30,330	950	1,400	1,330	22.80
	1981	29,717	1,155	1,400	1,617	18.38

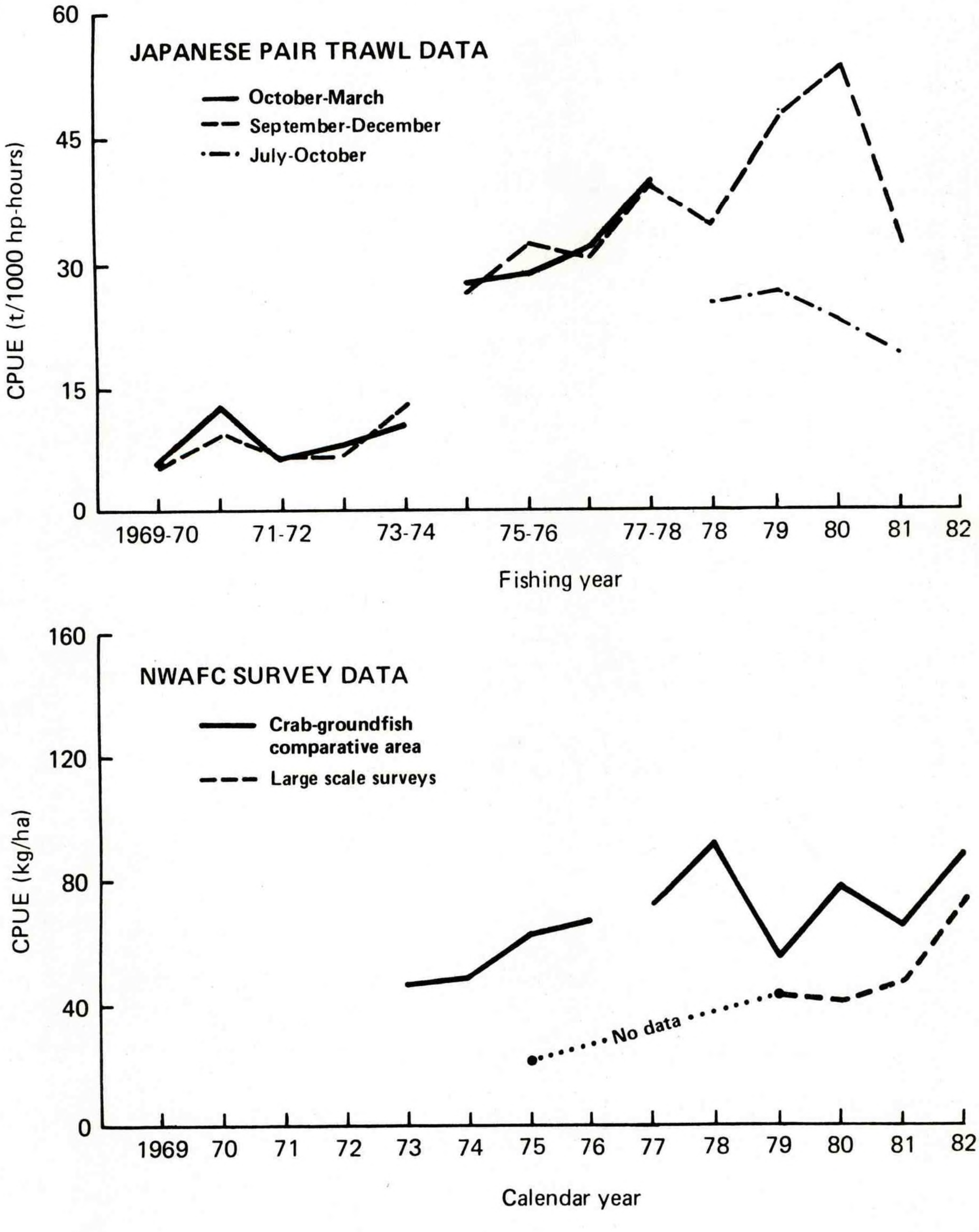

Figure 1.--Relative abundance (catch per unit of effort (CPUE)) of yellowfin sole in the eastern Bering Sea as shown by Japanese pair trawl data and by data from Northwest and Alaska Fisheries Center (NWAFC) demersal trawl surveys. Breaks in trend lines indicate changes in fishing gear or fishing techniques (see text).

relatively stable between 1978 and 1980 but showed a decrease in 1981. The decrease in abundance shown by the Japanese pair trawl data is not believed to be representative of the actual abundance trend of the population in view of the results from surveys and a cohort analysis that will be discussed later in the report.

The NWAFC research vessel survey data have also shown a major increase in abundance of yellowfin sole since 1973 (Figure 1). Data from the crab-groundfish comparative area in the southeastern Bering Sea (Figure 3, in the article on Pacific cod by Bakkala et al. in this Technical Memorandum, illustrates the comparative area) showed a lower level of abundance in 1979-81 than in 1978; however, this is believed to have been caused by a northward shift in the population of yellowfin sole in 1979-81 due possibly to the occurrence of relatively high bottom water temperatures in the eastern Bering Sea in those years. Actual trends in abundance are probably more accurately reflected for these recent years by data from the large-scale NWAFC surveys which have sampled the major portion of the eastern Bering Sea continental shelf. CPUE values from these comprehensive surveys showed an approximate doubling of the relative abundance (20 to 41 kg/ha) from 1975 to 1979. The 1980 value was similar (42 kg/ha) to that in 1979, and the 1981 value was somewhat higher at 48 kg/ha.

Preliminary analysis of this years survey data indicates that CPUE increased substantially in 1982 to 73.5 kg/ha. The 1982 survey was again a large-scale effort with extensive sampling of the eastern Bering Sea continental shelf north to the latitude of St. Matthews Island. Abundance estimates from the 1982 survey were considerably higher than those from the 1981 survey for a number of bottom tending species. In addition to yellowfin sole, substantial increases were shown for Pacific halibut, Hippoglossus stenolepis; flathead sole, Hippoglossoides elassodon; rock sole, Lepidopsetta bilineata;

and Alaska plaice, Pleuronectes quadrituberculatus. The reason for these major increases in abundance, which were so large for some of the species that they cannot be accounted for biologically, may be due to a change in the standard trawls used during the surveys. The 400-mesh eastern trawl had been the standard trawl used by most survey vessels up to 1981, but due to the increasing size of survey vessels in recent years, it has been necessary to adopt a larger trawl. The new standard trawl with an 83-foot footrope and 112-foot headrope is a larger version of the 400-mesh eastern trawl. Prior to the beginning of the 1982 survey, test fishing operations were conducted in the Bering Sea to assure that the new trawl tended bottom properly. As a consequence of these studies, the 83-112 trawl was rigged differently than in the past. Dandylines were changed from a single 25 fathom (fm) (46 m) section branching into two 15 fm (27 m) bridles for an overall length of 40 fm (73 m) to two 30 fm (55 m) double dandylines. In addition, 24 in (61 cm) chain extensions were attached between each end of the footrope and the lower dandyline to improve bottom contact of the footrope. The new rigging was assumed to result in good bottom tending characteristics of the trawl because substantial amounts of bottom debris were observed in catches.

Age composition

The primary reason for the increased abundance of yellowfin sole since the early 1970's has been the strength of the 1966-70 year-classes. These year-classes have predominated in research vessel catches, as well as in catches by the commercial fishery, since 1973 (Figure 2). The 1966-70 year-classes are now relatively old, ranging from 11 to 15 years in 1981. They still contribute the major share of commercial catches (55% in 1981), however, and may continue to contribute substantially to the commercial fishery in the next 3 or 4 years.

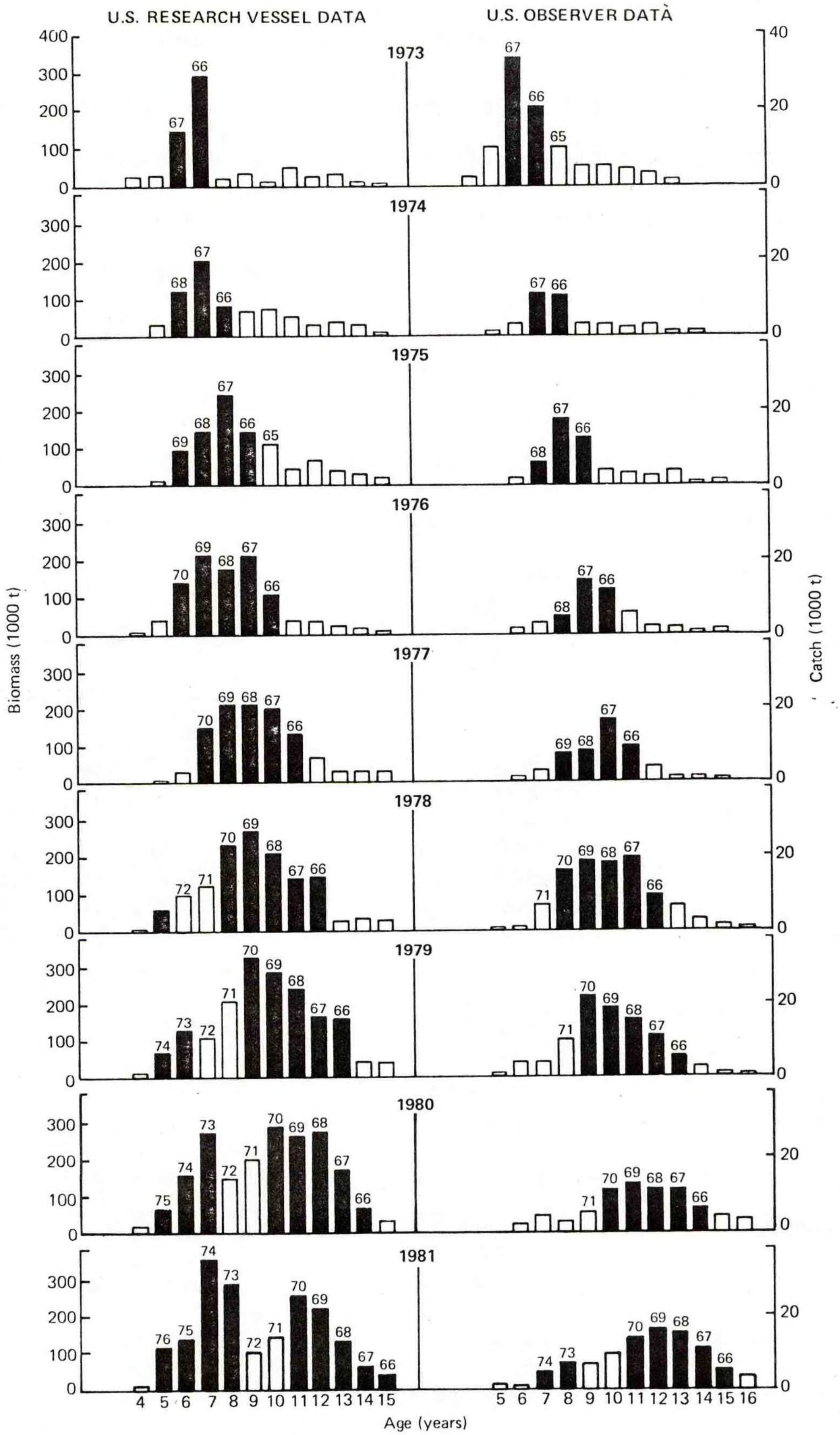

Figure 2.--Age composition of yellowfin sole of the eastern Bering Sea as shown by data from trawl surveys of the Northwest and Alaska Fisheries Center and by U.S. observer data from the foreign fishery. Year-classes for more abundant ages are shown with the appropriate bars, and darkened bars represent stronger than average year-classes.

The 1980 and 1981 NWAFC survey data indicated that a new series of strong year-classes have entered the population (Figure 2). These are the 1973 to 1976 year-classes which appear to be as strong, or in some cases even stronger, than the 1966-70 year-classes. The age structure of the population appears to be well balanced and should maintain the resource in a healthy state in the foreseeable future.

Biomass Estimates from Research Vessel Surveys

Biomass estimates from the large-scale NWAFC surveys and 95% confidence intervals around the mean estimates are as follows:

Year	Mean estimate(t)	95% Confidence interval(t)
1975	1,038,400	870,800 - 1,206,400
1976	1,192,600	661,700 - 1,723,600
1978	1,523,400	1,103,300 - 1,943,600
1979	1,932,600	1,669,000 - 2,196,100
1980	1,965,900	1,716,000 - 2,215,900
1981	2,039,900	1,791,000 - 2,288,800
1982 1/	3,322,518	2,675,900 - 3,970,100

1/ Preliminary estimate

Following the almost doubling of the biomass estimates between 1975 and 1979, there were only minor increases in 1980 and 1981. The 1982 estimate, however, was substantially higher (at 3.32 million t) than the 1979-81 estimates, an increase that cannot reasonably be attributed entirely to increased growth, recruitment, and decreased mortality. A possible contributing factor (discussed earlier) was the improved efficiency of the trawl used in 1982 compared to trawls used during previous surveys for capturing bottom tending species like yellowfin sole. Another factor accounting for the higher biomass estimate in 1982 compared to 1981 was that an area around Nunivak Island (Figure 2 in the article on walleye pollock by Bakkala and Wespestad in this Technical Memorandum), not surveyed in 1981, accounted for approximately 500,000 t of yellowfin sole in 1982. Although the preliminary 1982 estimate is extremely high and the accuracy of this estimate is still being examined, indications are that the biomass of the yellowfin sole population remains high.

Biomass Estimates from Cohort Analysis

Cohort analyses have previously been carried out for eastern Bering Sea yellowfin sole by Wakabayashi (1975), Wakabayashi et al. (1977), and Bakkala et al. (1981). The latter analysis has been updated by Bakkala et al. (1982) and expanded to include earlier years 1959-63. New estimates of biomass for the period of 1959-63 were calculated because of mounting evidence that natural mortality of yellowfin sole may be lower than the value of 0.25 used earlier by Wakabayashi (1975) and Wakabayashi et al. (1977).

Methods of Estimating Biomass Estimates from Cohort Analysis

A FORTRAN program based on the equations of Pope (1972) was used for the cohort analysis.

Input data: Catch-at-age data used in the analysis for the years 1959-1963 were from Wakabayashi (1975) and those for 1964-75 from Wakabayashi et al. (1977). For 1976-81 the catch in numbers at age was derived using catch data reported by foreign fisheries and age-composition data collected by U.S. observers from these fisheries. Length-weight relationships and growth parameters used to convert catch weights to numbers of fish and numbers of fish from the cohort analysis to biomass were calculated from research survey vessel data. Survey data were used for this purpose because weight data collected by U.S. observers from the fishery appeared to be unusually variable and inconsistent.

For each year from 1976 to 1979, a single overall annual age distribution was used because age distributions were not available from some elements of the fishery. Applying a single annual age distribution to all elements of the fishery was thought to create less bias than applying age distributions from one element of the fishery to catches in another. Biological sampling in the fishery was more complete in 1980 and 1981 and catches were apportioned to age by nation, vessel class, and quarter year in these years. The catch-at-age data used in the analysis are shown in Table 3.

Natural mortality: An estimate of natural mortality (M), either age-specific or an average value for all ages, is a necessary input variable for the cohort analysis. Natural mortality has not been clearly defined for yellowfin sole. Fadeev (1970) estimated M as 0.25 based on catch curve analysis of samples collected in 1958 prior to the development of an intensive fishery. In the same paper he reported M as 0.16 during the early 1960's, following the intense exploitation of the population in 1959-62, based on comparisons of total mortality and effort between years. Wakabayashi (1975) used the Alverson and Carney (1975) procedure to estimate M as 0.25.

Bakkala et al. (1981) ran cohort analyses varying M between 0.08 and 0.26 in increments of 0.02. They found that the biomass of age 6 and older fish showed a decrease in abundance between 1978 and 1979 using M values greater than 0.14 while M of 0.12 produced a positive trend in biomass comparable to that shown by research vessel surveys. The value of M used in the present cohort analysis was derived by a least squares analysis (Bledsoe and Lynde 1982). Catch-at-age data were fitted to pair trawl effort data while varying the catchability coefficient (q) and M simultaneously. The best fit to the data (the point where the residual variance was minimal) occurred with an M of 0.12 and q of 0.000067. This was the same value used by Bakkala et al. (1981).

Table 3.--Catch in number of yellowfin sole in the eastern Bering Sea, 1959-81.

Age (yr)	1959	1960	1961	1962	1963	1964
1	0	0	0	0	0	0
2	0	0	0	0	0	0
3	0	0	0	0	0	6723594
4	0	0	12211000	20000	0	11670211
5	43000	11000	25665000	12791000	1387000	19719090
6	6283000	25642000	23507000	138609000	25592000	50360512
7	24204000	120295000	158641000	256176000	35328000	133465272
8	55879000	175910000	422399000	361625000	63990000	233559552
9	112106000	248989000	591953000	356925000	94275000	55570601
10	158045000	306535000	550774000	273029000	89065000	62969061
11	143862000	291699000	369201000	184237000	63595000	66999397
12	95054000	219639000	197358000	115955000	40318000	46275989
13	53197000	141313000	92785000	70104000	24975000	14672095
14	27940000	83469000	41263000	41784000	15618000	5939147
15	14483000	47679000	18227000	25082000	9815000	1151574
16	7579000	27251000	8264000	15386000	6144000	259040
17	4057000	15924000	3922000	9728000	3830000	0

Age (yr)	1965	1966	1967	1968	1969	1970
1	0	0	0	0	0	0
2	0	0	0	0	0	0
3	0	0	0	0	0	0
4	598	5014	87464	0	1285	0
5	90509	35104	87464	238488	1043630	297410
6	1589045	811237	13825254	1362450	8367549	14054843
7	5639029	14580560	38051627	28933263	6928205	68608781
8	44352622	43836654	99373388	30452429	96990292	100576270
9	88833776	98842534	147145423	68903375	95491015	116358621
10	22124437	156105171	161736086	77131269	173961524	33464440
11	28150136	35307411	210406160	77338053	162682588	54684283
12	31096470	36809015	29106300	66943150	148507158	75496141
13	20079130	38612673	24403737	20036129	77383376	46522144
14	6183445	22385463	30626707	11410842	25164822	53240382
15	2127964	6720280	19690784	9849302	9273980	3491150
16	323315	1931171	7237420	6684740	6035161	2338472
17	260968	527349	1181296	3815143	8041342	0

Age (yr)	1971	1972	1973	1974	1975	1976
1	0	0	0	0	0	0
2	0	0	0	0	0	0
3	0	0	0	0	0	0
4	0	80781	0	0	0	25974
5	190992	3861702	2725872	531754	502396	4467442
6	25464974	32756203	14271388	8448739	2896033	15246445
7	164834257	66426170	90269313	29532672	24721512	24882614
8	103298779	22441324	87217312	69979393	42327088	28648771
9	102127987	38100420	59427732	47770398	112219136	80128250
10	104085462	25018629	38651846	20367250	84126344	55635239
11	26949318	21883206	39891960	21747765	33730543	25713766
12	48856493	13816074	37660524	12316794	13410457	8311520
13	44422501	10807110	28522871	12009322	16042210	8285547
14	48937687	7032301	13667326	8241797	10861805	1740225
15	39448665	0	6966172	5002828	4797379	4337575
16	1608163	1193096	1356458	1801061	3674851	1220755
17	0	0	3287656	303444	976733	441550

Age (yr)	1977	1978	1979	1980	1981
1	0	0	0	0	0
2	0	0	0	0	0
3	0	0	41642	0	0
4	380106	1560163	541340	206500	3510487
5	3522311	12730933	6162946	3251003	20190664
6	9578660	14103876	23194331	17797899	6757851
7	18650512	66837397	20654198	33140657	31066415
8	42546480	131677784	49428494	19740704	46191267
9	35679240	113767109	89612568	41251153	41740204
10	70547589	97791037	82949924	64094844	51734340
11	48273404	104343723	61254688	60753036	67242816
12	15812391	38879270	45056133	47678239	70640739
13	4738649	21592660	22902840	42362204	58389770
14	2888802	12294087	7120701	23223262	40197601
15	2179272	4493270	4080870	7353264	18477135
16	582828	2683481	1540737	10094428	5721428
17	253404	686472	1290887	4196986	4413815

The most accurate estimates of abundance from cohort analysis may be produced from age specific rates of natural mortality. Studies using the methods of Bledsoe and Lynde (1982) to produce such estimates are continuing.

Fishing mortality: In addition to M, estimates of fishing mortality (F) are required for all age groups in the last year of catch and for the oldest age group in prior years. Fishing mortality for age groups in the last year of catch data (1981) was computed by adjusting the terminal F's for the corresponding age groups in 1979 (the last year in the cohort analysis by Bakkala et al. 1981) relative to the change in survey CPUE and the age structure measured by research surveys. This method assumes that the surveys measure population age structure and abundance changes accurately. After an initial trial, F's in 1981 were adjusted until the estimated population age group distribution approximated the age group distribution of fully recruited fish (age 7 and older) observed in the 1981 survey. Terminal F's for the oldest age group in years prior to 1981 were adjusted to approximate the computed values of the next youngest age groups in the same year based on the assumption that catchabilities were similar. The F values generated in the analysis are shown in Table 4.

Results

The results of the cohort analysis are given in Table 5 in terms of numbers and in Table 6 in terms of biomass. It should be noted that cohort analysis is based on numbers of fish and conversion to biomass requires weight-at-age data. In this analysis, conversion to biomass was based on the average weight-at-age obtained from research vessel surveys in 1973-81 (Bakkala et al. 1982). Therefore, actual biomass may have been higher or lower in past years if growth rates were different than shown by these averages.

Table 4 .--Estimates of fishing mortality (F) by age for yellowfin sole of the eastern Bering Sea, 1959-81.

Age (yr)	1959	1960	1961	1962	1963	1964	1965	1966	1967
1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0065	0.0000	0.0000	0.0000
4	0.0000	0.0000	0.0072	0.0000	0.0000	0.0193	0.0000	0.0000	0.0001
5	0.0000	0.0000	0.0123	0.0085	0.0012	0.0211	0.0002	0.0000	0.0001
6	0.0036	0.0225	0.0313	0.0786	0.0195	0.0490	0.0019	0.0017	0.0193
7	0.0139	0.0811	0.1725	0.4961	0.0238	0.1232	0.0064	0.0203	0.0954
8	0.0386	0.1216	0.4069	0.6617	0.1995	0.1977	0.0504	0.0575	0.1714
9	0.1015	0.2206	0.6743	0.6510	0.3226	0.2436	0.0984	0.1390	0.2538
10	0.2006	0.3994	0.9561	0.6944	0.2986	0.3378	0.1322	0.2293	0.3218
11	0.2802	0.6202	1.0984	0.9263	0.3055	0.3497	0.2264	0.2935	0.4971
12	0.3114	0.8137	1.0657	1.2310	0.4721	0.3470	0.2473	0.4692	0.3813
13	0.3089	0.9478	0.9121	1.4357	0.8888	0.2845	0.2268	0.4987	0.5934
14	0.2886	1.0223	0.7343	1.4121	1.6322	0.4845	0.1700	0.3857	0.8635
15	0.2805	1.0317	0.5765	1.3583	1.7272	0.4187	0.2901	0.2576	0.6288
16	0.2401	1.1612	0.4353	1.3555	1.6000	0.1481	0.1799	0.4223	0.4413
17	0.2500	1.0300	0.4400	1.2870	1.6500	0.0000	0.2000	0.4500	0.4500

Age (yr)	1968	1969	1970	1971	1972	1973	1974	1975	1976
1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
5	0.0004	0.0014	0.0003	0.0001	0.0024	0.0013	0.0002	0.0001	0.0022
6	0.0024	0.0156	0.0208	0.0330	0.0268	0.0100	0.0044	0.0010	0.0048
7	0.0471	0.0138	0.1570	0.3263	0.1038	0.0883	0.0238	0.0148	0.0096
8	0.0947	0.2013	0.2574	0.3405	0.0611	0.1767	0.0841	0.0396	0.0197
9	0.1580	0.4326	0.3590	0.4097	0.1847	0.2082	0.1271	0.1728	0.0902
10	0.1872	0.6682	0.2406	0.5719	0.1507	0.2641	0.0937	0.3135	0.1114
11	0.2290	0.6727	0.4109	0.2837	0.2020	0.3458	0.2129	0.2027	0.1357
12	0.2626	0.8146	0.6973	0.7172	0.2102	0.5698	0.1553	0.1802	0.0644
13	0.4466	0.4967	0.5878	1.1053	0.3032	0.7866	0.3231	0.2833	0.1480
14	0.5571	1.5963	0.6912	2.9743	0.4472	0.7034	0.4937	0.4926	0.0409
15	0.6877	1.1496	0.9558	1.7847	0.0000	0.9937	0.5468	0.5430	0.3377
16	0.4080	1.1500	0.9500	1.7800	0.1852	1.0630	0.6850	0.9229	0.2318
17	0.4000	1.1500	0.0000	0.0000	0.0000	1.0000	0.6500	0.9200	0.2300

Age (yr)	1977	1978	1979	1980	1981
1	0.0000	0.0000	0.0000	0.0000	0.0000
2	0.0000	0.0000	0.0000	0.0000	0.0000
3	0.0000	0.0000	0.0000	0.0000	0.0000
4	0.0001	0.0003	0.0002	0.0000	0.0020
5	0.0025	0.0037	0.0016	0.0010	0.0047
6	0.0053	0.0115	0.0076	0.0051	0.0024
7	0.0067	0.0424	0.0193	0.0123	0.0101
8	0.0189	0.0551	0.0367	0.0212	0.0197
9	0.0283	0.0591	0.0444	0.0359	0.0525
10	0.0984	0.0929	0.0514	0.0373	0.0530
11	0.1225	0.1893	0.0712	0.0445	0.0460
12	0.1062	0.1260	0.1070	0.0670	0.0615
13	0.0437	0.1894	0.0934	0.1275	0.1005
14	0.0648	0.1401	0.0807	0.1187	0.1572
15	0.0607	0.1248	0.0580	0.1030	0.1200
16	0.0628	0.0909	0.0528	0.1820	0.1000
17	0.0630	0.0900	0.0530	0.1820	0.1036

Table 5.--Estimated numbers of yellowfin sole (billions of fish) in the eastern Bering Sea, 1959-81, based on cohort analysis.

Age (yr)	1959	1960	1961	1962	1963	1964	1965	1966	1967
1	2.040	1.620	0.931	1.407	1.108	1.047	1.320	1.519	2.394
2	2.308	1.810	1.437	0.826	1.248	0.983	0.928	1.171	1.347
3	2.826	2.047	1.605	1.275	0.733	1.107	0.871	0.823	1.039
4	1.029	2.506	1.815	1.424	1.130	0.650	0.976	0.773	0.730
5	1.382	0.912	2.223	1.599	1.263	1.003	0.565	0.865	0.685
6	1.856	1.226	0.809	1.947	1.406	1.119	0.871	0.501	0.767
7	1.865	1.640	1.063	0.696	1.596	1.223	0.945	0.771	0.444
8	1.565	1.632	1.342	0.793	0.376	1.383	0.959	0.832	0.670
9	1.234	1.336	1.282	0.792	0.363	0.273	1.006	0.809	0.697
10	0.923	0.989	0.950	0.579	0.366	0.233	0.190	0.809	0.624
11	0.625	0.670	0.588	0.324	0.256	0.241	0.148	0.147	0.570
12	0.377	0.419	0.320	0.174	0.114	0.168	0.151	0.104	0.097
13	0.213	0.245	0.165	0.098	0.045	0.063	0.105	0.104	0.058
14	0.118	0.138	0.084	0.059	0.021	0.016	0.042	0.074	0.056
15	0.063	0.079	0.044	0.036	0.013	0.004	0.009	0.031	0.045
16	0.038	0.042	0.025	0.022	0.008	0.002	0.002	0.006	0.022
17	0.019	0.026	0.012	0.014	0.005	0.000	0.002	0.002	0.003
	18.482	17.337	14.695	12.064	10.051	9.513	9.089	9.343	10.250

Age (yr)	1968	1969	1970	1971	1972	1973	1974	1975	1976
1	2.779	3.693	5.662	6.117	3.542	2.390	5.964	6.791	5.461
2	2.123	2.465	3.275	5.022	5.425	3.141	2.120	5.289	6.023
3	1.195	1.883	2.186	2.905	4.454	4.812	2.786	1.880	4.691
4	0.921	1.060	1.670	1.939	2.576	3.950	4.268	2.471	1.668
5	0.648	0.817	0.940	1.481	1.719	2.285	3.504	3.785	2.192
6	0.608	0.574	0.724	0.833	1.313	1.521	2.024	3.107	3.356
7	0.668	0.538	0.501	0.629	0.715	1.134	1.336	1.787	2.753
8	0.358	0.565	0.471	0.380	0.402	0.572	0.921	1.157	1.562
9	0.501	0.289	0.410	0.323	0.240	0.336	0.425	0.751	0.986
10	0.480	0.379	0.166	0.254	0.190	0.177	0.242	0.332	0.560
11	0.401	0.353	0.172	0.116	0.127	0.145	0.120	0.195	0.215
12	0.308	0.283	0.160	0.101	0.077	0.092	0.091	0.086	0.141
13	0.059	0.210	0.111	0.071	0.044	0.056	0.046	0.069	0.064
14	0.028	0.034	0.113	0.055	0.021	0.029	0.022	0.030	0.046
15	0.021	0.014	0.006	0.050	0.002	0.012	0.013	0.012	0.016
16	0.021	0.009	0.004	0.002	0.007	0.002	0.004	0.006	0.006
17	0.012	0.012	0.000	0.000	0.000	0.006	0.001	0.002	0.002
	11.130	13.177	16.571	20.276	20.856	20.659	23.885	27.751	29.743

Age (yr)	1977	1978	1979	1980	1981
1	7.389	2.674	0.000	0.000	0.000
2	4.843	6.554	2.372	0.000	0.000
3	5.342	4.296	5.813	2.104	0.000
4	4.161	4.738	3.810	5.155	1.866
5	1.479	3.690	4.201	3.379	4.572
6	1.940	1.308	3.261	3.720	2.993
7	2.963	1.711	1.147	2.870	3.283
8	2.418	2.610	1.455	0.998	2.514
9	1.358	2.105	2.191	1.244	0.867
10	0.799	1.171	1.759	1.859	1.064
11	0.444	0.642	0.946	1.482	1.588
12	0.167	0.349	0.472	0.782	1.258
13	0.118	0.133	0.273	0.376	0.648
14	0.049	0.100	0.098	0.220	0.293
15	0.039	0.041	0.077	0.080	0.174
16	0.010	0.033	0.032	0.064	0.064
17	0.004	0.008	0.027	0.027	0.048
	33.524	32.163	27.932	24.359	21.232

Table 6 ---Estimated biomass (in 1,000 t) of yellowfin sole in the eastern Bering Sea by age (with totals for all ages and ages 7 and above), 1959-81, based on cohort analysis.

Age (yr)	1959	1960	1961	1962	1963	1964	1965	1966	1967
1	10.	8.	5.	7.	6.	5.	7.	8.	12.
2	21.	16.	13.	7.	11.	9.	8.	11.	12.
3	51.	37.	29.	23.	13.	20.	16.	15.	19.
4	34.	83.	60.	47.	37.	21.	32.	26.	24.
5	77.	51.	124.	90.	71.	56.	32.	48.	38.
6	163.	108.	71.	171.	124.	98.	77.	44.	68.
7	209.	184.	119.	78.	179.	137.	106.	86.	50.
8	211.	220.	181.	107.	51.	187.	129.	112.	90.
9	196.	212.	204.	126.	58.	43.	160.	129.	111.
10	171.	183.	176.	107.	68.	43.	35.	150.	115.
11	131.	141.	124.	68.	54.	51.	31.	31.	120.
12	88.	97.	74.	40.	26.	39.	35.	24.	23.
13	56.	65.	43.	26.	12.	17.	28.	28.	15.
14	33.	39.	24.	16.	6.	5.	12.	21.	16.
15	19.	23.	13.	11.	4.	1.	3.	9.	13.
16	13.	15.	9.	8.	3.	1.	1.	2.	8.
17	7.	10.	4.	5.	2.	0.	1.	1.	1.
	1491.	1492.	1273.	938.	723.	733.	711.	744.	735.
7+	1135.	1189.	971.	592.	461.	523.	540.	593.	562.

Age (yr)	1968	1969	1970	1971	1972	1973	1974	1975	1976
1	14.	18.	28.	31.	18.	12.	30.	34.	27.
2	19.	22.	29.	45.	49.	28.	19.	48.	54.
3	22.	34.	39.	52.	80.	87.	50.	34.	84.
4	30.	35.	55.	64.	85.	130.	141.	82.	55.
5	36.	46.	53.	83.	96.	128.	196.	212.	123.
6	53.	51.	64.	73.	116.	134.	178.	273.	295.
7	75.	60.	56.	70.	80.	127.	150.	200.	308.
8	48.	76.	64.	51.	54.	77.	124.	156.	211.
9	80.	46.	65.	51.	38.	53.	68.	119.	157.
10	89.	70.	31.	47.	35.	33.	45.	61.	104.
11	84.	74.	36.	24.	27.	30.	25.	41.	45.
12	71.	66.	37.	24.	18.	21.	21.	20.	33.
13	16.	55.	29.	19.	12.	15.	12.	18.	17.
14	8.	9.	32.	15.	6.	8.	6.	8.	13.
15	6.	4.	2.	15.	1.	3.	4.	4.	5.
16	8.	3.	1.	1.	3.	1.	1.	2.	2.
17	4.	5.	0.	0.	0.	2.	0.	1.	1.
	664.	675.	622.	666.	717.	890.	1071.	1314.	1534.
7+	489.	469.	353.	317.	273.	371.	456.	631.	895.

Age (yr)	1977	1978	1979	1980	1981
1	37.	13.	0.	0.	0.
2	44.	59.	21.	0.	0.
3	96.	77.	105.	38.	0.
4	137.	156.	126.	170.	62.
5	83.	207.	235.	189.	256.
6	171.	115.	287.	327.	263.
7	332.	192.	128.	321.	368.
8	326.	352.	196.	135.	339.
9	216.	335.	348.	198.	138.
10	148.	217.	326.	344.	197.
11	93.	135.	199.	311.	334.
12	39.	81.	109.	181.	292.
13	31.	35.	72.	99.	171.
14	14.	28.	27.	62.	82.
15	12.	12.	23.	24.	51.
16	4.	12.	11.	23.	23.
17	2.	3.	10.	10.	17.
	1783.	2029.	2224.	2432.	2593.
7+	1216.	1401.	1450.	1708.	2012.

This latest cohort analysis (Bakkala et al. 1982) produced biomass estimates for years prior to 1977 that were lower than earlier cohort analysis estimates because of the lower value of natural mortality used. The analysis indicated that the biomass of age 7 and older yellowfin sole (ages fully recruited to research vessel catches) in the early years of high exploitation (1959-60) was approximately 1.1-1.2 million t. At the end of this period of high exploitation (1962), the biomass had decreased to about half that level; furthermore, the analysis showed that it remained at approximately this lower level through 1967 when there was a further decline to 273,000 t in 1972. Since then, the biomass has increased substantially, due mainly to the recruitment of the strong 1966-70 year-classes and the more recent series of strong year-classes spawned in 1973-76. In 1981, the abundance of age 7 and older yellowfin sole was estimated to be about 2.0 million t, the largest estimated biomass in the period 1959-81 based on results of the new cohort analysis.

ABUNDANCE PROJECTIONS, 1982-89

Future trends in abundance of the yellowfin sole population and potential levels of harvest were examined using a numeric population simulator (see the article on walleye pollock by Bakkala and Wespestad in this Technical Memorandum for a description of the simulator). The simulator projects numbers at age from a base year using estimates of natural (M) and fishing (F) mortality and recruitment.

The estimate of natural mortality used in the simulation was the same as that used in the cohort analysis (0.12). Two estimates of recruitment were used: 1.403 billion fish, which is the average recruitment at age 7 in 1959-81 from the cohort analysis and 1.074 billion fish, which is the average abundance at age 7 in this same period of years, but excluding the exceptionally strong year-classes of 1969, 1970, 1973, and 1974. These values are relatively conservative. For example, during the period of 1973-80 when population abundance was increasing, average recruitment at age 7 was 2.109 billion fish.

The simulations were carried out under four levels of fishing mortality corresponding to exploitation rates of 0.05, 0.10, 0.15, and 0.20. In the recent period of 1977-81, exploitation rates have averaged about 0.07 based on the estimates of abundance for that period from the cohort analysis and 0.06 based on abundance estimates from resource assessment surveys. A simulation was also run using a constant catch of 214,500 t which is the midpoint of the estimated maximum sustainable yield (MSY) range for yellowfin sole (Bakkala et al. 1981).

The projections derived from these input data are given in Tables 7-10 and include estimates of abundance for ages 7-17 (ages fully recruited to research vessel catches), ages 8-17 (major ages taken by the commercial fishery), rates of exploitation (E) and fishing mortality (F), and estimated mean weight of individual fish in the fishable population.

The simulations indicated that population abundance will remain high through at least 1985 under most of the proposed conditions. The abundance of the fishable population (ages 8-17) may remain as high as 2.0 million t, if exploitation rates remain low (0.05) and recruitment is at the higher average level (1.403 billion). Even at an exploitation rate as high as 0.15 (Tables 7 and 8) or with a constant catch of 214,500 t (Tables 9 and 10) the exploitable population would be expected to range between 1.4 and 1.7 million t in 1985. Only if exploitation rates were allowed to reach 0.20 would the fishable stock decline fairly rapidly, falling to 1.2-1.3 million t by 1985 (Tables 7 and 8).

Following 1985, the simulations indicated that population abundance would continue to decline at the given levels of recruitment. The fishable population

Table 7.--Forecast of yellowfin sole abundance in the eastern Bering Sea, 1982-89, under varying levels of exploitation (E), with natural mortality (M) = 0.12, and recruitment at the lower estimate for 1959-81. Projections are made for ages 7-17 (ages fully recruited to research vessel catches) and ages 8-17 (principal ages in commercial trawl catches).

	Estimated biomass						
Year	Ages 7-17 (1,000 t)	Ages 8-17 (1,000 t)	Recruits (millions)	Catch (1,000 t)	1/ E	2/ F	Mean individual fish weight (kg)
1981	2,012.1	1,644.5	3,282.0	97.3	0.059	0.060	0.193
1982	2,048.8	1,928.5	1,074.0	96.4	0.050	0.049	0.198
1983	2,069.3	1,949.0	1,074.0	97.5	0.050	0.049	0.208
1984	2,051.7	1,931.4	1,074.0	96.6	0.050	0.049	0.218
1985	2,010.8	1,890.5	1,074.0	94.5	0.050	0.049	0.227
1986	1,921.2	1,800.9	1,074.0	90.0	0.050	0.049	0.229
1987	1,754.8	1,634.5	1,074.0	81.7	0.050	0.049	0.222
1988	1,576.8	1,456.5	1,074.0	72.8	0.050	0.049	0.215
1989	1,514.9	1,394.6	1,074.0	69.7	0.050	0.049	0.222
1981	2,012.1	1,644.5	3,282.0	97.3	0.059	0.060	0.193
1982	2,048.8	1,928.5	1,074.0	192.8	0.100	0.107	0.192
1983	1,966.7	1,846.4	1,074.0	184.6	0.100	0.107	0.207
1984	1,861.1	1,740.8	1,074.0	174.1	0.100	0.107	0.217
1985	1,748.9	1,628.7	1,074.0	162.9	0.100	0.107	0.224
1986	1,612.2	1,491.9	1,074.0	149.2	0.100	0.107	0.224
1987	1,434.7	1,314.4	1,074.0	131.4	0.100	0.107	0.216
1988	1,270.6	1,150.3	1,074.0	115.0	0.100	0.107	0.208
1989	1,204.0	1,083.7	1,074.0	108.4	0.100	0.107	0.213
1981	2,012.1	1,644.5	3,282.0	97.3	0.059	0.060	0.193
1982	2,048.8	1,928.5	1,074.0	289.3	0.150	0.167	0.192
1983	1,866.7	1,746.4	1,074.0	262.0	0.150	0.167	0.207
1984	1,685.4	1,565.1	1,074.0	234.8	0.150	0.167	0.216
1985	1,520.5	1,400.2	1,074.0	210.0	0.150	0.167	0.221
1986	1,356.1	1,235.9	1,074.0	185.4	0.150	0.167	0.219
1987	1,181.6	1,061.3	1,074.0	159.2	0.150	0.167	0.210
1988	1,037.7	917.4	1,074.0	137.6	0.150	0.167	0.201
1989	975.7	855.4	1,074.0	128.3	0.150	0.167	0.204
1981	2,012.1	1,644.5	3,282.0	97.3	0.059	0.060	0.193
1982	2,048.8	1,928.5	1,074.0	385.7	0.200	0.232	0.192
1983	1,764.9	1,644.6	1,074.0	328.9	0.200	0.232	0.206
1984	1,517.0	1,396.7	1,074.0	279.3	0.200	0.232	0.214
1985	1,313.7	1,193.4	1,074.0	238.7	0.200	0.232	0.217
1986	1,136.5	1,016.2	1,074.0	203.2	0.200	0.232	0.214
1987	974.5	854.2	1,074.0	170.8	0.200	0.232	0.203
1988	854.1	733.8	1,074.0	146.8	0.200	0.232	0.194
1989	801.4	681.1	1,074.0	136.2	0.200	0.232	0.195

1/ E = Exploitation rate for fished population (ages 8-17).
2/ F = Fishing mortality.

Table 8.--Forecast of yellowfin sole abundance in the eastern Bering Sea, 1982-89, under varying levels of exploitation (E), natural mortality = 0.12, and recruitment at the higher estimate for 1959-81. Projections are made for ages 7-17 (ages fully recruited to research vessel catches) and ages 8-17 (principal ages in commercial trawl catches).

Year	Estimated biomass Ages 7-17 (1,000 t)	Estimated biomass Ages 8-17 (1,000 t)	Recruits (millions)	Catch (1,000 t)	1/ E	2/ F	Mean individual fish weight (kg)
1981	2,012.1	1,644.5	3,282.0	97.3	0.059	0.060	0.193
1982	2,085.6	1,928.5	1,403.0	96.4	0.050	0.049	0.192
1983	2,145.5	1,988.4	1,403.0	99.4	0.050	0.049	0.205
1984	2,167.1	2,010.0	1,403.0	100.5	0.050	0.049	0.214
1985	2,164.7	2,007.6	1,403.0	100.4	0.050	0.049	0.221
1986	2,112.0	1,954.9	1,403.0	97.7	0.050	0.049	0.222
1987	1,980.0	1,822.9	1,403.0	91.1	0.050	0.049	0.216
1988	1,835.1	1,678.0	1,403.0	83.9	0.050	0.049	0.210
1989	1,803.0	1,645.9	1,403.0	82.3	0.050	0.049	0.217
1981	2,012.1	1,644.5	3,282.0	97.3	0.059	0.060	0.193
1982	2,085.6	1,928.5	1,403.0	192.8	0.100	0.107	0.192
1983	2,043.0	1,885.8	1,403.0	188.6	0.100	0.107	0.205
1984	1,974.3	1,817.1	1,403.0	181.7	0.100	0.107	0.213
1985	1,896.4	1,739.3	1,403.0	173.9	0.100	0.107	0.218
1986	1,790.7	1,633.5	1,403.0	163.4	0.100	0.107	0.218
1987	1,640.5	1,483.3	1,403.0	148.3	0.100	0.107	0.210
1988	1,501.1	1,344.0	1,403.0	134.4	0.100	0.107	0.204
1989	1,455.6	1,298.4	1,403.0	129.8	0.100	0.107	0.208
1981	2,012.1	1,644.5	3,282.0	97.3	0.059	0.060	0.193
1982	2,085.6	1,928.5	1,403.0	289.3	0.150	0.167	0.192
1983	1,942.9	1,785.8	1,403.0	267.9	0.150	0.167	0.204
1984	1,796.4	1,639.3	1,403.0	245.9	0.150	0.167	0.211
1985	1,661.9	1,504.8	1,403.0	225.7	0.150	0.167	0.214
1986	1,523.5	1,366.4	1,403.0	205.0	0.150	0.167	0.212
1987	1,370.4	1,213.3	1,403.0	182.0	0.150	0.167	0.204
1988	1,244.9	1,087.7	1,403.0	163.2	0.150	0.167	0.197
1989	1,197.5	1,040.4	1,403.0	156.1	0.150	0.167	0.200
1981	2,012.1	1,644.5	3,282.0	97.3	0.059	0.060	0.193
1982	2,085.6	1,928.5	1,403.0	385.7	0.200	0.232	0.192
1983	1,841.1	1,684.0	1,403.0	336.8	0.200	0.232	0.204
1984	1,625.8	1,468.7	1,403.0	293.7	0.200	0.232	0.209
1985	1,449.2	1,292.1	1,403.0	258.4	0.200	0.232	0.210
1986	1,293.4	1,136.3	1,403.0	227.3	0.200	0.232	0.207
1987	1,147.9	990.8	1,403.0	198.2	0.200	0.232	0.197
1988	1,040.8	883.6	1,403.0	176.7	0.200	0.232	0.190
1989	998.0	840.9	1,403.0	168.2	0.200	0.232	0.191

1/ E = Exploitation rate for fished population (ages 8-17).
2/ F = Fishing mortality.

Table 9.--Forecast of yellowfin sole abundance in the eastern Bering Sea, 1982-89, with constant catches of 214,500 t, natural mortality = 0.12, and recruitment at the lower estimate for 1959-81. Projections are made for ages 7-17 (ages fully recruited to research vessel catches) and ages 8-17 (principal ages in commercial trawl catches).

	Estimated biomass						Mean individual
Year	Ages 7-17 (1,000 t)	Ages 8-17 (1,000 t)	Recruits (millions)	Catch (1,000 t)	1/ E	2/ F	fish weight (kg)
1981	2,012.1	1,644.5	3,282.0	97.3	0.059	0.060	0.193
1982	2,048.8	1,928.5	1,074.0	214.5	0.111	0.120	0.193
1983	1,944.5	1,824.3	1,074.0	214.5	0.118	0.128	0.207
1984	1,808.7	1,688.4	1,074.0	214.5	0.127	0.139	0.217
1985	1,658.4	1,538.1	1,074.0	214.5	0.139	0.154	0.223
1986	1,478.5	1,358.2	1,074.0	214.5	0.158	0.177	0.222
1987	1,258.6	1,138.3	1,074.0	214.5	0.188	0.216	0.213
1988	1,048.2	927.9	1,074.0	214.5	0.231	0.274	0.203
1989	906.3	786.0	1,074.0	214.5	0.273	0.334	0.203

1/ E = Exploitation rate for fished population (ages 8-17).
2/ F = Fishing mortality.

Table 10.--Forecast of yellowfin sole abundance in the eastern Bering Sea, 1982-89, with constant catches of 214,500 t, natural mortality = 0.12, and recruitment at the higher estimate for 1959-81. Projections are made for ages 7-17 (ages fully recruited to research vessel catches) and ages 8-17 (principal ages in commercial trawl catches).

	Estimated biomass						
Year	Ages 7-17 (1,000 t)	Ages 8-17 (1,000 t)	Recruits (millions)	Catch (1,000 t)	1/ E	2/ F	Mean individual fish weight (kg)
1981	2,012.1	1,644.5	3,282.0	97.3	0.059	0.060	0.193
1982	2,085.6	1,928.5	1,403.0	214.5	0.111	0.120	0.192
1983	2,020.8	1,863.6	1,403.0	214.5	0.115	0.125	0.205
1984	1,925.9	1,768.8	1,403.0	214.5	0.121	0.132	0.212
1985	1,817.4	1,660.2	1,403.0	214.5	0.129	0.142	0.217
1986	1,677.3	1,520.1	1,403.0	214.5	0.141	0.156	0.216
1987	1,494.0	1,336.8	1,403.0	214.5	0.160	0.180	0.208
1988	1,316.2	1,159.0	1,403.0	214.5	0.185	0.212	0.200
1989	1,208.2	1,051.1	1,403.0	214.5	0.204	0.237	0.202

1/ E = Exploitation rate for fished population (ages 8-17).
2/ F = Fishing mortality.

could decline to about 1.0 million t or less, if exploitation rates continued to exceed 0.10 after 1985.

MAXIMUM SUSTAINABLE YIELD

MSY for yellowfin sole has been estimated to range between 169,000-260,000 t with a mid-point of 214,500 t (Bakkala et al. 1981) based on the yield equation of Alverson and Pereyra (1969) and a range in virgin biomass of 1.3 million t (estimated by Alverson and Pereyra 1969) and 2.0 million t (estimated by Wakabayashi 1975). An M value of 0.25 was used in the yield equation of Alverson and Pereyra (1969).

Wakabayashi (1982) estimated MSY based on results of a yield-per-recruit analysis. His estimates and input data were as follows:

M	F_{MSY} 1/	Yield/recruit (g)	Recruitment at age 3 (billions of fish)		MSY (t)	
			Low	High	Low	High
0.25	0.30	34.1	3.84	8.27	131,000	282,000
0.20	0.25	46.8	2.30	5.78	108,000	271,000
0.12	0.22	86.0	1.11	3.30	95,000	284,000

1/ F values producing MSY

Bakkala et al. (1982) also considered estimates of MSY based on evidence that M may be lower than 0.25, and perhaps as low as 0.12. Substituting an M value of 0.12 in the yield equation of Alverson and Pereyra (1969) would produce an MSY range of 78,000-120,000 t--similar in magnitude to the above estimates by Wakabayashi (1982) for low recruitment levels.

MSY likely falls somewhere in the midportion of the estimates which vary from 78,000 to 284,000 t. Long-term (1959-81) exploitation of the yellowfin sole population has averaged 150,000 t, which may represent a reasonable estimate of MSY. This figure is similar to the long-term sustainable yield

(175,000 t) estimated from an ecosystem model (Bakkala et al. 1982). Thus, MSY is likely near 150,000-175,000 t.

EQUILIBRIUM YIELD

Bakkala et al. (1981) considered equilibrium yield (EY) in 1981 to be the midpoint of their MSY range of 169,000-269,000 t or 214,500 t. This estimate may no longer be valid if the M value of 0.25 used to derive MSY was overestimated. Nevertheless, there is evidence that the population is in excellent condition--with exploitable biomass at least as high as 2.0 million t. Abundance is apparently as high or higher than it was prior to the intense exploitation of the late 1950's and early 1960's. In addition, a new series of strong year-classes are entering the exploitable population.

Based on biomass estimates of the exploitable population from cohort analysis (Table 6), the annual surplus production of yellowfin sole in recent years (the change in biomass from one year to the next plus the catch) has been as follows:

Year	Estimated biomass (1,000 t)	Catch (1,000 t)	Annual surplus production (1,000 t)
1977	1,216	58	243
1978	1,401	138	187
1979	1,450	99	357
1980	1,708	87	391
1981	2,012	97	-

The mean annual surplus production in 1977-80 was about 295,000 t, indicating that the yellowfin sole stock has not been exploited to its fullest potential, which has probably contributed to the rapid increase in population biomass.

Evidence from abundance projections (Tables 7-10) based on long-term average recruitment levels, indicated that the population can be maintained at approximately its present level through 1985 with catches of about 200,000 t. Recruitment in 1973-80 has been higher (2.1 billion fish) than the long-term average (1.4 billion) and EY in 1983 is, therefore, estimated to exceed 200,000 t.

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GREENLAND TURBOT AND ARROWTOOTH FLOUNDER

by

Richard G. Bakkala and Terrance M. Sample

INTRODUCTION

The turbots, arrowtooth flounder, Atheresthes stomias, and Greenland turbot, Reinhardtius hippoglossoides, are large flatfishes having similar bathymetric distributions in the eastern Bering Sea, with adults generally found in waters of the continental slope and juveniles restricted to waters of the shelf region. Information collected during demersal trawl surveys indicated that Greenland turbot are generally distributed throughout the eastern Bering Sea with highest concentrations found along the continental slope at depths greater than 200 m. The distribution of arrowtooth flounder is generally restricted to the southern portion of the eastern Bering Sea and along the continental slope with highest abundance located in the 100-700 m depth zones. Catches of arrowtooth flounder may include Kamchatka flounder, A. evermanni, since taxonomic differences between the two forms are not readily apparent.

The target fishery on turbot by the Japanese landbased trawl fleet is distinct from other flatfish fisheries since turbot stocks of commercial abundance are located on the continental slope and generally segregated from other flatfish species. The turbot complex is therefore managed as an independent unit. The Japanese mothership-North Pacific trawl fishery has often accounted for more than half of the catch of turbot (Table 1), presumably as an incidental part of the target fishery for walleye pollock, Theragra chalcogramma and other species. A large part of these incidental catches of turbot are assumed to come from waters on the continental shelf and consist primarily of juvenile fish. The overall fishery, therefore, takes both juvenile and adult turbot.

Table 1.--All nation catches (t) of arrowtooth flounder and Greenland turbot, 1960-81.1/

Year	Eastern Bering Sea (east of 180°): Japan MS-LG-NPT 2/	Japan LBD 3/	USSR	ROK 4/	Other 5/ nations	Joint 6/ ventures	Total	Aleutian Island area: Japan MS-LG-NPT	Japan LBD	USSR	ROK	Joint ventures	Total	E. Bering Sea and Aleutian comb. total
ARROWTOOTH FLOUNDER AND GREENLAND TURBOT COMBINED														
1960	36,843	-	-				36,843	-	-	-			-	36,843
1961	57,348	-	-				57,348	-	-	-			-	57,348
1965	58,226	-	-				58,226	-	-	-			-	58,226
1963	31,565	-	-				31,565	-	7	-			7	31,572
1964	33,726	3	-				33,729	475	29	-			504	34,233
1965	7,648	299	1,800				9,747	299	1	-			300	10,047
1966	10,752	90	2,200				13,042	63	0	-	-		63	13,105
1967	20,574	656	2,639	-			23,869	167	227	-			394	24,263
1968	17,702	2,278	15,252	-			35,232	106	107	-	-		213	35,445
1969	13,525	5,706	16,798	-			36,029	51	177	-	-		228	36,257
1970	14,212	9,857	8,220	-			32,289	278	281	-	-		559	32,848
1971	29,313	12,483	17,460	-			59,256	1,329	1,002	-	-		2,331	61,587
1972	25,949	27,687	23,998	-			77,634	900	13,030	267	-		14,197	91,831
1973	31,082	17,201	16,214	-			64,497	1,478	10,531	362	-		12,371	76,868
1974	38,824	22,833	29,470	-	-		91,127	2,281	9,663	39	-		11,983	103,110
1975	32,382	21,484	31,785	-	-		85,651	926	2,685	143	-		3,754	89,405
1976	34,221	19,109	24,999	-	-		78,349	933	2,392	112	-		3,437	81,786
1977	16,375	15,454	5,333	-	-		37,162	640	3,824	24	-		4,488	41,650
1978	21,299	20,244	4,119	119	-		45,781	1,182	5,363	2	1		6,548	52,329
1979	24,492	14,885	1,574	1,948	20		42,919	1,227	11,620	0	0		12,847	55,766
1980	-	-	-	-	-	-	62,618	-	-		-	-	8,296	70,813
1981	-	-		-	-	-	66,394	-	-		-	-	8,040	74,434

Table 1.--(Continued)

	Eastern Bering Sea (east of 180°)							Aleutian Island area						E. Bering Sea and Aleutian comb. total
	Japan							Japan						
Year	MS-LG-NPT 2/	LBD 3/	USSR	ROK 4/	Other 5/ nations	Joint 6/ ventures	Total	MS-LG-NPT	LBD	USSR	ROK	Joint ventures	Total	
ARROWTOOTH FLOUNDER														
1970	9,047	307	3,244	-			12,598	274	0	-	-		274	12,872
1971	6,235	5,368	7,189	-			18,792	44	537	-	-		581	19,373
1972	1,261	2,562	9,300	-			13,124	194	1,023	106	-		1,323	14,447
1973	1,915	3,014	4,288	-			9,217	483	3,199	23	-		3,705	12,922
1974	1,221	1,602	18,650	-	-		21,473	1,378	1,817	0	-		3,195	24,668
1975	330	911	19,591	-	-		20,832	115	526	143	-		784	21,616
1976	139	1,535	16,132	-	-		17,806	96	1,274	-	-		1,370	19,176
1977	4,000	2,160	3,294	-	-		9,454	158	1,857	20	-		3,035	11,489
1978	4,598	1,093	2,576	91	-		8,358	524	1,256	2	0		1,782	10,140
1979	4,122	1,166	948	1,680	5		7,921	371	6,065	0	0		6,436	14,357
1980	-	-	-	-	-	-	13,674	-	-	-	-	-	4,603	18,277
1981	-	-	-	-	-	-	13,473	-	-	-	-	-	3,640	17,113
GREENLAND TURBOT														
1970	5,165	9,550	4,976	-			19,691	4	281	-	-		285	19,976
1971	23,078	7,115	10,271	-			40,464	1,285	465	-	-		1,750	42,214
1972	24,688	25,125	14,697	-			64,510	706	12,007	161	-		12,874	77,384
1973	29,167	14,187	11,926	-			55,280	995	7,332	339	-		8,666	63,946
1974	37,603	21,231	10,820	-	-		69,654	903	7,846	39	-		8,788	78,442
1975	32,052	20,573	12,194	-	-		64,819	811	2,159	0	-		2,970	67,789
1976	34,082	17,574	8,867	-	-		60,523	837	1,118	112	-		2,067	62,590
1977	12,375	13,294	2,039	-	-		27,708	482	1,967	4	-		2,453	30,161
1978	16,701	19,151	1,543	28	-		37,423	658	4,107	0	1		4,766	42,189
1979	20,370	13,719	626	268	15		34,998	856	5,555	0	0		6,411	41,409
1980	-	-	-	-	-	-	48,844	-	-	-	-	-	3,693	52,537
1981	-	-		-	-	-	52,921	-	-	-	-	-	4,400	57,321

1/ Sources of data: 1960-76, Wakabayashi and Bakkala 1978; 1977-79, Data submitted to U.S. by fishing nations; 1980-81, French et al. 1981, 1982.
2/ Mothership, North Pacific longline and North Pacific trawl fisheries combined. 3/ Landbased dragnet trawl fishery.
4/ Republic of Korea. 5/ Taiwan, Poland, and Federal Republic of Germany (West Germany). 6/ Joint ventures between U.S. fishing vessels and Japanese, Polish, ROK, West German, and USSR processing vessels.

Following a long period of relatively small catches in the eastern Bering Sea and Aleutian Island region during the 1960's, catches of turbot increased, reaching an all-time high of approximately 103,000 t in 1974. Catches have since declined, ranging from 41,650 to 55,800 t in 1977-79 according to catch data reported by nations fishing there. Catches, as shown by U.S. observer data, indicate that 70,800 and 74,400 t were taken in 1980 and 1981, respectively. The 1980 catch, according to U.S. observer estimates (French et al. 1981), was higher than that reported by the fishing nations. This difference appears to result primarily from different methods of categorizing reported catches of these species as turbots or as miscellaneous flatfish[1/], as shown below:

Sources of data	Greenland turbot	Arrowtooth flounder	Greenland turbot and arrowtooth flounder combined	Miscellaneous flatfish	Total all species
	------------------------ t ------------------------				
Fishing nations	39,559	14,806	54,365	13,327	67,692
French et al. 1981	52,536	18,277	70,813	937	71,750

Based on the observer data, catches of turbots in recent years may be higher than reported by fishing nations.

CONDITION OF STOCKS

Relative Abundance

Two sources of data are used to examine trends in relative abundance of Greenland turbot and arrowtooth flounder: commercial catch and effort data

1/ Includes mostly rex sole, *Glyptocephalus zachirus*, Dover sole, *Microstomus pacificus*, starry flounder, *Platichthys stellatus*, longhead dab, *Limanda proboscidea*, and butter sole, *Isopsetta isolepis*.

from the Japanese landbased dragnet fishery and data from Northwest and Alaska Fisheries Center (NWAFC) research vessel surveys. The Japanese landbased stern trawlers have targeted on Greenland turbot, and these data may provide reasonably good indices of abundance for adults of this species. The data may not provide good indices of abundance for arrowtooth flounder because this species is apparently only taken as an incidental part of the catch.

The NWAFC research vessel surveys have been limited to continental shelf waters in most years and essentially sampled only the juvenile portion of the population. The 1979 and 1981 joint surveys with the Fisheries Agency of Japan, however, surveyed major portions of the eastern Bering Sea shelf and slope from depths of 20 to 1,000 m to provide a better overall assessment of turbot than has previously been available. A similar extensive eastern Bering Sea survey was conducted in 1982, although Japanese data from sampling on the continental slope is not yet available.

The catch and effort data from the landbased fishery are analyzed in two ways. The first procedure involves using data from all 1/2° lat. and 1° long. statistical blocks and months in which the species were taken, and the second procedure uses only those statistical blocks in which Greenland turbot made up 50% or more of the catch. The first procedure (Figure 1) shows that after reaching a peak of 40 t/100 h trawled in 1972, the relative abundance of Greenland turbot declined to 29 t/100 h trawled in 1975, and then dropped sharply to 9 t/100 h trawled in 1977. The catch per unit of effort (CPUE) values have leveled off since 1977, remaining well below the values of 1972-76. The trend in relative abundance shown by the second procedure, which is assumed to more accurately reflect abundance of the exploitable population, is similar to that shown by the first procedure, except that CPUE increased from 26 t/100 h in 1978 to 36 t/100 h trawled in 1980. The 1981 value (34 t/100 h) was similar to that in 1980.

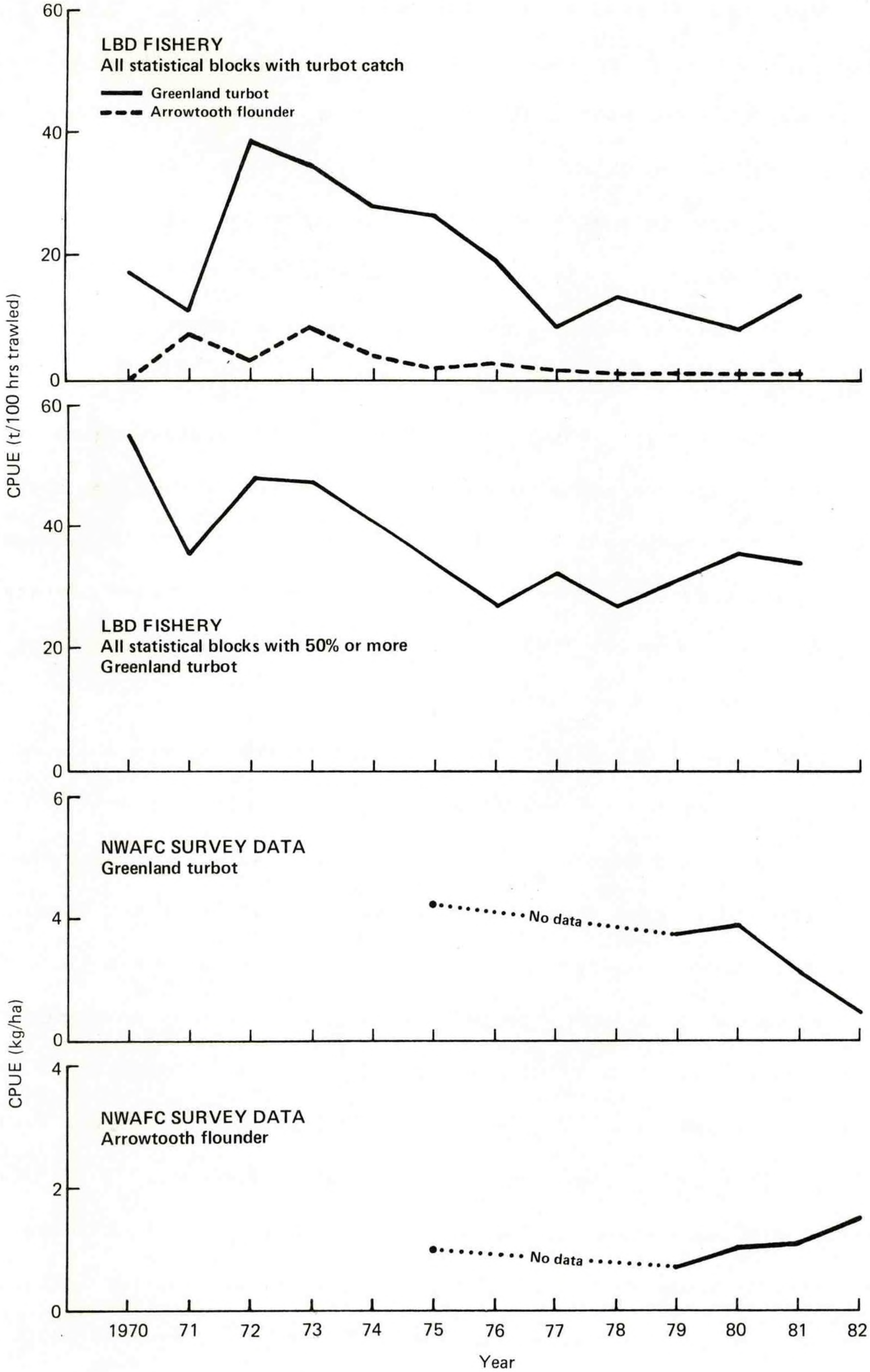

Figure 1.--Relative abundance (catch per unit of effort (CPUE)) of Greenland turbot and arrowtooth flounder as shown by data from the Japanese landbased dragnet (LBD) fishery and by large-scale surveys of the Northwest and Alaska Fisheries Center (NWAFC) that have sampled major portions of the eastern Bering Sea continental shelf.

Relative abundance values from large-scale NWAFC surveys in 1975 and 1979-82 (using data from comparable areas sampled on the continental shelf) reflected relative stability in abundance of juvenile Greenland turbot between 1975 and 1980 and then a marked decline with CPUE falling from 3.7 kg/ha in 1980 to 0.8 kg/ha in 1982. This apparent low recruitment of juvenile fish had apparently not affected the abundance of the adult stock through 1981. As shown above, CPUE values from the landbased fishery were higher in 1980-81 than in 1978-79 and CPUE values from sampling on the slope during the joint U.S.-Japan trawl survey increased from 33 kg/ha in 1979 to 54 kg/ha in 1981.

The trend in relative abundance for arrowtooth flounder, based on land-based fishery data from all statistical blocks (Figure 1), indicated a decline between 1973 and 1975 and then relative stability until 1981. Survey results on the slope from joint U.S.-Japan surveys show similar CPUE values in 1979 (9.8 kg/ha) and 1981 (9.4 kg/ha).

CPUE values from the large-scale NWAFC surveys on the continental shelf indicated no change in abundance of juvenile arrowtooth flounder between 1975 and 1980, but an increase from 1.0 kg/ha in 1980 to 1.5 kg/ha in 1982.

Biomass Estimates

Biomass estimates (t) based on data from the large-scale NWAFC surveys in 1975 and 1979-82 (for comparable areas sampled on the continental shelf) were as follows:

Species	1975	1979	1980	1981	1982
	t				
Arrowtooth flounder	28,000	42,000	51,300	48,800	69,900
Greenland turbot	126,700	143,300	155,600	92,500	37,700
Total	154,700	185,300	206,900	141,300	107,600

These estimates, which primarily represent biomass of only the juvenile portion of the population, indicated an increase in the abundance of juveniles through 1980, but a sharp decrease in 1981 and 1982 due to a major decline in the abundance of juvenile Greenland turbot.

Data from the Japanese and U.S. cooperative surveys in 1979 and 1981 provide the most comprehensive and latest abundance estimates for the overall juvenile and adult populations in the eastern Bering Sea. A cooperative survey between these nations in 1980 also provided an estimate for the Aleutian Islands region as follows:

Species	Eastern Bering Sea 1979	Eastern Bering Sea 1981	Aleutian region 1980
	t	t	t
Arrowtooth flounder	71,600	83,700	62,900
Greenland turbot	348,600	292,900	74,800
Total	420,200	376,600	137,700

The 1979 survey data is believed to be more representative of the overall population abundance because waters north of St. Matthew Island were sampled where Greenland turbot are relatively abundant. The combined sampled biomass of turbots from the 1979 eastern Bering Sea and 1980 Aleutian surveys was approximately 560,000 t with about 25% of the total located in the Aleutian Islands region.

Age Composition

Age data for arrowtooth flounder and Greenland turbot have been collected in recent years during U.S. research vessel surveys and by U.S. observers from the commercial fishery. The series is short, extending back to only 1976.

However, it begins to provide an understanding of the age composition of the two species in research vessel catches and the commercial fishery.

The age data for arrowtooth flounder from NWAFC research surveys on the continental shelf show that age groups taken by the research gear are mainly 2-4 yr olds (Figure 2). Age information collected on U.S. research vessels in 1978-81 indicated the 1975-77 year-classes to be relatively strong with the 1977 year-class the strongest of this series. The strong 1977 year-class should have become available to the commercial fishery in 1981-82 as 4-5 yr old fish. Age data for arrowtooth flounder from Japanese large trawlers in 1977 and Japanese small trawlers (mainly landbased trawlers) in 1978 indicated that arrowtooth flounder become recruited to the commercial fishery at about age 4 and that catches consist mainly of ages 4-7. The relatively high abundance of the 1972 year-class in the research survey area in 1976, and the subsequent predominance of this year-class in the 1977 and 1978 commercial catches indicated that abundance of juvenile fish as shown by survey data on the shelf may be useful in forecasting the abundance of year-classes in the adult stock.

Age data for Greenland turbot show that research vessel catches on the continental shelf of the southeastern Bering Sea are mainly age 1-3 yr fish (Figure 3). The recruitment of age 1 fish in research vessel catches in 1980 and 1981 appeared to be low and probably accounted for the decline in abundance of juvenile Greenland turbot noted from survey data.

Age data collected from catches of small Japanese trawlers in International North Pacific Fisheries Commission (INPFC) statistical areas I and II (170°W-180° long.) in 1978 and 1979 indicated a wide range of age groups (3 or 4-19 yr) were represented in commercial catches with age groups 4 and 5 predominant.

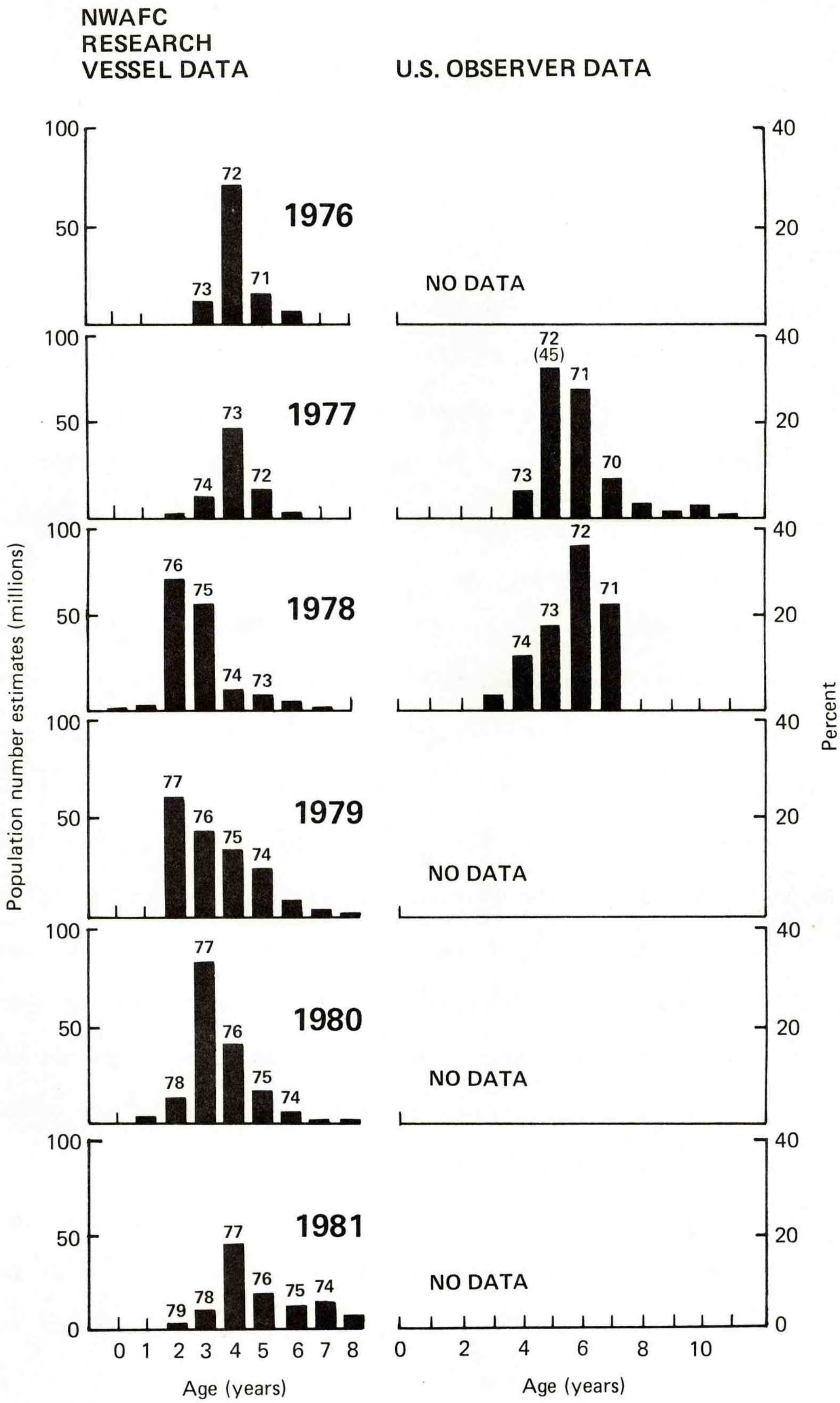

Figure 2.--Age composition of arrowtooth flounder as shown by data from Northwest and Alaska Fisheries Center (NWAFC) demersal trawl surveys and by data collected in the commercial fishery by U.S. observers.

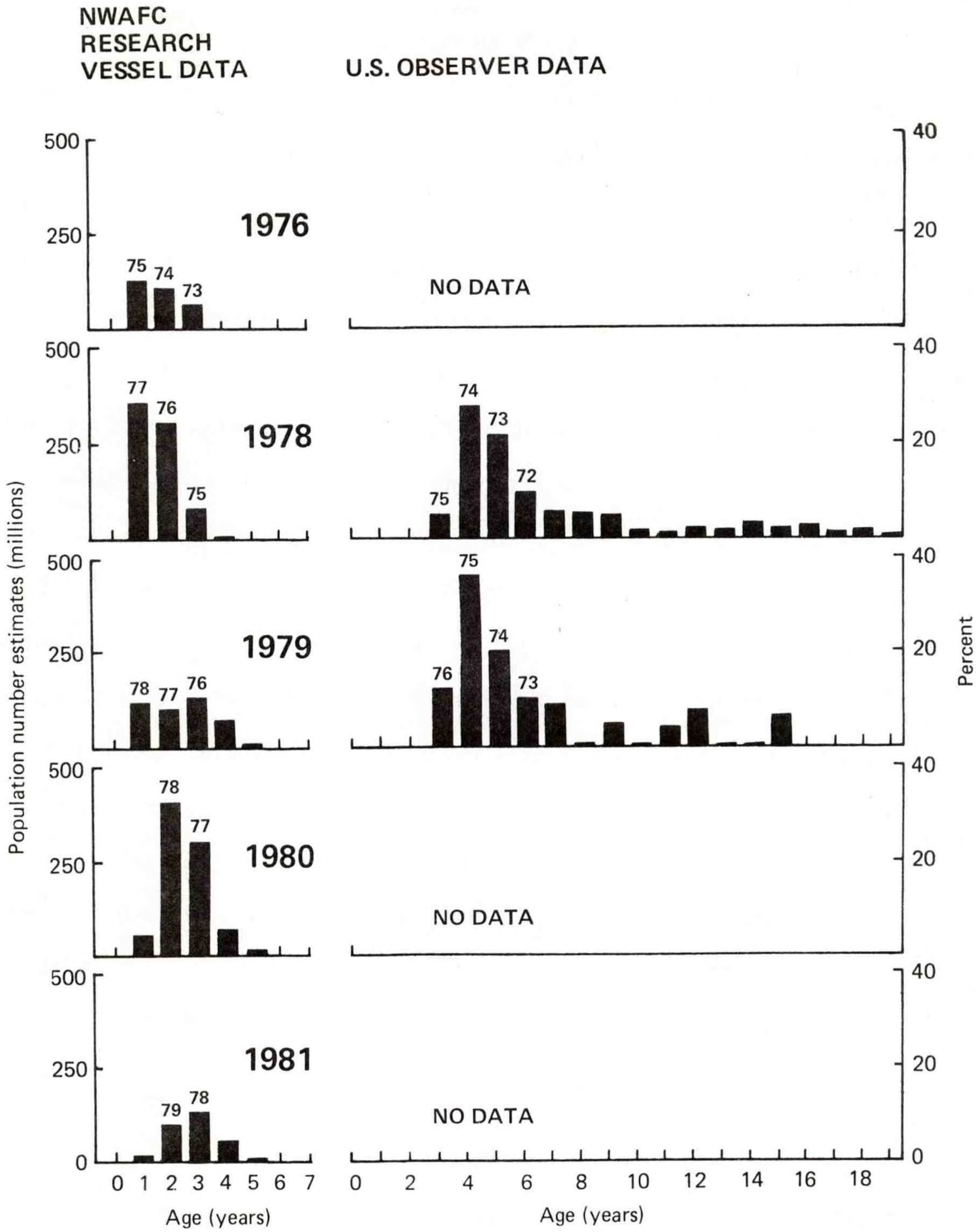

Figure 3.--Age composition of Greenland turbot as shown by data from Northwest and Alaska Fisheries Center (NWAFC) demersal trawl surveys and by data collected in the commercial fisheries by U.S. observers.

MAXIMUM SUSTAINABLE YIELD

Data from cooperative Japanese-U.S. surveys are now available for both the eastern Bering Sea and Aleutian Islands region from which an estimate of maximum sustainable yield (MSY) can be made for the complete Bering Sea management area. Using the biomass estimate from the 1979 survey as being most representative of the overall eastern Bering Sea population (348,600 t) and the 1980 estimate from the Aleutians (74,800 t) produced an overall estimated biomass for Greenland turbot of 423,400 t. Assuming that Greenland turbot have been fully exploited and the population has been reduced to a level that produces MSY (one-half the virgin population size), the virgin population would be estimated at 846,800 t. Based on the Alverson and Pereyra (1969) yield equation and a natural mortality coefficient of 0.19 (Okada et al. 1980), MSY is estimated as 0.5 x 0.19 x 846,800 t or 80,400 t.

Based on the above survey data the overall biomass of arrowtooth flounder from the eastern Bering Sea and Aleutians was estimated to be 134,500 t. Using the same assumptions as those for Greenland turbot, except that a value of 0.2 was used for natural mortality (Okada et al. 1980), MSY would be estimated as 0.5 x 0.2 x 269,000 t or 26,900 t.

The combined estimate of MSY for Greenland turbot and arrowtooth flounder from the overall management area is then 107,300 t.

EQUILIBRIUM YIELD

Catch rates and biomass estimates for juvenile Greenland turbot and arrowtooth flounder were relatively stable from 1975 to 1980 based on NWAFC research vessel survey data. The abundance of juvenile arrowtooth flounder remained stable in 1981 and then increased in 1982. The abundance of juvenile Greenland turbot has shown a sharp decline in 1981 and 1982, due apparently to the low recruitment of the 1979 and 1980 year-classes. Evidence from the

Japanese landbased fishery indicated that, following the decline in relative abundance of adult Greenland turbot during 1972-76 when catches averaged about 70,000 t annually, abundance stabilized between 1976 and 1979 when catches averaged 44,100 t, and then increased in 1980-81. Estimated biomass of the combined arrowtooth flounder and Greenland turbot stocks was 560,000 t based on the 1979 eastern Bering Sea and 1980 Aleutian surveys. The 1981 eastern Bering Sea survey data indicated some decrease in biomass, perhaps to 90% of the 1979-80 estimate, about 500,000 t. Although CPUE data from the landbased fishery have not shown any decrease through 1981, abundance of the adult stock may decline in immediate future years because of poor recruitment from the 1979 and 1980 year-classes.

MSY for Greenland turbot for the eastern Bering Sea and Aleutian regions has been estimated to be 80,400 t. Because average catches of 70,000 t during 1972-76 caused a decline in abundance of Greenland turbot when abundance was relatively high (see Figure 1), there is some question as to the accuracy of the MSY estimate. Catches of this magnitude represent an exploitation rate of about 0.20 which seems high for a long-lived species. Rather than risk over-fishing, it is recommended that catches be limited below the estimate of MSY until the reaction of the stock to these somewhat lower catches can be observed. A tentative equilibrium yield (EY) of 65,000 t was suggested which represents an exploitation rate of 0.15. Based on U.S. observer data, catches in 1980 (52,500 t) and 1981 (57,300) approached this level and will provide data on the response of the stock to the approximate suggested rate of exploitation.

MSY for arrowtooth flounder in the eastern Bering Sea was estimated to be 26,900 t. Catches in 1980 and 1981 were 18,300 t and 17,100 t, respectively, according to observer estimates. There is no evidence that 1980 and 1981 catches were harmful to the population. The estimate of MSY seems high, however, representing an exploitation rate of 0.20. It is therefore suggested that EY be reduced below MSY for arrowtooth flounder to 20,000 t, which like that for Greenland turbot, represents an exploitation rate of 0.15.

For the turbot complex combined, the suggested EY for the eastern Bering Sea and Aleutians is 85,000 t.

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OTHER FLATFISH

by Richard G. Bakkala

INTRODUCTION

This species complex is made up of the following small flatfish which have distributions that are mainly restricted to waters of the continental shelf: flathead sole, Hippoglossoides elassodon; rock sole, Lepidopsetta bilineata; Alaska plaice, Pleuronectes quadrituberculatus; and small amounts of miscellaneous flatfish including rex sole, Glyptocephalus zachirus; Dover sole, Microstomus pacificus; starry flounder, Platichthys stellatus; longhead dab, Limanda proboscidea; and butter sole, Isopsetta isolepis. Catches of these species are almost entirely from the eastern Bering Sea, with only small amounts taken in the Aleutians. All-nation catches of these species in the eastern Bering Sea and Aleutians were apparently relatively stable in the 1960s, ranging around 30,000 t, but increased to about 92,000 t in 1971 (Table 1). At least part of this increase was due to better species identification and reporting of catches in the 1970s. After 1971, catches declined to about 20,000 t in 1975 but reported catches increased to 43,000 t in 1978 and 35,600 t in 1979. The higher catches in 1978 and 1979 may be due to two causes; one the renewal of the USSR flounder fishery in those years and, secondly, the first reporting (starting in 1977) of catches of miscellaneous species of flatfish. As noted in the previous section on Greenland turbot, Reinhardtius hippoglossoides, and arrowtooth flounder, Atheresthes stomias, some fisheries may have categorized part of their turbot catch as miscellaneous flatfish which would have artificially inflated the catches of miscellaneous flatfish and, subsequently, the total catches of other flatfish in 1977-79. Catches in 1980 and 1981, based on U.S. observer data (French et al. 1981, 1982), were much lower at 20,500-23,400 t.

Table 1.--All-nation catches of other flatfishes in the eastern Bering Sea and Aleutian Islands region in metric tons (t)(1980 and 1981 data includes catches from joint venture operations between U.S. fishing vessels and non-U.S. processing vessels).1/

Year	Rock sole	Flathead sole	Alaska plaice	Miscellaneous flatfish2/	Total
	----	----	t	----	----
1963	5,029	29,639	975	-	35,643
1964	3,390	25,331	1,883	-	30,604
1965	3,825	6,841	1,020	-	11,686
1966	9,186	11,045	4,633	-	24,864
1967	4,787	23,469	3,853	-	32,109
1968	5,267	21,761	2,619	-	29,647
1969	9,242	18,565	6,942	-	34,749
1970	20,125	41,163	3,402	-	64,690
1971	40,420	51,040	992	-	92,452
1972	60,829	15,694	290	-	76,813
1973	23,837	18,165	1,917	-	43,919
1974	20,011	14,958	2,388	-	37,357
1975	12,014	5,888	2,491	-	20,393
1976	9,964	8,162	3,620	-	21,746
1977	5,319	7,586	3,119	7,578	23,602
1978	7,038	14,603	9,468	11,838	42,947
1979	5,874	6,777	15,572	7,376	35,599
1980	7,601	5,011	6,908	937	20,457
1981	9,021	5,193	8,653	561	23,428

1/ Sources of data: 1963-76, Wakabayashi and Bakkala 1978; 1977-79, data submitted to U.S. by fishing nations; 1980-81, French et al. 1981; 1982.

2/ Includes rex sole, Dover sole, starry flounder, longhead dab, and butter sole.

Alaska plaice, which has usually been a minor part of the overall catches of "other flatfish," have become a major contributor to catches since 1978 (Table 1).

CONDITION OF STOCKS

Relative Abundance

Because "other flatfishes" are taken incidentally in the target fisheries for other species, indices of abundance from commercial fisheries data do not accurately reflect trends in abundance for these species (Bakkala et al. 1979). It is, therefore, necessary to use research vessel survey data for assessing the condition of these stocks.

As described in the section on yellowfin sole, preliminary abundance estimates from the 1982 Northwest and Alaska Fisheries Center (NWAFC) survey were substantially higher than from the 1981 survey data for a number of bottom-tending species such as the flatfishes. Increases in catch per unit of effort (CPUE) were particularly large for rock sole increasing from 6.9 to 13.4 kg/ha and Alaska plaice from 10.6 to 14.5 kg/ha while that for flathead sole was moderate, increasing from 3.6 to 4.6 kg/ha. As discussed previously, these higher 1982 estimates may have been due in part to better bottom-tending characteristics of the trawls used in 1982 compared to those used in 1981 and earlier years.

CPUE values from surveys that have sampled major portions of the eastern Bering Sea since 1975 are illustrated in Figure 1. These trends indicate that abundance of rock sole and Alaska plaice may have increased from 1975 to 1978-79 and showed further increases in 1980-82. The relative abundance of flathead sole was relatively stable from 1975 to 1979 and then increased moderately each year in 1980, 1981, and 1982.

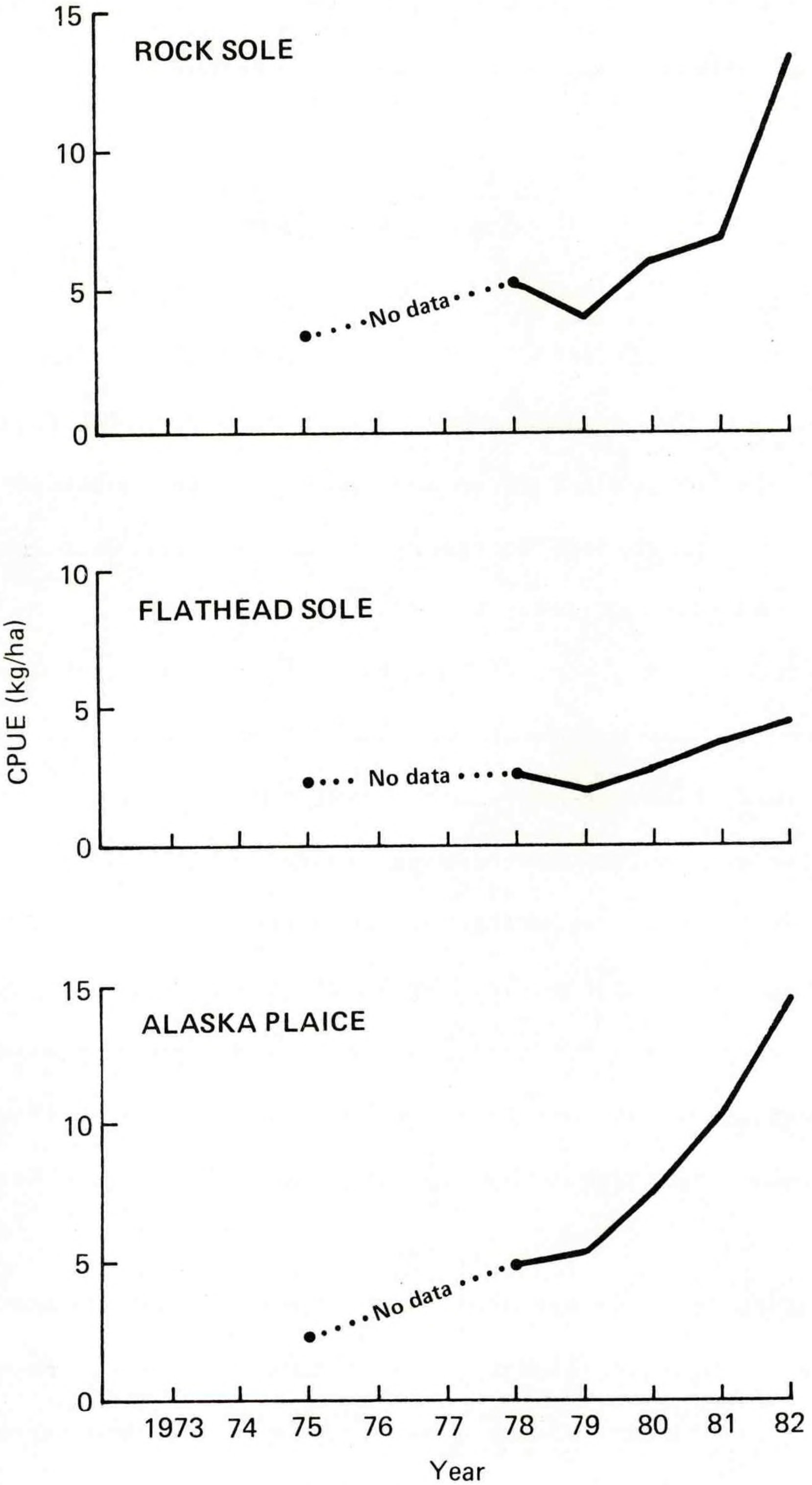

Figure 1 .--Relative abundance of rock sole, flathead sole, and Alaska plaice as shown by large-scale demersal trawl surveys of the Northwest and Alaska Fisheries Center that have sampled major portions of the eastern Bering Sea continental shelf.

Biomass Estimates

Biomass estimates from large-scale NWAFC surveys (Table 2) show little change in the combined biomass of rock sole, flathead sole, and other miscellaneous species between 1975 and 1979, but the biomass of Alaska plaice apparently more than doubled in that period. Estimates from the 1980 and 1981 NWAFC surveys show major increases in the mean biomass estimates for rock sole and Alaska plaice and a moderate increase for flathead sole and the miscellaneous species compared to 1979. The increases for rock sole and Alaska plaice were extremely large and may have been due in part to factors other than increases in stock abundance such as changes in distribution that increased their availability in the survey area.

Further large increases in biomass were observed in 1982 compared to 1981 for rock sole, Alaska plaice, and the other miscellaneous species of flatfish. The validity of these preliminary 1982 estimates is still being examined, but the large increases may be due in part to the higher efficiency of the trawls used in 1982 for flatfish than trawls used in 1981 and some earlier years. Also accounting for part of these increases for some species was sampling of waters around Nunivak Island in 1982 but not in 1981. This area, which was not sampled in 1981 (see Figure 2 in the article on walleye pollock by Bakkala and Wespestad in this Technical Memorandum) accounted for about 20,400 t of biomass for rock sole, 98,000 t of Alaska plaice and 24,200 t of miscellaneous species of flatfish in 1982. None of the 1982 biomass estimate for flathead sole was accounted for by this area. Assuming the same distribution of biomass in 1981 and 1982, this area accounted for 60% of the increase in biomass observed for Alaska plaice between 1981 and 1982, 32% of the increase for miscellaneous flatfish, but only 6.6% of the increase for rock sole.

Abundance of "other flatfish" is much lower in the Aleutian Islands region than in the eastern Bering Sea. The estimated biomass derived from the 1980

Table 2.--Estimated biomass of species in the "other flatfish" complex in the eastern Bering Sea (EBS) and Aleutian (Aleut) regions based on research vessel survey data in 1975 and 1978-82.

Year	Area	Species				Total all species excluding Alaska plaice	Total all species
		Rock sole	Flathead sole	Alaska Plaice	Others		
		t					
1975	EBS[1]	170,300	113,000	127,100	11,000	294,300	421,400
1978	EBS	177,700	85,600	165,200	31,800	295,100	460,300
1979	EBS	182,800	101,800	283,000	50,500	335,100	618,100
1980	EBS	283,000	128,400	348,800	59,000	470,400	819,200
	Aleut.[2]	35,100	3,800	0	3,700	42,600	42,600
1981	EBS	298,900	168,300	500,500	71,700	538,900	1,039,400
1982	EBS	609,500	211,600	663,700	147,000	968,100	1,631,800

1/ Eastern Bering Sea

2/ Aleutian Islands region

cooperative U.S.-Japan survey in the Aleutians was 42,600 t, most of which (35,100 t) was rock sole.

Age Composition and Year-Class Strength

Age data have been collected for rock sole during NWAFC research vessel surveys since 1973 (Figure 2). The 1965-70 year classes formed the principal part of the sampled population through 1977, with the 1969 and 1970 year classes being particularly strong. The 1969 and 1970 year classes continued to form a significant part of the overall population through 1980. The 1971-74 year classes may be below average strength, but the 1975, in particular, and the 1977-79 year classes may be of above average strength. This recruitment may account, at least in part, for the increases in estimates of relative and absolute abundance for rock sole.

The 1965-70 year classes formed the major part of commercial catches of rock sole in 1973-79 (Figure 2). The 1969 and 1970 year classes were particularly abundant in commercial catches in 1975-79, but recruitment of the 1971 and 1972 year classes into the fishery was low in 1979, paralleling results from research vessel data.

Age data have also been collected for flathead sole during research vessel surveys since 1973 and from the commercial fishery by U.S. observers since 1975 (Figure 3). The 1965 to 1969 year classes formed the bulk of the population sampled by research vessels in 1976 and 1977 and were a major component of catches by the commercial fishery along with the 1970 year class in 1975-79. In more recent years, there appears to be good recruitment from the 1974-77 year classes which may account for the higher abundance of flathead sole observed from survey data.

Recruitment of stronger than average year classes may also be the primary reason for the increase in abundance of Alaska plaice in recent years. The

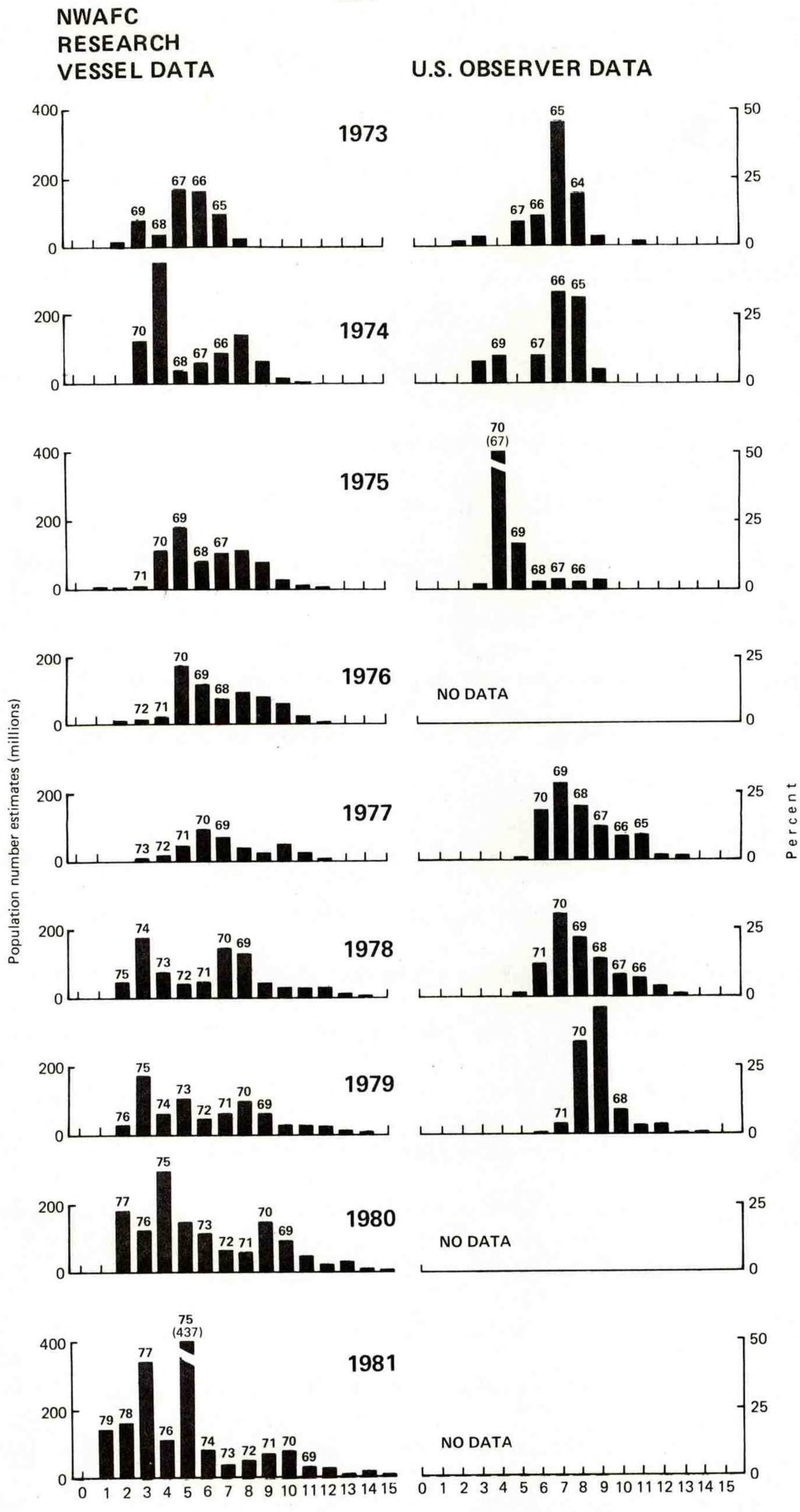

Figure 2.--Age composition of rock sole as shown by data from Northwest and Alaska Fisheries Center (NWAFC) demersal trawl surveys and by data collected by U.S. observers in the commercial fishery.

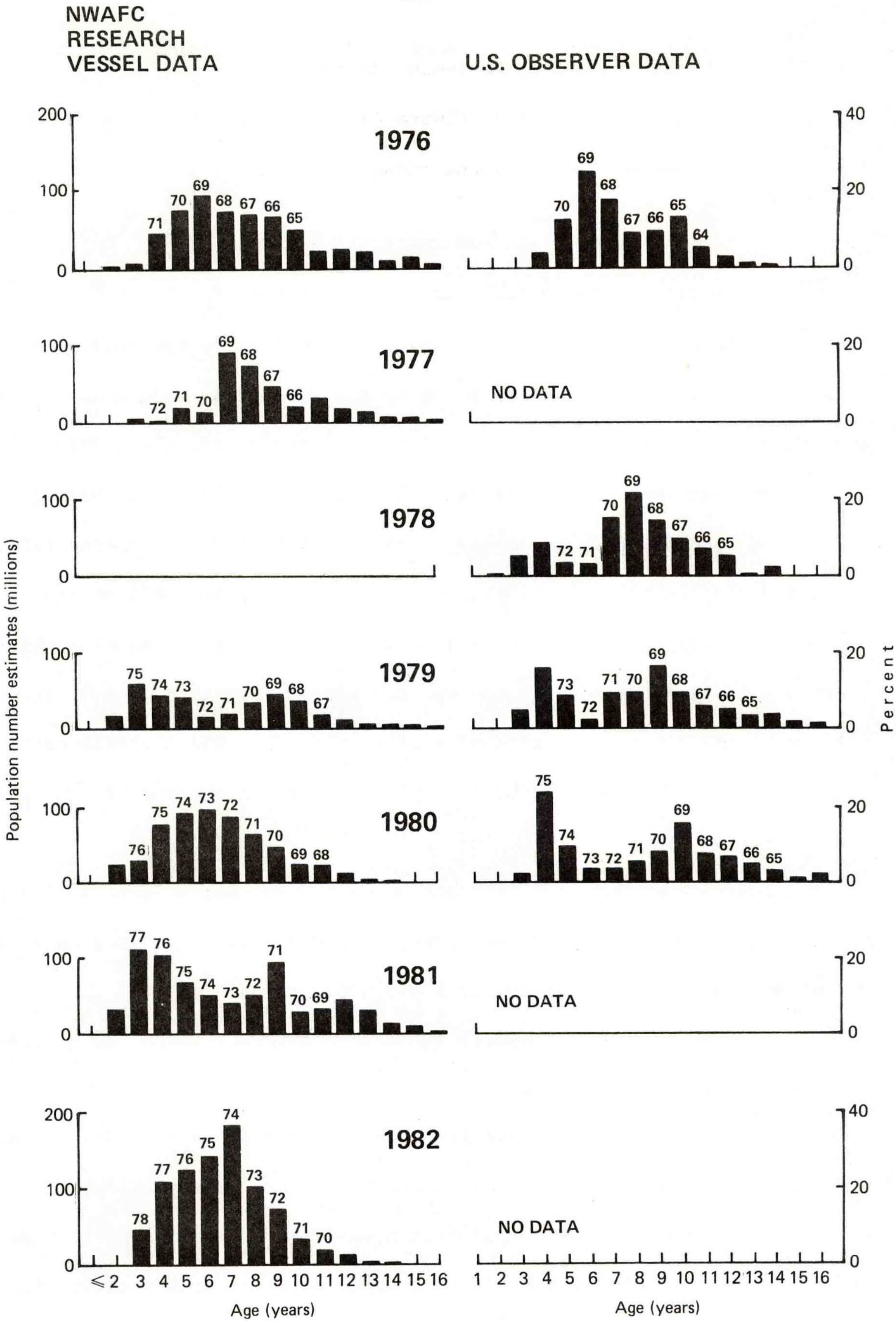

Figure 3.--Age composition of flathead sole as shown by data from Northwest and Alaska Fisheries Center (NWAFC) demersal trawl surveys and by data collected by U.S. observers in the commercial fishery.

1967-71 year classes appear relatively strong and the 1972-74 year classes may also be relatively abundant (Figure 4). The 1966-69 year classes were the primary age groups taken by the commercial fishery in 1978.

MAXIMUM SUSTAINABLE YIELD

Because of the absence of good population data for the other flounder complex, maximum sustainable yield (MSY) for this group was initially approximated. The approximations were based on the assumption that this species group was fully utilized prior to 1975. With this assumption, one approximation of MSY was provided by the average catch from 1963 to 1974, which was 43,000 t. The second approximation was based on the Schaefer model (Schaefer 1954), which indicated that, with full utilization prior to 1975, the 1975 biomass would be about half its virgin size. A large-scale NWAFC research vessel survey that covered the major portions of the eastern Bering Sea shelf in 1975 indicated that the standing stock of rock sole, flathead sole, and miscellaneous species of flatfish was 240,200-348,900 t, implying a virgin biomass of 480,400-697,800 t.

Assuming M is 0.23 for the rock sole-flathead sole-miscellaneous flatfish complex, the Alverson and Pereyra (1969) yield equation produces an estimate of MSY of 55,200-80,200 t (0.5 x 0.23 x 480,400 - 697,800 t).

Estimates of MSY, therefore, range from 43,000 t to 80,200 t based on the two methods of approximation.

The mean estimated biomass from the 1980 eastern Bering Sea and Aleutian surveys (513,000 t) and the 1981 eastern Bering Sea survey (538,900) falls within the estimated virgin population biomass derived from the 1975 data. The preliminary 1982 estimate (968,100 t) exceeds the estimated virgin biomass range, but this higher estimate needs validation. Nevertheless, the 1980-82 estimates indicate that these species are in good condition and can sustain catches in the MSY range.

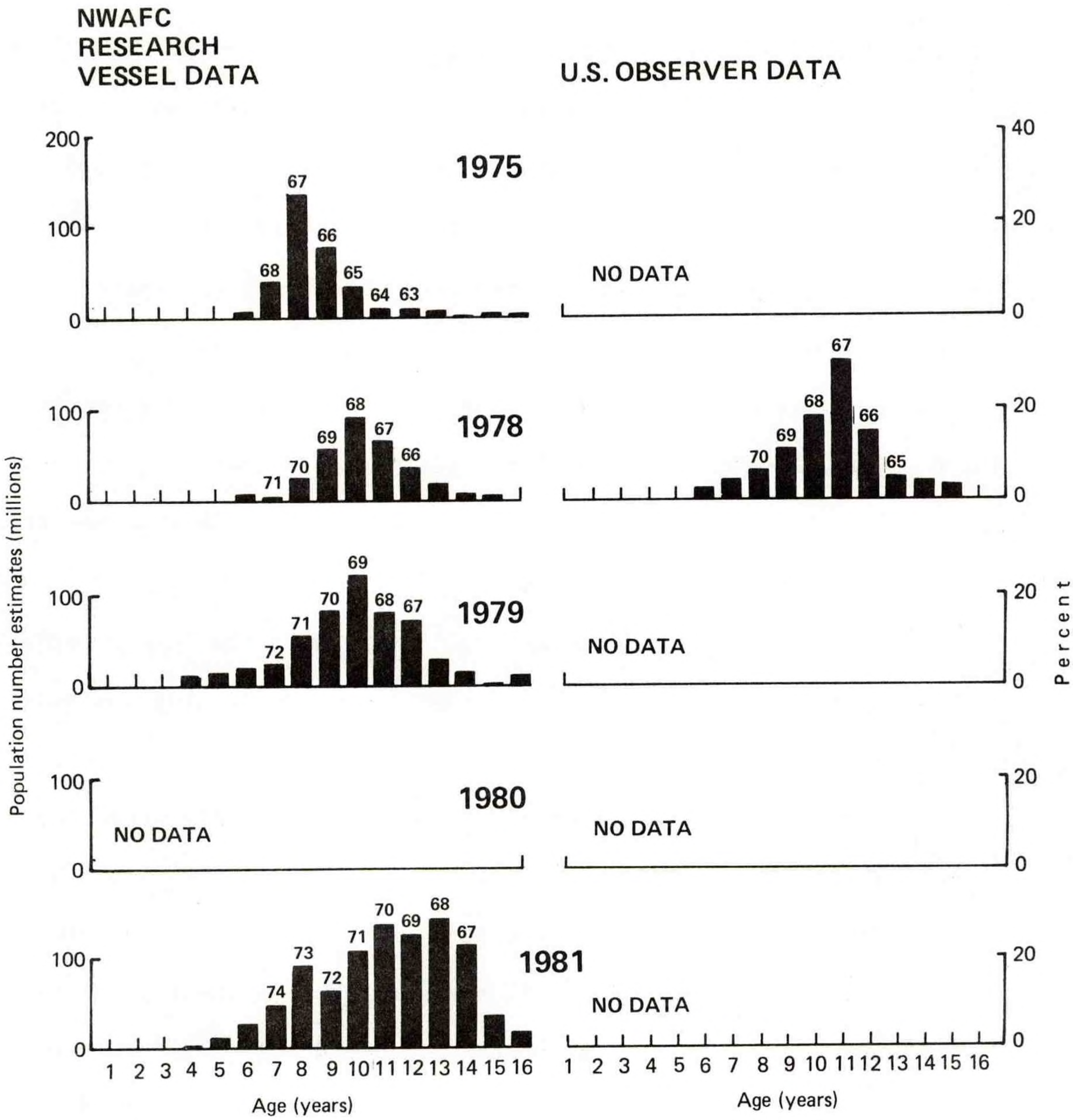

Figure 4.--Age composition of Alaska plaice as shown by data collected from Northwest and Alaska Fisheries Center (NWAFC) demersal trawl surveys and by data collected by U.S. observers in the commercial fishery.

Alaska plaice have not been incorporated into estimates of MSY for the rock sole-flathead sole-miscellaneous flatfish complex because they have not been exploited at the same rate as rock sole and flathead sole until recent years, probably because of their more inshore distribution which is removed from the main fishing areas. Inclusion of Alaska plaice would increase MSY and subsequent estimates of equilibrium yield (EY) and acceptable biological catch (ABC). This higher EY and ABC might be mainly used for rock sole and flathead sole rather than distributed among the three species and possibly lead to overexploitation of rock sole and flathead sole.

Separate estimates of MSY and EY have, therefore, been derived for Alaska plaice. Biomass estimates for Alaska plaice based on data from large-scale surveys since 1975 have been increasing and continued to increase through 1982. From an estimate of 127,100 t in 1975, they have increased to 348,800 t in 1980, 500,500 t in 1981, and 663,700 t in 1982. The latter estimate is preliminary and requires validation. MSY for Alaska plaice was estimated in 1980 based on the 95% confidence interval around the 1979 mean estimate, and assuming that, because this species has only been lightly exploited throughout the history of the fishery and because the biomass more than doubled between 1975 and 1979, the 1979 biomass may have approximated the abundance of the virgin population. The higher 1981 estimate may more nearly approximate the virgin biomass. Based on these assumptions, and using the yield equation and a natural mortality coefficient of 0.23, MSY was estimated to be (0.5 x 0.23 x 392,000-609,000 t) or 45,100-70,000 t.

EQUILIBRIUM YIELD

Indices of relative abundance and estimates of absolute abundance from large-scale NMFS research vessel surveys indicated that the population abundance of rock sole, flathead sole, and miscellaneous species of flatfish has increased between 1978 and 1981. The apparent good condition of these species indicates that the resources should be capable of producing catches at the mid-point of the MSY range. EY is, therefore, estimated to be 61,600 t.

Abundance of the Alaska plaice resource continues to increase and the population biomass may approximate the virgin population size. EY is estimated to equal at least the midpoint of the MSY range or 57,600 t.

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SABLEFISH

by

Renold E. Narita

INTRODUCTION

Sablefish, Anoplopoma fimbria, are widely distributed along the continental shelf and slope of the North Pacific Ocean (including the Bering Sea) from Hokkaido, Japan, to Baja, California. Longline vessels and occasionally trawlers fish for sablefish in relatively deep waters of 400-900 m. The eastern Bering Sea fishery was initiated by Japanese longliners in 1958. The fishery grew rapidly during the early 1960's and catches increased to a peak of 28,520 t in 1962 (Table 1). As fishing grounds used by longliners in the eastern Bering Sea became preempted by expanding trawl fisheries, new longlining areas were established in the Aleutian region. Catches peaked in the Aleutians at 3,580 t in 1972.

Catches generally declined between 1968 and 1978 in the eastern Bering Sea and since 1972 in the Aleutian region. Although Bering Sea catches have increased slightly since 1979, they have remained at reduced levels when compared to earlier years. The decline in catches has been largely due to declining stock abundance; catch restrictions placed on the fishery have also been a minor contributing factor in recent years. In 1981, all-nation catches for the eastern Bering Sea and Aleutian areas were 2,578 t and 377 t, respectively.

The sablefish resource is managed by discrete geographical regions since the degree of interchange between regional populations appears to be minor in relation to stock size (Low et al. 1976, Wespestad et al. 1977). Tagging studies show, nonetheless, that some long-distance migrations occur and, thus, the various populations of the northeastern Pacific Ocean may be interrelated to a degree.

Table 1.--Historical catches of sablefish in metric tons by nation in the eastern Bering Sea and Aleutian Region, 1958-81. 1/

	EASTERN BERING SEA				ALEUTIAN REGION				
YEAR	JAPAN 2/	USSR	OTHERS 3/	TOTAL	JAPAN 2/	ROK	USSR	OTHERS 4/	TOTAL
1958	32	--	--	32	5/	--	--	--	5/
1959	393	--	--	393	5/	--	--	--	5/
1960	1,861	--	--	1,861	5/	--	--	--	5/
1961	26,182	--	--	26,182	5/	--	--	--	5/
1962	28,521	--	--	28,521	5/	--	--	--	5/
1963	18,404	--	--	18,404	5/	--	--	--	5/
1964	8,262	--	--	8,262	975	--	--	--	975
1965	8,240	--	--	8,240	360	--	--	--	360
1966	11,981	--	--	11,981	1,107	--	--	--	1,107
1967	13,457	274	--	13,731	1,383	--	--	--	1,383
1968	14,597	4,256	--	18,853	1,661	--	--	--	1,661
1969	17,009	1,579	--	18,588	1,804	--	--	--	1,804
1970	9,627	2,874	--	12,501	1,277	--	--	--	1,277
1971	12,410	2,830	--	15,240	2,571	--	170	--	2,741
1972	13,231	2,137	--	15,368	3,307	--	269	--	3,576
1973	6,395	1,220	--	7,615	2,875	--	134	--	3,009
1974	5,081	77	--	5,158	2,506	--	14	--	2,520
1975	3,384	38	--	3,422	1,538	--	79	--	1,617
1976	3,267	29	--	3,296	1,573	--	61	--	1,634
1977	2,109	--	--	2,109	1,631	86	--	--	1,717
1978	1,007	--	132	1,139	798	23	--	--	821
1979	1,071	49	269	1,389	617	164	--	--	781
1980	1,649	--	522	2,171	233	26	--	8	267
1981	2,091	--	487	2,578	320	56	--	1	377

1/ JAPANESE CATCH DATA FOR 1958-77 FROM SASAKI (1976) AND PERS. COMMUN., T. SASAKI, FAR SEAS FISHERY RESEARCH LAB., SHIMIZU, JAPAN; USSR DATA FOR 1967-77 PROVIDED THROUGH U.S.-USSR BILATERAL AGREEMENTS; 1976 DATA FOR REPUBLIC OF KOREA (ROK) AND 1978-81 DATA FOR ALL NATIONS FROM U.S. FOREIGN FISHERIES OBSERVER PROGRAM.

2/ FOR YEARS PRIOR TO 1977, JAPANESE CATCH DATA ARE REPORTED BY FISHING YEAR (NOV.-DEC.); LATER JAPANESE CATCHES ARE REPORTED BY CALENDAR YEAR.

3/ INCLUDES REPUBLIC OF KOREA (ROK), TAIWAN, POLAND AND FEDERAL REPUBLIC OF GERMANY.

4/ INCLUDES TAIWAN, POLAND, AND FEDERAL REPUBLIC OF GERMANY.

5/ INCLUDED IN THE BERING SEA CATCHES.

CONDITION OF STOCKS

Relative Abundance from Commercial Fisheries

A considerable decline in catch per unit effort (CPUE) is apparent from Japanese longline and stern trawl data since 1970 for both the eastern Bering Sea and Aleutian areas (Table 2). To more clearly illustrate this trend, Japanese estimates of longline CPUE in units of kg/10 hachi from Table 2 are standardized below by setting the 1970 CPUE values to 100 units:

	Eastern Bering Sea		Aleutian region	
Year	All-nation catch (t)	Standardized CPUE	All-nation catch (t)	Standardized CPUE
1970	12,500	100	1,300	100
1971	12,200	77	2,700	83
1972	15,400	49	3,600	86
1973	7,600	61	3,000	85
1974	5,200	68	2,500	86
1975	3,400	54	1,600	70
1976	3,300	61	1,600	47
1977	2,100	56	1,700	45
1978	1,100	22	800	17
1979	1,400	20	800	16
1980	2,200	27	300	27
1981	2,600	31	400	40

The data show a general decline in CPUE through 1976 or 1977. In 1976 the CPUE value in the eastern Bering Sea was 61% of the 1970 level, while that for the Aleutians was 47% of the 1970 level. The CPUE values for 1978-81 may

Table 2.--Sablefish catch per unit effort trends in the eastern Bering Sea and Aleutian Region based on data from Japanese longline and trawl fisheries, 1964-81.

	EASTERN BERING SEA				ALEUTIAN REGION				
	JPN. ESTIMATES		U.S. ESTIMATES		JPN. ESTIMATES		U.S. ESTIMATES		
	LONGLINE		LONGLINE	TRAWL	LONGLINE		LONGLINE		TRAWL
	KG/10 HACHI 1/	T/ VESSEL DAY 2/	KG/10 HACHI 3/	KG/HR 3/	KG/10 HACHI 1/	T/ VESSEL DAY 2/	KG/10 HACHI 3/	T/ VESSEL DAY 3/	KG/HR 3/
1964	93	2.4	61		141	3.1	139		
1965	105	3.0	54		183	4.1	110		
1966	166	4.5	139		233	6.3	229		
1967	216	6.2	210	151	275	7.1	277		154
1968	140	5.1	143	134	161	5.9	165		259
1969	187	6.9	189	142	183	7.1	184		318
1970	241	8.7	231	50	241	9.4	189		112
1971	185	5.6	120	76	202	9.4	165	4.5	222
1972	117	3.3	50	62	208	11.6	203	11.8	123
1973	148	6.0	47	41	204	7.7	192	4.6	115
1974	164	7.4	141	24	208	7.8	187	4.4	44
1975	131	4.9	68	13	168	6.0	98	1.8	30
1976	147	5.6	69	6	114	4.5	71		7
1977	135	5.4	73	5	108	4.0	70	1.1	3
1978	52		16	1	40		24		2
1979	48		16	1	39		18		1
1980	64		21	2	66		17		2
1981	75		35	0	96		40		<1

1/ OKADA ET AL. (1982)
2/ FAR SEAS FISHERIES RESEARCH LABORATORY (1978)
3/ METHOD OF LOW (1977)
HACHI IS A UNIT OF LONGLINE GEAR AND IS 100 M LONG.

not be comparable to those from previous years due to changes in fishing patterns brought about by fishing regulations following enactment of the Magnuson Fishery Conservation and Management Act of 1976. However, it should be noted that CPUE levels continued to drop reaching lows of 20 and 16% of 1970 values in 1979 for the eastern Bering Sea and Aleutians, respectively. In 1981, rates increased to 31% of 1970 values in the eastern Bering Sea and to 40% in the Aleutians, still well below values of 1975 and earlier years.

Catch and effort data collected by U.S. observers aboard Japanese long-liners and small trawlers (Table 3) also showed an increase in CPUE from 1980 to 1981, while catch rates from large trawlers showed no apparent trend. Since sablefish are caught incidentally by the trawlers, their catch rates may not accurately reflect trends in abundance.

Abundance Estimates from Research Surveys

Eastern Bering Sea

Juvenile sablefish are not normally observed in research vessel catches on the continental shelf of the eastern Bering Sea. In 1978, for the first time since surveys were initiated in 1971, juveniles were taken in catches in shelf waters of the southeast Bering Sea (Bakkala et al. 1982). These were aged as 1 year old fish of the 1977 year-class. They were again observed in these waters during the 1979 and 1980 eastern Bering Sea surveys. In 1981 the juvenile sablefish were no longer present in shelf waters. It was assumed that the juveniles had recruited to continental slope waters between the summer 1980 and summer 1981 surveys.

Population estimates by length interval (Figure 1) from the 1979 and 1981 cooperative U.S.-Japan trawl surveys illustrate the recruitment of the 1977 year-class to continental slope waters. Research vessels, primarily Japanese, comprehensively sampled slope waters during these surveys. Results

Table 3.--Catch rate information on sablefish and the dominant species taken in foreign fisheries as collected by U.S. observers in the eastern Bering Sea and Aleutian region, 1977-81.

COUNTRY	VESSEL 1/	AREA 2/	YR	AVE. DEPTH (M)	RK 3/	KG/DAY	KG/HR 4/	1ST THREE SPECIES: ORDER OF ABUNDANCE 5/
JAPAN	SMALL TRAWL	I	77	461	4	462	30	TUR,POL,COD
			78	481	7	146	10	TUR,POL,AP
			79	495	7	230	15	TUR,COD,POL
			80	291	9	162	14	TUR,YSOL,RAT
			81	-	7	275	21	TUR,POL,POP
		II	77	373	9	35	3	POL,TUR,HER
			78	409	11	111	5	TUR,POL,AP
			79	450	15	73	5	TUR,POL,AF
			80	475	7	180	8	TUR,POL,AF
			81	-	7	285	18	TUR,POL,AF
		IV	77	224	25	1	-	POP,AM,NROC
			78	387	13	181	13	POL,TUR,SQU
			79	372	16	61	5	TUR,POP,AF
			80	279	18	45	6	POL,SQU,POP
			81	-	8	230	24	POL,TUR,POP
	LARGE TRAWL	I	77	243	20	2	-	POL,COD,SQU
			78	189	21	45	3	POL,COD,YSOL
			79	170	4	208	17	POL,COD,AF
			80	206	7	50	4	POL,COD,HER
			81	-	9	24	2	POL,COD,SQU
		II	77	196	-	-	-	POL,HER,COD
			78	213	40	1	-	POL,SQU,COD
			79	223	22	15	1	POL,COD,SQU
			80	254	32	2	<1	POL,COD,TUR
			81	-	12	14	1	POL,COD,SQU
	LONG-LINER	I	78	317	5	119	7	COD,TUR,POL
			79	459	4	447	31	COD,TUR,RAT
			80	552	3	95	61	TUR,COD,SAB
			81	538	3	1553	96	COD,TUR,SAB
		II	80	567	5	327	18	TUR,COD,RAT
			81	499	4	1173	73	TUR,COD,AF
		IV	77	593	2	1114	89	TUR,SAB,STR
			78	508	2	1186	92	TUR,SAB,RAT
			79	596	3	1084	72	TUR,RAT,SAB

(CONTINUED)

Table 3.--Continued.

COUNTRY	VESSEL 1/	AREA 2/	YR	AVE. DEPTH (M)	RK 3/	KG/DAY	KG/HR 4/	1ST THREE SPECIES: ORDER OF ABUNDANCE 5/
USSR	LARGE TRAWL	I	77	154	-	-	-	POL,SQU,SCUL
			78	67	52	1	0	YSOL,AP,POL
			79	67	-	-	-	YSOL,POL,COD
		II	77	162	-	-	-	POL,HER,SKATE
			78	204	-	-	-	POL,HER,COD
			79	178	12	76	8	POL,SCUL,YSOL
			80	233	-	-	-	POL,SAL,TUR
		IV	77	110	-	-	-	AM,NROC,POP
			78	175	40	0	0	AM,POL,COD
			79	162	-	-	-	AM,COD,POL
			80	152	-	-	-	AM,YIL,COD
ROK	LARGE TRAWL	I	77	268	27	2	0	POL,TUR,SQU
			78	226	13	22	2	POL,COD,SQU
			79	201	6	274	20	POL,COD,AM
			80	149	11	153	13	POL,YSOL,COD
			81	-	10	136	13	POL,YSOL,COD
		II	77	281	-	-	-	POL,LUM,SQU
			78	168	10	24	3	POL,TUR,SQU
			79	249	12	30	3	POL,SQU,COD
			80	430	9	42	4	POL,COD,SQU
			81	-	5	117	12	POL,COD,SQU
		IV	80	156	5	255	92	AM,POL,COD
			81	-	8	59	24	POL,AM,COD

1/ SMALL TRAWLER (<1,500 GR TONS), LARGE TRAWLER (>1,500 GR TONS).
2/ AREA I (BERING SEA, EAST OF 170 W LONG.), AREA II (BERING SEA, 170 W TO 180), AREA V (ALEUTIAN REGION).
3/ RANK OF SPECIES IN CATCHES BY WEIGHT.
4/ IN THE CASE OF LONGLINERS, CPUE IS IN KG PER 1000 HOOKS.
5/ TUR=GREENLAND TURBOT, POL=WALLEYE POLLOCK, COD=PACIFIC COD, HER=HERRING, AP=ALASKA PLAICE, POP=PACIFIC OCEAN PERCH, AM=ATKA MACKEREL, NROC=NORTHERN ROCKFISH, SQU=SQUID, YSOL=YELLOWFIN SOLE, SAB=SABLEFISH, RAT=RATTAIL, SCUL=SCULPIN, LUM=LUMPSUCKER, AF=ARROWTOOTH FLOUNDER, STR=SHORTSPINE THORNYHEAD ROCKFISH, YIL=YELLOW IRISH LORD, SAL=SALMON.

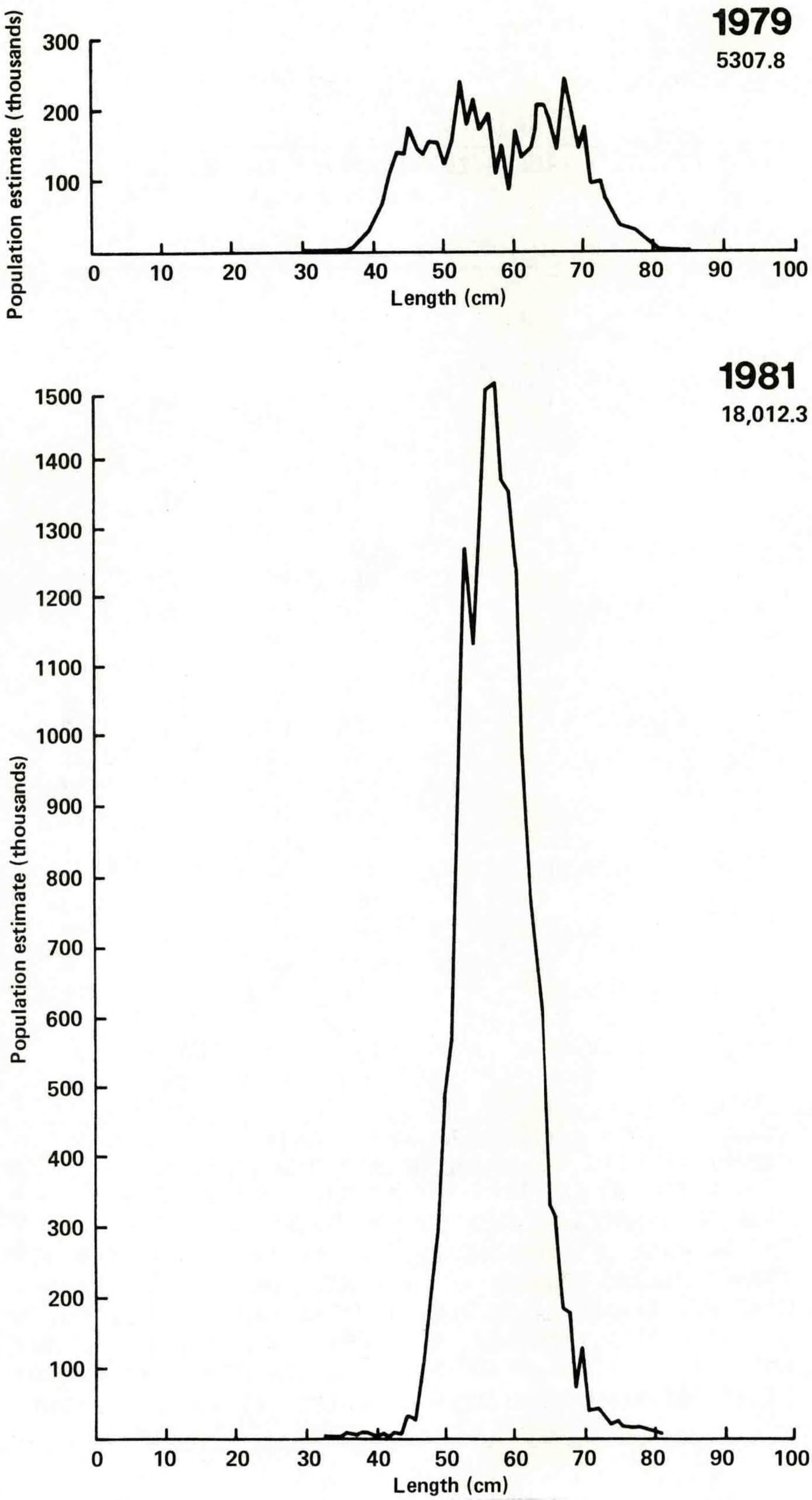

Figure 1.--Population estimates of sablefish by centimeter size interval on the continental slope of the eastern Bering Sea as shown by data from cooperative U.S.-Japan demersal trawl surveys in 1979 and 1981. Numbers below dates are total estimated population numbers (in thousands) in the areas surveyed.

of the surveys show a 3-fold increase in population numbers between 1979 (5.3 million) and 1981 (18.0 million). Estimated biomass from survey data in slope waters increased from 12,200 t in 1979 to 39,400 t in 1981.

Aleutian Islands Region

A joint U.S.-Japan resource assessment trawl survey of the Aleutian Islands region was conducted during July-August 1980 (Ronholt et al. 1982). This was the first comprehensive assessment of Aleutian groundfish resources in which the United States participated and encompassed areas north and south of the Aleutian chain between Attu Island and Unimak Pass (173°E-165°W long.).

The estimates of exploitable sablefish biomass based on survey data from the Aleutians portion of International North Pacific Fisheries Commission (INPFC) Area I and Aleutian region (Area V) were 8,500 t and 19,500 t, respectively, totaling 28,000 t (Table 4). Over 78% of the estimated available biomass was located east of 180° long.

The largest portion of the biomass (48%) was located in the 501-900 m depth interval. A notable exception was on the north side of the chain between 170°W and 180° long. where 81% of the estimated exploitable biomass was located in the 101-300 m depth interval. This was also the only area where small sablefish (less than 45 cm) were found in abundance; they were located in the 101-200 m depth interval (Figure 2). In general, largest fish were taken at the greatest depth intervals sampled.

Information on relative abundance and distribution of sablefish in the Aleutian region is also available from the joint Japan-U.S. longline survey during the summers of 1979, 1980, and 1981 (Okada et al. 1982). Data from these surveys showed a 669% increase in the relative population number of small-sized sablefish less than 58 cm in the eastern Aleutian area between 1979 and 1980 while the abundance of fish greater than 58 cm decreased by 31%. In 1981,

Table 4.--Estimates of mean catch per unit effort and exploitable biomass by depth interval for sablefish in the Aleutian Island waters, July-August 1980.

Area	Depth											
	1-100 m		101-200 m		201-300 m		301-500 m		501-900 m		7-900 m	
	kg/nmi	t	kg/nmi	t	kg/nmi	t	kg/nmi	t	kg/nmi	t	kg/nmi	t
Western Aleutians 173°E-180° long.												
North of chain	-	-	-	-	0.2	7	3	155	13	2,017	-	2,179
South of chain	-	-	-	-	0.1	6	1	115	9	2,023	-	2,144
Central Aleutians 170°W-180° long.												
North of chain	-	-	30	4,135	38	3,369	6	628	6	1,177	-	9,309
South of chain	-	-	0.2	35	5	667	12	1,418	28	3,713	-	5,832
Eastern Aleutians 165°W-170°W												
North of chain	4	640	2	159	70	2,300	18	790	62	4,563	-	8,453

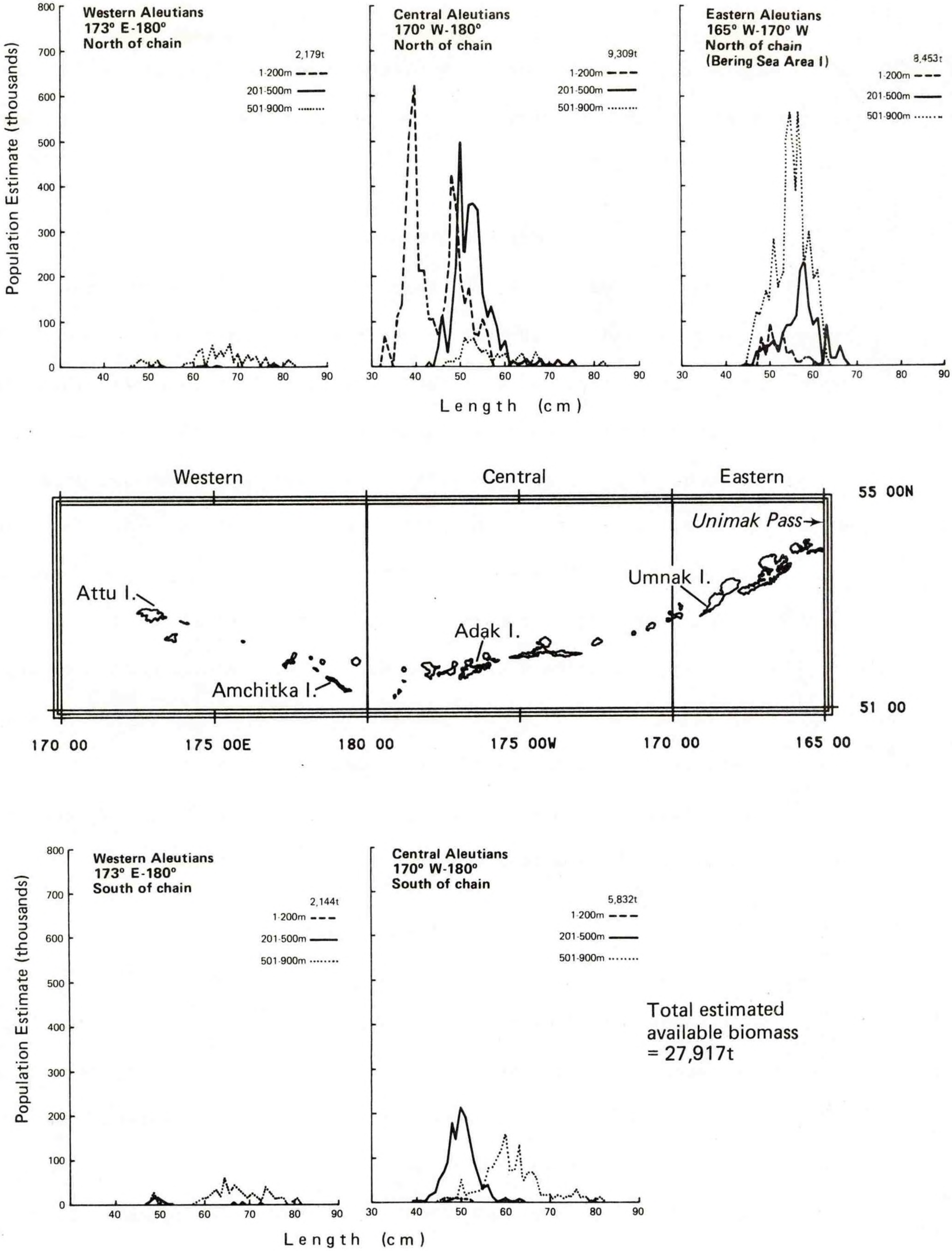

Figure 2.--Length composition of sablefish in the Aleutian Islands region by area and depth as shown by the 1980 U.S.-Japan cooperative trawl survey.

the abundance of the less than 58 cm group decreased 25% from the 1980 level, while the greater than 58 cm size group increased 10% in this period (Sasaki 1981, Okada et al. 1982).

MAXIMUM SUSTAINABLE YIELD

The long-term productivity of sablefish in each management region is believed to be related to the overall condition of the resource throughout its range from the Bering Sea to California. Based on this premise, U.S. scientists have estimated maximum sustainable yield (MSY) as 50,300 t for the Bering Sea to California region. The estimate is derived from a general production model. The MSY estimate has been apportioned to regions according to historical catches: Bering Sea, 25%; Aleutian region, 4%; Gulf of Alaska, 47%; and the British Columbia-Washington region, 25% (Low and Wespestad 1979).

Japanese scientists have estimated MSY for the overall North Pacific as 69,600 t based on the same general production model used by U.S. scientists, but using a different weighting of data among the regions.

On the basis of the U.S. estimate, MSY is 13,000 t in the eastern Bering Sea and 2,100 t in the Aleutian area.

EQUILIBRIUM YIELD

Estimated equilibrium yield (EY) levels in 1981 were 2,000 t for the eastern Bering Sea and 900 t for the Aleutians Region. These values were estimated largely from trends in CPUE and catch. Since then, trawl survey data have become available for estimating the biomass of sablefish. Biomass was estimated to be 47,900 t in the eastern Bering Sea and 19,500 t in the Aleutians Region. Based on these EY and biomass estimates, the exploitation rates would be 0.042 and 0.046 in the eastern Bering Sea and Aleutians Region, respectively.

The stock condition in both regions appears to be better in 1981 than in 1979-80. However, CPUE values from commercial fishery data, although improved, remain substantially below historical levels. Since significant increases in abundance of the adult stock are not yet clearly evident, it is difficult to determine how much, if any, EY has increased. Therefore, until increases in abundance are more definitive, EY's are estimated for 1983 to remain the same as 1982 or 2,000 t in the eastern Bering Sea and 900 t in the Aleutians Region.

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PACIFIC OCEAN PERCH

by

Daniel H. Ito

INTRODUCTION

Pacific ocean perch, Sebastes alutus, are found in commercial concentrations along the outer continental shelf and upper slope regions of the North Pacific Ocean and Bering Sea. Two main stocks have been identified in the Bering Sea by Chikuni (1975)--an eastern Bering Sea slope and an Aleutian Islands stock (Figure 1). Commercial catch records indicate that the Aleutian region supports a larger Pacific ocean perch population than the eastern Bering Sea slope region (Figure 2, Table 1).

Pacific ocean perch were highly sought after by Japanese and Soviet fisheries and supported a major fishery throughout the 1960's. This fishery began in the eastern Bering Sea slope region in about 1960 and by 1962 had expanded into the Aleutian region. Catches of Pacific ocean perch in the eastern Bering Sea reached a peak of 47,000 t in 1961 (Table 1). The peak catch in the Aleutian region was 109,000 t in 1965. Catches since then have declined substantially. In 1981, Pacific ocean perch harvests were but a small fraction of historic levels: 1,100 t from the eastern Bering Sea slope region and 3,500 t from the Aleutian region.

CONDITION OF STOCKS

Eastern Bering Sea

Relative Abundance

Catch per unit effort (CPUE) data from Japanese fisheries indicate that stock abundance has declined to very low levels in the eastern Bering Sea

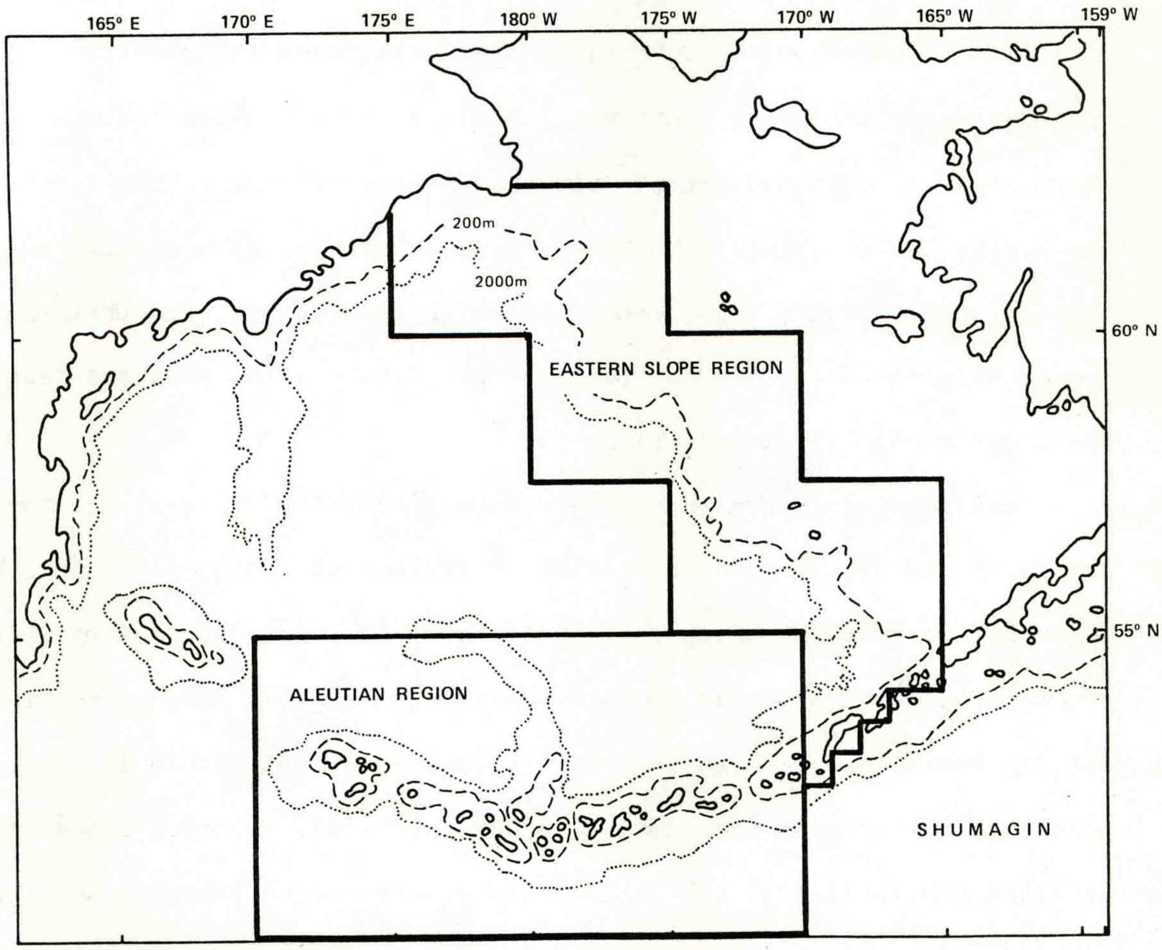

Figure 1.--The Bering Sea with the two main stock areas (regions) of Pacific ocean perch delineated.

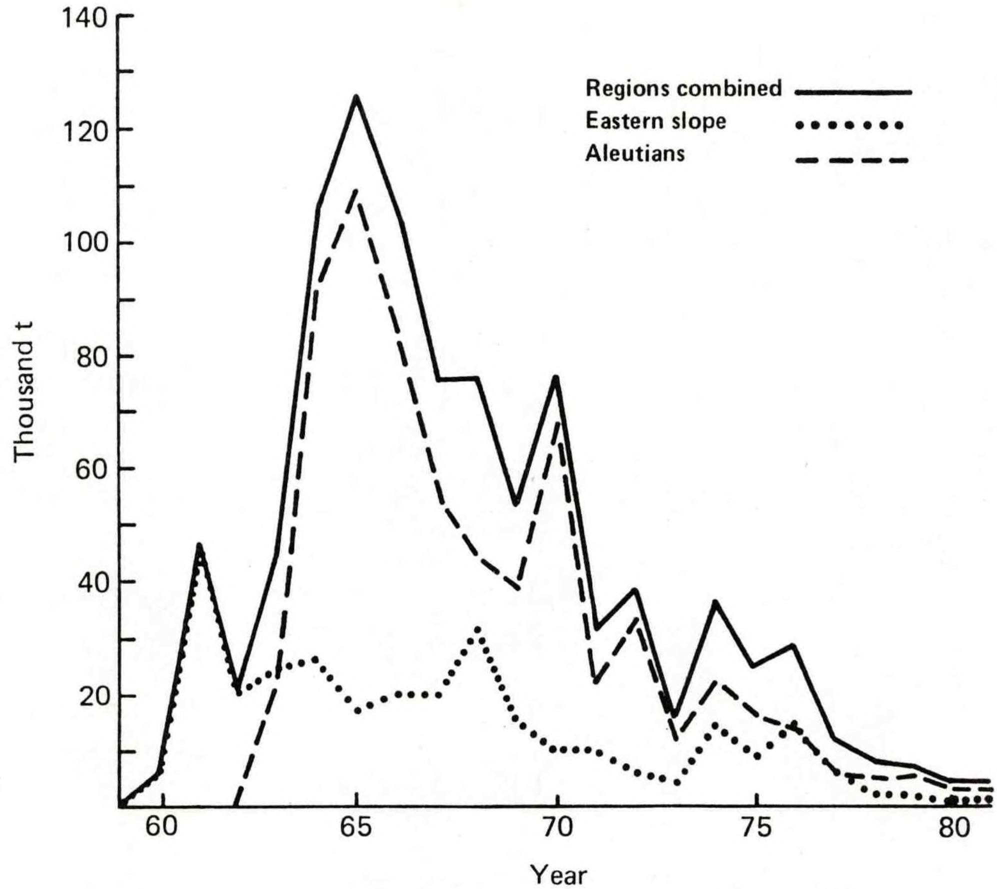

Figure 2 .--Catches of Pacific ocean perch in the eastern Bering Sea and Aleutian Islands regions, 1959-81.

Table 1.--Annual catches of Pacific ocean perch from the eastern Bering Sea and Aleutian Islands region (thousands of metric tons). 1/

Year	Japan 2/			USSR 3/			Other nations 4/			Total		
	E. Bering Sea	Aleutians	Total	E. Bering Sea	Aleutians	Total	E. Bering Sea	Aleutians	Total	E. Bering Sea	Aleutians	Total
1960	1.1	—	1.1	5.0	—	5.0	—	—	—	6.1	—	6.1
1961	13.0	—	13.0	34.0	—	34.0	—	—	—	47.0	—	47.0
1962	12.9	0.2	13.1	7.0	—	7.0	—	—	—	19.9	0.2	20.1
1963	17.5	0.8	18.3	7.0	20.0	27.0	—	—	—	24.5	20.8	45.3
1964	14.4	29.3	43.7	11.5	61.0	72.5	—	—	—	25.9	90.3	116.2
1965	7.8	38.1	45.9	9.0	71.0	80.0	—	—	—	16.8	109.1	125.9
1966	17.5	28.2	45.7	2.7	57.7	60.4	—	—	—	20.2	85.9	106.1
1967	19.6	9.3	28.9	—	46.6	46.6	—	—	—	19.6	55.9	75.5
1968	28.4	18.3	46.7	3.1	26.6	29.7	—	—	—	31.5	44.9	76.4
1969	14.5	15.6	30.1	0.0	23.2	23.2	—	—	—	14.5	38.8	53.3
1970	9.9	13.6	23.5	0.0	53.3	53.3	—	—	—	9.9	66.9	76.8
1971	9.8	14.6	24.4	0.0	7.2	7.2	—	—	—	9.8	21.8	31.6
1972	5.5	8.6	14.1	0.2	24.6	24.8	—	—	—	5.7	33.2	38.9
1973	2.7	9.3	12.0	1.0	2.5	3.5	—	—	—	3.7	11.8	15.5
1974	6.6	21.7	28.3	7.4	0.8	8.2	—	—	—	14.0	22.4	36.5
1975	3.2	8.5	11.7	5.4	8.1	13.5	—	—	—	8.6	16.6	25.2
1976	2.8	10.3	13.1	12.1	3.7	15.8	—	—	—	14.9	14.0	28.9
1977	2.7	5.7	8.4	3.5	0.1	3.6	0.4	0.1	0.5	6.6	5.9	12.5
1978	1.9	4.8	6.7	0.1	0.2	0.3	0.2	0.3	0.5	2.2	5.3	7.5
1979	1.6	5.3	6.9	Tr 5/	Tr	Tr	0.1	0.2	0.3	1.7	5.5	7.2
1980	0.4	3.3	3.7	0.0	0.0	0.0	Tr	Tr	Tr	0.5	3.3	3.8
1981	0.8	3.3	4.0	0.0	0.0	0.0	0.3	0.2	0.5	1.1	3.5	4.6

1/ Source: Bakkala et al. (1980) for catches through 1979; catches for 1980 and 1981 from data on file, Northwest and Alaska Fisheries Center, Seattle, Washington.
2/ Catches of mothership-longline North Pacific trawl fishery and landbased dragnet fishery.
3/ May include some amounts of rockfishes, Sebastes spp., other than Pacific ocean perch.
4/ Includes catches from Republic of Korea, Taiwan, Poland, and Federal Republic of Germany.
5/ Tr: Trace less than 50 t.

(Tables 2 and 3). CPUE from these fisheries, however, may not be good indices of stock abundance in recent years because most of the fishing effort is now directed to species other than Pacific ocean perch (Table 4). Nevertheless, overall fishing effort remains high in the eastern Bering Sea, and the low catches of Pacific ocean perch indicated that stock abundance is at a low level.

The eastern Bering Sea is subdivided into two areas, P and Z, (Figure 3) for examining catch trends. The fishery initially began in subarea P and then expanded to subarea Z, with the former area generally accounting for most of the Pacific ocean perch harvest (Table 5). Catches peaked in both areas in 1968 but declined rapidly thereafter. Currently, this species comprises but a minor fraction of total groundfish catches relative to its importance in earlier years.

Biomass Estimates

Data from 1979 and 1981 cooperative U.S.-Japan trawl surveys provide biomass estimates for Pacific ocean perch in the eastern Bering Sea. These surveys were conducted on both the continental shelf and slope but almost all catches of Pacific ocean perch were taken on the slope at depths greater than 200 m.

Survey results from the eastern Bering Sea slope region indicate that the biomass increased from 6,400 t in 1979 to 9,800 t in 1981 and population numbers from about 11.0 million in 1979 to 14.4 million in 1981 (Table 6). These abundance estimates, however, were characterized by relatively wide variances, and the 95% confidence intervals overlapped extensively, indicating that the mean estimates were not significantly different. The biomass estimates from the Aleutian Islands portion of International North Pacific Fisheries Commission (INPFC) statistical area 1 was 7,000 t based on data from the 1980 U.S.-Japan cooperative survey in the Aleutians Region (Table 6).

Table 2.--Pacific ocean perch catch and effort data from stern trawlers of the Japanese mothership-longline North Pacific trawl fishery by vessel class in the eastern Bering Sea slope region, 1968-81.

	Vessel class 1/						
Year	3	4	5	6	7	8	9
(A) Catch (metric tons, t)							
1968	895	3,847	695	1,938	378	10,012	1,776
1969	361	3,709	102	258	94	4,037	2,103
1970	77	215	78	55	301	3,168	1,495
1971	96	1,558	35	203	992	1,855	459
1972	—	1,005	317	7	410	313	1,276
1973	—	382	—	199	487	146	398
1974	—	640	90	520	700	609	735
1975	—	578	204	343	784	171	293
1976	—	323	188	152	772	70	545
1977	—	380	357	155	114	193	534
1978	—	531	154	178	54	130	545
1979	20	731	201	42	104	44	85
1980	2	186	13	4	6	9	2
1981	—	289	146	—	44	15	52
(B) Fishing effort (hundred hours trawled)							
1968	104	298	26	18	1	67	46
1969	95	264	17	15	12	95	125
1970	103	293	18	2	34	122	139
1971	125	411	21	19	35	146	266
1972	120	348	29	13	49	140	198
1973	—	267	13	16	35	118	397
1974	—	290	27	39	37	171	391
1975	—	419	55	41	38	158	363
1976	—	502	41	5	19	147	360
1977	—	444	30	15	5	99	318
1978	—	594	56	38	5	99	353
1979	54	562	53	33	17	94	302
1980	44	599	38	20	38	110	334
1981	—	616	27	6	36	108	302
(C) Pacific ocean perch in total catch (%)							
1968	4	19	3	10	2	49	9
1969	3	31	1	2	1	34	18
1970	1	4	1	1	6	58	27
1971	2	30	1	4	19	35	9
1972	—	29	9	+	12	9	37
1973	—	22	—	12	28	9	23
1974	—	19	3	15	21	18	22
1975	—	23	8	14	32	7	12
1976	—	15	9	7	37	3	26
1977	—	21	19	8	6	11	29
1978	—	32	9	11	3	8	33
1979	2	59	16	3	8	4	7
1980	1	84	6	2	3	4	1
1981	—	53	27	0	8	3	10

Table 2.--(cont'd).

Year	Vessel class 1/ 3	4	5	6	7	8	9
(D) Catch per unit of effort (t per hour trawled)							
1968	.08	.13	.26	1.10	2.55	1.50	.39
1969	.03	.14	.06	.18	.08	.42	.17
1970	.01	.01	.04	.23	.09	.26	.11
1971	.01	.04	.02	.11	.28	.13	.02
1972	—	.03	.10	.01	.07	.02	.05
1973	—	.01	—	.12	.14	.01	.01
1974	—	.02	.03	.13	.19	.04	.02
1975	—	.01	.04	.08	.21	.01	.01
1976	—	.01	.05	.33	.41	.01	.02
1977	—	.01	.12	.10	.25	.02	.02
1978	—	.01	.03	.05	.12	.01	.02
1979	2/	.01	.04	.01	.06	2/	2/
1980	2/	2/	2/	2/	2/	2/	2/
1981	—	2/	.05	2/	.01	2/	2/

1/ No data for classes 1 and 2. 1973–81 data converted to pre–1973 gross tonnage classification of:

1 = 71–100 4 = 301–500 7 = 1501–2500
2 = 101–200 5 = 501–1000 8 = 2501–3500
3 = 201–300 6 = 1001–1500 9 = 3501 and above

2/ Less than 0.01

Table 3.--Pacific ocean perch (POP) catch and effort data from stern trawlers of the Japanese landbased dragnet fishery in the eastern Bering Sea region, 1969-81.

Year	Catch of all species in (t)	Catch of Pacific ocean perch (t)	POP in total catch (%)	Total effort (h)	CPUE 1/ of POP (t per h)
1969	39,639	3,427	8.7	63,433	0.05
1970	48,205	3,643	7.6	85,325	0.04
1971	62,428	4,664	7.5	101,996	0.05
1972	71,853	1,587	2.2	121,241	0.01
1973	48,410	1,349	2.8	78,605	0.02
1974	65,410	3,045	4.7	110,240	0.03
1975	61,019	1,666	2.7	120,981	0.01
1976	56,841	1,115	2.0	131,869	0.01
1977	68,532	1,052	1.5	142,479	0.01
1978	82,106	414	0.5	133,838	Tr 2/
1979	57,363	492	0.9	99,431	Tr 2/
1980	61,325	178	0.3	116,839	Tr 2/
1981	63,409	234	0.4	115,822	Tr 2/

1/ CPUE = catch per unit of effort; POP = Pacific ocean perch
2/ Tr = Trace (< 0.005 t/h)

Table 4.-- Catch rate information on Pacific ocean perch and the dominant species taken by Japanese small trawlers and large surimi trawlers in the eastern Bering Sea (International North Pacific Fisheries Commission areas I and II) as shown by U. S. observer data.

			Pacific ocean perch				First three species caught in order of abundance 3/
					Catch rate		
Area	Vessel	Year	% 1/	Rank 2/	kg/day	kg/h	
I	small trawler	77	2.35	6	204	13	tur,pol,cod
		78	0.26	21	20	1	tur,pol,ap
		79	0.59	13	68	5	tur,cod,pol
		80	0.55	13	82	7	tur,yfs,rt
		81	5.93	3	641	50	tur,pol,pop
	surimi trawler	77	0.68	4	623	41	pol,cod,sqd
		78	0.13	11	129	11	pol,cod,yfs
		79	0.03	20	28	2	pol,cod,af
		80	0.01	18	5	Tr 4/	pol,cod,her
		81	0.05	6	39	3	pol,cod,sqd
	large freezer trawler	78	——	—	——	—	yfs,pol,cod
		79	0.33	12	100	11	yfs,pol,ap
		80	——	—	——	—	yfs,af,cod
		81	——	—	——	—	yfs,ap,cod
II	small trawler	77	0.55	10	33	2	pol,tur,her
		78	1.69	10	125	8	tur,pol,cod
		79	1.04	11	99	6	tur,pol,af
		80	0.16	21	16	1	tur,pol,af
		81	0.42	16	46	3	tur,pol,af
	surimi trawler	77	0.33	8	310	24	pol,her,cod
		78	0.11	8	124	11	pol,sqd,cod
		79	0.02	18	19	2	pol,cod,sqd
		80	0.01	23	5	Tr 4/	pol,cod,af
		81	0.00	31	1	Tr 4/	pol,cod,sqd
	large freezer trawler	78	0.14	12	39	3	pol,cod,af
		79	——	—	——	—	pol,cod,af
		80	0.09	8	33	2	pol,cod,af

1/ Percentage of Pacific ocean perch in the total catch.
2/ Rank order of Pacific ocean perch in the total catch by weight.
3/ af=arrowtooth flounder, ap=Alaska plaice, cod=Pacific cod, her=herring, pol=walleye pollock, pop=Pacific ocean perch, rt=rattail, sqd=squid, tur=Greenland turbot, yfs=yellowfin sole.
4/ Tr=Trace (<0.5 kg/h).

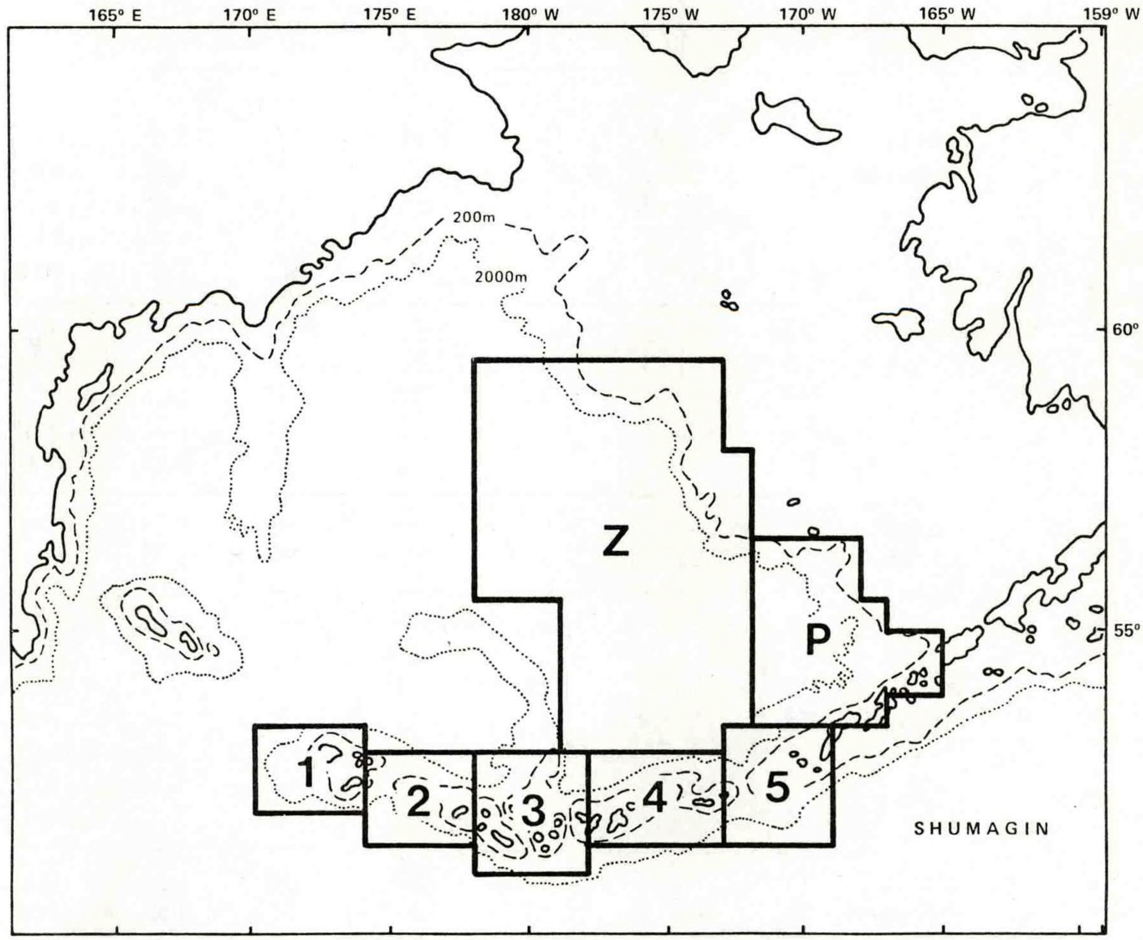

Figure 3.--Subdivisions of the eastern Bering Sea and Aleutian Islands region used to examine trends of catch and catch per unit of effort for Pacific ocean perch.

Table 5.--Annual catch of Pacific ocean perch (POP) (t), total catch of all species combined (t), and percentage of ocean perch in the total groundfish catch from the Japanese mothership-longline North Pacific trawl fishery for all Bering Sea subareas (stern trawls only), 1964-81.

	Aleutian 1			Aleutian 2			Aleutian 3			Aleutian 4			Aleutian 5			Bering Sea P			Bering Sea Z		
Year	POP catch	Total catch	% POP	POP catch	Total catch	% POP	POP catch	Total catch	% POP	POP catch	Total catch	% POP	POP catch	Total catch	% POP	POP catch	Total catch	% POP	POP catch	Total catch	% POP
1964	-	-	-	2,664	2,673	99.66	2,091	2,206	94.79	3,970	4,278	92.80	375	397	94.46	517	965	53.58	-	-	-
1965	-	-	-	9,195	9,549	96.29	4,830	4,987	96.85	2,206	3,108	70.98	619	817	75.76	2,133	7,127	29.93	49	205	23.90
1966	115	125	92.00	3,236	3,341	96.86	8,490	8,997	94.36	3,094	3,358	92.14	3,475	4,335	80.16	1,962	22,954	8.55	586	2,262	25.91
1967	57	68	83.82	5,173	5,583	92.66	2,396	2,977	80.48	2,877	3,368	85.42	2,714	3,340	81.26	4,889	116,233	4.21	3,492	14,852	23.51
1968	84	84	100.00	8,622	8,718	98.90	9,843	10,369	94.93	3,174	3,533	89.84	939	1,035	90.72	12,603	161,562	7.80	5,781	75,042	7.70
1969	76	98	77.55	5,526	5,599	98.70	2,482	2,707	91.69	4,375	4,512	96.96	482	640	75.31	6,144	306,786	2.00	3,867	55,194	7.01
1970	98	99	98.99	7,130	7,228	98.64	2,133	2,403	88.76	698	704	99.15	1,317	1,436	91.71	3,693	285,093	1.30	1,532	153,145	1.00
1971	405	425	95.29	6,570	6,773	97.00	2,545	3,155	80.67	846	1,662	50.90	5,047	6,520	77.41	2,505	466,882	0.54	1,538	221,665	0.69
1972	79	97	81.44	2,499	2,591	96.45	1,343	2,656	50.56	975	1,703	57.25	5,370	7,323	73.33	1,879	351,855	0.53	846	193,680	0.44
1973	807	914	88.29	2,562	2,961	86.52	1,210	1,774	68.21	695	1,295	53.67	3,393	4,809	70.56	509	155,881	0.33	363	407,696	0.09
1974	2,172	2,413	90.01	5,060	5,779	87.56	1,692	2,426	69.74	1,319	2,559	51.54	7,587	9,772	77.64	1,132	324,262	0.35	659	225,177	0.29
1975	765	1,982	38.60	4,083	8,099	50.41	387	882	43.88	183	746	24.53	5,164	7,598	69.97	414	326,588	0.13	916	224,139	0.41
1976	976	1,528	63.87	3,455	4,824	71.62	1,092	1,615	67.62	455	965	47.15	5,588	10,941	51.07	582	268,044	0.22	438	155,983	0.28
1977	531	1,461	36.34	1,223	3,244	37.70	813	2,133	38.12	358	1,423	25.16	2,156	6,025	35.78	831	132,526	0.63	314	149,915	0.21
1978	127	538	23.61	1,240	3,972	31.22	679	2,473	27.46	287	1,017	28.22	1,830	7,415	24.68	725	128,833	0.56	423	139,216	0.30
1979	516	2,394	21.55	889	2,917	30.48	548	2,192	25.00	263	627	41.95	1,798	6,653	27.03	855	169,595	0.50	120	103,846	0.12
1980	233	5,251	4.44	695	3,775	18.41	394	3,481	11.32	93	577	16.12	1,039	5,105	20.35	190	180,879	0.10	12	111,290	0.01
1981	81	3,646	2.22	424	2,807	15.11	285	1,907	14.94	131	564	23.23	1,731	8,732	19.82	191	186,887	0.10	14	88,918	0.02

Table 6.--Estimated population numbers and biomass of Pacific ocean perch in the eastern Bering Sea and Aleutian Islands region as shown by data from cooperative U.S.-Japan trawl surveys in 1979-81.

Area	Year	Mean estimates: Population numbers (millions)	Mean estimates: Biomass (t)	95% Confidence intervals for biomass estimates (t)
Eastern Bering Sea	1979	10.973	6,400	1,200- 11,600
	1981	14.380	9,800	5,600- 14,100
Aleutian Islands Region				
INPFC[1/] Area 1	1980	15.674	7,000	0- 23,000
INPFC Area 5	1980	214.774	101,100	32,900-169,100

1/ INPFC = International North Pacific Fisheries Commission.

The abundance estimates from these surveys probably underestimate the true population size of Pacific ocean perch. As pointed out by Bakkala et al. (1982), this species is known to occupy the water column above that sampled by the bottom trawls. Pacific ocean perch are also known to inhabit areas of rough bottom which were avoided during the surveys to prevent damage to the trawls. Unfortunately, that portion of the population unavailable to the trawl gear cannot be determined at this time.

Length Composition

Length data from the U.S.-Japan trawl surveys show that Pacific ocean perch ranged in length from 10 to 52 cm; the average lengths in the 1979 and 1981 surveys were 33.5 and 34.0 cm, respectively. The length distribution from the 1979 survey was unimodal, whereas the 1981 survey length data exhibited bimodality (Figure 4).

The 1981 bimodal length distribution suggests the possible presence of a relatively strong year-class in the population. Age data associated with these lengths are not yet available.

Aleutian Islands Region

Relative Abundance

The CPUE data from stern trawlers of the Japanese mothership, longline, and North Pacific trawl fisheries suggest that abundance in the Aleutian region has also declined to very low levels (Table 7). Vessel classes 4 and 7, which account for the majority of the Pacific ocean perch catch by stern trawlers, have shown drastic reductions in CPUE. From 1969 to 1979, the CPUE of vessel class 4 dropped 94.6% and has remained at the 1979 level for the past 3 years. CPUE from vessel class 7 reached its lowest level in 1981, falling 96.0% from its peak level in 1968. CPUE from the other vessel classes (5, 6, 8, and 9) have also shown substantial declines.

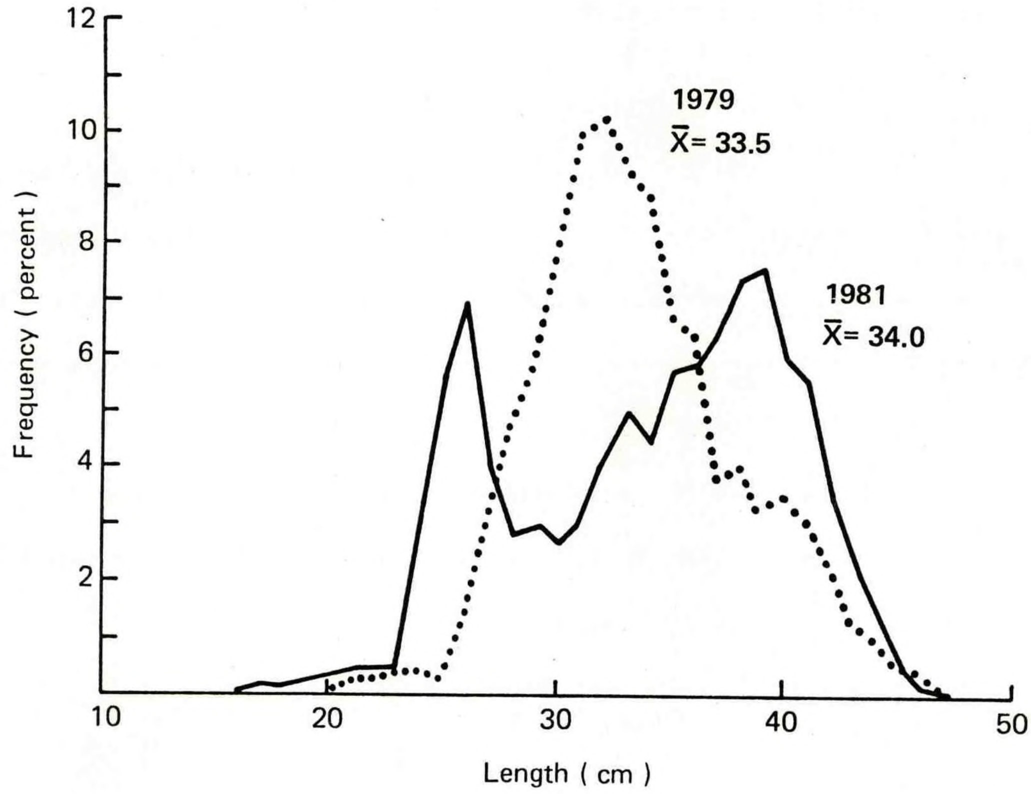

Figure 4 .--Size composition of Pacific ocean perch in the eastern Bering Sea as shown by data from cooperative U.S.-Japan demersal trawl surveys in 1979 and 1981.

Table 7.--Pacific ocean perch catch and effort data from stern trawlers of the Japanese mothership-longline North Pacific trawl fishery by vessel class in the Aleutian region, 1968-81.

	Vessel class 1/					
Year	4	5	6	7	8	9
(A) Catch (metric tons, t)						
1968	12,157	280	32	2,711	6,787	532
1969	7,290	440	0	4,839	1,125	144
1970	2,384	1,227	0	7,741	249	82
1971	3,322	889	1,038	4,984	2,249	449
1972	3,527	1,318	645	2,035	188	135
1973	4,596	0	995	1,881	0	0
1974	10,679	1,564	1,326	2,507	25	16
1975	3,916	972	764	1,815	666	0
1976	4,862	838	786	1,600	83	0
1977	2,802	771	219	580	37	0
1978	2,342	480	140	855	183	0
1979	2,265	691	50	696	141	16
1980	1,733	188	6	420	56	79
1981	1,590	279	96	298	2	46
(B) Fishing effort (hours trawled)						
1968	8,575	155	8	216	759	772
1969	1,952	333	0	910	178	38
1970	1,755	600	0	976	161	25
1971	4,546	634	383	720	785	174
1972	6,533	546	492	388	114	56
1973	3,989	0	658	530	36	0
1974	13,908	1,816	964	529	70	22
1975	12,333	1,233	543	521	509	0
1976	10,179	897	698	561	251	0
1977	7,594	1,095	248	400	89	0
1978	8,820	957	206	595	315	0
1979	9,484	1,097	67	631	213	29
1980	7,303	325	12	387	211	778
1981	8,920	1,206	376	561	481	318
(C) Pacific ocean perch in total catch (%)						
1968	54	1	+	12	30	2
1969	51	3	0	34	8	1
1970	20	10	0	66	2	1
1971	26	7	8	38	17	3
1972	45	17	8	26	2	2
1973	62	0	13	25	0	0
1974	66	10	8	16	0	+
1975	48	12	9	22	8	0
1976	60	10	10	20	1	0
1977	63	17	5	13	1	0
1978	58	12	3	21	5	0
1979	59	18	1	18	4	0
1980	70	8	0	17	2	3
1981	69	13	4	12	0	2

Table 7.--(cont'd)

Year	Vessel class 1/ 4	5	6	7	8	9
(D) Catch per unit of effort (t per hour trawled)						
1968	1.4	2.4	4.0	12.6	8.9	0.7
1969	3.7	1.3	—	5.3	6.3	3.8
1970	1.4	2.0	—	7.9	1.5	3.3
1971	0.7	1.4	2.7	6.9	2.9	2.6
1972	0.5	2.4	1.3	5.2	1.6	2.4
1973	1.2	—	1.5	3.5	—	—
1974	0.8	0.9	1.4	4.7	0.4	0.7
1975	0.3	0.8	1.4	3.5	1.3	—
1976	0.5	0.9	1.1	2.9	0.3	—
1977	0.4	0.7	0.9	1.5	0.4	—
1978	0.3	0.5	0.7	1.4	0.6	—
1979	0.2	0.6	0.7	1.1	0.7	0.6
1980	0.2	0.6	0.5	1.1	0.3	0.1
1981	0.2	0.2	0.3	0.5	0.0	0.1

1/ No data for classes 1, 2, and 3 which are mainly side and pair trawls.
1973–81 data converted to pre-1973 gross tonnage classification of:

1 = 71-100	4 = 301-501	7 = 1501-2500
2 = 101-200	5 = 501-1000	8 = 2501-3500
3 = 201-300	6 = 1001-1500	9 = 3501 and above

Data from the landbased dragnet fishery also indicate decreasing stock abundance with CPUE decreasing from 0.32 in 1969 to 0.02 in 1981 (Table 8). The CPUE data from 1977 to 1981, however, may not be reliable indices of population size in that Pacific ocean perch catches were low during this period, accounting for less than 5% of the total catch of all species combined.

Catch rate information collected by U.S. observers aboard Japanese small trawlers (<1,500 gr tons) indicate that abundance has continued to decline since 1977 (Table 9). CPUE in units of kg/day and kg/hr fell 79.0 and 84.1%, respectively, from 1977 to 1981. With the exception of 1978, Pacific ocean perch ranked among the top three species in the catch by small trawlers; and for years other than 1978 in this period, CPUE should, therefore, be a relatively good index of stock size.

The Aleutian region is subdivided into five areas (Figure 3) to examine catch and CPUE trends in more detail. Subareas 2, 3, and 5 have been the most important subareas in terms of annual harvests (Table 5). Based on their contribution to the total catch, Pacific ocean perch appear to have been the primary target species in all subareas until the mid 1970's. However, since 1977 Pacific ocean perch have not comprised more than 50% of the total groundfish catch.

Changes in abundance of Pacific ocean perch in 1977-81 were examined by analyzing CPUE of vessel class 4 stern trawlers in each subarea. These trawlers were used in the analysis because of their relatively high sustained annual catches of Pacific ocean perch during this period. The results indicated that abundance declined markedly in subareas 1-3. CPUE from the three subareas fell by at least 50% from 1977 to 1981 (Table 10). Subarea 4 CPUE indicated an increase in abundance; whereas, CPUE from subarea 5 remained fairly stable throughout the 5-year period examined.

Table 8.--Pacific ocean perch (POP) catch and effort data from stern trawlers of the Japanese landbased dragnet fishery in the Aleutian region, 1969-81.

Year	Catch of all species in (t)	Catch of Pacific ocean perch (t)	POP in total catch (%)	Total effort (h)	CPUE 1/ of POP (t per h)
1969	5,478	1,246	22.7	3,861	0.32
1970	4,549	1,956	43.0	5,079	0.39
1971	5,977	1,664	27.8	6,578	0.25
1972	17,781	651	3.7	17,145	0.04
1973	16,230	1,873	11.5	12,791	0.15
1974	24,851	5,571	22.4	22,629	0.25
1975	8,067	1,268	15.7	8,634	0.15
1976	8,514	2,633	30.9	9,611	0.27
1977	27,157	1,317	4.8	40,475	0.03
1978	25,940	760	2.9	40,539	0.02
1979	45,759	1,401	3.1	77,515	0.02
1980	64,841	856	1.3	69,367	0.01
1981	47,533	958	2.0	56,453	0.02

1/ CPUE = catch per unit of effort

Table 9.--Catch rates for Pacific ocean perch and the dominant species taken by Japanese small trawlers in the Aleutian region as shown by U. S. observer data.

Year	Pacific ocean perch			First three species caught in order of abundance
	Rank	kg/day	kg/h	
77	1	4,665	642	Pacific ocean perch Atka mackerel Northern rockfish
78	6	580	50	Greenland turbot Walleye pollock Pacific cod
79	2	1,319	106	Greenland turbot Pacific ocean perch Arrowtooth flounder
80	3	1,256	171	Walleye pollock Squid Pacific ocean perch
81	3	978	102	Walleye pollock Greenland turbot Pacific ocean perch

Table 10.--Annual catch and catch per unit of effort (CPUE) of Pacific ocean perch (POP) from Japanese class 4 stern trawlers (excluding landbased trawlers) by subarea in the Aleutian region, 1977-81.

	Subarea														
	1			2			3			4			5		
	All species	POP		All species	POP		All species	POP		All species	POP		All species	POP	
Year	catch (t)	Catch (t)	CPUE t/h	catch (t)	Catch (t)	CPUE t/h	catch (t)	Catch (t)	CPUE t/h	catch (t)	Catch (t)	CPUE t/h	catch (t)	Catch (t)	CPUE t/h
1977	1,458	529	0.46	2,839	1,026	0.49	1,839	672	0.55	834	109	0.09	1,738	399	0.21
1978	473	110	0.19	3,233	979	0.33	1,911	473	0.22	337	45	0.13	2,482	736	0.24
1979	2,305	465	0.21	2,379	653	0.24	1,540	378	0.23	207	37	0.13	2,709	697	0.26
1980	1,478	141	0.13	3,044	553	0.21	1,128	265	0.25	320	43	0.12	2,993	701	0.31
1981	483	72	0.20	1,931	254	0.15	1,009	247	0.25	348	76	0.18	5,142	1,067	0.24

Biomass Estimates

The biomass estimate for Pacific ocean perch of the Aleutian region (170°E-170°W long.) was 101,100 t (Table 6). The bulk of the biomass (83.7%) occurred in the depth range of 100-300 m. Pacific ocean perch averaged 31.4 cm in length and 0.43 kg in weight.

The 1980 survey results probably underestimated the true population size of Pacific ocean perch, as previously discussed. Based on the 1980 biomass estimate from the Aleutians and the average of the 1979-81 biomass estimates from the eastern Bering Sea, the abundance of the stock in INPFC Area 5 is about 7 times greater than the stock in INPFC Areas 1 and 2.

Age and Length Composition

Age and length data collected by U.S. observers aboard foreign fishing vessels extends back to 1977. These data were collected primarily aboard small Japanese stern trawlers (<1,500 gr tons). Only data collected from these vessels were examined.

Pacific ocean perch caught by these trawlers ranged in length from 16 to 50 cm (Figure 5). The average size increased from 30.8 cm in 1977 to 33.2 cm in 1981. Based on aging methods employed at the Northwest and Alaska Fisheries Center (NWAFC), the commercial fishery appears to be dependent on a wide range of ages, 4 to 20 years (Figure 5). From 1978 to 1980, the average age in the catch decreased from 11.0 to 9.2 years.

MAXIMUM SUSTAINABLE YIELD

Maximum sustainable yield (MSY) has been estimated at 32,000 t for the eastern Bering Sea slope stock and 75,000 t for the Aleutian stock (Chikuni 1975). Clearly, sustained exploitation at these levels was not possible (Table 1). The eastern Bering Sea slope region has produced catches in excess of

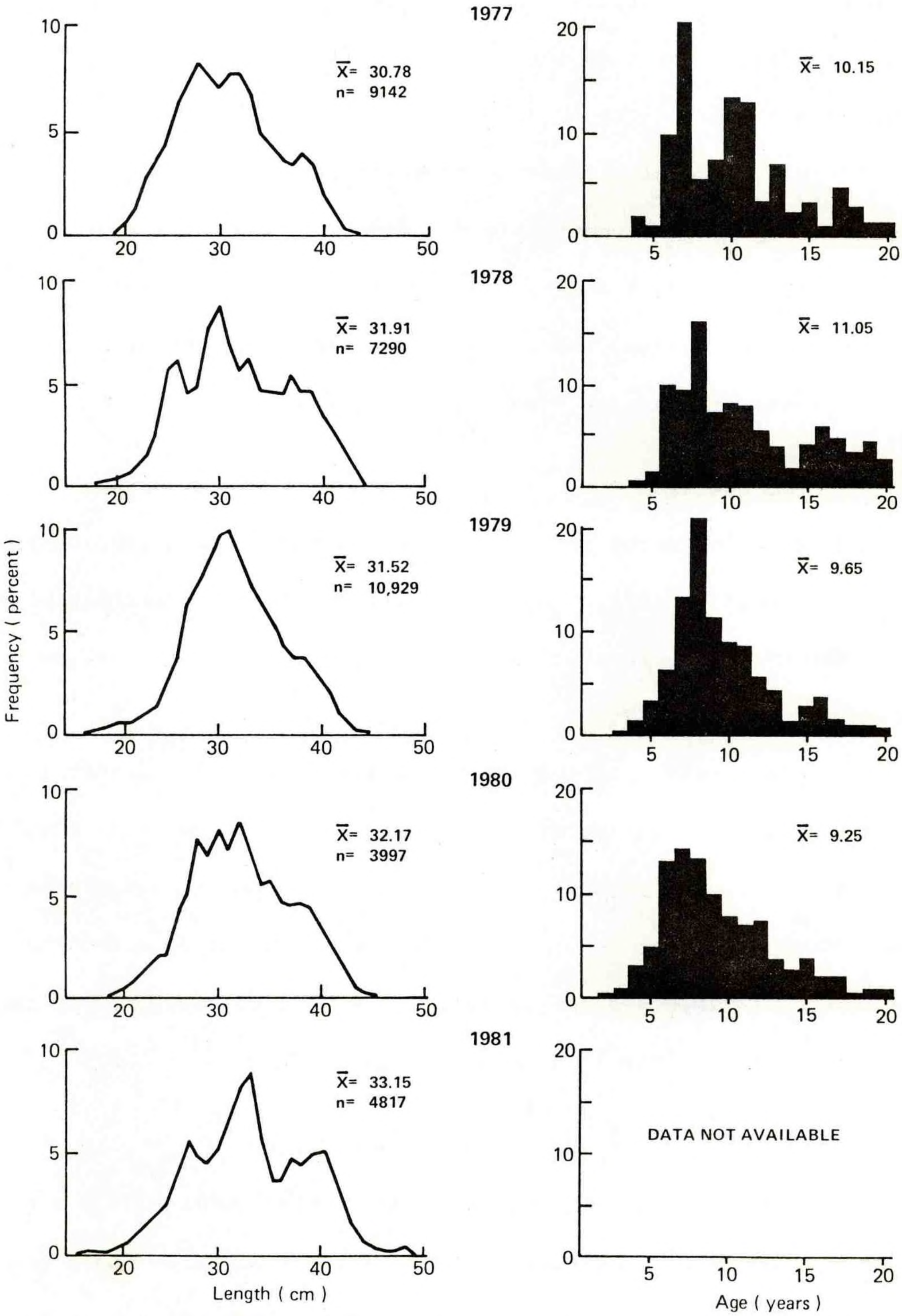

Figure 5 . Length and age composition of Pacific ocean perch in the Aleutian region as shown by data taken by U.S. observers from catches aboard Japanese small stern trawlers, 1977-81.

32,000 t only once. Pacific ocean perch harvests from the Aleutian region exceeded 75,000 t only three times throughout the history of this fishery. Low (1974), employing a stock production model, estimated MSY for both the eastern Bering Sea and Aleutian stocks combined at 12,000-17,000 t.

EQUILIBRIUM YIELD

In 1981, the equilibrium yield (EY) of the North Pacific Fishery Management Council's Fishery Management Plan was reported to be 5,000 t for the eastern Bering Sea and 13,000 t in the Aleutian region. Minimal biomass estimates from recent trawl surveys (Table 6) were 16,800 t in the eastern Bering Sea based on combined estimates from the 1980 Aleutians survey in INPFC Area 1 and the 1981 eastern Bering Sea survey and 100,100 t in the Aleutians region in 1980. Assuming that a 10% exploitation rate is sustainable for the two stocks and that actual biomasses of the populations may be underestimated by survey data, EY for 1982-83 is minimally estimated to be about 1,700 t in the eastern Bering Sea and 10,100 t in the Aleutian region.

Recent information suggests that both stocks are still in very poor condition. Catch and CPUE have continued to decline and are currently at extremely low levels relative to earlier years. There is no consistent evidence to suggest that either stock is rebuilding to former levels of abundance, despite reduced annual catch levels in 1978-81 of only 500-2,200 t in the eastern Bering Sea and 3,300-5,500 t in the Aleutian region. In order to promote rebuilding, it is, therefore, advisable to set catch levels below EY.

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OTHER ROCKFISH

by

Daniel H. Ito

INTRODUCTION

Other rockfish, which includes all species of Sebastes and Sebastolobus other than Pacific ocean perch, Sebastes alutus, have traditionally been grouped in commercial catch statistics. Because of this, commercial catch and effort data have not been available for individual species of "other rockfish." Since 1977, however, species of rockfish have been identified in commercial catches by U.S. observers, which has provided a means of estimating annual harvests of individual species. This report describes how these data, as well as available abundance data, have been used to assess the condition of the stocks of "other rockfish" from the eastern Bering Sea and Aleutian Islands region in 1977-81.

COMMERCIAL CATCHES

The methods of sampling commercial catches for rockfish and estimating catches from U.S. observer data have been described by Nelson, et al. (1980, 1981a, 1981b, 1982). U.S. observers have identified 15 species of rockfish in groundfish catches from the eastern Bering Sea and Aleutian Islands region and tentatively identified 14 others, although the latter identifications have not been verified (Table 1).

The 1977-81 catches of all rockfish (including Pacific ocean perch) by species and International North Pacific Fisheries Commission (INPFC) statistical area (see Figure 1 in the article on walleye pollock by Bakkala and Wespestad in this Technical Memorandum for the location of INPFC areas) are

Table 1.--The common and scientific names of rockfish (*Sebastes* and *Sebastolobus* spp.) identified in the Bering Sea-Aleutian Islands groundfish fisheries in 1977-81 by U.S. observers.

Common name	Scientific name
Species of known occurrence	
Black rockfish	*Sebastes melanops*
Blue rockfish	*Sebastes mystinus*
Darkblotched rockfish	*Sebastes crameri*
Dusky rockfish	*Sebastes ciliatus*
Harlequin rockfish	*Sebastes variegatus*
Longspine thornyhead	*Sebastolobus altivelis*
Northern rockfish	*Sebastes polyspinis*
Pacific ocean perch	*Sebastes alutus*
Redbanded rockfish	*Sebastes babcocki*
Redstripe rockfish	*Sebastes proriger*
Rougheye rockfish	*Sebastes aleutianus*
Sharpchin rockfish	*Sebastes zacentrus*
Shortraker rockfish	*Sebastes borealis*
Shortspine thornyhead	*Sebastolobus alascanus*
Silvergray rockfish	*Sebastes brevispinis*
Species of questionable identification 1/	
Aurora rockfish	*Sebastes aurora*
Blackgill rockfish	*Sebastes melanostomus*
Bocaccio	*Sebastes paucispinis*
Canary rockfish	*Sebastes pinniger*
Chilipepper rockfish	*Sebastes goodei*
Rosethorn rockfish	*Sebastes helvomaculatus*
Rosy rockfish	*Sebastes rosaceus*
Splitnose rockfish	*Sebastes diploproa*
Tiger rockfish	*Sebastes nigrocinctus*
Vermilion rockfish	*Sebastes miniatus*
Widow rockfish	*Sebastes entomelas*
Yelloweye rockfish	*Sebastes ruberrimus*
Yellowmouth rockfish	*Sebastes reedi*
Yellowtail rockfish	*Sebastes flavidus*

1/ The occurrence of these 14 species in the eastern Bering Sea and Aleutian Islands region have not been documented in the literature.

listed in Tables 2-6. Catches of all rockfish increased from 22,000 t in 1977 to 31,800 t in 1979. Since 1979 catches have decreased to a low of about 7,300 t in 1981. The large decrease from 1979 to 1980-81 was the result of placing "other rockfish" under a specific rockfish TALFF (total allowable level of foreign fishing)--a management action by the North Pacific Fisheries Management Council. Prior to 1980, only the catch of Pacific ocean perch was restricted by a specific TALFF whereas all other species of rockfish were placed under a large TALFF of "other groundfish."

The Aleutian region has accounted for the largest portion of the Bering Sea-Aleutians catch of rockfish in 1977-81. Catches in the Aleutians region increased from about 17,700 t in 1977 to about 20,000 t in 1979 but then decreased to 5,000 t by 1981. In each year, Pacific ocean perch was the dominant species taken. Northern, rougheye, shortraker, dusky, darkblotched, and shortspined thornyhead rockfish have also made up significant portions of the rockfish catch at times during the past 5 years.

With the exception of the Aleutian region, Bering Sea area 2 appears to be the most productive area for rockfish. Total removals in this area ranged from 1,300 t to 13,100 t from 1977 to 1981. Combined catches of shortraker and shortspine thornyhead rockfish accounted for over 82% of the total rockfish removals from area 2 in 1978. Rougheye rockfish accounted for over 49% in 1979. Bering Sea areas 1 and 3 are of relatively minor importance in terms of rockfish catches; combined catches from these areas have not exceeded 1,500 t annually in 1977-81.

Estimated catches of "other rockfish" (excluding Pacific ocean perch) were estimated by U.S. observers for 1977-81 as follows:

Table 2.--Catches (t) of all species of rockfish, *Sebastes* and *Sebastolobus* spp., by International North Pacific Fisheries Commission (INPFC) area in the Bering Sea-Aleutian Islands groundfish fishery in 1977 (Nelson et al., 1981a).

	INPFC statistical area									
	Area 1		Area 2		Area 3		Area 5		Total	
Species	(t)	(%)	(t)	(%)	(t)	(%)	(t)	(%)	(t)	(%)
Blue rockfish	-	-	1.2	T[1]	-	-			1.2	T
Darkblotched rockfish	2.4	0.2	-	-	-	-	0.4	T	2.8	T
Dusky rockfish	2.0	0.2	1.1	T	-	-	2,932.9	16.6	2,936.0	13.3
Harlequin rockfish	-	-	-	-	-	-	1.0	T	1.0	T
Northern rockfish	0.3	T	312.0	10.0	9.4	13.9	5,311.2	30.1	5,632.9	25.6
Pacific ocean perch	1,059.3	93.1	1,573.1	50.3	21.8	32.3	8,079.9	45.7	10,734.1	48.8
Rougheye rockfish	0.8	0.1	1,013.3	32.4	29.5	43.7	1,127.6	6.4	2,171.2	9.9
Sharpchin rockfish	-	-	-	-	-	-	3.2	T	3.2	T
Shortraker rockfish	1.4	0.1	-	-	-	-	102.9	0.6	104.3	0.5
Shortspine thornyhead	59.5	5.2	225.9	7.2	6.8	10.1	89.1	0.5	381.3	1.7
Other rockfish[2]	12.0	1.0	-	-	-	-	19.1	0.1	31.1	0.1
Total	1,137.7	99.9	3,126.6	99.9	67.5	100.0	17,667.3	100.0	21,999.1	99.9

1/ T = <0.1%.
2/ See Table 1 for explanation of "other rockfish" category.

Table 3.--Catches (t) of all species of rockfish, Sebastes and Sebastolobus spp., by International North Pacific Fisheries Commission (INPFC) statistical area in the Bering Sea-Aleutian Islands groundfish fishery in 1978 (Nelson et al., 1981a).

	INPFC statistical area									
	Area 1		Area 2		Area 3		Area 5		Total	
Species	(t)	(%)	(t)	(%)	(t)	(%)	(t)	(%)	(t)	(%)
Black rockfish	-	-	0.7	T[1]	-	-	1.6	T	2.3	T
Blue rockfish	-	-	8.9	T	-	-	-	-	8.9	T
Darkblotched rockfish	1.5	0.1	37.6	0.3	0.3	0.4	42.2	0.3	81.6	0.3
Dusky rockfish	3.5	0.3	52.9	0.4	0.1	0.1	11.3	0.1	67.8	0.2
Harlequin rockfish	0.7	T	1.4	T	0.1	0.1	8.1	T	10.3	T
Longspine thornyhead	-	-	0.4	T	-	-	0.2	T	0.6	T
Northern rockfish	27.6	2.3	91.1	0.7	28.9	37.1	3,781.9	27.0	3,929.5	13.8
Pacific ocean perch	886.9	72.8	1,323.7	10.1	10.8	13.9	5,285.7	37.7	7,507.1	26.4
Redbanded rockfish	-	-	1.2	T	0.6	0.8	81.8	0.6	83.6	0.3
Redstripe rockfish	4.5	0.4	60.1	0.4	1.0	1.3	127.0	0.9	192.6	0.7
Rougheye rockfish	48.7	4.0	588.7	4.5	22.8	29.3	2,938.4	20.9	3,598.6	12.6
Sharpchin rockfish	-	-	-	-	-	-	1.4	T	1.4	T
Shortraker rockfish	117.6	9.6	8,674.1	66.0	8.5	10.9	1,094.6	7.8	9,894.8	34.8
Shortspine thornyhead	106.9	8.8	2,178.0	16.6	3.9	5.0	546.8	3.9	2,835.6	10.0
Silvergray rockfish	-	-	0.8	T	-	-	-	-	0.8	T
Other rockfish[2]	20.2	1.6	128.3	1.0	0.8	1.0	102.0	0.7	251.3	0.9
Total	1,218.1	99.9	13,147.9	100.0	77.8	99.9	14,023.0	99.9	28,466.8	100.0

1/ T = <0.1%.
2/ See Table 1 for explanation of "other rockfish" category.

Table 4.--Catches (t) of all species of rockfish, Sebastes and Sebastolobus spp., by International North Pacific Fisheries Commission (INPFC) statistical area in the Bering Sea-Aleutian Islands groundfish fishery in 1979 (Nelson et al., 1980).

Species	INPFC statistical area								Total	
	Area 1		Area 2		Area 3		Area 5			
	(t)	(%)	(t)	(%)	(t)	(%)	(t)	(%)	(t)	(%)
Black rockfish	11.6	0.8	0.6	T[1/]	-	-	2.3	T	14.5	T
Blue rockfish	0.2	T	-	-	-	-	-	-	0.2	T
Darkblotched rockfish	20.7	1.4	42.1	0.4	-	-	1,641.8	8.2	1,704.6	5.3
Dusky rockfish	3.8	0.3	88.6	0.9	-	-	54.8	0.3	147.2	0.5
Harlequin rockfish	-	-	-	-	-	-	51.6	0.2	51.6	0.2
Longspine thornyhead	15.0	1.0	1.2	T	-	-	2.2	T	18.4	0.1
Northern rockfish	16.9	1.2	108.8	1.0	-	-	996.9	5.0	1,122.6	3.5
Pacific ocean perch	949.7	65.0	768.2	7.5	4.5	8.4	5,486.6	27.4	7,209.0	22.6
Redbanded rockfish	0.3	T	12.4	0.1	-	-	40.0	0.2	52.7	0.2
Redstripe rockfish	14.4	1.0	64.5	0.6	-	-	997.1	5.0	1,076.0	3.4
Rougheye rockfish	71.7	4.9	5,059.5	49.1	-	-	4,538.1	22.7	9,669.3	30.4
Sharpchin rockfish	3.7	0.2	2.0	T	-	-	73.0	0.4	78.7	0.2
Shortraker rockfish	24.4	1.7	2,702.1	26.2	-	-	4,418.4	22.0	7,144.9	22.4
Shortspine thornyhead	132.8	9.1	1,403.6	13.6	49.2	91.4	1,709.6	8.5	3,295.2	10.4
Silvergray rockfish	-	-	-	-	-	-	1.0	T	1.0	T
Other rockfish[2/]	194.6	13.3	52.6	0.5	0.1	0.2	16.2	0.1	263.5	0.8
Total	1,459.8	99.9	10,306.2	99.9	53.8	100.0	20,029.6	99.9	31,849.4	100.0

1/ T = <0.1%.
2/ See Table 1 for explanation of "other rockfish" category.

Table 5.--Catches (t) of all species of rockfish, Sebastes and Sebastolobus spp., by the International North Pacific Fisheries Commission statistical areas in the Bering Sea/Aleutian Islands groundfish fisheries in 1980 (Nelson et al., 1981b).

	Foreign fishery								Joint venture fishery							
	Area 1		Area 2		Area 5		Total		Area 1		Area 2		Area 5		Total	
Common Name	(t)	(%)	(t)	(%)	(t)	(%)	(t)	(%)	(t)	(%)	(t)	(%)	(t)	(%)	(t)	(%)
Black rockfish	0.06	T1/	-	-	-	-	0.06	T	-	-	-	-	-	-	-	-
Darkblotched rockfish	0.29	T	32.73	2.0	86.33	1.4	119.35	1.4	-	-	-	-	-	-	-	-
Dusky rockfish	14.35	1.9	4.59	0.3	2.79	T	21.73	0.3	1.24	2.0	-	-	-	-	1.24	2.0
Harlequin rockfish	3.41	0.4	6.69	0.4	60.75	1.0	70.85	0.8	-	-	-	-	-	-	-	-
Longspine thornyhead	-	-	0.29	T			0.29	T	-	-	-	-	-	-	-	-
Northern rockfish	47.65	6.4	10.11	0.6	373.98	6.2	431.74	5.1	11.02	17.6	-	-	-	-	11.02	17.6
Pacific ocean perch	357.44	48.0	692.88	41.8	4,699.63	77.5	5,749.95	67.9	47.33	75.6	T	T	0.16	100.0	47.49	75.6
Redbanded rockfish	0.31	T	2.96	0.2	6.76	0.1	10.03	0.1	-	-	-	-	-	-	-	-
Redstripe rockfish	0.18	T	0.03	T	51.31	0.8	51.52	0.6	-	-	-	-	-	-	-	-
Rougheye rockfish	74.47	10.0	108.73	6.6	468.77	7.7	651.97	7.7	0.33	0.5	-	-	T	T	0.33	0.5
Sharpchin rockfish	3.10	0.4	-	-	0.20	T	3.30	T	1.35	2.2	-	-	-	-	1.35	2.2
Shortraker rockfish	85.93	11.5	565.63	34.1	102.45	1.7	754.01	8.9	-	-	-	-	-	-	-	-
Shortspine thornyhead	157.79	21.2	231.45	14.0	210.68	3.5	599.92	7.1	-	-	-	-	T	T	T	T
Other rockfish2/	0.07	T	1.20	T	1.95	T	3.22	T	1.35	2.1	-	-	-	-	1.35	2.1
Total	745.05	99.8	1,657.29	100.0	6,065.60	99.9	8,467.94	99.9	62.62	100.0	T	T	0.16	100.0	62.78	100.0

1/ T <0.01 t or T <0.1%.
2/ See Table 1 for explanation of "other rockfish" category.

Table 6.--Catches (t) of all species of rockfish, Sebastes and Sebastolobus spp., by the International North Pacific Fisheries Commission statistical areas in the Bering Sea-Aleutian Islands groundfish fishery in 1981 (Nelson et al., 1982).

	Foreign fishery								Joint venture fishery							
	Area 1		Area 2		Area 5		Total		Area 1		Area 2		Area 5		Total	
Common Name	(t)	(%)	(t)	(%)	(t)	(%)	(t)	(%)	(t)	(%)	(t)	(%)	(t)	(%)	(t)	(%)
Black rockfish	T[1]	T	-	-	-	-	T	T	-	-	-	-	-	-	-	-
Blackgill rockfish	0.4	T	T	T	-	-	0.4	T	-	-	-	-	-	-	-	-
Darkblotched rockfish	19.0	1.9	36.1	2.7	7.0	0.1	62.1	0.8	-	-	-	-	-	-	-	-
Dusky rockfish	8.7	0.9	5.0	0.4	10.6	0.2	24.3	0.3	T	T	-	-	T	T	T	T
Harlequin rockfish	44.1	4.5	5.9	0.4	8.4	0.2	58.4	0.8	-	-	-	-	-	-	-	-
Longspine thornyhead	-	-	3.3	0.2	-	-	3.3	T	-	-	-	-	-	-	-	-
Northern rockfish	16.2	1.6	14.6	1.1	137.6	2.7	168.4	2.3	T	T	-	-	2.0	28.6	2.0	23.8
Pacific ocean perch	640.0	64.9	581.3	43.2	3,618.4	72.2	4,839.7	65.9	1.4	100.0	-	-	4.4	62.8	5.8	69.0
Redbanded rockfish	T	T	1.3	0.1	T	T	1.3	T	-	-	-	-	-	-	-	-
Redstripe rockfish	T	T	8.5	0.6	5.1	0.1	13.6	0.2	-	-	-	-	-	-	-	-
Rougheye rockfish	174.8	17.7	125.2	9.3	477.1	9.5	777.1	10.6	-	-	-	-	0.6	8.6	0.6	7.1
Sharpchin rockfish	-	-	4.0	0.3	0.1	T	4.1	0.1	-	-	-	-	-	-	-	-
Shortraker rockfish	30.3	3.1	414.0	30.8	450.8	9.0	895.1	12.2	-	-	-	-	-	-	-	-
Shortspine thornyhead	52.2	5.3	143.7	10.7	276.3	5.5	472.2	6.4	-	-	-	-	-	-	-	-
Silvergray rockfish	-	-	-	-	T	T	T	T	-	-	-	-	-	-	-	-
Other rockfish[2]	T	T	3.1	0.2	20.8	0.4	23.9	0.3	-	-	-	-	T	T	T	T
Total	985.7	99.9	1,346.0	100.0	5,012.2	99.9	7,343.9	99.9	1.4	100.0	0.0	100.0	7.0	100.0	8.4	99.9

1/ T <0.01 t or T <0.1%.
2/ See Table 1 for explanation of "other rockfish" category.

Region	Catch (t) 1977	1978	1979	1980	1981
Eastern Bering Sea	1,678	12,222	10,097	1,367	1,110
Aleutians	9,587	8,737	14,543	1,366	1,394

The low estimate for the eastern Bering Sea in 1977 was primarily due to the estimate being based on catch rates of rockfish observed in all fisheries while in 1978 and 1979 only rates from vessels taking rockfish were used. The 1978 and 1979 estimates are probably more representative of the actual catches taken in this region. The large decrease in catches from 1979 to 1980-81 was due to these species being placed under specific catch quotas in 1980. As discussed earlier, prior to 1980 they were included under a large quota of "other groundfish."

BIOMASS ESTIMATES

Estimates of biomass and maximum sustainable yield (MSY) for "other rockfish" have been calculated based on Japanese research vessel data (Ikeda 1979). These estimates were as follows:

Area	Estimated biomass (t)	Estimated range in MSY (t)
Eastern Bering Sea	55,000	7,000-15,000
Aleutians	167,000	23,000-45,000

The ranges in MSY estimates were derived using the above biomasses in the yield equation as representing virgin biomass to derive the lower MSY values and as representing one-half virgin biomass to derive the upper MSY values. Because Ikeda (1979) had limited survey data and used a number of assumptions which need verification, these estimates should be viewed with caution and should be used only as a first approximation.

The biomass estimate from the 1979 cooperative U.S.-Japan trawl survey of the eastern Bering Sea was 6,100 t for "other rockfish" (Bakkala et al. 1982). A cooperative survey similar to that in 1979 indicated that the biomass of "other rockfish" increased to 9,900 t in 1981. It is questionable whether the abundance estimate in 1981 actually represented a significant increase in population size from 1979 because the two estimates were characterized by a relatively low degree of precision. Based on the 1980 cooperative U.S.-Japan survey of the Aleutians region, there was another 2,800 t of "other rockfish" in the Aleutian Islands portion of INPFC area 1 (north side of Aleutians from 165°W to 170°W long.). Thus, an overall estimate for the eastern Bering Sea region from the 1980 Aleutian and 1981 eastern Bering Sea survey data is 12,600 t. These survey results are assumed to have substantially underestimated the true abundance of these species. The commercial catch alone in 1979 was 12,000 t.

Preliminary biomass estimates from the 1980 U.S.-Japan cooperative survey in the Aleutian Islands (INPFC area 5, 170°W to 170°E long.) was 55,000 t for "other rockfish." This estimate is lower than the 167,000 t estimated by Ikeda (1979) from survey data in the early 1970's.

MAXIMUM SUSTAINABLE YIELD

MSY estimates for "other rockfish" were given by Ikeda (1979). These estimates were expressed as a range of values: 7,000-15,000 t for the eastern Bering Sea and 23,000-45,000 t for the Aleutians.

EQUILIBRIUM YIELD

Equilibrium yield (EY) for "other rockfish" was estimated as 11,000 t for both the eastern Bering Sea and Aleutian region in 1981 based on the estimated catches in 1977-79 from observer data. Equal estimates of EY for the two regions does not now appear reasonable given the apparent fourfold difference in biomasses in the two regions. Appropriate estimates of EY are difficult to determine based on available data which is summarized below:

Region	Average catches (t)	1979-81 survey biomass estimates (t)	Data of Ikeda (1979) Biomass estimates (t)	MSY estimates (t)
Eastern Bering Sea	11,000 (1978-79)	12,600	55,000	7,000-15,000
Aleutians	11,000 (1977-79)	55,000	167,000	23,000-45,000

Biomass estimates from recent surveys are assumed to underestimate the actual biomass of the populations. The average catch in the Aleutians in 1977-79 may be a reasonable estimate of EY using the assumption that population abundance is greater than shown by the survey biomass estimates. The eastern Bering Sea population appears to be 23-33% the size of the Aleutian population based on the biomass estimates for the two regions from recent surveys and those reported on by Ikeda (1979). Using the midpoint of this range (28%) and applying it to the EY for the Aleutians, the EY for the eastern Bering Sea would be estimated at 3,100 t.

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ATKA MACKEREL

by

Lael L. Ronholt

INTRODUCTION

Atka mackerel, Pleurogrammus monopterygius, are found throughout the Aleutian and Komandorskiye Islands, westward to the east coast of Kamchatka, north to the Pribilof Islands and eastward throughout the Gulf of Alaska to southeastern Alaska. Commercial catches occur in both the eastern Bering Sea and Aleutians, but the highest catches by far have come from the Aleutian region which, from 1978 to 1981, produced over 76% of the total Bering Sea landings (Table 1). Based on the 1980 cooperative U.S.-Japanese groundfish resource assessment survey, Atka mackerel is the third most abundant species in the Aleutian Islands region after grenadiers (rattails, family Macrouridae) and walleye pollock, Theragra chalcogramma.

STOCK UNITS

Levada (1979a) compared 21 morphological and meristic characters in a study of the stock structure of Atka mackerel from the Aleutian Islands region and the Gulf of Alaska. Although the author felt further studies were needed, the results of his study indicated that differences in meristic and morphological characters between areas suggested the existence of distinct populations in the Gulf of Alaska and Aleutian Islands. Characters that showed differences between the two regions in their order of significance were number of vertebrae, rostral length, greatest body height, number of rays in the anal fin, and head length. These five characters were responsible for more than half of all differences. Atka mackerel populations in the Aleutians and Gulf of Alaska are managed as separate stocks, and these studies, although far from conclusive, support the validity of this management policy.

Table 1.--Atka mackerel landings by International North Pacific Fisheries Commission (INPFC) area in the Bering Sea.

Region	INPFC area	Year 1978	1979	1980	1981
		---------- t ----------			
Eastern Bering Sea	I	422	1,653	4,230	2,307
Eastern Bering Sea	II	410	332	461	721
Central Bering Sea	III	0	0	0	0
Aleutians	V	23,418	21,279	15,534	15,028
Total		24,250	23,264	20,225	18,056

1/ Totals do not include joint venture catches (see Table 2).

CONDITION OF STOCK

Catch statistics

The total annual landings of Atka mackerel increased throughout the 1970's peaking in 1978 at 24,250 t, but have since declined to 19,700 t in 1981 (Table 2). Landings have generally increased in the eastern Bering Sea and declined in the Aleutian region (Table 1). From 1970 to 1979, the Soviet Union was the principal harvester of Atka mackerel in the Bering Sea. Since the cessation of Soviet fishing in 1980, the Republic of Korea (ROK) has become the primary harvester landing 86% and 71% of the total landings in 1980 and 1981, either with their own fishing vessels or through joint-venture operations. Japan's landings, which ranged from 1,500-1,700 t in 1978-80, increased over threefold to 5,600 t in 1981.

Largest landings of Atka mackerel occurred during the winter-early spring and late summer-fall periods with 66% of the nonjoint-venture catch being harvested by large freezer trawlers, 33% by small trawlers, and 1% by surimi motherships or trawlers.

Size and Age Composition

Size composition data for Atka mackerel of the Aleutian region are available from collections by the U.S. observer program and from Levada (1979b). Based on the data of Levada (1979b), the mean size of Atka mackerel increased from 26.5 cm in 1975 to 28.7 cm in 1977 (Figure 1). U.S. observer data has indicated that mean size in commercial catches increased from 29.1 cm in 1977 to 37.0 cm in 1981 (Figure 2).

The size composition of the commercial landings of Atka mackerel from the Bering Sea in 1981 varied considerably by statistical area. In the Aleutians, which produced 83% of the total landing, they ranged from 29 to 45 cm with 75%

Table 2.--Reported catches (t) of Atka mackerel in the eastern Bering Sea and Aleutian Islands region by nation, 1970-81.

Nation	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
USSR	949	1/	5,907	1,712	1,377	13,326	13,126	20,975	22,622	20,277	937	0
Japan								1/	1,531	1,656	1,719	5,615
ROK								1/	97	1,329	17,483	12,385
West Germany											42	38
Poland										2	44	18
USJV2/											265	1,633
Total	949	-	5,907	1,712	1,377	13,326	13,126	20,975	24,250	23,264	20,309	19,689

1/ Reported in other species category, if any caught.
2/ U.S.-Republic of Korea (ROK) joint venture.

Source: 1970-76 data provided to the U.S. under U.S.-USSR bilateral agreement.

Since 1977, data provided to the U.S. under provisions of the Magnuson Fishery Conservation and Management Act of 1976 (Public Law 94-265).

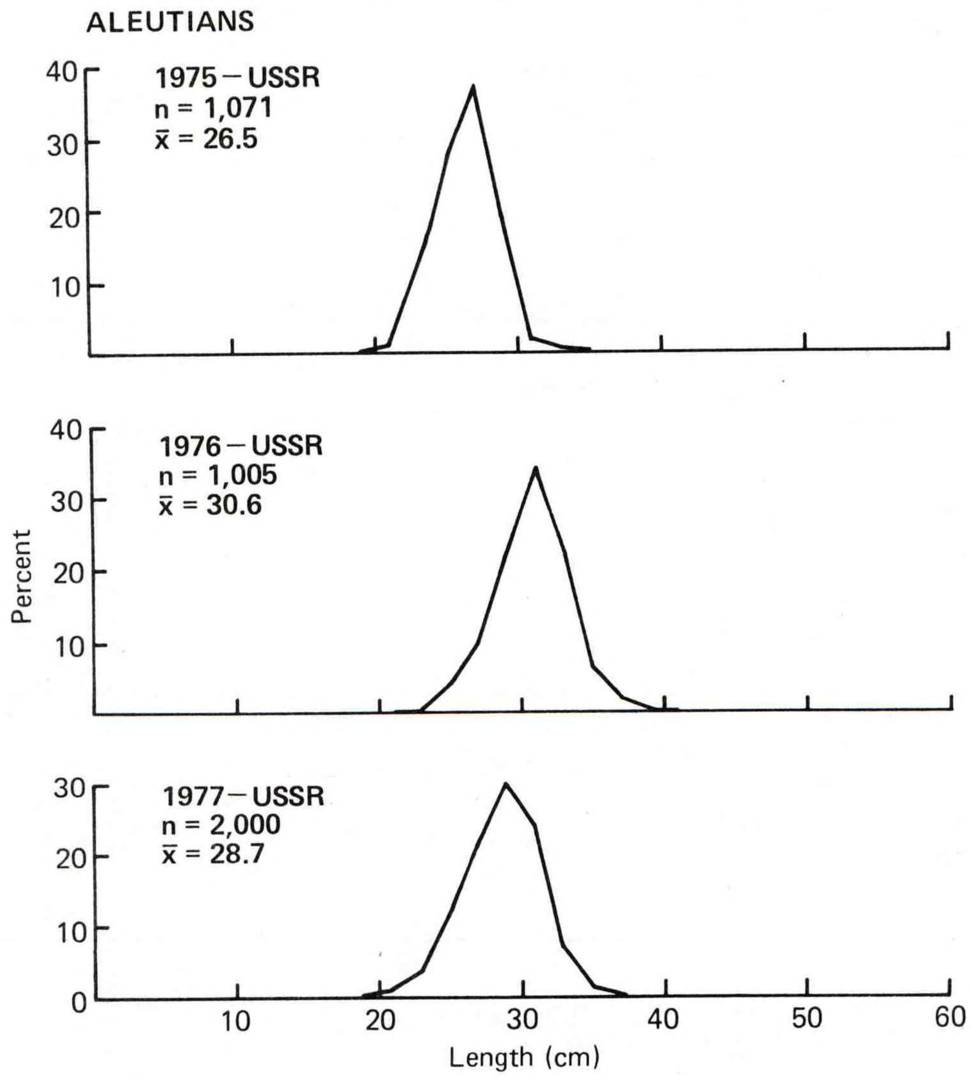

Figure 1.--Size composition of Atka mackerel in catches by USSR fisheries in the Aleutian Islands region, 1975-77 (Levada 1979b).

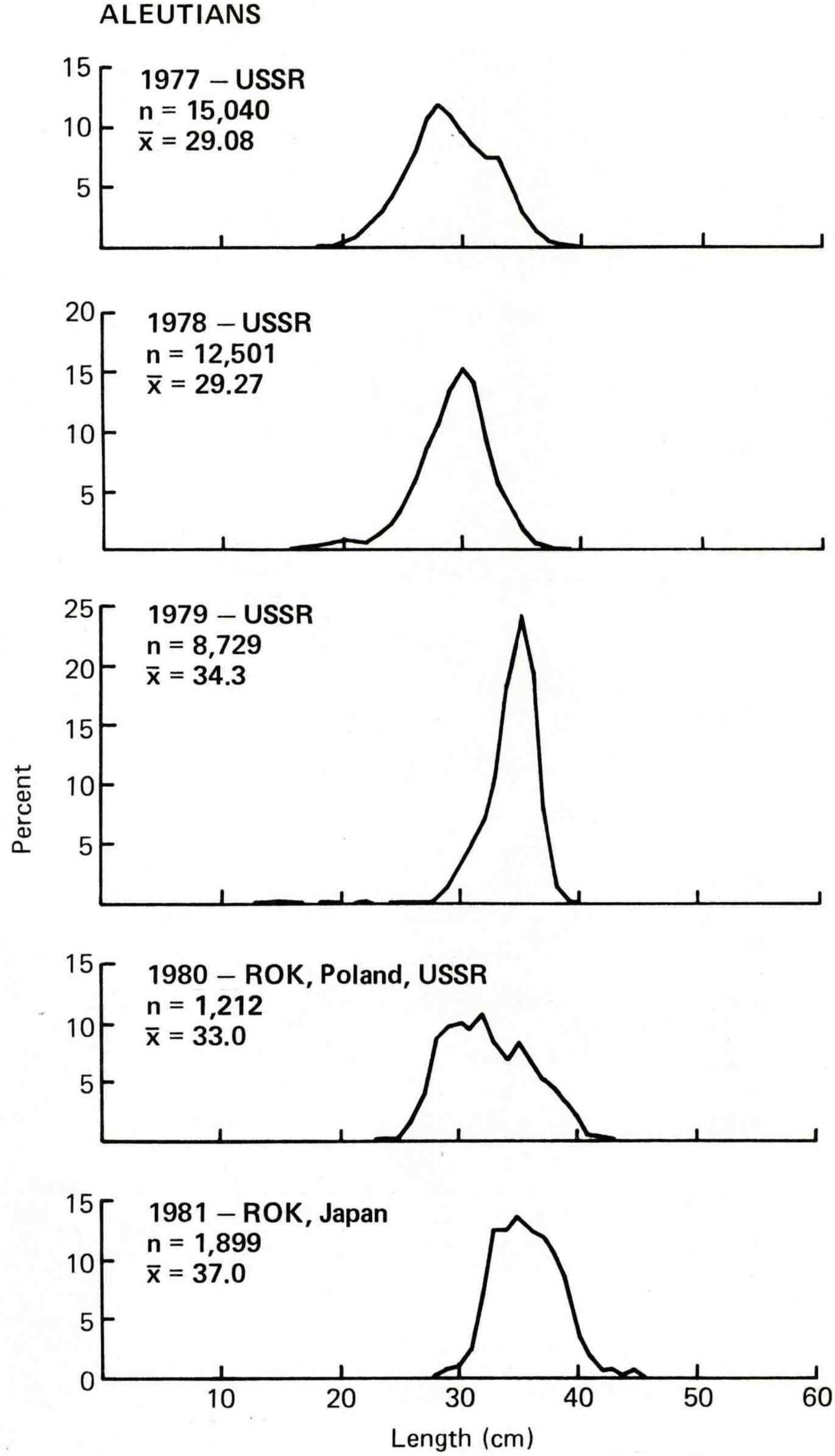

Figure 2.--Size composition of Atka mackerel in the Aleutian Islands region as shown by data collected by U.S. observers from the commercial fisheries and by data submitted to the U.S. by the Republic of Korea (ROK), 1977-81.

of the catches ranging from 33 to 38 cm (Figure 3). In International North Pacific Fisheries Commission (INPFC) statistical area 2 in the eastern Bering Sea, the size range of the commercial landings was similar to that of the Aleutians, but the length-frequency was bimodal with 51% of the catch found in the 32-34 cm size interval and 27% in 36-39 cm interval. Atka mackerel landed in area 1 of the eastern Bering Sea were of a larger size, ranging from 29 to 51 cm, and contained a higher percentage of fish over 40 cm than catches in areas 2 and 5.

Age data for 1977-79 are available for Atka mackerel from samples collected by the U.S. observer program and for 1980 from the U.S.-Japan cooperative resource assessment survey (Table 3). These data indicated that a single large year class (1975) has been moving through the fishery. Since 1977, nearly 40,000 t or 44% of the total catch of Atka mackerel has been accounted for by this year class. During 1977 and 1978 when the 1975 year-class was age 2 and 3, respectively, 18,378 t were harvested as compared to 2,822 and 4,480 t for the 1976 and 1977 year-classes at the same ages (Table 4). The 1976 year-class was the second most abundant available to the fishery in 1980.

Available data does not indicate any incoming year classes as strong as the 1975 year-class; however, adequate data were not available from the commercial fishery in 1980-81 to show the strength of most recent year-classes. Abundance of Atka mackerel in the Bering Sea may, therefore, decline once the strong 1975 year-class passes out of the population.

Abundance estimates

The ability to evaluate the conditions of the Atka mackerel stocks in the Bering Sea is restricted by limited biological data and measures of relative and absolute abundance of the stock. Levada (1979b) presented data which showed that mean catch per unit of effort (CPUE) increased in 1972-76 from 0.8

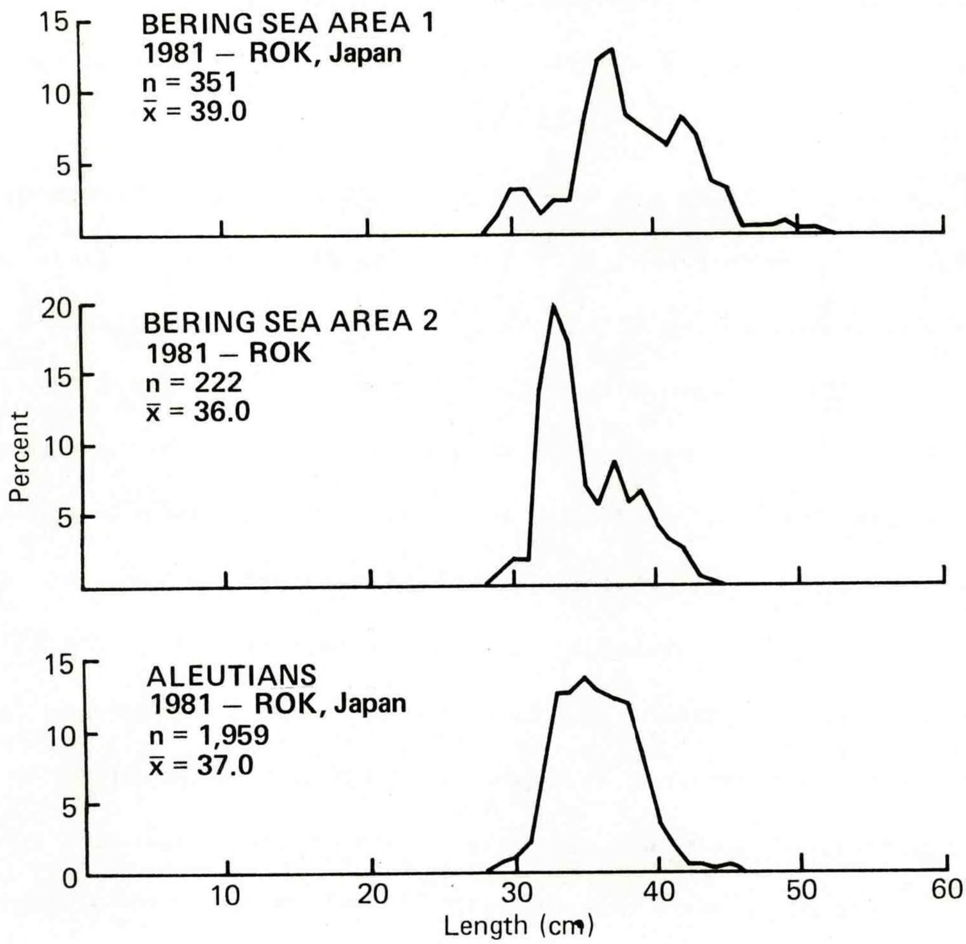

Figure 3.--Size composition of Atka mackerel in International North Pacific Fisheries Commission (INPFC) statistical areas in the eastern Bering Sea and Aleutian Islands region, as shown by data collected by U.S. observers from commercial fisheries of the Republic of Korea (ROK) and Japan in 1981.

Table 3.--Age frequency and length-at-age of Atka mackerel in the Aleutian Islands region based on U.S. observer and resource assessment data.

	Age (yr)[1]							
Year	2	3	4	5	6	7	8	9
A. Age frequency (%)								
1977	10	42	26	19	2	Tr[2]	Tr	-
1978	4	64	17	10	4	Tr	Tr	Tr
1979	Tr	9	57	26	5	2	-	-
1980[3]	10	8	25	45	15	3	Tr	-
B. Length-at-age (cm)								
1977	23.7	27.6	30.3	32.9	34.6	35.6	-	-
1978	20.7	28.6	30.9	32.4	33.4	33.6	-	-
1979	20.5	30.6	34.5	35.0	34.9	34.9	-	-
1980[3]	22.9	31.9	35.5	36.9	37.7	39.3	40.0	-

1/ Atka mackerel spawn from July to October and do not form an annulus in their first winter of life. One year has, therefore, been added to the actual age readings.

2/ Less than 1%.

3/ U.S. research data.

Table 4.--Yearly landings (t) of Atka mackerel in the Aleutian Islands region by age group, 1977-80.

Year	Age (yr) 2	3	4	5	6	7	8	Total
	-----	-----	-----	-----	t	-----	-----	-----
1977	1,888	8,810	5,663	4,195	420	210	Tr	21,186
1978	728	16,490	4,123	2,425	970	243	Tr	24,979
1979	233	2,094	13,028	6,281	1,163	465	233	23,497
1980	405	4,247	4,652	8,292	1,618	405	202	19,821
						Total		89,483

to 5.2 t/h. Data collected in 1977-81 by the U.S. Observer Program, during the Northwest and Alaska Fisheries Center (NWAFC) resource assessment survey in 1980, and by the Republic of Korea National Fisheries Research and Development Agency in 1980-81 are given in Table 5. These data show that mean lengths and weights have increased since 1977. Based on U.S. observer data, CPUE increased from 3.9 t/h in 1977 to 9.1 t/h in 1979, and then decreased to 5.3 t/h in 1981.

The average CPUE for Atka mackerel during the 1980 U.S.-Japan cooperative survey was 25.9 kg/ha for the Aleutian Islands portion of INPFC area 1 (from 165° W to 170°W long.) and 18.2 kg/ha in INPFC area 5 (170° W to 170° E long.). Biomass estimates from the survey were 24,500 t in the Aleutian Islands portion of INPFC area 1 and 158,300 t for INPFC area 5 for a total estimate of 182,800 t.

MAXIMUM SUSTAINABLE YIELD

Maximum sustainable yield (MSY) for Atka mackerel of the Aleutian region was estimated by Soviet scientists to be 33,000 t based on biomass estimates from hydroacoustic trawl surveys in 1974-75. The biomass estimates ranged from 35,000 to 110,000 t of which Soviet scientists believed 30% or 10,500-33,000 t was exploitable. In 1980, Soviet scientists reported that the biomass had increased to 180,000-200,000 t which would yield a MSY of 54,000-60,000 t based upon 30% of the stock being harvestable.

Estimates of maximum sustained yield of stocks which are in virgin or near-virgin states can be derived using the equation of Alverson and Pereyra (1969):

$$MSY = aMB_o$$

where a = constant = 0.4 (Gulland 1969) or 0.5 (Alverson and Pereyra 1969)

M = instantaneous natural mortality, and

B_o = virgin biomass.

Table 5.--Mean age, length, and weight and catch per unit of effort (CPUE) of Atka mackerel in the Aleutian Islands region, based on U.S. observer data unless otherwise noted.

Parameter	Year 1977	1978	1979	1980	1981
Mean age (yr)	3.66	3.51	4.34	4.45 1/	
Mean length (cm)	29.10	29.30	34.30	34.7 1/ 33.4 33.0 2/	35.0 37.0 2/
Mean weight (kg)	.27	.27	.46	.36	.70
Mean CPUE (t/h)	3.90	4.53	9.10	7.62	5.28
Percent female	56	54	56	48	
Sample size	14,610	12,374	8,683	2,521 1/ 103 1,212 2/	824 1,899 2/

1/ Data from NWAFC resource assessment survey.

2/ Data reported by the Republic of Korea National Fisheries Research and Development Agency.

Using the methods described by Efimov (1981) and Alverson and Carney (1975), the instantaneous rate of natural mortality has been estimated as 0.31 based on the following equation:

$$M = \frac{3K}{e^{t_{mb} K} - 1} \quad : \quad t_{mb} \text{ (time of maximum biomass) } = 0.25\ t_m$$

where t_m (time of maximum age) = 12 years, and

K (Von Bertalanffy growth parameter) = 0.67.

The estimate of the Von Bertalanffy growth parameter K and, therefore, the calculated M is dependent upon the interpretation of age structures. Misintrepretation of these structures would result in unreliable values of M, which in turn affect estimates of MSY. Since the U.S. aging method, based on counts of winter growth rings on otoliths, has not been verified, the validity of the age data is uncertain.

Although Soviet scientists have not published estimates of M for Atka mackerel in the Aleutian Islands, data from the Gulf of Alaska have yielded estimates of 0.60 (Efimov 1981).

Using the M value of 0.31 and the biomass estimate of 182,800 t from the cooperative 1980 U.S.-Japan Aleutian trawl survey, MSY is estimated as 28,300 t using a = 0.5 in the yield equation and 22,666 t using a = 0.4. The yield equation requires estimates of virgin or near virgin biomass to determine MSY, and it is unknown if the sampled biomass from the 1980 U.S.-Japan survey was greater or less than the virgin biomass of the Aleutian Islands population. USSR data (Levada 1979b) have indicated that CPUE was relatively stable from 1972-75 and then increased in 1976. U.S. observer data shows that CPUE, mean length, mean weight, and mean age increased from 1977 to 1980 and demonstrated the presence of a strong year-class in the population in those years. Thus the sampled population biomass in 1980 may have been at a high level relative to the biomass of the population in early years of the fishery.

EQUILIBRIUM YIELD

There was no evidence to suggest that equilibrium yield should vary from MSY. Equilibrium yield is, therefore, estimated at the mid-point of the MSY estimates or 25,500 t.

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SQUID

by

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INTRODUCTION

With the exception of some recent publications (Bubblitz 1981; Mercer 1981; Fiscus and Mercer 1982; and Wilson and Corham 1982), there is little information available on distribution, abundance, and biology of squid stocks in the eastern Bering Sea and Aleutian Islands regions. Squid are generally taken incidentally or are temporarily targeted upon by trawl fisheries when large concentrations are encountered. *Berryteuthis magister* and *Onychoteuthis borealijaponicus* are the major components of squid catches.

B. magister predominates in catches made in the eastern Bering Sea, whereas *O. borealijaponicus* is the principal species encountered in the Aleutian Islands region. Squid catches (t) by nation for the eastern Bering Sea-Aleutians areas are as follows:

Nation	1977	1978	1979	1980	1981
	t				
Japan	8,316	9,138	5,739	4,622	4,680
Republic of Korea	1/	215	1,233	1,620	1,097
Taiwan	1/	35	14	39	55
USSR	1/	23	6	0	0
West Germany	-	-	-	53	9
Poland	-	-	25	19	96
Joint venture	-	-	-	-	4
Total	8,316	9,411	7,017	6,353	5,941

1/ Catch, if any, reported as other species.

Overall catches have declined after 1978 with a total all-nation catch of 5,941 t in 1981. Approximately 70% of the total squid catch in 1981 came from the eastern Bering Sea region.

MAXIMUM SUSTAINABLE YIELD

Maximum sustainable yield is unknown but is believed to be at least equal to the highest recent catch. Therefore, the minimum estimate of MSY is 10,000 t.

EQUILIBRIUM YIELD

Catches of 10,000 t are believed to be sustainable.

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OTHER SPECIES

by

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INTRODUCTION

The "other species" category has been established by the North Pacific Fishery Management Council to account for species which are currently of slight economic value and not generally targeted upon, but have potential economic value or are important ecosystem components. Because there is insufficient data to manage each species separately, they are considered collectively. Catch records of this species category as a whole must be maintained by the fishery and a "total allowable catch" is established by the council for this group.

Table 1 lists the four categories of fish and invertebrates established for management purposes by the North Pacific Fishery Management Council in the Bering Sea-Aleutian Islands regions. The "other species" category consists of five groups of species: sculpins, sharks, skates, smelts, and octopuses. Numerous species of sculpins occur in the eastern Bering Sea and Aleutians with 34 identified during a cooperative U.S.-Japan survey of the eastern Bering Sea in 1979 (Bakkala et al. 1982). Species of smelt occurring in the regions are capelin, *Mallotus villosus*; rainbow smelt, *Osmerus mordax dentex*; and eulachon, *Thaleichthys pacificus*. Sharks are rarely taken during demersal trawl surveys in the Bering Sea. The species normally caught is spiny dogfish, *Squalus acanthias*, but one occurrence of Pacific sleeper shark, *Somniosus pacificus*, has also been recorded. Two species of octopuses have been recorded with *Octopus dofleini* the principal species and *Opisthoteuthis californiana* appearing intermittently in catches.

Table 1.--Species categories which apply to the Bering Sea-Aleutian groundfish fishery.

Prohibited species 1/	Target species 2/	Other species 3/	Nonspecified species 4/	
FINFISHES				
Salmonids	Walleye pollock	Sculpins	Eelpouts (Zoarcidae)	
Pacific halibut	Cod	Sharks	Poachers (Agonidae) and alligator fish	
	Flounders	Skates	Snailfish, lumpfishes, lump-suckers (Cyclopteridae)	
	Herring	Smelts	Sandfishes (*Trichodon* sp.)	
	Atka mackerel		Rattails (Macrouridae)	
	Sablefish		Ronquils, searchers (Bathymasteridae)	
	Pacific ocean perch		Lancetfish (Alepisauridae)	
	Other rockfish		Pricklebacks, cockscombs, warbonnets, shanny (Stichaeidae)	
			Prowfish (*Zaprora silenus*)	
			Hagfish (*Eptatretus* sp.)	
			Lampreys (*Lampetra* sp.)	
			Blennys, gunnels, (various small bottom dwelling fishes of the families Stichaeidae and Pholidae)	
INVERTEBRATES				
King crab	Squids	Octopuses	Anemones	Jellyfishes
Snow (Tanner) crab			Starfishes	Tunicates
Coral			Egg cases	Sea cucumber
Shrimp			Sea mouse	Sea pen
Clams			Sea slug	Isopods
Horsehair crab			Sea potato	Barnacles
Lyre crab			Sand dollar	Polychaetes
Dungeness crab			Hermit crab	Crinoids
			Mussels	Crab - unident.
			Sea urchins	Misc. - unident.
			Sponge-unident.	

1/ Must be returned to the sea.
2/ Optimum yield established for each species.
3/ Aggregate optimum yield established for the group as a whole.
4/ List not exclusive; includes any species not listed under Prohibited, Target, or "Other" categories.

A second category of noncommercial species "nonspecified species," which includes fish and invertebrates of no current or foreseeable economic value, has also been established by the North Pacific Fishery Management Council (Table 1). These species are only taken in the fishery as a by-catch of target fisheries. The "total allowable catch" for this category is any amount taken, whether retained or discarded, by the fishery while fishing for target species. If retained, catch records must be kept. The most abundant families of fishes in the Bering Sea-Aleutian Island regions included in this category are eelpouts (Zoarcidae), poachers (Agonidae), snailfishes (Cyclopteridae), and rattails (Macrouridae).

Estimates of maximum sustainable yield (MSY) and equilibrium yield (EY) have previously been derived for the "other species" category but these estimates were based on abundance of fish in both the "other species" and "nonspecified species" categories (Bakkala et al. 1981). To conform to the new definitions by the North Pacific Fisheries Management Council, MSY and EY estimates in this report are restricted to only those groups designated as "other species."

COMMERCIAL CATCHES AND ABUNDANCE ESTIMATES

Reported catches of the "other fish" category reached a peak of 133,340 t in 1972, but have since declined to less than half that level, ranging between 42,800 and 51,700 t in 1979-81 (Table 2). The species composition of these catches is unknown and it is likely that they include species from both the other fish and nonspecified species categories.

Data from large-scale surveys of the eastern Bering Sea in 1975 and 1979-82 and the Aleutian Islands region in 1980 provide abundance estimates for the other species category and the relative importance of the various species comprising this category (Table 3). The estimates illustrate that sculpins

Table 2.--All-nation catches of other fish, 1964-81 1/.

Year	Aleutian Island region	Eastern Bering Sea	Total
	----------	t	----------
1964	66	736	802
1965	768	2,218	2,986
1966	131	2,239	2,370
1967	8,542	4,378	12,920
1968	8,948	22,058	31,006
1969	3,088	10,459	13,547
1970	10,671	15,295	25,966
1971	2,973	33,496	36,469
1972	22,447	110,893	133,340
1973	4,244	55,826	60,070
1974	9,724	60,263	69,987
1975	8,288	54,845	63,133
1976	7,053	26,143	33,196
1977	16,170	35,902	52,072
1978	12,436	61,537	73,973
1979	12,934	38,767	51,701
1980	13,004	33,949	46,953
1981	7,274	35,551	42,825

1/ Data for 1964-80 from catches reported to the U.S. by fishing nations; 1981 data from French et al. (1982).

Table 3.--Biomass estimates of other species from large-scale demersal trawl surveys in 1975 and 1979-82 1/.

Species group	Eastern Bering Sea 1975	Eastern Bering Sea 1979 1/	Eastern Bering Sea 1980	Eastern Bering Sea 1981 1/	Eastern Bering Sea 1982	Aleutian Islands region 1980
	----------	----------	----------	t	----------	----------
Sculpins	122,500	251,800	281,100	350,200	291,300	39,300
Skates	42,000	88,700	114,900	246,800	168,000	15,500
Smelts	28,700	11,500	15,500	4,200	10,100	0
Sharks	0	200	0	0	0	800
Octopuses	8,600	49,500	17,400	13,100	13,100	2,300
Total	201,800	401,700	428,900	614,300	482,500	57,900

1/ The biomass estimates for the eastern Bering Sea are from the approximate area shown in Figure 2 of the article on walleye pollock by Bakkala and Wespestad in this Technical Memorandum. The 1979 and 1981 data includes estimates from continental slope waters (200-1000 m), but the 1975, 1980, and 1982 data do not.

are the major component of the other species category, but that skates have become an increasingly important component in the eastern Bering Sea. The estimates indicate that the abundance of the group as a whole may have doubled in the eastern Bering Sea between 1975 and 1979 and have shown some further increase through 1981-82.

It should be pointed out that smelts may be poorly sampled by demersal trawls because species of this family may primarily inhabit pelagic waters. The abundance of this family is, therefore, assumed to be substantially underestimated. Estimates indicate that the other species group may be approximately one-tenth as abundant in the Aleutian Islands region as they are in the eastern Bering Sea (Table 3).

MAXIMUM SUSTAINABLE YIELD

Estimates of MSY derived last year (Bakkala et al. 1981) were based on abundance estimates of both the other fish and nonspecified species groups. Last year's estimates, therefore, need to be revised to consider only the other fish group.

In view of the apparent major increase in abundance of the other species category in the eastern Bering Sea (Table 3), this aggregation of stocks in 1981 may have been somewhere between a level that produces MSY and the level of the virgin population size. Using this assumption, the combined biomass estimates from the 1981 eastern Bering Sea survey (the most recent estimate, including sampling from continental slope waters, and the 1980 Aleutians survey (the only available estimate from this region), and a natural mortality coefficient of 0.2, the Alverson and Pereyra (1969) yield equation, would indicate that MSY (i.e., MSY = 0.5 x 0.2 x 614,300 t) is 61,400 t.

EQUILBRIUM YIELD

The condition of these resources is uncertain. The long history of exploitation of these species as a by-catch in target fisheries for other species would suggest that abundance has been reduced below the virgin biomass level. The major increase in biomass since 1975, however, implies that the abundance of these species may be relatively high, and the 1981 survey biomass estimate may provide a reasonable estimate of the virgin biomass. Based on these considerations, the other species category is probably capable of producing catches at the calculated MSY level or 61,400 t.

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