NOAA Technical Memorandum NMFS F/NWC-52

Condition of Groundfish Resources of the Gulf of Alaska in 1982

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November 1983

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

CONDITION OF GROUNDFISH RESOURCES OF THE GULF OF ALASKA IN 1982

by

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November 1983

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ABSTRACT

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

Most of the resources in the Gulf of Alaska management region appear to be in good condition, including walleye pollock, *Theragra chalcogramma*; sablefish, *Anoplopoma fimbria*; Pacific cod, *Gadus macrocephalus*; Atka mackerel, *Pleurogrammus monopterygius*; and the flatfishes. Pacific ocean perch, *Sebastes alutus*, stocks are in poor condition and remain at low levels of abundance. The equilibrium yield for the groundfish complex as a whole is estimated between 433.6 and 719.4 thousand t, with a mean of about 576.5 thousand t.

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WALLEYE POLLOCK

by

Miles S. Alton and Richard B. Deriso

Walleye pollock, *Theragra chalcogramma,* is indigenous to the North Pacific and adjacent seas. Its greatest abundance lies at continental shelf depths of 100 to 300 m where most of the harvest has taken place. It is a schooling fish and may be found on or near the sea bottom, as well as at mid- and near-surface depths. Adult pollock beyond the shelf have been found in near surface and in the upper water layers. This has been observed in the Bering Sea Basin, south of the Aleutian Islands, and off southeast Alaska. The total pollock biomass has been estimated to exceed 20 million metric tons (t) (Natural Resources Consultants 1981).

Fisheries for pollock take place in Canadian waters, the Gulf of Alaska, Bering Sea, Aleutian Islands area, off Kamchatka Peninsula, the Kurile Islands area, and in Japanese and Korean waters. Individual stocks are often associated with these main fishing regions. For 1979, the latest year of complete statistics for all regions, 3.6 million t were caught in the western Pacific and 1 million t in the eastern Pacific. In the eastern Pacific the bulk of the catch is taken in the eastern Bering Sea, followed by the Gulf of Alaska (Figure 1).

There is evidence that pollock in the Gulf of Alaska increased substantially in biomass between the early 1960's and early and mid-1970's (Figure 2). During the 1973-77 period, its biomass was estimated to be 1 million t based on research trawl surveys. The majority of that biomass was found to lie in the western Gulf of Alaska. Potential yield was set at 166 thousand t (Alton et al. 1977).

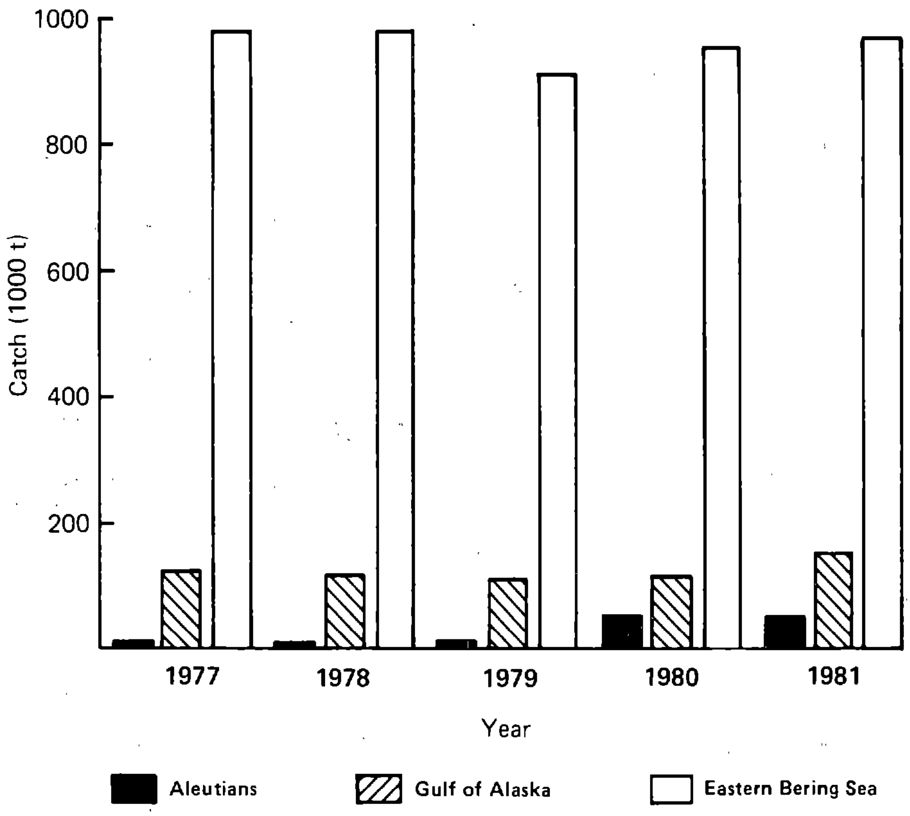

Figure 1.--All nation annual walleye pollock catch in the Aleutian Islands, Gulf of Alaska, and eastern Bering Sea, 1977-81.

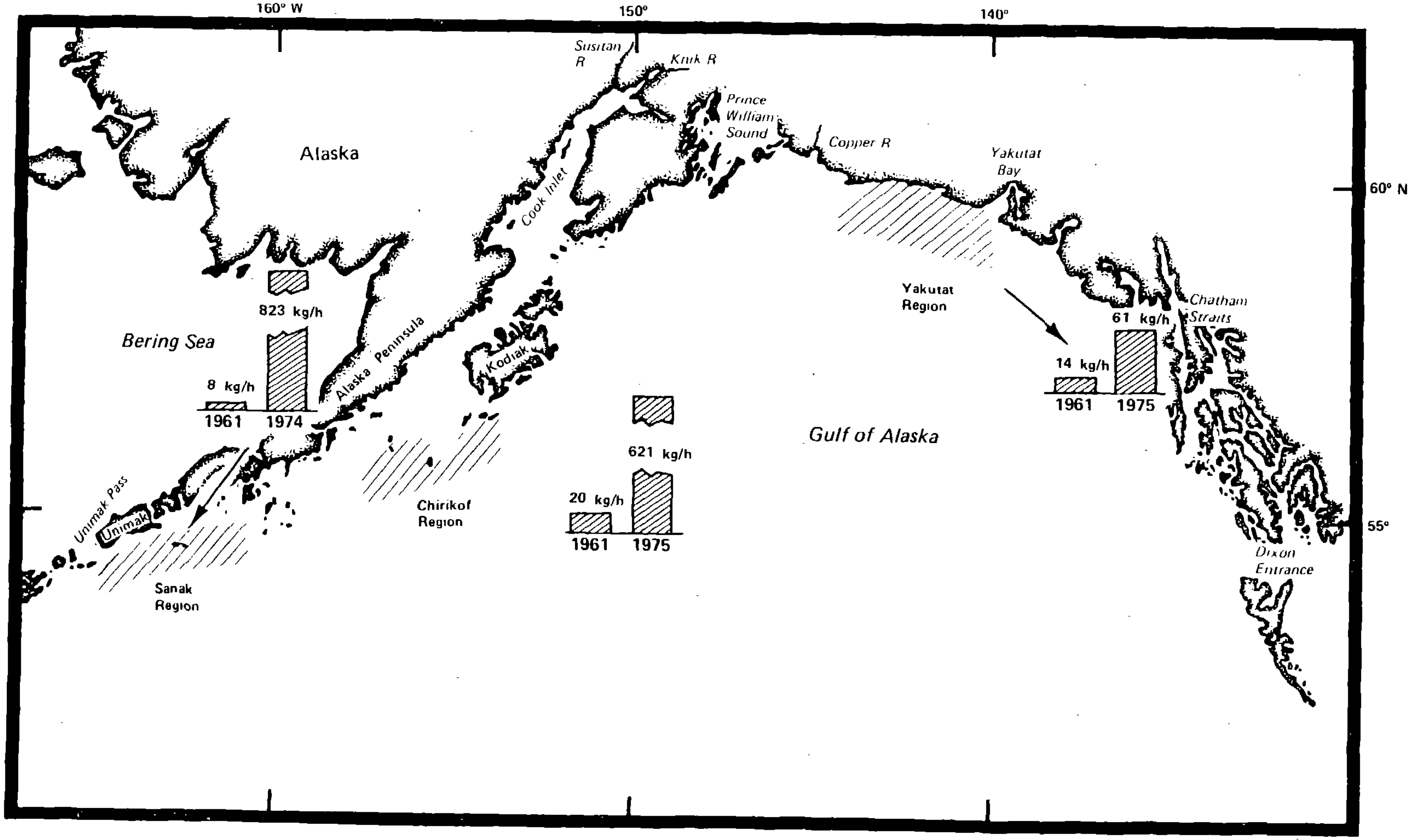

Figure 2.--Changes in stock density of walleye pollock in the Gulf of Alaska as suggested from changes in survey catch rates (kg/h) between 1961 and 1974-75.

Foreign nationals were the first to harvest significant amounts of pollock in the Gulf of Alaska. They began trawling operations in the Gulf in 1962, targeting on rockfish, mainly Pacific ocean perch, Sebastes alutus. As rockfish abundance declined, there was a shift to pollock. Between 1962 and 1971 the annual catch ranged from 1.1 to 17.6 thousand t. Pollock were either taken in an intermittent directed fishery by Japan or as a by-catch in the Japanese and U.S.S.R. rockfish fisheries. Reported catches for this period are considered minimal because of the inadequacy of the Soviet statistics. In 1972 the foreign catch of pollock rose sharply to 34.1 thousand t and has continued to rise so that by 1977 it began to exceed 100 thousand t (Table 1). The highest annual catch has been 130.3 thousand t in 1981.

Restrictions on the foreign fisheries of the Gulf of Alaska began in 1966 when the United States established a 12 mi (19.3 km) contiguous fishing zone which prohibited foreign fishing and support of such fisheries in this zone. This had very little or no effect on the foreign trawl fisheries for pollock since the main fishing areas by the trawlers lie outside of this zone. In the early 1970's, however, other restrictions were introduced through bilateral agreements which limited the amount of pollock that could be harvested, restricted access to pollock and other groundfish on certain fishing grounds during certain periods of the year, and regulated the way trawls could be fished. With the passage of the Magnuson Fishery Conservation and Management Act (MFCMA) in 1976 and its implementation in 1977, licensing, catch, and time-area restrictions were placed on foreign vessels fishing in the U.S. 200 mi (321.9 km) fishery conservation zone (FCZ). Groundfish allocations, including pollock, were set for each nation. Pollock allocations for more recent years, 1979-82, are given in Table 2. Time-area closures and

Table 1 .--Annual catch (t) of walleye pollock by foreign nation, 1964-81.

Year	Japan	U.S.S.R.	R.O.K.	Poland	Mexico	Total
	- - - - - - - - - - - - - - t -					
1964	1,126	Unknown				1,126
1965	2,749	"				2,749
1966	8,932	"				8,932
1967	6,276	"				6,276
1968	6,164	"				6,164
1969	17,553	"				17,553
1970	9,343	"				9,343
1971	9,018	440				9,458
1972	13,696	20,385				34,081
1973	6,706	30,130				36,836
1974	30,433	31,000	447			61,880
1975	13,032	39,949	5,900	631		59,512
1976	11,796	37,825	36,906	---		86,527
1977	41,953	41,588	35,579	1,256		120,376
1978	26,093	41,956	27,052	1,226		96,327
1979	31,920	17,300	25,739	19,551	8,677	103,187
1980	37,897	37,001	25,013	13,085	---	112,996
1981	51,885	---	38,552	39,886	---	130,323

Table 2.--Foreign fisheries allocations (t) of Gulf of Alaska walleye pollock by nation and area in 1979[1], 1980[2], and 1981[3].

Nation	Shumagin			Chirikof-Kodiak			Yakutat-Southeastern			All areas		
	1979	1980	1981	1979	1980	1981	1979	1980	1981	1979	1980	1981
	t											
Japan	3,042	360	29,819	30,878	40,915	44,352	4,359	5,470	9,054	38,279	46,745	83,225
U.S.S.R.	16,436	16,025	none	30,008	24,917	none	3,864	none	none	50,308	40,942	none
Republic of Korea	22,116	24,878	17,082	none	none	19,178	5,914	3,727	4,478	28,030	28,605	40,738
Poland	9,489	12,293	16,216	10,034	15,172	26,210	none	none	4,251	19,523	27,465	46,677
Mexico	6,842	none	none	3,510	7,611	none	1,818	5,806	none	12,170	13,417	none
All nations	57,925	53,556	63,117	74,430	88,615	89,740	15,955	15,003	17,783	148,310	157,174	170,640

1/ 1 Dec. 1978 to 31 Oct. 1979.

2/ 1 Nov. 1979 to 31 Oct. 1980.

3/ 1 Nov. 1980 to 31 Dec. 1981.

gear restrictions put further limitations on the trawl fisheries for pollock and other groundfish. The most current summary of these restrictions is given in Figures 3 and 4.

After passage of the MFCMA, foreign fishing companies and state-run fisheries enterprises began to enter into joint-venture arrangements with U.S. fishing vessels in order to gain additional access to U.S. resources. The joint-venture arrangement consists of a contract between a foreign and U.S. interest in which U.S. vessels catch the fish and land them on foreign processing vessels. Such ventures began at a modest level in the Gulf of Alaska in 1978 and have grown rapidly in terms of volume of catch so that in 1982 the joint-venture catch in the Gulf of Alaska reached some 75 thousand t (99% pollock) by June of that year.

In 1982 the pollock catch by the foreign trawl fisheries and joint ventures may easily exceed 170 thousand t.

The rapid rise in the Gulf of Alaska pollock catch in recent years and its growing importance to U.S. commercial interests necessitates a critical evaluation of the condition of the resource. This includes fundamental questions, such as, does our present knowledge about this resource allow us to determine whether the resource is declining, maintaining itself, or increasing in abundance? In this report the condition of the resource and the adequacy of our information base are examined. An attempt is also made to project future stock condition and recommend ways by which the current information base can be improved.

STOCK UNITS

Biochemical genetic studies by Iwata (1975a,b) and Johnson (1977) found differences between Asian stocks of walleye pollock and those in the eastern

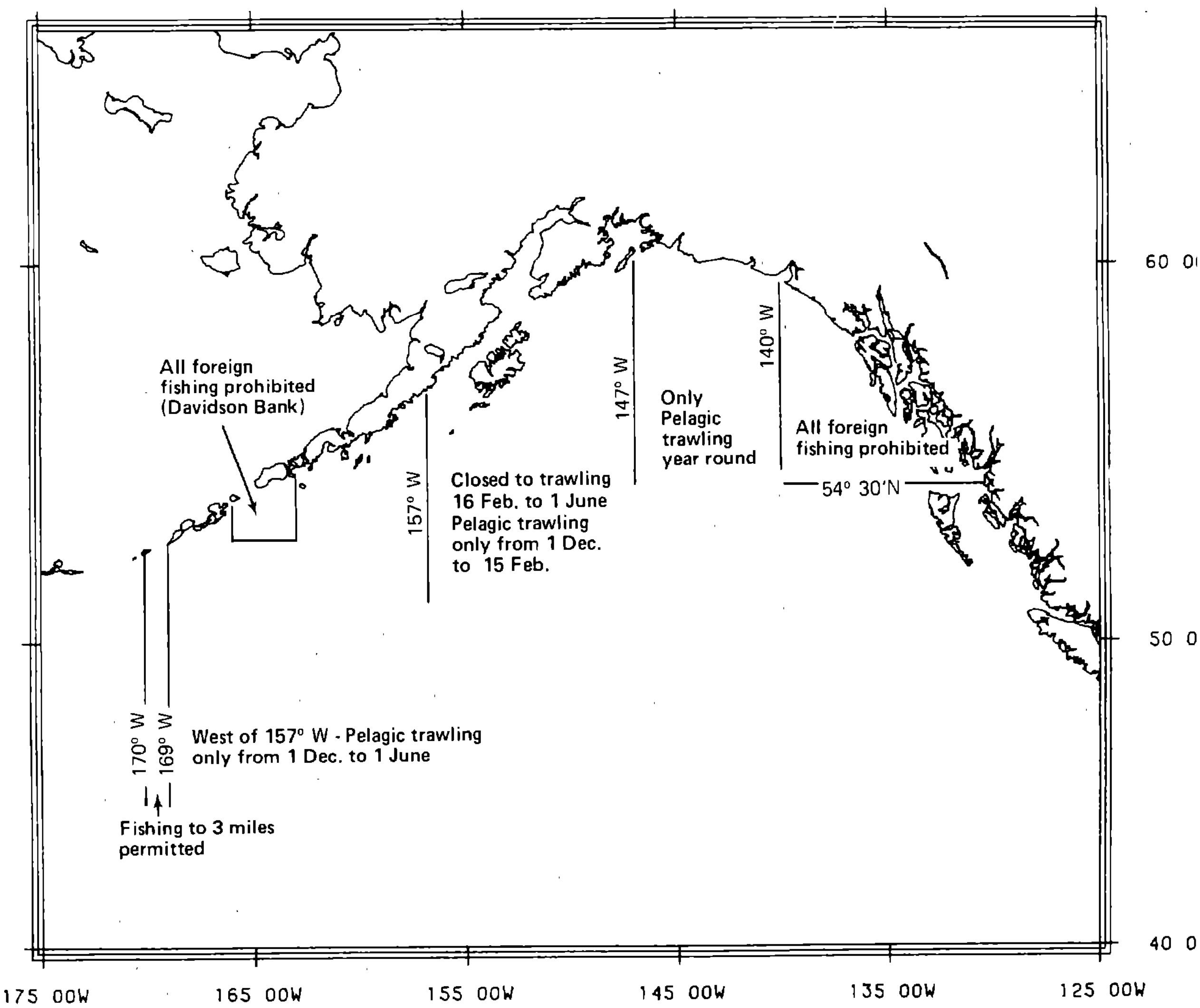

Figure 3. --Restrictions affecting foreign trawl fisheries for Gulf of Alaska walleye pollock and other groundfish.

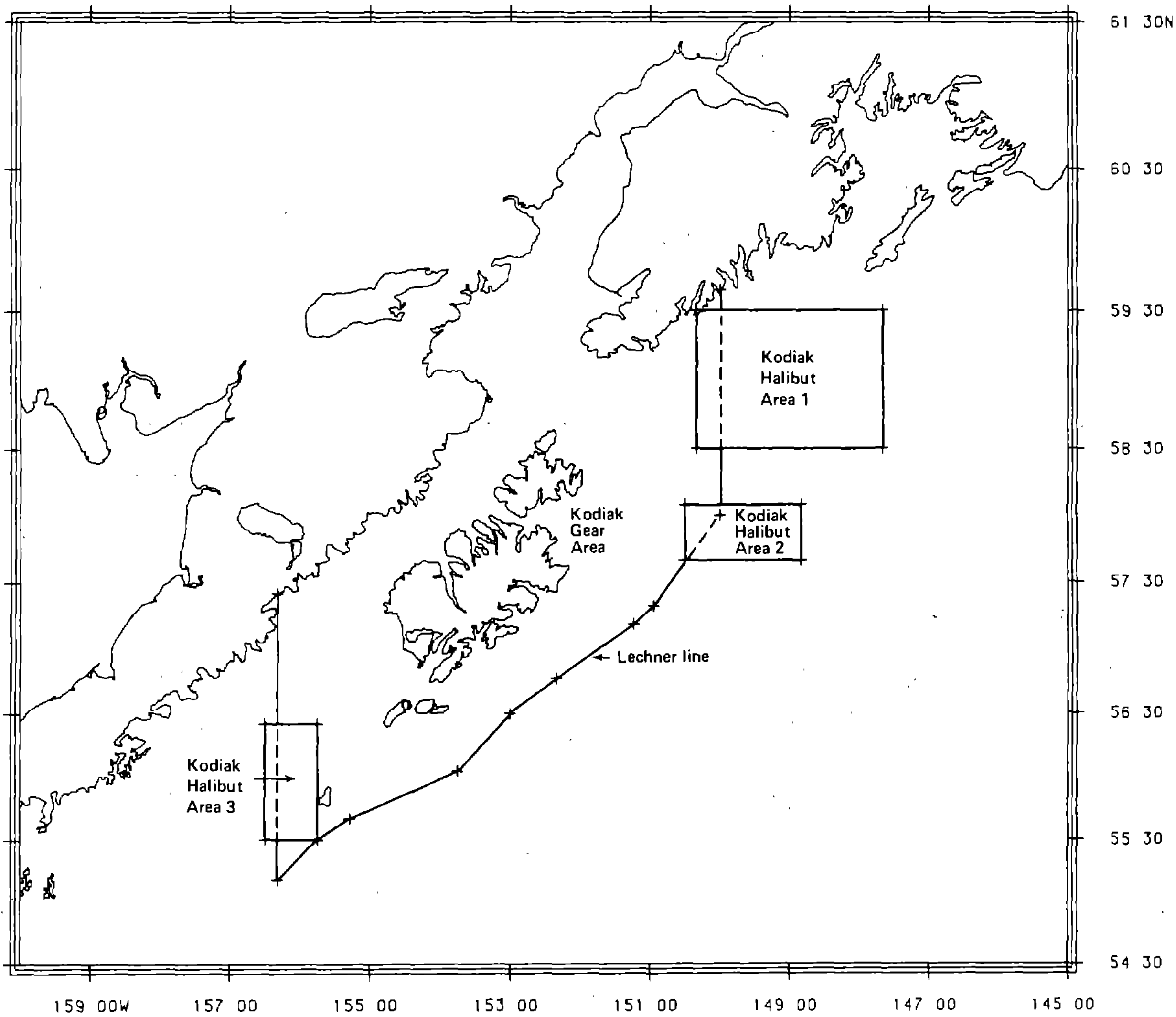

Figure 4 .--The Kodiak gear area (Lechner Line) and three Kodiak halibut, Hippoglossus stenolepis, areas. The Kodiak gear area is closed to trawling from 2 days prior to the opening of king crab season through 15 February. The Kodiak halibut areas area closed to trawling from 5 days before until 5 days after the first opening of the U.S. halibut season.

Bering Sea and Gulf of Alaska. Grant and Utter (1980) were able to find small but detectable genetic differences between walleye pollock of the southeastern Bering Sea and those of the Gulf of Alaska. In their cluster analysis for genetic similarities, their samples fell into two groups that generally corresponded to the southeastern Bering Sea fish and Gulf of Alaska fish. Only one Gulf of Alaska sample was included in the "Bering Sea" group; two Bering Sea samples fell within the "Gulf of Alaska" group. The Gulf of Alaska sample which showed affinity to the Bering Sea samples was obtained from the Shelikof Strait region of the Gulf of Alaska in February while the remainder of the Gulf samples were taken east of the Shelikof region during July. The Bering Sea samples, like the Shelikof sample, were collected during the late-winter/spring or spawning period. The affinity of the Shelikof sample to Bering Sea fish suggests a closer association of western Gulf pollock with Bering Sea pollock than with pollock south of Kodiak and in the eastern Gulf of Alaska. Further biochemical studies appear to be in order to clarify the relationship of Bering Sea and western Gulf of Alaska fish.

If the placing of the Shelikof Strait fish with the Bering Sea fish is correct, then this would support the suggestion by Hughes and Hirschhorn (1979) that an east-west separation of stocks may exist in the vicinity of Kodiak Island. They found from the examination of research survey sampling that occurred in 1973-75 that an east-west difference in the density of two prominent year-classes was apparent. The 1967 year-class appeared in high density only west of southeast Kodiak while the 1970 year-class was most dense in the southeast Kodiak area and to the east. They also found east-west growth differences in these year-classes.

Findings subsequent to the study by Hughes and Hirschhorn (1979) revealed that major spawning of walleye pollock occurs in the Shelikof Strait region

(Nunnallee et al. 1982). U.S.-U.S.S.R. ichthyoplankton surveys have also suggested other, but perhaps minor, spawning areas west of the Shelikof region (Figure 5). These surveys have covered the western Gulf of Alaska from the vicinity of the Kenai Peninsula to Unimak Pass (Boretz 1981). No concentration of spawning fish was evident between the Kenai Peninsula and Kodiak Island. The findings of spawning areas in the Shelikof region and to the westward raise questions as to the relationship of the pollock that spawn in these areas to pollock in other areas of the Gulf, such as those south of Kodiak and the Kenai Peninsula and in the Yakutat and southeastern Alaska areas. There has not been an ichthyoplankton survey of the eastern Gulf of Alaska during the main spawning months (March-April), so that the possibility that mass spawning also occurs in this region cannot be ruled out. Concentrated spawning is known for the inside waters of southeastern Alaska.

We would emphasize that walleye pollock may be found in spawning condition throughout the Gulf of Alaska (W. Hirschberger, Northwest and Alaska Fisheries Center, Seattle, WA 98112. Pers. commun., 1982). Small quantities of eggs and larvae may be encountered at almost any time of the year (A. Kendall, Northwest and Alaska Fisheries Center, Seattle, WA 98112. Pers. commun., 1982). But concentrations of fish for spawning appears to be confined to specific areas during the spring months.

The results of the 1973-77 NMFS bottom trawl surveys were used to estimate the walleye pollock biomass and its distribution in the Gulf of Alaska (Alton et al. 1977) (See Table 3). About 91% of the biomass lies in the western Gulf of Alaska from approximately Prince William Sound to 170° C west longitude. They computed a potential yield for each of the International North Pacific Fisheries Commission (INPFC) areas (Shumagin, Chirikof, Kodiak, Yakutat, and

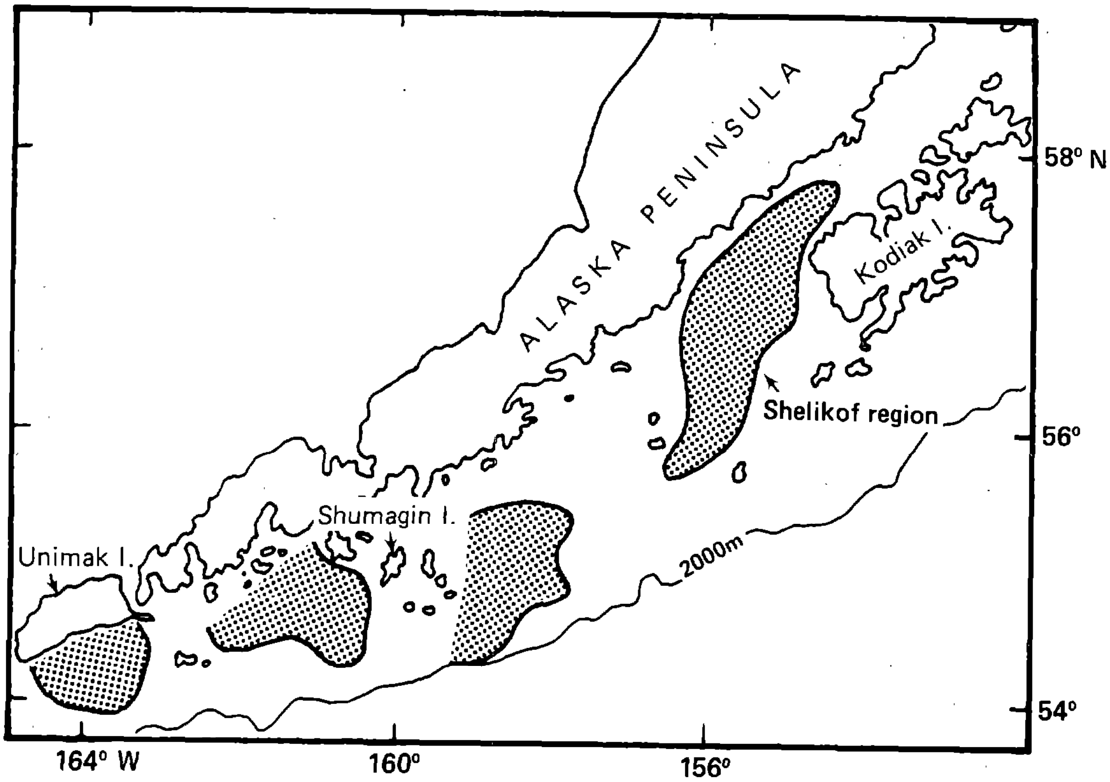

Figure 5.--General regions of walleye pollock spawning as adduced from icthyoplankton surveys in 1980. The Shelikof Strait region is a major spawning area. The other three are considered minor spawning regions.

Table 3.-- Estimates of exploitable biomass and potential yield of walleye pollock in the Gulf of Alaska by statistical areas of the International North Pacific Fisheries Commission (in thousand t).

Area	Biomass (B)[1]	Yield (MSY = ABC)[2]	Year of Survey
Shumagin	357-713	57-114	1974
Chirikof	340-680	54-109	1973, 1975
Kodiak	255-511	41-82	1973
Yakutat	78-155	12-25	1975
Southeastern[3]	11-22	2-4	1976, 1977
All areas	1,041-2,081	166-334	

1/ Range of biomass is based on catchability coefficient of 0.5 and 1.0.

2/ Maximum sustainable yield (MSY) = M(0.4)(B) = (0.4)(0.4)(B).

3/ Outside waters.

Southeastern). Originally allowable biological catch and allocations were made for these INPFC areas to prevent any disproportionate amount of pollock from being removed from any one area; Allocations are currently made by three regions.: Shumagin, Chirikof-Kodiak, and Yakutat-Southeastern (Table 2). These regional allocations are based on resource distribution.

In summary, there is some tentative evidence for an east-west stock separation of pollock in the vicinity of Kodiak Island based on studies by Hughes and Hirschhorn (1979) on year-class density and growth features, and on biochemical genetic studies by Grant and Utter (1980). These studies need to be followed up by others for clarification. It is in the Kodiak area that pollock density increases substantially and continues at relatively high levels westward, as evidenced from research surveys and the fisheries. Areas of concentrated spawning have been located in Shelikof Straits and west of there. There needs to be surveys in the eastern Gulf to determine whether spawning concentrations occur there too. It is not known whether the pollock that engage in these areas of concentrated spawning represent individual stocks nor where they reside at other times of the year. Current management sets optimum yield (OY) by three regions of the Gulf of Alaska based on resource distribution from research trawl surveys.

FISHERIES

Catch Patterns

Prior to 1973 Japan was the only foreign fishing nation that was reporting its fishery statistics in the Gulf of Alaska in a detailed and consistent manner. Through INPFC, Japan provided annual fishery statistics to the U.S. by statistical blocks of 1/2° lat. and 1° long. by month, gear type, and vessel size (tonnage classification). By 1977 the MFCMA required that all nations fishing in the FCZ (3 to 200 miles offshore) report their catch and effort statistics in the same manner as established by INPFC.

The U.S. observer program, which was expanded with the passage of the MFCMA, began to compile their own estimate of the foreign catch by major species and groups to ensure that allocations were not exceeded. The U.S. observer program annually provides what they consider their best estimate of the catch within the Shumagin, Chirikof, Kodiak, Yakutat, and Southeastern areas by species, nation, vessel class, and gear for each month. The estimation procedure, described by Wall et al. (1981), is a method of extrapolating catch estimates per time period from vessels having observers aboard to vessels having no observer coverage. Observer coverage (number of observer days/total vessel days x 100) grew from 10.2% in 1977 to 16.3% in 1979 and then declined to 11% in 1981. Coverage will increase in 1982. This estimation procedure was fully implemented in 1978. We use estimates based on that procedure for the more recent (1978-81) catch information on pollock. The foreign reported catch is used for previous years.

Foreign Trawl Fisheries

Japan, Republic of Korea (R.O.K.), U.S.S.R., and Poland nationals have been the principal harvesters of walleye pollock in the Gulf of Alaska (Table 1). Most of their catch has been from the Shumagin, Chirikof, and Kodiak areas (Table 4 and Figure 6). In 1981 the Chirikof catch of almost 65 thousand t was the highest on record for that area, but the Kodiak catch declined from 26.5 to 9.1 thousand t. The sharp contrast in catches between the two adjacent areas in 1981 is believed to be the result of shifts in the availability of pollock and the possible avoidance of the Kodiak area where there is a tendency of high incidental catches of prohibited species.

Table 4.--Walleye pollock catch (t) by area and foreign nation in the Gulf of Alaska (1977-82).[1/]

Nation	Year	Western (Shumagin)	Central (Chirikof-Kodiak)	Eastern (Yakutat-Southeastern)
		- - - - - - - - - - - - t - - - - - - - - - - - - -		
Japan	1977	8,626	25,969	7,358
	1978	3,539	19,026	3,528
	1979	1,366	27,700	2,862
	1980	378	32,975	4,544
	1981	14,125	33,604	4,156
Republic of Korea	1977	34,166	1,413	-
	1978	26,268	784	-
	1979	23,312	-	2,427
	1980	24,926	-	87
	1981	17,191	16,961	4,400
USSR	1977	13,981	27,262	345
	1978	1,494	40,462	-
	1979	170	17,087	43
	1980	15,495	21,506	-
	1981	-	-	-
Poland	1977	-	1,256	-
	1978	-	1,226	-
	1979	249	19,302	-
	1980	5,848	7,237	-
	1981	16,244	23,624	18
All nations	1977	56,773	55,900	7,703
	1978	31,301	61,498	3,528
	1979[2/]	30,218	67,597	5,372
	1980	46,647	61,718	4,631
	1981	47,560	74,189	8,574

1/ For 1977, reported catch by foreign nations indicated; for 1978-80, a "best blend" estimate as described by Wall et al. (1981), was used.

2/ Includes catch by Mexico

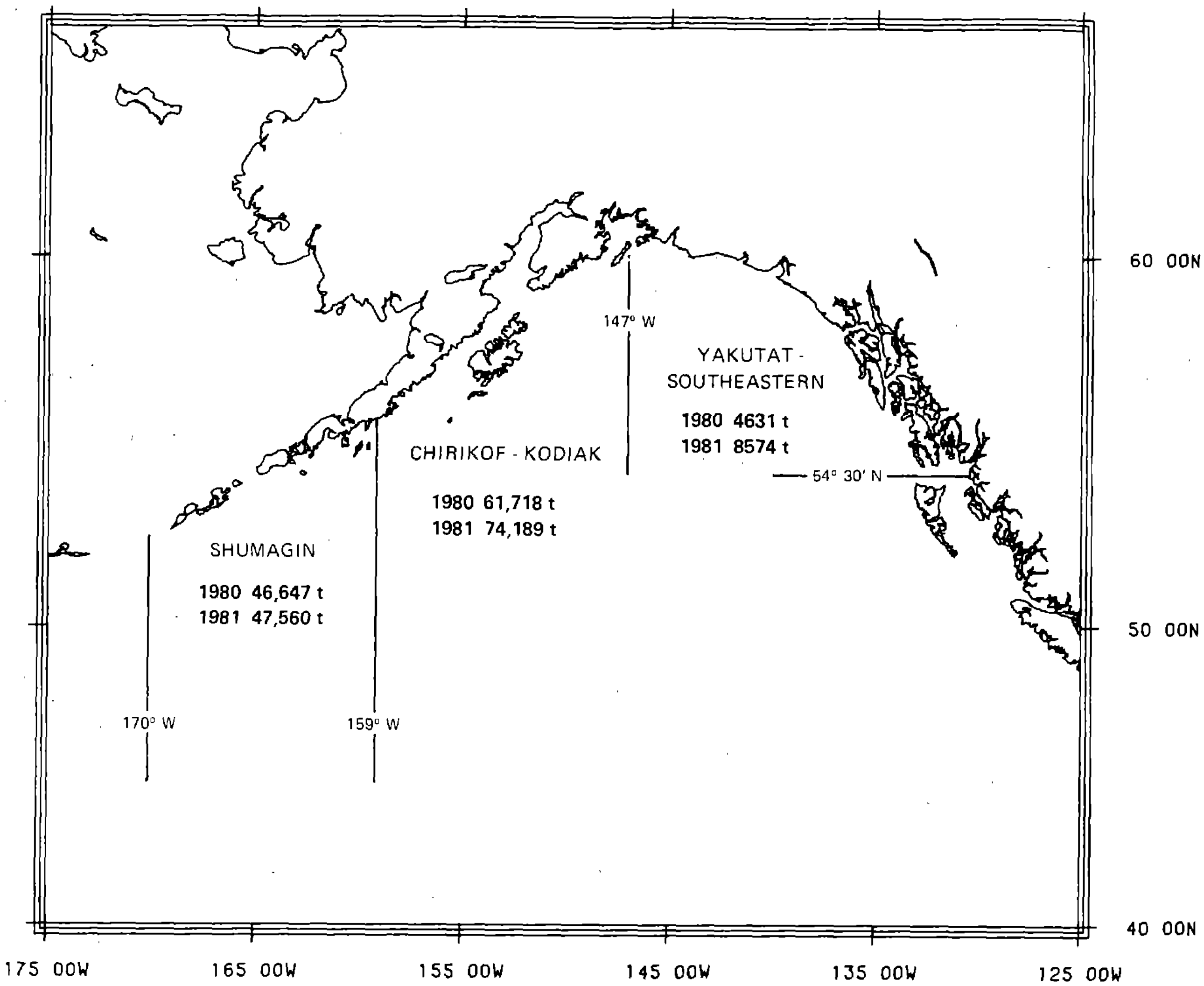

Figure 6.--Total foreign catch of walleye pollock in 1980 and 1981 by regulatory areas of the Gulf of Alaska.

Foreign trawling has mainly taken place in recent years during June to November, probably because of the time-area closures and gear restrictions during the early part of the year. This is reflected in the distribution of the pollock catch during the year (Figure 7). There are exceptions such as the U.S.S.R. operations in certain years (1978 and 1980) when the majority of their pollock catch was taken from January to May. The Polish fishery also harvested more pollock in the early part of the year in both 1980 and 1981. Most pollock are taken, however, during June to November.

The Japanese have had a long history of harvesting pollock in the Gulf of Alaska (Table 1). In recent years (1979-81) their catch of pollock has been larger than that of other nations. They have also been given the highest pollock allocations in both 1980 and 1981, however, their catches for these years have been less than their allocations. Since 1973 they have what could be described as two types of trawl fisheries in the Gulf of Alaska. One type uses large trawlers that have the capability of producing minced fish called surimi, as well as frozen fish and meal. These trawlers target on pollock. The other fisheries involve freezer trawlers that fish for pollock as well as other groundfish. The U.S. observer program places these latter freezer trawlers into two categories, small freezer trawlers and large freezer trawlers., Many of the small freezer trawlers have a gross tonnage between 350 and 600 and frequently target on pollock, usually freezing the pollock whole or dressed (headed and gutted). Their catch of pollock increased substantially in 1981, exceeding that of the large freezer trawlers (Table 5). The latter type vessel has a gross tonnage of 1,500 or greater and target usually on pollock or rock-fish. They produce frozen fillets from pollock above a certain size or weight and dressed fish from an intermediate size category. Small fish and offal are

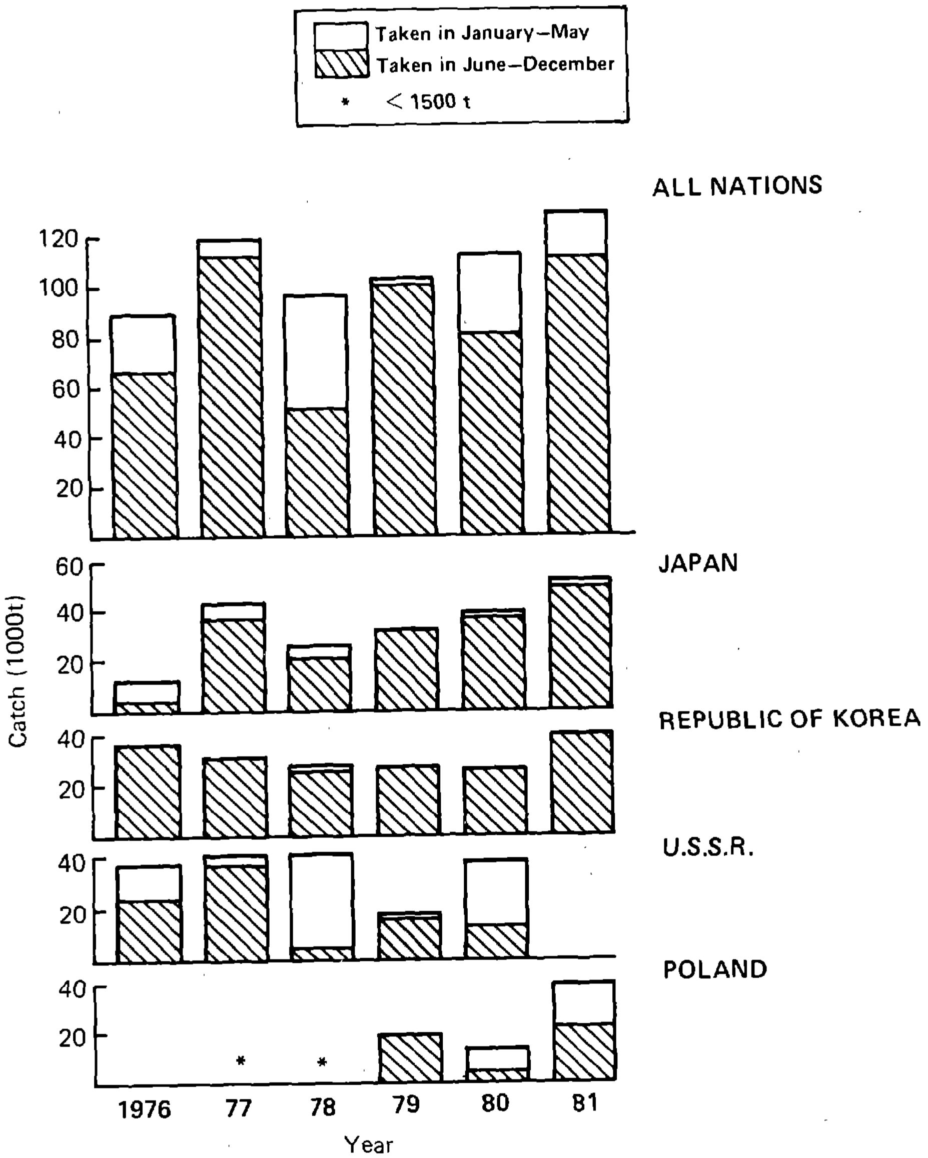

Figure 7.--Annual foreign catch of walleye pollock from the Gulf of Alaska by nation and two time periods -- January to May and June to December (1976-81).

Table 5.--Annual catch of Gulf of Alaska walleye pollock by Japanese trawler vessel category (1976-81).

Year[1]	Surimi factory trawler (1,505->4,505 gr tons)	Small freezer trawler (<1,499 gr tons)	Large freezer trawler (1,500-4,504 gr tons)	Total
	- - - - - - - - - - - - - - -	1,000 t	- - - - - - - - - - - - - - - -	
1976	4.9	0.3	6.6	11.8
1977	19.0	7.0	15.0	41.0
1978	17.8	6.7	1.5	26.0
1979	10.6	5.5	15.7	31.8
1980	20.4	8.6	8.5	37.5
1981	30.4	12.3	8.8	51.5

[1] Foreign reported catch for 1976 and 1977; best blend estimate for 1978-81.

made into fish meal. The surimi type trawlers have, since 1977, been the largest producers of pollock in the Japanese fisheries landing some 30.4 thousand t of pollock in 1981. Bottom trawling is generally the mode of fishing for Japanese trawlers, although some off-bottom trawling takes place.

The annual catch of pollock in the U.S.S.R. trawl fisheries is not known for the years prior to 1971 and even the accuracy of their reported catches for the early 1970's may be questionable. The U.S.S.R. pollock catch has been substantial since 1972 and reached 42 thousand t in 1978. The U.S.S.R. was not given any allocation of pollock or any other fish resource in the Gulf of Alaska in 1981.

The Soviet fleet is composed of only large freezer trawlers of two types--BMRT's of 2,300 to 3,800 gr tons and RTM's of 2,100-2,200 gr tons (Nelson et al. 1981). Pollock is frequently a targeted species. In the years 1977-80, pollock constituted 56 to 68% of their total Gulf of Alaska groundfish catch (Table 6). As mentioned earlier, there were some years (1978 and 1980) in which a significant portion of their catch was taken in the early part of the year. Both pelagic and on-bottom trawling is used in capturing pollock, which are frozen whole, dressed, or as fillets. Small fish and offal are used for fish meal.

The R.O.K., for the most part, uses large freezer trawlers in the Gulf of Alaska. Until 1981, the Koreans have focused much of their effort toward pollock, which is reflected in the high proportion of pollock in their total catch (Table 6). In 1981, however, a greater proportion of Atka mackerel, *Pleurogrammus monopterygius*, and other species were taken, as compared to previous years, but the total pollock catch reached its highest level so far in their Gulf of Alaska fisheries.

Table 6.--Total groundfish catch (in thousand t) and, in parentheses, the percentage of walleye pollock taken. in the foreign trawl fisheries of the Gulf of Alaska, 1977-81.

Year	Japan	R.O.K.	U.S.S.R.	Poland	All nations
1977	86.1 (49)	36.2 (98)	64.7 (64)	1.3 (97)	188.3 (64)
1978	50.9 (51)	34.3 (79)	62.6 (67)	1.3 (92)	149.1 (65)
1979 1/	56.1 (57)	29.1 (88)	31.0 (56)	19.7 (99)	146.3 (70)
1980	71.7 (53)	31.4 (80)	54.6 (68)	13.3 (98)	171.0 (66)
1981	82.5 (63)	74.7 (52)	-	41.1 (97)	198.3 (66)

1/ Includes catch by Mexico.

Another marked change in 1981 was the increase in the pollock catch in the Chirikof-Kodiak area. Prior to 1981 most of the R.O.K. pollock catch was taken in the Shumagin area and particularly from a small area between 168°W long. and Davidson Bank (Figure 3). In the R.O.K. fisheries, pollock is frozen in the round or filleted, with small fish and offal turned into fish meal.

Polish trawlers began fishing on a small scale in the Gulf of Alaska in 1975. By 1979 their catch reached 19.6 thousand t and in 1981 39.9 thousand t was taken. In 1980 and 1981 Polish vessels took a considerable amount of their annual catch during the early part of the year. Pelagic trawls are used exclusively and this accounts for the high proportion of pollock in the total groundfish catch of the Polish fishery (Table 6). Pollock above a certain size are made into frozen fillets and intermediate size fish are headed and gutted. Small pollock go into fish meal.

Joint-Venture Fisheries

Various Japanese, R.O.K., and German (Federal Republic of Germany) fishing companies and state fisheries (Poland) have entered into joint-venture fisheries in the Gulf of Alaska with U.S. interests. Such fisheries have grown rapidly in recent years. Walleye pollock is the main species in these fisheries and in 1982 the pollock catch as of June was 74.3 thousand t (Table 7). In both 1981 and 1982 the joint-venture fisheries operated mainly or completely in the Shelikof region on concentrations of prespawning and spawning pollock. The U.S. catcher vessels are small stern trawlers that range in length between 25 and 50 m and from 120 to 200 gr tons. In the Shelikof fishery, pelagic trawls are used in which the content of the catches is almost all pollock. The individual catches are not taken aboard the catcher vessel but are transferred via detached codends to the foreign processing vessel where the pollock are processed into various products--frozen fillet blocks, roe, fish frozen in the round, and fish meal.

Table 7.--Walleye pollock catch (t), in joint ventures in the Gulf of Alaska, 1980-82.

Year	Shumagin	Chirikof	Kodiak	All areas
1980	113	496 1/	527 1/	1,136
1981	21	16,836 2/	-	16,856
1982 4/	-	74,282 3/	-	74,282

1/ April-May

2/ February-April

3/ January-May

4/ As of June 1982

U.S. Fisheries

In 1981 the pollock catch in strictly U.S. fisheries continued to remain at a low level--less than 1 thousand t.

Length and Age Composition

Length and age information on pollock have come from the U.S. observer program for the period 1976-82. A description of the sampling procedures for length and age, as well as other information used by U.S. observers aboard foreign vessels are described by Nelson et al. (1981). Length-frequency measurements are taken from random samples of about 150 fish per day by the observer when walleye pollock was the target species. The age sample consisted of otoliths from five fish of each sex and for each 1 cm interval. Only one age sample was obtained per observer vessel trip.

In estimating the age composition of the annual catch by all nations for the combined major fishing areas of the Gulf of Alaska (Shumagin, Chirikof, and Kodiak INPFC areas) the following stepwise procedure was used.

1. For a given year a weighted length composition by sex was obtained for geographical blocks of 1 1/2° lat. and 2° long. for each nation-vessel class and by month. Weighting was calculated by converting the weight of the catch per day aboard the observer vessels to numbers of fish; this was applied to the daily length composition. The mean weight of the fish in a sample was divided into the daily catch by weight to obtain the number in the catch.
2. For each nation-vessel class the block-month length compositions were combined based on correspondence in length range, modes, and sharpness of modes. This may have involved up to 4-5 adjacent geographical blocks for up to 2-4 consecutive months. The combined blocks generally

corresponded to 5 geographical areas: western Shumagin, eastern Shumagin-Chirikof, Shelikof, western Kodiak, and eastern Kodiak (Figure 8). When combining block-months or time-area cells by nation-vessel class, the length compositions were weighted by the best blend catch converted to numbers.

3. The length composition of each time-area cell for a given nation-vessel class was converted to numbers at age using an age-length key from age data collected in that time-area cell. If the age data for a time-area cell were insufficient because of mismatch between the length composition and the age-length data or if the age sample was too small, the age data from adjacent time-area cells were used to build a sufficient key.
4. The age compositions of the time-area cells for each major geoqraphi-cal area were combined for each nation-vessel class to give annual catch in numbers at age.
5. These annual catch in numbers at age by nation-vessel class were further combined to give an all nation-vessel class age composition for each major geographical area. Finally, these were combined for an annual catch at age for all nations and vessel classes for the Shumagin to Kodiak area.

Age data on pollock in the Yakutat and Southeastern INPFC areas were very limited and have not been examined in sufficient detail for inclusion in this report.

Foreign Trawl Fisheries

The mean length and range of pollock from weighted length frequencies were examined by nation-vessel class for the January to June and July to December

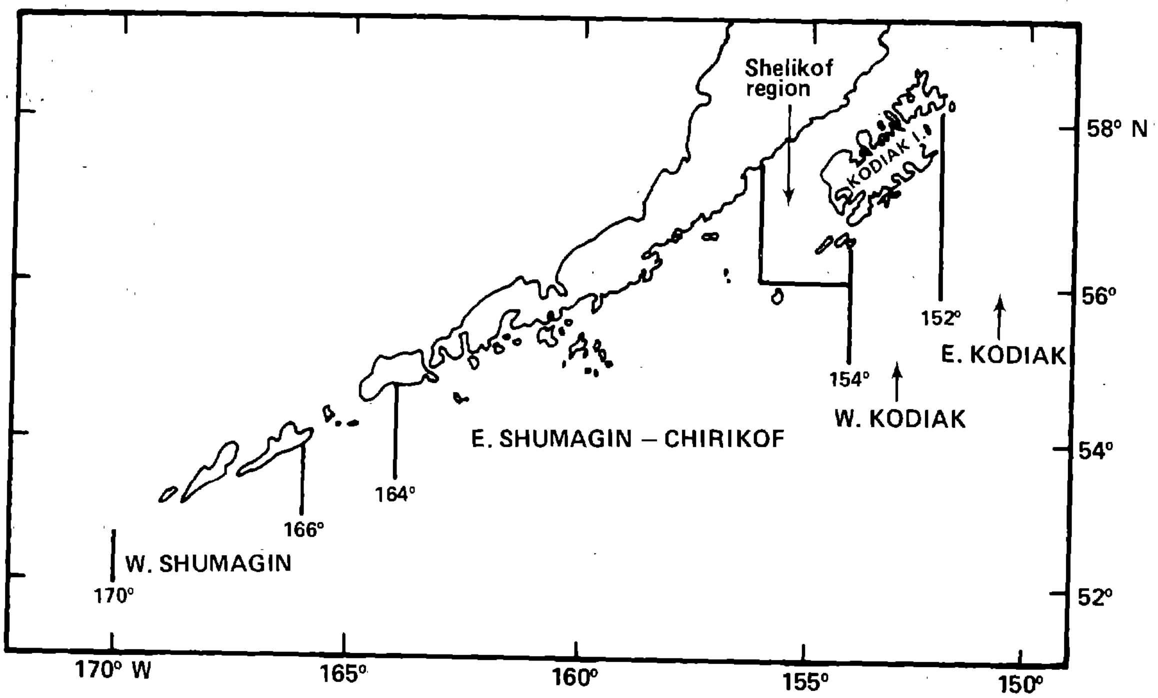

Figure 8.--Geographical subdivision used in estimating length composition of walleye pollock weighted by catch in numbers.

periods (Figures 9 and 10). Considerable variation is apparent in the mean length of fish taken in the eastern Shumagin-Chirikof area in the first half of the year for 1978 to 1980. The low mean length of pollock in the Soviet fisheries accounts for some of this variation. As mentioned earlier, the Soviets have taken a considerable amount of their annual pollock catch in the early part of the year in 1978 and 1980. Their 1978 catch had a high proportion of 2- and 3-year-old fish (Table 8).

For other areas during the June to December period there is generally a correspondence in the mean fish length between nation-vessel classes for the same area and time period. The range certainly varies considerably with a tendency for the east Shumagin-Chirikof area of having smaller length fish. In the second half of the year, the mean length appears stable, with no apparent trend -of increase or decrease in the major pollock fishing areas (Figure 9). For most nation-vessel classes and time-area periods the mean length is around 40 cm and greater.

The contribution of individual year-classes to the catch varied considerably during the 1976-81 period. In 1976 the 1972 year-class as 4-year-olds dominated the catch in both numbers and weight (Figure 11). The importance of #is year-class became evident as early as 1973 when, as 1-year-olds, they occurred frequently and in large numbers in the National Marine Fisheries Service (NMFS) surveys in the Kodiak area. In 1977 and 1978, this year-class continued to be important in the fisheries. The two year-classes following the 1972 year-class (1973 and 1974) were relatively poor contributors to the fisheries. In 1978, two year-classes (1975 and 1976) appeared in large numbers in the catch as 2- and 3-year-olds and continued to be important in the fisheries in 1979 through 1981. The 1977 year-class has also been important

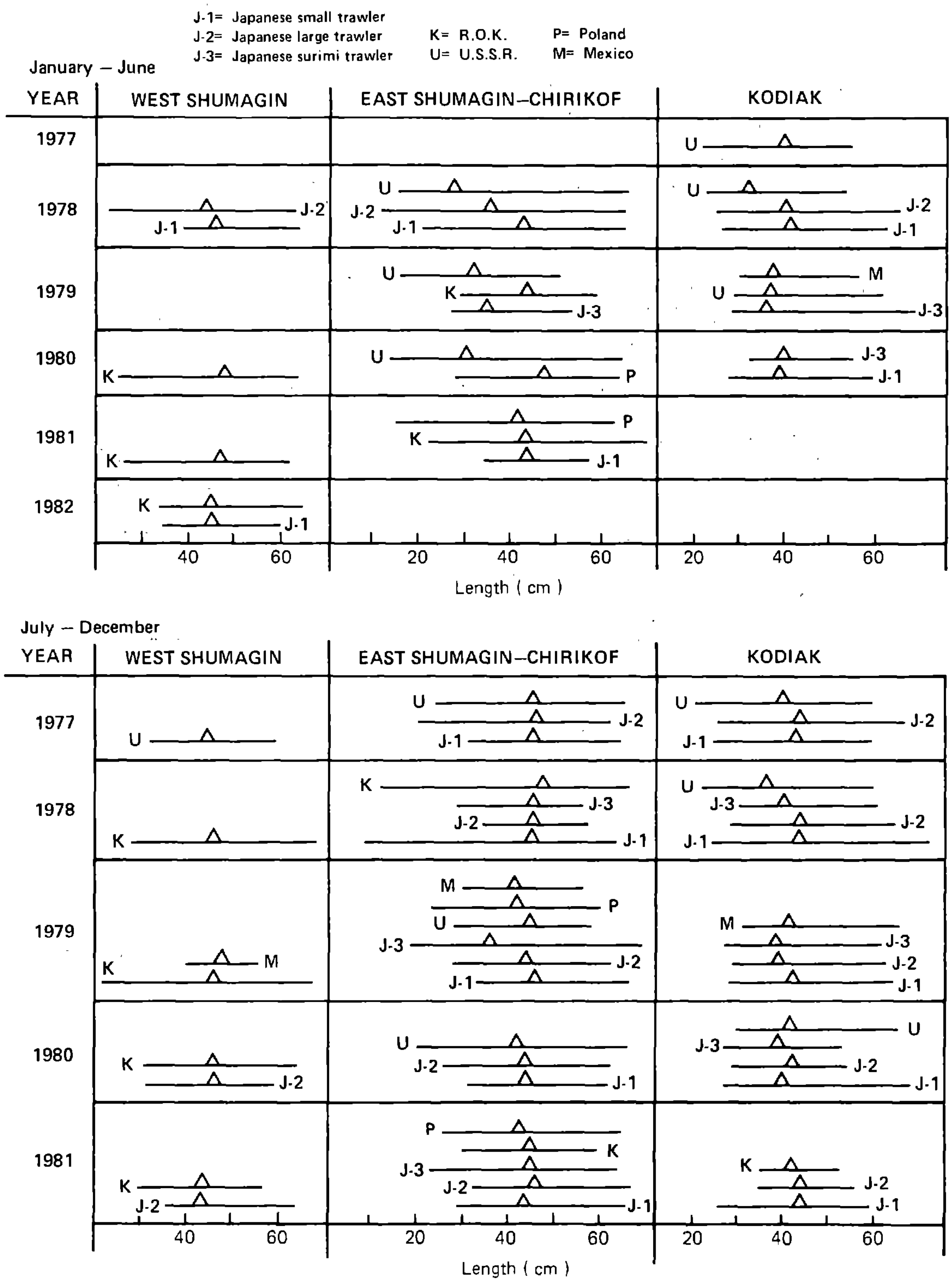

Figure 9.--Mean length and length range of walleye pollock in the foreign trawl catch from the Shumagin and Kodiak areas.

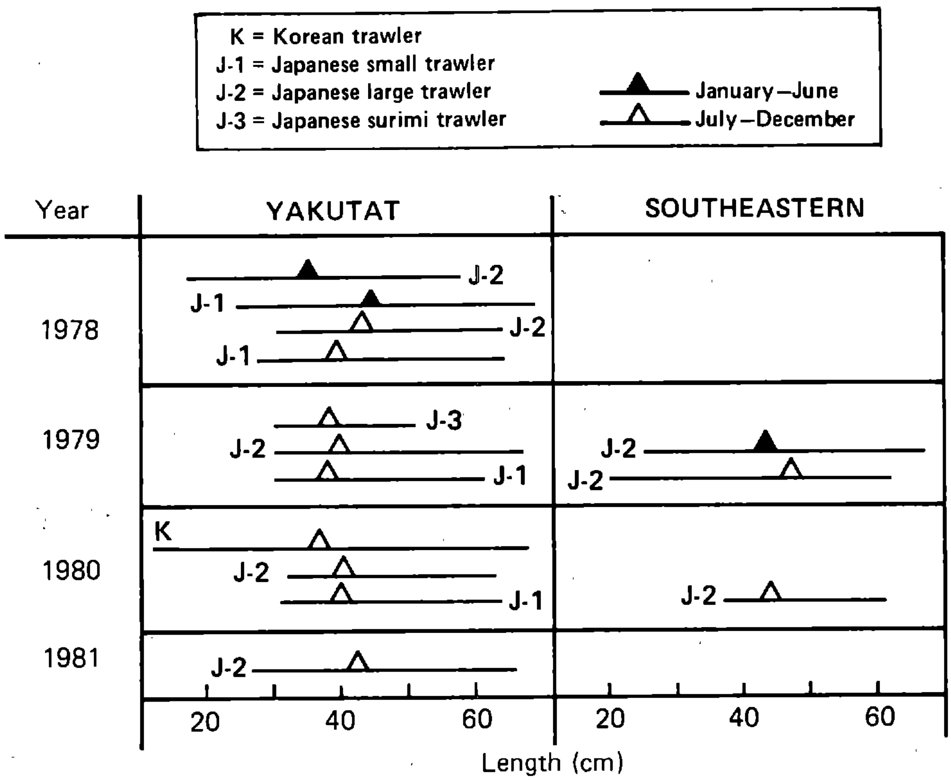

Figure 10.--Mean length and length range of walleye pollock in the foreign trawl catch from the Yakutat and Southeastern International North Pacific Fisheries Commission (INPFC) statistical areas.

Table 8.--Estimates of the annual catch-at-age of walleye pollock in the western and central Gulf of Alaska (Shumagin, Chirikot and Kodiak International North Pacific Fisheries Commission areas) by age, 1976-81, by foreign trawlers and joint-venture fisheries. Catch, age, and size of fish converted to age information from U.S. observer data. Insufficient age information for years prior to 1976.

	1976			1977			1978[1/]			1979			1980			1981		
Age (yr)	Nos (10^3)	Weight (t)	Mean wt. (kg)	Nos (10^3)	Weight (t)	Mean wt. (kg)	Nos (10^3)	Weight (t)	Mean wt. (kg)	Nos (10^3)	Weight (t)	Mean wt. (kg)	Nos (10^3)	Weight (t)	Mean wt. (kg)	Nos (10^3)	Weight (t)	Mean wt. (kg)
0	---	---	---	---	---	---	12	<1	---	---	---	---	---	---	---	---	---	---
1	---	---	---	50	2	0.04	497	11	0.02	262	46	0.18	360	28	0.08	543	72	0.13
2	603	121	0.20	13,189	2,346	0.18	47,651	5,327	0.11	1,773	440	0.25	65,806	11,187	0.17	6,439	1,360	0.21
3	13,562	4,409	0.32	7,676	3,149	0.41	111,332	26,357	0.24	76,305	28,678	0.38	30,386	15,497	0.51	33,195	16,597	0.50
4	94,005	46,651	0.50	18,821	9,013	0.48	13,819	7,977	0.58	55,977	32,184	0.57	54,088	31,912	0.59	75,766	53,936	0.71
5	32,137	19,166	0.60	92,616	64,281	0.69	19,338	12,785	0.66	9,669	7,607	0.79	31,732	21,895	0.69	55,285	39,805	0.72
6	8,997	6,703	0.74	24,204	20,156	0.83	34,446	27,144	0.79	7,661	6,486	0.85	11,526	9,567	0.83	16,868	13,663	0.81
7	2,515	2,129	0.85	8,990	9,016	1.00	7,684	7,340	0.96	14,473	13,918	0.96	6,768	6,565	0.97	4,617	4,386	0.95
8	2,515	2,508	1.00	1,823	2,034	1.12	2,669	2,793	1.05	4,951	5,115	1.03	7,123	7,052	0.99	3,752	3,901	1.04
9	1,561	1,447	0.93	795	833	1.05	1,488	1,744	1.17	1,591	1,766	1.11	2,888	2,946	1.02	3,760	3,797	1.01
10	1	1	1.00	1,105	1,115	1.01	548	551	1.01	708	907	1.28	918	927	1.01	687	800	1.16
11+	---	---	---	574	728	1.27	574	693	1.21	499	634	1.27	666	766	1.15	202	266	1.32
Total	155,896	83,135[2/]		169,843	112,673[2/]		240,058	92,722[3/]		173,869	97,781[3/]		212,261	108,342[3/]		201,114	138,583[3/]	

1/ Low average wt. of 2 and 3 yr olds due to bulk of catch of these ages taken by U.S.S.R. in winter and spring of that year.
2/ Foreign reported catch.
3/ Best blend estimate from U.S. Observer Program.

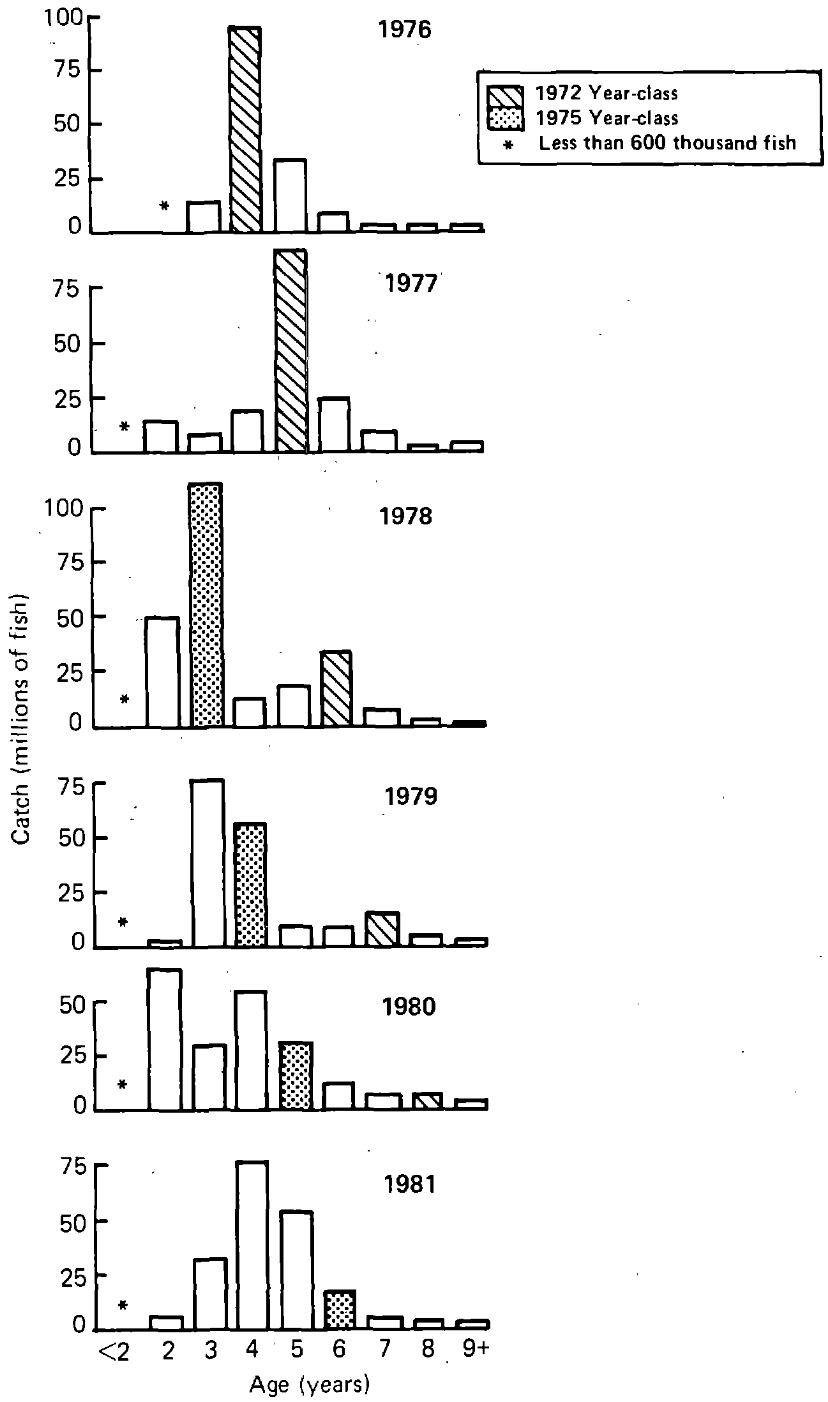

Figure 11 .--Age composition of the annual walleye pollock catch in numbers for all nations from the combined Shumagin, Chirikof, and Kodiak International North Pacific Fisheries Commission (INPFC) statistical areas, 1976-81.

in the catch in 1980 and 1981. Thus, in recent years those consecutive year-classes (1975-77) have made important contributions to the catch. The 1978 year-class also appears to be relatively strong from its contribution to the catch in 1980 and 1981 as 2- and 3-year-olds.

Joint-Venture Fisheries

The mean length of fish in the joint-venture fisheries of the Shelikof region has declined over the period 1980-82, but the mode has increased (Figure 12). This appears to be due to a reduction of fish age-7 and older on the one hand and variations in the contribution of age groups 4, 5, and 6 for 1980-82 on the other hand (Table 9). The 1978 year-class which was of growing importance in the foreign trawl fisheries in 1980 and 1981 was first in abundance in the joint-venture fisheries in 1982, followed by the 1976 and 1977 year-classes.

The joint-venture fisheries take a disproportionate number of male pollock (Table 9). This is believed to be the result of off-bottom or mid-depth trawl fishing in the joint-venture fisheries. Observers aboard foreign trawlers fishing outside of the Shelikof region have often noted the shift to more males occurs when trawling off the sea bottom. Another possibility for the greater number of males in the joint-venture fisheries is that the males may actually be more abundant in the Shelikof region during the pre-spawning and spawning period. They may enter the area and remain there during this period, whereas the females may move in to spawn and then depart.

MAXIMUM SUSTAINABLE YIELD

A first approximation of the annual potential yield was obtained from the following relationship:

$$MSY = 0.4\ M\ P_w \text{ (see Alverson and Pereyra 1969)} \qquad (1)$$

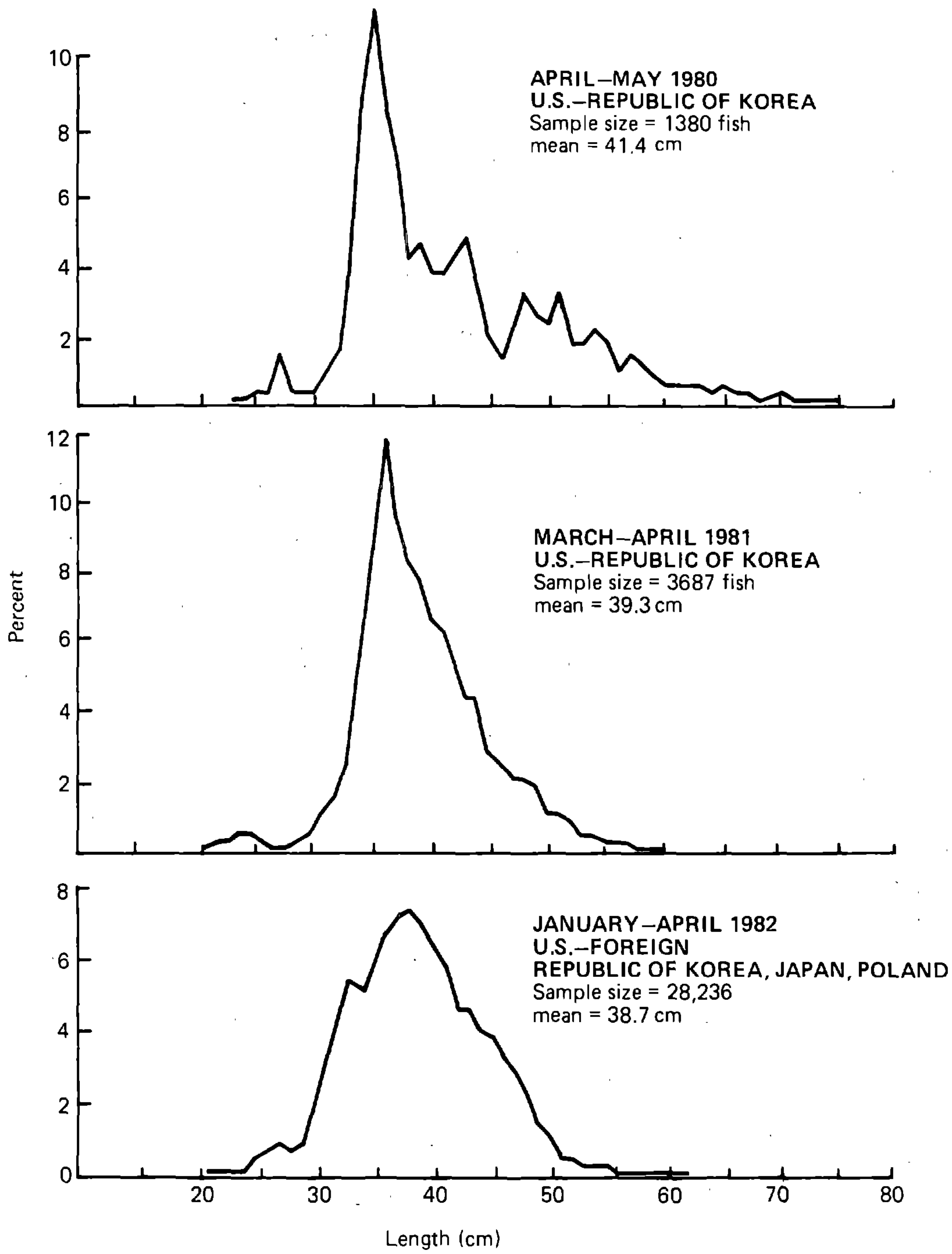

Figure 12. --Length composition of the walleye pollock catch in the U.S.-foreign joint venture fisheries in the Shelikof region of the Gulf of Alaska, 1980-82 (U.S. observer data).

Table 9.--Walleye pollock age and sex composition of the catch of United States-Republic of Korea joint-venture fisheries in the Shelikof region of the Gulf of Alaska in spring of 1980-82.

Year	Months	Age (%)									Sex ratio (M/F)
		1	2	3	4	5	6	7	8	9+	
1980	April - May		2	6	31	29	11	11	7	4	1.5
1981	March - April		1	4	8	58	17	6	2	3	2.1
1982	March - April		1	14	31	27	24	3			1.6

where MSY is the maximum sustainable yield, M is the natural mortality rate, and P_w is the standing stock or exploitable biomass. Natural mortality was estimated to be 0.4 which approximated the 0.43 estimated by the Japan Fishery Agency (1974) for Bering Sea pollock and is the maximum of the range (0.2-0.4) calculated for Gulf of Alaska pollock by Hughes and Hirschhorn (1979). Implicit in the above relationship was the assumption that P_w is a virgin biomass, although in reality the Gulf of Alaska pollock had been under some fishing pressure at the- time this MSY estimate was made in 1977. Exploitable biomass was estimated from NMFS bottom trawl surveys conducted during the years 1973-1977 by using the relationship:

$$P_w = \frac{(CPUE)\ (A)}{c \quad a} \tag{2}$$

where A is the total area, a is the average bottom area covered by the trawl, and c is a coefficient of catchability. For Gulf of Alaska pollock, c was assumed to range between 0.5 and 1.0 and, thus, a range of biomass and MSY estimates was determined. These are shown in Table 3 by INPFC areas. The lower end of the range has been used for allowable biological catch (ABC) for the years 1977-81.

The validity of the MSY equation above has been questioned in recent literature (Francis 1974), and alternative equations have been developed (Deriso 1982). We find little reason to place much confidence in the above MSY equation and, consequently, in the MSY estimates in Table 3. Alternative productivity estimates are developed later in this paper for use in estimating short-term production. Long-term productivity measures, such as a reliable estimate of MSY, will be available, in our opinion, only after a large number of years of data on pollock abundance have been collected.

CHANGE IN ABUNDANCE

In this section, research survey results, catch per unit of effort (CPUE) from the fisheries, and catch-at-age as a means of determining annual change in abundance are examined.

Direct Resource Assessment

Gulf of Alaska pollock has not been directly assessed at frequent enough intervals nor in a manner to monitor abundance change over time. Bottom trawl surveys in themselves may be adequate to detect major changes in pollock abun-ance of several magnitudes, as was observed between the early 1960 International Pacific Halibut Commission (IPHC) surveys and those of NMFS in the mid-1970's (Alton 1981), but for changes of less than a magnitude there is too much varia-tion or imprecision in the estimates to make any meaningful comparisons. There is also the problem of the catchability of the bottom trawl. The catchability is assumed to be a constant, but it seems certain that it varies from survey to survey. Pollock is semidemersal in its schooling and hence its availability varies by depth, season, and area.

The strategy of the Northwest and Alaska Fisheries Center (NWAFC) regarding the direct assessment of pollock is that surveys must include a combination of both bottom trawling and acoustical assessment with midwater trawl sampling and be done synoptically. For monitoring change, such surveys should occur at least every 2 to 3 yr. Such an approach has begun in the assessment of eastern Bering Sea pollock. In the Gulf of Alaska, hydroacoustical assessment of pollock has taken place in only a limited area--Shelikof Strait in 1980 and 1981.

The hydroacoustic surveys in the Shelikof Strait region were directed on pre-spawning and spawning fish. The 1981 surveys were the most comprehensive, covering the period of peak spawning in late March and early April. Only one survey occurred in 1980 after the peak of spawning which accounts for the much lower estimate compared to those for 1981 (Table 10). The decline in the the estimates during the period of the 1981 surveys (Table IO) suggest that the biomass may have reached a maximum in early March. Although a substantial biomass of pollock was found in the spawning area, there did exist unknown amounts outside of the area during the period from March to May. The evidence for this comes from three sources:

1. Foreign fisheries were harvesting pollock outside of the region during the pre-spawning and spawning period in March and April, 1980 (Figure 13).
2. Ichthyoplankton, surveys have found evidence of mass spawning in localities west of the Shelikof region (Figure 5).
3. A U.S.S.R. research trawl survey that occurred during March-May of 1981 found a considerable amount of pollock within, as well as outside of, the Shelikof region (Table 11).

The Soviet survey results must be viewed with caution however, particularly in terms of absolute biomass since large research catches are not weighed using scales but are approximated by looking at the volume of the catch, i.e., the hailed weight (see article by Brown and Rose, in this Technical Memorandum, on the spring 1981 Soviet survey).

In summary, little can be said at this time about the relative or absolute change in walleye pollock abundance during the 1970's and early 1980's through direct research surveys.

Catch Per Unit of Effort

The use of CPUE as a measure of abundance change in pollock is complicated by 1) the changing nature of the fisheries (nation, area, and time); 2) the inability to separate direct effort of pollock and corresponding catch from total effort on all species and catch; and 3) variability in the availability of pollock. These complications are common to the assessment of many fishery

Table 10.--Estimates of walleye pollock biomass in the Shelikof region of the Gulf of Alaska as determined from acoustic surveys in 1980 and 1981.

Year	Month	Biomass (1,000 t)	
		Point estimate	95% confidence interval
1980	April 11-14	709	566 - 852
1981	March 3-15	4,380	2,922 - 5,838
1981	March 24-27	3,147	2,074 - 4,230
1981	April 4-10	3,050	2,022 - 4,078

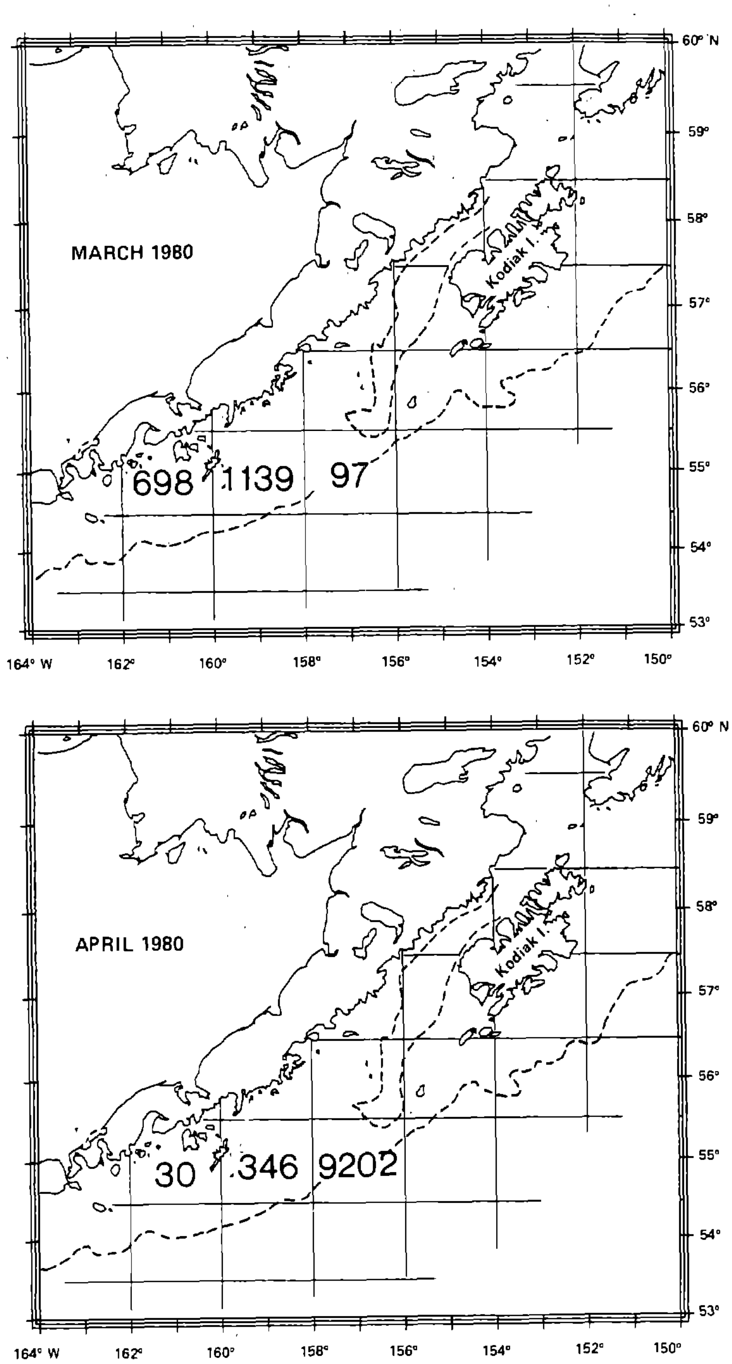

Figure 13.--Catch of walleye pollock (t) by U.S.S.R. trawlers outside the Shelikof spawning area, March and April 1980.

Table 11.--Estimates of walleye pollock biomass in central Gulf of Alaska areas; the estimates were made by U.S. scientists and were based on bottom trawl catches obtained during a 14 March-28 May 1981 survey by the U.S.S.R. ship *Shantar* (see article by Brown and Rose, in this Technical Memorandum, on the spring 1981 Soviet survey).

Area	Biomass (1,000 t)
Shelikof	521
Albatross Bank	380
Chirikof	163
Total	1,064

resources but are more serious with pollock, since it is caught in multispecies trawl fisheries and its schools vary with depth relative to the sea bottom.

In the evaluation of the Gulf of Alaska pollock resource by Balsiger and Alton (1981), the reported catch and effort of surimi trawlers were used to compute CPUE because these trawlers fish almost exclusively for pollock. However, the annual CPUE's were limited (1977-80) and for 1980 it was difficult to identify the catch and effort of surimi trawlers from those of similar tonnage class vessels in the Japanese frozen fish fisheries. In 1981 the Japanese discontinued reporting surimi trawler catch and effort from those of the other trawl fisheries.

A special request was submitted to the Japan Fishery Agency in 1982 for statistics in the surimi trawler operations plus data on the freezer or frozen fish trawlers.

For the surimi operations, annual series of CPUE were examined for vessels of 2,505 to 3,504 gr tons and for vessels of 4,505 gr tons and greater. CPUE for only those years in which there was substantial catch (greater than 1,000 t) for each category of vessel was used to compute CPUE. The larger trawlers (4,505 gr tons and greater) were used from 1973-77. For vessels of 2,505 to 3,504 gr tons there was a continuous series of adequate data for the period 1978-81 and only 1 yr of data (1973) for years prior to 1978.

A comparison of the 1973 CPUE's (Figure 14) indicated the greater fishing power of the higher vessel tonnage class and justified the examination of the CPUE's of the two vessel classes separately. The CPUE's of the greater tonnage class declined from 1973 to 1975 and then rose to its highest value of 12.3 t/h in 1977. For vessels of 2,505 to 3,504 gr tons, CPUE was highest in 1973.(7.9 t/h) and ranged from 5.2 to 6.2 t/h in later years (1978-81).

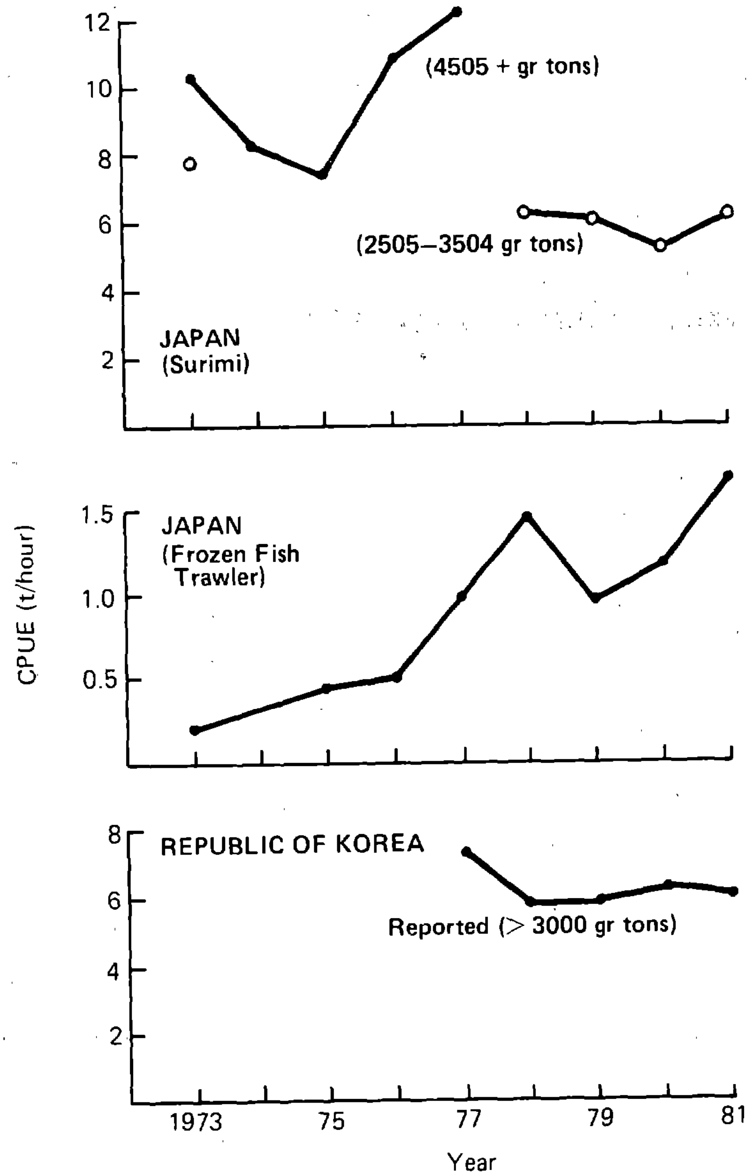

Figure 14.--Catch per unit of effort (CPUE) of walleye pollock from the Japanese and Republic of Korea trawl fisheries in the Gulf of Alaska, 1973-81.

The trends in surimi trawl CPUE's suggest that stock density may have declined between 1973 and 1975 and then reached a high point in 1977. Since 1977, stock density would appear to have been stable.

Japanese scientists have computed a standardized CPUE for frozen fish trawlers. The reference class was vessels of 2,505 to 3,504 gr tons. The standardized CPUE increased from 0.2 t/h in 1973 to 1.5 t/h in 1978, declined to 1.0 t/h in 1979 and then increased again to its highest level (1.7 t/h) in 1981 (Figure 14). It is not possible to say how well those CPUE trends reflect changes in stock density. As mentioned above, frozen fish trawlers target on other groundfish besides pollock and both targeted and nontargeted effort relative to pollock were used in computing the CPUE's.

The R.O.K. trawlers] as do the surimi trawlers, frequently target on pollock. The CPUE's from R.O.K.'s reported catch and effort since 1977, their first year of complete statistics, is shown in Figure 14. These CPUE's were computed for the Shumagin-Chirikof area combined, the principal areas fished by the R.O.K. during these years. CPUE was highest in 1977 (7.4 t/h) and declined to 5.9 t/h in 1978 and 1979, and then rose slightly in 1980-81. There has been some question about the accuracy of the R.O.K. reporting, and there has been a significant decline in the proportion of their total annual catch consisting of pollock (Table 6).

In summary, CPUE as a direct measure of stock abundance change may not be applicable to Gulf of Alaska pollock because of the problems of determining directed effort and shifts in availability. But as a general indicator of stock change, it may be said that there appears to be no sign from CPUE information of resource deterioration. Stock abundance may have been unordinarily high in 1977, as suggested from the surimi trawls (4,505+ gr tons) CPUE and that of

R.O.K. It was in 1977 that the strong year-class of 1972 was important in the fisheries as-5-year-olds. Its importance declined in 1978 and there followed two relatively unimportant year-classes (1973-74) in the fisheries. In more recent years (1980-81) the choice is either that resource abundance is stable or that it is increasing, depending on which CPUE series is used.

Age Structure Analysis

Analysis was made of the age composition data of annual catches of pollock in the western Gulf of Alaska. The objective here is to provide estimates of exploitable biomass, surplus production, and other quantities characterizing the status of this stock. Some of the terms used in this section may not be familiar to the reader, so they are defined here. Exploitable biomass is the sum over age-classes- of age-specific exploitable biomass. Exploitable biomass by age is the product of age-specific biomass multiplied by the proportion of this age-class fully vulnerable to fishing gear. The latter term accounts for both partial recruitment of year-classes into the fishery and selectivity of gear. Productivity of the pollock resource can be measured with annual exploitable surplus production. Annual surplus production represents the annual change in biomass adjusted for removals by the fishery. It is calculated as the biomass at the beginning of the year minus the biomass at the start of the prior year plus annual catch. Exploitable annual surplus production (ASP) is calculated in a similar manner, except that it applies only to the exploitable part of the stock.

The analysis procedures used employed the nonlinear regression methods presented in Doubleday (1976). The basis of this method is the Baranov catch equation (Baranov 1918):

$$C_{an} = \frac{F_{an}}{F_{an} + M_{an}} [1 - \exp(-F_{an} - M_{an})] N_{an} \qquad (3)$$

where C is catch (in numbers of fish), N is abundance at the beginning of the year, F is fishing mortality, M is natural mortality, and subscripts a and n refer to age and year, respectively. Abundance is given as function of year-class strength and survival from cumulative fishing and natural mortality. Fishing mortality is represented as a product of selectivity by age (s) and full-recruitment fishing mortality (f_n), i.e.,

$$F_{an} = s_a \cdot f_n \quad . \qquad (4)$$

This representation for fishing mortality is a critical assumption because it allows such a substantial reduction in the number of parameters to be estimated that only catch-at-age data are needed as input data. Parameter estimation is achieved by nonlinear regression of log-transformed observed and predicted catch. A number of applications of this methodology was made.

Results of Catch-Age Analysis

Application of the method to Gulf of Alaska pollock was made first with catch-age data for ages 3 to 10 during the years 1976 to 1981. Natural mortality was set to 0.4 for all ages and selectivity was assumed to be 1.0 for ages 7 to 10. Estimates of exploitable biomass and ASP are given in Table 12 along with estimates from other applications discussed later. Estimates of year-class strength at age 3 and full-recruitment fishing mortality are given in Table 13. Estimates of age selectivity and average weight appear in Table 14.

The second set of applications of this method were made to examine the sensitivity of results above to changes in the assumed value for natural

Table 12.--Estimates of exploitable biomass of walleye pollock and exploitable annual surplus production obtained from catch-at-age analysis.

Year	All foreign nation-vessel-gear types combined M=0.3 (a)	M=0.4 (b)	M=0.5 (c)	Nations stratified[1/] M=0.4 (d)	Nation-vessel-gear stratified[2/] M=0.4 (e)
	Exploitable biomass				
1976	464	575	740	-	-
1977	608	699	835	402	392
1978	658	696	768	394	396
1979	1,132	1,085	1,093	560	601
1980	1,837	1,583	1,438	874	982
1981	2,698	2,081	1,698	1,441	1,641
Average	1,233	1,120	1,095	734	802
	Exploitable annual surplus production				
1976	228	207	178	-	-
1977	159	106	42	101	114
1978	561	476	412	254	292
1979	802	594	442	410	477
1980	959	596	357	665	756
Average	542	396	286	357	410

1/ Includes joint venture fishery; for Japan, freezer and surimi trawler catches are combined.

2/ Japan's freezer and surimi trawler catch kept separate.

Table 13.--Estimates of year-class strength of walleye pollock at age 3 and full recruitment fishing mortailty rate obtained from catch-age analysis. Abundance given in units of 10^7 numbers of fish. Fishing mortality for combined nations is inside parentheses.

Year	Year class	Combined nations	Nations stratified	Nations and Japan vessels stratified
1976	1973	50 (0.16)	-	-
1977	1974	39 (0.16)	31	33
1978	1975	174 (0.15)	110	130
1979	1976	257 (0.11)	228	273
1980	1977	232 (0.10)	229	268
1981	1978	216 (0.07)	409	481
	Average	161 (0.13)	201	237

Table 14.--Age selectivity of walleye pollock from catch-at-age analysis. These numbers give the proportion of individuals fully vulnerable to fishing mortality. Average weight (kg) from catch samples is given in parentheses.

Age (yr)	Combined nations	Poland	U.S.S.R.	R.O.K.	Japan stern	Japan surimi	Joint venture
3	0.25 (0.39)	0.09	0.29	0.06	0.17	0.10	0.01
4	0.57 (0.57)	0.30	0.34	0.32	0.69	0.43	0.06
5	0.86 (0.69)	0.26	0.71	0.66	0.98	0.66	0.69
6	0.95 (0.81)	0.54	0.68	1.00	1.29	0.94	0.72
7[1]	1.00 (0.95)	1.00	1.00	1.00	1.00	1.00	1.00
8[1]	1.00 (1.04)	1.00	1.00	1.00	1.00	1.00	1.00
9[1]	1.00 (1.05)	1.00	1.00	1.00	1.00	1.00	1.00
10[1]	1.00 (1.08)	1.00	1.00	1.00	1.00	1.00	1.00

1/ Assumed selectivity values.

mortality. Runs with M = 0.3 and M = 0.5 show (Table 12) that both exploitable biomass and ASP estimates are affected by this parameter. Exploitable biomass estimates for 1976-78 increase as natural mortality is increased, but for 1979-81, biomass decreases as M is increased from 0.3 to 0.5. The 1976 and 1981 biomass estimates are affected most from changes in M. We have assumed that natural mortality is 0.4, but estimates of M have ranged from 0.2 to 0.43.

The third set of applications of the catch-age method examines the sensitivity of results to the assumption that fishing mortality can be partitioned into selectivity and full-recruitment mortality without regard to differences between nation vessels. Two analyses were made. The first involves a stratification of catch-age data into the four major nations involved in the Alaskan walleye pollock fishery (Poland, Japan, U.S.S.R., R.O.K.) along with an additional category for the joint-ventures fishery. This stratification is accomplished by fitting Equation (3) to each nation's catch-age data, where the numerator in Equation (3) is replaced by a parameter, $a^{F}ng$, for each nation (g), and where the other fishing mortalities in that equation are the sum of fishing mortalities over nation classes. Data for this stratification were not available for the year 1976; consequently, this application covers the years 1977 to 1981. The second stratification is similar to the one above except that Japan's catch is stratified into two vessel classes: one is for stern trawlers and the other is for surimi-type trawlers. Similar results were found between the two stratification schemes, but for the nonstratified treatment exploitable biomass is markedly higher for a given year than that resulting from the stratified analysis (Table 12). As for ASP, the results between the nonstratified and stratified treatments are considered acceptably similar. The trend of increasing biomass and ASP over the period 1977-81 occurs for all treatments.

Standard deviations of the population estimates were made in our last set of applications with the catch-age method. Owing to the complexity of parameterization in our model, a Monte Carlo simulation method known as the bootstrap technique (Efron 1982) was employed in the variance calculations. Thirty different catch-age data sets were stochastically generated from the predictions of 'the combined nation model and then sample means and standard deviations were calculated from output of nonlinear regressions to those data sets. Estimation bias can also be examined, since sample means were calculated, Estimates for exploitable biomass and ASP are given in Table 15.

Discussion of Catch-Age Analysis Results

Results from our analyses of catch-age data indicate the walleye pollock stock of the western Gulf of Alaska has been recently increasing, both in exploitable biomass and in surplus production (Table 12). Results of the combined nation model with natural mortality at 0.40 place average biomass and ASP of the exploitable stock at 1,120 and 396 thousand t, respectively (Table 12). The increasing trend in biomass is principally a consequence of increased year-class strength in the 1979-81 time period, as compared to recruitment in the years 1976 to 1977 (Table 13).

Several analyses were made in order to examine the uncertainty of results obtained for the combined nation model. The sensitivity analyses presented earlier address the type of estimation uncertainty that arises from assumptions made in the combined nation model about the numerical value for natural mortality and the parametric structure of fishing mortality. The Monte Carlo bootstrap method applied earlier shows estimation uncertainty in the combined nation results due to statistical bias of estimates and statistical uncertainty of estimates. Generally, the standard errors of these results span results

Table 15.--Sample means and standard deviations of exploitable biomass of walleye pollock and exploitable annual surplus production estimated in the combined nation catch-at-age model (M=0.4) using the Monte Carlo bootstrap method. Standard deviations are in parentheses, and units are in thousands of metric tons.

Year	Exploitable biomass	Exploitable ASP1/
1976	590 (220)	177 (63)
1977	689 (243)	70 (84)
1978	669 (260)	429 (213)
1979	1,010 (457)	543 (259)
1980	1,450 (697)	502 (306)
1981	1,831 (937)	-
Average	1,040 (448)	344 (164)

1/ ASP = annual surplus production.

obtained in. sensitivity analysis. By taking a one standard deviation error around sample means, average biomass, and surplus production of the exploitable stocks were found to range (in thousands of t) from 592 to 1,448 and from 180 to 508, respectively. Although these ranges are rather large, the overall precision of these nonlinear regressions has been high, as indicated by close agreement between observed and predicted catches in Figure 15 and also by the fact that squared correlations (R^2) all exceed 0.95 in the regressions.

The estimates of biomass and surplus production from the Monte Carlo bootstrap analysis (Table 15) are preferred because they are less affected by statistical bias than those, given in Table 12. The range in average biomass and ASP (mean + st. dev.) spans those respective estimates computed from the combined and stratified treatments for M = 0.4 (Table 12).

CURRENT STOCK CONDITION

Maximum sustainable yield (MSY) for walleye pollock in the Shumagin to Kodiak areas is estimated to be 152 to 305 thousand t with a midpoint of 228 thousand t. Exploitable annual surplus production (ASP) is estimated to have averaged from 180 to 508 thousand t for the years 1976-80, with a point estimate of 344 thousand t. The difference between MSY and ASP is attributed to 1) the statistical imprecision of survey biomass estimates and catch by age, and the assumptions concerning the catchability of the trawl; 2) the validity of the MSY equation; and 3) values of natural mortality. Annual catches for the Shumagin to Kodiak areas combined reached some 139 thousand t in 1981, a level that is below the lower estimates of both ASP and MSY. Apparently, the pollock resource of the Shumagin to Kodiak areas has, as yet, not been fully harvested.

The equilibrium yield (EY) in recent years (1976-80) for the Shumagin to Kodiak INPFC areas has been estimated to fall within the range from 180 to 508

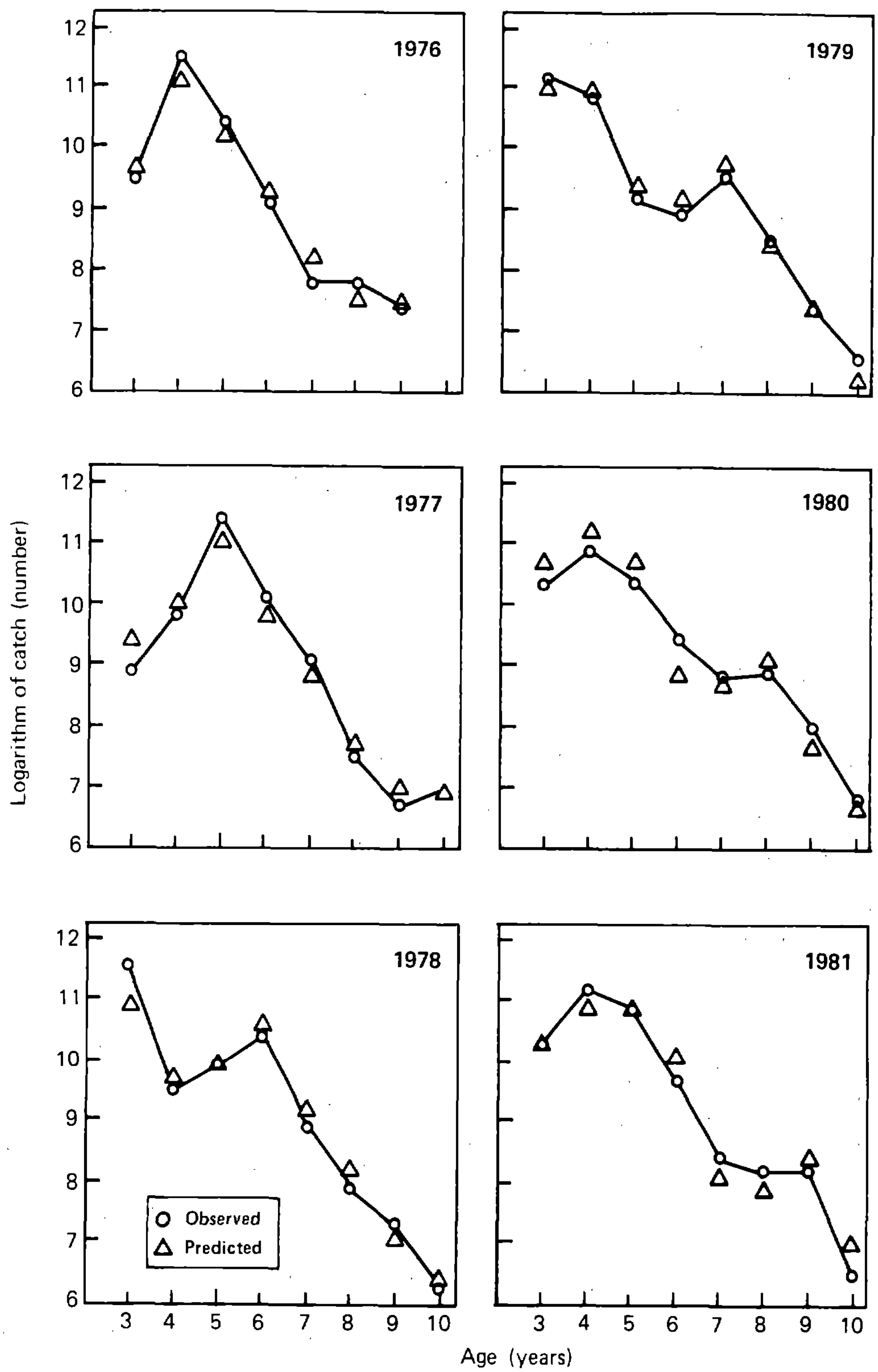

Figure 15.--Observed annual walleye pollock catch by age in the Shumagin to Kodiak areas compared to that predicted from the age-structure model.

thousand t, the average exploitable surplus production. Although there has been relatively strong recruitment since 1978, with estimates of high levels of exploitable surplus production and biomass, there should be caution in using the higher level of the EY range for setting ABC in 1983. The age-structure analysis covers only a small number of years (1976-81); additional years will give us more confidence in the results. Research surveys in the central Gulf of Alaska in 1981 have not encountered any significant amount of prerecruit fish (see article by Brown and Rose, in this Technical Memorandum, on resource assessment surveys). Although CPUE is considered only a general indicator of abundance, there has not been any sharp increase in this indicator for any nation-vessel class that might have been expected from the rise in exploitable surplus production in 1978. For these reasons it would be prudent to consider EY for the near term (1982-83) as falling in the lower part of the range, i.e.., 180 to 344 thousand t.

Until a better understanding of stock structure, resource distribution, and recruitment processes is achieved, the ABC should be partitioned between the combined Kodiak-Chirikof and Shumagin INPFC areas proportional to the geographical distribution of biomass from the 1973-75 research trawl surveys: Shumagin (37%), Chirikof-Kodiak (63%).

For the eastern Gulf of Alaska, the Southeastern-Yakutat INPFC areas, the MSY is considered EY and ranges from 14 to 29 thousand t (Table 3).

RESEARCH NEEDS

Stock Units

Studies by Hughes and Hirschhorn (1979) and Grant and Utter (1980) suggest that an east-west separation of stocks may exist for pollock in the vicinity of Kodiak Island. There needs to be clarification of the result of these studies by further examining year-class growth and biochemical genetic factors. Pollock tagging feasibility studies were begun in 1982, and if results of these studies are favorable, tagging will be conducted- to examine movements relative to known spawning areas.

Recruitment Processes

Spawning of pollock, as observed in the Shelikof Strait region, is very intense, occurring during a brief period at the end of March to early April (A. Kendall, Northwest and Alaska Fisheries Center, Seattle, WA 98112, pers. comm. 1982). This has been consistent for the 3 yr, 1980-82, of observations and suggests that such precise timing is anticipatory for events (currents, food) favorable for survival of the eggs and larvae. Studies on the distribution and survival of the eggs and larvae, as well as the young pollock in their first and second year of life, would be useful in understanding changes in year-class strength, as well as stock structure. More precise information on the relative importance of known spawning sites is needed as well as disclosure of other spawning sites in the Gulf of Alaska.

Distribution and Abundance of Adults

The discovery that the Shelikof Strait region is a major spawning area for pollock has raised questions about the origin of these fish relative to other areas of the Gulf of Alaska. In 1983, NMFS plans a synoptic survey of pollock in the Shumagin to Kodiak areas to estimate resource distribution, abundance, and composition during the known spawning months (March-April). Bottom trawl surveys will be conducted for the on-bottom component of the pollock population. Biomass and its composition will be estimated by acoustic surveys for off-bottom pollock. Ichthyoplankton surveys will be made in selective areas such as the Shelikof Strait region to estimate spawning biomass from egg abundance, fecundity, and other parameters. The trawl-acoustic survey will be the first of a time series to monitor pollock abundance and composition.

The foreign fisheries will continue to be sampled for estimates of age and size composition and for estimates of effective effort. Each additional year of catch-at-age data adds to our series begun in 1976 and will improve our estimates of biomass and surplus production through age structure analysis. The joint-venture fisheries in the Shelikof Strait region on pre-spawning and spawning fish is expected to grow over that of 1982. Although U.S. observers sample the catches brought aboard the processing vessels in these fisheries for estimates of age and size composition, there has been no formal means of obtaining estimates of directed effort and the catch of discards. This is a serious discrepancy since the joint-venture fisheries are on the increase, the catch is almost all pollock, and CPUE from such fisheries would provide not only a measure of stock change but, associated with age data, a means of estimating total mortality (z) and its components (M and F).

Environment and Species Interaction

Modeling studies, and supportive field research must be emphasized to 1) understand the role of the physical environment in determining year-class strength and growth differences between regions and year-classes, and 2) estimate the potential impact of changes in pollock abundance and size composition on commercially important prey (shrimp, young stages of crab) and predators (Pacific cod, Gadus macrocephalus; marine mammals; and Pacific halibut, Hippoglossus stenolepis).

SUMMARY

1. Gulf of Alaska walleye pollock continue to grow in commercial importance. Since 1977 the annual catch has exceeded 100 thousand t, and in 1981, the latest year of complete statistics, the catch reached 148 thousand t. Most of the 1981 catch was taken by foreign fisheries (130.3 thousand t), but the annual joint-venture fisheries catch increased sharply to 16.9 thousand t in 1981. Between January and June of 1982 the joint-venture pollock catch was 74.3 thousand t.

2. The results of the 1973-77 NMFS bottom trawl surveys indicated that 91% of the pollock biomass of the Gulf of Alaska lies west of 148° west long. Over 90% of the annual catch is taken from this region, i.e., the INPFC areas Kodiak, Chirikof, and Shumagin.

3. Maximum sustainable yield (MSY) for the Gulf of Alaska was estimated using the relationship: $MSY = 0.4\ M\ P_w$, where M was 0.4 and P_w was exploitable biomass estimated from the 1973-77 NMFS surveys. The range of MSY was 166 to 334 thousand t. The lower figure has been used in setting the allowable biological catch (ABC) because of the imprecision of the bottom trawl survey biomass estimate and the questionability as to the assumptions in the above equation. The ABC is currently distributed among three regions (Shumagin, Chirikof-Kodiak, and Yakutat-Southeastern) based on biomass distribution.

4. The mean length of pollock taken by most nation-vessel classes in the foreign trawl fisheries has been around 40 cm or greater during the years 1976-81. In the joint-venture fisheries the mean length has been 39 to 41 cm.

5. The 1972 year-class was important in the foreign catch during the years 1976-78. This year-class was followed by two year-classes, 1973 and 1974,

which were of relatively little importance in the fisheries. In recent years three consecutive year-classes (1975-77) have been important contributors to the pollock catch. The 1978 year-class has been of growing importance in the foreign fisheries in 1980 and 1981 and was first in abundance in the joint-venture fisheries in 1982.

6. Catch per unit of effort (CPUE) as a direct measure of stock abundance change is of limited applicability to Gulf of Alaska pollock because of the problems of determining directed effort and shifts in availability. As a general indicator of stock change, CPUE trends show no signs of resource decline.

7. Results for the analysis of annual catch-at-age for the years 1976-81 and for the Shumagin, Chirikof, and Kodiak INPFC areas combined indicate an increasing trend in exploitable biomass and surplus production. Average biomass and surplus production of the exploitable stocks range (in thousands of t) from 592 to 1,448 and from 180 to 508, respectively.

8. Results from the age-structure analysis are considered the best estimates of recent stock conditions. The equilibrium yield (EY) in recent years (1976-80) for the Shumagin to Kodiak INPFC areas has fallen in the range of 180 to 508 thousand t, the average exploitable surplus production for those years. We advise that the EY for 1982 and 1983 be set within the lower half of the range (180-344 thousand t) and that ABC be partitioned among the Shumagin, and Chirikof-Kodiak INPFC areas based on the proportional distribution of biomass estimated from NMFS 1973-75 bottom trawl surveys.

9. We recommend further research on identification of stock units, recruitment processes, and the interaction of walleye pollock with other species and the physical environment.

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SABLEFISH

by

James W. Balsiger

The sablefish, *Anoplopoma fimbria*, resource in the northeast Pacific Ocean is found in waters off northern Mexico to the Gulf of Alaska, westward to the Aleutian Islands region, and into the Bering Sea. This resource has been harvested by U.S. and Canadian fisheries since early in this century, but catches were relatively small and generally limited to areas near fishing ports from California to southeast Alaska. Catches in the Gulf of Alaska averaged about 1,500 metric tons (t) from 1930 to 1950 and exploitation rates remained very low until Japanese longliners began operations in the eastern Bering Sea in 1958. The Japanese fishery expanded very rapidly and took 30,000 t as early as 1962 (Narita 1982). In 1963 the Japanese longline fleet expanded to the Aleutian region and the Gulf of Alaska, and catches rapidly escalated until the record all-nation catch from the northeast Pacific reached 67,000 t in 1972. Following this peak year, northeast Pacific total catch averaged about 50,000 t from 1973 to 1976.

Evidence of declining stock abundance led to significant fisheries restrictions since 1977, and total catches have been reduced substantially. Until 1977, the majority of the sablefish harvest was taken from the Gulf of Alaska. Beginning in 1978, regulations on foreign fleets in the Gulf of Alaska, coupled with sharply increased U.S. effort off Washington-California, have reduced the proportion of total sablefish harvested in the Gulf. Sablefish catches off Washington to California from 1978 to 1981 were 10,700 t, 17,300 t, 9,500 t, and 11,600 t, respectively, and catches off Canada for this same time period averaged about 3,500 t (Parks 1982). Gulf of Alaska landings are shown in Table 1.

Table 1 .--Historical catches of sablefish in metric tons (t) by area and nation in the Gulf of Alaska; 1958-1981.

	Gulf of Alaska (Shumagin-Southeastern)					
Year	U.S.	Canada	Japan[1/]	U.S.S.R.	R.O.K.	Total
	- - - - - - - -	- - - - - - - -	- - - - t	- - - - - - - -	- - - - - - - -	- - - - -
1958	--	2/	--	--	--	--
1959	967	2/	--	--	--	--
1960	1,348	2/	--	--	--	--
1961	606	2/	--	--	--	--
1962	684	2/	--	--	--	--
1963	617	2/	1,681	--	--	2,298
1964	1,173	2/	1,041	--	--	2,214
1965	1,048	2/	2,107	--	--	3,155
1966	1,051	2/	3,514	--	--	4,565
1967	947	2/	4,217	--	--	5,164
1968	112	2/	13,886	--	--	13,998
1969	302	2/	19,587	--	--	19,889
1970	369	2/	21,397	--	--	21,766
1971	270	15	25,636	--	--	25,921
1972	1,387	16	34,259	535	308[3/]	36,505
1973	867	16	29,246	109	58[3/]	30,296
1974	771	10	23,300	38	2,431[3/]	26,550
1975	1,088	16	21,561	33	3,000[3/]	25,698
1976	1,145	23	22,947	41	3,000[3/]	27,514
1977	1,173	3	14,367	4	1,586	16,785
1978	1,813	0	6,458	4	665	8,940
1979	2,341	0	5,919	152	759	9,226[4/]
1980	2,204	0	4,831	416	891	8,342
1981	1,783	0	6,911	0	1,062	9,756[5/]

1/ Japanese catch is reported by fishing year through 1976; all others are reported by calendar year.
2/ Data not available.
3/ Includes catches from other areas in the northeastern Pacific.
4/ Includes 55 t by Mexico.
5/ Includes 7 t by Poland.

Source: U.S. data through 1973 from Fishery Statistics of the U.S., Statistical Digests 49-68; 1974-76 data from Pacific Marine Fisheries Commission (PMFC) data series, groundfish section; 1977-81 from Alaska Department of Fish and Game Extended Jurisdiction Section Canadian data 1971-76 from PMFC data series, groundfish section; 1958-70 data not available. Japanese, U.S.S.R., R.O.K. data from International North Pacific Fisheries Commission document 1883; pers. commun., T. Sasaki, Far Seas Fisheries Lab., Shimizu, Japan; U.S. Foreign Fisheries Observer Program; Northwest and Alaska Fishieries Center, 2725 Montlake Blvd. E., Seattle, WA 98112.

The directed foreign sablefish fishery in the Gulf of Alaska is limited by regulation to longline gear. An allowance is made for incidental catches in the trawl fisheries, and from 1979 to 1981 the-foreign trawl catch of sablefish was 686 t, 1,422 t, and 919 t, respectively; an annual, average catch of about 1,000 t.

Domestic sablefish gear in the Gulf of Alaska has consisted almost exclusively of longline gear although occasional small catches with pot gear have been made. Significant regulations affecting Gulf of Alaska sablefish fisheries consist of maximum catch quotas derived from estimates of equilibrium yield (EY). From 1971 to 1981, a catch quota of 13,000 t was in effect for foreign and domestic fisheries. For 1982 that catch quota was reduced to 8,230 t. On the surface it appears that the catch quotas from 1977 to 1981 were not restrictive since total catch for each of those years remained well below 13,000 t. However, the allocation of catch quotas to foreign fleets was often late in the year and probably affected the effectiveness of their operations.

Beginning in 1978, those portions of the Gulf of Alaska east of 140° W long. were closed to foreign longlining. This eliminated a formerly productive part of the foreign longline fishing grounds. Likewise, the implementation of the Fishery Management Plan (FMP) for Gulf of Alaska Groundfish (North Pacific Fisheries Management Council) in 1979 closed the Davidson Bank area (163°04' W long. to 166°00' W long.) to all foreign fishing.

CONDITION OF STOCKS

Stock Structure

Experiments designed to identify sablefish stock structure in the Gulf of Alaska continue. The National Marine Fisheries Service (NMFS), Alaska Department of Fish and Game (ADF&G), Japanese, and Canadian fisheries scientists have released tagged sablefish over the past several years. The results of these experiments indicated that sablefish throughout the northeast Pacific are of one genetic pool. There is less agreement on the degree of interchange of fish between regions. Wespestad (1981) reported that interregional migration is small in comparison to stock size within each region and agreed with previous reports (Low et al. 1976; Wespsstad et al. 1978) that management of the resource is best conducted by discrete geographic regions.

Bracken (1982), however, described an analysis of Gulf-wide sablefish tagging data and suggested that sablefish move extensively throughout the Gulf of Alaska. The analysis showed fish under 60 cm tended to move westward while fish 60 cm or greater tended to migrate eastward.

Bracken (1982) also presented a conceptual model that identified south-eastern Alaska and British Columbia as a pooling area for large fish and that much of the spawning occurs in that region. Small fish inhabit the shallow nearshore areas and then enter deep water in their third or fourth year. From there a significant portion of the fish migrate to open ocean and move westward until they reach maturity. A large portion of the mature fish then migrate back into the eastern Gulf to spawn. Bracken concluded by recommending management of sablefish as a single stock Gulf-wide and suggested that lower harvest levels throughout the Gulf of Alaska would speed rebuilding of the depleted spawning population in the southeastern area.

Currently, management of sablefish is by five management regions in the Gulf of Alaska: West, Central, Yakutat, Southeast inside waters, and Southeast outside waters. Clearly, the questions of migration and stock structure are basic to rational management of sablefish, but are yet unresolved.

Year-Class Strength

U.S. observers on Japanese longline vessels in the Gulf of Alaska have collected data on length-frequency of sablefish taken in this fishery. Figures l-4 depict these length frequencies by International North Pacific Fisheries Commission (INPFC) area, year, and sex for the directed Japanese longline fishery which operates in depths greater than 500 m. For the years 1977-79 in all areas except Yakutat, the distribution is unimodal and similar to the size distribution in the historic fishery with mean size of approximately 65 cm. In the Yakutat area in 1979, a group of fish of about 47-49 cm appeared; in 1980 the fishery took a large percentage of fish at a size of 49-51 cm in all areas; by 1981 the size of this first mode was approximately 55 cm. This apparent strong year-class has been noted by others and has usually been identified as the 1977 year-class (Balsiger and Alton 1981; Zenger 1981; Zenger and Hughes 1981; and Sasaki 1981). No other strong year-classes subsequent to 1977 are yet apparent in the fisheries data.

Catch per Unit of Effort Data of the Japanese Longline Fishery

Until 1977, catch and effort statistics from the Japanese North Pacific longline fishery provided consistent information for assessing the condition of sablefish stocks in the Gulf of Alaska. Catch per unit of effort (CPUE) in terms of kilograms of sablefish per 10 hachi units of effort are shown in Table 2.

Prior to 1974, CPUE was generally greater than 200 (kg/l0 hachi) in all INPFC areas. In 1975, CPUE dropped to as low as 154 in the Shumagin area and was generally about 185 in the other areas. In 1976, CPUE increased in all areas of the Gulf of Alaska. From 1976 to 1977, CPUE dropped in all areas with the decline ranging from 13 to 34% and averaging about 25%.

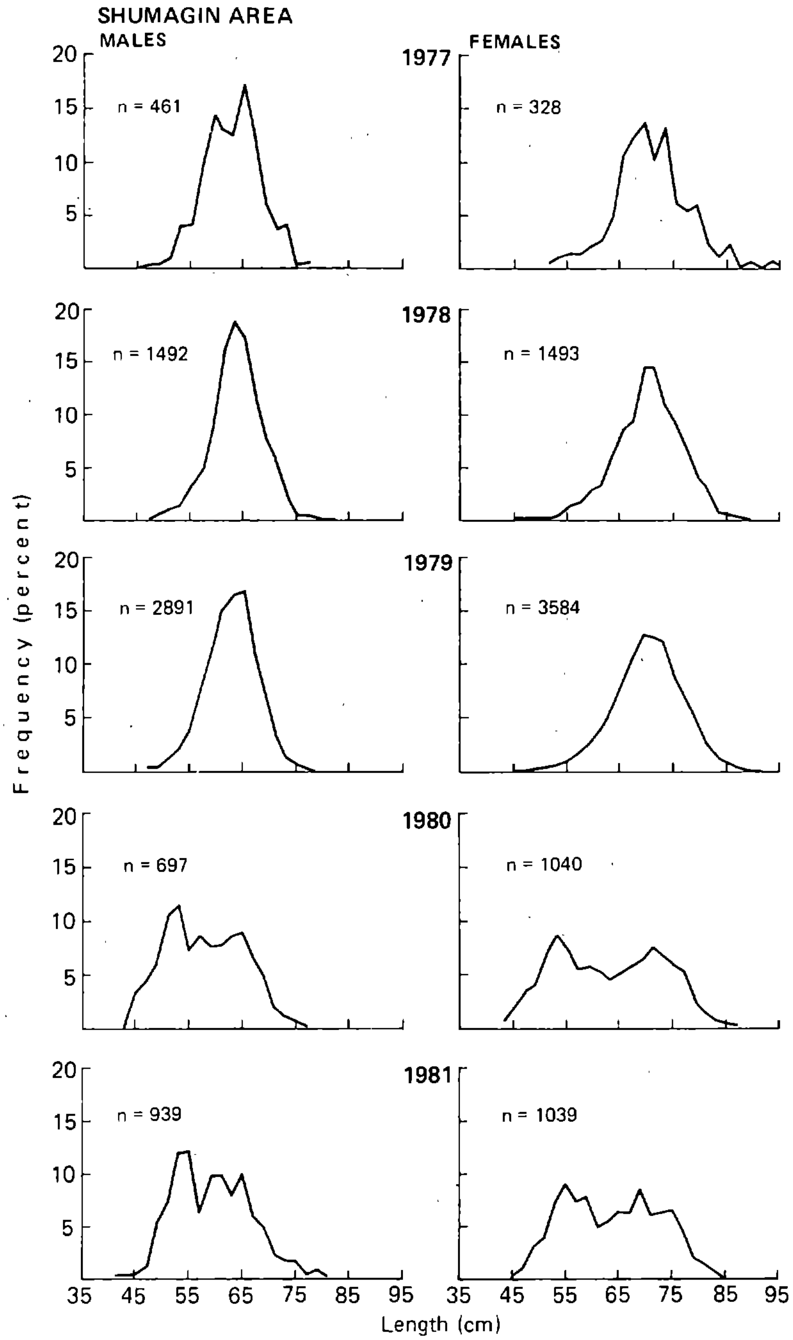

Figure 1 .--Sablefish length-frequency by U.S. observers on Japanese longline vessels in the Shumagin International North Pacific Fisheries Commission (INPFC) statistical area, deeper than 500 m, from 1977 to 1981.

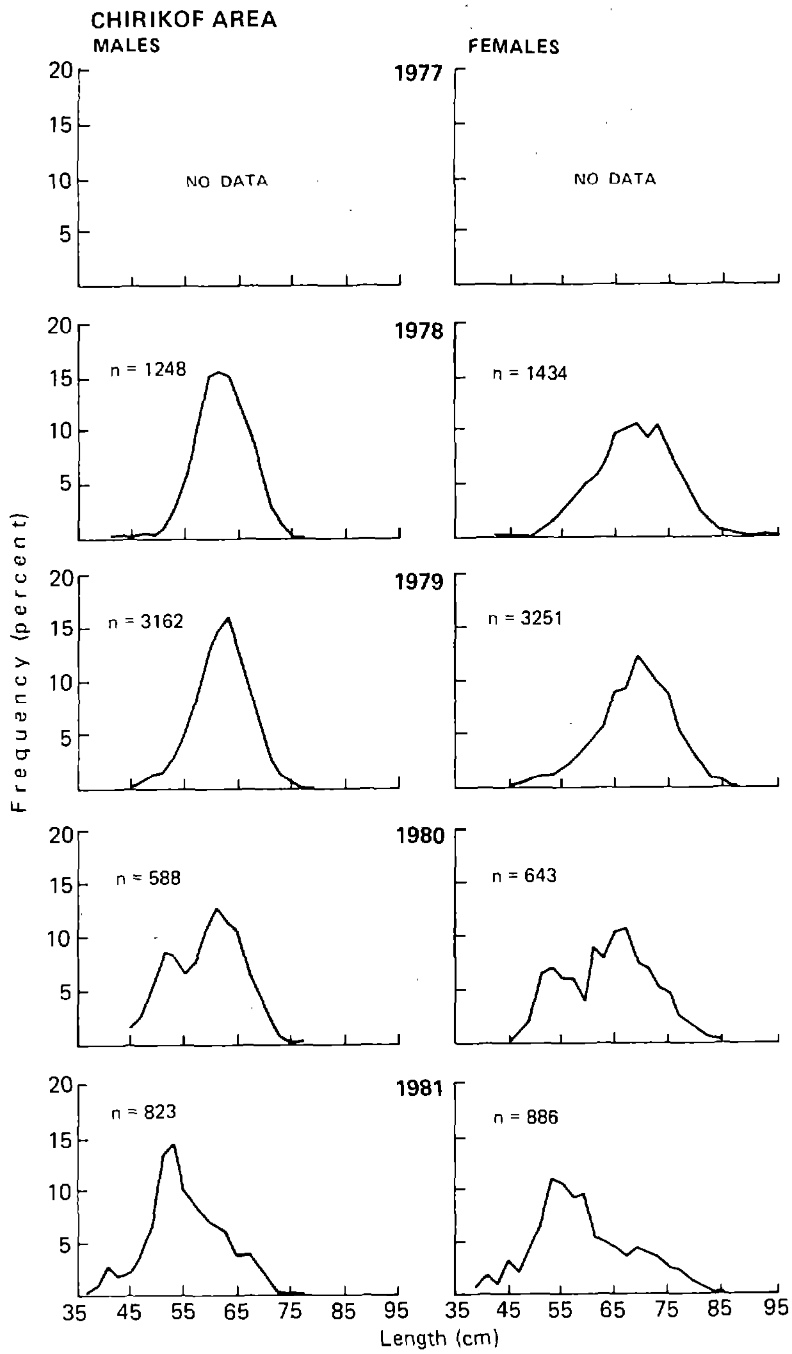

Figure 2. --Sablefish length-frequency by U.S. observers on Japanese longline vessels in the Chirikof International North Pacific Fisheries Commission (INPFC) statistical area, deeper than 500 m, from 1977 to 1981.

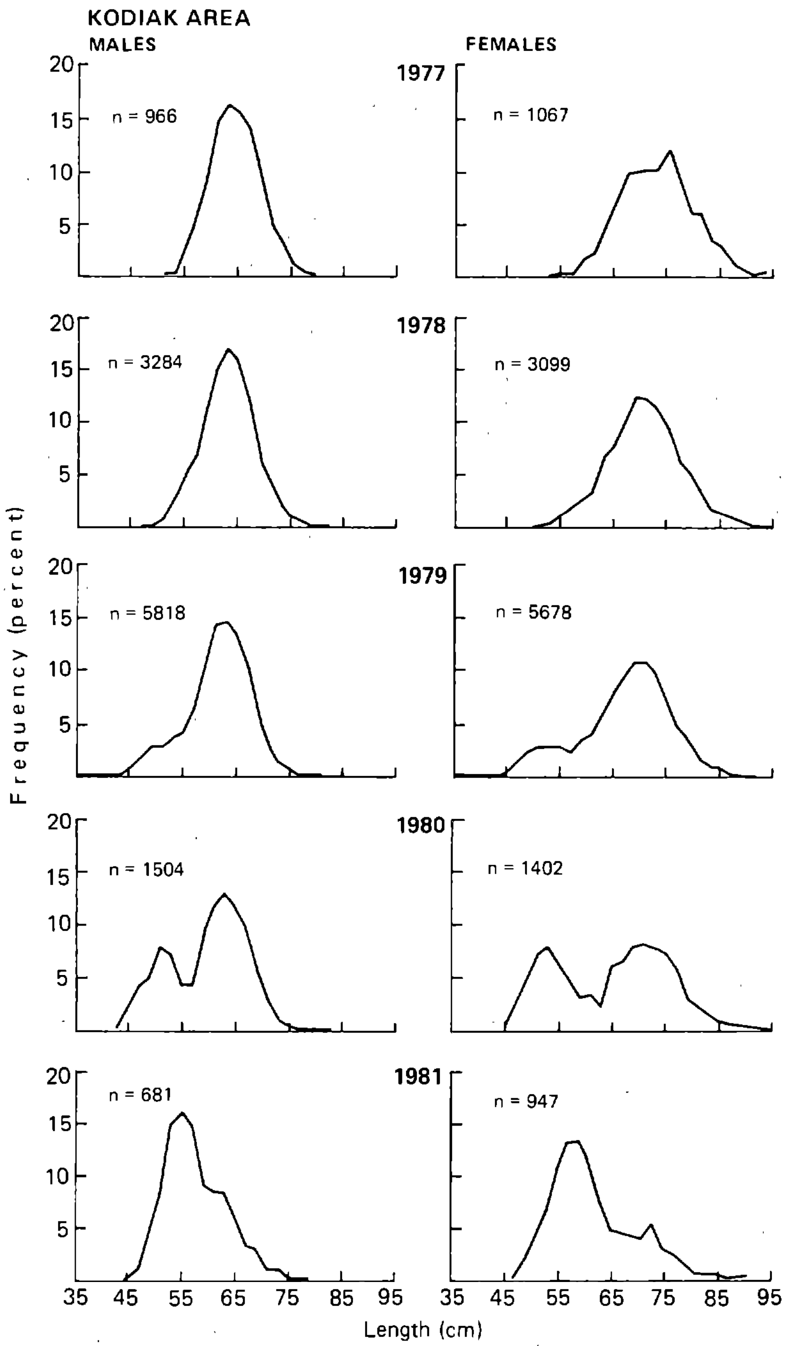

Figure 3.--Sablefish length-frequency by U.S. observers on Japanese longline vessels in the Kodiak International North Pacific Fisheries Commission (INPFC) statistical area, deeper than 500 m, from 1977 to 1981.

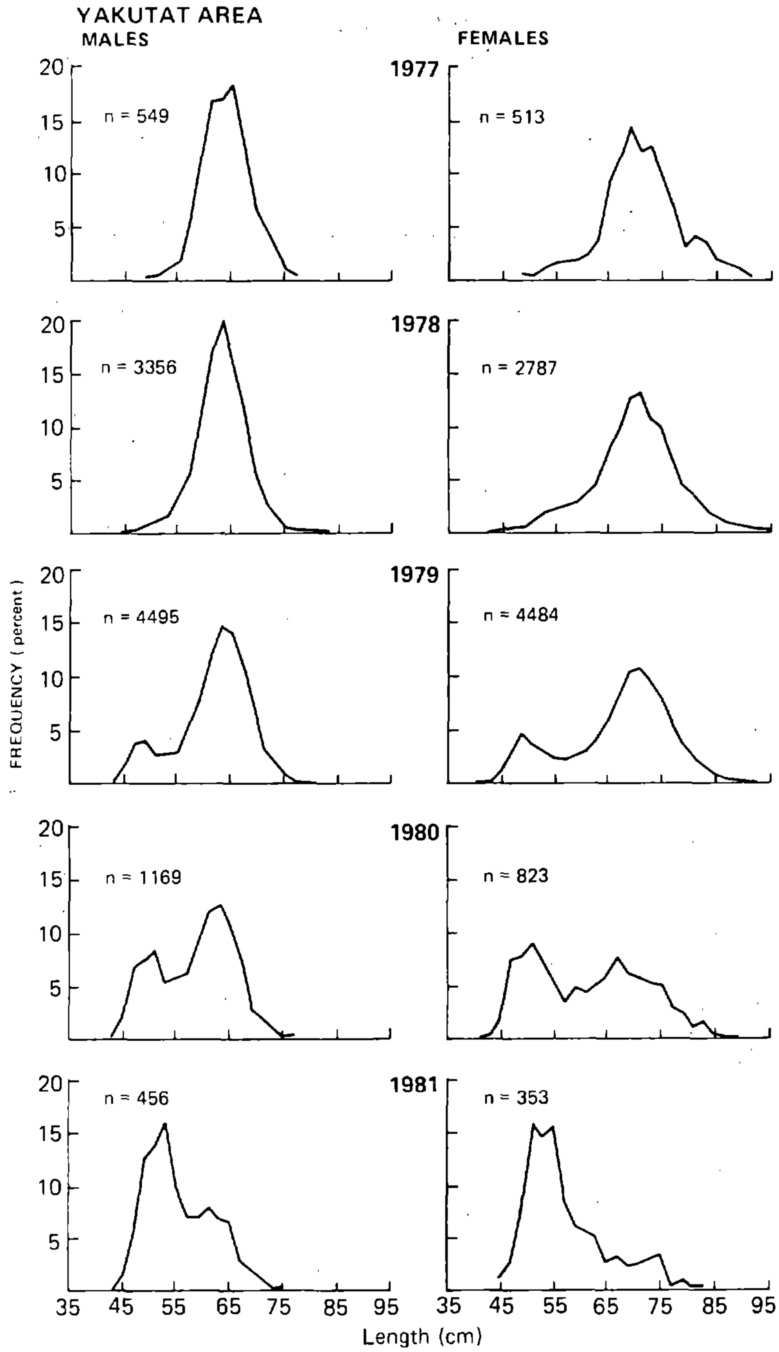

Figure 4.--Sablefish length-frequency by U.S. observers on Japanese longline vessels in the Yakutat International North Pacific Fisheries Commission (INPFC) statistical area, deeper than 500 m, from 1977 to 1981.

Table 2.--Catch per unit of effort (kg/10 hachi) of sablefish in the Gulf of Alaska, 1967-79 (Okada et al. 1982).

Year	Shumagin	Chirikof	Kodiak	Yakutat	Southeastern	Weighted average Shumagin-Southeastern
1967	184	234	175	175	301	212
1968	153	226	272	282	257	263
1969	239	246	239	238	229	235
1970	221	245	266	255	229	235
1971	177	206	207	223	204	207
1972	220	198	210	203	207	208
1973	214	216	213	206	203	209
1974	181	191	185	191	195	190
1975	154	188	181	186	184	177
1976	165	201	182	196	191	186
1977	144	133	133	142	139	139
1978	*1/	*	136	137	---2/	135
1979	*	*	60	74	---	109
1980	*	*	*	*	---	122
1981	*	*	*	*	---	151

1/ Prior to 1978, Japanese longliners were not permitted to fish in depths shallower than 500 m. Since 1978, some of these longliners have been permitted to fish in waters shallower than 500 m for Pacific cod. Therefore, the total longline fishing effort no longer reflects total effort on sablefish.

2/ No foreign longlining has been permitted east of 140°W long. since 1978.

In 1978, fishing regulations in the Gulf of Alaska were changed to permit Japanese longliners to fish in depths shallower than 500 m in the Shumagin-Chirikof region for Pacific cod, *Gadus macrocephalus*. In 1979, the permission was extended to the rest of the Gulf. Also in 1978, catch limits for the Japanese longline fishery were imposed. This resulted in a shift of Japanese longline fishing effort towards Pacific cod in depths of 100-300 m, while in the past all the effort was directed at sablefish in depths generally greater than 500 m. Since target effort cannot be detected in the Japanese reported statistics, this source of information is available only through 1977. Okada et al. (1982) provided Gulf-wide CPUE's to continue this data series (Table 2), but it is not clear how effort directed specifically at sablefish was estimated. These latest data points show significant increases in 1980 and 1981.

U.S. Observer Data

Beginning in 1977 a new data source for evaluating sablefish stocks became available as U.S. observers were deployed on Japanese longline vessels. The observers collected a variety of information, including depth of fishing gear. Using this depth information, Japanese longline effort in the Gulf was identified as 1) directed at Pacific cod in the less than 300 m zone, or 2) directed at sablefish in the deeper than 500 m zone (Balsiger and Alton 1981).

A new data series of Japanese longline CPUE was calculated using only effort directed at sablefish as described above. These observer CPUE rates are shown in Tables 3 and 4. Comparing the combined CPUE's for the Shumagin to Yakutat area for 1977-80, it appears that a 25% decline occurred from 1977 to 1979, but in 1980 stocks recovered to about the 1977 level.

In 1981, CPUE was up sharply in the Chirikof and Kodiak areas, but decreased significantly in the Yakutat area. It should be noted that the observer sample

Table 3.--Catch per unit of effort (t/1000 hooks) for sablefish in Japanese lonqline fishery for observed hauls from >500 m depth as determined by U.S. observers. Number of observed hooks in thousands is shown in parentheses.

Year	Shumagin	Chirikof	Kodiak	Yakutat	Southeast	Shumagin-Yakutat
1977	.237 (191)	---	.247 (510)	.361 (500)	.428 (773)	.293
1978 1/	.236 (549)	.204 (494)	.241 (1,525)	.232 (1,155)	?	.232
1979 1/	.140 (1,041)	.202 (931)	.228 (1,781)	.268 (1,359)	?	.216
1980 1/	.286 (273)	.275 (211)	.350 (347)	.254 (209)	---	.298
1981	.238 (375)	.419 (220)	.491 (203)	.194 (104)	---	.334

Table 4.--Catch per unit of effort (t/1000 hooks) for large sablefish (67 cm and greater) in the Japanese longline fishery for hauls from >500 m depth as determined by U.S. observers. Number of observed hooks in thousands is shown in parentheses.

Year	Shumagin	Chirikof	Kodiak	Yakutat	Southeast	Shumagin-Yakutat
1977	.123 (191)	---	.169 (510)	.211 (500)	.269 (773)	.179
1978	.140 (549)	.107 (494)	.141 (1,525)	.126 (1,155)	---	.132
1979	.085 (1,041)	.109 (931)	.117 (1,781)	.149 (1,359)	---	.117
1980	.133 (273)	.089 (211)	.174 (347)	.086 (209)	---	.131
1981	.112 (375)	.130 (220)	.167 (203)	.037 (104)	---	.122

1/ The area east of 140° W long. in Yakutat was closed to foreign longlining in 1978 and 1979.

in the Yakutat area in 1981 was smaller than for any other year-area in the table. This raises some question as to the accuracy of this particular statistic since it can be seen from Table 5 that the Yakutat area provided a major part of the Japanese longline catch of sablefish in 1981. It is unlikely that operations would have continued in the area if catch rates for the entire season had remained at only about 50% of catch rates in the rest of the Gulf.

CPUE rates determined from the same observer data for sablefish 67 cm or greater in the Japanese longline fishery can also be calculated (Table 4). The apparent absence of large fish in the Yakutat area fishery is a cause for concern; however, the sampling problem, as noted above, should be considered.

Japan-U.S. Cooperative Longline Survey

Each year since 1978, Japan and the U.S. have cooperatively conducted a longline survey in the Gulf of Alaska to study stock conditions of sablefish and other longline-caught species. Results of the 1978 to 1981 surveys, as reported by Okada et al. (1982), are shown in Table 6. The index of abundance is a summation of the CPUE of the longline gear for each of several depth categories multiplied by the area of the fishing grounds which lies in those depth categories. The results depicted in Table 6 show the sablefish resource in the Gulf of Alaska increased strongly from 1978 to 1980 and remained at about the same level in 1981.

Sasaki (1981) and Okada et al. (1982) noted that size composition data in the 1980 and 1981 surveys indicated young sablefish were in very high abundance. They predicted an increase in the sablefish resource in the coming years as the very abundant young fish grow.

U.S. Pot Index Survey

The NMFS pot index survey conducted annually since 1978 has become an important means of assessment for sablefish stocks in the Southeast area since

Table 5.--Distribution of Japanese longline catch of sablefish in the Gulf of Alaska.

Year	Area			
	Shumagin	Chirikof	Kodiak	Yakutat
	t			
1979	775	1059	1723	1890
1980	705	1204	1032	1154
1981	1225	1345	1167	2507

Table 6.--Index[1/] of sablefish stock size from the Japan-U.S. cooperative longline survey in the Gulf of Alaska.

Area	Index 1978	1979	1980	1981
Shumagin	2,605	5,347	8,163	12,892
Chirikof	4,717	30,716	25,947	23,032
Kodiak	19,044	24,134	28,877	23,063
Yakutat	8,223	14,873	27,189	28,332
Southeastern	8,725	10,428	14,395	16,229
All Areas	43,314	85,498	104,571	103,548

l/ Index is a function of catch per unit of effort in numbers of fish.

the foreign longline fishery no longer operates there. Based on results of surveys from 1978 to 1980, Zenger and Hughes (1981) estimated the stock was capable of producing an allowable biological catch (ABC) of 2,580 t in 1981. Following the 1981 survey (Zenger 1981) the population index appeared to be down about 50% from the previous year. The 1982 survey encountered problems with weather and two stations were fished with inferior bait which made the results more difficult to interpret. The results, however, showed little change from the 1981 survey.

Growth of Sablefish

The ability to predict future yields of the sablefish resource and to determine the current stock condition is dependent on the ability to accurately age and determine the growth rate of sablefish.

Sablefish growth rates reported in the literature vary widely. Sasaki et al. 1975 (in Low et al. 1976) fitted a Bertalanffy growth curve to length-at-age data for Bering Sea sablefish of both sexes (Figure 5). The growth curve appears to be about average compared to other female-only curves (Figure 5A) even though it includes the effects of the slower growing males. The pooled sex growth rate is substantially faster than male-only curves (Figure 5B). Balsiger and Terry (1981) derived a growth curve. for Gulf of Alaska sablefish of each sex based on following modal sizes in successive years in a number of data sets. This growth curve shows relatively small initial sizes-at-age for both sexes (Figure 5A and 5B), but displays a relatively fast rate of growth such that size-at-age is larger than most other curves by age-7.

Beamish and Chilton (1982) used a new technique of breaking and burning otoliths prior to counting annuli. They obtained much slower growth rates than

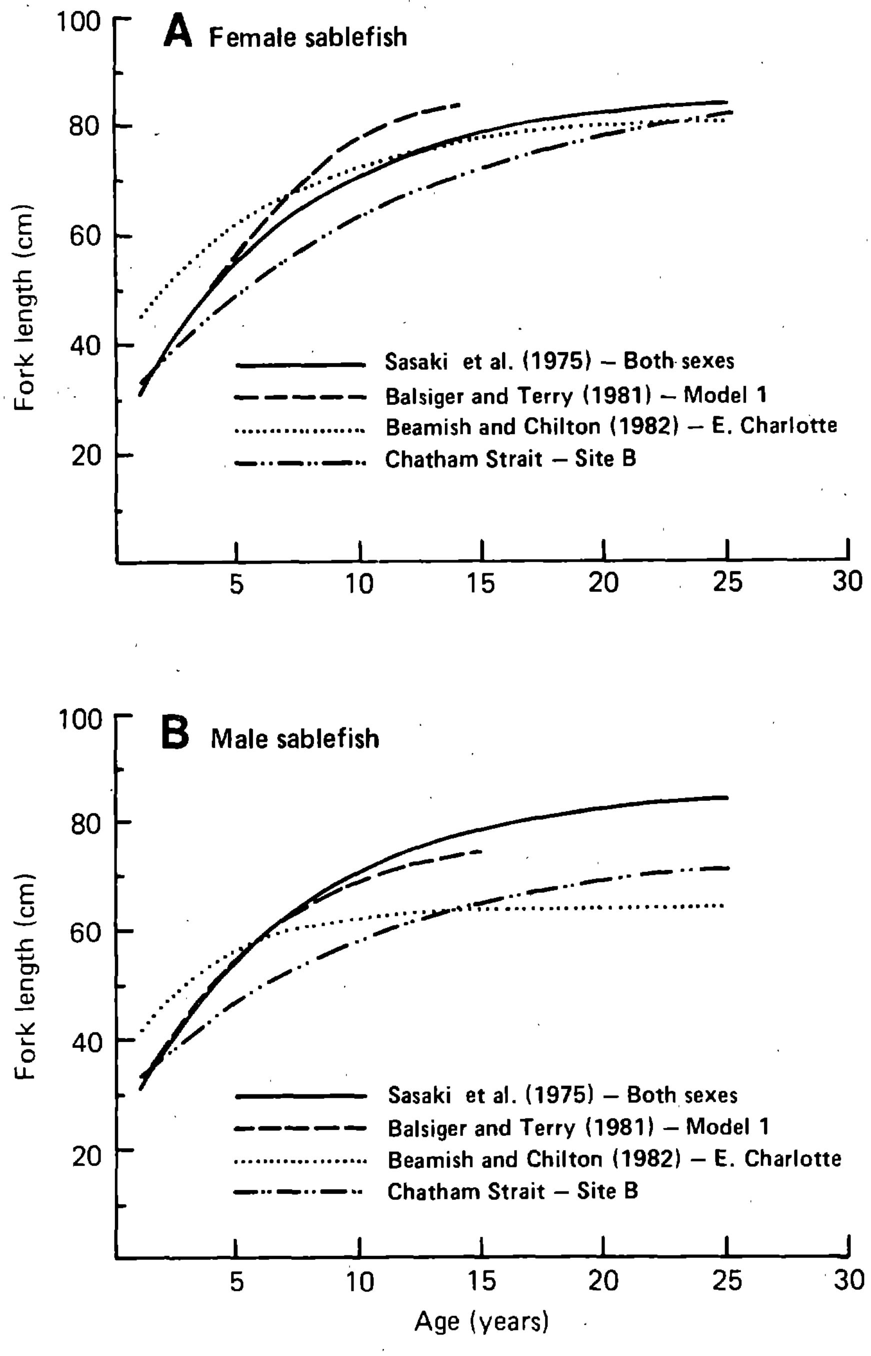

Figure 5.--Comparison of growth curves for female and male sablefish in the North Pacific and Bering Sea (from Bracken and Funk 1982).

previously reported. The growth curve attributed to Beamish and Chilton in Figure 5 is relatively typical of their curves and is shown for comparison with Japanese, NMFS, and ADFG growth curves (Bracken and Funk 1982). Beamish and Chilton's curves display large initial sizes-at-age, but relatively slow growth rates, for both males and females. Bracken and Funk's Chatham Strait Site B growth curve is intermediate between two other curves he produced from different sites for both females and males and is shown in Figure 5 for comparison with Japanese, NMFS, and Canadian growth curves. The growth curves for both males and females in Chatham Strait displays small initial sizes-at-age and slow growth rates but does not reach an asymptote as quickly as the curves of Beamish and Chilton (1982).

The large differences in growth observed in north Pacific and Bering Sea sablefish could potentially be due to differences in aging techniques or to actual differences in the growth rate in various areas of the Gulf of Alaska and Bering Sea. The break-and-burn aging technique of Beamish and Chilton (1982) has been validated by oxytetracycline injections and tagging studies and appears to give accurate ages. Bracken (1982) gives some evidence for the validation of the surface reading technique, using tagging recoveries and following modes in population length distributions. Simultaneous aging of the same otoliths using both break-and-burn and surface reading techniques will be necessary to fully compare the two methods. Further aging-analysis of sablefish from the central and western areas of the Gulf of Alaska will be necessary before gulf-wide growth rates can be reliably established.

MAXIMUM SUSTAINABLE YIELD

Although the sablefish resource is managed by regions, the long-term productivity in each region is assumed to be related to the overall condition of the resource. Japanese and U.S. scientists have estimated maximum sustainable yield (MSY) of the resource as a whole and apportioned an MSY to each region based on historic production trends. The Japanese estimate of MSY for the entire resource from California to the Bering Sea is 69,600 t (Sasaki 1978). Using essentially the same general production model as the Japanese, but with a different weighting of data among regions, Low and Wespestad (1979) estimated MSY for the California to Bering Sea resource at 50,300 t.

By region, historical catches were Bering Sea (25%), Aleutian region (4%), Gulf of Alaska (47%), and British Columbia-Washington region (25%). The apportioned MSY estimates were then compared to MSY estimates derived by applying general production models region by region. The resulting mean and overall estimate of MSY was 25,100 t for the Gulf of Alaska (Low and Wespestad 1979).

EQUILIBRIUM YIELD

Determination of potential yield from a population of fish is dependent on the size at which an individual fish becomes available to the fishery. Equilibrium yield (EY) for sablefish, as presented in the FMP, is based on data from the Japanese longline fishery. Hence, the implicit size at entry to the fishery for which the EY figure is appropriate is the size of entry to the Japanese longline fishery. Table 7 demonstrates that although there was variability by year and area, the average size did not change significantly from 1969 to 1979. (However, in 1981 the average size was less than 60 cm, probably reflecting the increased availability of the 1977 year class to the fishery.) Thus, the current EY reflects yields with sablefish entering the fishery from about 42 cm (0.55 kg dressed weight) until the fish are fully recruited at sizes of 62-65 cm (1.91-2.18 kg dressed weight). Fish are 50% recruited at 55 cm (1.27 lb dressed weight) (Balsiger and Alton 1981).

Table 7.--Average size (cm) of sablefish taken by the Japanese longline fleet in the Gulf of Alaska from 1969 to 1981. (Data from foreign reported fishery statistics for 1969-78, and from U.S. observer data for 1979-81).

Year	All Areas	Shumagin	Chirikof	Kodiak	Yakutat	Southeast
	-----	-----	-----	cm	-----	-----
1969	67.2	-	65.2	-	68.7	-
1970	66.2	-	-	60.5	67.8	68.6
1971	65.4	61.4	60.6	63.6	66.3	66.0
1972	62.3	62.4	60.8	60.8	63.9	63.5
1973	62.8	63.2	61.2	63.7	63.7	64.4
1974	-	-	-	-	-	-
1975	67.1	66.4	-	-	-	67.9
1976	66.2	66.3	65.5	64.1	65.9	68.4
1977	64.7	-	60.9	-	64.6	65.0
1978	67.4	65.8	67.0	67.0	69.9	-
1979	-	66.3	64.7	63.5	63.5	-
1980	-	60.4	60.9	61.8	59.1	-
1981	-	58.9	56.1	59.7	55.8	-
Average	64.6	64.5	62.0	63.5	66.3	65.7

On the basis of the decline of CPUE from 1976 to 1977 (Table 2), Low and Wespestad (1979) determined EY for the Gulf of Alaska to be 14,000 t. The FMP allocates 61% of the sablefish allocation to the area west of 140°W long. The EY for this area where foreign longlining is permitted would have been 8,540 t. Table 3 shows some increase in CPUE in 1981 for the Japanese longline fishery and this evidence is supported by the 1981 Japan-U.S. cooperative longline survey results. However, as noted above, much of the indicated increase is due to the increased availability of small fish. Harvest levels in the Gulf of Alaska west of 140°W long. averaged 6,700 t from 1978 to 1980. If the estimated EY for the area of 8,540 t was correct, some rebuilding of the stock should have occurred by 1981, even in the large size categories. Evidence of increased abundance of large-sized fish is lacking, as the CPUE's in Table 4 are not persuasive.

Due to uncertainty about when the abundant smallfish will attain the size for which the estimate of EY pertains, there is insufficient evidence to suggest a change in EY west of 140°W long. The estimate for that area of the Gulf remains at 8,540 t.

Due to the termination of foreign fishing in the eastern Gulf, it is more difficult to estimate EY for that area. Zenger and Hughes (1981) defined marketable-size fish as those 57 cm or larger (1.36 kg dressed weight), and estimated allowable biological catch (ABC) of that portion of the stock at 2,500 t in 1980 for the Southeast area. The 1981 pot index survey (Zenger 1981) showed a decline of 50% in this size range and EY for southeastern Alaska was estimated at 1,290 t (Balsiger and Alton 1981).

It is quite unlikely that the resource suffered 50% mortality from 1980 to 1981. There was more likely a change in availability to both the pot index gear and the U.S. commercial gear fished in the Southeast area. If EY is to be considered average production over a few years, than it was probably inappropriate to estimate EY at 1,290 t based on the reduction observed from 1980 to 1981 in the pot index survey.

The 1982 pot index survey encountered difficulty, as described earlier; and although results showed stock levels similar to those in 1981, this information is not compelling. Until catch, effort, and size information from the 1982 U.S. fishery in the Southeast area is available, present stock condition is difficult to assess. The value of EY is probably best established as a range of 1,290 to 2,580 t.

Almost no current information is available for the portion of the Yakutat area east of 140°W long. other than the Japan-U.S. cooperative longline survey. The present estimate of 1,135 t for the area was based partly on the sharp decline noticed in the 1981 pot index survey in the Southeast area. Hence, the estimate for this area should be discounted for the same reasons described above for the Southeast area. A range for EY can be estimated using the 1980 estimate as the upper bound and the reduced 1981 estimate as the lower bound: 1,135 to 1,510 t. Estimated EY values (t) by area are then:

Western	Central	Yakutat W of 140°W	Yakutat E of 140°W	Southeast
2,225	4,075	2,240	1,135-1,510	1,290-2,580.

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PACIFIC COD

by

Harold H. Zenger, Jr., and Nancie J. Cummings

INTRODUCTION

In North American waters, Pacific cod, Gadus macrocephalus, occur on the continental shelf and upper slope from Santa Monica Bay, California (34° N lat.) north through the Gulf of Alaska, Aleutian Islands, and eastern Bering Sea to Norton Sound (Bakkala et al. 1981).

Four nations, Japan, Republic of Korea, Poland, and the United States, reported catches of Pacific cod from the Gulf of Alaska in 1981. Japan led all with a catch of almost 28,000 t or 74% of the total all-nations catch of 37,728 t (Table 1). During the past 10 yr, Japan and the U.S.S.R. have harvested the cod resource in the Gulf of Alaska most heavily, although the U.S.S.R. was excluded from fishing in U.S. waters during 1981.

Historically foreign trawl and longline fisheries have taken cod incidentally to target species, such as walleye pollock, Theragra chalcogramma, and sablefish, Anoplopoma fimbria, but often targeted on cod when found in commercial concentrations. In November 1979, the North Pacific Fishery Management Council permitted "a directed longline fishery for Pacific cod between 140° and 157° W longitude seaward of 12 miles except during the U.S. halibut season." This allowed increased harvest of Pacific cod by foreign longliners primarily in the Chirikof and Kodiak statistical areas of the International North Pacific Fisheries Commission (INPFC).

The all-nation catch of Pacific cod more than doubled from 1979 to 1980. In the same period, the Japanese catch almost tripled, primarily due to

Table 1.--Annual catch in metric tons (t) of Pacific cod in the Gulf of Alaska by International North Pacific Fisheries Commission (INPFC) area from 1971 to 1981 as reported for Japan, U.S.S.R., Republic of Korea (R.O.K.), Poland, Mexico, the United States 1/, and U.S.-foreign joint venture 2/.

	Year										
	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
	------	------	------	------	------	t	------	------	------	------	------
Japan											
Shumagin	119	167	329	689	1,451	1,542	377	4,073	3,067	6,624	9,032
Chirikof	57	83	957	614	746	492	296	3,537	5,598	17,403	14,807
Kodiak	262	453	972	1,185	694	760	457	971	1,414	4,551	2,334
Yakutat	23	70	332	440	362	479	285	199	294	1,961	1,517
Southeastern	0	43	15	44	27	35	13	66	55	43	78
Total	461	816	2,605	2,972	3,280	3,308	1,428	8,846	10,428	30,582	27,768
U.S.S.R.											
Shumagin			739	40	309	267	196	86	6	361	
Chirikof			829	4/	0	514	50	995	165	906	
Kodiak 3/	176	2,696	1,732	2,096	2,226	1,520	279	60	663	675	
Yakutat			95	4/	16	694	0	0	1		
Total	176	2,696	3,395	2,136	2,551	2,995	525	1,141	835	1,942	
R.O.K.											
Shumagin								1,361	788	1,627	2,241
Chirikof								8			4,069
Kodiak											25
Yakutat									56 5/	3	731
Total								1,369	844	1,666	7,066
Poland											
Shumagin									9	9	41
Chirikof									118	46	94
Kodiak								14			
Total								14	127	55	135
Mexico											
Shumagin									100		
Chirikof									376		
Kodiak									463		
Total									939		

.......continued

Table 1.--continued.

	Year										
	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
	-----	-----	-----	-----	-----	t -----	-----	-----	-----	-----	-----
U.S.											
Shumagin		36		2	1	13	53	64		70	238
Chirikof				1	42	52	16	167	267	49	38
Kodiak	12	10	28	71	40	96	140	443	606	415	679
Yakutat				2	10	8	6	2	27	4	2
Southeastern	7	15	31	67	34	52	55	107	85	190	30
Total	19	61	59	143	127	221	270	783	985	728	987
U.S.-Foreign joint ventures											
Shumagin								7	11	13	T
Chirikof									17	223	58
Kodiak									683[6/]	230	
Total								7	711	466	58
Grand total	656	3,573	6,059	5,251	5,958	6,524	2,223	12,160	14,869	35,439	36,014
Percent of total ground-fish catch	0.5	1.8	3.4	2.6	3.3	2.2	1.2	7.4	9.1	17.0	15.1

1/ Data supplied by Alaska Department of Fish and Game.
2/ Data source NMFS Foreign Observer Program (French et al., 1981a and 1981b).
3/ Reported as western Gulf in 1971 and 1972; includes Shumagin, Chirikof, and Kodiak INPFC areas.
4/ Catch, if any, reported in Other Species category.
5/ Includes 7t from the Southeastern area.
6/ Includes 0.6 t from the Yakutat area.

increased longline effort. Longline vessels accounted for approximately 90% of the total Japanese cod catch in the Gulf of Alaska from 1979 to 1981 (Table 2).

Recently Pacific cod has become an important commercial species for U.S. fishermen. In 1978 the first joint venture harvesting of Pacific cod began, and salteries and onshore filleting and freezing facilities were established in the Shumagin Islands and at Kodiak. However, domestic landings for the Gulf of Alaska have remained relatively small at less than 1,000 t through 1981. Joint venture catches in 1981 were about 1,800 t, with the majority harvested from the Chirikof area.

CONDITION OF STOCKS

The maturity condition of adult Pacific cod collected during the spring resource assessment surveys conducted by the Northwest and Alaska Fisheries Center (NWAFC) of the National Marine Fisheries Service (NMFS) in 1981 and 1982 indicated that significant spawning occurs in lower Shelikof Strait and at Seguam Pass in the Aleutian Islands. A large spawning concentration was located between Cape Sarichef and Akutan Island in early 1982. Scattered spawning occurred throughout the western Gulf of Alaska and on the north side of the Aleutian Islands at least as far west as Seguam Pass.

Mean lengths of Pacific cod captured in the Gulf of Alaska by research vessels in 1981 ranged primarily between 45 and 60 cm (Table 3). Pacific cod length-frequency data collected from Japanese longline fisheries in the Shumagin, Chirikof, and Kodiak INPFC areas by NMFS observers show that the catches in 1978 and 1979 were composed primarily of fish that were estimated to be 4 or more years old (Figures 1 and 2). The impact of 3-yr-old cod entering the fishery in the 40-55 cm range in 1980 and dominating the 1981 catches as 50-60 cm fish is seen in Figures 3 and 4.

Table 2.--Annual Japanese longline catch, in metric tons (t) of Pacific cod, by International North Pacific Fisheries Commission (INPFC) statistical area, and the percentage of the total Japanese all-gear cod catch harvested by longliners, 1978-81.

Year	INPFC area				Total longline catch	Percentage of Japanese cod catch
	Shumagin	Chirikof	Kodiak	Yakutat		
	---------- t ----------					
1978	3,812	2,971	15	2	6,800	77
1979	2,952	5,467	935	184	9,538	91
1980	5,958	17,061	2,787	1,525	27,331	89
1981	8,509	13,847	1,870	1,048	25,274	91

Table 3.--Mean and modal lengths of Pacific cod sampled during research vessel surveys in 1981 in the Gulf of Alaska.

International North Pacific Fisheries Commission (INPFC) area	Vessel and Cruise No.	Mean length (cm)	Mean length (cm)	No. of fish
Shumagin	Pat San Marie, 81-1	48.6	49	3,719
Chirikof	Pat San Marie, 81-1	52.2	53	3,229
	NOAA ship Miller Freeman, 81-3	50.5	50	799
	Shantar, 81-1	49.6	52	715
Kodiak	Miller Freeman, 81-3	49.4	42	630
	Shantar, 81-1	60.0	56	221
	Oh Dae San, 81-1	46.5	54	136
	Ocean Harvester, 81-1	61.1	61	165
Yakutat	Oh Dae San, 81-1	47.1	48	598
	Ocean Harvester, 81-1	47.3	45	240
Southeastern	Ocean Harvester, 81-1	48.5	42	25

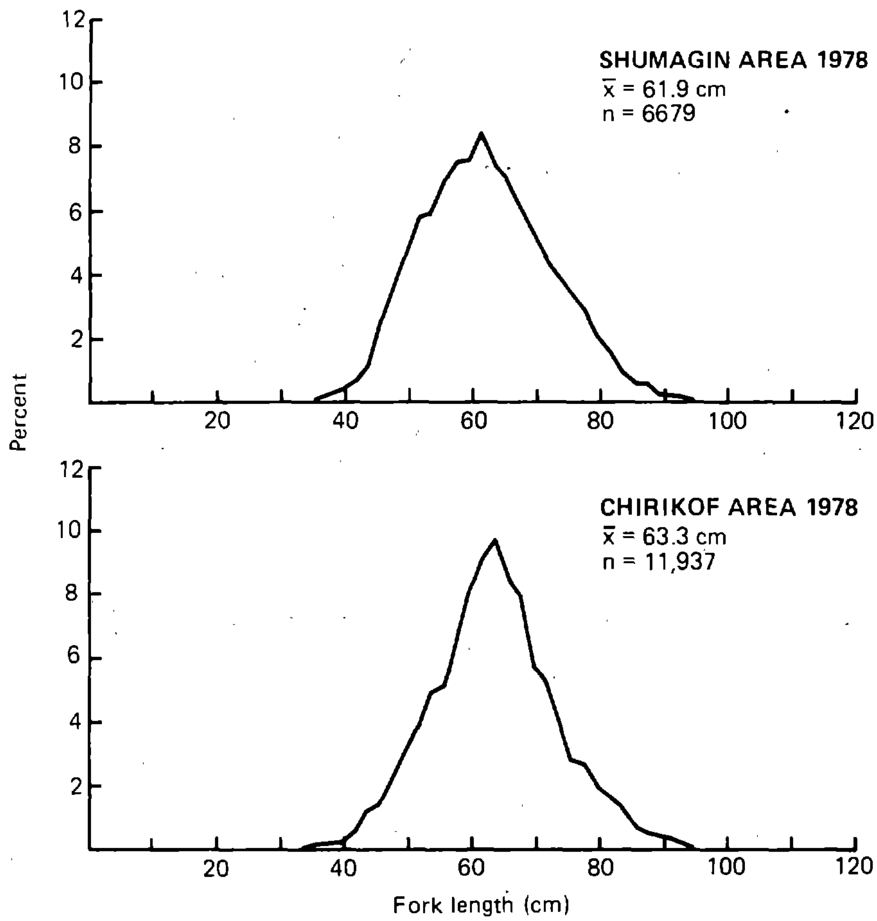

Figure 1. --Length-frequencies of Pacific cod collected from Japanese longling fisheries in the Shumagin and Chirikof International North Pacific Fisheries Commission (INPFC) statistical areas during 1978 by National Marine Fisheries Service observers.

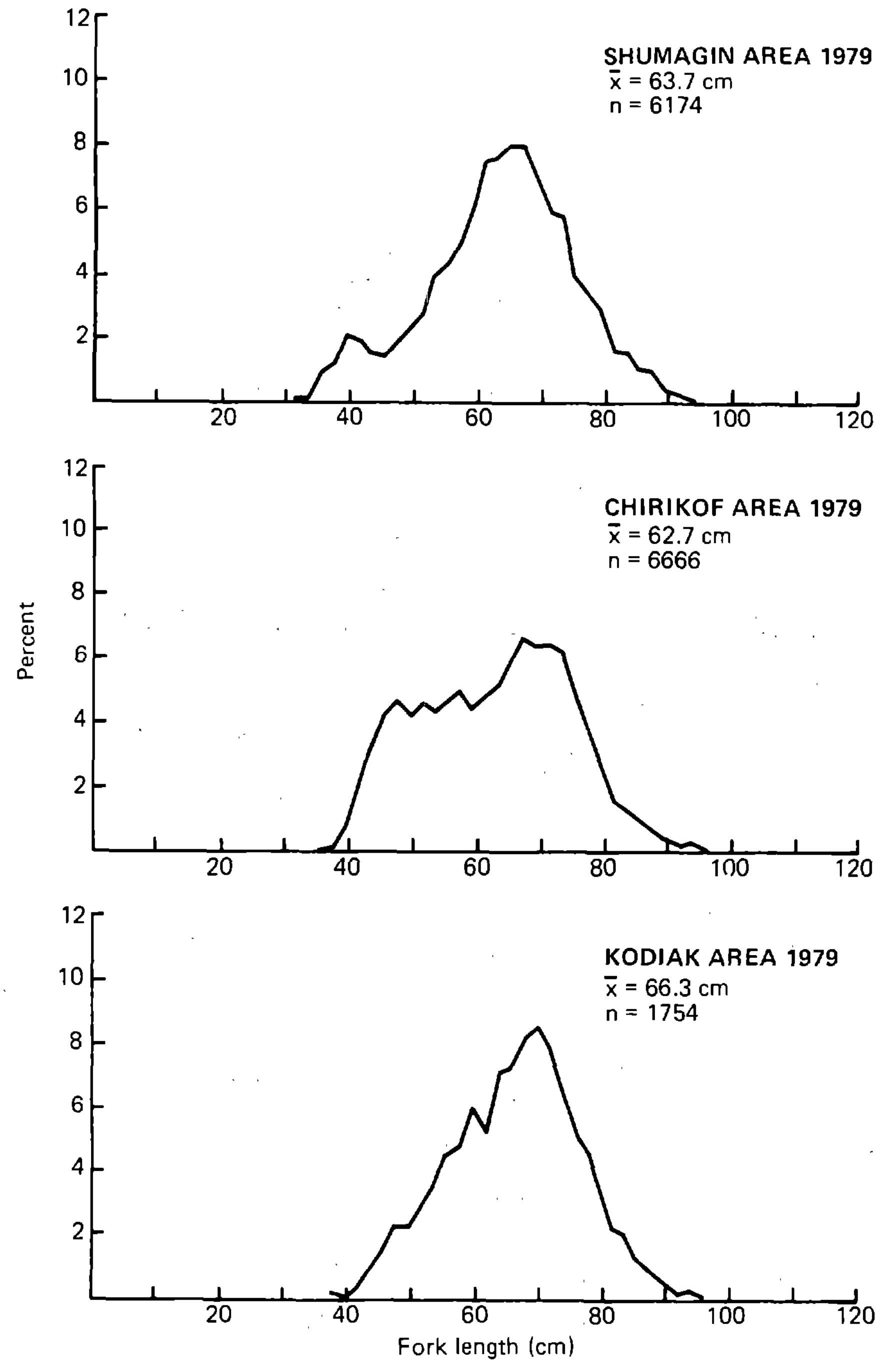

Figure 2.--Length-frequencies of Pacific cod collected from Japanese longline fisheries in the Shumagin, Chirikof, and Kodiak International North Pacific Fisheries Commission (INPFC) statistical areas during 1979 by National Marine Fisheries Service observers.

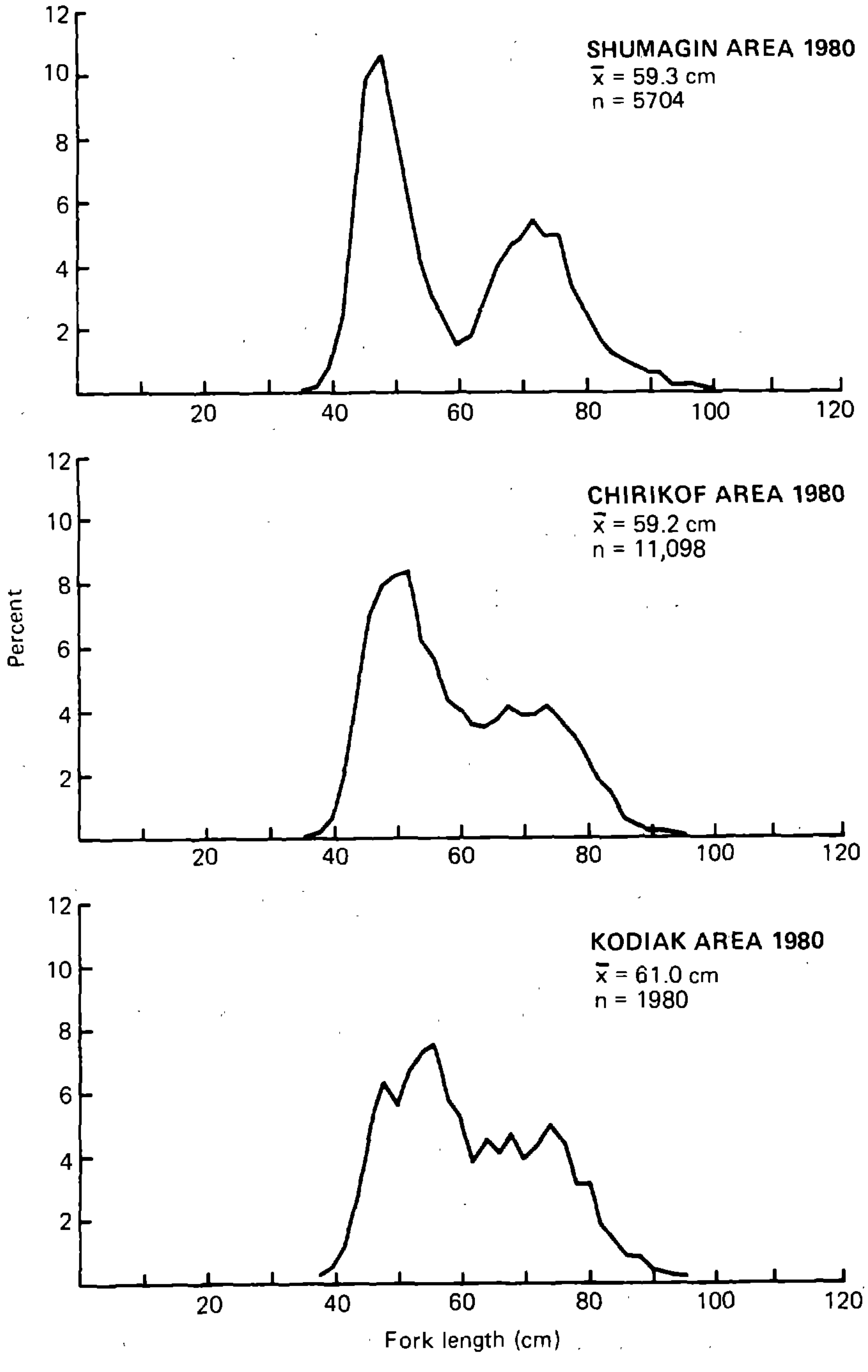

Figure 3.--Length-frequencies of Pacific cod collected from Japanese longline fisheries in the Shumagin, Chirikof, and Kodiak International North Pacific Fisheries Commission (INPFC) statistical areas during 1980 by National Marine Fisheries Service observers.

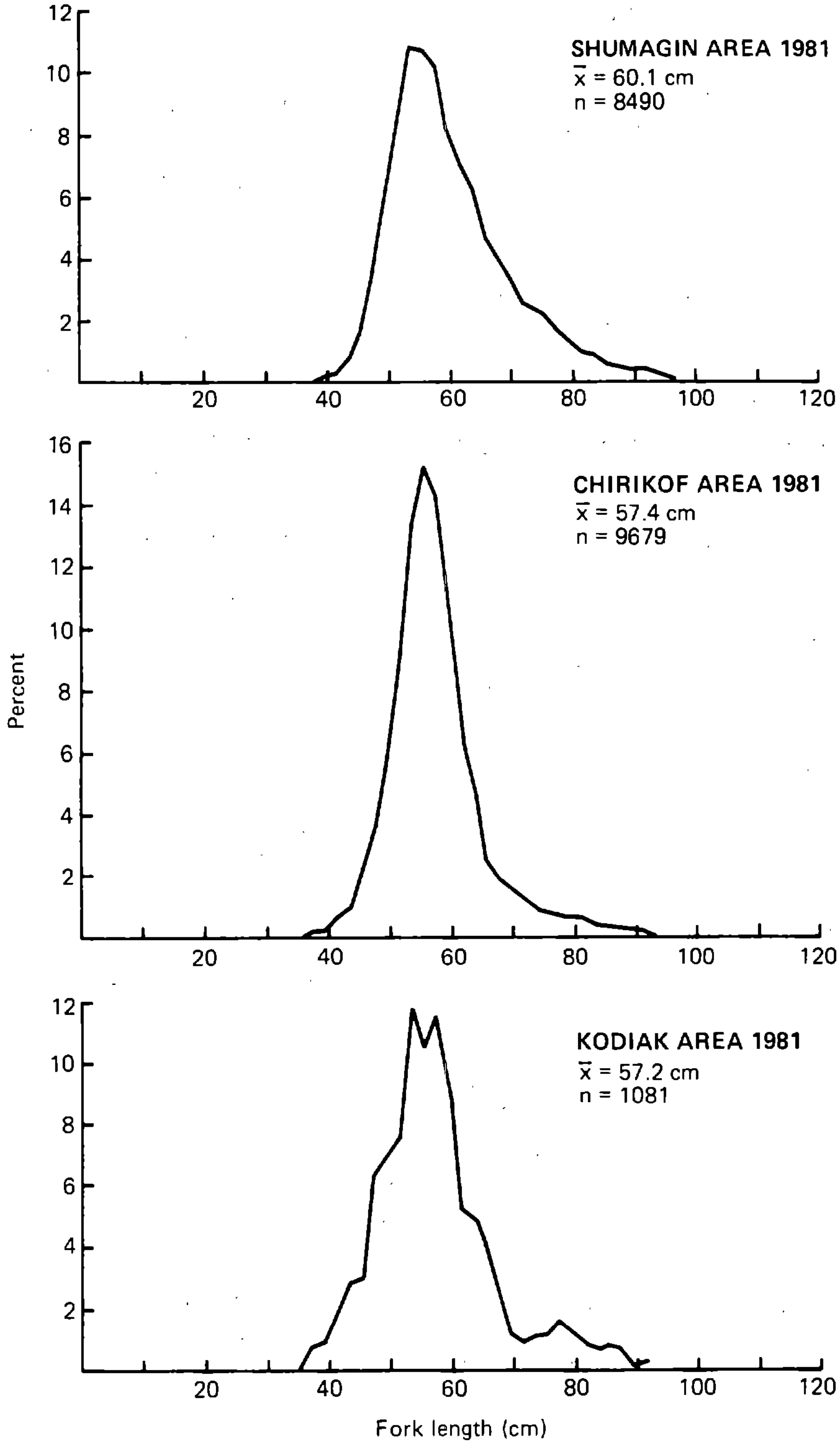

Figure 4. --Length-frequencies of Pacific cod collected from Japanese longline fisheries in the Shumagin, Chirikof, and Kodiak International North Pacific Fisheries Commission (INPFC) statistical areas during 1981 by National Marine Fisheries Service observers.

Techniques used to determine the age of Pacific cod from scales are currently under review at NWAFC. In this report cod ages have been estimated by separation of length-frequency modes (MacDonald and Pitcher 1979).

The age composition of the-Gulf of Alaska stock continues to be dominated by the 1977 year-class. No indications of other strong following year-classes have been found, although 2- and 3-year-old Pacific cod were in evidence in the Chirikof and Kodiak areas during 1981 surveys.

Current estimated total exploitable biomass is based on the results of six research vessel surveys conducted during 1981, one in 1980, and one in 1982.

The standing stock for each INPFC area was estimated from research vessel catches, using the following relationship:

$$P_W = (CPUE)(A)/ca$$

where P_w equals the average standing stock of the exploitable population, A equals the total area encompassed by the survey, a is the average area swept by the trawl during a standard tow, and c is an efficiency coeffficient related to the ability of the trawl to catch cod. The coefficient c is not precisely known but is assumed to lie in the range 0.5-1.0. The standing stock estimates were derived with c = 1 and are assumed to represent minimum values of P_w.

For each cruise, biomass estimates were determined for their respective INPFC areas and depth intervals (Table 4). Surveys-in the Shumagin, Chirikof, and Kodiak INPFC areas offered good areal coverage, whereas surveys in the Yakutat and Southeastern areas were limited to NWAFC rockfish and flatfish abundance indexing sites. Biomass estimates for nonsurveyed regions in the Yakutat and Southeastern areas were not included since the distribution of

Table 4.--Minimum exploitable biomass estimates by International North Pacific Fisheries Commission (INPFC) area or segments thereof and by depth interval resulting from data collected during research vessel surveys conducted from summer 1980-late winter 1982.

INPFC area	Vessel and Cruise No.	Estimated biomass (metric tons) 51-100 m	101-200 m	201-300 m	301-400 m	Total
Shumagin (154°00'-163°00' W long.)	Pat San Marie, 81-1	161,455	21,491	-	-	182,946
Shumagin (165°00'-170°00' W long.)	Ocean Harvester, 80-2	25,195	25,876	1,335	-	52,406
Shumagin (165°00'-170°00' W long.)	Ocean Harvester, 82-1	-	22,342	-	-	22,342
Chirikof (total area)	Pat San Marie, 81-1 Miller Freeman, 81-3	56,740	49,885	4,082	-	110,707
Chirikof (total area)	Shantar, 81-1	6,263	54,952	2,994	8	64,217
Kodiak (150°30'-154°00' W long.)	Shantar, 81-1	-	14,997	74	5	15,076
Kodiak (151°00'-154°00' W long.)	Miller Freeman, 81-3	-	11,763	315	-	12,078
Kodiak (150°00'-153°00' W long.)	Oh Dae San, 81-1	2,770	21,115	-	-	23,885

.......continued

Table 4.--continued.

INPFC area	Vessel and Cruise No.	Estimated biomass (metric tons)				
		51-100 m	101-200 m	201-300 m	301-400 m	Total
Kodiak (149°00'-153°00' W long.)	*Ocean Harvester*, 81-1	-	32,745	6,860	-	39,605
Yakutat (139°00'-141°30' W long.)	*Oh Dae San*, 81-1	2,197	3,177	308		5,682
Yakutat (140°00'-142°00' W long.)	*Ocean Harvester*, 81-1 *Pat San Marie*, 81-2	187	1,168	223		1,578
Southeastern (55°00'-57°00' N lat.)	*Ocean Harvester*, 81-1 *Pat San Marie*, 82-1	-	1,430	699	6	2,135

Pacific cod does not appear to be continuous throughout those areas (Ronholt et al. 1978). Therefore, a projected area-wide standing stock figure may have overestimated cod abundance. Past practice has been to report the shallowest depth interval as 0-100 or 0-91 m (0-50 fathom), often including area not usually surveyed. In this report that interval was limited to 51-100 m and the area (A) was reduced accordingly., Reducing the area used to calculate exploitable biomass for the shallowest depths had a relatively small effect on estimates for the Yakutat and Southeastern areas where the regions with bottom depths less than 50 m and cod density were relatively small. However, in the Shumagin, Chirikof, and Kodiak areas, regions with depths less than 50 m and cod density were much larger. No sampling was conducted in waters shallower than 50 m in the latter areas in 1981, but echo-sounder transects showed very little sign on the shallower banks. Thus it appeared justifiable to use the 51-100 m interval to avoid inflated exploitable biomass estimates (Table 5). Pacific cod density in the 0-91 m interval cited in the 1979 status-of stocks document (Table 6) shows that the shallowest depths were the least productive, whereas cod were most abundant in 51-100 m in the most recent surveys.

Differences in estimates of exploitable biomass between 1979 and 1981 were apparently influenced by a number of factors:

1) The 1981 estimates were based on research vessel survey data that was less disjointed in time and space than those used for the 1979 estimates;

2) Since the 1979 estimates were made, a large year-class has appeared and dominated the cod population in the Gulf of Alaska, possibly increasing the available biomass;

3) The 1981 estimates of available biomass for the Shumagin area were based on the most extensive survey that had been performed since the early 1960's;

Table 5.--Estimated exploitable biomass in metric, tons of Pacific cod by International North Pacific Fisheries Commission (INPFC) areas and depth strata from 1981 research vessel surveys, using trawl efficiency coefficient c = 1.0.

Depth stratum (meters)	INPFC area					
	Shumagin	Chirikof	Kodiak	Yakutat	Southeastern	Total
	t					
51-100 m	186,650	56,740	2,770	2,197	-	248,357
101-200 m	47,367[1/]	49,885	32,745	3,177	1,430	134,604
201-300 m	1,335[1/]	4,082	6,860	308	699	13,284
Total	235,352	110,707	42,375	5,682	2,129	396,245

1/ Includes data collected during summer 1980 from the south side of the Aleutian Islands to 170°W long.

Table 6.--Estimate& exploitable biomass in metric tons of Pacific cod by International North Pacific Fisheries Commission (INPFC) areas and depth strata from NMFS Northwest and Alaska Fisheries Center resource assessment surveys, 1973-1978 (Low et al. 1979).

Depth stratum (m)	INPFC area					
	Shumagin	Chirikof	Kodiak	Yakutat	South-eastern2/	Total
	- - - - - - - - - - - - t - - - - - - - - - - - -					
0-91 m	10,597	502	8,585	8,452	-	28,136
92-183 m	22,554	141,775	70,516	9,062	-	243,997
184-366 m	6,388	44,129	39,111	524	-	90,152
Total	39,539	186,406	118,212	18,038	5,922	368,117

1/ Estimates in the Kodiak and Chirikof regions are from data obtained during January-April 1977-78. Estimates from the remaining regions are from April-October 1973-75.

2/ No depth breakdown.

4) The 1981 biomass estimates for the Yakutat and Southeastern areas were based on limited areal coverage and are probably low;

5) The exploitable biomasses calculated for the Chirikof and Kodiak areas in 1979 reflected large catches of cod made near the south and southwest sides of Kodiak Island during 1977 and 1978 research vessel surveys. Since then neither research nor commercial vessels have located comparable cod concentrations in those areas. Thus, notably reduced estimates of available biomass resulted from the 1981 surveys; and

6) The Shumagin area's 101-200 m depth interval (Table 5) shows 47,367 t as the exploitable biomass. This figure represents the summation of estimates from the Pat San Marie's spring cruise (number 81-1) in the eastern Shumagin area and the Ocean Harvester's summer survey (number 80-2) in the western Shumagin area (Table 4). The figure for the Ocean Harvester's cruise (number 82-1) for the 101-200 m depth interval was similar to the previous Ocean Harvester's survey results from the same depth and region, suggesting that the cod population in the western Shumagin area may be relatively stable.

MAXIMUM SUSTAINABLE YIELD

Calculations of maximum sustainable yield (MSY) were based on the Gulland (1969) equation, $MSY = 0.4\ B_0 M$, and assumed that the biomass approximated virgin stock levels and that natural mortality equaled 0.6, as reported by Ketchen (1964) for Pacific cod stocks in British Columbia.

The term B_0 was assumed to equal the total exploitable standing stock limits of 396,000-792,000 t, estimated from 1980 and 1981 research vessel survey data, using c = 1.0 and 0.5 respectively (Table 5). Maximum sustainable yield was calculated to lie within the range of 95,000-190,000 t. The range previously calculated by Low et al. (1979) was 88,000-177,000 t.

EQUILIBRIUM YIELD

Previously, equilibrium yield (EY) was assumed to equal MSY, and allowable biological catch (ABC) was set at a lower level to reduce the incidental catch of Pacific halibut, *Hippoglossus stenolepis*. The ABC for Pacific cod was established at 60,000 t in 1980 and has remained at that level. The North Pacific Fishery Management Council apportioned total ABC to the western, central, and eastern reporting areas on the basis of trawl survey estimates of available biomass in each (Table 7). ABC's were assigned at 28% to the western, 56% to the central, and 16% to the eastern reporting areas. If the 1981 estimates of' biomass and their areal distributions are accepted as the best current information, then the percentages would be distributed as 59%, 39% and 2%, respectively. That distribution is supported by trends in Japanese longline CPUE in the Gulf of Alaska. Catch rates of cod taken in the Chirikof area have remained relatively stable from 1978 to 1981 (Table 8). However, catch rates in the Shumagin area have increased steadily over that 4-yr period, approaching that of the Chirikof area in 1980 and surpassing it in 1981. This suggests an increase of considerable note for the westward portion of the Pacificcod stocks since the 1977 year-class appeared in the fishery in 1980. While the mean exploitable biomass may be relatively stable across the Gulf of Alaska, the geographic distribution may change over time and the apportionment of ABC may require more timely fine tuning as catch levels approach ABC in a given area.

Recent catch levels have been slightly more than half of ABC, but there appears to be no biological reason why ABC cannot be reached. One possible reason why ABC has not been taken is that cod tend to disperse after spawning, greatly reducing their vulnerability to capture.

Table 7.--ABC's, estimated exploitable biomasses (1,000 t), 1981 all-nation catch of Pacific cod (1,000 t), and percentages of each by Gulf of Alaska (GOA) management region.

	GOA management region[1]		
	Western	Central	Eastern
Allowable biological catch (GOA Management plan)	16.6 28%	33.5 56%	9.9 16%
Exploitable biomass (GOA management plan)	40-79 28%	82-161 56%	24-48 16%
Exploitable biomass (1981 research vessel surveys)	235-470 59%	153-306 39%	7-14 2%
1981 all-nation catch (NMFS best blend estimates)	11.6 31%	23.8 63%	2.4 6%

1/ Western = Shumagin International North Pacific Fisheries Commission (INPFC) area.
Central = Chirikof and Kodiak INPFC areas.
Eastern = Yakutat and Southeastern INPFC areas.

Table 8.--Annual Japanese commercial longline catch (t), effort (1,000 hooks); and catch per unit effort (CPUE) (t/1,000 hooks) of Pacific cod by International North Pacific Fisheries Commission (INPFC) area, 1978-81.

Year	INPFC area	Catch (t)	Effort (1,000 hooks)	CPUE (t/1,000 hooks)
1978	Shumagin	465.9	900.9	0.517
	Chirikof	1,106.8	1,717.5	0.644
	Kodiak	-	-	-
	Yakutat	-	-	-
1979	Shumagin	573.7	982.0	0.584
	Chirikof	800.5	1,313.7	0.609
	Kodiak	140.1	236.1	0.594
	Yakutat	2.9	15.2	0.193
1980	Shumagin	579.7	923.5	0.628
	Chirikof	1,048.9	1,660.2	0.632
	Kodiak	126.6	251.0	0.504
	Yakutat	-	-	-
1981	Shumagin	911.2	1,318.6	0.691
	Chirikof	1,013.0	1,611.0	0.629
	Kodiak	49.4	136.9	0.360
	Yakutat	-	-	-

As appeared to be the case in 1978, the commercial catches in 1981 were dominated by 4-yr-old or older Pacific cod with no evidence of a large following recruit year-class. Trends in abundance have not been predicted for the cod population in the Gulf of Alaska.

Recent harvests have not approached the established catch quotas in the Gulf of Alaska. It appears feasible to increase quotas even more if a suitable fishing gear or strategy can be devised to reduce the catch of prohibited species.

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ATKA MACKEREL

by

Lael L. Ronholt

INTRODUCTION

Atka mackerel, Pleurogrammus monopterygius, are distributed throughout the Gulf of Alaska, but are primarily found in the Kodiak, Chirikof, and Shumagin International North Pacific Fisheries Commission (INPFC) statistical areas of the western Gulf of Alaska at depths from 50 to 350 m. Morphological studies by a Soviet scientist suggest that there are separate stocks in the Gulf of Alaska and Aleutian Islands (Levada 1979a).

Atka mackerel are harvested exclusively by foreign nations. Soviet fleets dominated the fishery from 1972 to 1980 while the Republic of Korea (R.O.K.) dominated in 1981. Since 1978, Atka mackerel has ranged from second to fourth in relative importance by total weight landed (Table 1).

During 1981, the bulk of the 18,727 t of Atka mackerel was taken by the R.O.K. (79%) and Japan (19%), Table 2. Fishing occurred mainly in the summer and early fall. Japan harvested 61% of their total catch with large freezer trawlers and 39% with small trawlers, while the R.O.K. harvested 83% with large freezer trawlers and 17% with small trawlers. The Chirikof INPFC statistical area produced the bulk of the landings, 12,537 t, followed by Shumagin (3,471 t), Kodiak (1,415 t), Yakutat (1,278 t), and Southeastern (25 t).

-Since 1974, landings of Atka mackerel in the Gulf have ranged from 10,950 to 27,776 t. Catches peaked in 1975, declined through 1979, and then increased again in 1980 and 1981. With the exception of 1978 and 1981, the Kodiak area has produced roughly 75% or more of the total yearly catch since 1975. The Chirikof area provided most of the landings in 1978 and 1981.

Table 1.--Foreign landings in the Gulf of Alaska for major species or species group.

Year	Species	Weight (t)
1978	Walleye Pollock	96,327
	Atka mackerel	19,585
	All flounder	14,314
	Pacific cod	11,369
	Pacific ocean perch	8,169
1979	Walleye pollock	103,187
	All flounder	13,474
	Pacific cod	13,174
	Atka mackerel	10,950
	Pacific ocean perch	9,750
1980	Walleye pollock	112,996
	Pacific cod	34,243
	All flounder	15,496
	Atka mackerel	13,162
	Pacific ocean perch	12,447
1981	Walleye pollock	130,323
	Pacific cod	34,968
	Atka mackerel	18,727
	All flounder	14,442
	Pacific ocean perch	12,177

Table 2.--Foreign catches of Atka mackerel in metric tons in the Gulf of Alaska by International North Pacific Fisheries Commission (INPFC) statistical areas.

		INPFC statistical areas					
		Shumagin	Chirikof	Kodiak	Yakutat	Southeastern	Total
		t					
1974	U.S.S.R.	4,742	2,748	10,041	-	-	17,531
	Japan	-	-	-	-	-	3/
							17,531
1975	U.S.S.R.	2,132	743	23,688	1,213	-	27,776
	Japan	-	-	-	-	-	3/
							27,776
1976	U.S.S.R.	-	-	19,721 1/	311 2/	-	20,032
	Japan	-	-	-	-	-	3/
							20,032
1977	U.S.S.R.	69	2,056	17,120	0	0	19,245
	Japan	-	-	-	-	-	3/
							19,245
1978	U.S.S.R.	184	17,320	883	0	0	18,387
	Japan	243	265	338	125	165	1,136
	R.O.K.	61	2	0	0	0	63
							19,586
1979	U.S.S.R.	5	708	9,552	0	0	10,265
	Japan	322	8	227	11	0	568
	R.O.K.	81	0	0	0	0	81
	Mexico	11	4	21			36
							10,950
1980	U.S.S.R.	899	90	9,484	0	0	10,473
	Japan	35	179	1,511	171	Tr	1,896
	R.O.K.	736	0	0	0	0	736
	Poland	48	9	0	0	0	57
							13,162
1981	Japan	699	1,331	1,369	212	25	3,636
	R.O.K.	2,551	11,147	46	1,066	0	14,811
	Poland	221	59	0	0	0	280
							18,727

1/ Reported as western Gulf of Alaska.
2/ Reported as eastern Gulf of Alaska.
3/ Reported as "other species" category.

Annual size composition data for Atka mackerel are available only from the Kodiak INPFC area (Figures l-2). The 1971-77 data are from Levada 1979b, who describes them only as representing the Gulf of Alaska. It is evident from Levada's discussions and from an analysis of related catch statistics that these data came primarily from the Kodiak area. The length frequency curves for 1971-77 shown in Figures 1 and 2 are characterized by a single mode peaking near 29-34 cm and having a high percentage of the sample condensed into a 3-4 cm interval. With the exception of 1973, the mean length varied from 29-32 cm, thus indicating continued steady recruitment.

Size composition data for the 1975-81 Kodiak fishery are available from either the U.S. observer program or the Soviet literature (Levada 1979a,b; Fadeev and Kharin 1981) (Figures 3 and 4). From 1975 to 1977 the U.S. observer data and the Soviet data are similar with mean size ranging from 27-31 cm. In 1978-79 the catch size composition curves were biomodal with increasing mean size, while in 1980-81 the curves were again of single mode with the mean size continuing to increase up to 41.8 cm in 1981. The 1978 and 1981 U.S. observer data should be viewed cautiously due to the small sample size.

The 1981 size compositions of Atka mackerel are very similar for all INPFC areas, with specimens ranging from 30 to 50 cm and averaging 39-40 cm (Figure 5). The data from the Kodiak INPFC area should be viewed cautiously due to the small sample size. No age data are available from the 1981 foreign catch of Atka mackerel which consisted of 63% females and 37% males.

Condition of Stocks

Only limited information is available to define spawning time and areas for Atka mackerel in the Gulf of Alaska. Fadeev and Kharin (1981)

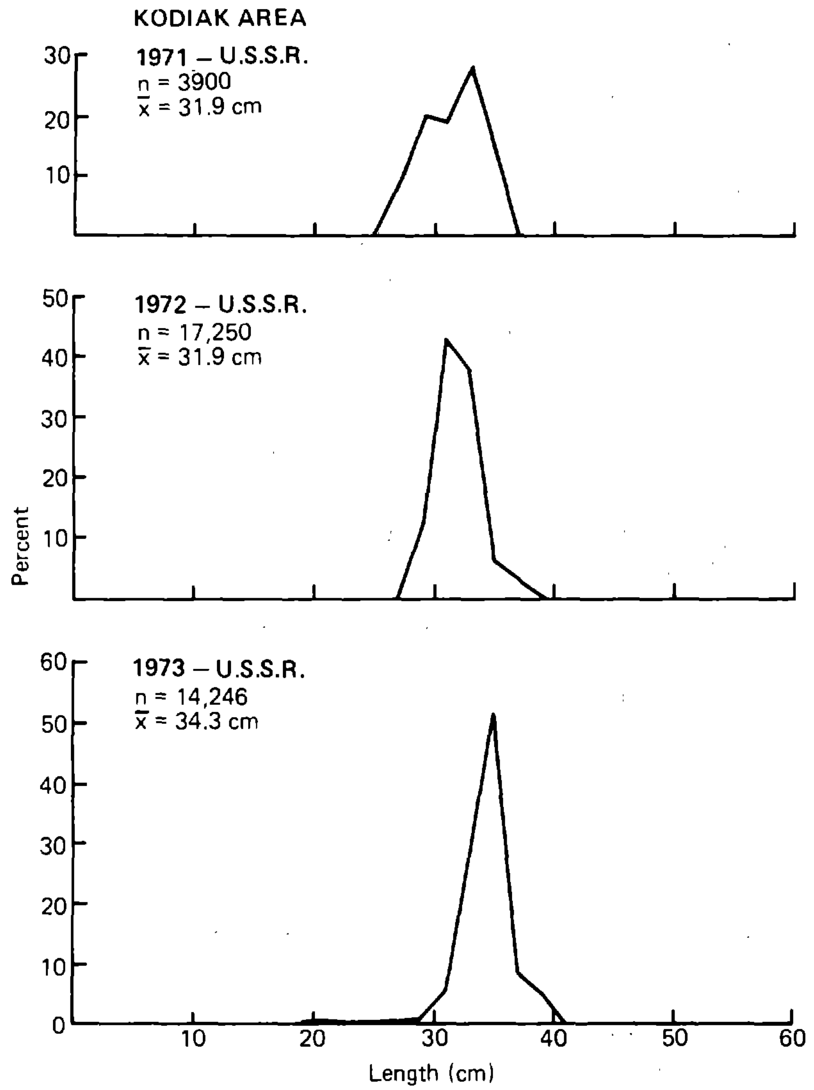

Figure 1 .--Size composition of Atka mackerel in the 1971-73 U.S.S.R. landings in the Kodiak International North Pacific Fisheries Commission (INPFC) statistical area (Levada 1979b).

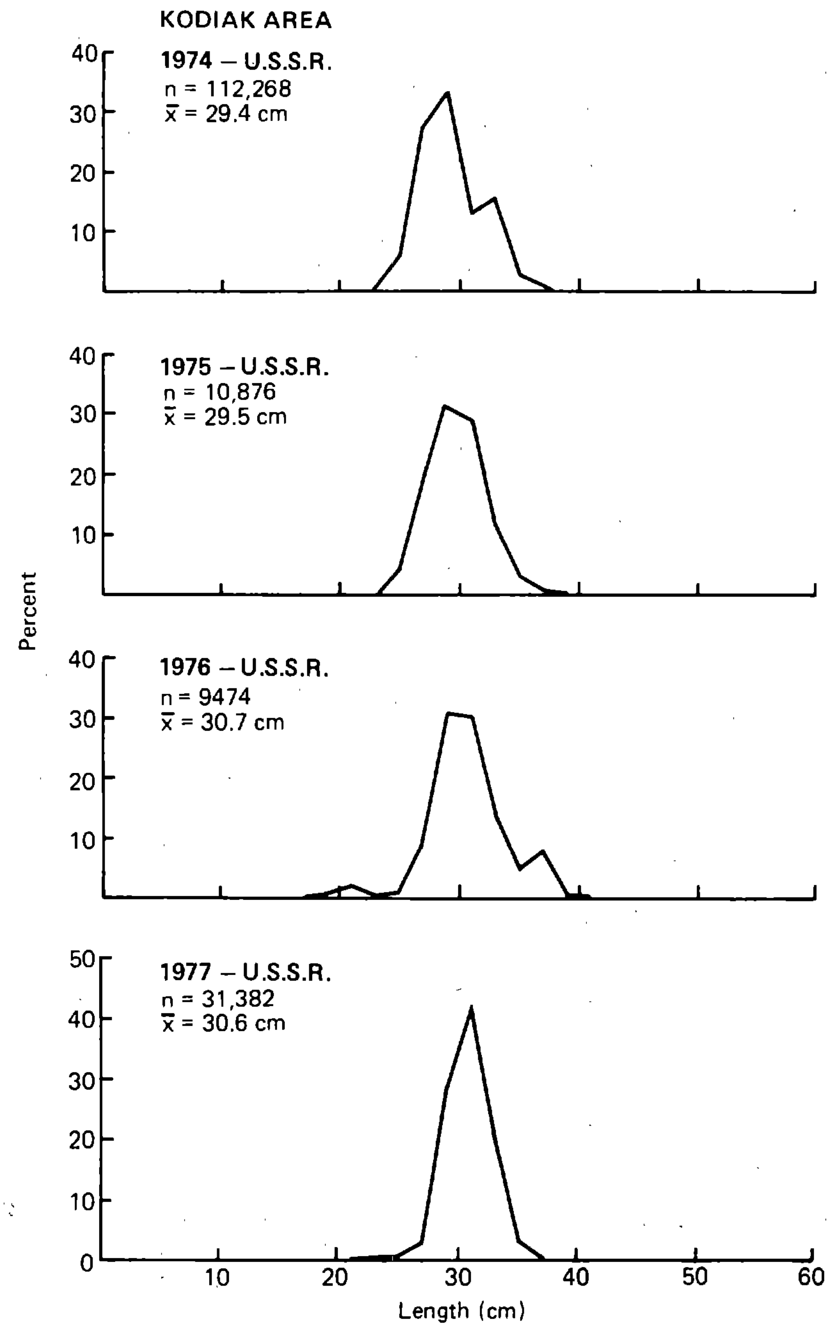

Figure 2.--Size composition of Atka mackerel in the 1974-77 U.S.S.R. landings in the Kodiak International North Pacific Fisheries Commission (INPFC) statistical area (Levada 1979b).

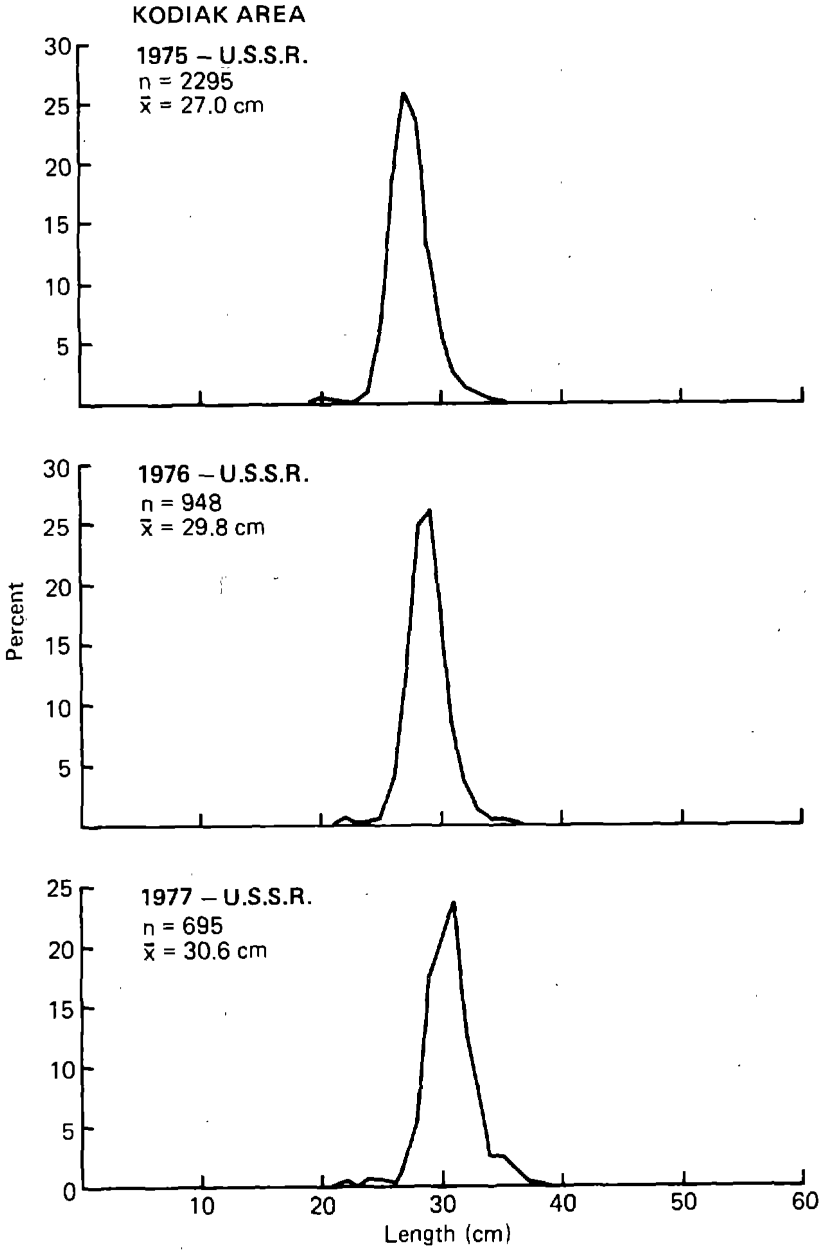

Figure 3.--Size composition of Atka mackerel in the 1975-77 U.S.S.R. landings in the Kodiak International North Pacific Fisheries Commission (INPFC) statistical area (Source: U.S. observer program).

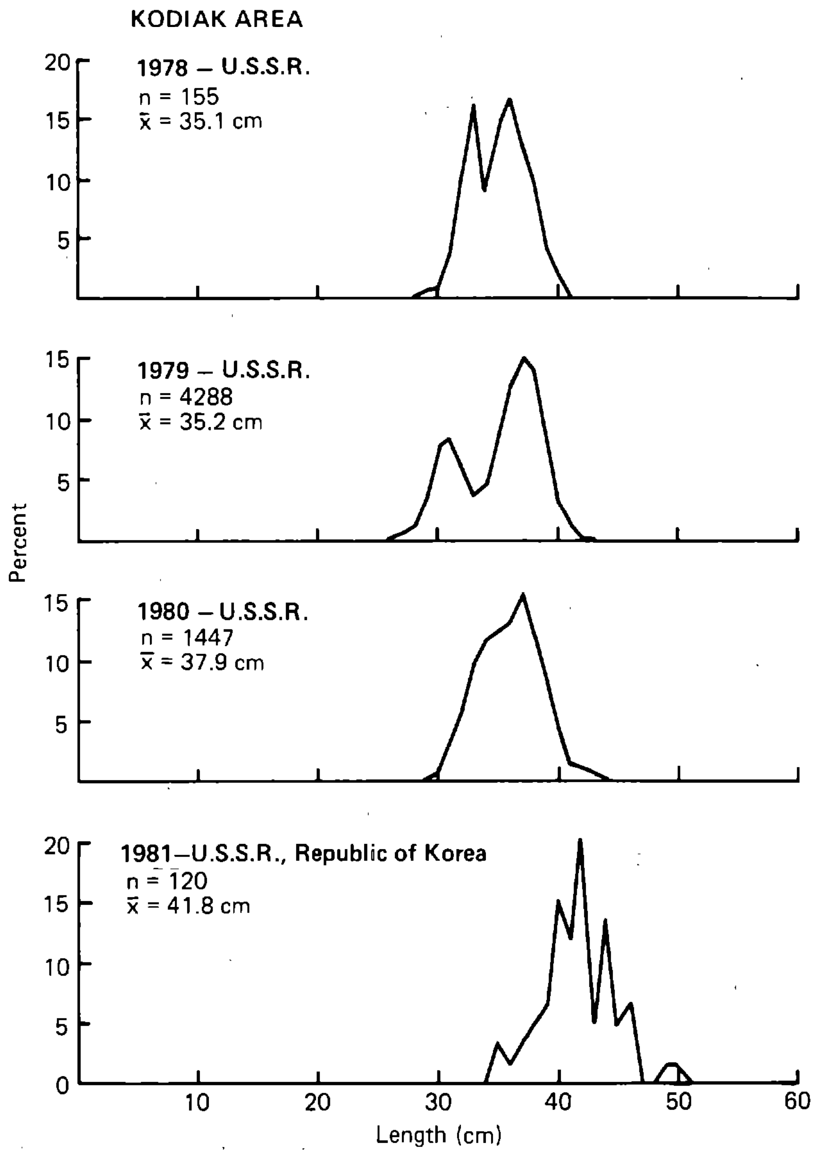

Figure 4.--Size composition of Atka mackerel in the 1978-81 landings by nation from the Kodiak International North Pacific Fisheries Commission (INPFC) statistical area (Source: U.S. observer program and Republic of Korea).

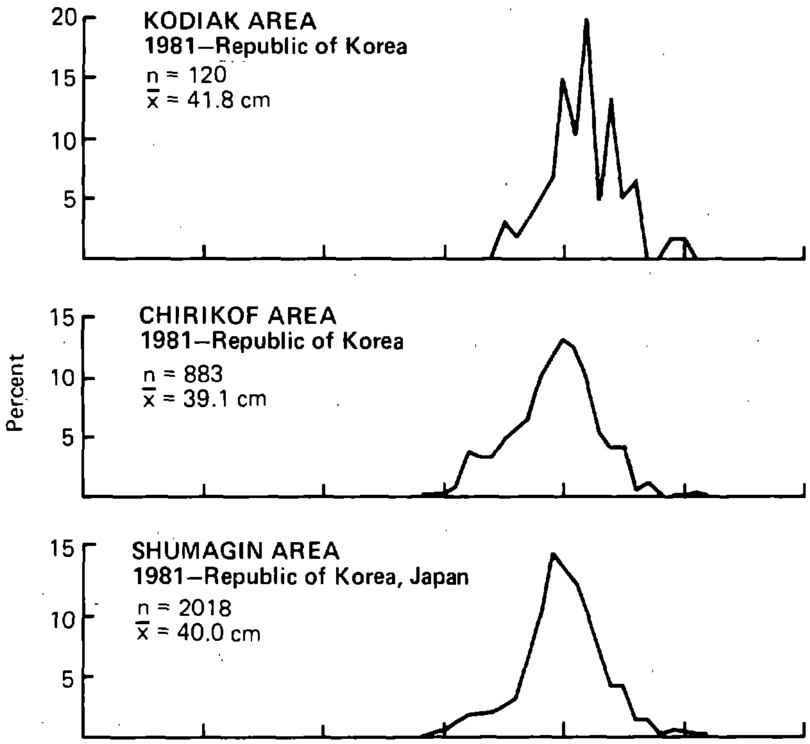

Figure 5.--Size composition of Atka mackerel in the 1981 landings from the Gulf of Alaska by International North Pacific Fisheries Commission (INPFC) statistical areas and nation (Source: U.S. observer program).

by analysis of data collected aboard Soviet research and commercial fishing vessels have confirmed that spawning occurs from July to October in the Albatross Bank area in the Kodiak INPFC area. Since Atka mackerel eggs are adhesive, plankton surveys have yielded data only on the locations and occurrence of larvae. The occurrence of Atka mackerel larvae on Albatross Bank to Portlock Bank from October through March has been documented (Kendall et al. 1980). The Soviet research vessel Seskar conducted an ichthyoplankton survey from Unimak Pass to Portlock Bank from 4 April to 24 May 1978 (Borets 1979). Atka mackerel larvae were encountered throughout the survey area. In most instances larval concentration occurred in close proximity to known areas of adult Atka mackerel aggregations.

Catch per unit of effort (CPUE) data are available from U.S. observers aboard foreign vessels and from Soviet fishery publications (Table 3). Although the absolute. values of the CPUE data vary considerably, the same trends are evident for comparable. 1977-80 data from both resources.

Age determinations by Soviet scientists using scales and U.S. scientists using otoliths do not agree; therefore, the age analysis for Gulf of Alaska data has provided only questionable information (Levada 1979a,b; Fadeev and Kharin 1981).

Data from the U.S. observer program, which U.S. scientists have analyzed for indications of year-class strength, are shown in Table 4. These data indicated that for those years when data are available the largest percentage of the harvested fish were usually 3- or 4-year-olds. Estimates of mean length at age by U.S. scientists using otoliths collected by U.S. observers have been highly variable (Table 5).

Table 3.--Mean length, weight, and catch per unit of effort (CPUE) of Atka mackerel taken in foreign fisheries in the Kodiak International North Pacific Fisheries Commission. statistical area, as determined by data collected by the U.S. Observer Program and as reported by Fadeev and Kharin (1981) and Levada (1979a,b).

Year	Mean length (cm)	Mean weight (g)	Observer CPUE (t/h)	Soviet estimated CPUE (t/h)
1974-75	27.0	0.26	--	1.5 1/
1976	30.0	0.31	--	2.0 1/
1977	--	--	0.24	2.2 1/
1978	35.0	0.53	0.05	1.1 2/
1979	35.2	0.66	3.73	3.1 2/
1980	--	0.74	0.71	1.9 2/

1/ Fadeev and Kharin (1981).
2/ Levada (1979a,b).

Table 4.--Age and sex composition of Atka mackerel from the Soviet fishery in the Kodiak International North Pacific Fisheries Commission statistical area, 1974-80. (Data collected by U.S. observers).

Year	Month	Composition (%) by age group							Sample size	Percentage female
		1	2	3	4	5	6	7		
1974-5	11,12,1	-	1	94	5	Tr1/	-	-	2,294	50
1976	12	-	1	71	24	3	-	-	937	50
1977	-	-	-	-	-	-	-	-	695	50
1978	6	-	-	5	53	8	28	5	154	86
1979	8	-	28	7	49	14	2	-	4,282	56
1980	-	-	-	-	-	-	-	-	-	-

1/ Trace (less than 1%).

Table 5.--Mean length at age of Atka mackerel in the Soviet fishery in the Kodiak International North Pacific Fisheries Commission statistical area, 1974-79. (Data collected by U.S. observers).

	Age (yr)						
Year	1	2	3	4	5	6	7
	Length (cm)						
1974-5	-	20	27	32	35	-	-
1976	-	22	30	30	31	-	-
1977	-	-	-	-	-	-	-
1978	-	-	32	34	37	36	38
1979	-	31	34	37	38	39	-

MAXIMUM SUSTAINABLE YIELD

In 1977 the available biomass of Atka mackerel in the Gulf of Alaska was estimated at 110,000 t based upon Soviet hydroacoustic and trawl surveys in the Gulf of Alaska and Aleutian Islands. Based upon Soviet research which supports the harvesting of 30% of the exploitable biomass, the maximum sustainable yield (MSY) was established at 33,000 t.

During 1979, the Soviets conducted a trawl survey of Atka mackerel in the Gulf of Alaska. Based on this survey and on the assumption that 30% of the biomass was harvestable annually, biomass was estimated at 95,552 t and MSY at 28,700 t (Fadeev 1980).

More recent analysis of the stock condition and MSY was conducted by Efimov (1981). To circumvent the disagreement concerning aging, Efimov used fishery data to estimate biomass ranging from 69,210 t in 1975 to 89,167 t in 1979 (Table 6). He further estimated the MSY at 28,300 t for fish of harvestable age (3 to 8 yr).

This MSY for Atka mackerel was derived from high biomass level rather than the average population that can be expected over a long period (1975-79). The stability of the mean size of the individuals in the catch (1971-77) and the increasing CPUE (1975-77) (Levada 1979b) demonstrated continued strong annual recruitment into the commercial stock over that period and, therefore, continued good condition of the stock. The increasing CPUE's and particularly the increasing mean size from 1975 to 1979 (Table 6) indicated a strong year-class or classess moved through the fishery resulting in increased biomass. Estimated MSY should be based upon the average biomass of the early 1970's when the stock was stable and not on the years of increasing biomass (1975-79).

Table 6.--Mean catch per unit of effort (CPUE) and estimated biomass of Atka mackerel in the Gulf of Alaska.

Year	Mean CPUE (t/hr)	Biomass (t)	Mean size (cm)
1971	-	-	31.9 3/
1972	-	-	31.9 3/
1973	-	-	34.3 3/
1974	-	-	29.4 3/
1975	1.5 1/	69,210 1/	29.5 3/
1976	2.0 1/	80,128 1/	30.7 3/
1977	2.2 1/	84,354 1/	30.6 3/
1978	2.3 1/	88,286 1/	-
1979	2.5 1/	89,167 1/	35.2 4/
1980	1.9 2/	-	39.0 2/
1981	-	-	-

1/ Efimov (1981).
2/ Fadeev and Kharin (1981).
3/ Levada (1979).
4/ U.S. observer program data.

The MSY can also be estimated, using the equation developed by Alverson and Pereyra (1967) and modified by Gulland (1969):

$$MSY = a\ M\ B_o$$

where

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

M = instantaneous natural mortality rate, and

B_o= virgin biomass.

Using the value of M = 0.6 (Efimov 1981), a = 0.4, and Efimov's minimum biomass estimate of 69,210 t, a conservative MSY of 16,610 t can be calculated for the 3- to 5-year-old fish. Similarly, a less conservative MSY value of 26,750 t can be obtained using M = 0.6, a = 0.5, and B_o, = 89,167 t. The estimated range for MSY is then 16,610 to 26,750 t with a mean value of about 22,000 t.

EQUILIBRIUM YIELD

There are no data which suggest that the equilibrium yield (EY) should vary from the MSY.

ALLOWABLE BIOLOGICAL CATCH.

Increasing mean CPUE's in the Soviet commercial fishery 1975-79 viewed in conjunction with an increasing biomass and increasing mean size demonstrated #at one or more larger than normal year-classes are moving through the fishery. Fadeev and Kharin (1981), using data collected by Soviet scientists aboard commercial and research vessels, found two prominent year-classes prevalent in the Gulf of Alaska in 1980 (1976-77). These two year-classes produced 89% of the total catch. Therefore, in 1981 availability of the 1976 year-class decreased drastically and in 1982 the production of the 1977 year-class should drop similarly. Without indication of strong recruitment, the available surplus yield may be expected to decline. Fadeev and Kharin (1981) also report a reduction in the mean CPUE of the Soviet fleet from 2.5 t/h in 1979 to 1.3 t/h in 1980.

It now appears that during 1978 and 1979 the allowable biological catch (ABC) for Atka mackerel in the Gulf of Alaska could have been higher to allow harvesting the increased biomass created by two larger than normal year-classes moving through the fishery.

The decreasing mean CPUE of the Soviet fleet in 1980 and the projected passing of the two dominant year-classes through the fishery without indication of strong recruitment suggest that the ABC far 1983 should be set no higher than the mean MSY estimate (22,000 t).

RECENT RESEARCH RESULTS, REQUIREMENTS AND SCHEDULE

During March-April 1978 the Northwest and Alaska Fisheries Center conducted a groundfish resource survey along the southeast coastline of Kodiak Island. As part of this survey certain biological data were collected from Atka mackerel for the first time (Table 7). Length-weight relationships were described as follows:

Males: weight (g) $= 0.0078196\ (\text{length (cm)})^{3.114099}$

Females: weight (g) $= 0.04818\ (\text{length (cm)})^{2.569168}$.

Data gathered during a repeat survey in the winter of 1980 revealed that in the Kodiak area the weight-length relationships were very similar:

Males: weight (g) $= 0.010062\ (\text{length (cm)})^{3.049887}$

Females: weight (g) $= 0.047911\ (\text{length (cm)})^{2.58848}$.

Table 7.--Length-weight relationships for Atka mackerel in the Kodiak International North Pacific Fisheries Commission statistical area, March-April 1978 and February-April 1980.

	Weight (g)			
	1978		1980	
Length (cm)	Males	Females	Males	Females
23	136	-	-	-
24	155	-	-	-
25	176	-	-	-
26	199	208	208	-
27	224	229	234	-
28	251	252	261	267
29	280	275	290	292
30	311	301	322	319
31	345	327	356	347
32	381	354	392	377
33	419	384	431	408
34	460	415	472	441
35	503	447	515	476
36	549	480	561	512
37	598	515	610	549
38	-	552	662	588
39	-	590	716	629
40	-	629	774	-
41	-	-	835	-
Sample size	402	439	171	200

However, one sample collected in the Chirikof INPPC area (1980) indicated a higher exponential value or heavier fish for a given size (Table 8):

$$\text{Males: weight (g)} = 0.0034443\ (\text{length (cm)})^{3.372805}$$

$$\text{Females: weight (g)} = 0.0043341\ (\text{length (cm)})^{3.285695}.$$

Comparison indicated that the Soviet 1975-77 data (Levada 1979a) and the weight-at-length for Atka mackerel in the Kodiak, area are similar, with the Soviet length-weight relationship showing slightly lighter individuals in the 25-35 cm range and heavier individuals at > 37 cm (Table 9). The difference in the length-weight relationship may be due to sampling error.

The relationship developed from the Soviet data, sexes combined, was $\text{weight (g)} = 0.00159\ (\text{length (cm)})^{3.56}$.

During 1978 and 1980 the Northwest and Alaska Fisheries Center conducted trial tagging studies during their groundfish surveys. Atka mackerelwere tagged using the "T"-bar type plastic tag successfully used on sablefish. During 1978, tagged specimens were retained in a live tank aboard the NOAA ship <u>Miller Freeman</u> and returned to Seattle where they were placed in a live tank at the Seattle Aquarium. Although there was steady attrition and some tag loss, several specimens survived nearly 8 months, still retaining tags.

Age readings of the samples collected during the U.S. groundfish surveys in 1978 and 1980 have not been completed. Age data are available, however, from scale samples collected by the U.S.S.R., Levada (1979a,b) gives the following relationship between length and age:

Age (yr)	Mean length (cm)
1	12.2
2	20.4
3	24.8
4	29.0
5	32.2
6	34.6
7	36.7
8	38.4

The age composition of Atka mackerel in the Gulf of Alaska in 1975-77 is presented in Table 10 (Levada 1979b). In 1975-77 nearly 60% of the catch consisted of 5-yr age group specimens and 25-30% 6-yr fish, while in 1980, 44 and 45% of the catch was aged to be 4- and 5-yr groups (Fadeev and Kharin 1981). Data provided by Levada shows that 5-year-old fish, on the average, are 32.2 cm, while the 1981 data indicated 5-year-old fish are 38.7 cm. These discrepancies in mean size at age indicate problems in aging interpretation.

Analysis of the available U.S. data base, therefore, has indicated. lack of validity which makes it difficult to assess the status of the Atka mackerel in the Gulf of Alaska. To adequately manage this resource, data on the size-sex composition of the catch, mean length, mean weight, annual CPUE, and age are necessary. The greatest need is to resolve the discrepancies in aging techniques obtained from otoliths and scales. Tagging studies should also be undertaken as an aid to defining stocks, their boundaries, and their migrations within areas. The majority of information

Table 8--Length-weight relationships for Atka mackerel in the Chirikof International North Pacific Fisheries Commission statistical area, February-April 1980.

Length (cm)	Weight (g) Male	Weight (g) Female
31	-	344
32	411	382
33	456	423
34	504	467
35	556	513
36	611	563
37	670	616
38	734	672
39	801	732
40	872	796
41	948	863
42	1,028	934
43	1,113	1,009
Sample size	98	71

Table 9.--Comparison of U.S.-U.S.S.R. length-weight data (sexes combined).

Length (cm)	Weight (g)			
	U.S.S.R. data	U.S. data		
	Kodiak, 1975-77	Kodiak, 1978	Kodiak, 1980	Chirikof, 1980
12	12	-	-	-
20	66	-	-	-
25	162	176[1/]	-	-
29	264	277	291	-
32	362	365	385	397
35	464	475	495	534
37	608	556	580	643
38	695	-	625	702
40	-	-	-	834
41	-	-	-	905
42	-	-	-	981
43	-	-	-	1,061

1/ Males only

Table 10.--Age composition of Atka mackerel landings from the Gulf of Alaska 1975-77.

	Composition (%) by age group							Mean length of catch
Year	1	2	3	4	5	6	7	(cm)
1975[1/]	-	-	4	60	30	5	1	30.3
1976[1/]	-	1	5	58	29	5	2	30.7
1977[1/]	-	1	10	61	25	2	1	31.2
1980[2/]	-	3	44	45	7	1	-	39.0

1/ Levada (1979b).
2/ Fadeev and Kharin (1981).

available for Atka mackerel has been provided by the Soviets from research surveys and the commercial fishery. With cessation of Soviet fishing efforts in the Gulf of Alaska, continuity of the existing data will be lost. A new data series can be developed based upon data collected by observers sampling aboard foreign fishing vessels and data provided by foreign nations harvesting the resource.

No specific research is presently scheduled by the Northwest and Alaska Fisheries Center for Atka mackerel in the Gulf of Alaska.

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FLATFISH

by

Craig S. Rose and Eric S. Brown

INTRODUCTION

From 1978 to 1981, the catch of flatfish, excluding Pacific halibut, Hippoglossus stenolepis, in the Gulf of Alaska has fluctuated around 14,500 metric tons (t) (Table 1). Japan, historically the primary exploiter of this resource, continues to take most of the catch. The Republic of Korea (R.O.K.), which extended their fishing operations from the Shumagin International North Pacific Fisheries Commission (INPFC) statistical area to the Chirikof and Yakutat areas, accounted for 35% of the total Gulf of Alaska flatfish catch in 1981. The U.S.S.R. fishery, which had taken 6% of the flatfish catch in 1980, was excluded from the Gulf in 1981. In addition to these fisheries, small catches of flatfish have been taken by Poland and Mexico, as well as by joint venture fisheries between U.S. harvesters and U.S.S.R. and R.O.K. processors.

A large portion of the flatfish catch has been incidental to targeted efforts on other species. The catch per unit effort (CPUE) for flatfish, therefore, may be affected as much by the coincidence of their distribution with that of the target species as by their actual abundance. At this time, no analysis is available which effectively separates out effort directed at flatfish. Also, flatfish age-composition data obtained from the commercial catch is not sufficiently complete and consistent enough to allow an analysis by time and area.

Table 1.--Catch of flatfish (t) by nation from the Gulf of Alaska during 1978-81.

International North Pacific Fisheries Commission statistical area	Japan	U.S.S.R.	R.O.K.	Poland	Mexico	Joint-venture U.S.-U.S.S.R.	Joint-venture U.S.-R.O.K.	Total
	- - -	- - -	- - -	- - -	t	- - -	- - -	- - -
Shumagin								
1978	2,268	-	270	-	-	-	-	2,538
1979	2,202	26	557	15	17	-	-	2,817
1980	336	976	1,710	-	-	8	-	3,030
1981	1,229	-	1,984	11	-	-	-	3,224
Chirikof								
1978	2,268	188	26	-	-	-	-	2,482
1979	488	107	-	4	19	-	-	618
1980	936	40	-	-	-	-	106	1,082
1981	1,349	-	2,300	4	-	-	18	3,671
Kodiak								
1978	3,809	8	-	13	-	-	-	3,830
1979	4,100	231	-	-	77	-	-	4,408
1980	5,086	823	-	-	-	-	92	6,001
1981	2,099	-	7	-	-	-	-	2,106
Yakutat								
1978	2,955	-	-	-	-	-	-	2,955
1979	3,238	5	47	-	-	-	-	3,290
1980	4,071	-	24	-	-	-	-	4,095
1981	2,573	-	735	-	-	-	-	3,308
Southeastern								
1978	2,536	-	-	-	-	-	-	2,536
1979	2,341	-	1	-	-	-	-	2,342
1980	1,495	-	-	-	-	-	-	1,495
1981	2,153	-	-	-	-	-	-	2,153
Total								
1978	13,836	196	296	13	-	-	-	14,341
1979	12,369	369	605	19	113	-	-	13,475
1980	11,924	1,839	1,734	-	-	8	198	15,703
1981	9,403	-	5,026	15	-	-	18	14,462

While the flatfish fishery includes many species, it is managed as one stock. The major species, which account for approximately 90% of the total flatfish catch, are arrowtooth flounder, Atheresthes stomias; flathead sole, Hippoglossoides elassodon; rock sole, Lepidopsetta bilineata; rex sole, Glyptocephalus zachirus; and Dover sole, Microstomus pacificus. To allow a more complete view of this fishery, the distribution of the catches from fisheries statistics and the apparent abundance observed from resource assessment surveys are presented for individual species and then for all flatfish combined.

The research survey data presented in the following figures are derived from a series of cruises from 1978 to 1981. Catch rates were calculated by depth strata and compiled by 2° long. sections. These catch rates were then expanded into a biomass estimate for the total bottom area of each section by an area-swept method, assuming that all flatfish in the path of the trawl were caught (catchability = 1.0). Although no definite values are available for the true catchability, it is probably less than 1.0; therefore, it is recommended that these figures be used for relative comparisons only.

ARROWTOOTH FLOUNDER

During the period 1978-81, the foreign catch of arrowtooth flounder ranged from 11,600 to 12,700 t and accounted for 81-86% of the total flatfish catch (Table 2). Catches were evenly distributed among the five INPFC statistical areas with the Yakutat and Kodiak areas providing the largest yearly catches.

Data from resource assessment surveys (Figure 1) show that the Kodiak and Chirikof regions contained by far the largest components of available biomass but that the remaining regions also contributed significantly to the total estimate. Also, except for rock sole in the Shumagin region, the abundance of arrowtooth flounder exceeded that of any other flatfish species in each area.

Table 2.--Commercial catch (t) of arrowtooth flounder from the Gulf of Alaska by year and International North Pacific Fisheries Commission (INPFC) statistical area.

Year	INPFC statistical area: Southeastern	Yakutat	Kodiak	Chirikof	Shumagin	Total	% of total flatfish
	t						
1978	2,223	2,568	2,610	2,052	2,256	11,709	81.8
1979	2,273	3,022	3,480	520	2,345	11,640	86.4
1980	1,415	3,736	4,528	871	2,138	12,688	80.8
1981	2,119	3,111	1,726	2,671	2,207	11,834	84.5

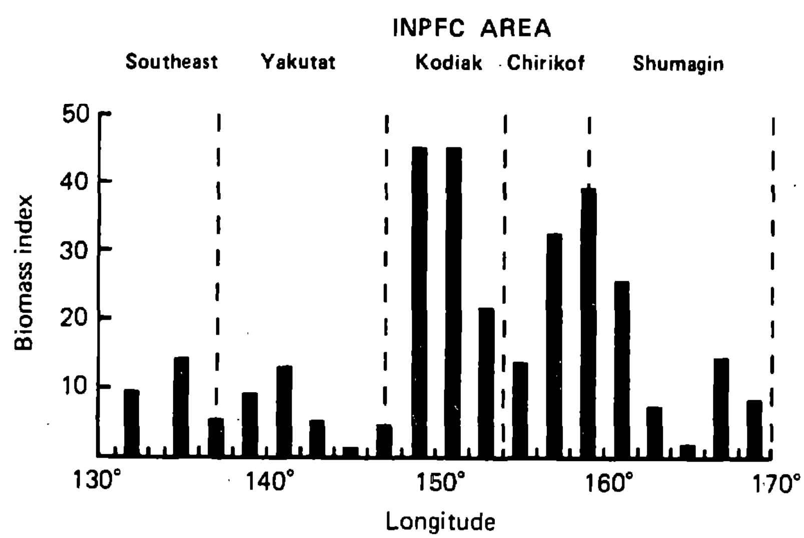

Figure 1.--Biomass index (thousand t) of arrowtooth flounder based on trawl surveys conducted in the Gulf of Alaska International North Pacific Fisheries Commission (INPFC) statistical areas in 1978-81.

ROCK SOLE

In recent years, the bulk of the rock sole catch from the Gulf of Alaska has come from the Shumagin area where 627 and 235 t were taken in 1980 and 1981, respectively (Table 3). The total Gulf-wide catch reached 719 t in 1980 but fell to 447 t in 1981.

Research cruise data indicated that rock sole may be the second most abundant flatfish species in the Gulf. This data and information from the commercial fishery show rock sole abundance to be highest in the central and western Gulf, particularly in the Shumagin region (Figure 2).

FLATHEAD SOLE

The few hundred metric. tons of flathead sole taken during 1978-79 were taken mostly from the Yakutat and Kodiak INPFC areas (Table 4). In 1980, the catch increased substantially to 822 t with a larger proportion coming from the western Gulf. In 1981, the total catch fell slightly but there was a significant shift of the catch distributions with 87% coming from the Chirikof area alone.

Research cruise data (Figure 3) indicated that most of the population resides in the central and western Gulf with the Kodiak area containing the largest portion of the apparent biomass followed by the Chirikof and Shumagin areas.

REX SOLE

The Gulf of Alaska commercial catch of rex sole has decreased in the last 4-yr from 1,257 to 371 t (Table 5). The distribution of the catches has shown a shift to the west, though the largest catches have consistently come from the Kodiak area.

Table 3.--Commercial catch (t) of rock sole from the Gulf of Alaska by year and International North Pacific Fisheries Commission (INPFC) statistical area.

Year	INPFC statistical area					Total	% of total flatfish
	Southeastern	Yakutat	Kodiak	Chirikof	Shumagin		
	t						
1978	4	5	37	21	65	132	0.9
1979	3	6	88	6	254	357	2.7
1980	Trace	Trace	89	2	627	719	4.6
1981	-	18	9	186	235	447	3.2

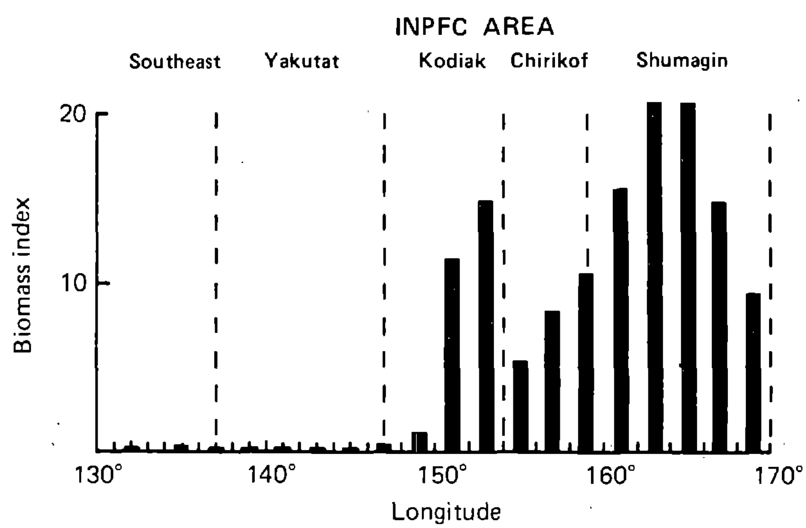

Figure 2.--Biomass index (thousand t) of rock sole based on trawl surveys conducted in the Gulf of Alaska International North Pacific Fisheries Commission (INPFC) statistical areas in 1978-81.

Table 4.--Commercial catch in metric tons (t) of flathead sole from the Gulf of Alaska by year and International North Pacific Fisheries Commission (INPFC) area.

Year	INPFC statistical area					Total	% of total flatfish
	Southeastern	Yakutat	Kodiak	Chirikof	Shumagin		
	t						
1978	Trace	136	114	7	28	285	2.0
1979	Trace	23	113	19	17	179	1.3
1980	Trace	222	409	102	89	822	5.2
1981	-	31	24	606	37	700	5.0

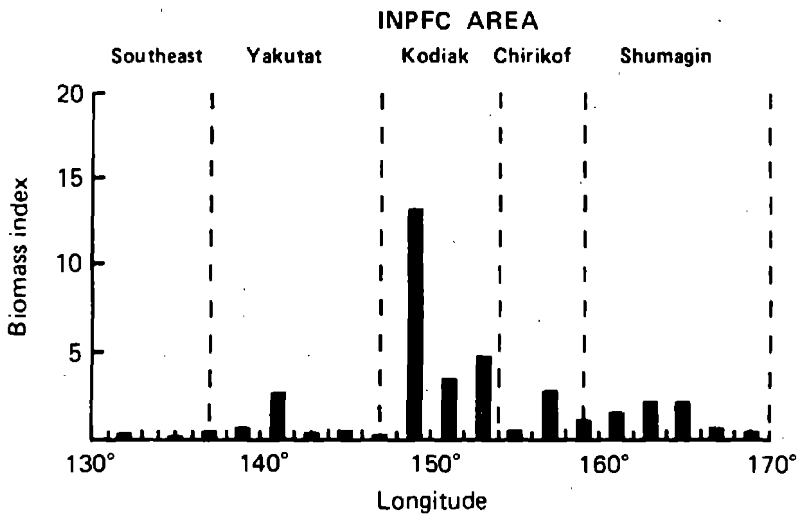

Figure 3.--Biomass index (thousand t) of flathead sole based on trawl surveys conducted in the Gulf of Alaska International North Pacific Fisheries Commission (INPFC) statistical areas in 1978-81.

Table 5.--Commercial catch (t) of rex sole from the Gulf of Alaska by year and International North Pacific Fisheries Commission (INPFC) statistical area.

Year	INPFC statistical area					Total	% of total flatfish
	Southeastern	Yakutat	Kodiak	Chirikof	Shumagin		
	- - - - - - - - - - - - - t - - - - - - - - - - - - -						
1978	272	69	507	269	140	1,257	8.8
1979	32	89	415	36	90	662	4.9
1980	22	53	592	70	85	821	5.2
1981	19	20	148	93	90	371	2.7

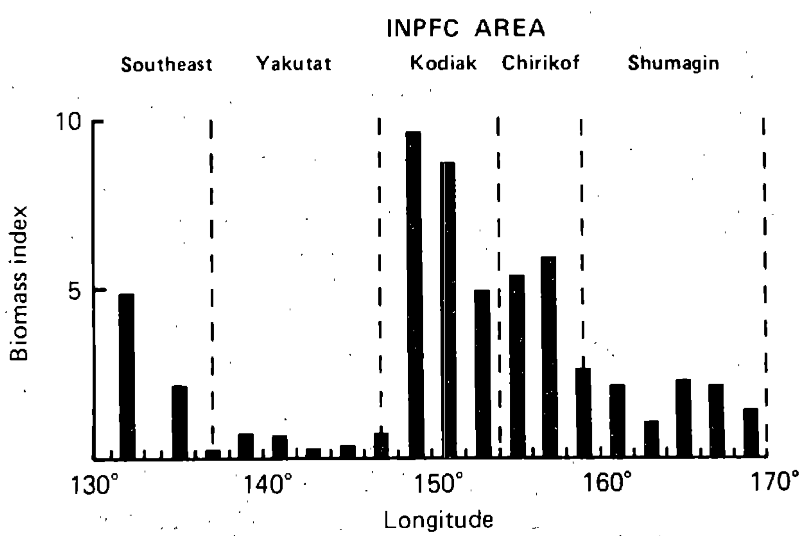

Figure 4. --Biomass index' (thousand t) of rex sole based on trawl surveys conducted in the Gulf of Alaska International North Pacific 'Fisheries Commission (INPFC) statistical areas in 1978-81.

The research cruises have indicated that the greatest abundance of this species is in the Kodiak area and westward (Figure 4). However, there is also a significant abundance of rex sole in the Southeastern area.

DOVER SOLE

Until 1981, the catch of Dover sole from the Gulf of Alaska came mostly from the Kodiak area. Yearly catches have slowly decreased from 827 t in 1978 to 454 t in 1981 (Table 6).

The research data show that abundance of Dover sole is highest in the Kodiak region, (Figure 5), but not as dominant as the commercial catches might indicate. Yakutat, the second most productive commercial area, had relatively low biomass, as indicated by research surveys.

TOTAL FLATFISH

The total catch of flatfish has remained relatively constant over the 1978-81 period, ranging from 13,400 to 15,700 t (Table 7). The catch has also remained evenly distributed across the Gulf with only a slight shift to the west. Research cruise data indicated that a large percentage of the flatfish abundance is found in the central and western Gulf (Figure 6).

Other flatfish species captured in the Gulf of Alaska are listed in Table 8. Of these, the most consistently occurring is the Greenland turbot, *Reinhardtius hippoglossoides,* which is usually taken by deep longline fisheries in the far western Gulf.

Considering the apparent status and state of knowledge of flatfish stocks in the Gulf of Alaska, there is little reason to change the current allowable biological catch (ABC) for these species at this time (Table 9). Catch levels for principal species, as well as for all species, have been very minor compared

Table 6.--Commercial catch (t) of Dover sole from the Gulf of Alaska by year and International North Pacific Fisheries Commission (INPFC) area.

Year	INPFC statistical area					Total	% of total flatfish
	Southeastern	Yakutat	Kodiak	Chirikof	Shumagin		
	---------- t ----------						
1978	33	132	548	78	36	827	5.8
1979	24	83	304	33	85	529	3.9
1980	57	81	380	31	21	570	3.6
1981	15	126	196	69	48	454	3.3

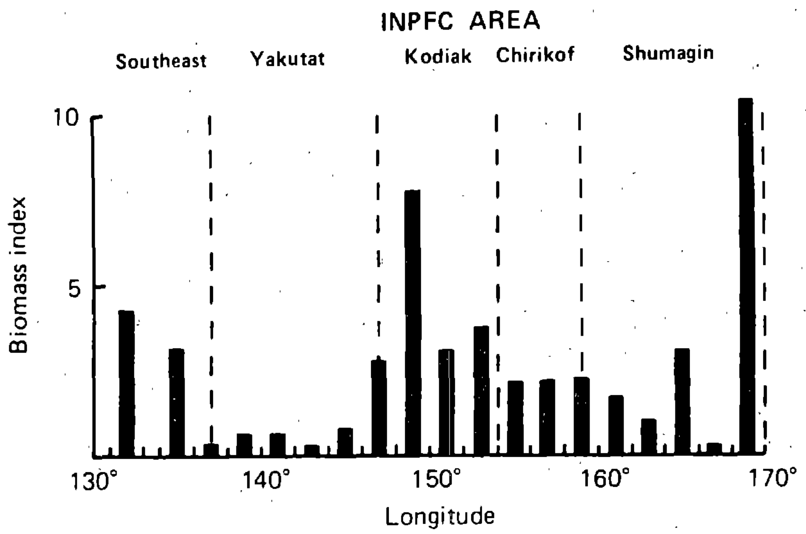

Figure 5.--Biomass index (thousand t) of Dover sole based on trawl surveys conducted in the Gulf of Alaska International North Pacific Fisheries Commission (INPFC) statistical areas in 1978-81.

Table 7.--Commercial catch (t) of all flatfish (except Pacific halibut) from the Gulf of Alaska by year and International North Pacific Fisheries Commission (INPFC) statistical area.

	INPFC statistical area					
Year	Southeastern	Yakutat	Kodiak	Chirikof	Shumagin	Total
	t					
1978	2,536	2,955	3,830	2,482	2,538	14,341
1979	2,342	3,290	4,408	618	2,817	13,475
1980	1,495	4,095	6,001	1,082	3,030	15,703
1981	2,153	3,308	2,106	3,671	3,224	14,462

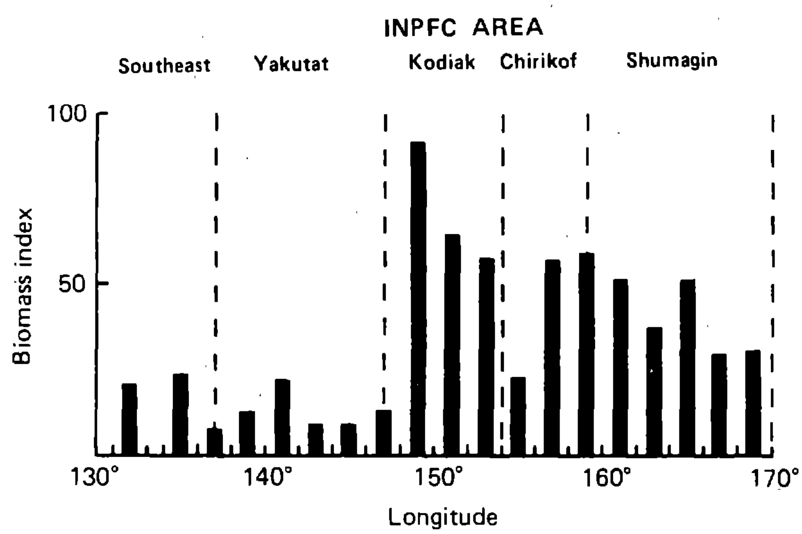

Figure 6.--Biomass index (thousand t) of total flatfish (excluding Pacific halibut) based on trawl surveys conducted in the Gulf of Alaska International North Pacific Fisheries Commission (INPFC) statistical areas in 1978-81.

Table 8.--Names of "other species" of flatfish commonly encountered in Gulf of Alaska fisheries.

Common name	Scientific name
Petrale sole	*Eopsetta jordani*
Greenland turbot	*Reinhardtius hippoglossoides*
Deepsea sole	*Embassichthys bathybius*
Slender sole	*Lyopsetta exilis*
Starry flounder	*Platichthys stellatus*
English sole	*Parophrys vetulus*
Butter sole	*Isopsetta isolepis*
Yellowfin sole	*Limanda aspera*

Table 9.--Exploitable biomass and allowable biological catch (APC)[1/] of Gulf of Alaska flatfish[2/]

Item	Area			
	Western	Central	Eastern	Total
	- - - - - - - - - 1,000 t - - - - - - - -			
Exploitable biomass	220	346	206	772
Allowable biological catch	20.8	30.6	16.6	67

1/ ABC has been set equal to maximum sustainable yield (MSY) and was apportioned between the three areas on the basis of trawl survey data.

2/ From Gulf of Alaska Groundfish Management Plan (North Pacific Fishery Management Council).

to the abundance of these species and the maximum sustainable yield (MSY) of the flatfish complex.

Future monitoring of flatfish stocks in the Gulf of Alaska will continue to consider both commercial fisheries data and resource assessment surveys. Based on historical fishery and research data, index areas have been designated which will be surveyed periodically to monitor changes in the abundance, age, and size composition and distribution of flatfish. Present plans of the Northwest and Alaska Fisheries Center include surveying these areas at least once every 3 yr.

PACIFIC OCEAN PERCH

by

Herbert H. Shippen and James W. Stark

INTRODUCTION

Pacific ocean perch, Sebastes alutus, are captured throughout the breadth of the Gulf of Alaska fishery conservation zone administered by the North Pacific Fishery Management Council (NPFMC). Its range, however, extends well beyond the Gulf of Alaska from southern California to northeastern Asia (Major and Shippan 1970).

During the 1950's and early 1960's, Pacific ocean perch was identified as the dominant rockfish, as well as a prominent species in the demersal community. Alverson et al. (1964) considered Pacific ocean perch to be "the dominant form in the aggregate species catch" at depths from 100 to 149 fathoms (183-272 m). Similarly,. inreporting the results of Canadian research in surveys conducted from 1963 to 1966 throughout the Gulf of Alaska, Westrheim (1970) stated that Pacific ocean perch made up 90% of the rockfish catch.

STOCK UNITS

Identification of stocks of Pacific ocean perch, as well as the determination of patterns of migration, is hampered by the inability of these fish to survive the rigors of capture and tagging, especially the decompression in being removed from depth to the surface. For this reason, scientists studying migrations of Pacific ocean parch have had to base their conclusions on apparent changes in abundance or sex ratio. Recently, biochemical methods have been employed to study stock identification.

On the basis of changes in distribution and sex ratio, Lyubimova (1963, -1965) hypothesized that female Pacific, ocean perch, after spending the summer and fall in foraging in the western part of the Gulf of Alaska near Unimak Pass, leave that area and migrate in September and October to the southeastern part of the Gulf where their young develop to be spawned the next spring.-

Another Soviet scientist (Fadeev 1968), however, reviewed the same evidence as Lyubimova and came to different conclusions: 1) Pacific ocean perch do not make extreme seasonal migrations along the shelf; 2) seasonal movements of Pacific ocean perch are largely between deep and shallow bottoms within a limited geographical area; 3) Pacific ocean perch form a series of local populations which are only partly intermixed. Fadeev cautioned those fishing for Pacific ocean perch that because of the fragmented population and slow rate of reproduction, fishing activities should be carefully distributed so as to avoid exceeding the reserves of each local group.

After a Gulf-wide survey of rockfishes, particularly Pacific ocean perch, Westrheim (1970) on the basis of year-class strength and size composition identified a division between Pacific ocean perch in the Gulf of Alaska and those found off British Columbia south of Dixon Entrance.

Based on differences in length composition, growth, fecundity, etc., Chikuni (1975) identified four stocks of Pacific ocean perch: 1) Gulf of Alaska; 2) eastern Pacific (British Columbia to California); 3) Aleutian Islands; and 4) eastern slops (Bering Sea to Kurile Islands).

Studies using biochemical methods have refined the earlier work described above. Wishard et al. (1980) identified three stocks of *S. alutus,* one off Washington and Oregon, another from the Gulf of Alaska, and a third from the vicinity of Prince William Sound in the northern Gulf which had previously not been recognized.

CATCHES OF PACIFIC OCEAN PERCH IN THE GULF OF ALASKA

Historical Catches

Commercial fisheries of the United States and Canada for Pacific ocean perch began in the late 1940's off the Pacific Northwest coast (Major and Shippen 1970).

Soviet fisheries in the eastern Pacific Ocean started in the 1950's in the Aleutian Islands area and Bering Sea and expanded into the central Gulf of Alaska in 1960. A fleet of 160 Soviet ships operated in the eastern Gulf of Alaska in 1965 (Chitwood 1969). A substantial part of the Soviet catch was Pacific ocean perch, but no records have been provided by the U.S.S.R. except as part of a general rockfish catch.

Japan began trawl fishing operations in the Gulf of Alaska in 1963 (Chitwood 1969) and has provided catch records for Pacific ocean perch since 1964. The Pacific ocean perch catch by Japan peaked at about 64,000 t in 1966 and declined to about 20,000 t in 1977. In 1978, with the establishment of regulation by the NPFMC, other nations, principally the Republic of Korea (R.O.K.), have taken a substantial part of the catch, and Japan's portion has been about 10,000 t (Table 1).

The R.O.K. began fishing in the Gulf of Alaska in 1966 (Chitwood 19691, but records of her catch of Pacific ocean perch begin with 1976. The R.O.K. took nearly half the Pacific ocean perch catch from the Gulf of Alaska in 1978, but has taken relatively little since then.

Poland, Mexico, and the Federal Republic of Germany also have participated in the fishery for Pacific ocean perch in the Gulf of Alaska, but their catches have been minor in comparison to the amounts taken by the U.S.S.R., Japan, and the R.O.K.

Table 1.--Pacific ocean perch catches[1/] from the Gulf of Alaska by nation and INPFC[2/] region, 1964-81 (does not include unknown catches by U.S.S.R. prior to 1977).

Nation	Year	Shumagin	Chirikof	Kodiak	Yakutat	South-eastern	Total
		- - - - - - - -	- - - - - - - -	- - t - -	- - - - - - - -	- - - - - - - -	- - - - - - - -
Japan	1964	1,610	1,150	10,614	11	0	13,385
Japan	1965	9,171	12,555	20,839	33	0	42,598
Japan	1966	14,373	21,068	28,368	422	718	64,949
Japan	1967	5,834	6,967	17,922	13,625	9,162	53,510
Japan	1968	1,216	2,481	8,236	30,874	12,163	54,970
Japan	1969	2,027	5,772	11,346	18,404	16,090	53,639
Japan	1970	504	5,592	11,366	10,602	16,317	44,381
Japan	1971	2,800	5,033	12,125	14,159	13,960	48,077
Japan	1972	4,233	2,837	11,439	15,481	16,628	50,618
Japan	1973	4,796	5,678	9,505	17,087	10,307	47,373
Japan	1974	4,082	3,497	8,096	10,690	10,615	36,980
Japan	1975	4,158	3,996	10,016	8,420	7,541	34,131
Japan	1976	4,557	3,645	8,730	9,625	8,796	35,353
R.O.K.	1976	1,339	26	177	45	28	1,615
Total	1976	5,896	3,671	8,907	9,670	8,824	36,968
Japan	1977	1,567	2,531	4,977	5,428	4,744	19,247
R.O.K.	1977	560	T	0	0	0	560
U.S.S.R.	1977	536	594	588	108	4	1,830
Total	1977	2,663	3,125	5,565	5,536	4,748	21,637
Japan	1978	429	430	1,203	1,337	1,149	4,548
R.O.K.	1978	3,021	25	0	0	3	3,049
Poland	1978	0	0	4	0	0	4
U.S.S.R.	1978	193	280	82	7	8	570
Total	1978	3,643	735	1,287	1,344	1,160	8,171
Japan	1979	652	116	832	1,714	4,083	7,397
R.O.K.	1979	193	0	0	498	134	825
Poland	1979	2	3	0	0	0	5
U.S.S.R.	1979	30	122	908	5	0	1,065
Mexico	1979	67	18	372	0	0	457
Total	1979	944	259	2,112	2,217	4,217	9,750
Japan	1980	169	533	2,507	4,649	2,912	10,770
R.O.K.	1980	353	0	0	55	0	408
Poland	1980	29	1	0	0	0	30
U.S.S.R.	1980	290	123	826	0	0	1,239
Total	1980	842	656	3,333	4,704	2,912	12,447
Japan	1981	741	1,495	1,882	3,927	2,297	10,343
R.O.K.	1981	463	862	16	444	0	1,785
Poland	1981	29	13	0	7	0	49
Total	1981	1,234	2,370	1,898	4,377	2,297	12,177

1/ Values for 1964 to 1977 are foreign reported statistics as submitted to the U.S. Values from 1978 are from Anonymous 1979; 1979, Nelson et al. 1980; 1980, French et al. 1981; and 1981, Nelson et al. 1982.

2/ INPFC = International North Pacific Fisheries Commission.

Current Catches

The total catch of Pacific ocean perch from the Gulf of Alaska in 1981 was 12,178 t, most of which was taken by foreign trawlers. United States domestic fisheries, including joint ventures, took 1.3 t.

In 1980 and 1981, the Gulf of Alaska catch of Pacific ocean perch by foreign vessels and by International North Pacific Fishery Commission (INPFC) statistical area was as follows:

INPFC	1980		1981	
areas	Metric tons	Percent	Metric tons	Percent
Shumagin	841.7	6.8	1,234.5	10.1
Chirikof	656.5	5.2	2,370.0	19.5
Kodiak	3,332.8	26.8	1,898.2	15.6
Yakutat	4,703.6	37.8	4,377.4	36.0
Southeastern	2,912.3	23.4	2,297.1	18.9
Total	12,446.9	100.0	12,177.2	100.1

The distribution of the catch of Pacific ocean perch reflects allocations by the NPFMC which has established the following three management, or regulatory, areas in the Gulf of Alaska: the Western (Shumagin), the Central (Chirikof and Kodiak), and the Eastern (Yakutat and Southeastern) areas (Figure 1). Of the 1981 allocation for the Gulf of Alaska, slightly more than half was assigned to the Eastern area, about one-third to the Central area, and the remainder to the Western area (Table 2). About 82% of the catch was allocated to foreign nations while domestic harvesters, including joint ventures, were allowed 8%; in addition, part of the Eastern area allocation was held in reserve.

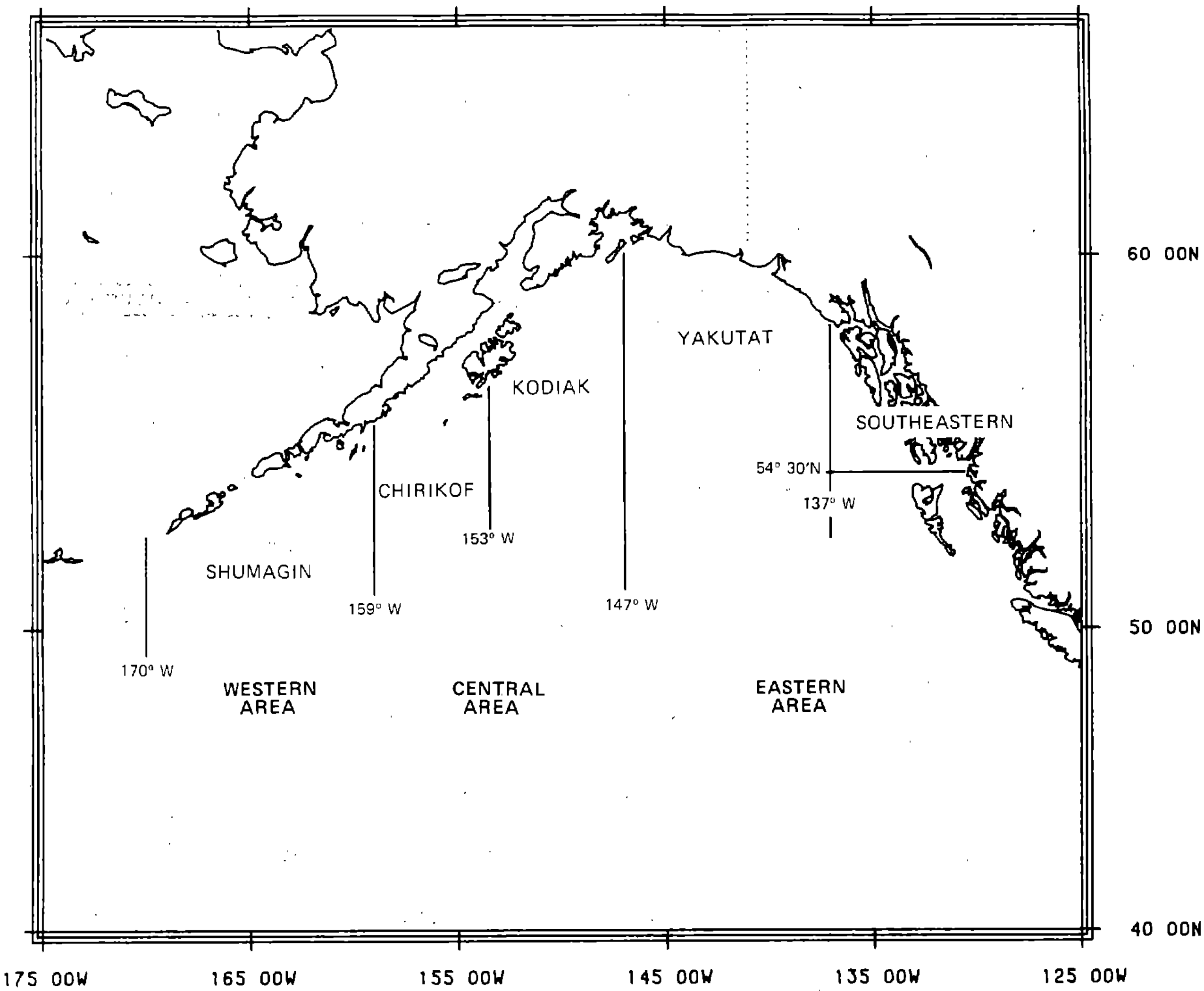

Figure 1 .--Regulatory areas in the Gulf of Alaska of the North Pacific Fishery Management Council (NPFMC).

Table 2.--Domestic and foreign allocations[1/] of Pacific ocean parch within the Gulf of Alaska in 1981[2/].

NPFMC area	Domestic	Foreign	Unallocated	Total	
	- - - - - - - -	t - - - - - - - -	- - - - - -	(t)	(%)
Western	102	3,048	-	3,150	12.2
Central	365	8,852	-	9,217	35.7
Eastern	1,534	8,920	2,986	13,440	52.1
Total	2,001	20,820	2,986	25,807	100.0
%	7.8	80.7	11.6	100.0	

1/ Based on a 14-month fishing year.
2/ Source: North Pacific Fishery Management Council (NPFMC) Gulf of Alaska Groundfish Fishery Management Plan.

Japan received most (73%) of the Pacific ocean perch allocated to foreign nations while other nations received lesser amounts (R.O.K., 18% and Poland, 9%) (Table 3).

Most of the catch of Pacific ocean perch from the Gulf of Alaska was taken during the summer and fall months (Table 4). This seasonal distribution was influenced by NPFMC regulations that prohibit or restrict trawl fishing during the early part of the year to protect the domestic fishery for the Pacific halibut, *Hippoglossus stenolepis*.

Of the four vessel classes participating in the fishery by Japan for Pacific ocean perch, only two classes, the large freezer trawlers which took 63% of the catch and the small trawlers which took 32%, made significant contributions (Table 4).

ABUNDANCE CHANGES

Research Survey Results

Demersal resource assessment surveys to depths of 400 m were conducted over the entire Gulf of Alaska in 1961 and again in 1973-76. Results of these surveys, conducted before and after a period of intense fishing for Pacific ocean perch during the mid-1960's, document a substantial decrease in the relative abundance of the species (Table 5).

Recent surveys of rockfish resources suggest that there have been some increases in the relative abundance of Pacific ocean perch. In the summer of 1978 the catch per hour for Pacific ocean perch remained at the low levels experienced in 1973-76, but some improvement is evident in surveys conducted in 1979 and 1981 (Table 6).

Table 3.--Pacific ocean perch allocations by foreign nation and NPFMC area in 1981[1/].

Nation	NPFMC area Western	Central	Eastern	Total (t)	(%)
	- - - - - - - - - t - - - - - - - - -				
Japan	2,125	6,295	6,779	15,199	73.0
Poland	318	914	626	1,858	8.9
R.O.K.	605	1,643	1,515	3,763	18.1
Total	3,048	8,852	8,920	20,820	100.0
%	14.6	42.5	42.8	100.0	

1/ Source: North Pacific Fishery Management Council (NPFMC) Gulf of Alaska Groundfish Fishery Management Plan.

Table 4.--Pacific ocean perch catch in the Gulf of Alaska by Japan in 1981 by region, vessel class, and month (includes *Sebastes alutus*, *S. aleutianus*, *S. polyspinis*, *S. borealis*, and *S. zacentrus*) (Nelson et al. 1982).

INPFC[1/] region - vessel class	1	2	3	4	5	6	7	8	9	10	11	12	Total
							t						
Shumagin													
Small trawler						28.6	44.5	1.6	31.5	71.1	108.6		285.9
Surimi trawler							11.0	19.8	2.6	0.7	0.7		34.8
Large freezer trawler						145.3	2.1	93.0	1.7	14.1	83.2	31.5	370.9
Longliner	5.1	4.7	9.0	2.1	0.6	3.4	8.5	3.5	4.6	1.4	6.1	1.3	50.3
Total	5.1	4.7	9.0	2.1	0.6	177.3	66.1	117.9	40.4	87.3	198.6	32.8	741.9
Chirikof													
Small trawler						55.7	25.9	8.7	1.1	1.1	11.6		104.1
Surimi trawler	5.6						13.3	5.6	24.4	4.4	7.4	0.4	61.1
Large freezer trawler						65.1	281.8	732.0	79.5	18.3	131.2	1.8	1309.7
Longliner	0.9	1.6	1.1	0.7	1.1	2.0	3.3	1.4	2.2	0.7	3.4	1.9	20.3
Total	6.5	1.6	1.1	0.7	1.1	122.8	324.3	747.7	107.2	24.5	153.6	4.1	1495.2
Kodiak													
Small trawler						225.8	127.6	63.7	215.8	126.0	141.1		900.0
Surimi trawler	0.4					74.5	7.4	28.3	14.6	0.0			125.2
Large freezer trawler						516.8	108.1	71.8	94.8	22.9	23.6		838.0
Longliner	0.3	0.0	0.3	0.2	0.0	1.1	2.9	1.8	4.6	0.4	3.8	2.9	18.3
Total	0.7	0.0	0.3	0.2	0.0	818.2	246.0	165.6	329.8	149.3	168.5	2.9	1,881.5
Yakutat													
Small trawler						322.1	416.4	289.2	319.5	549.7	1.6		1898.5
Surimi trawler					1.1			133.4					134.5
Large freezer trawler						445.7	845.0	172.2	281.5	122.8			1867.2
Longliner	0.2	0.7	0.1	0.1	0.1	2.9	1.1	1.5	4.6	3.2	6.4	6.1	27.0
Total	0.2	0.7	0.1	0.1	1.2	770.7	1262.5	596.3	605.6	675.7	8.0	6.1	3927.2

.......continued

Table 4.--continued.

INPFC region - vessel class	Month												
	1	2	3	4	5	6	7	8	9	10	11	12	Total
	t												
Southeastern Alaska													
Small trawler						25.8		12.0	7.5	71.4	52.5		169.2
Surimi trawler													
Large freezer trawler						294.0	41.6	44.2	824.0	522.5	400.6		2126.9
Longliner													
Total						319.8	41.6	56.2	831.5	593.9	453.1		2296.1
All regions													
Small trawler	6.0					658.0	614.4	375.2	575.4	819.3	315.4		3357.7
Surimi trawler					1.1	74.5	31.7	187.1	41.6	5.1	8.1	0.4	355.6
Large freezer trawler						1466.9	1242.3	1136.2	1209.6	701.3	550.0	33.3	6513.5
Longliner	6.5	7.0	10.5	3.1	1.8	9.4	15.8	8.2	16.0	5.7	19.7	12.2	115.9
Total	12.5	7.0	10.5	3.1	2.9	2208.8	1904.2	1706.7	1842.6	1531.4	893.2	45.9	10343.0

1/ International North Pacific Fisheries Commission.

Table 5.--Average catch per unit of effort (CPUE) for Pacific ocean perch in the Gulf of Alaska, 1961 and 1973-76, by region and depth zone[1/].

Region[2/]	1961 CPUE (kg/h)		1973-76 CPUE (kg/h)	
	101-200 m	201-400 m	101-200 m	201-400 m
Fairweather	7.4	149.7	2.9	0.0
Yakutat	66.3	85.0	4.6	6.2
Prince William	48.8	80.1	10.9	1.5
Kenai	80.4	31.8	4.7	0.0
Kodiak	25.2	2.9	2.4	11.7
Shelikof	2.4	10.5	1.4	1.0
Chirikof	135.0	67.8	18.3	0.4
Shumagin	29.3	431.4	-	-
Sanak	7.2	228.6	0	53.5
Total	50.1	75.6	6.1	3.4

1/ Source: Ronholt, Shippen, and Brown 1978.
2/ Regions do not correspond to International North Pacific Fisheries Commission statistical areas.

Table 6.--Relative abundance of Pacific ocean perch (catch in kilograms per hour) in resource assessment surveys, 1978-81.

Year	Area	No. of station samples	Relative abundance (kg/h)	Reference
1978	Southeastern	74	53	1/
1978	Yakutat	100	4	1/
1978	Kodiak	53	4	1/
1978	Chirikof	24	4	1/
1979	Kodiak	73	114	2/
1979	Chirikof	55	98	2/
1979	Shumagin	43	131	2/
1979	Southeastern	15	84	2/
1981 3/	Yakutat	63	335	4/
1981 3/	Yakutat	59	193	4/
1981 3/	Cape Ommaney	72	143	4/
1981 3/	Kodiak	17	80	4/

1/ Feldman and Rose 1981.
2/ Cruise results, Nore-Dick 79-1.
3/ Beginning with 1981, surveys were confined to index sites which were areas of recorded high production by commercial fisheries and thus are not directly comparable to earlier surveys.
4/ Cruise results, Ocean Harvester 81-1 and Pat San Marie 81-2.

Commercial Fishery

Statistical information from Japanese trawl fisheries in the Gulf of Alaska documented a general decline-in Pacific ocean perch CPUE since the inception of the fishery in 1964 until the present (Figure 2). For the Gulf of Alaska as a whole the commercial CPUE during the 3-yr period from 1964 to 1966 was about 5.5 t/h, but during the most recent 3-yr period, 1979-81, it has declined to about 0.3 t/h. It should be recognized, however, that more fishing effort was directed toward Pacific ocean perch during the early years of this fishery than has been the case more recently except perhaps in the Southeastern area where rockfish, including Pacific ocean perch, have remained a principal target species.

AGE AND SIZE COMPOSITION

During the early 1960's, before the period of intense fishing of Pacific ocean perch by Japan and the U.S.S.R., the dominant age group in the catch was 6-9 yr. About three-fourths of the catch was calculated to be 10 yr of age or younger (Lyubimova 1964).

Otoliths from Pacific ocean perch for age interpretation have been collected by U.S. observers on foreign ships beginning with 1976. These otoliths have been interpreted by a technical staff at the Northwest and Alaska Fisheries Center. A review of the age structure of Pacific ocean perch catches collected between 1976 and 1980 suggests that few, if any, year-classes of notable strength have been recruited to the fishable part of the population in those years. In the Shumagin area, the 345 otoliths examined from 1977 indicated no markedly successful year-classes in the catch; although in the next year, 1978, there was some increase in the 6- to 8-year-olds, these year-classes were virtually

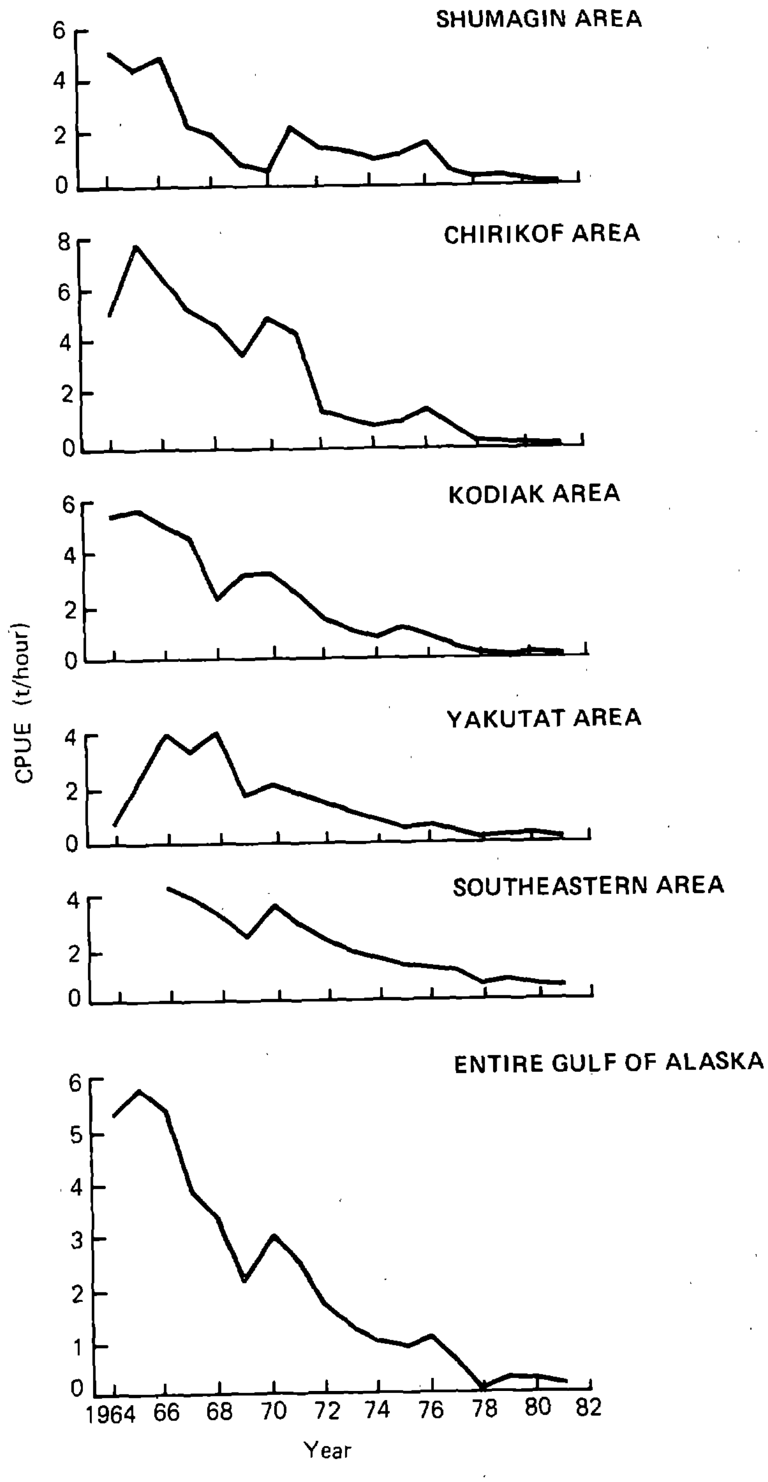

Figure 2.--Catch per unit of effort by International North Pacific Fisheries Commission (INPFC) statistical areas for Pacific ocean perch in the Japanese Gulf of Alaska trawl fisheries, 1964-81.

depleted by 1979 (Figures 3 and 4). In the Chirikof area, remnants of year-classes from the 1960's were evident in 1978, together with a fair showing of 7- to g-year-old specimens. The scanty data from 1980, however, suggest that little remained of these year-classes by that time. In the, Kodiak area, specimens from the 1971 and older year-classes appeared in the 1976 catch, and this group of fish was present in 1977 and 1978. In 1979 and 1980, however, these previously strong year-classes have declined, and no younger year-classes are evident. In the Yakutat area, the fishery in 1975-77 had representatives from the year-classes of 1963-70, but these fish appeared to be gone in 1978 and 1979. Some modest recruitment of Pacific ocean perch seems to have occurred in 1980 in the Yakutat area. In the Southeastern area, the fishery in 1976 was dominated by 12- to 17-year-old specimens. This group of fish apparently depleted during the next two years and was virtually gone by 1978. Modest numbers of Pacific ocean perch from the 1962-71 year-classes appeared in 1979 in the Southeastern area, but they declined substantially in the 1980 catch. Thus, no new and successful year-class in the Gulf of Alaska stocks of Pacific ocean perch since 1972 is evident in 1980.

Length composition information has been collected from Pacific ocean perch in the Gulf of Alaska by U.S. observers stationed aboard foreign fishing vessels (Table 7). The specimens taken in the Southeastern area are considerably larger than those commonly taken from the Chirikof area.

MAXIMUM SUSTAINABLE YIELD

Maximum sustainable yield (MSY) is defined by the NPFMC management plan as the largest average catch that can be taken continuously from a stock under current environmental conditions. At present, the NPFMC estimates the Gulf of

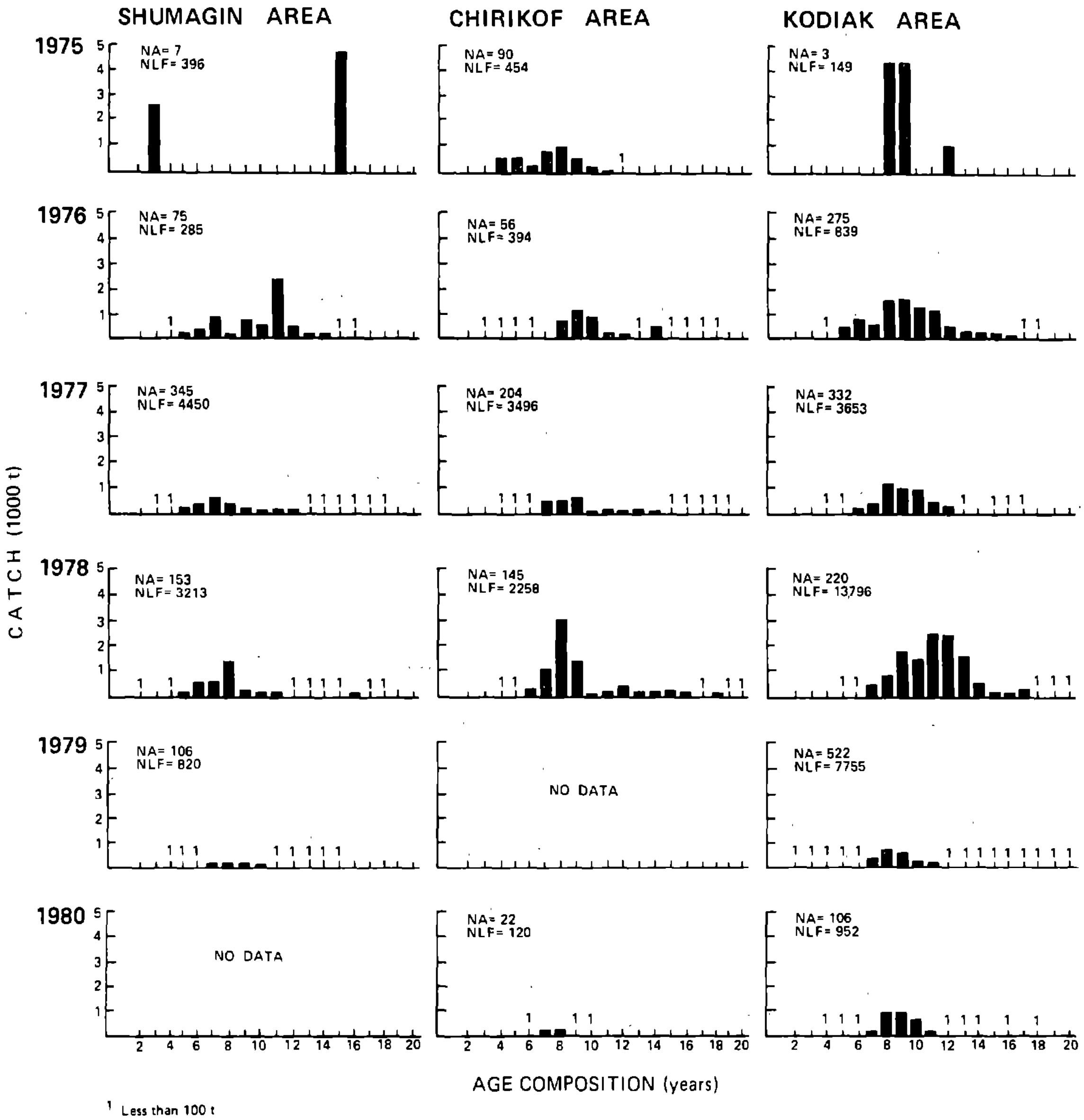

Figure 3.--Age composition of Pacific ocean perch captured in the Shumagin, Chirikof, and Kodiak International North Pacific Fisheries Commission (INPFC) statistical areas by foreign trawlers, 1975-80.

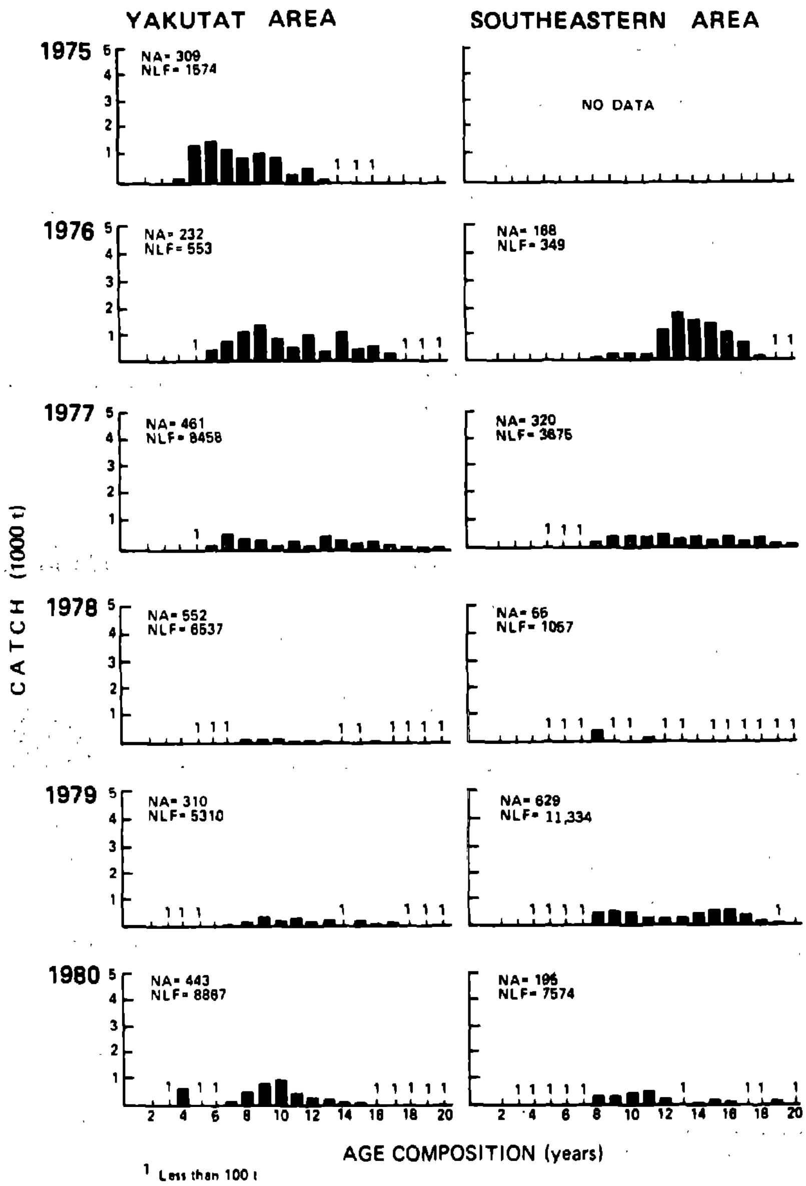

Figure 4. --Age composition of Pacific ocean perch captured in the Yakutat and Southeastern International North Pacific Fisheries Commission (INPFC) statistical areas by foreign trawlers, 1975-80.

Table 7.--Mean size composition (fork length) of the catch of Pacific ocean perch catch from the Gulf of Alaska as determined from samples collected by U.S. observers, 1975-81.

Sex and INPFC[1] area	1975	1976	1977	1978	1979	1980	1981
Males				cm			
Shumagin	30.2	30.7	29.2	29.6	32.1	-	31.6
Chirikof	28.5	30.4	31.1	30.9	31.4	33.2	28.2
Kodiak	31.4	31.1	32.5	32.8	33.8	34.2	33.4
Yakutat	31.2	33.6	33.5	34.3	34.3	33.9	33.9
Southeastern	36.6	36.0	34.8	33.9	35.8	36.1	36.3
Females							
Shumagin	30.3	30.6	29 1	29.8	32.4	-	32.4
Chirikof	29.1	30.0	31.2	31.3	31.1	30.8	28.3
Kodiak	32.2	31.0	33.1	33.5	33.1	34.9	34.0
Yakutat	31.2	33.7	34.5	35.4	35.6	35.1	35.1
Southeastern	37.4	37.7	35.8	34.8	37.4	37.5	37.7

[1] International North Pacific Fisheries Commission statistical areas.

Alaska MSY for Pacific ocean perch to be 125,000 t but recognizes that current stock levels are well below the numbers that might produce this level. Chikuni (1975) estimated the potential MSY for Pacific ocean perch in the Gulf of Alaska at about 150,000 t, but he also added a reservation that stocks must first recover from their present low levels.

EQUILIBRIUM YIELD

Equilibrium yield (EY) is defined by the NPFMC management plan as the annual or seasonable harvest that allows the stock to be maintained at approximately the same level of abundance over a period of several years apart from the effects of the environment.

The NPFMC plan as of September 1979 placed the Gulf-wide EY for Pacific ocean perch at 50,000 t, a level well below the estimated 125,000 t MSY, but a level which still has not resulted in increased recruitment to the population.

ALLOWABLE BIOLOGICAL- CATCH

The allowable biological catch (ABC) may be set lower than MSY to help rebuild depleted fish stocks. In the Gulf of Alaska the ABC for Pacific ocean perch is set at 50,000 t, the same as the EY. The ABC for 1981 was apportioned to the three NPFMC regulatory areas as follows: Western, 5,300 t; Central, 15,700 t; and Eastern, 29,000 t. The basis for the relative apportionment was the distribution of the Pacific ocean perch catch by Japan in 1973-75.

Optimum yield (OY) may deviate from ABC for economic, social, or ecological objectives; in the case of Pacific ocean perch in the Gulf of Alaska, the OY was set for 1981 at 29,167 t, apportioned as follows to the three regulatory areas: Western, 3,150 t; Central, 9,217 t; and Eastern, 16,800 t. The reported amounts actually caught by the foreign fisheries in 1981 were approximately half of the allocation in each area (Table 8).

For 1982 the outlook is for a sharp reduction in the OY for Pacific ocean perch under Amendment No. 10 to the Fishery Management Plan which is expected to become effective in early 1982. Under this provision, the OY for Pacific ocean perch will decrease to 875 t in the Eastern NPFMC regulatory area; the Southeastern INPFC area will be closed to foreign trawling; and the Yakutat INPFC area will be open to foreign trawling with pelagic gear only.

COMMENT ON THE CURRENT CONDITION OF PACIFIC OCEAN PERCH STOCKS IN THE GULF OF ALASKA

There is little evidence of any improvement in the condition of Pacific ocean perch stocks. Recruitment to the fishable stocks is sporadic and transient. The catch for 1981 was only about one-quarter of the allocated ABC. Because of the slow growth rate of the individual fish and apparent lack of successful year-classes, it may be several years before any significant change in the status quo can be expected.

Table 8.--Allowable biological catch, optimum yield, foreign catch allocation, and reported foreign catch for Pacific ocean perch in the Gulf of Alaska in 1981.

NPFMC area	Allowable biological catch1/	Optimum yield1/	Foreign catch allocation1/	Reported foreign catch
	- - - - - - - - - - - - - -	t	- - - - - - - - - - - - - -	
Western	5,300	3,150	3,048	1,234.5
Central	15,700	9,217	8,852	4,268.2
Eastern	29,000	16,8002/	11,906	6,674.5
Total	50,000	29,167	23,806	12,177.2

1/ Source: North Pacific Fisheries Management Coucil (NPFMC) Fishery Management Plan.
2/ Includes 3,360 t held in reserve.

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WALLEYE POLLOCK DATA FROM THE 1977-81 GULF OF ALASKA RESOURCE ASSESSMENT SURVEYS

by

Eric S. Brown and Craig S. Rose

INTRODUCTION

From 1977 to 1981, Northwest and Alaska Fisheries Center (NWAFC) groundfish surveys were carried out throughout the Gulf of Alaska and Aleutian Islands region. Surveys taking place in the late spring and summer (1978-81) used the high-opening 90/105' Noreastern trawl with roller gear and concentrated principally on rockfish along the Gulf of Alaska and Aleutian outer shelf and upper slope (100-500 m). Winter surveys (1977-81) were primarily located in the Kodiak Island area, where the Noreastern trawl was used along with the 83/112' Eastern trawl with and without roller gear. These cruises surveyed the Kodiak and Chirikof continental shelf and upper slope and Shelikof Strait. This report examines the survey results relative to walleye pollock, Theragra chalcogramma, which is a frequently occurring and abundant species in the 100-500 m depth zone.

CATCH PER UNIT OF EFFORT

Catch per unit of effort (CPUE) values indicating walleye pollock density from the 1978-81 summer surveys are presented in Table 1 by depth and longitude. This table indicates that while pollock are present in the eastern Gulf, their density is relatively low. The central Gulf contains the highest density of pollock, particularly in the Kodiak region. Finally, the western Gulf also supports a relatively high pollock density, with highest CPUE's occurring in the eastern Aleutian Islands region (1660-1680 W long.).

Table 1 .--Catch per unit of effort (kg/nmi)[1/] of walleye pollock by 2° long. strips from 1978-81 Gulf of Alaska summer surveys (T indicates less than 1 kg/nmi).

Location		Depth interval (m)			
Longitudinal (° W. Long.)	INPFC[2/] areas	0-100	100-200	200-300	300-500
	------------	- - - - - - - - - - kg/nmi	- - - - - - - - -		
130-132		0	9	15	1
132-134	Southeastern	-	3	3	1
134-136		-	1	2	1
136-138	------------	-	Trace	0	Trace
138-140		-	4	Trace	-
140-142	Yakutat	-	3	3	11
142-144		-	2	4	1
144-146		-	1	-	-
146-148	------------	-	Trace	1	-
148-150		-	29	30	Trace
150-152	Kodiak	-	142	143	1
152-154	------------	-	210	128	1
154-156		-	248	86	Trace
156-158	Chirikof	-	135	42	0
158-160	------------	-	201	12	-
160-162		-	68	16	-
162-164		-	29	129	-
164-166	Shumagin	2	88	119	42
166-168		68	418	317	0
168-170	------------	Trace	35	113	0

1/ kg per nautical mile.

2/ International North Pacific Fisheries Commission statistical area.

SIZE AND AGE COMPOSITION

Annual and semiannual NWAFC groundfish assessment surveys, carried out in the Kodiak and Chirikof International North Pacific Fisheries Commission (INPFC) statistical areas since 1977, have provided a data base for estimating yearly pollock size and age compositions which are presented in Figures l-3. Although the objectives, and hence the methods, of these surveys have varied somewhat, this does not introduce sufficient variation to prevent the primary character= istics of size and age structure from becoming apparent.

Year-classes first appear in research catches in the late winter as l0-15 cm fish. Growth continues to 15-20 cm during spring and summer, reaching the 20-25 cm range by the following winter. Beyond 2 yr, variable growth within year-classes makes it difficult to follow age groups using size composi- tion graphs alone.

The 1975 and 1976 year-classes are prominent in survey catches in the Kodiak, Chirikof, and Shelikof INPFC statistical areas (Figure 2). The 1975 year-class dominates through 1979, followed in 1980 and 1981 by the 1976 year- class. A significant concern in the management of these stocks is that research cruise data shows no indication of any subsequent strong year classes. The only exception was a relatively strong showing of age-l fish in the Shelikof region during the spring of 1981, which may have been due to very shallow sampling. If no new strong year-class appears, the pollock fishery may begin a period of decline as the 1975 and 1976 year-classes age out of the fishery.

Similar, though limited, data in the Shumagin area are shown in Figure 3. The 1979 data show the 1975-76 year-classes to be rather small, with most of the fish coming from the 1973 and 1972 year classes. Most sampling was carried

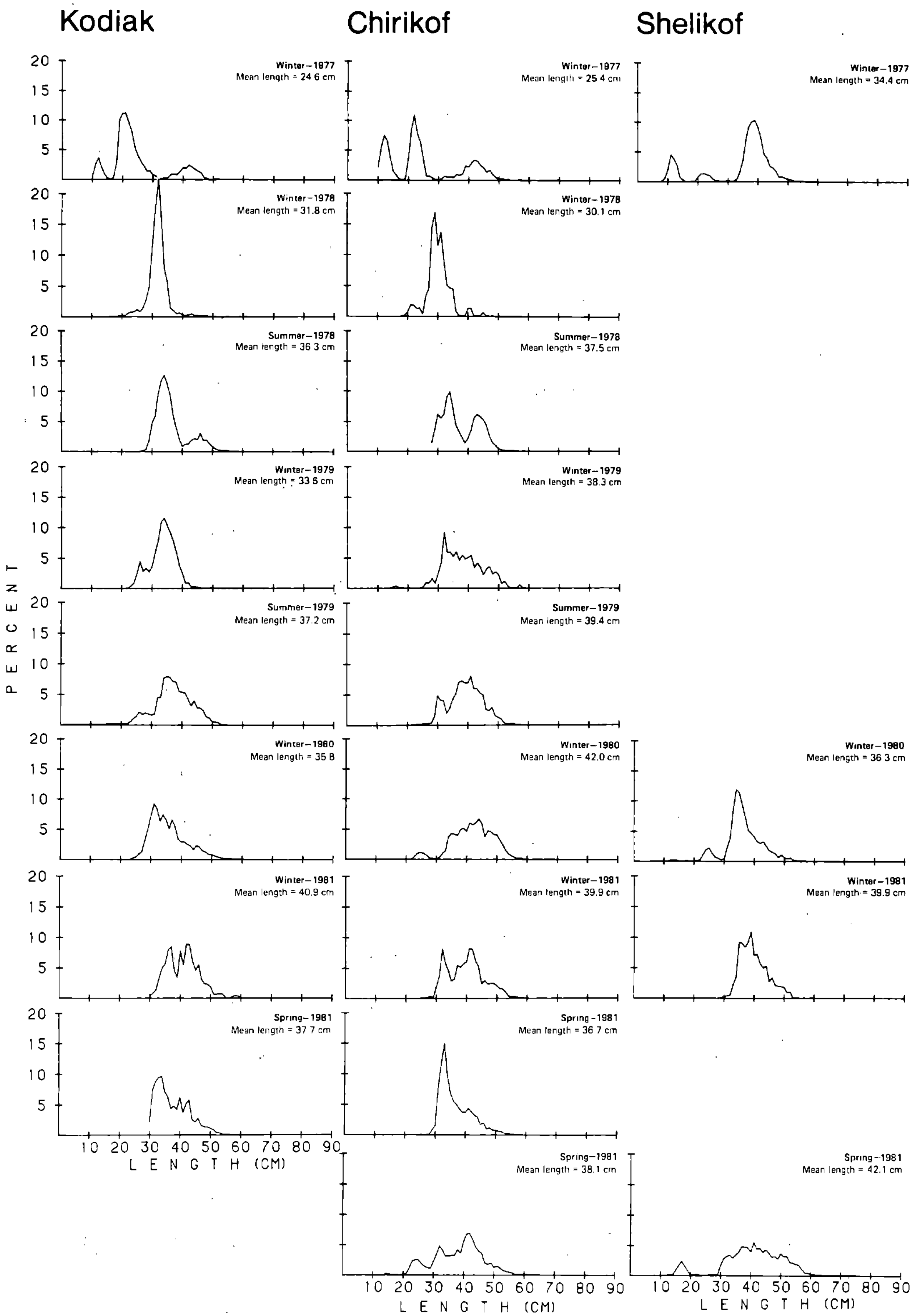

Figure 1.--Size composition of walleye pollock from 1977-81 trawl surveys in the Kodiak, Chirikof, and Shelikof International North Pacific Fisheries Commission (INPFC) statistical areas.

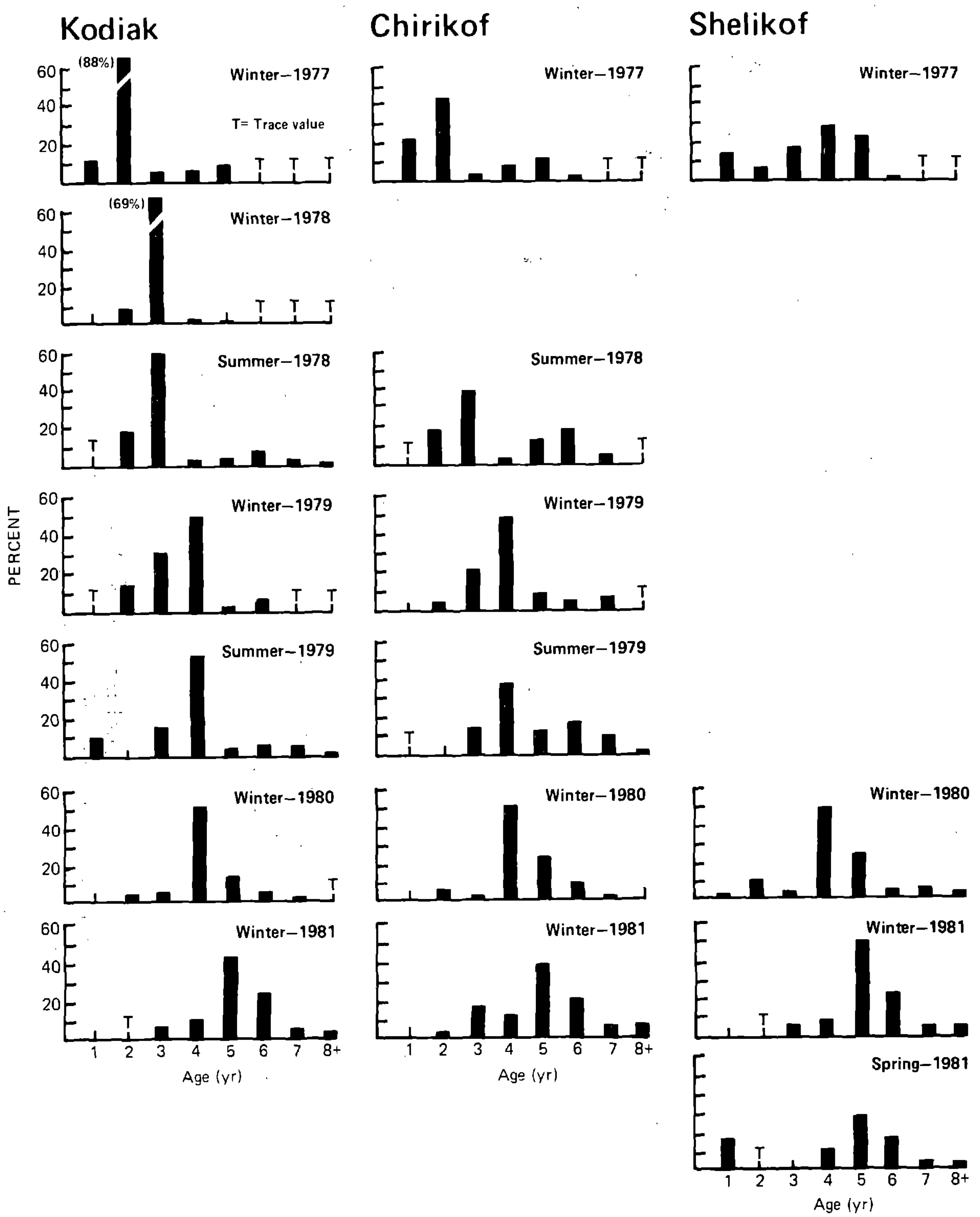

Figure 2.--Age composition of walleye pollock from 1977-81 trawl surveys in the Kodiak, Chirikof, and Shelikof International North Pacific Fisheries Commission (INPFC) statistical areas.

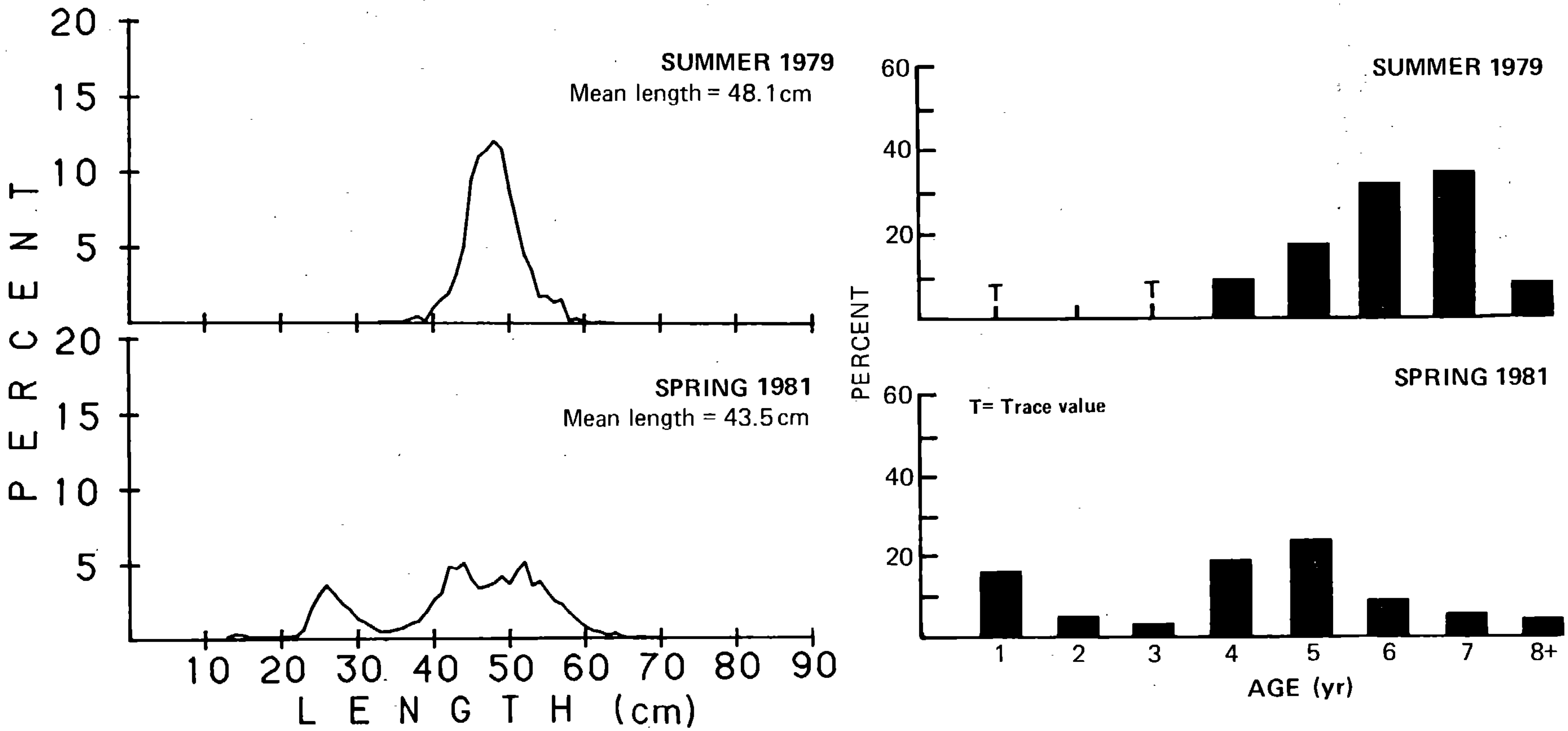

Figure 3.--Size and age composition of walleye pollock from 1979 and 1981 trawl surveys of the Shumagin International North Pacific Fisheries Commission (INPFC) statistical area.

out along the outer edge of the continental-shelf, which may account for some, but not all, of the dominance of older and larger fish. The 1981 survey concentrated more in shallow water and took considerable amounts of age-l fish along with individuals from the 1976 and 1977 year-classes.

MEAN LENGTH AT AGE

Mean lengths at age for year-classes observed during winter surveys in the central Gulf of Alaska are presented in Table 2. Almost all year-classes pass 30 cm by their third year, 40 cm by their fifth year, and 50 cm by their eighth year. There is a definite trend for mean lengths of the dominant 1975 and 1976 year-classes to be somewhat smaller than other classes at the same ages. Though this difference is relatively small and decreases with age, this may be an indication of density-dependent growth.

AGE AT MAXIMUM BIOMASS

Estimates of the rate of increase in mean individual weights were obtained from the mean length at age data and a length-weight regression. Ricker (1975) notes that the age of maximum biomass for a year-class occurs when the rate of individual growth equals the mortality rate. Based on the year-classes observed in. the Kodiak, Chirikof, and Shelikof areas, if the mortality rate is between 0.2 and 0.5, maximum biomass is achieved at around 4-yr of age with results for nearly all year-classes falling between 3 and 5 yr. This agrees with the estimates of Hughes and Hirschhorn (1979) who derived an age range of 3.60-5.45.

Table 2.--Mean lengths at age (cm) of walleye pollock observed during winter surveys in the central Gulf of Alaska.

INPFC[1] statistical area and year-class	Age (yr)									
	1	2	3	4	5	6	7	8	9	10
	cm									
Kodiak										
1967										51.9
1968									54.4	50.9
1969								48.0	56.5	58.0
1970							48.8	49.6	53.3	51.2
1971						44.8	46.8	51.3	53.0	47.9
1972					42.7	45.9	44.8	49.9	48.3	
1973				40.7	44.5	42.8	43.9	45.7		
1974			34.6	38.8	39.6	39.3	44.4			
1975		22.2	32.1	35.6	40.4	42.4				
1976	13.5[2]	26.4	32.7	36.6	40.0					
1977	16.0[2]	26.6	33.4	39.1						
1978		26.6	34.6							
1979		34.4								
Chirikof										
1967										52.8
1968									54.9	
1969								49.0		52.1
1970							49.3		51.6	51.4
1971						45.5		50.6	52.4	47.1
1972					43.1		47.4	50.0	49.3	
1973				40.7		46.3	47.8	47.1		
1974			34.9		43.5	48.0	45.4			
1975		22.7		37.6	43.7	42.2				
1976	12.0[2]		32.7	40.3	39.8					
1977		27.6	38.1	37.6						
1978		24.9	32.5							
1979	12.7[2]	29.7								
Shelikof										
1967										54.4
1968									54.4	
1969								50.7		
1970							50.1			44.5
1971						44.3			51.6	47.2
1972					41.4			46.2	47.3	
1973				39.0			44.4	45.7		
1974			36.3			43.2	43.7			
1975		23.1			38.9	41.2				
1976	11.8[2]			35.2	39.2					
1977			34.0	38.7						
1978		25.2	34.7							
1979	13.7[2]	30.0								

1/ International North Pacific Fisheries Commission.
2/ Approximate values.

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WALLEYE POLLOCK DATA FROM THE SPRING 1981 SOVIET SURVEY OF GROUNDFISH IN THE KODIAK REGION

by

Eric S. Brown and Craig S. Rose

INTRODUCTION

During the spring of 1981, scientists from the Northwest and Alaska Fisheries Center (NWAFC), Seattle, and the Pacific Scientific Research Institute of Fisheries and Oceanography (TINRO), Vladivostok, U.S.S.R. participated in a cooperative survey of groundfish resources in the Kodiak Island area. Information on walleye pollock, *Theragra chalcogramma,* based on data collected aboard the Soviet research vessel *Shantar* is presented in this paper.

The primary objectives of the survey were to evaluate the composition, distribution, and abundance of groundfish inhabiting the area with particular emphasis on walleye pollock and, to a lesser extent, Atka mackerel, *Pleurogrammus monopterygius*. Trawling was accomplished with midwater and bottom trawls while fish eggs and larvae were sampled with bongo and neuston nets.

CRUISE PERIOD AND AREAS SURVEYED

Research was conducted from 14 May 1981 through 28 May 1981 over an area which included the eastern Kodiak Island outer shelf (Albatross Bank) southwest to the Shumagin Islands and portions of Shelikof Strait (Figure 1).

The demersal portion of the survey consisted of one major survey period from 20 April to 21 May and an earlier, shorter period from 14 to 30 March. The early period coincided with an ichthyoplankton survey of the study area with relatively few bottom trawls being completed.

The major survey period consisted of two surveys. The first trawl survey was conducted from the Chirikof Island area to just east of the Shumagin

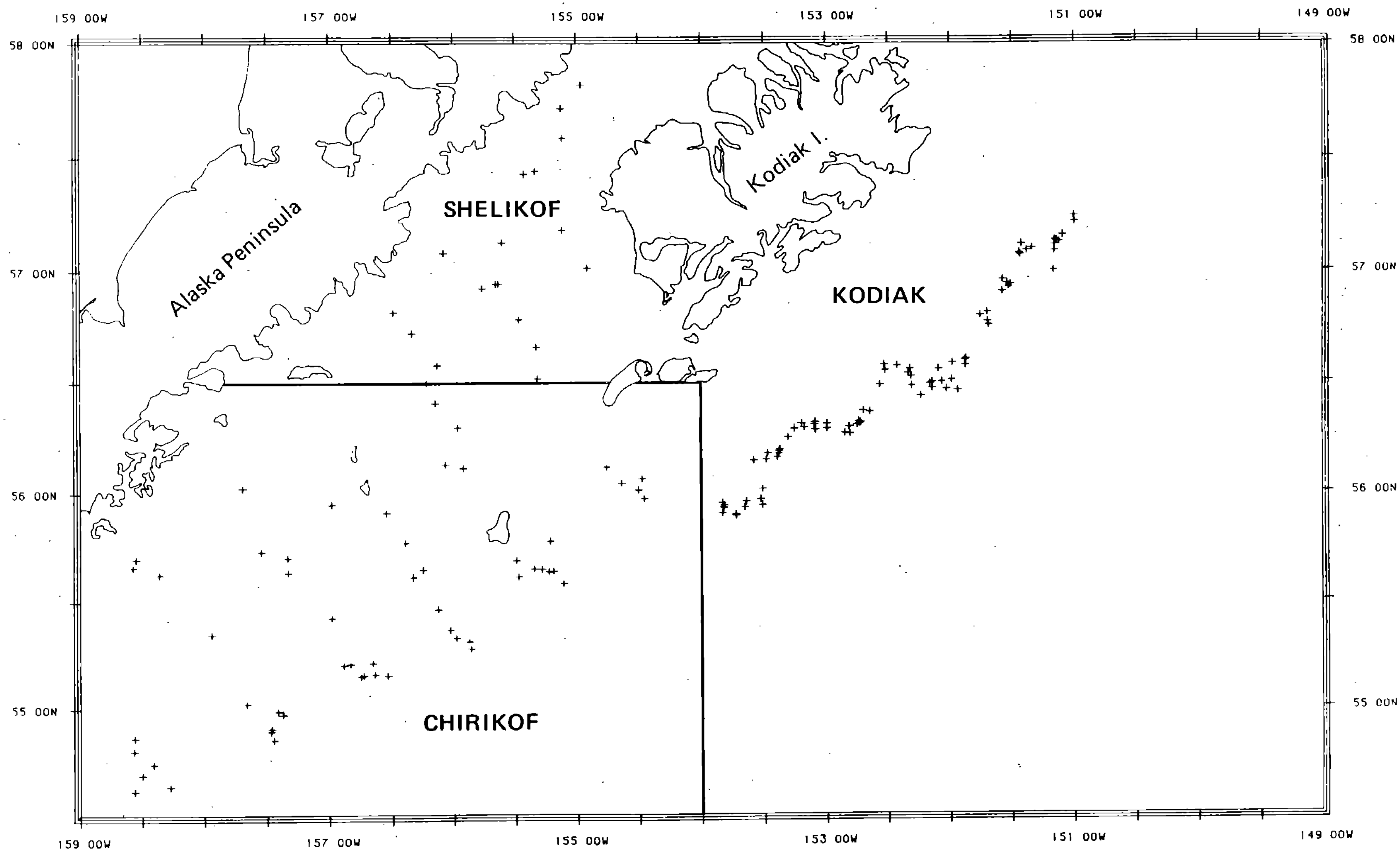

Figure 1.--Locations of 1) successful bottom trawl stations completed during the Soviet research vessel Shantar spring 1981 survey of the Kodiak Island area and 2) subareas used for data analysis.

Islands and included a portion of western Shelikof Strait. The second survey covered Albatross Bank from 151°W long. to the Chirikof Island area.

SURVEY METHODS

Vessel

The Shantar is a Soviet BMRT style fisheries research vessel. No data are available on overall length, tonnage, or horsepower, although typical vessels of this class are approximately 3,000 gr tons and 91 m in length.

Gear

The demersal sampling gear used aboard the Shantar was a 31 m bottom trawl equipped with steel bobbins on the footrope. This trawl has a 6 m estimated vertical mouth opening, 20 m horizontal opening, with 90 mm mesh in the wings and 30 mm mesh in the cod end. Oval steel doors measuring 5.5 m were used throughout the survey.

Sampling Methods

Sampling continued on a 24-h per day basis with each station trawled for 1 h or less, depending upon bottom conditions. Large catches were estimated by the Soviet method of "expert assessment" (Fadeev and Borets 1981) where two or three of the most experienced crew members would estimate the catch which was later corrected by the factory production. It was noted by the Soviet scientists that by mid-cruise, estimates by the experts, including members of the scientific staff, were nearly identical. The species composition of large catches was determined by several samples taken from the same catch while small catches of 1 t or less were completely processed.

Survey Design

The sampling pattern for the survey of the eastern Kodiak outer continenta. shelf, jointly agreed upon by U.S. and Soviet scientists, consisted of sections that were 3 mi of lat. by 5 mi of long. wide. In each section, one haul was completed at 150-200, 200-250, 250-300, and 350-400 m depths. During the earlier survey from lower Kodiak Island to the Shumagin Islands, including Shelikof Strait, the Soviets sampled stations which they had previously selected.

RESULTS

Of the 182 completed trawls, there were 8 midwater trawls and 17 opportunisitc trawls leaving 156 bottom trawls available for analysis. One of these tows, considerably west of the Shumagin Islands, was not included in the analysis. Fifty-six trawls were selected from the Chirikof area, 18 from the Shelikof area, and 81 from the Kodiak area.

Catch Per Unit of Effort

Catch per unit of effort (CPUE) was calculated by dividing the catch of walleye pollock per trawl haul by the distance towed in nautical miles (nmi). Mean CPUE's for each area and depth strata were calculated where data-were available.

CPUE's were generally highest in the Shelikof area, 111-1,663 kg/nmi, and lowest in the Chirikof area, 14-332 kg/nmi (Table 1). There was no apparent relationship between CPUE and depth except that values were most consistent in the 100-200 m depth zone (111-500 kg/nmi) and least consistent in the 200-300 m (19-1,663 kg/nmi) and 0-100 m depth intervals (14-427 kg/nmi).

Table 1.--Catch per unit of effort (kg/nmi) for walleye pollock by areas and depths of the Kodiak region.

	Area		
Depth (m)	Shelikof	Chirikof	Kodiak
	- - - - - - - - - - kg/nmi - - - - - - - - - -		
0-100	427.3	14.1	--
100-200	110.7	332.0	499.0
200-300	1,663.3	18.6	87.1
300-500	3.6	20.0	4.5
> 500	--	0.3	0.1

Biomass

The standing stock or biomass in each area was approximated using the following relationship:

$$P_w = \frac{(CPUE)(A)}{ca}$$

where P_w, is equal to the average standing stock in weight of the exploitable population, A is the total area, a is the average bottom area covered by the trawl per nautical mile, and c is a coefficient related to the degree which pollock are vulnerable to capture when in the path of the trawl. A similar method was used to estimate the population of pollock with numbers being substituted for weight in the CPUE function. For walleye pollock in the Gulf of Alaska, the coefficient c is not known; in this report, estimates of biomass have been calculated using a catchability coefficient of 1.0.

Based on a total survey area of nearly 28,000 nmi^2 (Table 2), the biomass of pollock in the surveyed regions has been estimated at 1,063,000 t (Table 3). The Shelikof survey area contained nearly half (521,000 t) of the total estimated biomass followed by the Kodiak (380,000 t) and Chirikof (163,000 t) regions. By depths, the Shelikof 200-300 m interval (412,000 t) and the Kodiak 100-200 m interval (369,000 t) provided the highest estimates followed by the Chirikof 100-200 m depth strata (136,000 t). Estimates of biomass declined significantly in the 300-500 m depth intervals and were not calculated at depths greater than 500 m.

SIZE COMPOSITION

The size composition of pollock was estimated in areas and depths where sufficient length-frequency data were collected. Data from individual catches were expanded by their respective catches and applied to the total population derived from the standing stock estimates to obtain the percentage of the population at each centimeter length interval.

Table 2.--Areas (nmi^2) of the Kodiak region surveyed by the Soviet research vessel Shantar and the number of successful bottom trawls by areas and depths.

Depth (m)	Shelikof Area (nmi^2)	Shelikof No. hauls	Chirikof Area (nmi^2)	Chirikof No. hauls	Kodiak Area (nmi^2)	Kodiak No. hauls
0-100	2,094	4	4,941	7	--	--
100-200	2,500	2	4,419	19	7,989	27
200-300	2,674	11	1,338	13	1,294	36
300-500	1/	1	177	10	461	16
> 500	--	--	1/	7	1/	2
TOTAL	7,269	18	10,874	56	9,743	81

1/ Not calculated.

Table 3.--Biomass and population estimates for walleye pollock by areas and depths of the Kodiak region.

Depth (m)	Area: Shelikof Biomass (t)	Shelikof Population ($X10^6$)	Chirikof Biomass (t)	Chirikof Population ($X10^6$)	Kodiak Biomass (t)	Kodiak Population ($X10^6$)
0-100	83,008	260	24,494	64	-	-
100-200	25,855	72	135,626	333	368,774	721
200-300	411,866	984	2,268	6	10,433	20
300-500	-	-	318	1/	181	1/
TOTAL	520,729	1,316	162,706	403	379,388	741

1/ Less than 1 $x10^6$ individuals.

Length-frequency samples from each area are characterized by a dominant 30-40 cm mode and a lesser 40-50 cm mode (Figure 2). The Shelikof and Chirikof size distributions are further characterized by the presence of 20-30 cm individuals not seen in the Kodiak area. This difference would, to some degree, be a result of sampling shallower depths in the Shelikof and Chirikof regions compared to the deeper waters sampled in outer Albatross Bank. The size frequency curve for the Shelikof area is further characterized by sharp narrow peaks throughout the range of lengths, a result of small sample sizes from the relatively few trawls completed in the area. Mean lengths ranged from 37.6 cm in the Chirikof area to 40.6 cm in the Shelikof area.

AGE COMPOSITION

Pollock age structures collected during the Shantar cruise are not presently available for interpretation and analysis by NWAFC scientists. Instead, ages derived from pollock otoliths collected aboard the NOAA ship Miller Freeman in the same areas and time periods were used along with the Shantar size composition data to estimate the age composition from each area.

Individuals aged as 5- and 6-year-olds clearly dominated the standing stock from each area (Table 4). In the Kodiak and Shelikof areas, these fish, which represent the 1975 and 1976 year-classes, account for 65% of the total estimated standing stock. In the Chirikof area, these two combined year-classes represented 54% with 2- and 3-year-old fish being better represented than in the other areas.

CONCLUSION

Several aspects of the SHANTAR survey and subsequent data analysis should be treated with caution. In each survey area, biomass calculations were extrapolated over adjacent areas not sampled. In the Chirikof and Shelikof areas

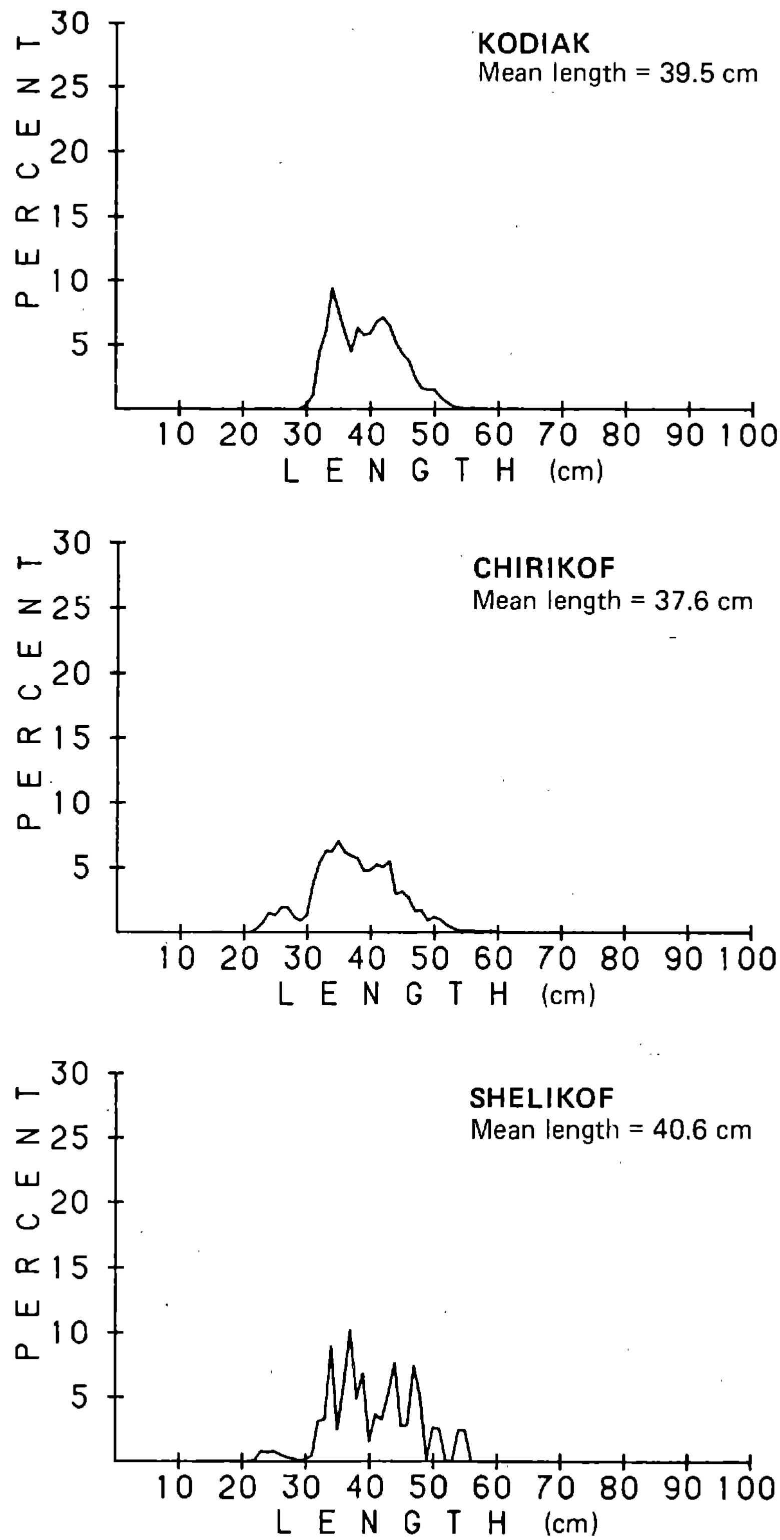

Figure 2.--Length-frequency distributions of walleye pollock (sexes combined) in the Kodiak Island subareas (Figure 1), research vessel Shantar spring 1981 survey.

Table 4.--Estimated age composition (%) of walleye pollock taken in trawl catches by the Soviet research vessel *Shantar*.

Age (yr)	Area		
	Shelikof	Chirikof	Kodiak
	- - - - - - - - - - % - - - - - - - - - - - -		
1	Trace	0	0
2	3.6	8.0	0.2
3	7.9	16.6	12.0
4	8.0	11.7	12.6
5	42.3	37.7	43.9
6	23.0	16.6	21.0
7	5.8	4.2	5.0
8	4.3	2.7	3.0
9	3.7	1.8	1.7
10	1.3	0.6	0.6
11	0.1	Trace	Trace
12	Trace	Trace	Trace

where sampling was relatively widespread, only minor portions of each area went unsurveyed. In the Kodiak area, sampling wasconcentrated along the outer shelf so that biomass calculations extrapolated to the unsurveyed inshore gully areas of similar depths may have created some unknown degree of bias. Other sources of possible bias include the relatively sparse sampling of Shelikof Strait, where only 18 bottom trawls were completed, and the untested Soviet method of estimating the volume of large catches which differs from quantitative methods used during NWAFC groundfish surveys.

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1982 U.S. RESEARCH SURVEYS AND RESEARCH PLANS FOR 1983 IN THE NORTHEAST PACIFIC OCEAN

by

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FIELD RESEARCH CONDUCTED IN 1982

United States

a) Gulf of Alaska

1) Groundfish index sites

Bottom trawling surveys took place at various sites during the spring to summer months to monitor changes in the relative abundance and composition of rockfish and other groundfish. The NOAA ship *Miller Freeman* was used in sampling the Cape Ommaney site off southeastern Alaska. Cooperative surveys involving Soviet research vessels took place at sites in the Shumagin Islands, off Kodiak Island, and near Middleton Island. The Kodiak and Middleton sites were surveyed again in cooperative efforts involving a Republic of Korea research vessel.

2) Sablefish index sites

The four established sablefish, *Anoplopoma fimbria*, indexing sites off southeastern Alaska were monitored again during May and June 1982 by the NOAA ship John N. Cobb. Auke Bay personnel began assuming responsibility for the southeastern Alaska sablefish indexing survey and will conduct the survey in future years.

3) Pacific cod

The western part of the Shumagin International North Pacific Fisheries Commission (INPFC) statistical area was surveyed in February-March. The objective of the survey was to find means of improving the assessment of Pacific cod, *Gadus macrocephalus*.

4) Walleye Pollock

The Soviet research vessel Mys Dalnii completed two ichthyoplankton surveys totaling 145 stations, using U.S. bongo plankton samplers, between Kodiak and Unimak Pass during April-May. The major objective was to locate concentrations of walleye pollock, *Theragra chalcogramma*, eggs and larvae. Also, the NOAA ship Chapman collected pollock ovaries in Shelikof Strait in early April. These samples, along with others collected in the area by observers from the joint ventures, will be used to determine pollock fecundity and associated information about spawning.

b) Washington-California

1) Widow Rockfish Assessment Feasibility study

A commercial midwater trawl vessel was chartered for 25 days during March-April to conduct a study on the feasibility of assessing widow rockfish, *Sebastes entomelas*, distribution and abundance. The work was conducted on five commercial grounds between 42°55' and 44°40'N. lat. off central Oregon. Objectives were to 1) identify acoustically detected schools and determine species composition of the demersal and semidemersal fish complex on widow rockfish grounds, 2) obtain estimates of widow rockfish biomass by ground and to assess the variability of such estimates over time, 3) determine size and age composition of widow rockfish populations, 4) examine feeding and schooling behavior and how it varies diurnally, and 5) determine the feasibility of applying sonar-hydroacoustic methods to line transect theory in assessing widow rockfish on a coastwide basis.

Sonar-hydroacoustic data were collected from 725 km of tracklines. Ten midwater trawls were completed to identify species composition of schools with different acoustic signatures. Predominant midwater schooling species on the grounds were widow rockfish; Pacific whiting, Merluccius productus; and shortbelly rockfish, Sebastes jordani. Length, age, maturity, and stomach samples were taken from Pacific whiting and widow rockfish.

2) Sablefish Abundance Indexing Survey

A 40-day cruise will commence in November 1982 to obtain indices of sablefish at two index sites off California. This work is a continuation of an indexing program initiated in 1980 intended to track changes in population abundance in that region. Relative abundance is measured by catches taken in traps fished 10 to a groundline in 5 depth zones from 411 to 1,006 m. Fishing time is standardized to 24-h per set using corrodible magnesium clips which release tunnel closing devices. Healthy sablefish which are surplus to the need for biological data are tagged and released in a continuing effort to determine migrational behavior and to identify management units.

FIELD RESEARCH PLANS FOR 1983

United States

a) Gulf of Alaska'

1) Groundfish index sites

Tentative plans are to continue U.S.-foreign cooperative bottom trawl surveys at selected sites to monitor abundance and composition changes in rockfish and other groundfish.

2) Sablefish index sites

Monitoring of sablefish abundance and composition will continue at selected sites in the eastern Gulf of Alaska using fish traps.

3) Walleye Pollock

An acoustic-midwater trawl survey of walleye pollock will be conducted in the western Gulf region during March-April. This work will be a major part of a survey effort directed at obtaining a more accurate fishery-independent estimate of the biomass of the exploitable resource. It will involve two vessels and require a minimum of 50 days. The region to be surveyed extends from the east side of Kodiak Island to Unimak Pass, including Shelikof Strait. The survey effort will be focused around the peak of pollock spawning in Shelikof Strait and will be coordinated with research vessels conducting bottom trawl sampling in the same region. Tentative plans are to investigate the ecology of pollock larvae resulting from the spawning in Shelikof Strait.

b) Washington-California

Major comprehensive bottom trawl-hydroacoustic surveys were conducted off the west coast in 1977 and 1980. The third triennial comprehensive survey will be conducted during July-September 1983. Two bottom trawl vessels and one hydroacoustic-midwater trawl vessel will operate between central California and northern Vancouver Island in waters 55-366 m deep. Objectives will be to 1) determine the distribution and abundance of commercially available Pacific whiting and selected shelf rockfishes, 2), assess major biological characteristics of target species, and 3) obtain measurements of acoustic target strengths of certain semi-demersal species.