NOAA Technical Memorandum NMFS F/NWC-53

Condition of Groundfish Resources of the Eastern Bering Sea and Aleutian Islands Region in 1983

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March 1984

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service

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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 1983. 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 yields and equilibrium yields are presented to guide management of the 1984 fishery. These estimates and assessments of the condition of individual stocks are summarized in Table A.

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 remain at low levels of abundance. The equilibrium yield for the groundfish complex as a whole was estimated to be 2.2 million metric tons (t) in 1983 compared to 2.0 million t in 1981 and 2.1 million t in 1982.

Table A.--Estimated biomass, MSY, and EY (in thousand t), and views on stock condition of groundfish in the Eastern Bering Sea/Aleutian Islands Region from assessments in 1983.

Species	Estimated biomass	MSY	EY	Stock condition	Abundance trend
Pollock					
(Eastern Bering Sea)	>7,800	1,500	1,200	Good	Average abundance but weaker 1979-81 year classes recruiting to fishable stock
(Aleutians)	≈1,000	100	100	Good	
Pacific cod	1,126	--	291.3	Very good	Abundance at historic high, but expected to decline rapidly
Yellowfin sole	3,952	150-175	310	Very good	Abundance at historic high and stable
Turbots	352	96.2	67.5		
(Arrowtooth flounder)	(152)	(24.2)	(20.0)	Good	Abundance average and stable
(Greenland turbot)	(200)	(72.0)	(47.5)	Fair	Abundance below average
Other flatfish	1,964	88-150	150		
(Alaska plaice)	(745)	(45-70)	(70)	Very good	Abundance above average and stable
(Rock sole-flathead sole-other flatfish)	(1,219)	(43-80)	(80)	Very good	Abundance above average and stable
Sablefish	68.7	15.1	6.2		
(Eastern Bering Sea)	(49.2)	(13.0)	(4.4)	Poor but improving	Abundance low with some improvement
(Aleutians)	(19.5)	(2.1)	(1.8)	Poor but improving	
Pacific ocean perch	121.4	12-17	12.2		
(Eastern Bering Sea)	(13.6)	--	(1.4)	Poor	Abundance low and stable
(Aleutians)	(107.8)	--	(10.8)	Poor	Abundance low and stable
Other rockfish	63.3	30-60	14.1		
(Eastern Bering Sea)	(11.2)	(7-15)	(3.1)	Fair	Unknown
(Aleutians)	(52.1)	(23-45)	(11.0)	Fair	Unknown
Atka mackerel	182.8	23-28	26	Good	Abundance above average and stable
Squid	-	>10	10	--	Unknown
Other species	532	61	61	Good	Abundance average and stable
TOTAL GROUNDFISH	17,162	2,085-2,212	2,248		

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WALLEYE POLLOCK

by

Richard G. Bakkala and Jimmie J. Traynor

INTRODUCTION

The walleye pollock, *Theragra chalcogramma*, resource in the eastern Bering Sea supports the largest single-species fishery in the northeast Pacific Ocean. Walleye pollock became a highly sought-after species when mechanized processing of minced meat was successfully implemented on Japanese commercial vessels in the mid-1960s. As a result, walleye 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 have increased to range from 956,000 to 974,000 t in 1980-82. An additional 55,500-58,200 t were taken annually in this latter period in the Aleutian Islands region (Table 2). Figure 1 shows the locations of International North Pacific Fisheries Commission (INPFC) statistical areas 1 to 5, which is the study area.

Japanese fisheries have usually accounted for over 80% of total catches. since 1970. Most of the remaining catch was taken by the U.S.S.R. until 1978, but in more recent years catches by the Republic of Korea (R.O.K.) have been the second largest, reaching 150,500 t in 1982. Catches by joint-venture operations between U.S. fishing vessels and processing vessels from Japan, Poland, R.O.K., Federal Republic of Germany (F.R.G.), and the U.S.S.R. have also increased, reaching 52,600 t in 1982.

Table 1.--Annual catches of walleye pollock in metric tons (t) in the eastern Bering Sea in International North Pacific Fisheries Commission statistical areas 1 and 2 (see Fig. 1).[a]

Year	Japan	U.S.S.R.	R.O.K.[b]	Taiwan	Poland	F.R.G.[c]	Joint ventures[d]	Total
	----------	----------	----------	t	----------	----------	----------	----------
1964	174,792							174,792
1965	230,551							230,551
1966	261,678							261,678
1967	550,362							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
1982	746,972		150,525	4,220		1,625	52,622	955,964

[a]Catch data for 1964-79 as reported by fishing nation (except 1967-76 R.O.K. catches which were based on U.S. surveillance reports) and for 1980-82 from U.S. observer estimates as reported by French et al. 1981, 1982; Nelson et al. 1983.

[b]Republic of Korea.

[c]Federal Republic of Germany.

[d]Joint ventures between U.S. fishing vessels and R.O.K., Japanese, Polish, F.R.G., and U.S.S.R. processors.

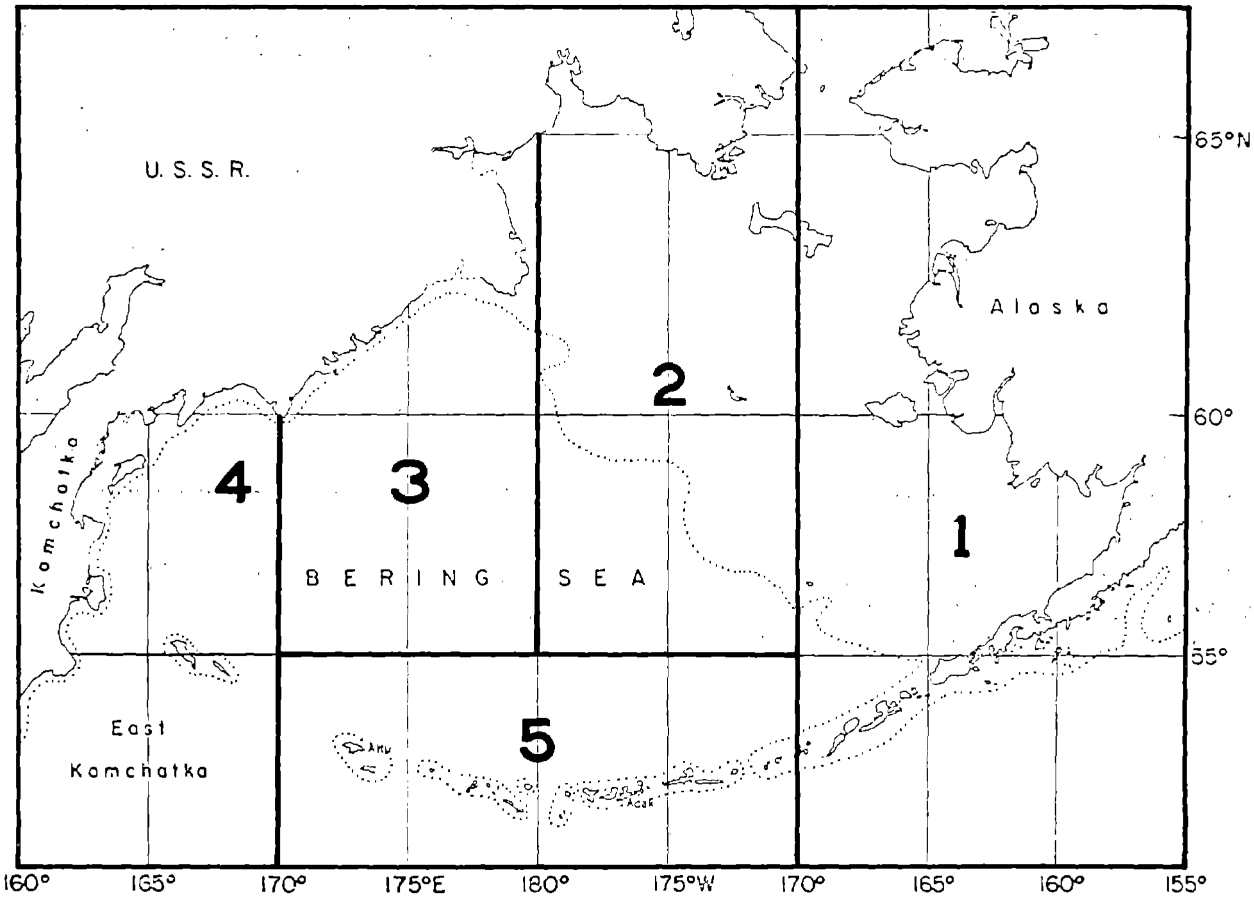

Figure 1.--Bering Sea and Aleutian Islands region showing location of International North Pacific Fisheries Commission statistical areas 1 to 5.

Table 2.--Annual catches of walleye pollock in metric tons (t) in the International North Pacific Fisheries Commission Aleutian Islands statistical area 5 (see Fig. 1).[a]

Year	Nation						Total
	Japan	U.S.S.R.	R.O.K.	Poland	Joint Ventures	Others[b]	
	t						
1977	5,667	1,618	325			15	7,625
1978	5,025	1,193	64				6,282
1979	8,047	1,412	45				9,504
1980	46,052	1	6,256	5,806		41	58,156
1981	37,980		11,074	5,593		869	55,516
1982	33,160		8,112	0	1,983	14,499	55,754

[a]Catch data for 1977-79 as reported by fishing nations and for 1980-82 from French et al. 1981, 1982; Nelson et al. 1983.
[b]Federal Republic Of Germany and Taiwan.

CONDITION OF STOCKS

Relative Abundance

Four procedures, described by Low et al. (1977), have been used to examine trends in abundance of walleye pollock as indicated by catch per unit of effort (CPUE) (Table 3). Results obtained with the INPFC workshop procedure, which are representative of trends obtained from other procedures, indicated abundance declined rapidly from 1972 to 1975 and then generally stabilized at the reduced level through 1982, with a relatively small increase in 1979.

Trends in CPUE from large-scale Northwest and Alaska Fisheries Center (NWAFC) trawl surveys (Fig. 2) have been more variable than those from the fishery (Table 3). For example, the sharp decline in abundance indicated by survey data in 1980 was more severe than the decline shown by fishery data, and a large increase in abundance was indicated by the 1983 survey data. The sharp decline in abundance indicated by survey data in 1980 apparently overestimated the severity of the decline which may have been more accurately reflected by fishery data. The 1983 survey data indicate a major increase in abundance which is believed to represent an extraordinary availability of large pollock to the demersal survey trawls rather than an actual increase in abundance of the overall population.

Analysis of survey and fishery data last year (Bakkala and Wespestad 1983) led to the conclusion that the abundance of pollock remained stable through 1982, but that the 1979, 1980, and 1981 year-classes were below average strength which was anticipated to lead to a possible decline in abundance in 1983 and immediate future years. An increase in abundance from the 1983 survey data was therefore not anticipated. Figure 3 illustrates the much higher catch rates observed during the 1983 survey than during the 1982 survey. Catch rates were particularly high in the northern and southeastern portions of the

Table 3.--Relative indices of walleye pollock stock abundance in the eastern Bering Sea, 1964-83 (Doc. 2697).

	Japanese pair trawl data			
Year	U.S. method[a] (t/1,000s of horsepower hours)	Japanese method[b] (t/h)	INPFC[c] workshop method[d] (% 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	13.7	166	--
1974	10.4	10.4	118	--
1975	9.3	9.8	100	66.0
1976	9.4	9.8	103	--
1977	8.6	9.2	98	--
1978	9.4	9.7	105	--
1979	9.4	9.8	110	63.5
1980	6.7	9.3	88	32.2
1981	8.4	9.6	88	57.6
1982	--	10.9	92	58.7
1983	--	--	--	133.0

[a]Alton and Fredin (1974).
[b]Okada et al. (1982).
[c]International North Pacific Fisheries Commission.
[d]Low and Ikeda (1980).

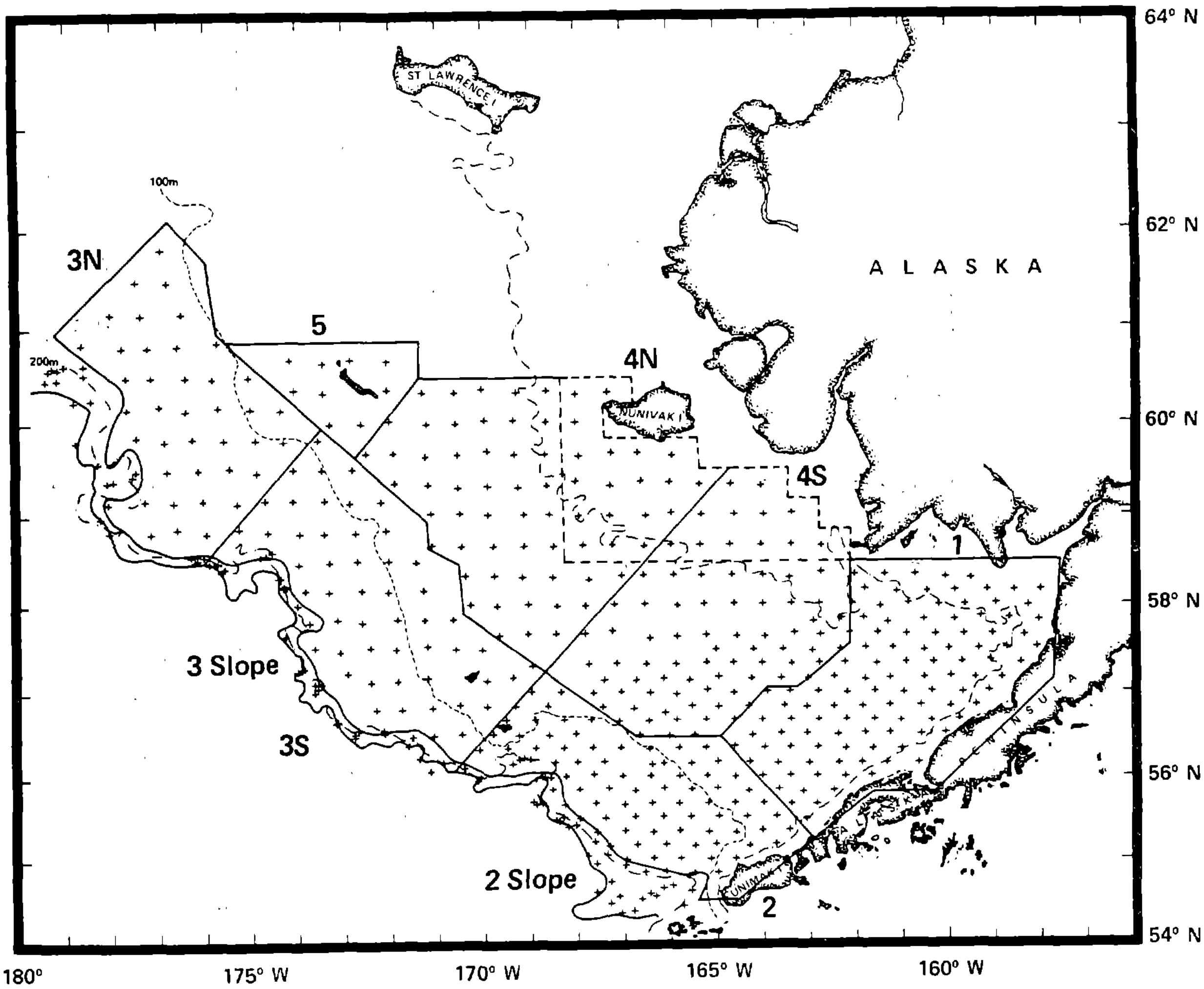

Figure 2 .--Area of the eastern Bering Sea generally sampled during large-scale surveys by the Northwest and Alaska Fisheries Center in 1975 and 1979-82. Survey subareas are delineated by the solid lines and subarea numbers are shown adjacent to the subareas. Area within the dashed lines in the vicinity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

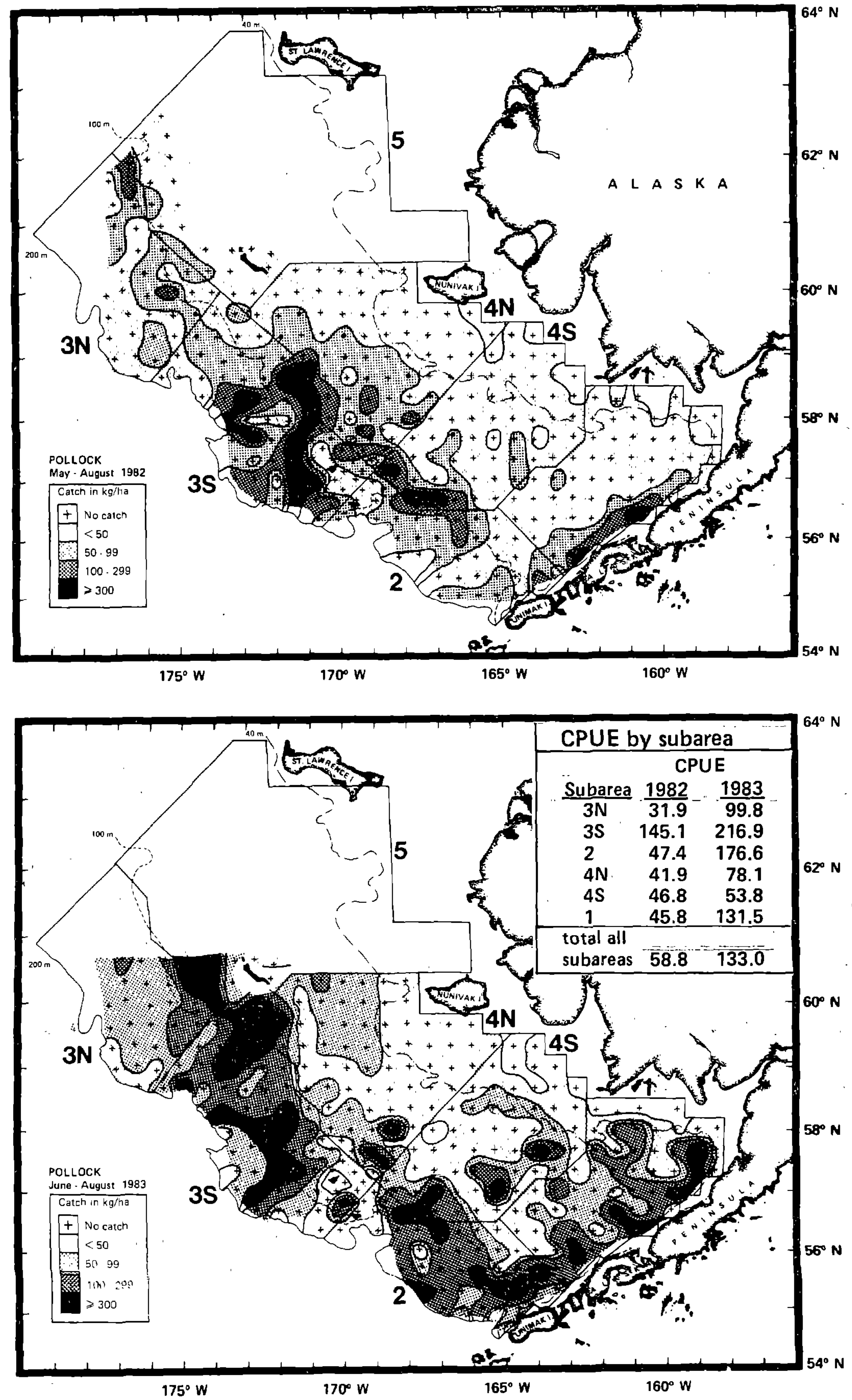

Figure 3. --Distribution and relative abundance of walleye pollock in the eastern Bering Sea in 1982 and 1983 as shown by Northwest and Alaska Fisheries Center demersal trawl surveys.

survey area in 1983 compared to 1982. By individual subarea, mean CPUE values ranged from 1.3 to 4.0 times higher in 1983 than 1982 and for the overall survey area 2.3 times higher.

An additional source of data for examining the condition of the pollock stock are the surveys by Japanese Danish seiners. These surveys may be particularly valuable because they cover a large portion of the eastern Bering Sea continental shelf in the relatively short period of about 2 weeks. Yamaguchi (1983) has summarized results from these surveys as follows:

Year	1976	1977	1978	1979	1980	1981	1982
CPUE (t/haul)	4.2	3.6	3.2	2.8	4.2	3.0	2.5

These data show relative high CPUE values of 4.2 t/haul in 1976 and 1980 with a decline following 1980 to a low value of 2.5 t/haul in 1982.

Biomass Estimates from Research Vessel Surveys

In 1982, a second combined hydroacoustic-demersal and midwater trawl survey was conducted in the eastern Bering Sea to sample the overall pollock population. Unlike the 1979 survey, when the hydroacoustic survey only covered a portion of the outer continental shelf and slope area (100-500 m), the 1982 hydroacoustic survey covered the entire eastern Bering Sea shelf and slope from 37 to 500 m and northward to approximately 60°N, similar in area to that covered by the 1982 demersal trawl survey. For the first time in 1982, age 0 pollock (1982 year-class) were surveyed. Almost all of the juvenile and adult pollock (>age 0) were observed in the outer shelf area (>100 m), while almost all age 0 pollock observed were inside the 100 m isobath.

Estimated population numbers from the combined demersal trawl-hydroacoustic surveys were reduced from levels observed in 1979 (Table 4). Most of the reduction was due to a substantial decrease in the abundance of age 1 and 2

Table 4.--Population number (billions) estimates of walleye pollock derived from demersal and hydroacoustic midwater trawl surveys in the eastern Bering Sea, 1979 and 1982.

Age (yr)	1979 Midwater	1979 Demersal	1979 Total	1982 Midwater	1982 Demersal	1982 Total
1	69.11	7.75	76.86	0.10	0.91	1.01
2	41.13	5.76	46.89	3.40	2.16	5.56
3	3.88	2.39	6.27	4.10	2.24	6.34
4	0.41	1.19	1.60	7.67	2.95	10.62
5	0.53	0.78	1.31	1.86	1.04	2.90
6+	0.35	0.88	1.23	0.80	0.41	1.21
Total	115.41	18.75	134.16	17.93	9.71	27.64

fish. The population estimates for age 1 and 2 pollock (1980 and 1981 year-classes) were 1.0 and 5.6 billion, respectively, in 1982, compared to values of 76.9 billion for age 1 (1978 year-class) and 46.9 billion for age 2 fish (1977 year-class) in 1979. The extremely low values from the 1982 data indicate an almost complete failure of the 1981 year-class and low abundance of the 1980 year-class. The abundance of older fish (>age 2) was higher than that observed in 1979, particularly for age 4 (1978 year-class) and age 5 (1977 year-class) fish.

Total biomass estimated in 1979 was 11.1 million t (7.5 million t-in mid-water; 3.6 million t demersal). In 1982, the demersal estimate was 2.9 million t and the pelagic estimate 4.9 million t for a total estimate of 7.8 million t. In 1979; 86.0% by number (67.6% by weight) of the population occupied midwater whereas, in 1982, 64.9% by number (63.7% by weight) were observed in midwater.

The initial sampling of age 0 pollock indicated that highest densities occurred in the inner shelf region based on catches in a broad scattering layer using a small midwater trawl equipped with a codend liner small enough (9.5 mm stretched mesh) to retain the 30-100 mm age 0 pollock. The layer occurred, over most of the inner shelf area (55,400 nmi^2) between bottom depths of 35 and 91 m and averaged about 40 m in thickness. Only minor quantities of age 0 pollock were observed over bottom depths greater than 100 m. Catches within the layer were composed primarily of jellyfish and age 0 fish.

A very rough estimate of the number of age 0 pollock in the survey area was made using the catch rates from the small midwater trawl. Areal density (D) assuming 100% trawl efficiency and that the vertical-path of the trawl sampled the entire layer, was calculated for each trawl haul as:

$$D = N/wd, \text{ where}$$

N = number of age 0 pollock captured, w = width of the trawl (61.1 m), and d = distance fished. The average areal density estimated in the inner shelf area was 1.94 million fish/nmi^2, resulting in an abundance estimate of 108 billion age 0 pollock. Assuming age 0 pollock were distributed throughout the layer, the estimate would be conservative since the vertical extent of the layer was usually several times larger that the vertical mouth opening of the trawl. Trawl efficiency was almost certainly less than 100% which would also result in a conservative estimate. A compensating bias may have resulted from a tendency during the survey to trawl in high density areas. However,, it is felt that the abundance of age 0 pollock was several times larger than estimated by the above procedure. The magnitude of the scattering layer suggested that the 1982 year-class may be large. Since this is the first survey of age 0 pollock in the eastern Bering Sea and comparative data is not available, it is difficult to judge the relative abundance of the 1982 year-class. However, as will be discussed later, results of the 1983 demersal survey indicate that the abundance of the 1982 year-class is the largest since the 1978 year-class.

Mean biomass estimates from all large-scale demersal trawl and hydro-acoustic surveys that have sampled the major part of the eastern Bering Sea since 1975 have been 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[a]
	U.S. hydroacoustic	7,458,000
1980	U.S. demersal trawl	1,509,000
1981	U.S.-Japan demersal trawl	2,768,500[a]
1982	U.S.-Japan demersal trawl	2,869,000
	U.S. hydroacoustic	4,900,700
1983	U.S. demersal trawl	6,050,588

[a]1979 and 1981-82 values include estimates from the continental slope while estimates from demersal trawl data in other years are from the continental shelf region only.

The biomass estimate from the 1983 demersal trawl survey was 6.1 million t which was lower than the combined demersal trawl-hydroacoustic estimate in 1982 but far exceeds any of the previous estimates based solely on demersal trawl data. As will be shown in the following section, the reason for this high estimate was the high abundance of large fish in the population.

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 Fig. 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 for most years with age 3 fish often predominating, and ages 2 and 4 also contributing substantially to catches. Research vessel catches have consisted primarily of age groups 1-4.

The 1980-82 survey data indicated that recruitment of the 1979, 1980, and 1981 year-classes at age 1 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 and 1982 according to U.S. observer data (Fig. 4). Catches of the 1980 year-class were also low in the 1982 fishery and the age composition of 1982

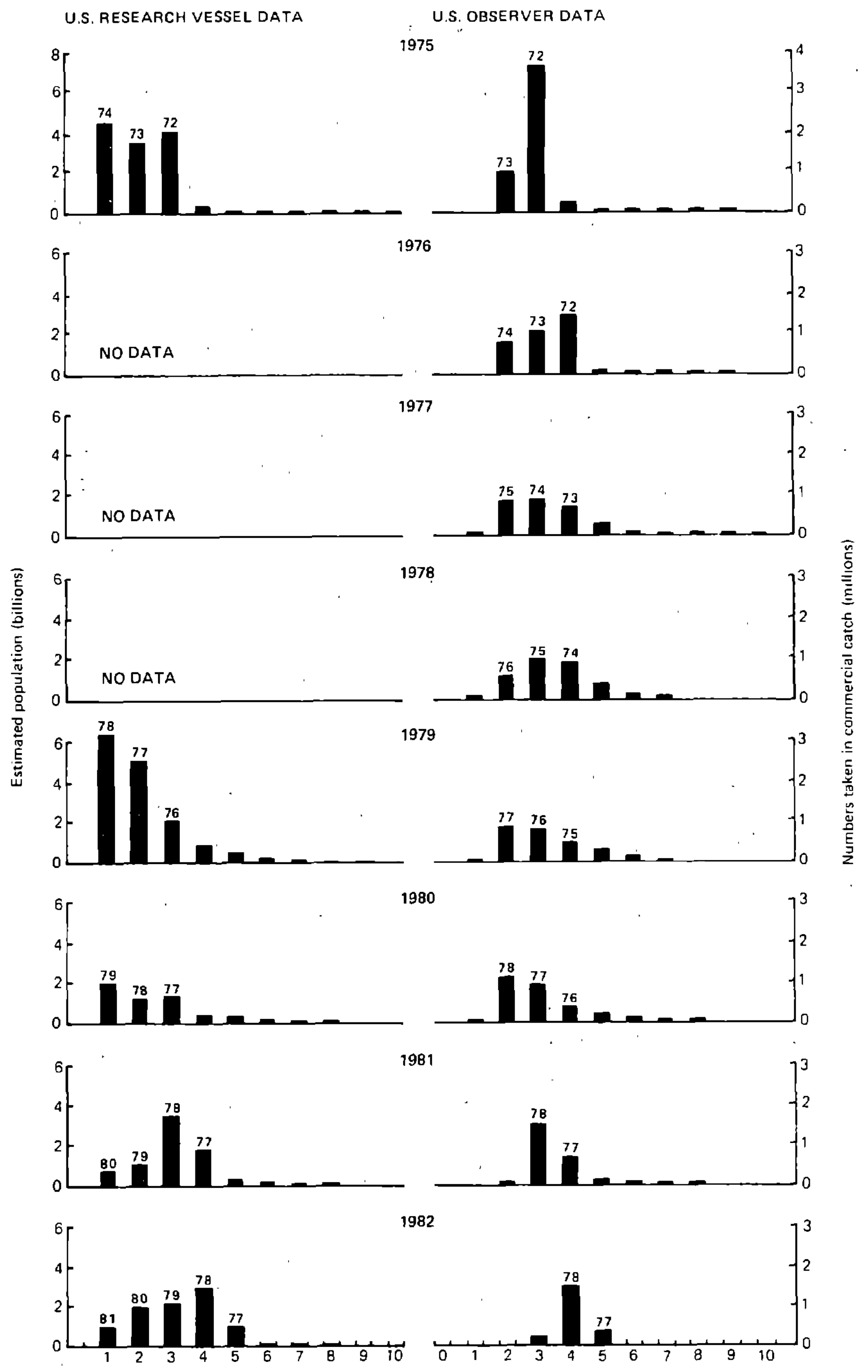

Figure 4. --Age composition of walleye pollock in the eastern Bering Sea as shown by data from. Northwest and Alaska Fisheries Center research vessel surveys and by data collected in the commercial fishery by U.S. observers. Numbers above the bars indicate the principal year-classes.

commercial catches was unusual in that age 4 pollock predominated and made up a large proportion of the catch. Age 4 pollock of the 1978 year-class also predominated in the survey catches.

Length-frequency data from samples obtained during demersal trawl surveys in 1979 and 1981-83 were used to further examine recruitment of age 1 fish and the abundance of older age groups through 1983 (Fig. 5). As evidenced by the population numbers between 10 and 20 cm which principally represent age 1 fish, the abundance of age 1 pollock was low in 1981 (the 1980 year-class) and 1982 (the 1981 year-class) relative to the abundance of this age group in 1979 (the 1978 year-class). The 1979 year-class, also does not appear to be abundant based on the low population numbers observed between 22 and 24 cm in 1981 compared to those observed at that length in 1979 and, as pointed out earlier, from catches of this year-class in the commercial fishery. Thus, the abundance of three consecutive year-classes (the 1979-81 year-classes) may be below average strength. The low abundance of these year-classes accounts for the unusual age distribution in survey and commercial catches in recent years (Fig. 4) and the unusual size composition observed from 1983 survey data (Fig. 5).

The 1983 size composition data suggest that the abundance of age 1 fish in 1983 was higher than it was in 1981 and 1982, but not as high as it was in 1979. Population estimates of age 1 pollock based on age analyses (Fig. 4) were 8.7 billion in 1979, 1.0 billion in 1981, 0.9 billion in 1982, and based on population numbers of pollock under 20 cm, 3.5 billion in 1983. Thus, the 1982 year-class should provide better recruitment to the fishery than the three previous year-classes.

The low abundance of the 1980 and 1981 year-classes in the population is reflected by the low population numbers between about 20 and 35 cm in the 1983

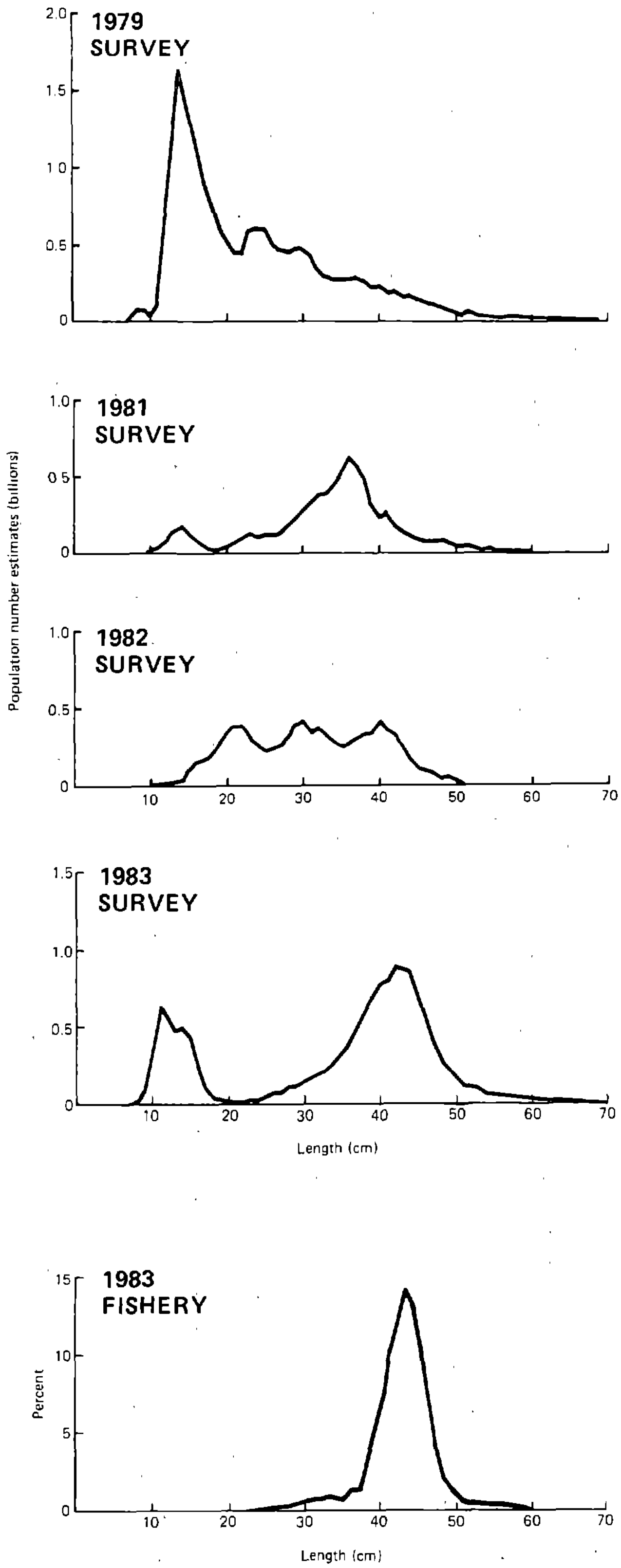

Figure 5.--Population estimates of walleye pollock by centimeter size interval, as shown by Northwest and Alaska Fisheries Center demersal trawl data from the continental shelf of the eastern Bering Sea in 1979-83 and size composition of pollock taken by the commercial fishery during May-August 1983.

size composition data. The large mode with a peak at 42 cm in the 1983 size composition is believed to mainly represent age 5 pollock of the 1978 year-class. The unusually large numbers of these relatively old fish is the primary reason for the substantial increase in abundance of pollock in the 1983 survey catches. Pollock over 30 cm accounted for almost 4.7 million t of the total biomass estimate of 6.1 million t. They were also the main component of catches in the commercial fishery during May-August 1983 (Fig. 5).

Based on these survey data, the pollock population in 1983 was extraordinary and exhibited a number of characteristics that have not previously been observed. One of these was the very low population numbers between about 20 and 35 cm resulting from the poor recruitment of recent year-classes. Further, there is the dominance of large fish in the population which appear to mainly represent age 5 pollock of the 1978 year-class (the average length of age 5 pollock have ranged from 41.0 to 44.6 cm). The fact that large numbers of this year-class still remain in the population seems remarkable, and the extraordinary high abundance of this year-class was not evident from survey data in 1980-82. In contrast, the previous, inordinately large 1972 year-class did not appear to produce large numbers of old fish. The age composition of commercial catches indicates that the abundance of the 1972 year-class was reduced to low levels after age 4 (Fig. 4). Finally, the high availability of pollock to the demersal trawls during the 1983 survey is unusual. Reasons for the availability of large numbers of older pollock to the survey trawls in 1983 are not now apparent, but raise the question of whether the resident population on the eastern Bering Sea shelf was supplemented by immigration of fish from other areas such as the Aleutian Basin.

MAXIMUM SUSTAINABLE YIELD

Maximum sustainable yield (MSY) for walleye pollock in the eastern Bering Sea 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 (1978), 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 to 1.9 million t, CPUE stabilized in 1976-81 when catches ranged from 0.9 to 1.2 million t. The continued stability of CPUE estimates through 1982 (Table 3) indicates that abundance remained at much the same level as in earlier years. This suggests that catches in the range of 0.9-1.2 million t have been close to an equilibrium yield (EY) since 1975.

However, abundance estimates from combined demersal trawl-hydroacoustic surveys indicate that the overall biomass of pollock declined from 11.0 million t in 1979 to 7.8 million t in 1982. This decline can be attributed to the low recruitment of the 1979-81 year-classes. Based on combined hydroacoustic-demersal trawl survey data, these year-classes at ages 1-3 contributed only about 1.6 million t to the overall biomass in 1982 compared to 8.3 million t contributed by the 1976-78 year-classes at age 1-3 in 1979. CPUE values from the fishery have not reflected this decline because the 1979-81 year-classes had only partially recruited to the fishery in 1982 and the abundance of age 4 and older pollock was higher in 1982 than 1979 according to the hydroacoustic-demersal trawl data. The age 4 and older pollock contributed about 2.3 million t to the 1979 estimate but 3.6 million t to the 1982 estimate.

The biomass estimate from the demersal trawl survey alone in 1983 was 6.1 million t, almost all of which consisted of large pollock greater than 35 cm. An examination of echogram records taken at demersal trawl stations revealed no apparent major reduction in the abundance of pollock occupying the water column above that sampled by the demersal trawls. Thus, the overall biomass of pollock in 1983 is believed to be at least as high as 7.8 million t and possibly higher. Considering that a large part of this biomass consists of relatively large pollock and that the improved recruitment of age 1 pollock in 1983 will add to the exploitable stock in 1984, it is projected that EY will be maintained at 1.2 million t in the eastern Bering Sea and 100,000 t in the Aleutian Islands region. An EY of 1.2 million t represents an exploitation rate of 15% based on the conservatively approximated biomass of 7.8 million t in 1983.

If the large population of older pollock is not available in the eastern Bering Sea in 1984 because of migration out of the area. or other reasons and the population is primarily supported by the weak 1979-81 year-classes, some in-season assessment of EY may be required in 1984.

PACIFIC COD

by

Richard G. Bakkala and Vidar G. Wespestad

INTRODUCTION

Pacific cod, *Gadus macrocephalus,* are distributed widely over the Bering Sea continental shelf and slope and have a distributional pattern similar to that of walleye pollock, *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 joint venture fisheries, involving U.S. catcher boats delivering catches to processing vessels from other nations, began operations in the eastern Bering Sea and Aleutian Islands areas, with catches of 13,700 t in 1980 increasing to 38,400 t in 1982.

Annual catches of Pacific cod by all nations in the eastern Bering Sea and Aleutians increased from 13,600 t in 1964 to 70,400 t in 1970; since then, catches have varied between 36,600 and 66,600 t (Table 1). Catches in 1980-82 increased markedly from the level of the previous 3 yr, primarily because of catches by the U.S. joint-venture and domestic fisheries. Catches by these U.S. fisheries exceeded those by fisheries from other nations for the first time in 1982.

Table 1 .--Commercial catches (t) of Pacific cod by area and nation, 1964-82.[a]

	Eastern Bering Sea							Aleutian Islands Area							E. Bering Sea and Aleutian
Year	Japan	U.S.S.R.	R.O.K.[b]	Other nations[c]	Joint ventures[d]	U.S[e]	Total	Japan	U.S.S.R.	R.O.K.	Other nations	Joint ventures	U.S.	Total	Comb. Total
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		15	33,335	3,162	100	-				3,262	36,597
1978	41,234	419	859	-		31	42,543	3,165	120	6			4	3,295	45,838
1979	28,532	1,956	2,446	47		780	33,761	5,171	414	6			2	5,593	39,354
1980	27,334	7	6,346	1,371	8,370	2,433	45,861	2,834	4	58	9	86	2,797	5,788	51,649
1981	27,570	-	6,147	2,481	7,410	8,388	51,996	2,426	-	476	12	1,749	5,799	10,462	62,458
1982	17,380		8,151	647	9,312	19,550	55,040	1,730		259	7	4,280	5,250	11,526	66,566

[a]Catch data for 1964-79 as reported by fishing nations and for 1980-82 from French et al. 1981, 1982; Nelson et al. 1983.
[b]Republic of Korea.
[c]Taiwan, Poland, and Federal Republic of Germany.
[d]Joint ventures between U.S.-R.O.K. and U.S.-U.S.S.R.
[e]U.S. vessels delivering catches to domestic processors.

CONDITION OF STOCKS

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 six-fold between 1976 and 1979 (Fig. 1) based on NWAFC research survey data in a comparative fishing area in the southeast Bering Sea (Fig. 2). Based on data from large-scale surveys that have sampled major portions of the eastern Bering Sea (see Fig. 2 in the section on walleye pollock in this report), 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. Survey data since 1979 show some additional increases with the value in the large-scale survey area reaching 24.8 kg/ha in 1983.

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), because cod are a nontarget species in these fisheries. Data from the Japanese longline fishery, which targets on Pacific cod at times, may be more representative of stock abundance. Figure 1 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 but decreased moderately to 2.6 t/100 hachi in 1982. An increase in the Aleutians was not evident until 1981, and the CPUE continued to increase in this region through 1982. Survey data in 1978

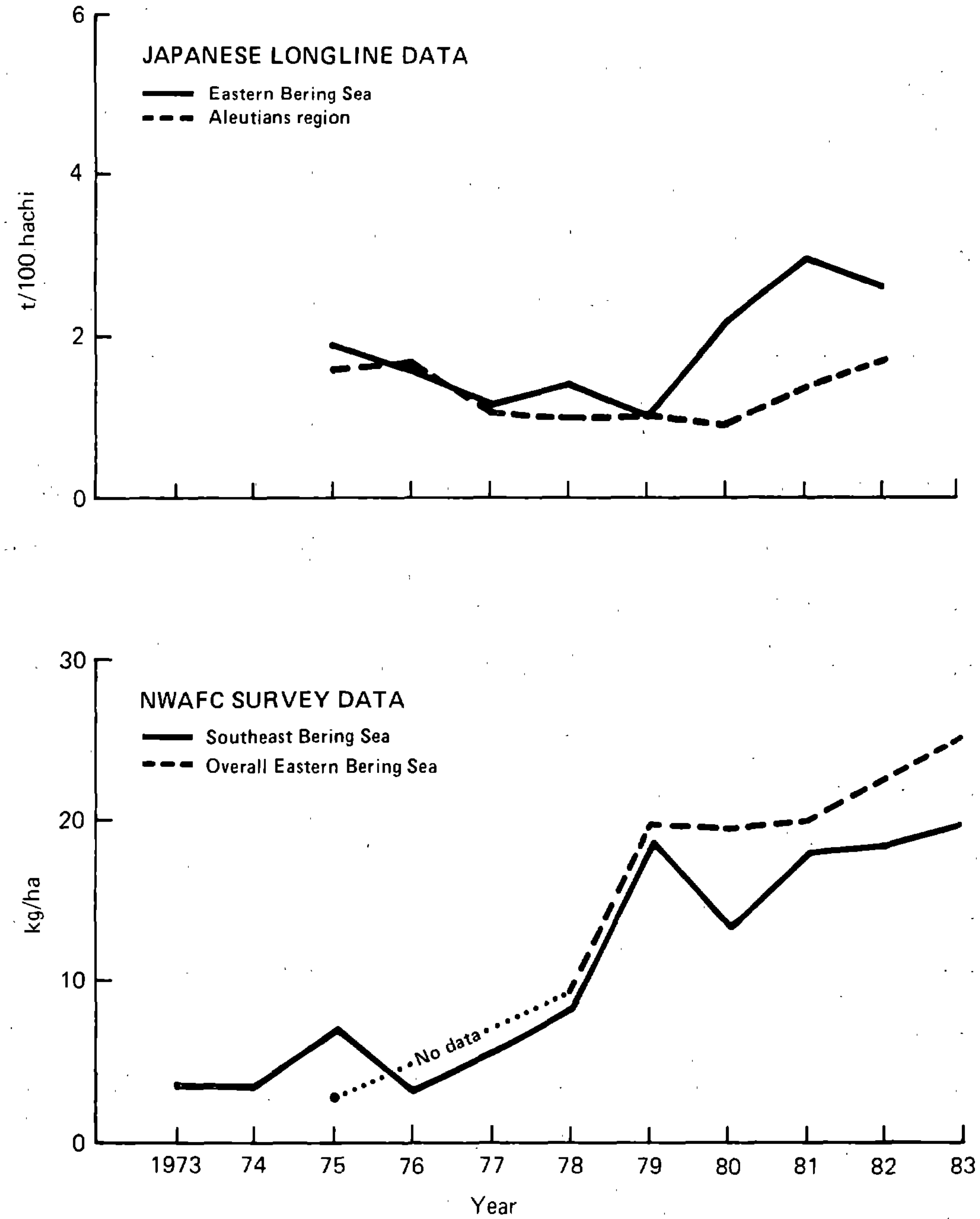

Figure 1. --Relative abundance of Pacific cod as shown by Japanese longline fishery data in the eastern Bering Sea and Aleutian Islands area and by data from Northwest and Alaska Fisheries Center (NWAFC) surveys in the eastern Bering Sea (a hachi is a unit of longline gear 100 m long).

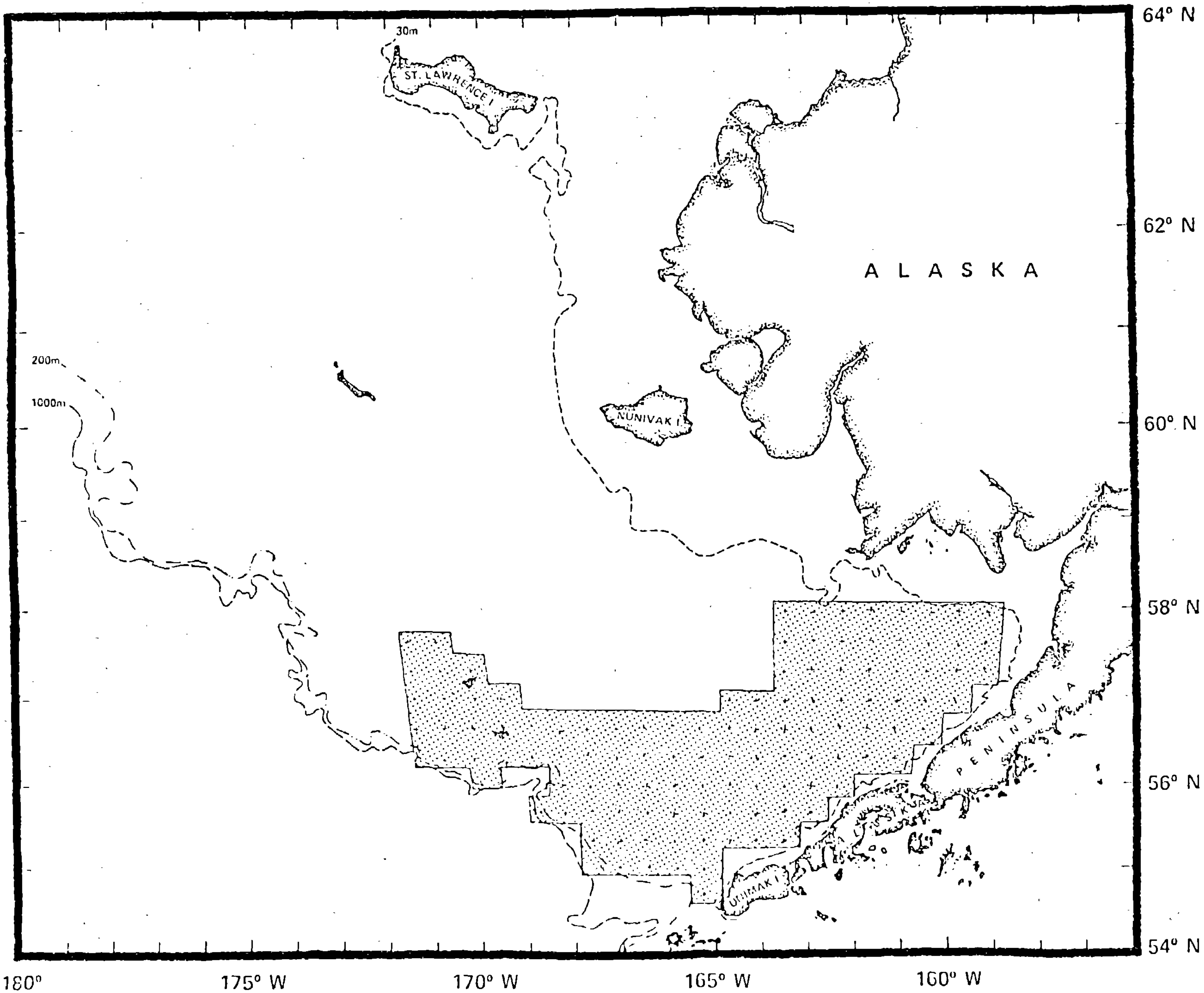

Figure 2.--Comparative fishing area sampled annually during Northwest and Alaska Fisheries Center demersal trawl surveys in 1973-83.

showed the increase in abundance of cod earlier 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
1983	1,126,400	904,000 - 1,348,800

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 1982 and 1983 estimates were higher than the 1980 and 1981 values, The 95% confidence intervals in these latter 3 yr overlapped, however, indicating that these estimates were not significantly different.

Two biomass estimates have been calculated for the Aleutian Islands region, one based on data from a summer 1980 cooperative U.S.-Japan survey of the overall Aleutians and the other on a U.S. winter survey in the eastern Aleutians (Bakkala et al. 1983). The estimates were 231,100 t from the 1980 summer survey and 282,300 t from the 1982 winter survey. The winter survey estimate from the eastern Aleutians exceeds that from the 1980 summer 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 (Fig. 3). In 1982 and 1983, this year-class no longer formed a prominent mode in the overall size distribution of the population but its contribution was still apparent from the relatively large numbers of fish greater than 50-60 cm in 1982 and 1983 compared to earlier years. Also of interest was the evidence of moderately good recruitment of age 1 cod in 1983. Population numbers of this age group (those fish less than about 20 cm) appear to be higher than any year except 1978 when the large 1977 year-class recruited to the survey area.

The size compositions of cod in the Aleutian region as shown by the summer 1980 and winter 1982 surveys are illustrated in Figure 4. The 1980 distribution was predominantly fish with a modal length at 47 cm. A second smaller mode was observed at 69 cm. The mode at 47 cm represents age 3 fish of the 1977 year-class based on the mean length of age 3 cod during the 1982 Aleutian survey (Table 2). 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 (>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 (Fig. 4). This mode primarily represented fish of the 1977 year-class (Table 2).

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

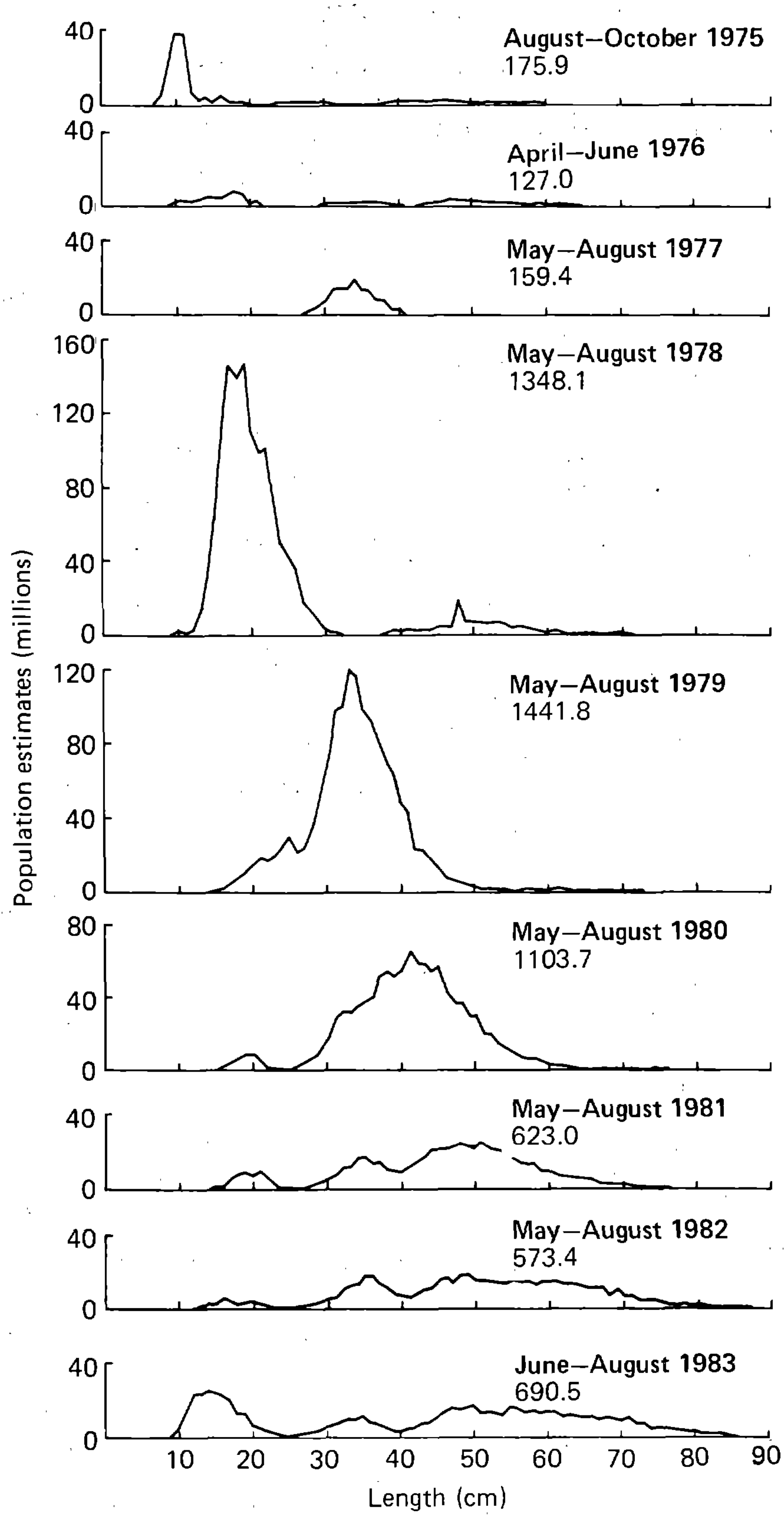

Figure 3.--Population estimates of Pacific cod by centimeter length interval in the eastern Bering Sea as shown by annual Northwest and Alaska Fisheries Center demersal trawl surveys in 1975-83. Numbers below dates are estimated population numbers within the survey areas.

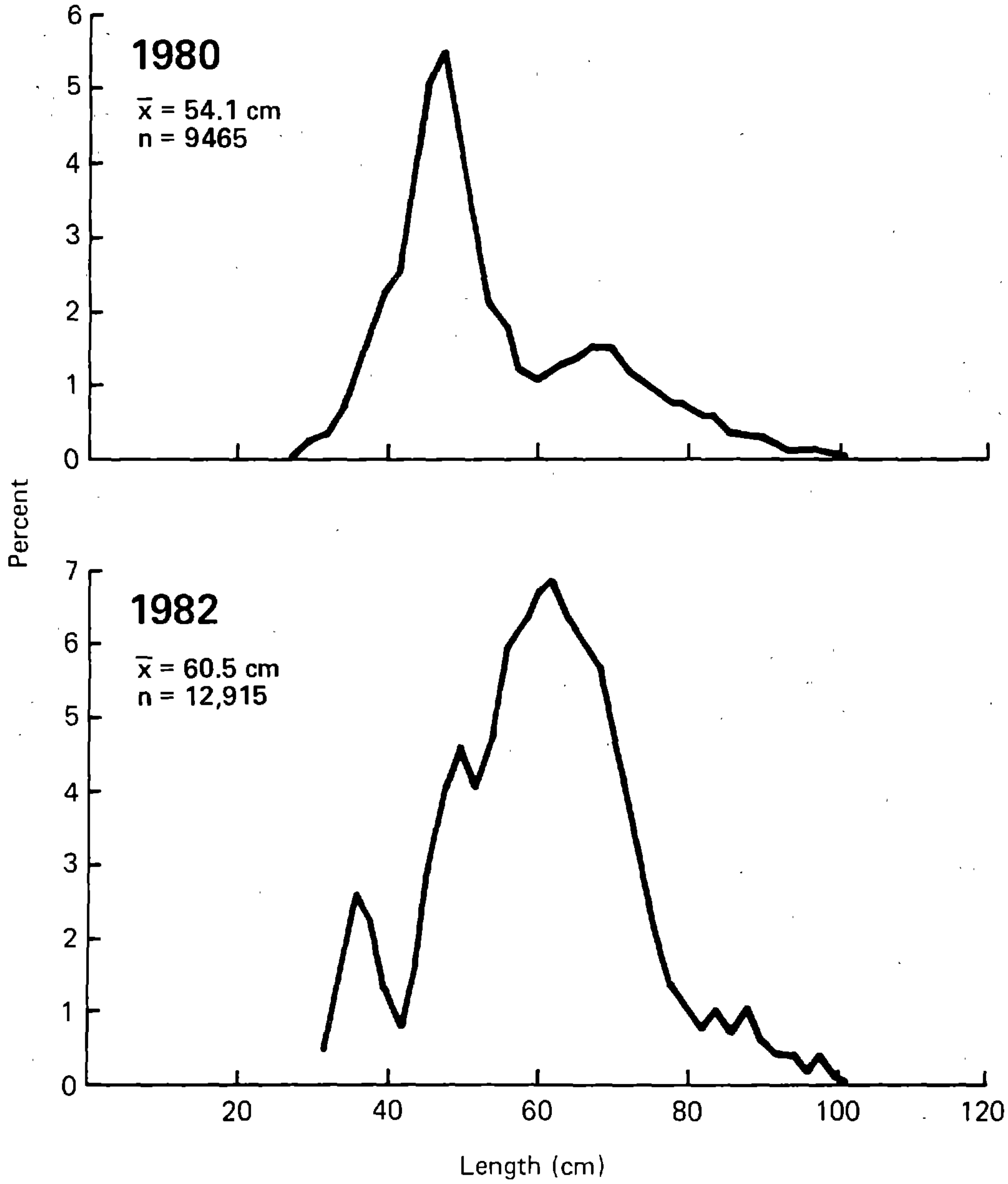

Figure 4.--Length-frequency distributions of Pacific cod sampled throughout the Aleutian Islands region during July-August 1980 and in the eastern Aleutian Islands during February-March 1982. Numbers of fish measured are given below mean lengths.

Table 2.--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	

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 2 and 3). The modal analysis may notaccurately separate population numbers to age groups, 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 3), 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 survey in the Aleutian Islands Region have been aged using the length-frequency modal analysis, but samples from the summer 1980 Aleutian survey have not been analyzed. Examination of the winter survey data indicates that cod sampled in the Unimak Pass to Atka Island-area in February and March 1982 consisted of age groups 2-11 yr (Table 2). The 1977 year-class at age 5 predominated--representing an estimated 36.7% of the total population numbers. Older age groups (6-11 yr) 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 3).

PROJECTIONS OF ABUNDANCE

Abundance of eastern Bering Sea cod was projected through 1986 by Bakkala et al. (1983) using a numeric population simulator and 1982 survey population estimates as base year data, 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).

Table 3.--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[a]	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	6.3	2.1	22.1
8	0.3	2.8	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

[a]The 1977 survey was limited to the southeast Bering Sea as shown in Figure 2. 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.

The projections indicated that population numbers of age 2 and older cod in 1983 would be 476.2 million fish with a biomass of 692,900 t. The 1983 survey estimates of ages 2 and older cod were 492.0 million fish with a biomass of 1.1 million t. Thus, the projected population numbers were slightly under-estimated relative to survey data but the biomass was apparently more severely underestimated. One reason for the low projections was that commercial catches in 1983 were much less than the estimated catch of 228,000 t used in the projection. Additionally, it is believed that the natural mortality value of 0.7 used in the projection may be too high.

Because of the discrepancy between abundance estimates from the projections and the -survey, projections were rerun by using 1979 data as base year data, survey estimates of recruitment at age 2, and three levels (0.5, 0.6, and 0.7) of natural mortality. The intent was to find the natural mortality coefficient that most nearly duplicated the annual survey biomass estimates in 1980-83 given the observed levels of recruitment and catch. The natural mortality coefficient which most nearly projected trends in biomass shown by the 1980-83 surveys was also anticipated to provide the most reliable estimates of abundance in 1984-86. Of the three natural mortality coefficients used, 0.5 most nearly duplicated the trends in biomass shown by the survey data (Table 4). The projections indicate that the biomass of age 2 and older cod will be 688,000 t in 1984, 462,000 t in 1985, and 385,000 t in 1986.

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

Table 4.--Forecast of biomass of the Pacific cod population in the eastern Bering Sea in 1980-86 using a natural mortality coefficient of 0.5.

Year	Projected biomass age 2 and above (t)	Projected biomass age 3 and above (t)	Recruitment at age 2[a] (millions)	Catch (t)	Exploitation rate	Fishing mortality
1979	965,600	349,100	1,106	33,800	0.097	0.124
1980	1,271,300	1,024,800	442	45,900	0.045	0.052
1981	1,267,200	1,181,800	153	52,000	0.044	0.051
1982	1,100,300	1,053,800	83	60,000	0.059	0.071
1983	882,000	835,400	83	120,000	0.144	0.193
1984	687,500	581,300	190	232,500	0.400	0.671
1985	462,100	355,900	190	142,400	0.400	0.671
1986	384,700	278,500	190	111,400	0.400	0.671

[a]Recruitment for 1979-83 from survey estimates in those years and for 1984-86 from the average recruitment from survey estimates in 1980-83.

population over a period of low or stable abundance is not available. In addition, survey data for only 1 yr 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.

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 of Bakkala et al. (1983), the allowable catch in the eastern Bering Sea and Aleutian Islands region was estimated to be 298,200 t in 1983.

In view of the 1983 survey results which indicate that the biomass of cod in the eastern Bering Sea remained approximately the same in 1983 as 1982 (about 1 million t) and the revised projections of abundance which fore-cast an exploitable biomass (age 3 and above) of about 581,300 t in 1984, the allowable catch in 1984 is estimated to be higher than previously projected. because a large part of the population biomass consists of large, relatively old fish that should be utilized before they are lost to natural mortality, it is again recommended that an exploitation rate of 0.4 be used to estimate the allowable catch in 1984. This exploitation rate applied to the exploitable biomass of 581,300 t provides an allowable catch of 232,500 t for the eastern Bering Sea region in 1984.

A second U.S.-Japan cooperative survey in the Aleutian Islands region in 1983 will provide an updated abundance estimate for that region in the near future. In the interim, an allowable catch for the Aleutians can be approximated by assuming that the relationship between the total biomass estimate in the Aleutians in 1980 (the only survey estimate available for this region) and the exploitable biomass in 1984 is the same as that of the eastern Bering Sea. The proportion between the 1984 exploitable biomass and 1980 total biomass in the eastern Bering Sea is 581,300 t/913,300 t or 0.636. Applying this proportion to the 1980 estimated biomass in the Aleutians (0.636 x 231,100 t = 146,980 t) and using an exploitation rate of 0.4 produces an allowable catch of 58,800 t (Table 5).

Table 5.--Forecast of biomass of the Pacific cod population in the Aleutian Region for 1984-86 and projected acceptable biological catches.[a]

Year	Projected biomass age 3 and above (t)	Catch (t)	Exploitation rate
1980	231,100		
1984	147,000	58,800	0.4
1985	90,100	36,000	0.4
1986	70,500	28,200	0.4

[a]Northwest and Alaska Fisheries Center, September 1983.

The overall allowable catch for the combined eastern Bering Sea and Aleutian region in 1984 is thus 291,300 t or approximately the same as that estimated for 1983.

Following the same procedure of biomass projection, the expected allowable catches are predicted to be 178,400 t in 1985 and 139,600 t in 1986. These projections, however, will be revised as more data become available.

YELLOWFIN SOLE

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 1960s. 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 1960s reduced the exploitable biomass to a third or less of pre-1960 levels. The resource began to recover in about 1972 and abundance in recent years 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
1978-82	5	87,391 - 138,433	103,571

Catches in 1972-77 were relatively low due primarily to the absence of a directed fishery for yellowfin sole by the U.S.S.R. The U.S.S.R. reentered the yellowfin sole fishery in 1978-79, which in part was the reason for the higher catches in the more recent period of 1978-82. The U.S.S.R. was prohibited from fishing in the U.S. 200-mile fishery conservation zone in 1980-82, although they were allowed to process catches taken by U.S. fishermen in joint- venture operations. As a result of the absence of the U.S.S.R. fishery, overall catches of yellowfin sole declined to 87,400 t in 1980 but increased to 95,700-97,300 t in 1981-82. These recent increases have resulted from generally higher catches by all of the principal fisheries.

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

Year	Japan	U.S.S.R.	R.O.K.[b]	Others	Joint venture	Total
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
1982	68,009		10,277	45	17,381	95,712

[a]Source of catch data: 1954-76, Wakabayashi and Bakkala 1978; 1977-79, data submitted to the United States by fishing nations; 1980-82, French et al. 1981, 1982; Nelson et al. 1983.
[b]Republic of Korea.

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 survey data from Northwest and Alaska Fisheries Center (NWAFC) resource assessment surveys. The pair trawl catch and effort data used are those from 1/2° latitude by 1° longitude 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 shifted 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 been calculated for the September-December and July-October periods. The trends shown by the October-March and September-December data were similar (Table 2; Fig. 1).

The CPUE trend lines from the October-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 (Fig. 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. Since about 1980, both September-December and July-October data have shown decreases in CPUE. The declining abundance shown by the Japanese pair trawl data is not believed to be representative of the actual abundance of the population in view of the results from surveys and a cohort analysis that will be discussed later in this report.

Table 2.--Catch, effort, and catch per unit of effort (CPUE) for yellowfin sole by Japanese pair trawlers in 1/2° lat. by 1° long. 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
	1982	21,993	648	1,400	907	24.25
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
	1982	27,855	1,411	1,400	1,975	14.10

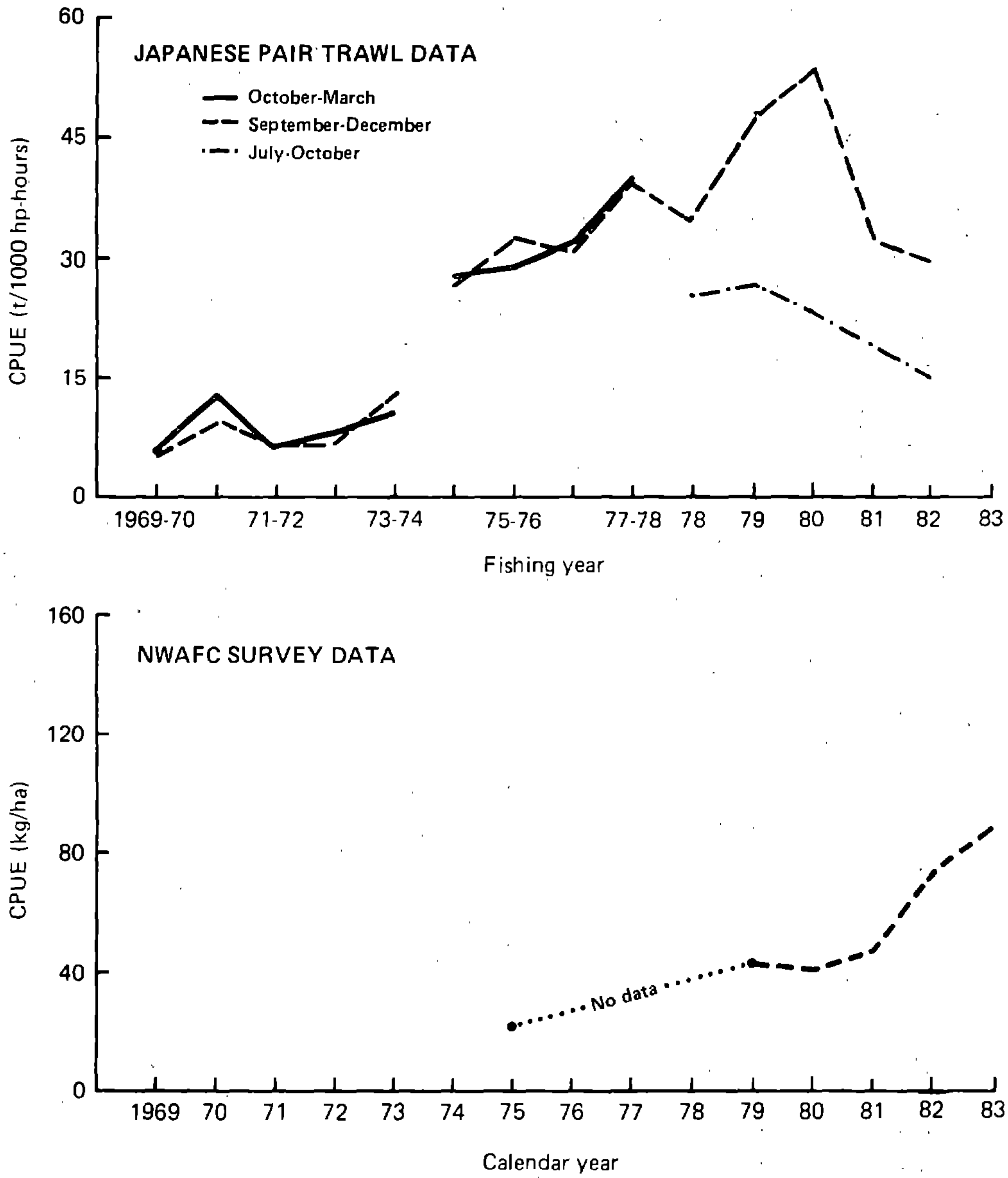

Figure 1.--Relative abundance (catch per unit of effort (CPUE)) of yellowfin sole in the eastern Bering Sea as shown by Japanese pair trawl data and by data from Northwest and Alaska Fisheries Center (NWAFC) demersal trawl surveys. Breaks in trend lines indicate changes in fishing gear or fishing techniques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

The NWAFC survey data have also shown a major increase in abundance of yellowfin sole since 1975 (Fig. 1). CPUE values from these comprehensive surveys showed an approximate doubling of the relative abundance (20-41 kg/ha) from 1975 to 1979. There was an apparent leveling off of abundance in 1980, but CPUE values have shown further substantial increases through 1983.

The increase in CPUE between 1981 and 1982 was extremely large increasing from 48 to 70.3 kg/ha. Abundance estimates from the 1982 survey were considerably higher than those from the 1981 survey for a number of bottom dwelling 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, is 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-ft footrope and 112-ft 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 footrope of the new trawl was in contact with the bottom. 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 (46 m) section branching into two 15 fathom (27 m) bridles for an overall length of 40 fathom (73 m) to two 30 fathom (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 contact with the bottom because substantial amounts of bottom debris were observed in catches.

High CPUE estimates from the survey again in 1983 provide evidence that the new rigging has in fact increased the efficiency of the trawls for bottom tending species such as flatfish. However, the CPUE rose rather markedly again from 70.3 kg/ha in 1982 to 86.5 kg/ha in 1983.

Age Composition

The primary reason for the increased abundance of yellowfin sole since. the early 1970s has been the recruitment of abundant year-classes. Initial increases in abundance were from the strong 1966-70 year-classes which have predominated in research vessel and commercial fishery catches since 1973 (Fig. 2). These year-classes are now relatively old, ranging from 12 to 16 yr in 1982. They still contributed the major share of commercial catches (55%) in 1981, however, and may continue to contribute substantially to the. commercial fishery in the next few years.

A new series of strong year-classes (1973-77) have now entered the population and 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	3,322,518	2,675,900 - 3,970,100
1983	3,951,535	3,459,200 - 4,443,900

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 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 (see Figure 2 in the section on walleye pollock in this report), not surveyed in 1981, accounted for approximately 500,000 t of yellowfin sole in 1982. The 1983 estimate was again substantially higher at 3.95 million t, about 600,000 t more than the 1982 estimate.

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 was 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

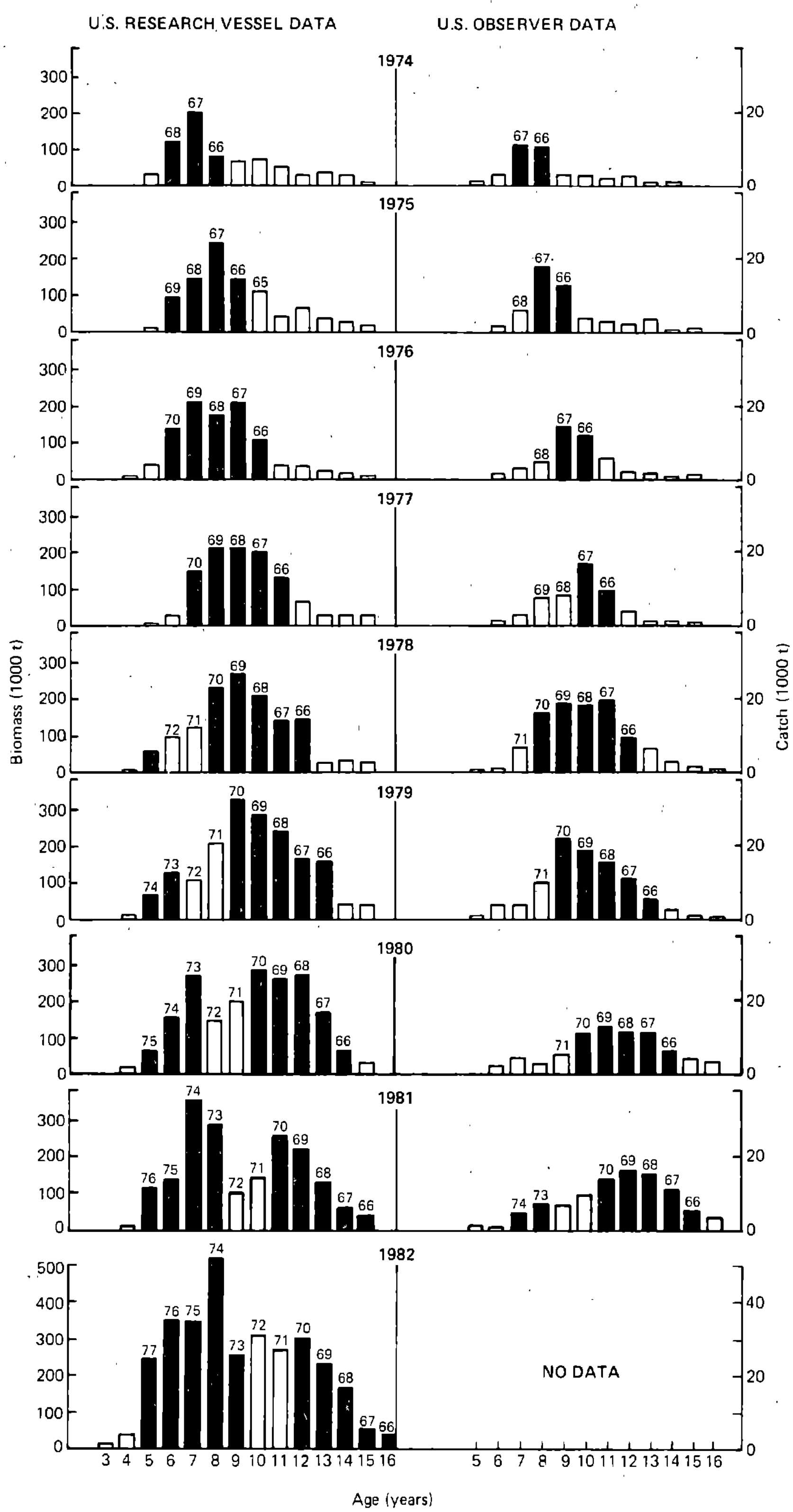

Figure 2.--Age composition of yellowfin sole of the eastern Bering Sea as shown by data from trawl surveys of the Northwest and Alaska Fisheries Center and by U.S. observer data from the commercial fishery. Year-classes for more abundant ages are shown with the appropriate bars, and darkened bars represent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

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 1959-63 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 vessel survey 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

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	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

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 1960s, 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.

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 Fs 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 Fs 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 Fs 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.

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 1973-77. 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.

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 6.--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.

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 section on walleye pollock in this report 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 recruitmentat 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 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 was the midpoint of the estimated maximum sustainable yield (MSY) range for yellowfin sole estimated by 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, 8) or with a constant catch of 214,500 t (Tables 9, 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, 8).

Following 1985, the simulations indicated that population abundance would continue to decline at the given levels. of recruitment. The fishable population could decline to about 1.0 million t or less, if exploitation rates continued to exceed 0.10 after 1985.

MAXIMUM SUSTAINABLE YIELD

Maximum sustainable yield (MSY) for yellowfin sole was estimated to range between 169,000 and 260,000 t with a midpoint 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}[a]	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

[a]F values producing MSY.

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						Mean individual
Year	Ages 7-17 (1,000 t)	Ages 8-17 (1,000 t)	Recruits (millions)	Catch (1,000 t)	E[a]	F[b]	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

[a]E = Exploitation rate for fished population (ages 8-17).
[b]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)	E[a]	F[b]	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

[a]E = Exploitation rate for fished population (ages 8-17).
[b]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						
Year	Ages 7-17 (1,000 t)	Ages 8-17 (1,000 t)	Recruits (millions)	Catch (1,000 t)	E[a]	F[b]	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	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

[a]E = Exploitation rate for fished population (ages 8-17).
[b]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).

Year	Estimated biomass Ages 7-17 (1,000 t)	Estimated biomass Ages 8-17 (1,000 t)	Recruits (millions)	Catch (1,000 t)	E[a]	F[b]	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

[a] E = Exploitation rate for fished population (ages 8-17).
[b] F = Fishing mortality.

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

Evidence from survey data indicates that the yellowfin sole population is in excellent condition. The biomass of the population is extremely high and averaged 3.1 million t during 1981-83. Moreover, the age composition of the population is well balanced with the strong 1966-70 year-classes still providing a major share of commercial catches and a new series of strong year-classes entering the exploitable population.

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 1973-82 has been higher (2.1 billion fish) than the long-term average (1.4 billion) and survey biomass estimates in 1982 and 1983 exceeded projected estimates for these years. Equilibrium yield in 1984 is, therefore, estimated to range well above 200,000 t and assuming a 10% exploitation rate is estimated to be 310,000 t.

GREENLAND TURBOT AND ARROWTOOTH FLOUNDER

by

Terrance M. Sample and Richard G. Bakkala

INTRODUCTION

The turbots, arrowtooth flounder, Atheresthes stomias, and Greenland turbot, Reinhardtius hippoglossoides, are large flatfishes hating 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 arrow-tooth flounder is primarily 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; 1960-82.[a]

	Eastern Bering Sea (east of long. 180°)							Aleutian Island area						E. Bering Sea and Aleutian comb. total
	Japan							Japan						
Year	MS-LG-NPT [b]	LBD [c]	USSR	ROK [d]	Other nations [e]	Joint ventures [f]	Total	MS-LG-NPT	LBD	USSR	ROK	Joint ventures	Total	
Arrowtooth Flounder and Greenland Turbot Combined														
1960	36,843	-	-				36,843	-	-	-			-	36,843
1961	57,348	-	-				57,348	-	-	-			-	57,348
1962	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
1982	-	-	-	-	-	-	49,624	-	-		-	-	6,258	55,882

Table 1.--(Continued).

Year	Eastern Bering Sea (east of long. 180°): Japan MS-LG-NPT[b]	Japan LBD[c]	USSR	ROK[d]	Other nations[e]	Joint ventures[f]	Total	Aleutian Island area: Japan MS-LG-NPT	Japan LBD	USSR	ROK	Joint ventures	Total	E. Bering Sea and Aleutian comb. 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
1982	-	-		-	-	-	8,352	-	-	-	-	-	1,742	10,094
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
1982	-	-	-	-	-	-	41,272	-	-	-	-	-	4,516	45,788

[a]Sources of data: 1960-76, Wakabayashi and Bakkala 1978; 1977-79, Data submitted to United States by fishing nations; 1980-82, French et al. 1981, 1982; Nelson et al. 1983.
[b]Mothership, North Pacific longline and North Pacific trawl fisheries combined. [c]Landbased dragnet trawl fishery.
[d]Republic of Korea. [e]Taiwan, Poland, and Federal Republic of Germany (F.R.G.). [f]Joint ventures between U.S. fishing vessels and Japanese, Polish, R.O.K., F.R.G., and U.S.S.R. processing vessels.

Following a long period of relatively small catches in the eastern Bering Sea and Aleutian Island region during the 1960s, catches of turbot increased, reaching an all-time high of approximately 103,000 t in 1974. Catches then declined, ranging from 41,650 to 55,800 t in 1977-79 according to catch data reported by nations fishing in the area. Catches, as shown by U.S. observer data, increased to 70,800 and 74,400 t 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. However, observer estimates show a substantial decline in catches during 1982 to 55,900 t.

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 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, 1981 and 1982 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.

Greenland turbot catch and effort data from the landbased fishery were analyzed by 1/2° latitude and 1° longitude statistical blocks and by month in which Greenland turbot comprised 50% or more of the overall reported catch. This method is assumed to fairly accurately reflect abundance trends of the exploitable population since -it is based on effort targeting on Greenland turbot. Figure 1 shows that following relatively high annual catch rates in 1972 and 1973 at approximately 48 t/100 hr trawled, CPUE declined to about 27 t/100 hr trawled by 1976. CPUE values fluctuated somewhat during 1977-78, began to increase in 1979, and remained at moderately high levels of about 35 t/100 hr trawled during 1980-81. However, CPUE declined significantly in 1982 to 21 t/100 hr trawled.

Relative abundance values from large-scale NWAFC surveys in 1975 and 1979-83 (using data from comparable areas sampled on the continental shelf) reflected relative stability in the abundance of juvenile Greenland turbot between 1975 and 1980 and then a marked decline with CPUE falling from

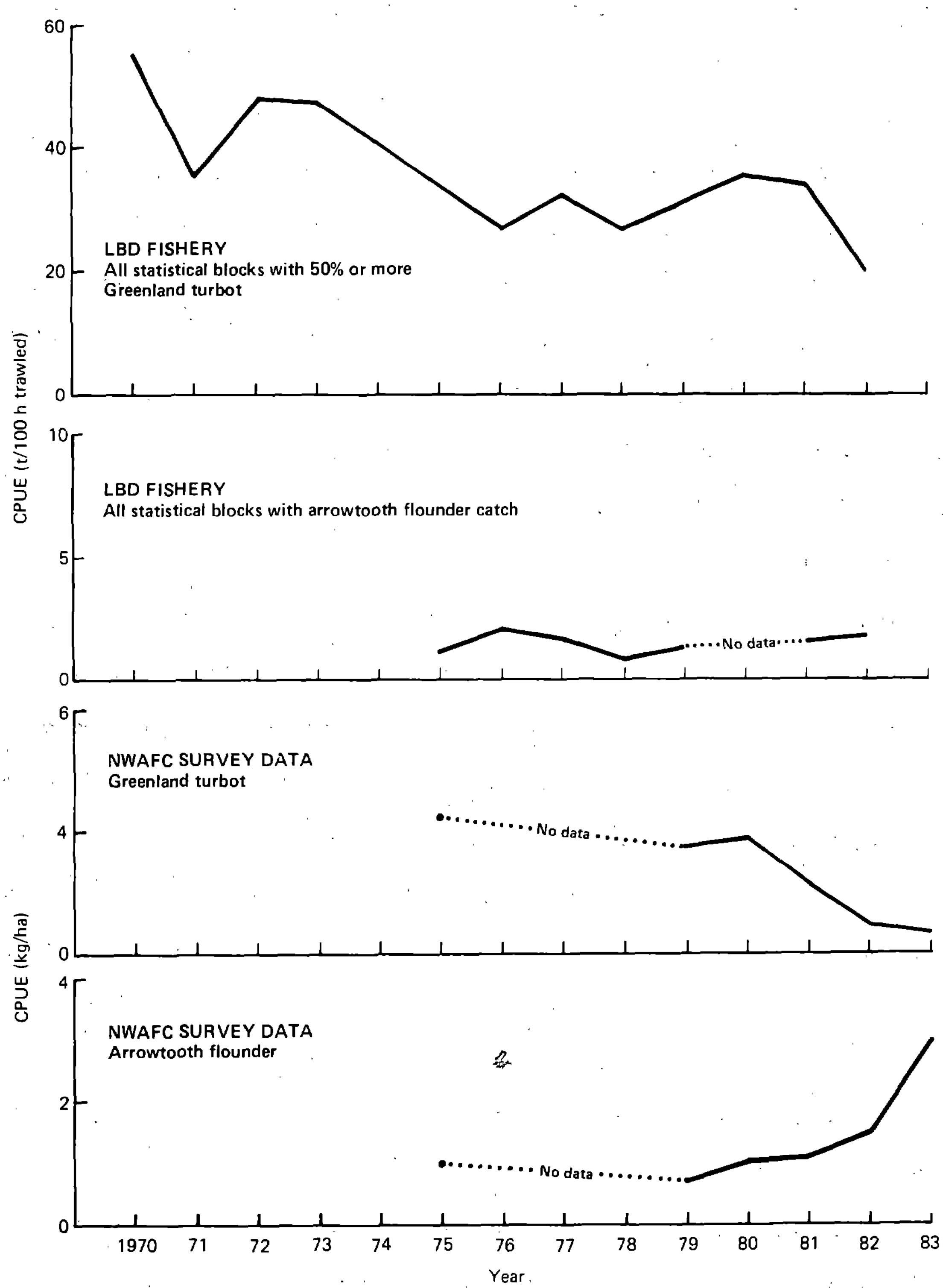

Figure 1.--Relative abundance (catch per unit of effort (CPUE)) of Greenland turbot and arrowtooth flounder as shown by data from the Japanese landbased dragnet (LBD) fishery and by large-scale surveys of the Northwest and Alaska Fisheries Center (NWAFC) that have sampled major portions of the eastern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

3.7 kg/ha in 1980 to about 0.8 kg/ha in 1982 and 1983. This low recruitment of juvenile fish apparently resulted in the decrease in abundance of the adult stock in 1982. CPUE values from sampling on the slope during joint U.S.-Japan trawl surveys remained stable from 1979 to 1981 at about 27 kg/ha and then declined to 24 kg/ha in 1982 which follows the trend seen in the fishery.

The trend in relative abundance for arrowtooth flounder, based on land-based fishery data from all statistical blocks in which the species was taken (Fig. 1), indicated a decline in CPUE between 1976 and 1978 and then relative stability until 1982. Survey results on the slope from joint U.S.-Japan surveys show similar CPUE values in 1979 and 1981 at around 9 kg/ha trawled and then ,a decrease to about 7 kg/ha during 1982.

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. Preliminary analysis of the 1983 eastern Bering Sea survey data indicated a further increase to 3.3 kg/ha trawled.

Biomass Estimates

Biomass estimates (t) based on recently reevaluated data from large-scale NWAFC surveys in 1975 and 1979-83 (for comparable areas sampled on the continental shelf) were as follows:

Species	1975	1979	1980	1981	1982	1983
	t					
Arrowtooth flounder	28,000	42,000	47,800	53,400	70,200	149,300
Greenland turbot	126,700	146,900	172,200	81,900	41,800	35,100
Total	154,700	188,900	220,000	135,300	112,000	184,400

These estimates, which primarily represent biomass of only the juvenile portion of the population, indicate 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. The significant increase in apparent biomass during 1983 is attributed to the greater abundance of arrowtooth flounder while the biomass of Greenland turbot continued to decline.

Data from the Japanese and U.S. cooperative surveys in 1979 and 1981-82 from the eastern Bering Sea and in 1980 from the Aleutian Islands region provide the most comprehensive and latest abundance estimates for the overall juvenile and adult populations:

	Eastern Bering Sea[a]			Aleutian region
Species	1979	1981	1982	1980
	--- t ---			
Arrowtooth flounder	58,100	85,500	89,000	62,900
Greenland turbot	304,300	185,800	124,900	74,800
Total	362,400	271,300	213,900	137,700

[a]Assuming equal fishing powers between U.S. and Japanese vessels.

The 1979 and 1982 survey data are 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 500,100 t with about 28% of the total located in the Aleutian Islands region.

Size and 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 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 (Fig. 2). Age information collected on U.S. research vessels in 1978-82 indicated the 1975-77 year-classes to be relatively strong with the 1977 year-class the strongest of this series. The 1979-80 year-classes also appear to be relatively strong. 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 (Fig. 3). The recruitment of age 1 fish in research vessel catches in 1980-82 was low and accounts for the decline in abundance of juvenile Greenland turbot noted from survey data.

Age data collected from catches by small Japanese trawlers in International North Pacific Fisheries Commission (INPFC) statistical areas I and II' 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. The poor recruitment of the 1979-81 year-classes, which were ages 2-4 in 1982, is believed to account for the decline in abundance shown by the 1982 fishery data.

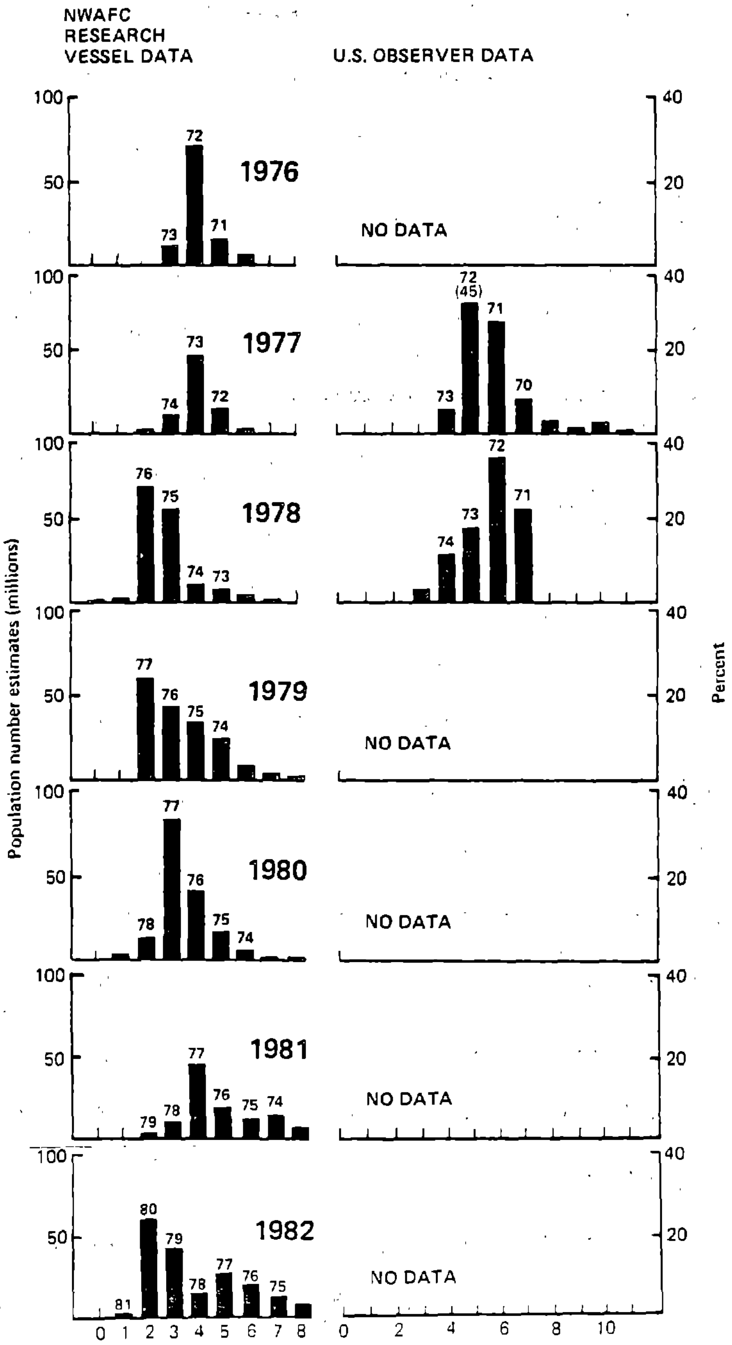

Figure 2 .--Age composition of arrowtooth flounder as shown by data from Northwest and Alaska Fisheries Center (NWAFC) demersal trawl surveys and by data collected in the commercial fishery by U.S. observers .

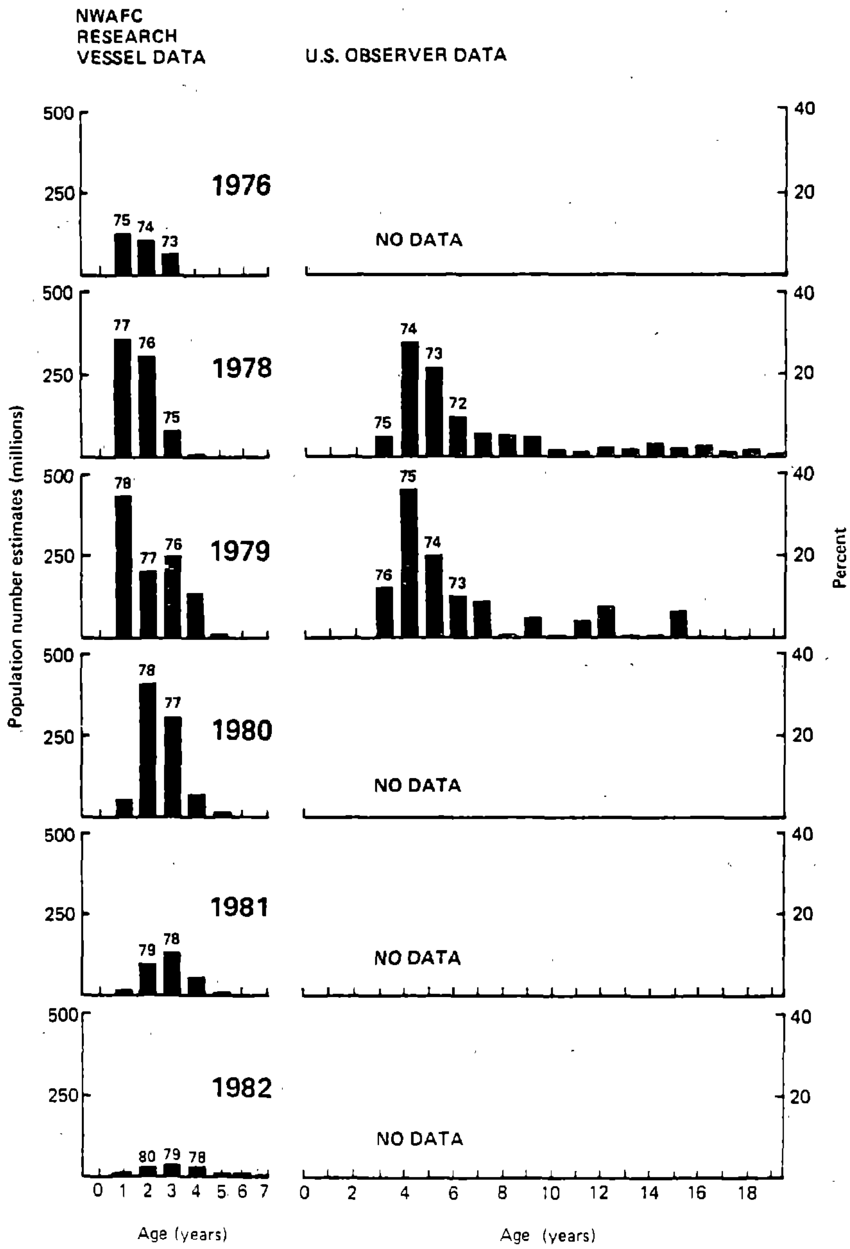

Figure 3 .--Age composition of Greenland turbot as shown by data from Northwest and Alaska Fisheries Center (NWAFC) demersal trawl surveys and by data collected in the commercial fisheries by U.S. observers.

Size composition information from research vessel surveys indicates a significant decrease in population numbers of juvenile Greenland turbot from comparable continental shelf waters surveyed in 1981-83 (Fig. 4). Overall population estimates decreased from approximately 289 million fish in 1981 to 115 million in 1982. Preliminary analysis of the most recent survey data indicate the Greenland turbot population decreased further to about 65 million during 1983. The largest decrease between 1981 and 1982 was seen in the 25-40 cm size category which represented age 2-4 fish of the 1977-79 year-classes.

Data collected during cooperative U.S.-Japan surveys in 1979, 1981, and 1982 were examined for trends in the adult populations. The Greenland turbot population on the slope decreased by approximately 50% from 53 million fish in 1979 to 27 million and 25 million in 1981 and 1982, respectively. A decrease in Greenland turbot abundance was also seen in the Japanese landbased dragnet fishery from the period of 1979-81 when CPUE values ranged from about 32-35 t/100 h trawled to approximately 2lt/lOO h trawled in 1982.

Numbers of juvenile arrowtooth flounder increased from about 171 million in 1981 to 236 million in 1982 on the continental shelf (Fig. 5). Initial estimates from the 1983 survey place the juvenile population still higher at nearly 600 million fish. The increase during 1983 is largely attributed to 2-year-olds of the apparently strong 1981 year-class.

Arrowtooth flounder abundance decreased on the continental slope from about 41 million in 1979 to 25 million by 1982, but the average size increased in this period which probably accounts for the rather stable estimates of abundance by weight until 1982.

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

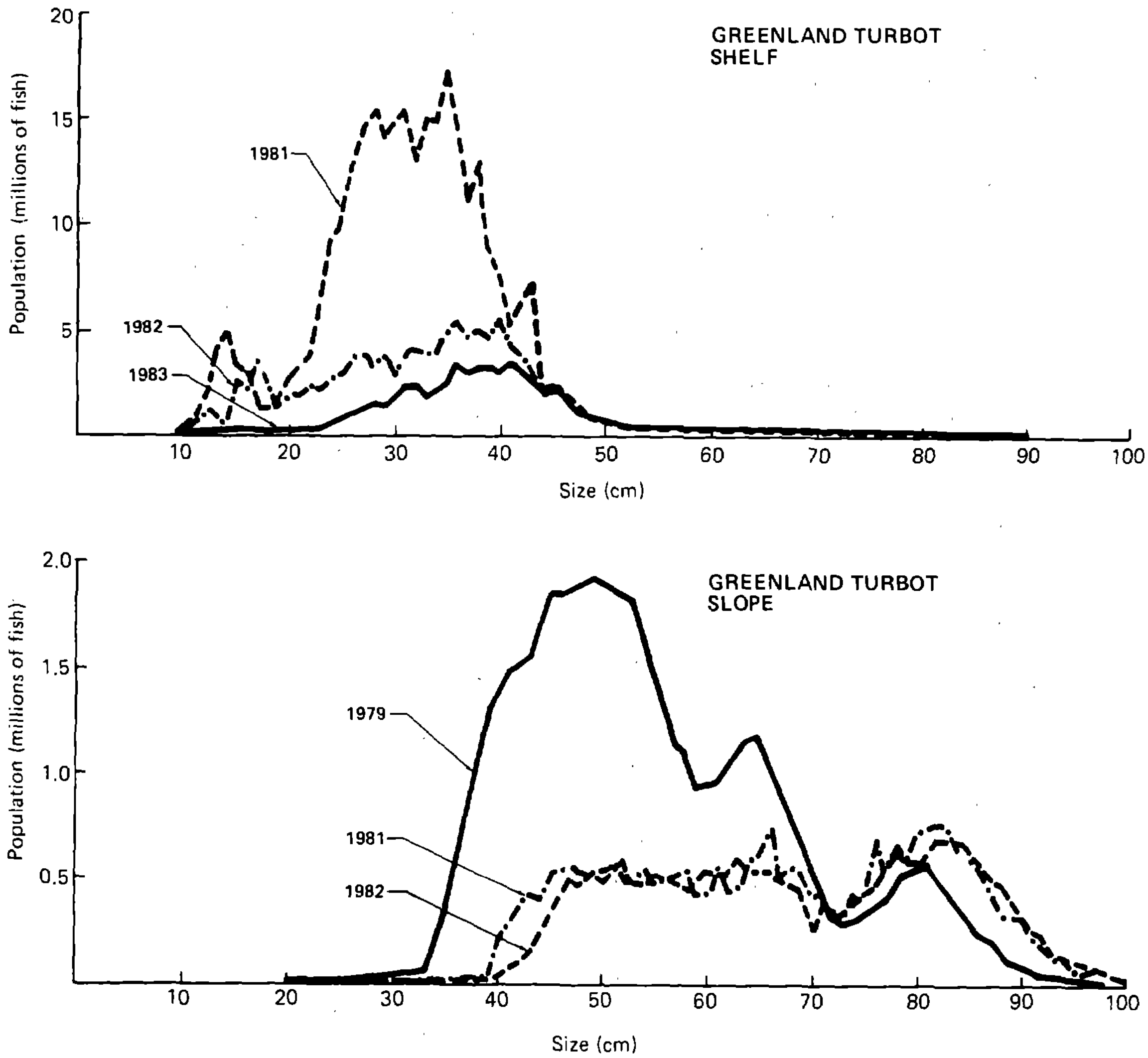

Figure 4. --Size composition of Greenland turbot on the eastern Bering Sea continental shelf and slope during research vessel surveys, 1979-83.

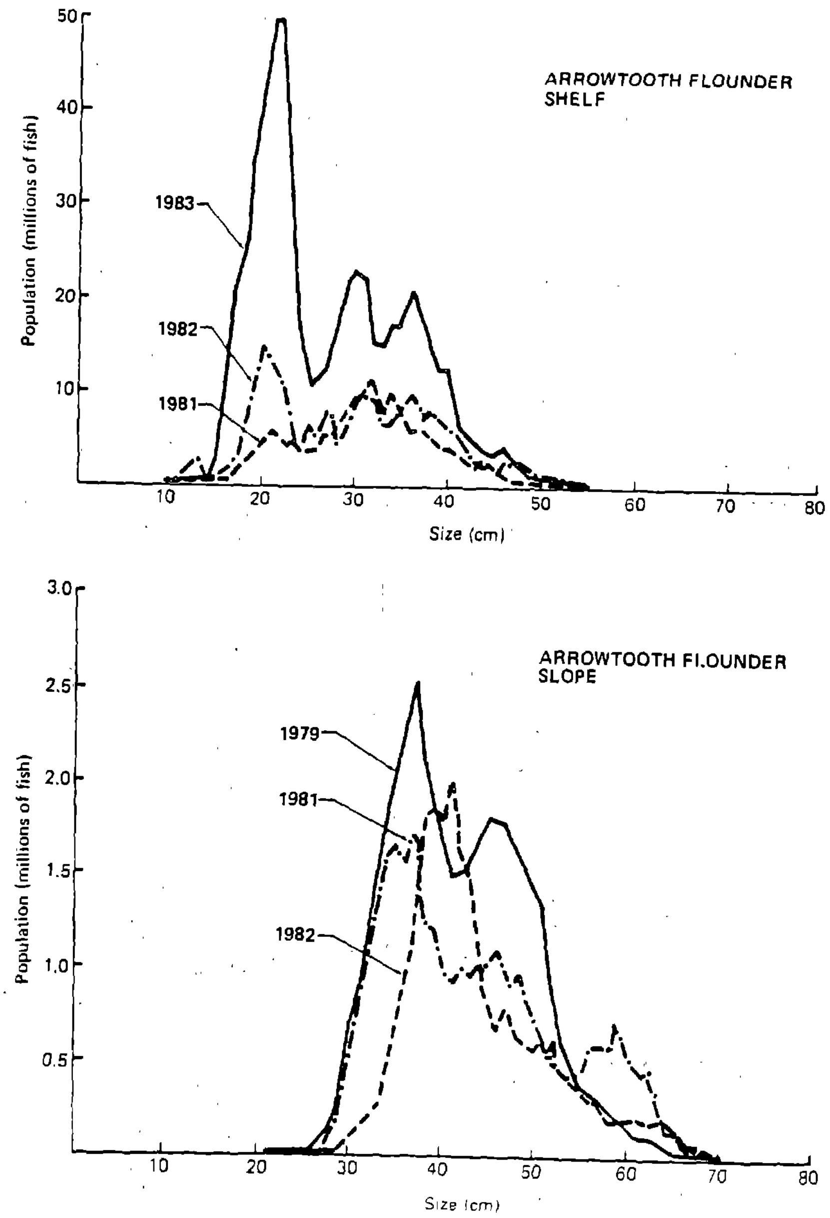

Figure 5. --Size composition of arrowtooth flounder on the eastern Bering Sea continental shelf and slope during research vessel surveys, 1979-83.

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 (304,300 t) and the 1980 estimate from the Aleutians (74,800 t) produced an overall estimated biomass for Greenland turbot of 379,100 t. Biomass estimates for 1979 and 1981 from the eastern Bering Sea have been revised from those reported by Bakkala and Sample (1983). The previous higher estimates were believed to overestimate MSY for Greenland turbot and arrowtooth flounder; the revised estimate may produce more realistic estimates. Assuming that Greenland turbot have been fully exploited and the population had been reduced to a level in 1979 that produces MSY (one-half the virgin population size), the virgin population would be estimated at 758,200 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 758,200 t or 72,000 t.

Based on the above survey data, the overall biomass of arrowtooth flounder from the eastern Bering Sea and Aleutians was estimated to be 121,000 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 242,000 t or 24,200 t.

The combined estimate of MSY for Greenland turbot and arrowtooth flounder from the overall management area is then 96,200 t.

EQUILIBRIUM YIELD

Catch rates and biomass estimates for juvenile Greenland turbot, after being relatively stable from 1975 to 1980, declined sharply in 1981 and 1982 and remained at the lower level in 1983. This decline has been the result of poor recruitment of the 1979-81 year-classes. The impact of this poor recruitment on the adult stock was apparent in 1982 from a decline in CPUE from the fishery and from reductions in CPUE and biomass estimates from research surveys on the slope. Based on the assumption that the stock was producing at the MSY level in 1979 and that the CPUE from the fishery in 1982 (21 t/100 h) was 66% of the 1979 value (32 t/100 h), equilibrium yield in 1984 is estimated to be 66% of the MSY estimate (72,000 t) on 47,500 t.

The CPUE and biomass estimates for juvenile arrowtooth flounder have increased in 1979-82 as a result of good recruitment of the 1979 and 1981 year-classes. Measures of abundance for the adult stock have been relatively stable. Based on the stability of the adult population and the good recruitment of juvenile fish, it is recommended that the equilibrium yield for arrowtooth flounder remain the same as last year or 20,000 t.

For the combined turbot complex, the best estimates of equilibrium yield for the eastern Bering Sea and Aleutians is 67,500 t.

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--the renewal of the U.S.S.R. flounder fishery in those years and 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 arrow-tooth flounder, *Atheresthes stomias*, some fisheries may have categorized part of their turbot catch as miscellaneous flatfish which would have artificially inflated the catches of these 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 (20,500-23,400 t) but increased to 32,700 t in 1982 (Nelson et al. 1983).

Table 1.--All-nation catches of other flatfishes in the eastern Bering Sea and Aleutian Islands region in metric tons (t)(1980-82 data includes catches from joint venture operations between U.S. fishing vessels and non-U.S. processing vessels).[a]

Year	Rock sole	Flathead sole	Alaska plaice	Miscellaneous flatfish[b]	Total
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
1982	14,450	8,183	8,612	1,421	32,666

[a]Sources of data: 1963-76, Wakabayashi and Bakkala 1978;
1977-79, data submitted to United States by fishing nations;
1980-82, French et al. 1981; 1982; Nelson et al. 1983.

[b]Includes rex sole, Dover sole, starry flounder, longhead dab, and butter sole.

This increase was mainly the result of a catch of 8,600 t of rock sole by the U.S.-U.S.S.R. joint venture fishery.

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, 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-contact of the trawls used in 1982 compared to those used in 1981 and earlier years. CPUE values were again high in 1983 suggesting that the new rigging has in fact increased the efficiency of the trawls for flatfish.

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 1980-83. The relative abundance of flathead sole was relatively stable from 1975 to 1979 and then increased moderately each year in 1980-83.

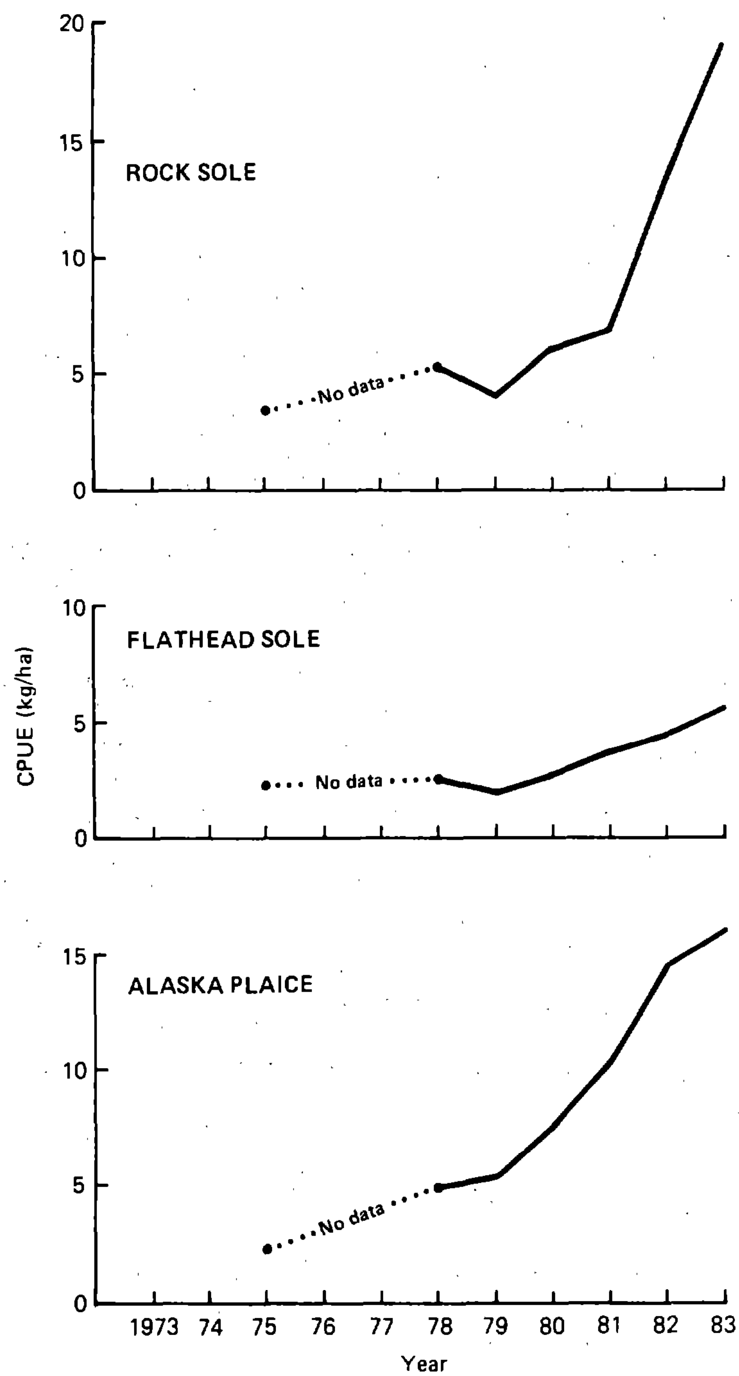

Figure 1. --Relative abundance (catch per unit of effort (CPUE)) of rock sole, flathead sole, and Alaska plaice as shown by large-scale demersal trawl surveys of the Northwest and Alaska Fisheries Center that have sampled major portions of the eastern Bering Sea continental shelf.

Biomass Estimates

Biomass estimates from large-scale NWAFC surveys (Table 2) indicate that the abundance of Alaska plaice has been steadily increasing from 127,100 t in 1975 to 745,400 t in 1983. For the other two major species in this group, estimates were relatively stable through 1979, but then increased substantially for rock sole from 182,800 t in 1979 to 869,700 t in 1983, and for flathead sole from 101,800 t in 1979 to 279,200 t in 1983. The other miscellaneous species of flatfish have also shown moderate increases in abundance.

The large increases in biomass between 1981 and 1982, representing a 104% increase for rock sole, 26% increase for flathead sole, and a 33% increase for Alaska plaice, are due in part to the greater efficiency of the 1982 trawls for flatfish than the trawls used in 1981. Also accounting for part of these increases for some species was sampling of waters in the vicinity of Nunivak Island in 1982, but not in 1981. The area not sampled in 1981 (see Fig. 2 of the section on walleye pollock in this report) accounted for about 20,400 t of biomass for, rock sole, 98,000 t of Alaska plaice, and 24,200 t of miscellaneous flatfish species 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 20% of the 33% increase in biomass observed for Alaska plaice, but only 7% of the 104% increase for rock sole. Reasons for the additional increases in the 1983 biomasses compared to 1982 are difficult to explain, unless they are due to real increases in abundance and/or greater availability of the species to the survey trawls. The same trawls were used and the same area sampled in 1982 and 1983.

Although the actual magnitude of changes in abundance of other flatfish over the past several years is difficult to judge because of the changes in fishing gear and areas sampled, real increases in abundance are believed

Table 2.--Estimated biomass (in metric tons) of species in the other flatfish complex in the eastern Bering Sea and Aleutian regions based on research vessel survey data in 1975 and 1978-83.

		Species				Total all species excluding	Total
Year	Area	Rock sole	Flathead sole	Alaska Plaice	Others	Alaska plaice	all species
1975	EBS[a]	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.[b]	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
1983	EBS	869,700	279,200	745,400	69,700	1,218,600	1,964,000

[a]Eastern Bering Sea.
[b]Aleutian Islands region.

to have taken place. These higher levels of abundance are probably due to good recruitment in recent years as will be discussed later. Even though increases in abundance between 1975 and 1983 may not be as large as indicated by the survey data, a real increase is believed to have occurred and abundances estimated by the 1982 and 1983 surveys indicate that the abundance of these species is high.

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 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 (Fig. 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. These year-classes also formed the major part of commercial catches of rock sole in 1973-79 (Fig. 2). Based on survey data, 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 as evidenced by both survey and fishery data, but the 1975-80 year-classes appear to be above average strength. This recruitment is believed to account, at least in part, for the increases in estimates of relative and absolute abundance for rock sole.

Age data collected during research vessel surveys since 1973 and from the commercial fishery by U.S. observers in 1975-79 for flathead sole (Fig. 3) show that the 1965-69 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

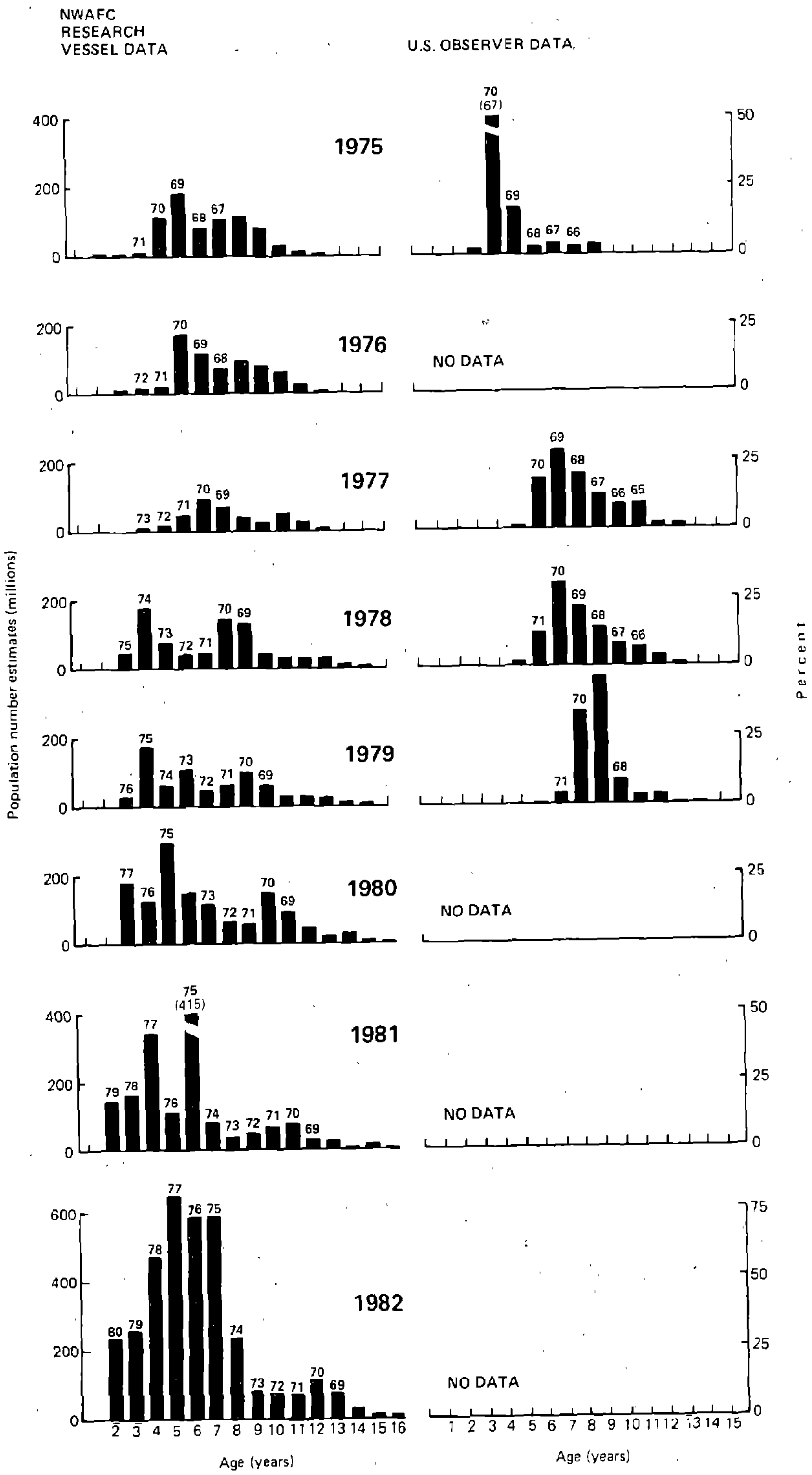

Figure 2.--Age composition of rock sole as shown by data from Northwest and Alaska Fisheries Center (NWAFC) demersal trawl surveys and by data collected by U.S. observers in the commercial fishery.

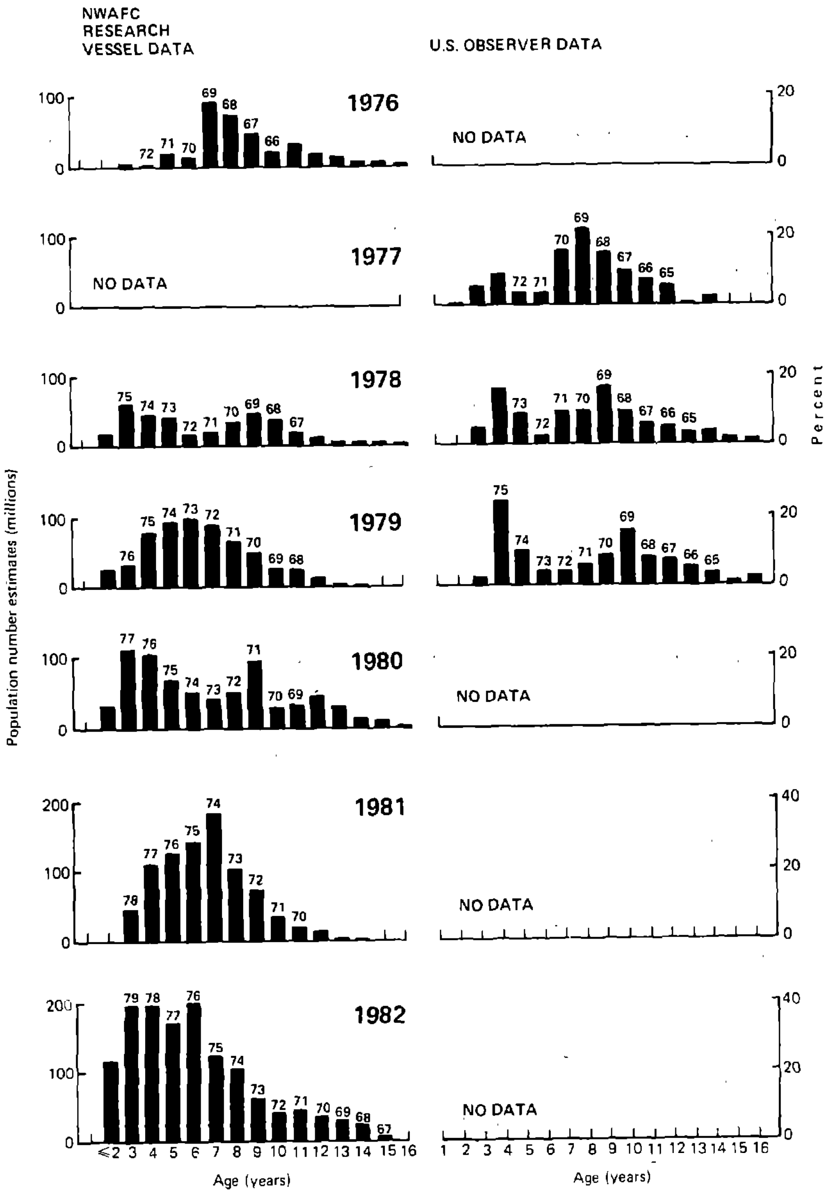

Figure 3.--Age composition of flathead sole as shown by data from Northwest and Alaska Fisheries Center (NWAFC) demersal trawl surveys and by data collected by U.S. observers in the commercial fishery.

more recent years, there appears to be good recruitment from the 1974-79 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 1967-71 year-classes have formed the major portion of the population since 1978 and continued to predominate in the population through 1982 at the relative old ages of 11-15 yr (Fig. 4). Some later year-classes also appear to be abundant, particularly the 1974 and 1975 year-classes.

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 to 697,800 t).

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

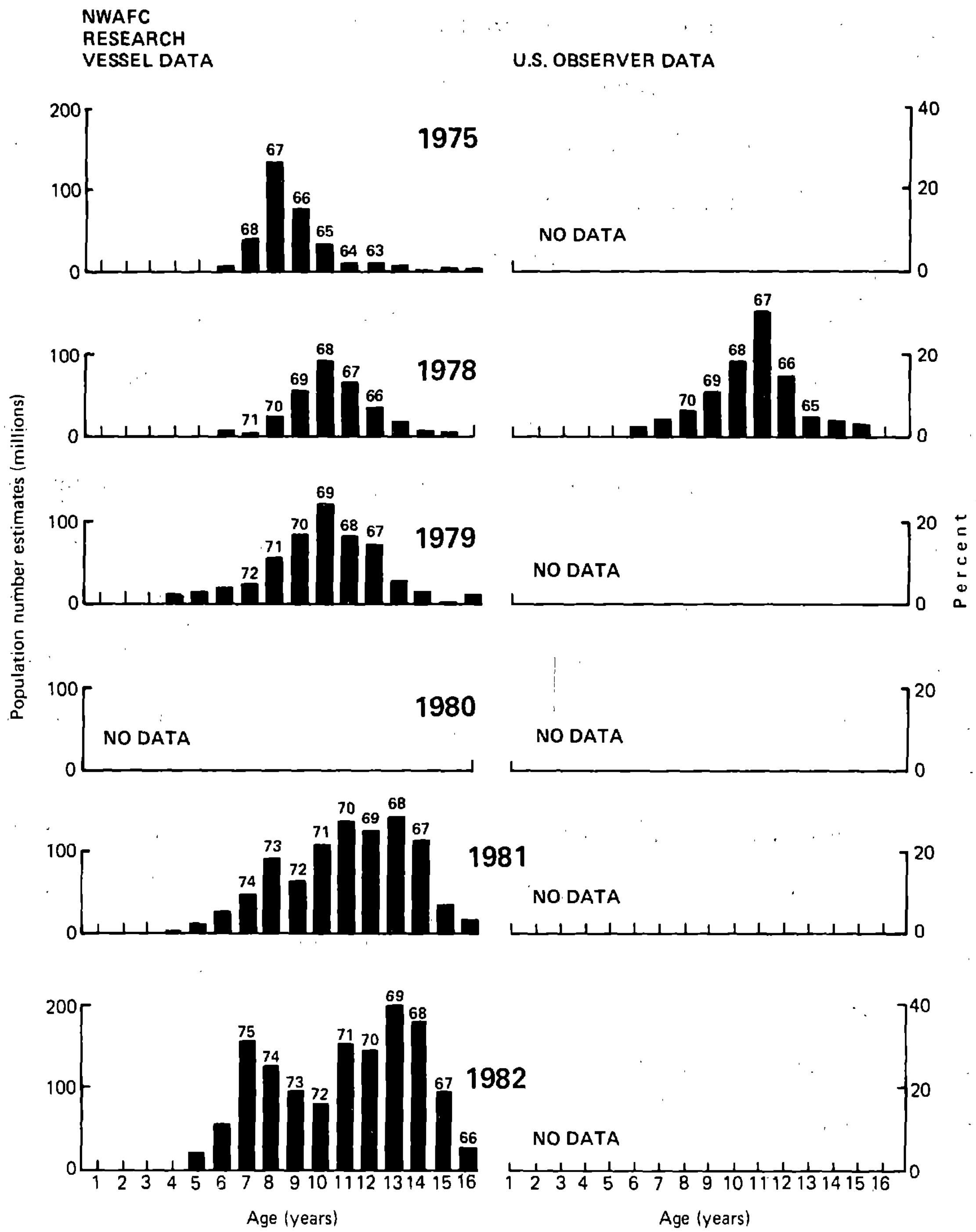

Figure 4.--Age composition of Alaska plaice as shown by data collected from Northwest and Alaska Fisheries Center (NWAFC) demersal trawl surveys and by data collected by U.S. observers in the commercial fishery.

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 1982 (968,100 t) and 1983 (1,218,600 t) estimates exceed the estimated range in virgin biomass and indicate that these species are in good condition and can sustain catches in the MSY range.

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 1983. From an estimate of 127,100 t in 1975, they show an apparent increase to 745,400 t in 1983. 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 to 609,000 t) or 45,100-70,000 t.

EQUILIBRIUM YIELD

Recent estimates from large-scale NWAFC research vessel surveys show that the abundances of rock sole, flathead sole, and miscellaneous species of flatfish were substantially higher than in previous years. The higher estimates (1.2 million t in 1983) are believed to result from the use of more efficient trawls for these species in 1982 and 1983 and also to actual increases in abundance of the populations. In view of the present high abundance of these species, the resources should be capable of producing catches at the upper end of the MSY range. EY is, therefore, estimated to be at least as high as 80,200 t.

Abundance of Alaska plaice continues to increase and is at a high level relative to past years with an estimated biomass of 745,000 t in 1983. The population should be capable of producing catches at the high end of the MSY range or 70,000 t.

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SABLEFISH

Renold E. Narita

INTRODUCTION

Sablefish, *Anoplopoma fimbria*, are widely distributed in the North Pacific Ocean from Baja California, northward to the Gulf of Alaska and Bering Sea, and westward to the Kamchatka Peninsula and northern Japan. In the eastern Bering Sea and Aleutian Islands area, sablefish are exploited primarily by longliners and incidentally by trawlers at depths between 150 and 1,000 m along the continental shelf and slope. Eastern Bering Sea sablefish were extensively harvested for the first-time in 1958 by Japan's distant-water longline fishery. This fishery expanded rapidly during the early 1960s when a peak annual catch of 28,520 t was recorded in 1962 (Table 1). Japanese trawl fisheries began to displace the longliners in the eastern Bering Sea in the mid-1960s and new longlining areas were established in the Aleutian region. In 1972, a peak all-nation catch of 3,580 t was landed in the Aleutians by Japan and the U.S.S.R. Since 1972, declining catches have been primarily due to reduced stock abundance; catch restrictions placed on the fishery have also been minor contributing factors in recent years. In 1982, all-nation catches of 3,030 t and 809 t in the eastern Bering Sea and Aleutian regions, respectively, showed increases over 1981 levels. As in past years, Japan accounted for a major portion of the catch (76% in the eastern Bering Sea, 88% in the Aleutians), while the Republic of Korea, Taiwan, and Federal Republic of Germany (West Germany) also contributed to the catch. Sablefish is taken incidentally in all the fisheries conducted by these other nations, except the Korean longline fishery.

Table 1 .--Historical catches of sablefish in metric tons by area and nation, in the Bering Sea/Aleutians, 1958-82.a

	Eastern Bering Sea				Aleutian Region				
Year	Japan[b]	U.S.S.R.	Others[c]	Total	Japan[b]	R.O.K.	U.S.S.R.	Others[d]	TOTAL
1958	32	--	--	32	e	--	--	--	e
1959	393	--	--	393	e	--	--	--	e
1960	1,861	--	--	1,861	e	--	--	--	e
1961	26,182	--	--	26,182	e	--	--	--	e
1962	28,521	--	--	28,521	e	--	--	--	e
1963	18,404	--	--	18,404	e	--	--	--	e
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
1982	2,315	--	715	3,030	715	92	--	1	809

[a]Japanese catch data for 1958-77 from Sasaki (1976) and pers. commun., T. Sasaki, Far Seas Fishery Research Lab., Shimizu, Japan; U.S.S.R. data for 1967-77 provided through U.S .-U.S.S.R. bilateral agreements; 1976 data for Republic of Korea (R.O.K.), and 1978-82 data for all nations from U. S. foreign fisheries observer program.

[b]For years prior to 1977, Japanese catch data are reported by fishing year (Nov.-Dec.); later Japanese catches are reported by calendar year.

[c]Includes Republic of Korea (R.O.K.), Taiwan, Poland, and Federal Republic of Germany.

[d]Includes Taiwan, Poland, and Federal Republic of Germany.

[e]Included in the Bering Sea catches.

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). In the Bering Sea, the two management units are the eastern Bering Sea unit and the Aleutian region unit.

CONDITION OF STOCKS

Relative Abundance

The interpretation of catch per unit effort (CPUE) data is complicated by varied gear types, differing assumptions made in data selection, and management regulations which have influenced fishing patterns. Recognizing these limitations, CPUE data from commercial fisheries may only provide general indications of abundance trends.

Sablefish CPUE has been estimated from data taken from the Japanese longline and stern trawl fisheries (Table 2). A considerable decline in CPUE has been apparent since 1972 for both the eastern Bering Sea and Aleutian areas. To more clearly illustrate the historical decline in catch rate, Japanese estimates of longline CPUE (kg/10 hachi from Table 2) are standardized below and are expressed as percentages of the 1970 CPUE values:

	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

Year	Eastern Bering Sea All-nation catch (t)	Eastern Bering Sea Standardized CPUE	Aleutian Region All-nation catch (t)	Aleutian Region Standardized CPUE
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

Not available

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 not be comparable to those from previous years due to changes in fishing patterns brought about by fishing regulations following enactment of the U.S. Fishery Conservation and Management Act in 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, CPUE increased to 31% in the eastern Bering Sea and 40% in the Aleutians of 1970 values.

In 1982, the U.S. estimate for the Japanese longline CPUE, which has paralleled the trends of the corresponding Japanese estimate, continued to increase to 47 kg/10 hachi in the eastern Bering Sea and 76 kg/10 hachi in the Aleutian region.

Catch and effort data collected by U.S. observers aboard Japanese long-liners (Table 3) also showed an increase in CPUE in 1982 in all areas, while catch rates from trawlers showed no apparent trend. However, since sablefish are caught incidentally by the trawlers, their catch rates may not accurately reflect trends in sablefish abundance. Table 4 shows monthly CPUE data of

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, 1964-82.

	Eastern Bering Sea				Aleutian Region				
	Japan estimates		U. S. estimates		Japan estimates		U.S. estimates		
	longline		longline	trawl	longline		longline		trawl
	kg/10 hachi[a]	T/ vessel day[b]	kg/10 hachi[c]	kg/h[c]	kg/10 hachi[a]	T/ vessel day[b]	kg/10 hachi[c]	T/ vessel day[c]	kg/h[c]
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
1982			47	2			76		<1

[a] Okada et al. (1982)
[b] Far Seas Fisheries Research Laboratory (1978)
[c] Method of Low et al. (1977).
Hachi is a unit of longline gear and is 100 m long.

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, 1977-82..

Country	Vessel[a]	Area[b]	Yr	Ave. depth (m)	Rk[c]	kg/day	kg/h[d]	First three species: order of abundance[e]
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
			82	452	8	82	6	Ysol, Tur, Pol
		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
			82	473	8	68	4	Tur, Pol, Cod
		V	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
			82	445	12	43	3	Rat, Pol, Tur
	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
			82	207	10	44	3	Pol, Jel, Cod
		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
			82	248	16	10	1	Pol, Her, 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
			82	517	3	2067	146	Tur, Cod, Sab
		II	80	567	5	327	18	Tur, Cod, Rat
			81	499	4	1173	73	Tur, Cod, Rat
			82	437	3	1344	88	Tur, Cod, Sab

Table 3.--Continued.

Country	Vessel[a]	Area[b]	Yr	Ave. Depth	Rk[c]	kg/day	kg/h[d]	First three species: order of abundance[e]
Japan	Long-liner	V	77	593	2	1114	89	Tur, Sab, Str
			78	508	2	1186	92	Tur, Sab, Rat
			79	596	3	1084	72	Tur, Rat, Sab
			82	376	1	1961	209	Sab, Cod, Tur
U.S.S.R.	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
		V	77	110	-	-	-	Am, Nroc, Pop
			78	175	40	0	0	Am, Pol, Cod
			79	162	-	-	-	Am, Cod, Pol
			80	152	-	-	-	Am, Yil, Cod
R.O.K.	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
			82	117	13	38	6	Pol, Cod, Ysol
		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
			82	245	3	27	9	Pol, Pop, Sab
		V	80	156	5	255	92	Am, Pol, Cod
			81	-	8	59	24	Pol, Am, Cod
			82	167	10	30	11	Am, Pol, Pop
	Long-liner	I	82	332	1	1964	34	Sab, Cod, Tur
		II	82	308	2	1976	0.1	Cod, Sab, Tur
		V	82	650	1	1462	61	Sab, Rat, Skate

[a]Small trawler (<1,500 GRT), large trawler (>1,500 GRT)
Footnotes continued next page.

Table 3.--Continued.

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[b]Area I (Bering Sea east of 170° w), Area II (Bering Sea 170° W to 180°), Area V (Aleutian region).
[c]Rank of species in catches by weight
[d]In the case of longliners, CPUE is in kg per 1000 hooks
[e]Tur-Greenland turbot, Pol-Pollock, Cod-Pacific Cod, Her-Herring, Ap-Alaska plaice, Pop-Pacific ocean perch, Am-Atka mackerel, Nroc-Northern rockfish, Squ-Squid, Ysl-yellowfin sole, Sab-Sablefish, Rat-Rattail, Scul-Sculpin, Lum-Lumpsucker, Af-Arrowtooth flounder, Str-Shortspine thornyhead rockfish, Yil-Yellow Irish lord, Sal-Salmon,, Jel-Jellyfish.

Table 4.--Japanese longline CPUE data on sablefish collected by U. S. observers in the Aleutians, 1977-79, 1982.

Year	Area	Month	Days	Sets	Hooks	Ave. depth (m)	Sable-fish (t)	Percent of total catch	Catch per 1000 hooks[a]
1982	Aleutians	3	22	15	131,428	117	5.685	9	43
1982	Aleutians	4	12	6	104,150	543	16.440	29	158
1982	Aleutians	5	9	5	91,200	615	23.883	45	262
1982	Aleutians	6	9	9	105,848	414	37.663	51	356
1982	Aleutians	7	10	10	132,056	473	27.644	40	209
1982	Aleutians	8	6	6	81,354	443	15.132	42	186
1982	Aleutians	9	5	5	50,632	355	16.379	63	323
1982	Aleutians	10	7	2	27,750	150	2.301	20	83
1982	Aleutians	11	5	5	73,310	485	21.541	46	294
1979	Aleutians	1	2	2	21,000	152	.004	<1	<1
1979	Aleutians	2	1	1	20,000	750	3.373	32	169
1979	Aleutians	3	25	21	342,780	707	20.500	17	60
1979	Aleutians	4	26	21	345,313	518	27.834	17	81
1979	Aleutians	5	27	22	394,290	581	31.181	22	79
1979	Aleutians	6	27	25	499,795	603	34.697	19	69
1979	Aleutians	9	5	4	79,287	637	4.760	16	60
1978	Aleutians	6	19	20	293,036	466	18.275	20	62
1978	Aleutians	7	3	2	15,540	369	.013	<1	<1
1978	Aleutians	8	5	4	68,880	617	11.761	28	171
1978	Aleutians	9	7	4	68,880	552	10.801	28	157
1977	Aleutians	9	14	13	172,900	592	15.325	29	89

[a]kg per 1000 hooks

Japanese longliners, which in 1982 resumed fishing in the Aleutian region for the first time since 1979. The 1982 sablefish catch rates and percentage of sablefish in the total catch made was markedly higher than those of the previous years. These values, however, may not be directly comparable since the average depths fished in 1977-79 (more then 500 m) were usually greater than the average depth fished in 1982 (376 m).

Abundance Estimates from Research Surveys

Eastern Bering Sea

Increased commercial catches and longline CPUE indicate the recruitment of an unusually strong 1977 year-class into the fishery. This year-class was first observed as age 1 juveniles in 1978 during the annual U.S. demersal crab-groundfish trawl survey on the continental shelf of the eastern Bering Sea (Fig. 1). Sablefish have rarely been observed on the shelf since the survey was initiated in 1971, but appeared in abundance in 1978. More recent crab-groundfish surveys indicated that the 1977 year-class persisted in continental shelf waters of the eastern Bering Sea in 1979-80.

In 1981, however, the survey results showed that the abundance of this year-class on the shelf had dramatically decreased.

Also in 1981, findings of the cooperative U.S.-Japan trawl survey along the continental slope gave evidence of the recruitment of the 1977 year-class to the adult population on the. slope. Population estimates by length interval (Fig. 2) from the 1979, 1981, and 1982 surveys show that population numbers tripled between 1979 (5.3 million) and 1981 (18.0 million). Estimated biomass increased from 12,200 t in 1979 to 39,400 t in 1981. In 1982, the population number (22.7 million) and biomass (42,700 t) were similar in magnitude to those in 1981. For the combined shelf and slope areas of the eastern Bering Sea,

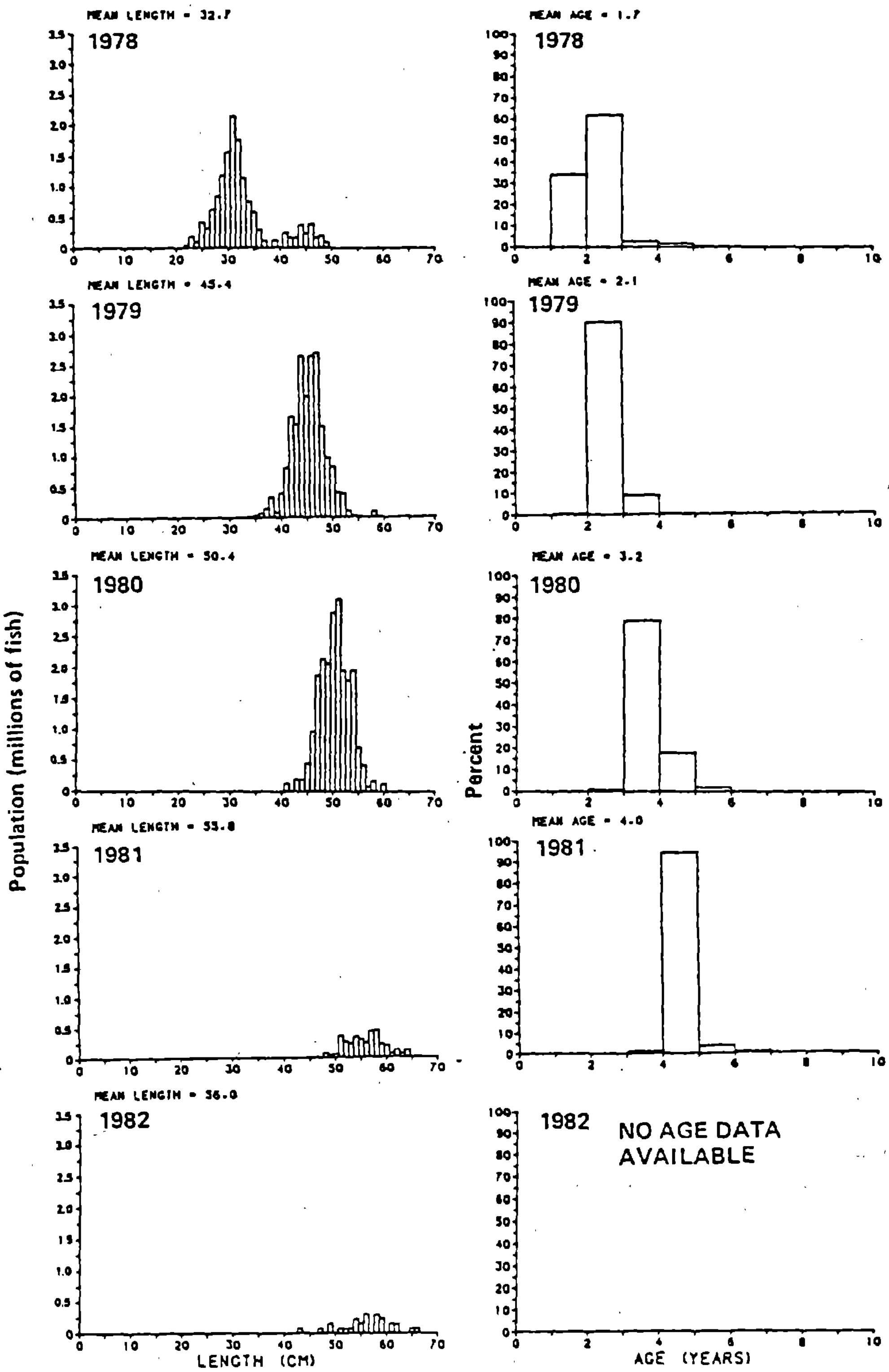

Figure 1 .--Size and age canposition of sablefish within the continental shelf comparative fishing area surveyed by U.S. research vessels, 1978-82. Age determinations for 1978 may be inaccurate due to differences in aging structures; scales were used in 1978, and otoliths were used in subsequent years (Umeda et al. 1983)

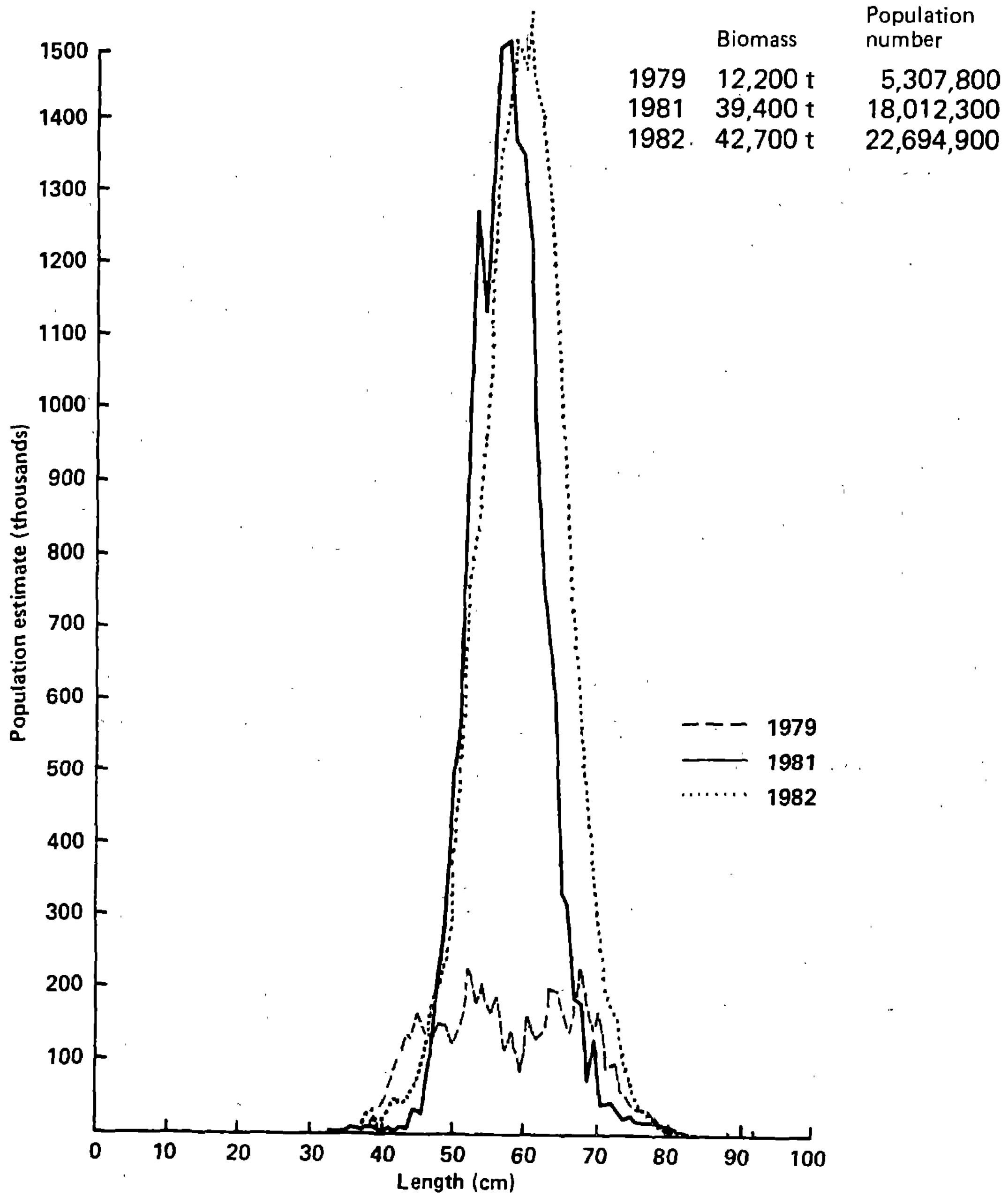

Figure 2.--Population estimates of sablefish by centimeter size interval on the continental slope of the eastern Bering Sea as shown by data from cooperative U.S. -Japan demersal trawl surveys in 1979, 1981, 1982. Total estimated biomass and population number for the slope areas surveyed are also given.

survey results show a 4% increase in population biomass between 1981 (47,100 t) and 1982 (49,200 t).

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 survey was the first comprehensive assessment of Aleutian groundfish resources in which the United States has participated and encompassed areas north and south of the Aleutian chain between Attu Island and Unimak Pass.

The survey estimates of exploitable sablefish biomass in the Aleutians portion of INPFC Area I and Aleutian region (Area V) were 8,500,t and 19,500 t, respectively (Table 5). Over 78% of the estimated available biomass was located east of long. 180°.

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 longs. 170°W and 180° W 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 (<45 cm) were found in abundance; they were located in the 101-200 m depth interval (Fig. 3). In general, largest fish were taken at the greatest depth intervals sampled.

Evidence of improving sablefish abundance in the Aleutian region, coincident with the recruitment of the 1977 year-class, has been collected by recent Japan-U.S. joint longline surveys during the summers of 1979-82 (Sasaki 1983). The indices of sablefish biomass (relative population weight (RPW) for small (<58 cm) and middle-to-large (>58 cm) size fish (which have a higher commercial value) were as follows:

Area	Year	Total RPW	Total Annual change (%)	Small size RPW	Small size Annual change (%)	Middle-large size RPW	Middle-large size (%)
West Aleutian	1980	6,473		262		6,211	
			- 7		- 3		- 7
	1981	6,014		254		5,760	
			+ 29		+ 56		+ 28
	1982	7,740		395		7,345	
East Aleutian	1979	12,545		1,459		11,086	
			+ 74		+618		+ 2
	1980	21,768		10,474		11,294	
			- 1		- 12		+ 9
	1981	21,486		9,169		12,317	
			+ 8		+ 2		+13
	1982	23,244		9,335		13,909	
Total	1980	28,241		10,736		17,505	
			- 3		- 12		+ 3
	1981	27,500		9,423		18,077	
			+ 13		+ 3		+ 18
	1982	30,984		9,730		21,254	

In the eastern Aleutian area, where sablefish are most abundant in the Aleutians, a 618% increase in RPW for small fish was observed between 1979 and 1980 indicating the recruitment of the 1977 year-class to this region. In 1982, the abundance of the small fish remained about the same as in 1979-80. Meanwhile, the middle-to-large sized fish increased moderately in weight from 1980-81 (9%) and 1981-82 (13%). For the overall stock in the entire Aleutian area, RPW declined slightly (3%) from 1980 to 1981, but increased moderately (13%) from 1981 to 1982. Improving stock abundance is at least partially attributable to the recruitment of the 1977 year-class.

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 MSY as 50,300 t for the Bering Sea to California region.

Table 5.--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 kg/nmi	1-100 m t	101-200 m kg/nmi	101-200 m t	201-300 m kg/nmi	201-300 m t	301-500 m kg/nmi	301-500 m t	501-900 m kg/nmi	501-900 m t	1-900 m kg/nmi	1-900 m t
Western Aleutians long. 173°E-180°												
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 long. 170°W-180°												
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 long. 165°W-170°W												
North of chain	4	640	2	159	70	2,300	18	790	62	4,563	-	8,453

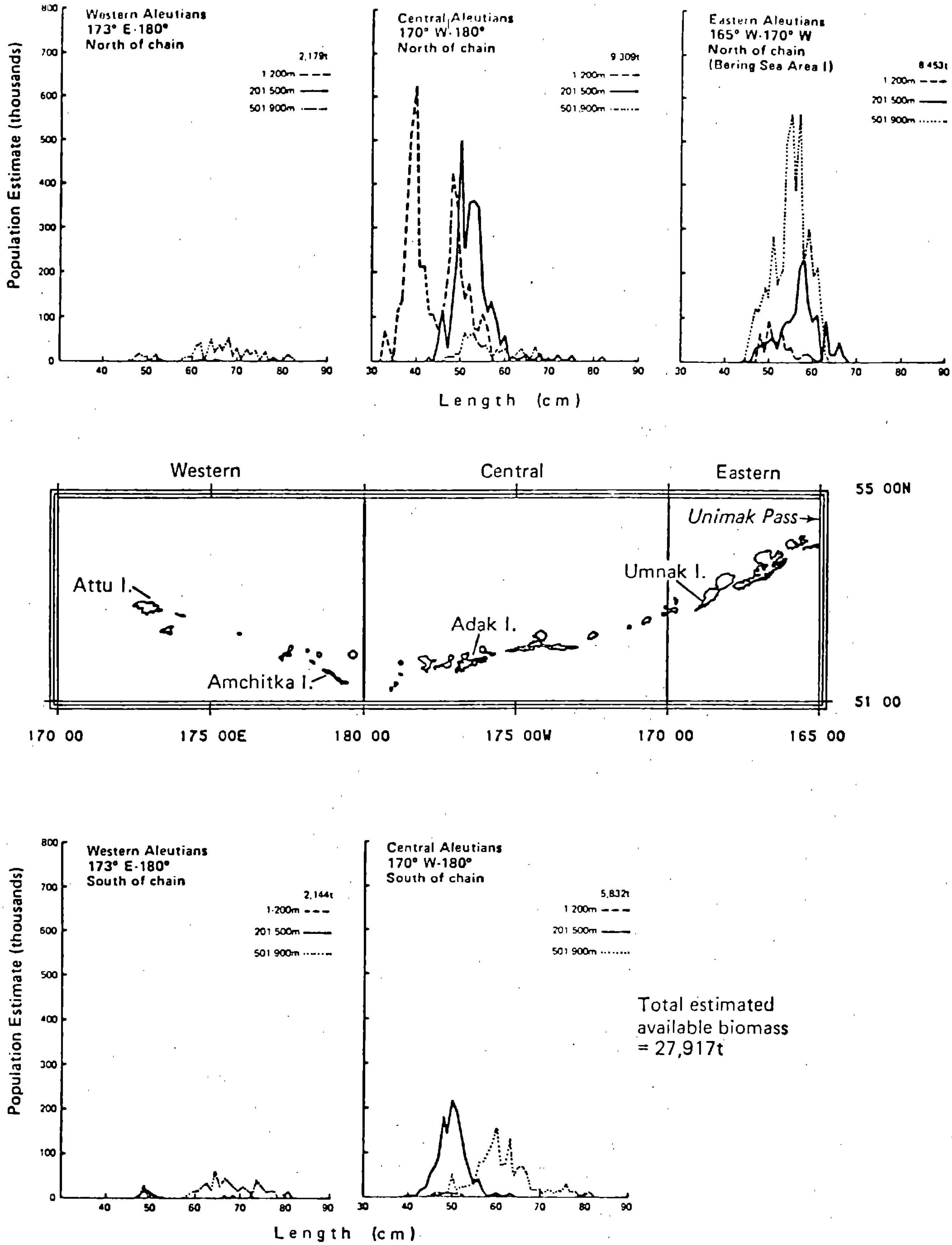

Figure 3.--Length composition of sablefish in the Aleutian Islands region by area and depth as shown by the 1980 U.S.-Japan cooperative trawl survey.

The estimate is derived from a general production model. The MSY estimate has been apportioned to regions according to historical catches: Bering Sea, 13%; Aleutian region, 7%; Gulf of Alaska, 67%; and the British Columbia-Washington region, 13% (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 are&.

EQUILIBRIUM YIELD

Estimated 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 49,200 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 0.041 and 0.046 in the eastern Bering Sea and Aleutians Region, respectively.

The stock condition in both regions appears to be better in 1982 than in 1979-80. However, CPUE values from commercial fishery data, although improved, remain substantially below historical levels and it is difficult to determine how much EY has increased. The exploitation rate of 4.1% to 4.6% appears fairly conservative for sablefish. Sasaki (1983) has suggested a sustainable exploitation rate of 9%. Applying this rate to the latest biomass estimates (49,200 t in 1982 in the eastern Bering Sea and 19,500 t in 1980 in the Aleutians), the EY for sablefish is 4,430 t in the eastern Bering Sea and 1,755 t in the Aleutian 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 (Fig. 1). Commercial catch records (Table 1) indicate that the Aleutian region supports a larger Pacific ocean perch population than the eastern Bering Sea slope region.

Pacific ocean perch were highly sought after by Japanese and Soviet fisheries and supported a major trawl fishery throughout the 1960s. 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 peaked at 47,000 t in 1961 (Table 1); the peak catch in the Aleutian region occurred in 1965 with a removal of 109,000 t. Catches since then have declined substantially. In 1982, Pacific ocean perch harvests were but a small fraction of historic levels: 600 t from the eastern Bering Sea slope region and 1,500 t from the Aleutian region.

CONDITION OF STOCKS

Eastern Bering Sea Region

Relative Abundance

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

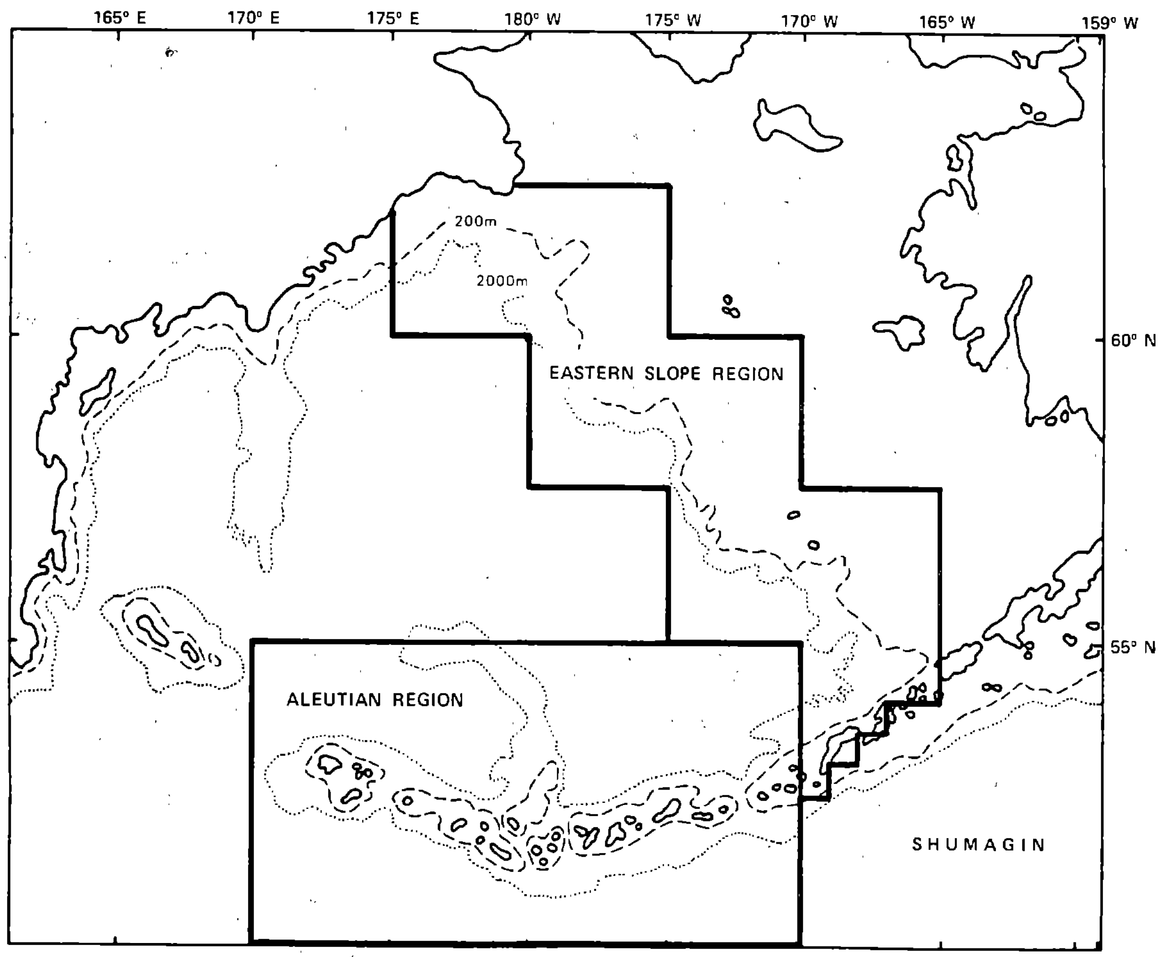

Figure 1. -The Bering Sea with the two main stock areas regions) of Pacific ocean perch delineated.

Table 1 .--Annual catch of Pacific ocean perch from the eastern Bering Sea and Aleutian Islands regions (thousands of metric tons).[a]

Year	Eastern Bering Sea				Aleutian Islands				Regions Combined			
	Japan [b]	USSR [c]	Other nations [d]	Total	Japan	USSR	Other nations	Total	Japan	USSR	Other nations	Total
1960	1.1	5.0	---	6.1	---	---	---	---	1.1	5.0	---	6.1
1961	13.0	34.0	---	47.0	---	---	---	---	13.0	34.0	---	47.0
1962	12.9	7.0	---	19.9	0.2	---	---	0.2	13.1	7.0	---	20.1
1963	17.5	7.0	---	24.5	0.8	20.0	---	20.8	18.3	27.0	---	45.3
1964	14.4	11.5	---	25.9	29.3	61.0	---	90.3	43.7	72.5	---	116.2
1965	7.8	9.0	---	16.8	38.1	71.0	---	109.1	45.9	80.0	---	125.9
1966	17.5	2.7	---	20.2	28.2	57.7	---	85.9	45.7	60.4	---	106.1
1967	19.6	---	---	19.6	9.3	46.6	---	55.9	28.9	46.6	---	75.5
1968	28.4	3.1	---	31.5	18.3	26.6	---	44.9	46.7	29.7	---	76.4
1969	14.5	0.0	---	14.5	15.6	23.2	---	38.8	30.1	23.2	---	53.3
1970	9.9	0.0	---	9.9	13.6	53.3	---	66.9	23.5	53.3	---	76.8
1971	9.8	0.0	---	9.8	14.6	7.2	---	21.8	24.4	7.2	---	31.6
1972	5.5	0.2	---	5.7	8.6	24.6	---	33.2	14.4	24.8	---	39.2
1973	2.7	1.0	---	3.7	9.3	2.5	---	11.8	12.0	3.5	---	15.5
1974	6.6	7.4	---	14.0	21.7	0.8	---	22.4	28.3	8.2	---	36.5
1975	3.2	5.4	---	8.6	8.5	8.1	---	16.6	11.7	13.5	---	25.2
1976	2.8	12.1	---	14.9	10.3	3.7	---	14.0	13.1	15.8	---	28.9
1977	2.7	3.5	0.4	6.6	5.7	0.1	0.1	5.9	8.4	3.6	0.5	12.5
1978	1.9	0.1	0.2	2.2	4.8	0.2	0.3	5.3	6.7	0.3	0.5	7.5
1979	1.6	Tr [e]	0.1	1.7	5.3	Tr [e]	0.2	5.5	6.9	Tr [e]	0.3	7.2
1980	0.4	0.0	0.4	0.8	3.3	0.0	0.4	3.7	3.7	0.0	0.8	4.5
1981	0.8	0.0	0.4	1.2	3.3	0.0	0.2	3.5	4.1	0.0	0.6	4.7
1982	0.4	0.0	0.2	0.6	1.3	0.0	0.2	1.5	1.7	0.0	0.4	2.1

[a] Source: Bakkala et al. (1980) for catches through 1979; catches for 1980-82 from data on file, Northwest and Alaska Fisheries Center, Seattle, Washington.
[b] Catches from mothership-longline, North Pacific trawl, and landbased dragnet fisheries.
[c] May include some amounts of rockfishes, Sebastes spp., other than Pacific ocean perch.
[d] Includes catches from Republic of Korea, Taiwan, Poland, and Federal Republic of Germany.
[e] Tr: Trace less than 50 t.

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

The eastern Bering Sea is subdivided into two areas, P and Z (Fig. 2), for examining catch and CPUE trends in greater detail. Subarea P generally accounted for most of the Pacific ocean perch harvest; catches peaked in both areas in 1968 but declined rapidly thereafter (Table 5). Currently, this species comprises only a minor fraction of the total groundfish catch relative to its importance in earlier years. The lowest reported Pacific ocean perch harvest occurred in both subareas in 1982: 126 t from subarea P and 2 t from subarea Z.

In subareas P and Z, CPUE has declined precipitously since the early 1960s (Table 5). These values, however, may not be satisfactory indices of stock abundance. Pacific ocean perch is no longer a major target species in either subarea; within the past 10 yr, this species never comprised more than 0.63% of the total groundfish catch. As mentioned previously, total trawl effort remains high and incidental catches of Pacific ocean perch remain extremely low, suggesting a depressed stock condition.

Chikuni (1975) derived a relative abundance index based on changes in CPUE in the Japanese trawl fisheries from 1964 to 1972. Stern trawlers of vessel class 8 (Table 2) were employed as the standard vessel. Since Pacific ocean perch are caught in a multispecies fishery, Chikuni attempted to account for effort directed only toward this species. To accomplish this

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, 1968-82.

	Vessel class[a]						
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
1982	--	108	8	68	34	11	13
(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
1982	--	534	11	7	28	90	285

Table 2.--Continued.

Year	Vessel class[a] 3	4	5	6	7	8	9
(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
1982	--	45	3	28	14	5	5
(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	b	.01	.04	.01	.06	b	b
1980	b	b	b	b	b	b	b
1981	--	b	.05	b	.01	b	b
1982	--	b	.01	.01	.01	b	b

[a]No data for classes 1 and 2. 1973-82 data converted to pre-1973 gross tonnage classification of:

1 = 71-100	4 = 301-500	7 = 1,501-2,500
2 = 101-200	5 = 501-1,000	8 = 2,501-3,500
3 = 201-300	6 = 1,001-1,500	9 = 3,501 and above

[b]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, 1969-82.

Year	Catch of all species (t)	Catch of Pacific ocean perch (t)	POP in total catch (%)	Total effort (h)	CPUE[a] of POP (t/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[b]
1979	57,363	492	0.9	99,431	Tr[b]
1980	61,325	178	0.3	116,839	Tr[b]
1981	63,409	234	0.4	115,822	Tr[b]
1982	54,696	148	0.3	126,419	Tr[b]

[a]CPUE = catch per unit of effort.
[b]Tr = Trace (< 0.005 t/h).

Table 4.--Catch rate information on Pacific ocean perch and the dominant species taken by Japanese small trawlers, large surimi trawlers, and large freezer 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[c]
					Catch rate		
Area	Vessel	Year	Percent[a]	Rank[b]	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
		82	0.13	21	14	1	yfs,tur,pol
	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[d]	pol,cod,her
		81	0.05	6	39	3	pol,cod,sqd
		82	0.01	15	10	1	pol,jel,cod
	large freezer trawler	78	----	--	---	--	yfs,pol,cod
		79	0.33	12	100	11	yfs,pol,ap
		80	----	--	---	--	yfs,af,cod
		81	----	--	---	--	yfs,ap,cod
		82	----	--	---	--	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
		82	0.13	22	7	Tr[d]	tur,pol,cod
	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[d]	pol,cod,af
		81	0.00	31	1	Tr[d]	pol,cod,sqd
		82	0.00	34	1	Tr[d]	pol,her,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

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

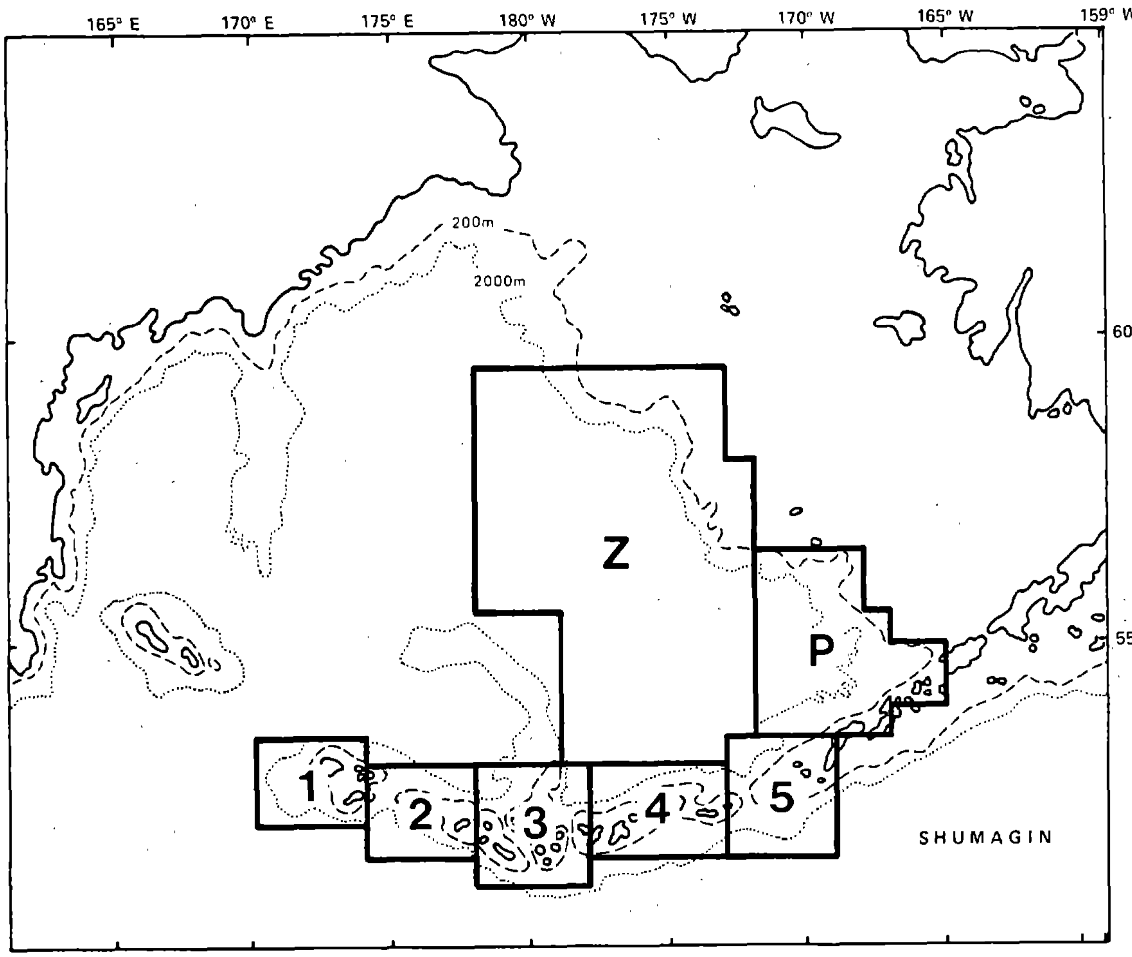

Figure 2. --Subdivisions of the eastern Bering Sea and Aleutian Islands region used to examine trends of catch and catch per unit of effort (CPUE) for Pacific ocean perch.

Table 5.--Annual catch (t) of Pacific ocean perch (POP), total catch of all species combined, percentage of POP in the total groundfish catch, total trawl effort (h), and catch per unit of effort (CPUE) (t/h) from the Japanese mothership longline North Pacific trawl-fishery for the eastern Bering Sea subareas (stern trawls only), 1963-82.

	Subarea P					Subarea Z				
Year	POP catch	Total catch	% POP	Total effort	POP CPUE	POP catch	Total catch	% POP	Total effort	POP CPUE
1963	559	1,350	41.41	324	1.73	381	943	40.40	189	2.02
1964	517	965	53.58	250	2.07	51	593	8.60	126	0.40
1965	2,133	7,127	29.93	1,135	1.88	49	205	23.90	73	0.67
1966	1,962	22,954	8.55	2,850	0.69	586	2,262	25.91	771	0.76
1967	4,889	116,233	4.21	14,785	0.33	3,492	14,852	23.51	3,366	1.04
1968	12,603	161,562	7.80	23,626	0.53	5,781	75,042	7.70	23,443	0.25
1969	6,144	306,786	2.00	35,483	0.17	3,867	55,194	7.01	18,367	0.21
1970	3,693	285,093	1.30	31,505	0.12	1,532	153,145	1.00	26,911	0.06
1971	2,505	466,882	0.54	48,541	0.05	1,538	221,665	0.69	42,579	0.04
1972	1,879	351,855	0.53	47,018	0.04	846	193,680	0.44	27,938	0.03
1973	509	155,881	0.33	24,006	0.02	363	407,696	0.09	43,196	0.01
1974	1,132	324,262	0.35	52,604	0.02	659	225,177	0.29	32,988	0.02
1975	414	326,588	0.13	51,719	0.01	916	224,139	0.41	46,155	0.02
1976	582	268,044	0.22	52,457	0.01	438	155.983	0.28	32,831	0.01
1977	831	132,526	0.63	33,890	0.02	314	149,915	0.21	30,511	0.01
1978	725	128,833	0.56	43,884	0.02	423	139,216	0.30	25,557	0.02
1979	855	169,595	0.50	46,386	0.02	120	103,846	0.12	21,403	0.01
1980	190	180,879	0.10	47,694	Tr[a]	12	111,290	0.01	23,202	Tr[a]
1981	191	186,887	0.10	52,144	Tr[a]	14	88,918	0.02	17,026	Tr[a]
1982	126	130,059	0.10	48,502	Tr[a]	2	75,369	0.00	15,827	Tr[a]

[a]Tr = Trace: less than 0.005 t/h

he regressed CPUE of vessel class 8 against the percent composition of Pacific ocean perch in the annual groundfish catch. The density index was then determined by inserting an arbitrarily set percentage figure (95%) into the regression equation. This adjusted CPUE supposedly represents what the true CPUE would be if all the effort was directed solely to harvesting Pacific ocean perch. Chikuni's density index depicts a period of increasing stock size from 1964 to 1966 followed by a decline to 1969 and then an increase through 1972 (Fig. 3).

Absolute Abundance

Trawl Surveys--Data from 1979, 1981, and 1982 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 by Japanese trawlers fishing on the slope at depths greater than 200 m. For this reason, only data collected by Japanese vessels were employed to calculate Pacific ocean perch abundance estimates.

Survey results from the eastern Bering Sea slope region indicate that biomass increased from 4,459 t in 1979 to 9,821 t in 1981 and then decreased to 5,505 t in 1982 (Table 6); population numbers and CPUE parallel this trend. These estimates, however, were characterized by relatively wide variances. The 95% confidence intervals overlapped extensively indicating that the. point estimates may not be significantly different.

A Japanese groundfish survey conducted in 1969 along the eastern Bering Sea slope provided sufficient information. to estimate Pacific ocean perch biomass within the 189-366 m (100-200 fathom) depth strata. Biomass estimates were also calculated for the 189-366 m depth strata from 1979-82 survey data.

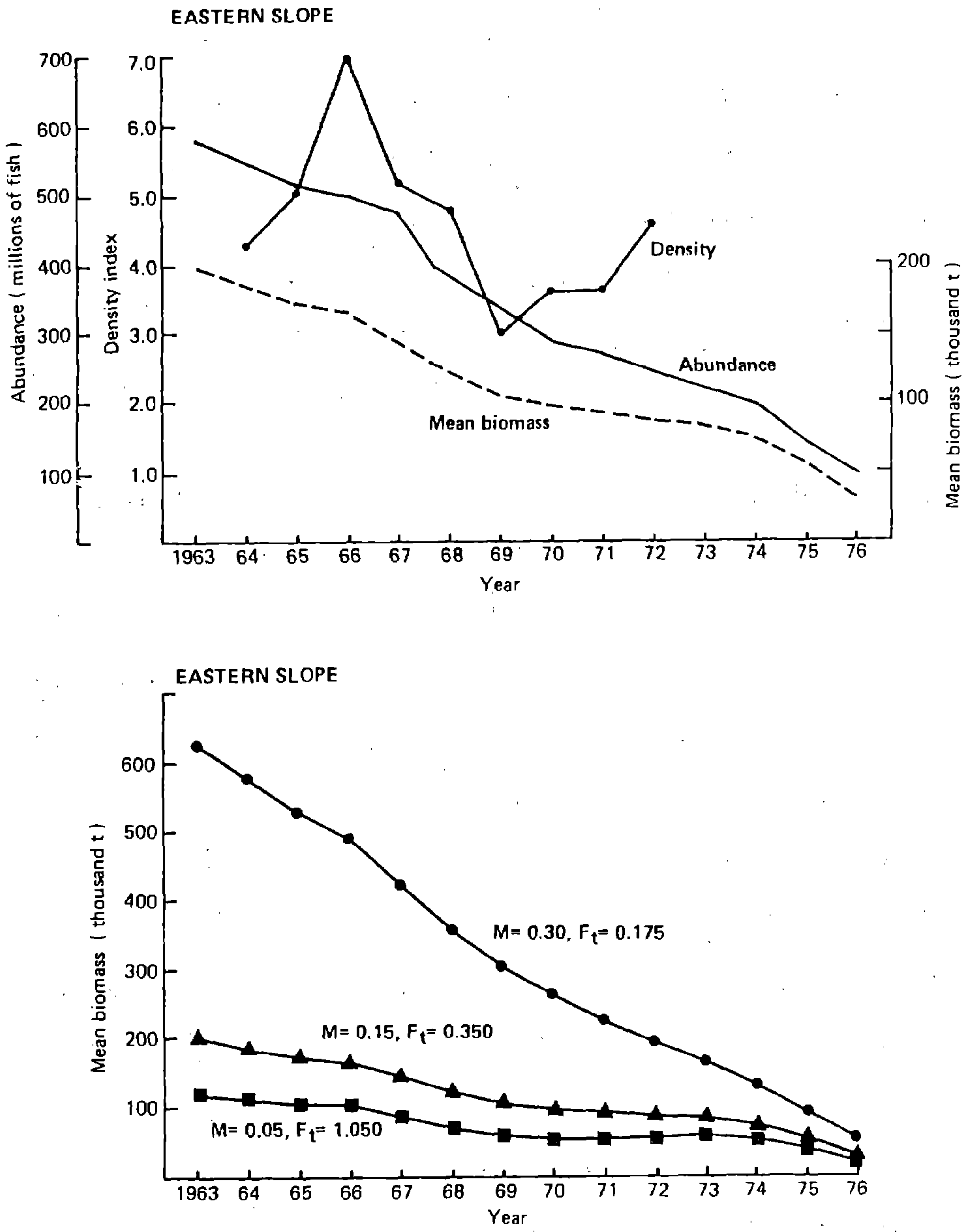

Figure 3. --Trends in abundance shown by biomass and population number estimates for Pacific ocean perch of the eastern Bering Sea from cohort analysis (Ito 1982), and density indices (Chikuui 1975) (upper panel), and upper and lower levels of biomass using various estimates of fishing and natural mortality from cohort analysis (Ito 1982) (lower panel).

Table 6.--Estimated catch per unit effort (CPUE), population numbers, and biomass of Pacific ocean perch in the eastern Bering Sea region as shown by data from cooperative U.S.-Japan trawl surveys in 1979-82 and the trawl survey conducted by Japan in 1969.

		Mean Estimates			
Depth strata	Year	CPUE (kg/ha)	Population numbers (millions)	Biomass (t)	95% confidence intervals for biomass estimates (t)
>100 m	1979	1.20	6.322	4,459	0 - 9,217
	1981	2.63	14.317	9,821	5,567 - 14,074
	1982	1.48	7.781	5,505	3,074 - 7,937
189-366 m	1969	22.64	--	31,329	12,732 - 49,926
	1979	3.15	6.273	4,363	--
	1981	5.41	10.814	7,486	4,065 - 10,908
	1982	3.80	7.490	5,254	2,834 - 7,673

Although the sampling design and trawl gear employed during the 1969 and 1979-82 surveys were different, the data should provide an approximation of changes in abundance between the two periods. The data indicate that Pacific ocean perch biomass fell approximately 86% during the 10-yr period from 1969 to 1979 (Table 6). Recently, biomass in the 189-366 m depth strata appears to have stabilized at a low level, averaging about 5,700 t during the 1979-82 survey period.

The abundance estimates from these surveys probably underestimate the true population size of Pacific ocean perch. As pointed out by Bakkala et al. (1982a), 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.

Cohort Analysis

Commercial CPUE data have become increasingly difficult to interpret. Standardizing and partitioning total groundfish effort into effort directed solely toward Pacific ocean perch is extremely difficult, particularly in the eastern Bering Sea. Increased quota restrictions, effort shifts to different target species, and rapid improvements in fishing technology have confounded the estimation of effective fishing effort. These factors must be considered if CPUE is to accurately reflect changes in stock abundance.

An alternative to commercial CPUE and trawl survey stock assessments is cohort analysis. Cohort analysis techniques have been developed to circumvent the need for reliable effort statistics. These techniques estimate past population numbers and biomass at age and age-specific rates of instantaneous fishing mortality. Historical catch-at-age data, an estimate of natural mortality (M), and an estimate of terminal fishing mortality (F(t)) for each year-class are required for the analysis.

Ito (1982) applied cohort analysis to catch-at-age data from the eastern Bering Sea Pacific ocean parch stock. The technique employed was based on the equations of Pope (1972). Catch and age data (1963-79) were derived from Chikuni (1975), foreign reported catches, and U.S. observer data bases. Natural and terminal fishing mortalities were estimated from the literature.

Assuming M=0.15 and F(t)=0.35 represented reasonable estimates, mean stock biomass in the eastern Bering Sea was estimated to decline from 201,461 t in 1963 to 30,970 t in 1976, a reduction of about 85%. These results do not correlate well with the trend of Chikuni's (1975) density index (Fig. 3). This index indicates two periods of increasing stock size during 1964-66 and 1969-72. The results from cohort analysis, on the other hand, indicate a continuous long-term decline in stock abundance from 1963 to 1976.

The Chikuni index assumes that the percentage of Pacific ocean perch in the total groundfish catch represents the fraction of the total effort directed toward catching Pacific ocean perch. However, if all the effort was directed to catching this species and this species represented only 20% of the total groundfish catch, no adjustment to the CPUE figure should be required. Chikuni's density index, however, would still make the correction to CPUE as if only 20% of the total effort was directed toward Pacific ocean perch. The density index in this case would be biased toward the high side. Furthermore, this method involves other potential biases such as that introduced by arbitrarily fixing the standard catch proportion at 95% for the eastern Bering Sea stocks.

When employing CPUE as an index of stock abundance, the major source of bias stems from the measurement of effective fishing effort. Effective effort is very difficult to quantify, particularly in multispecies fisheries. Chikuni (1975) attempted to estimate effective fishing effort, but as noted above, there were drawbacks with this method. Furthermore, none of the CPUE indices considered in his analysis made adjustments for learning and skill factors.. Rapid developments in technology and fishing skill undoubtedly occurred throughout the history of the Pacific ocean perch fishery, and unless these factors are considered, CPUE may be seriously biased as an index of stock abundance.

The abundance results from cohort analysis do not depend on accurate measures of effective fishing effort, and stock size is measured as an absolute value, rather than as an index. Although cohort analysis is free from errors associated with the estimation of effective fishing effort, this type of analysis is subject to its own set of errors such as incorrect estimates of M, F(t), and catch at age.

Because of the uncertainty regarding the true values of the input parameters (M and F(t)), Ito (1982) examined their effect on the abundance estimates from cohort analysis. Natural mortality (M) was varied using values of 0.05, 0.10, 0.15, 0.20, and 0.30. The values of F(t) employed were 0.175, 0.350, 0.525, 0.700, and 1.050. Based on the literature, these values encompassed a conceivable range for the model parameters. Twenty-five computer runs were necessary to accommodate all possible combinations of these trial values.

The paired values of M=0.05, F(t)=1.050, and M=0.30, F(t)=0.175 yielded the lowest and highest estimates respectively of stock abundance for any given year. Abundance estimates based on these two sets of parameter values established a "range" about the base (M=0.15, F(t)=0.350) population estimate. The trend in mean biomass, regardless of the parameter set employed, was downward (Fig. 3). When M=0.30 and F(t)=0.175 were used, the decline in biomass was much steeper than when the other two parameter sets were employed. Overall, the abundance estimates were highly sensitive to changes in M, more so than changes in F(t).

During the 1983 U.S.-Japan bilateral meetings, the Japanese scientific delegation indicated that the F(t) values used in Ito's (1982) cohort analysis were too high. On the contrary, these values do not appear high if one considers that recent removals were taken from a depleted stock. This would justify high F(t) values since Pacific ocean perch catches, although mostly incidental in nature, still represent significant removals from the stock. Nevertheless, the cohort analysis results will be reanalyzed in the the future employing smaller F(t) values.

Age composition employed in the cohort analysis was based on data from Chikuni (1975) and the U.S. observer program. Although these data were assumed accurate, recent aging studies indicate that Pacific ocean perch may be much older than previously thought (Beamish 1979; Archibald et al. 1981). It is beyond the scope of the present report, however, to discuss the consequences of incorrect age data on the cohort analysis results.

Length and Age Composition

Length data collected by Japan during the U.S.-Japan trawl surveys show that Pacific ocean perch ranged in length from 10 to 56 cm; the average lengths in 1979, 1981, and 1982 were 36.4, 34.0, and 35.0 cm, respectively. The 1981 and 1982 length distributions suggest the recruitment of a strong year-class (Fig. 4). The first modal peak in 1981 occurred at 26 cm; the following year it shifted to 28 cm. The relative strength of

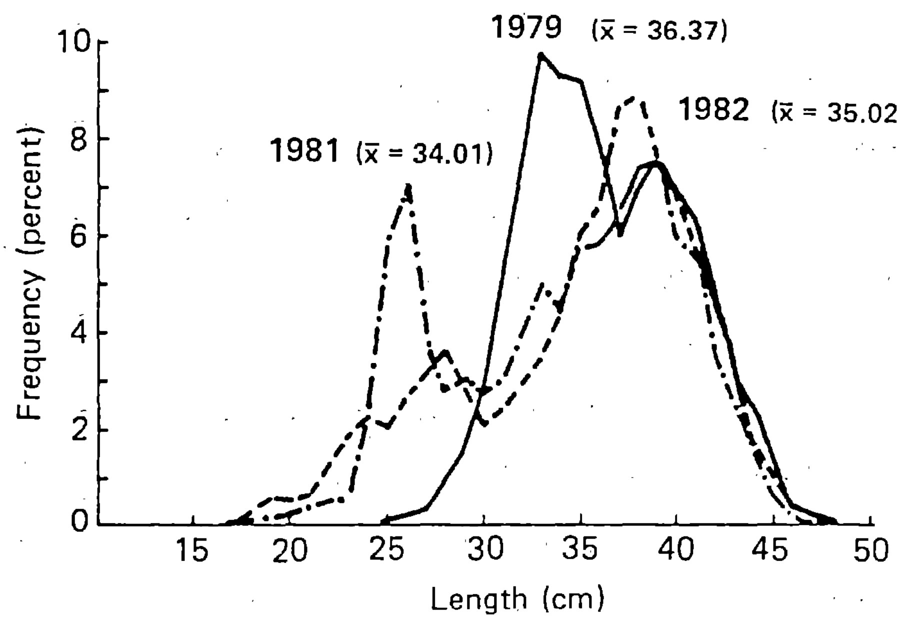

Figure 4.--Size composition of Pacific ocean perch in the eastern Bering Sea as shown by data collected by Japanese trawlers during the cooperative U.S.-Japan demersal trawl surveys in 1979, 1981, and 1982.

this year-class cannot be determined because of the absence of comparative data for other year-classes except that in 1979.

To determine the year-class represented by the incoming modes in 1981 and 1982, modal peak lengths were inserted in the von Bertalanffy growth equations with growth parameters calculated by Ito (1982) and Chikuni (1975) and the equation solved for age. The age represented by the 1981 mode was 5.88 and 6.63 yr, respectively based on the two sets of growth parameters. The 1982 mode represented an age between 6.81 and 7.63 yr. Assuming the mode in 1981 represented an age of 6 yr and in 1982 an age of 7 yr, the modes would represent the 1975 year-class.

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 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, show drastic reductions in CPUE. From 1969 to 1979, the CPUE of vessel class 4 dropped 94.6% and has remained at or below the 1979 level for the past 4 yr. 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) also showed substantial declines.

Catch and effort data from the landbased dragnet fishery also indicate decreasing stock abundance. CPUE fell from 0.32 in 1969 to 0.01 in 1982 (Table 8). The CPUE data from 1977 to 1982, however, may not be reliable indices of population size. Pacific ocean perch catches were low during this period, accounting for less than 5% of the total catch of all species combined.

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, 1968-82.

Year	Vessel class[a] 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
1982	325	103	252	284	13	0
(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
1982	6,607	889	1,003	228	516	236

Table 7.--Continued.

Year	Vessel class[a] 4	5	6	7	8	9
(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
1982	33	11	26	29	1	0
(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
1982	Tr[b]	0.1	0.3	1.2	Tr[b]	0.0

[a]No data for classes 1, 2, and 3 which are mainly side and pair trawls.
1973-82 data converted to pre-1973 gross tonnage classification of:

1 = 71-100	4 = 301-501	7 = 1,501-2,500
2 = 101-200	5 = 501-1,000	8 = 2,501-3,500
3 = 201-300	6 = 1,001-1,500	9 = 3,501 and above

[b]Less than 0.1.

Table 8. Pacific ocean perch (POP) catch and effort data from stern trawlers of the Japanese landbased dragnet fishery in the Aleutian region, 1969-82.

Year	Catch of all species in (t)	Catch of Pacific ocean perch (t)	POP in total catch (%)	Total effort (h)	CPUE[a] 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
1982	41,384	367	0.9	59,289	0.01

[a]CPUE = catch per unit of effort

Catch rate information collected by U.S. observers aboard Japanese small trawlers (<1,500 gr tons) indicates that abundance has continued to decline since 1977 (Table 9). CPUE in units of kg/d and kg/h fell 92.2 and 95.6%, respectively, from 1977 to 1982. With the exception of 1978 and 1982, Pacific. ocean perch ranked among the top three species in the catch by small trawlers. For years other than 1978 and 1982, CPUE should be a fairly good index of stock size.

The Aleutian region was subdivided into five areas (Fig. 2) to examine catch and CPUE trends in more detail. Annual CPUE was plotted for each subarea (Fig. 5). To evaluate the significance of the CPUE trends, the percentage of Pacific ocean perch in the total groundfish catch was plotted as well. If Pacific ocean perch comprised greater than 80% of the total groundfish catch, it was assumed that this species was the primary target for the trawl fishery. In such cases, CPUE should function well as an index of stock abundance.

The greatest reductions in CPUE occurred in subareas 2, 3, and 4 (Fig. 5). CPUE in subarea 2 dropped 92% during the 11-yr period from 1964 to 1974. yet during this period, Pacific ocean perch accounted for over 95% of the total groundfish catch. Subareas 3 and 4 show similar declines in CPUE. From 1963 to 1971, CPUE in subareas 3 and 4 fell 86 and 76%, respectively; Pacific ocean perch averaged well over 80% of the total groundfish catch in both subareas. With the 5 subareas combined, CPUE declined 79% during 1963-71. CPUE declined further after 1971, but these values may not be indicative of actual changes in stock abundance. The percent composition of Pacific ocean perch in the total groundfish catch never exceeded 80% after 1971.

Changes in abundance of Pacific ocean perch in 1977-82 were examined analyzing CPUE of vessel class 4 stern trawlers in each subarea. These were

Table 9.--Catch rates for Pacific ocean parch and the dominant species taken by Japanese small trawlers in the Aleutian region as shown by U.S. observer data, 1977-82.

Year	Pacific ocean perch Rank	kg/d	kg/h	First three species caught in order of abundance
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
82	6	366	28	Rattail - unidentified Walleye pollock Greenland turbot

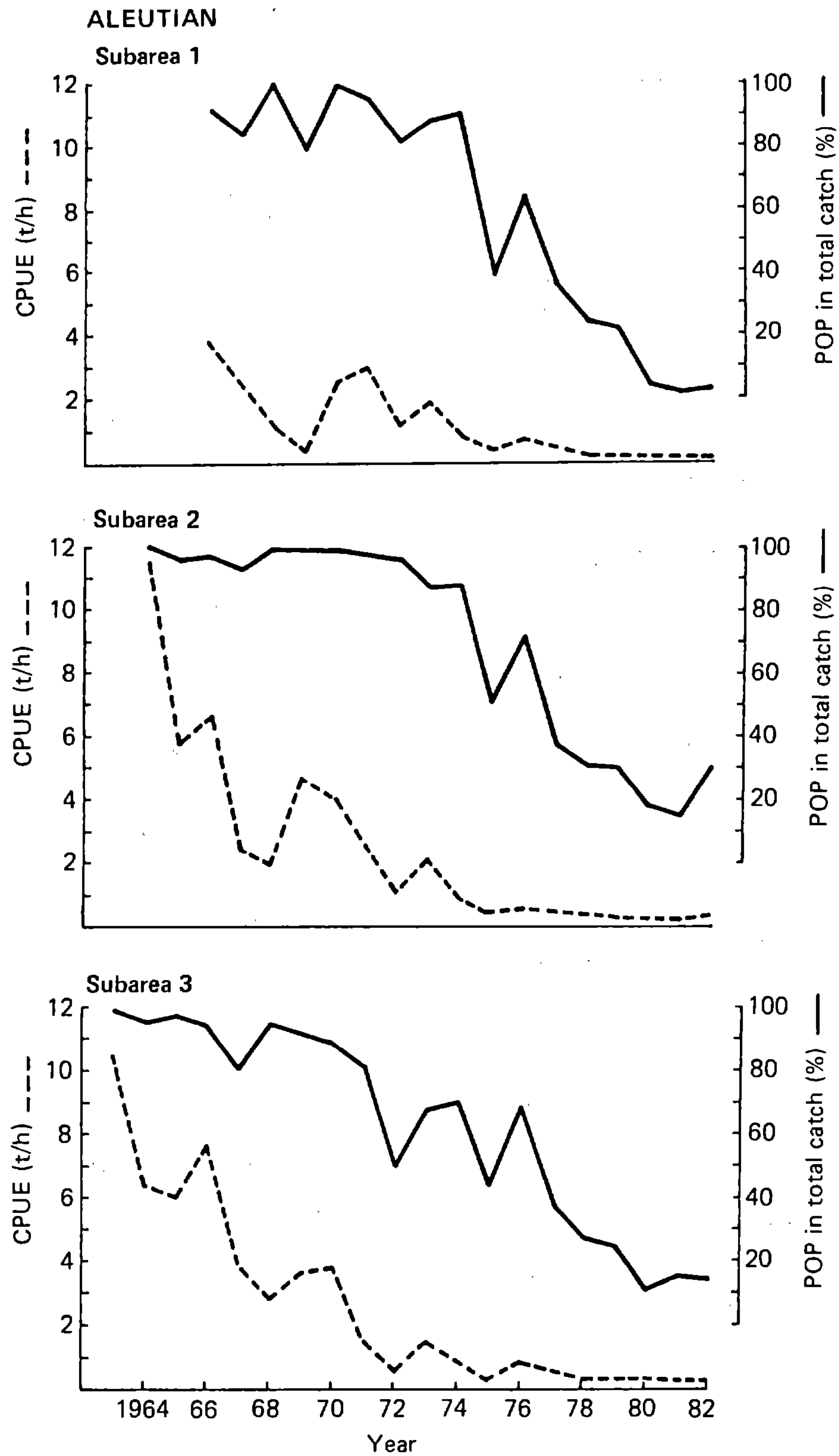

Figure 5. --Annual changes in the percentage of Pacific ocean perch (POP) in the total groundfish catch and POP catch per unit effort (CPUE) in subareas of the Aleutian Islands.

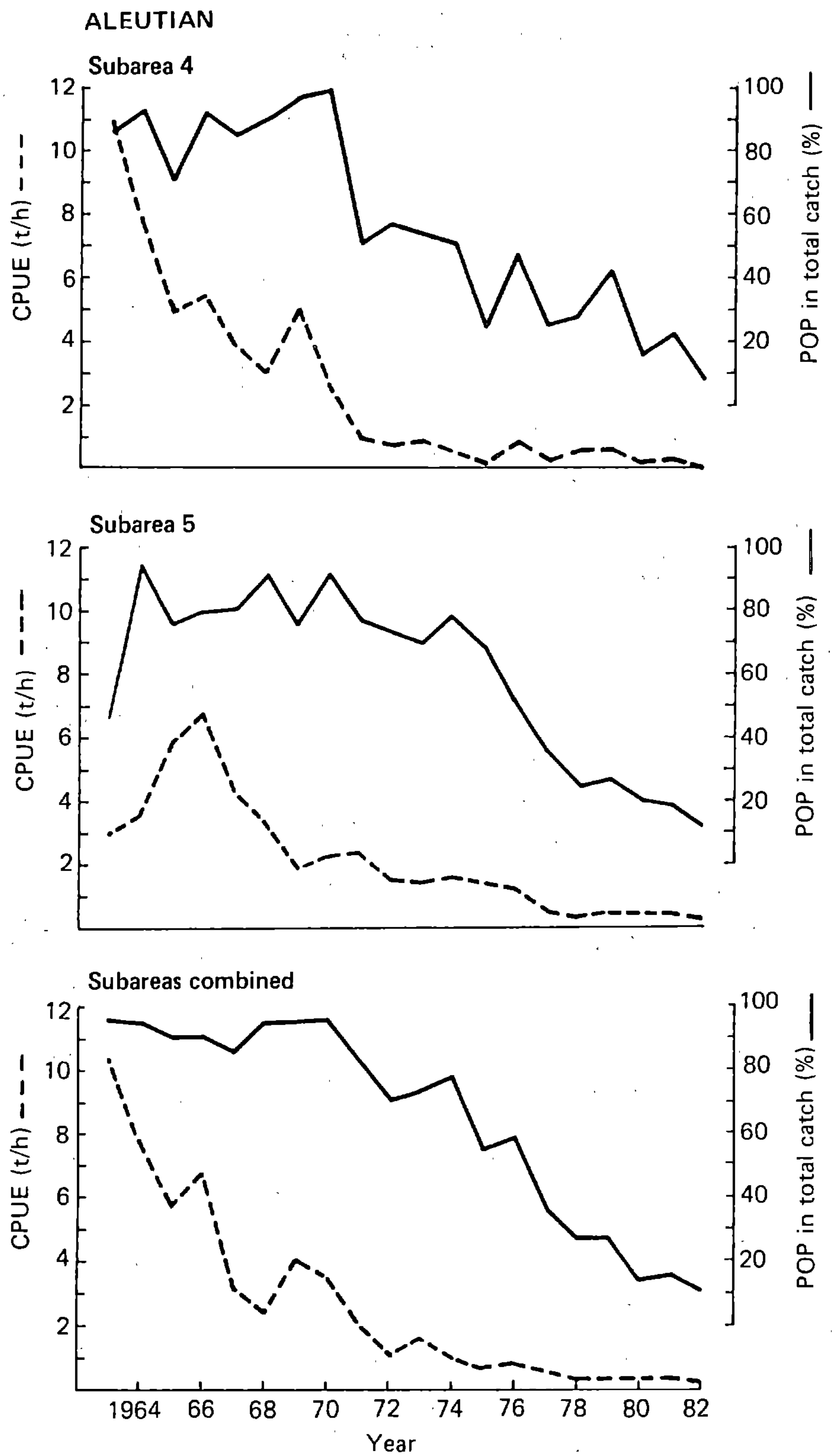

Figure 5. --Continued.

used in the analysis because of their relatively high sustained annual catches of Pacific ocean perch during this period. The results indicate that abundance declined markedly in subareas 1-3; CPUE fell by at least 50% in 1977-82 (Table 10). With the exception of subarea 1, CPUE in 1982 dropped to its lowest level since 1977.

Chikuni (1975) derived a density index for the Aleutian region based on changes in CPUE in the Japanese trawl fisheries during 1964-72. The method employed to derive this index was the same as that described in the above section for the eastern Bering Sea stock. The results indicate that abundance decreased during 1965-66, increased the following year, and then continually decreased from 1967 to 1972 (Fig. 6).

Absolute Abundance

Trawl Surveys--During the summer-fall of 1980, the Northwest and Alaska Fisheries Center, in cooperation with the Japan Fishery Agency, conducted a groundfish survey of the Aleutian Islands from Unimak Pass to Attu Island. This was the first National Marine Fisheries Service (NMFS) resource assessment survey of groundfish conducted in the Aleutian Islands region. Therefore, no previous survey data bases are available to measure changes in the status of Pacific ocean perch stocks in the survey area.

The exploitable biomass of Pacific ocean perch in the Aleutian Islands region (long. 170°E-170°W) was estimated at 107,800 t. The biomass estimate from the Aleutian Islands portion of International North Pacific Fisheries Commission (INPFC) statistical area 1 was about 7,000 t. The bulk of the biomass (86.2%) occurred in the depth range from 100 to 300 m. Pacific ocean perch averaged about 31.0 cm in length and 0.4 kg in weight.

Table 10.--Annual catch and catch per unit of effort (CPUE) of Pacific oceanperch (POP) from Japanese class 4 stern trawlers (excluding landbased trawlers) by subarea in the Aleutian region, 1977-82.

	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
1982	585	93	0.22	558	107	0.14	259	33	0.10	132	11	0.08	1,305	66	0.04

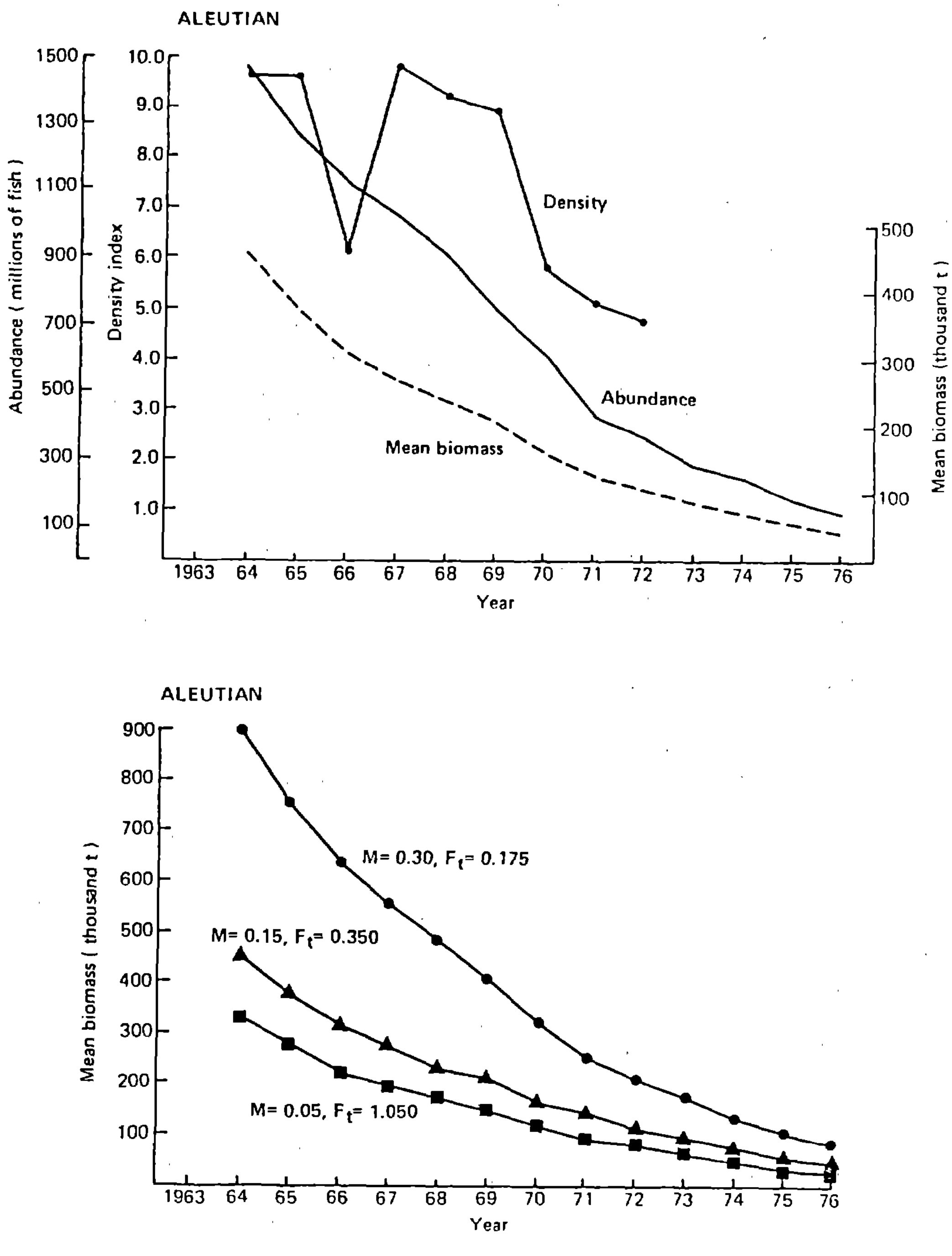

Figure 6. --Trends in abundance shown by biomass and population number estimates for Pacific ocean perch of the Aleutian Islands from cohort analysis (Ito 1952) and density indices (Chikuni 1975) (upper panel) and upper and lower levels of biomass using various estimates of fishing and natural mortality from cohort analysis (Ito 1982) (lower panel).

Cohort Analysis

Ito (1982) applied cohort analysis to catch-at-age data from the Aleutian Islands Pacific ocean perch stock. As with the eastern Bering Sea cohort analysis, the catch and age data (1964-79) were derived from Chikuni (1975), foreign reported catches, and U.S. observer data bases. Natural and terminal fishing mortalities were estimated from the literature.

Assuming M=0.15 and F(t)=0.35 represented reasonable parameter estimates, the cohort analysis indicated that mean stock biomass in the Aleutian Islands declined from 453,046 t in 1964 to 40,104 t in 1976, a reduction of about 91% (Fig. 6). Unlike the trend of the Chikuni (1975) density index, the results from cohort analysis indicate a continuous long-term decline in stock abundance from 1964 to 1976.

Because of the uncertainty regarding the true values of the input parameters, Ito (1982) examined their effect on the cohort analysis results. Natural and terminal fishing mortalities were varied using the same parameters as those used for the eastern Bering Sea stock. These values ranged from 0.05 to 0.30 for M, and from 0.175 to 1.050 for F(t).

The paired values of M=0.05, F(t)=1.050, and M=0.30, F(t)=0.175 yielded the lowest and highest estimates of stock abundance, respectively, for any given year. Abundance estimates based on these two parameter sets established a "range" about the base (M=0.15, F(t)=0.350) population estimate (Fig. 6). The trend in mean biomass, regardless of the parameter set employed, was downward. When M=0.30 and F(t)=0.175 were used, the decline in-biomass was much steeper than when the other two parameter sets were employed. Like the eastern Bering Sea cohort analysis results, the abundance estimates from the Aleutian region were highly sensitive to changes in M, more so than changes in F(t).

The 1976 biomass estimate from the cohort analysis base run probably underestimates the true population size of Pacific ocean perch. This estimate is about 67,700 t less than the 1980 U.S.-Japan trawl survey estimate and suggests that the value of M used in the cohort analysis was too low and/or the value of F(t) was too high. Regardless of which parameter values are employed, however, the trend in mean biomass is most likely to be downward (Fig. 6). The cohort analysis data, nevertheless, will be re-analyzed at a future date using lower values of F(t).

Length and Age 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. The average size increased from 30.8 cm in 1977 to 33.2 cm in 1981 and then decreased sharply to 30.1 cm in 1982 (Fig. 7). Based on aging methods employed at the NWAFC, the commercial fishery appears to be dependent on a wide range of ages, 4 to 20 yr. From 1978 to 1980, the average age in the catch decreased from 11.0 to 9.2 yr. The dominant mode in the 1982 length distribution with a peak at 28 cm indicates, as did the eastern Bering Sea data, that the 1975 year-class is also relatively strong in the Aleutians.

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

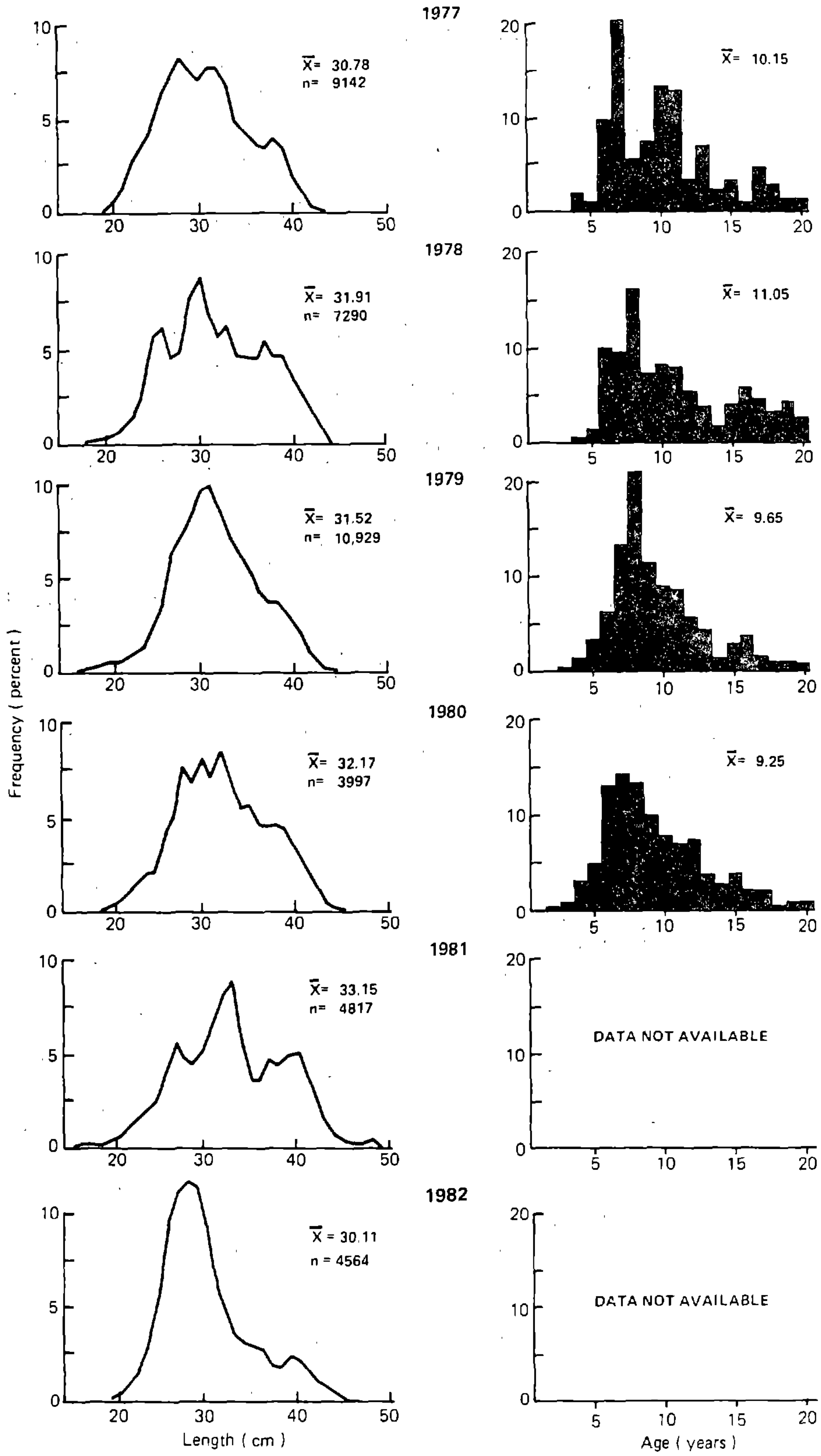

Figure 7.--Length and age composition of Pacific ocean perch in the Aleutian region as shown by data taken by U.S. observers from catches aboard Japanese small stern trawlers, 1977-82.

1975). Clearly, sustained exploitation at these levels was not-possible (Table 1). The eastern Bering Sea slope region has produced catches in excess of 32,000 t only once. Pacific ocean perch harvest 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 were 13,600 t in the eastern Bering Sea based on combined estimates from the 1980 Aleutians survey in INPFC statistical area 1 and the mean of the 1979-82 eastern Bering Sea surveys and 107,800 t in the Aleutians region in 1980. Assuming that a 10% exploitation rate is sustainable from the two stocks and that actual biomasses of the populations may be underestimated by survey data, EY for 1983-84 is minimally estimated to be about 1,360 t in the eastern Bering Sea and 10,800 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. Trawl surveys and cohort analysis results also suggest substantial declines in abundance. Although evidence was presented to indicate that the 1975 year-class may be relatively strong in both the eastern Bering Sea and Aleutians, there is no evidence as yet that this year-class has substantially increased abundance, despite reduced annual catch levels in 1978-82 of only 600-2,200 t in the eastern Bering Sea and 1,500-5,500 t in the Aleutian region. Ito (1982) points out that even incidental catches made while seeking other groundfish species may be sufficiently great to keep Pacific ocean perch stocks in a depleted state. In order to promote rebuilding, it is therefore advisable to set catch levels below EY.

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. As a result, 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 1977-82.

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, 1983). 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 1977-82 catches of all rockfish (including Pacific ocean perch) by species and International North Pacific Fisheries Commission (INPFC) statistical area (see Fig. 1 in the section on walleye pollock in this report for the location of INPFC areas) are listed in Tables 2-7. Catches of all rockfish increased from 22,000 t in 1977 to 31,800 t

Table 1.--The common and scientific names of rockfish (<u>Sebastes</u> and <u>Sebastolobus</u> 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[a]	
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*

[a]The occurrence of these 14 species in the eastern Bering Sea and Aleutian Islands region has not been documented in the literature.

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[a]	-	-			1.2	T[a]
Darkblotched rockfish	2.4	0.2	-	-	-	-	0.4	T[a]	2.8	T[a]
Dusky rockfish	2.0	0.2	1.1	T[a]	-	-	2,932.9	16.6	2,936.0	13.3
Harlequin rockfish	-	-	-	-	-	-	1.0	T[a]	1.0	T[a]
Northern rockfish	0.3	T[a]	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[a]	3.2	T[a]
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[b]	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

[a]T = <0.1%.
[b]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[a]	-	-	1.6	T[a]	2.3	T[a]
Blue rockfish	-	-	8.9	T[a]	-	-	-	-	8.9	T[a]
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[a]	1.4	T[a]	0.1	0.1	8.1	T[a]	10.3	T[a]
Longspine thornyhead	-	-	0.4	T[a]	-	-	0.2	T[a]	0.6	T[a]
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[a]	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[a]	1.4	T[a]
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[a]	-	-	-	-	0.8	T[a]
Other rockfish[b]	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

[a]T = <0.1%.
[b]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: Area 1 (t)	Area 1 (%)	Area 2 (t)	Area 2 (%)	Area 3 (t)	Area 3 (%)	Area 5 (t)	Area 5 (%)	Total (t)	Total (%)
Black rockfish	11.6	0.8	0.6	T[a]	-	-	2.3	T[a]	14.5	T[a]
Blue rockfish	0.2	T[a]	-	-	-	-	-	-	0.2	T[a]
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[a]	-	-	2.2	T[a]	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[a]	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[a]	-	-	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[a]	1.0	T[a]
Other rockfish[b]	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

[a]T = <0.1%.

[b]See Table 1 for explanation of "other rockfish" category.

Table 5.--Catches (t) of all species of rockfish, Sebastes and Sebastolobus spp., by International North Pacific Fisheries Commission statistical area in the Bering Sea-Aleutian Islands groundfish fishery 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	T[a]	-	-	-	-	0.06	T[a]	-	-	-	-	-	-	-	-
Darkblotched rockfish	0.29	T[a]	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[a]	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[a]	-	-	0.29	T[a]	-	-	-	-	-	-	-	-
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[a]	T[a]	0.16	100.0	47.49	75.6
Redbanded rockfish	0.31	T[a]	2.96	0.2	6.76	0.1	10.03	0.1	-	-	-	-	-	-	-	-
Redstripe rockfish	0.18	T[a]	0.03	T[a]	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[a]	T[a]	0.33	0.5
Sharpchin rockfish	3.10	0.4	-	-	0.20	T[a]	3.30	T[a]	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[a]	T[a]	T[a]	T[a]
Other rockfish[b]	0.07	T[a]	1.20	T[a]	1.95	T[a]	3.22	T[a]	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

[a] T <0.01 t or T <0.1%.
[b] See Table 1 for explanation of "other rockfish" category.

Table 6.--Catches (t) of all species of rockfish, Sebastes and Sebastolobus spp., by International North Pacific Fisheries Commission statistical area 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[a]	T[a]	-	-	-	-	T[a]	T[a]	-	-	-	-	-	-	-	-
Blackgill rockfish	0.4	T[a]	T[a]	T[a]	-	-	0.4	T[a]	-	-	-	-	-	-	-	-
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[a]	T[a]	-	-	T[a]	T[a]	T[a]	T[a]
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[a]	-	-	-	-	-	-	-	-
Northern rockfish	16.2	1.6	14.6	1.1	137.6	2.7	168.4	2.3	T[a]	T[a]	-	-	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[a]	T[a]	1.3	0.1	T[a]	T[a]	1.3	T[a]	-	-	-	-	-	-	-	-
Redstripe rockfish	T[a]	T[a]	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[a]	4.1	0.1	-	-	-	-	-	-	-	-
Shortraker rockfish	30.3	3.1	414.0	30.8	450.8	9.0	895.1	12.1	-	-	-	-	-	-	-	-
Shortspine thornyhead	52.2	5.3	143.7	10.7	276.3	5.5	472.2	6.4	-	-	-	-	-	-	-	-
Silvergray rockfish	-	-	-	-	T[a]	T[a]	T[a]	T[a]	-	-	-	-	-	-	-	-
Other rockfish[b]	T[a]	T[a]	3.1	0.2	20.8	0.4	23.9	0.3	-	-	-	-	T[a]	T[a]	T[a]	T[a]
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

[a]T <0.01 t or T <0.1%.
[b]See Table 1 for explanation of "other rockfish" category.

Table 7.--Catches (t) of all species of rockfish, <u>Sebastes</u> and <u>Sebastolobus</u> spp., by International North Pacific Fisheries Commission statistical area in the Bering Sea-Aleutian Islands groundfish fishery in 1982 adapted from (Nelson et al. 1983).

	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)	(%)
Blackgill rockfish	0.1	T[a]	0.8	0.1	4.8	0.1	5.7	0.1	-	-	-	-	-	-	-	-
Darkblotched rockfish	1.9	0.4	5.3	0.9	7.6	0.2	14.8	0.3	-	-	-	-	-	-	-	-
Dusky rockfish	10.7	2.2	3.2	0.6	3.8	0.1	17.7	0.3	1.3	4.7	-	-	-	-	1.3	4.3
Harlequin rockfish	1.0	0.2	1.4	0.2	0.4	T[a]	2.8	0.1	-	-	-	-	-	-	-	-
Longspine thornyhead	0.6	0.1	0.4	0.1	2.1	0.1	3.1	0.1	-	-	-	-	-	-	-	-
Northern rockfish	62.6	13.0	5.4	0.9	193.1	5.1	261.1	5.4	1.7	6.1	-	-	-	-	1.7	5.7
Pacific ocean perch	110.7	22.9	100.8	17.8	1,011.9	26.6	1,223.4	25.2	3.4	12.2	-	-	2.1	100.0	5.5	18.3
Redstripe rockfish	5.2	1.1	3.3	0.6	2.2	0.1	10.7	0.2	4.6	16.5	-	-	-	-	4.6	15.3
Rougheye rockfish	28.2	5.8	121.9	21.5	158.8	4.2	308.9	6.4	T[a]	T[a]	-	-	-	-	T[a]	T[a]
Sharpchin rockfish	3.1	0.6	0.6	0.1	14.5	0.4	18.2	0.4	-	-	-	-	-	-	-	-
Shortraker rockfish	137.5	28.5	216.9	38.3	312.1	8.2	666.5	13.7	12.0	43.0	-	-	-	-	12.0	40.0
Shortspine thornyhead	119.2	24.7	100.2	17.7	2,089.1	54.9	2,308.5	47.6	4.9	17.6	-	-	-	-	4.9	16.3
Splitnose rockfish	0.4	0.1	4.4	0.8	3.3	0.1	8.1	0.1	-	-	-	-	-	-	-	-
Other rockfish[b]	1.3	0.3	2.4	0.4	0.7	T[a]	4.4	0.1	T[a]	T[a]	-	-	-	-	T[a]	T[a]
Total	482.5	99.9	567.0	100.0	3,804.4	100.1	4,853.9	100.0	27.9	100.1	-	-	2.1	100.0	30.0	99.9

[a]T <0.01 t or T <0.1%.
[b]See Table 1 for explanation of "other rockfish" category.

in 1979. Since 1979 catches have decreased to a low of about 4,800 t in 1982. The large decrease from 1979 to 1980-82 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 Fishery 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 accounted for the largest portion of the Bering Sea-Aleutians catch of rockfish in 1977-82. Catches in the Aleutians region increased from about 17,700 t in 1977 to about 20,000 t in 1979 but then decreased to 3,800 t by 1982. In each year, Pacific ocean perch was the dominant species taken, except in 1982, when shortspined thornyhead rockfish dominated. Northern, rougheye, shortraker, dusky, darkblotched, and shortspine thornyhead rockfish have also made up significant portions of the rockfish catch at times during the past 6 yr.

In areas other than the Aleutian region, INPFC area 2 has been the most productive area for rockfish. Total removals in this area ranged from about 600 t to 13,100 t in 1977-82. Combined catches of shortraker, rougheye, and shortspine thornyhead rockfish have accounted for 40-89% of the total rockfish removals from area 2 in 1977-82. Bering Sea areas 1 and 3 are of relatively minor importance in terms of rockfish catches; combined catches from these areas did not exceed 1,500 t annually in 1977-82.

Estimated catches of "other rockfish" (excluding Pacific ocean perch) were estimated by U.S. observers for 1977-82 as follows:

Region	Catch (t) 1977	1978	1979	1980	1981	1982
Eastern Bering Sea	1,678	12,222	10,097	1,367	1,110	838
Aleutians	9,587	8,737	14,543	1,366	1,394	2,792

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 1980-82 was due to these species being placed under specific catch quotas since 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 yields (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.

Data from the 1979, 1981, and 1982 cooperative U.S.-Japan trawl surveys provide biomass estimates for "other rockfish" in the eastern Bering Sea. These surveys were conducted on both the continental shelf and slope but almost all catches of "other rockfish" were taken by Japanese trawlers fishing on the slops at depths greater than 200 m. For this reason, only data collected by Japanese vessels were employed to calculate abundance estimates.

Survey results indicate that the biomass of "other rockfish" in the eastern Bering Sea increased from 5,646 t in 1979 to 9,385 t in 1981 and 10, 180-t in 1982. These abundance estimates, however, should be viewed with caution because of their relatively low degree of precision. Based on the 1980 cooperative U.S .-Japan survey of the Aleutian region, there was another 2,800 t of "other rockfish" in the Aleutian Islands portion of INPFC area 1 (north side of Aleutians from long. 165°W to 170°W). Thus, an overall estimate for the eastern Bering Sea region, based on the 1980 Aleutian survey data and the mean of the 1979-82 eastern Bering sea survey data, is 11,204 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, long. 170°W to 170°E) was 52,100 t for other rockfish. This estimate is lower than the 167,000 t estimated by Ikeda (1979) from survey data in the early 1970s.

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 for 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)	1979-82 survey biomass estimates (t)	Data of Ikeda (1979) Biomass estimates (t)	Data of Ikeda (1979) MSY estimates (t)
Eastern Bering Sea	11,000 (1978-79)	11,200	55,000	7,000-15,000
Aleutians	11,000 (1977-79)	52,100	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 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

Lael L. Ronholt

INTRODUCTION

Atka mackerel, *Pleurogrammus monopterygius*, are found throughout the Aleutian and Komandorskiye Islands, westward to the east coast of the Kamchatka Peninsula, 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 largest landings have come from the Aleutian region which, from 1978 to 1982, 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 (in metric tons) by International North Pacific Fisheries Commission (INPFC) area in the Bering Sea.

Region	INPFC area	Year 1978	1979	1980	1981	1982
Eastern Bering Sea	I	422	1,653	4,235	2,307	155
Eastern Bering Sea	II	410	332	462	721	173
Central Bering Sea	III	0	0	0	0	0
Aleutians	V	23,418	21,279	15,793	16,661	19,546
Total		24,250	23,264	20,490	19,689	19,874

CONDITION OF STOCK

Catch Statistics

The total annual landings of Atka mackerel increased throughout the 1970s peaking in 1978 at 24,250 t, but have declined to about 20,000 t since then (Table 2). From 1979 to 1981, landings have generally increased in the eastern Bering Sea and declined slightly in the Aleutian region; however, for 1982, the reverse trend was noted (Table 1). From 1970 to 1979, the U.S.S.R. was the principal harvester of Atka mackerel in the Bering Sea. After the cessation of Soviet fishing in 1980, the Republic of Korea (R.O.K.) became the primary harvester landing 86% and 71% of the total landings in 1980 and 1981, while in 1982 the U.S. joint-venture fishery was the principal harvester landing 12,475 t. Japan's landings, which ranged from 1,500 to 1,700 t in 1978-80, increased over threefold to 5,600 t in 1981 but decreased to only 888 t in 1982.

Largest landings of Atka mackerel have occurred during the winter-early spring and late summer-fall periods. Of the nonjoint-venture catch, 66% has been 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 (Fig. 1). U.S. observer and U.S.-U.S.S.R. cooperative research data have indicated that mean size in commercial catches increased from 29.1 cm in 1977 to 37.0 cm in 1981 and decreased slightly to 36.5 cm in 1982 (Fig. 2).

Table 2.--Reported catches (t) of Atka mackerel in the eastern Bering Sea and Aleutian Islands region by nation, 1970-82.

Nation	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982
U.S.S.R.	949	[a]	5,907	1,712	1,377	13,326	13,126	20,975	22,622	20,277	937	0	0
Japan								[a]	1,531	1,656	1,719	5,615	888
R.O.K.								[a]	97	1,329	17,483	12,385	6,385
West Germany											42	38	126
Poland										2	44	18	0
USJV[b]											265	1,633	12,475
Total	949	-	5,907	1,712	1,377	13,326	13,126	20,975	24,250	23,264	20,490	19,689	19,874

[a]Reported in other species category, if any caught.
[b]U.S.-Republic of Korea (R.O.K.) joint venture.

Source: 1970-76 data provided to the United States under U.S.-U.S.S.R. bilateral agreement.

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

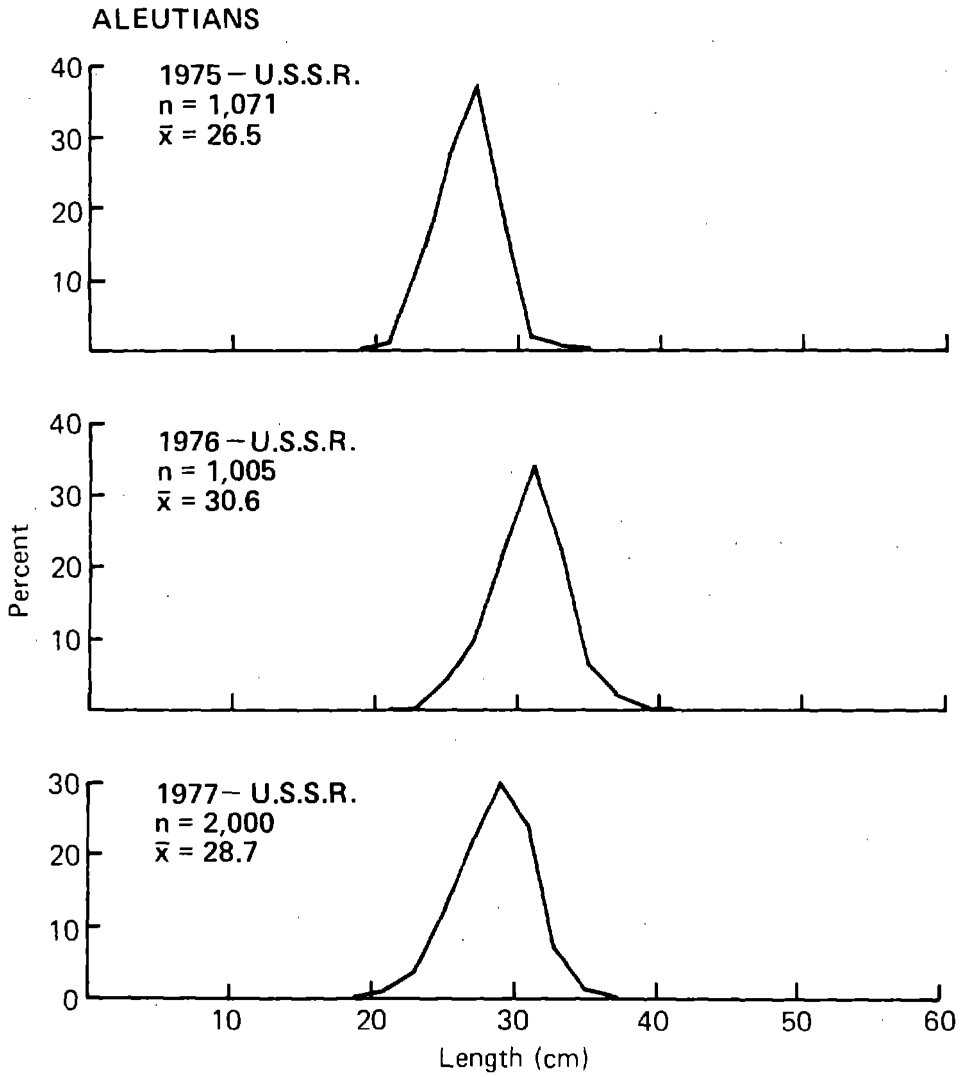

Figure 1.--Size composition of Atka mackerel in catches by U.S.S.R. fisheries in the Aleutian Islands region, 1975-77 (Levada 1979b).

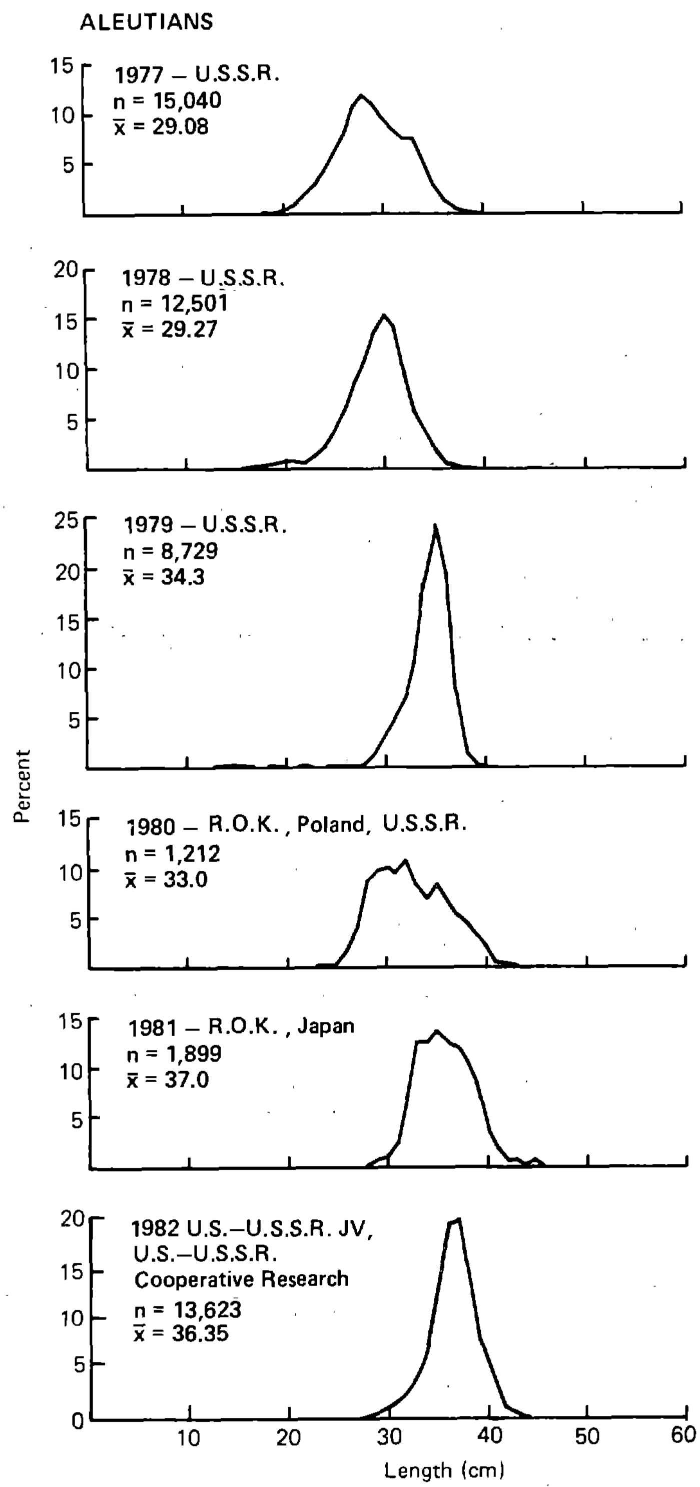

Figure 2. --Size composition of Atka mackerel from samples collected by the U . S . observer and U.S. -U.S.S.R. cooperative research programs, 1977-82.

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 do not indicate any incoming year classes as strong as the 1975 year-class; however, adequate data are not available in 1981-82 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 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.

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)[a]							
Year	2	3	4	5	6	7	8	9
A. Age frequency (%)								
1977	10	42	26	19	2	Tr[b]	Tr[b]	-
1978	4	64	17	10	4	Tr[b]	Tr[b]	Tr[b]
1979	Tr[b]	9	57	26	5	2	-	-
1980[c]	10	8	25	45	15	3	Tr[b]	-
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[c]	22.9	31.9	35.5	36.9	37.7	39.3	40.0	-

[a]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.
[b]Less than 1%.
[c]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
1977	1,888	8,810	5,663	4,195	420	210	Tr[a]	21,186
1978	728	16,490	4,123	2,425	970	243	Tr[a]	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

[a]Tr = trace (>1 t)

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[a]	
Mean length (cm)	29.10	29.30	34.30	34.7[a] 33.4 33.0[b]	35.0 37.0[b]
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[a] 103 1,212[b]	824 1,899[b]

[a]Data from Northwest and Alaska Fisheries Center resource assessment survey.
[b]Data reported by the Republic of Korea National Fisheries Research and Development Agency.

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 (long. 165°W-170°W) and 18.2 kg/ha in INPFC area 5 (long. 170°W-170°E). 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.

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:

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

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

K (von Bertalanffy growth parameter) = 0.67.

The estimate of the von Bertalanffy growth parameter K and, therefore, the calculated M is dependent on the interpretation of age structures. Misinterpretation 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 at 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. U.S.S.R. data (Levada 1979b) have indicated that CPUE was relatively stable from 1972-75 and then increased in 1976. U.S. observer data show 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

Terrance M. Sample

INTRODUCTION

With the exception of some recent publications (Bubblitz 1981; Mercer 1981; Fiscus and Mercer 1982; 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 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 0. *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	1982
Japan	8,316	9,138	5,739	4,622	4,680	4,485
Republic of Korea	a	215	1,233	1,620	1,097	495
Taiwan	a	35	14	39	55	37
U.S.S.R.	a	23	6	0	0	0
Federal Republic of Germany	-	-	-	53	9	16
Poland	-	-	25	19	96	-
Joint venture	-	-	-	-	4	5
Total	8,316	9,411	7,017	6,353	5,941	5,038

[a]Catch, if any, reported as other species.

Overall catches declined after 1978 with a total all-nation catch of 5,038 t in 1982.

MAXIMUM SUSTAINABLE YIELD

Maximum sustainable yield: is unknown but is believed to he 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.

OTHER SPECIES

by

Richard G. Bakkala

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, 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 all 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. 1983). 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[a]	Target species[b]	Other species[c]	Nonspecified species[d]	
FINFISHES				
Salmonids	Walleye pollock	Sculpins	Eelpouts (Zoarcidae)	
Pacific halibut	Cod	Sharks	Poachers (Agonidae) and alligator fish	
	Flounders	Skates	Snailfish, lumpfishes, lumpsuckers (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.	

[a] Must be returned to the sea.
[b] Optimum yield established for each species.
[c] Aggregate optimum yield established for the group as a whole.
[d] 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 (Cyclop-teridae), and rattails (Macrouridae).

Estimates of maximum sustainable yield (MSY) and equilibrium yield (EY) have previously been derived for the "other species" category but these estimatea-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 Fishery Management Council, MSY and EY estimates were revised to include only those species groups designated as "other species" (Bakkala 1983).

COMMERCIAL CATCHES AND ABUNDANCE ESTIMATES

Reported catches of the "other fish" category reached a peak of 133,340 t in 1972, but have since substantially declined and were only 23,400 t in 1982 (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 1979-83 and the Aleutian Islands region in 1980 provide abundance estimates for the "other species" category and the relative importance of the various species

Table 2.--All -nation catches of other fish, 1964-82.[a]

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
1982	5,167	18,200	23,367

[a]Data for 1964-80 from catches reported to the United States by fishing nations; 1981 and 1982 data from French et al. (1982) and Nelson et al. (1983).

Table 3.--Biomass estimates of other species from large-scale demersal trawl surveys in 1975 and 1979-83.[a]

Species group	Eastern Bering Sea 1975	1979[a]	1980	1981[a]	1982	1983	Aleutian Islands region 1980
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Sculpins	122,500	251,800	281,100	350,200	291,300	277,008	39,300
Skates	42,000	88,700	114,900	246,800	168,000	188,249	15,500
Smelts	28,700	11,500	15,500	4,200	10,100	5,078	0
Sharks	0	200	0	0	0	0	800
Octopuses	8,600	49,500	17,400	13,100	13,100	3,407	2,300
Total	201,800	401,700	428,900	614,300	482,500	473,742	57,900

[a]The biomass estimates for the eastern Bering Sea are from the approximate area shown in Figure 2 of the section on walleye pollock in this report. The 1979 and 1981 data include estimates from continental slope waters (200-1,000 m), but the 1975, 1980, 1982, and 1983 data do not.

comprising this category (Table 3). The estimates illustrate that sculpins 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 1981-83.

It should be pointed out that smelts may he 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

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 and the 1980 Aleutians survey and using 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 and the continued high abundance of the "other species" category, these stocks are probably capable of producing catches at the calculated MSY level or 61,400 t.

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