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Condition of Groundfish Resources of the Gulf of Alaska in 1988

Edited by
Thomas K. Wilderbuer

from reports authored by
Barry E. Bracken, Eric S. Brown, David M. Clausen,
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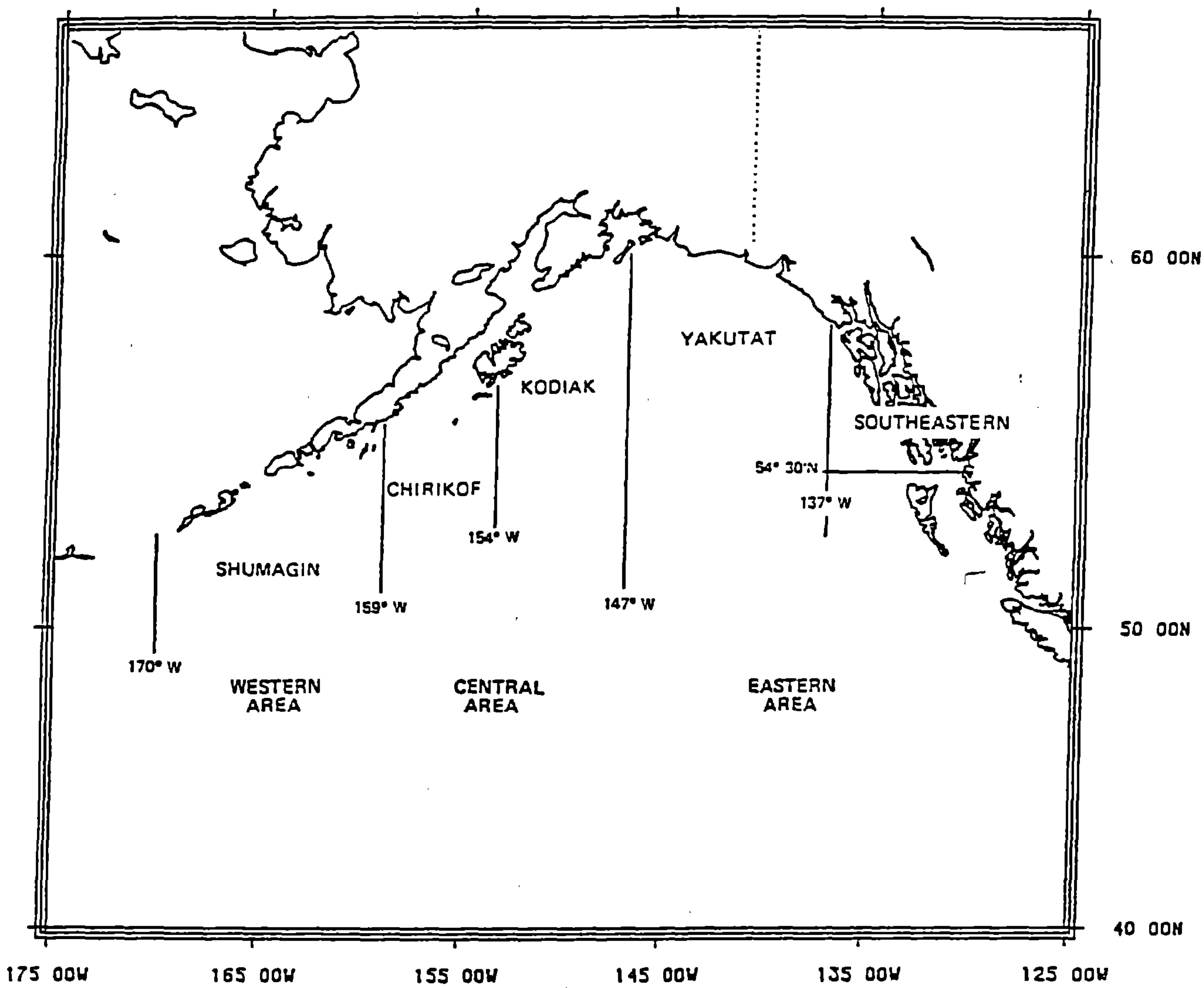

Gulf of Alaska: International North Pacific Fisheries Commission statistical areas (Shumagin, Chirikof, Kodiak, Yakutat, and Southeastern) and North Pacific Fishery Management Council regulatory areas (Western, Central, and Eastern).

PREFACE

The all-nation catch of groundfish in the Gulf of Alaska in 1987 was 142,657 metric tons (t), an increase of 9% from 124,870 t in 1986. Catches of walleye pollock (*Theragra chalcogramma*) declined 15% (10,793 t) between years to the lowest level since the implementation of the Magnuson Fishery Management Act of 1976 (Table A). Increased catches were observed for sablefish (*Anoplopoma fimbria*), Pacific cod (*Gadus macrocephalus*), shortspine thornyheads (*Sebastolobus alascanus*), the rockfish species of the slope rockfish assembledge (*Sebastes* spp.), and the species comprising the flatfish category.

The fishery category composition of the catch continued to change from 1986 to 1987. During 1986, the joint venture fishery caught 52% of the total groundfish catch, where in 1987 the U.S. domestic fisheries portion of the catch increased from 48 to 77% of the total. No non-U.S. fishing was allowed in the Gulf of Alaska in 1987.

Although the 1988 fishing season is still under way at this writing, the overall catch may increase again (partially by regulatory design). From 1986 to 1987, total catch quotas were increased for sablefish, Pacific cod, slope rockfish species, and the flatfish species which may increase the final total catch.

Presented here are 14 papers contributed by U.S. scientists dealing with the Gulf of Alaska groundfish resources. Eleven papers summarize current (1988) information on commercial species or groups of species. There is also a description of the Shelikof Straits pollock population as discerned from the 1988 midwater/hydroacoustic survey and an evaluation of the gulfwide sablefish resource from the cooperative Japan-U.S. longline survey. Finally, the 1988 U.S. research surveys are reviewed and plans for 1989 outlined..

Table A.--Gulf of Alaska groundfish: optimum yield/target quota (OY/TQ), catch in metric tons (t) 1977-88,[a] and current status of stocks for the major species and species management groups.

Species and year	OY/TQ	Catch: Foreign	Catch: J. venture	Catch: Domestic	Catch: Total	Status of stock
Walleye pollock						
1977	150,000	117,834	0	228	118,062	
1979	168,800	96,392	34	1,044	97,470	
1980	168,800	103,187	566	2,031	105,784	
1981	168,800	130,324	16,857	563	147,744	
1982	168,800	92,612	73,917	2,217	168,746	
1983	256,600	81,358	134,131	120	215,609	
1984	416,600	99,260	207,104	329	306,693	
1985	321,600	31,587	237,860	15,379	284,826	
1986	116,600	114	62,591	10,088	72,793	
1987	108,000	--	22,800	39,200	62,000	
1988	93,000	--	--	20	20	Fair
Sablefish						
1977	22,000	15,597	0	1,179	16,776	
1978	15,000	7,128	0	1,738	8,866	
1979	13,000	6,885	18	3,447	10,350	
1980	13,000	6,139	20	2,384	8,543	
1981	12,300	7,975	0	1,941	9,916	
1982	12,300	5,645	1	2,910	8,556	
1983	8,980	4,965	275	3,761	9,001	
1984	8,980	1,108	528	8,594	10,230	
1985	8,980	38	226	12,215	12,479	
1986	15,000	1	45	20,748	20,794	
1987	20,000	--	180	26,145	26,325	At MSY
1988	28,000	--	--	22,725	22,725	Level
Pacific cod						
1977	6,300	1,988	0	270	2,258	
1978	40,600	11,371	7	785	12,163	
1979	34,800	13,174	713	985	14,872	
1980	60,000	34,245	466	611	35,322	
1981	60,000	34,969	58	1,060	36,087	
1982	60,000	29,936	193	2,250	32,379	
1983	60,000	29,777	2,426	4,198	36,401	
1984	60,000	15,897	4,649	3,231	23,777	
1985	60,000	9,086	2,266	2,954	14,306	
1986	75,000	15,211	1,357	8,052	24,620	
1987	50,000	--	1,978	29,150	31,128	
1988	80,000	--	942	24,415	25,357	Good

Table A. --Continued.

Species and year	OY/TQ	Catch: Foreign	J. venture	Domestic	Total	Status of stock
Atka mackerel						
1977	22,000	19,455	0	0	19,455	
1978	24,800	19,588	0	0	19,588	
1979	26,800	10,948	1	0	10,949	
1980	28,700	13,163	3	0	13,166	
1981	28,700	18,727	0	0	18,727	
1982	28,700	6,760	0	0	6,760	
1983	28,700	11,470	790	0	12,260	
1984	28,700	537	585	31	1,153	
1985	5,278	2	1,846	0	1,848	
1986	5,278	Tr	4	0	4	
1987	240	--	1	0	1	
1988	240	--	0	42	42	Depressed
Pacific ocean perch						
1977	30,000	23,439[b]	0	12	23,451	
1978	25,000	8,174	0	5	8,179	
1979	25,000	9,750	68	105	9,923	
1980	25,000	12,447	20	4	12,471	
1981	25,000	12,176	1	7	12,184	
1982	11,475	7,988	3	2	7,993	
1983	11,475	5,416	1,975	15	7,406	
1984	11,475	2,599	1,734	119	4,452	
1985	6,083	8	254	825	1,087	
1986	3,702	0	36	2,924	2,960	
1987	5,000	--	112	4,868	4,980	
1988	16,800[c]	--	5	11,637	11,642	Depressed
Thornyheads						
1977	--	0[d]	0[d]	0[e]	0	
1978	--	0[d]	0[d]	0[e]	0	
1979	--	0[d]	0[d]	0[e]	0	
1980	3,750	1,351	0	0[e]	1,351	
1981	3,750	1,340	0	0[e]	1,340	
1982	3,750	788	0	0[e]	788	
1983	3,750	718	12	0[e]	730	
1984	3,750	164	19	24	207	
1985	3,750	4	8	69	81	
1986	3,750	0	1	861	862	
1987	3,750	--	20	1,945	1,965	
1988	3,750	--	0	1,769	1,769	Fair

Table A.--Continued.

Species and year	OY/TQ	Catch: Foreign	J. venture	Domestic	Total	Status of stock
Flatfish						
1977	23,500	16,038	0	684	16,722	
1978	33,500	14,341	5	852	15,198	
1979	33,500	13,474	70	384	13,928	
1980	33,500	15,497	209	140	15,846	
1981	33,500	14,443	18	403	14,864	
1982	33,500	8,986	18	274	9,278	
1983	33,500	9,531	2,692	439	12,662	
1984	33,500	3,033	3,449	432	6,914	
1985	33,500	170	2,447	461	3,078	
1986	14,380	71	961	1,519	2,551	
1987	13,500	--	7,207	2,718	9,925	
1988	23,000	--	1,000	6,423	7,423	Good
Squid						
1977	--	0[d]	0	0	0	
1978	2,000	322	0	0	322	
1979	5,000	425	0	0	425	
1980	5,000	841	0	0	841	
1981	5,000	1,135	0	0	1,135	
1982	5,000	278	16	0	294	
1983	5,000	267	4	0	271	
1984	5,000	120	5	0	125	
1985	5,000	6	7	0	13	
1986	5,000	0	7	0	7	
1987	5,000	--	4	0	4	Probably
1988	5,000	--	35	0	35	good
Other species[f]						
1977	16,200	4,642	0	NA	4,642	
1978	16,200	5,989	1	NA	5,990	
1979	16,200	4,081[d]	34[d]	NA	4,115	
1980	16,200	5,555	49	NA	5,604	
1981	16,200	7,112	33	NA	7,145	
1982	16,200	2,049	301	NA	2,350	
1983	18,743	2,255	391	NA	2,646	
1984	28,780	576	1,268	NA	1,844	
1985	22,460	97	2,246	NA	2,343	
1986	12,186	146	255	NA	401	
1987	10,312	--	178	75	253	Appears
1988	10,312	--	99	515	614	good

Tr = Trace.

NA = Not available.

Notes continued next page.

Table A.--Continued.

[a]Catch in 1988 includes landings reported through 20 August 1988.

[b]Japan reported only a "rockfish catch," reported here as Pacific ocean perch.

[c]TQ value is for the "slope rockfish" management assemblage and includes species other than Pacific ocean perch.

[d]There probably were small catches of thornyheads in 1977 and 1978 (and squid in 1977) but the source used here (Berger et al. 1986) does not list them because OY had not yet been established.

[e]Thornyheads were included in the "other species" category.

[f]After numerous changes, the "other species" category was stabilized in 1981 to include sharks, skates, sculpins, eulachon, capelin (and other smelts in the family Osmeridae) and octopus.

Sources: 1) the OY and the foreign joint venture catches 1977-84. adapted from Berger et al. (1986), 2) the OY and the foreign joint venture catches 1985: Berger et al. (1987), and 3) the OY and the foreign and joint venture catches 1986: personal communication with Jerald Berger, U.S. Foreign Fisheries Observer Program, Northwest and Alaska Fisheries Center, National Marine Fisheries Service, NOAA, 7600 Sand Point Way NE., BIN C15700, Building 4, Seattle, WA 98115 3) domestic catches 1977-80: Rigby (1984) and 4) domestic catches 1981-88: Pacific Fishery Information Network (PacFIN), Pacific Marine Fisheries Commission, 305 State Office Building, 1400 SW. Fifth Avenue, Portland, OR 97201.

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CONTENTS

GULF OF ALASKA WALLEYE POLLOCK: POPULATION ASSESSMENT AND STATUS OF THE RESOURCE AS ESTIMATED IN 1988

by

Bernard A. Megrey

INTRODUCTION

Walleye pollock (Theragra chalcogramma) is a semidemersal schooling fish that is widely distributed throughout North Pacific temperate and subarctic waters. In the Gulf of Alaska, major exploitable concentrations are found primarily in the central and western regulatory areas (long. 170-147°W) (Fig. 1). Pollock from this region are managed as a unit stock since they are considered separate from those in the Bering Sea, Aleutian Islands, and the eastern Gulf of Alaska (Alton and Megrey 1986). Shelikof Strait is a known major pollock spawning area in the Gulf of Alaska although other spawning locations in the western and central Gulf have been inferred from the occurrence of eggs and larvae (Nelson and Nunnallee 1985; Nelson and Nunnallee 1987). Previously these areas were judged to be of minor relative importance when compared to the Shelikof area.

The pollock fishery in 1987 remained essentially unchanged. The North Pacific Fisheries Management Council established an acceptable biological catch (ABC) in 1987 of 90,000 t. All of this was allocated to domestic fisheries. By midyear only a portion of this amount was taken by domestic fisheries so 20,000 t of the ABC was transferred to joint venture fisheries. Foreign fisheries once again received no allocation.

In this report current findings on the central and western Gulf of Alaska walleye pollock resource are presented in three main sections. First, summary catch statistics of pollock fisheries in the Gulf of Alaska from 1987 along with preliminary data from the spring 1988 fishery are presented including data through 10 August 1988. Second, the-status of the resource is updated on the basis of an age-structured analysis that includes catch-at-age data through the 1987 calendar year. Third, a series of stock forecasts (1986-90, 1987-90, and 1988-90) of stock abundance and composition is presented.

CATCH HISTORY

Catches of pollock from the Gulf of Alaska in 1987 were taken by three distinct fisheries: a spring domestic fishery fishing primarily in Shelikof Strait, a fall domestic fishery fishing entirely on the east side of Kodiak Island, and a fall

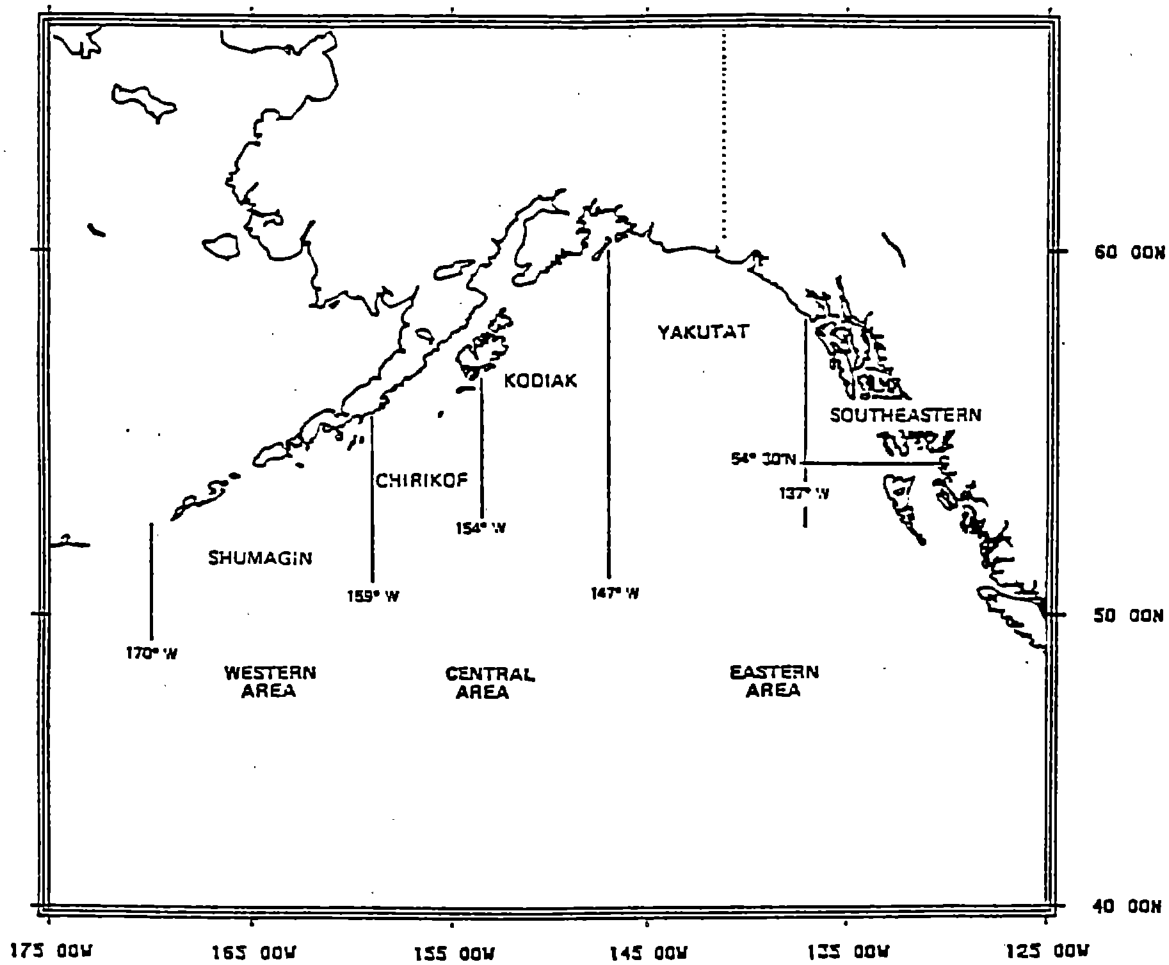

Figure 1.--International North Pacific Fisheries Commission statistical areas and North Pacific Fisheries Management Council Regulatory Areas of the Gulf of Alaska.

joint venture fishery fishing exclusively in the International North Pacific Fisheries Commission (INPFC) Shumagin statistical area during October. The port sampling program, which was initiated in the spring of 1987 to sample catches from the domestic fisheries, was carried out again in the spring of 1988. Additionally, a pilot domestic observer program began which placed observers directly on the domestic fishing vessels.

Prior to 1987, estimates of length and age composition of pollock taken by the joint venture fisheries were based on data collected by U.S. observers. These data served as the primary means of monitoring length and age composition trends in the exploited stock. The new port sample and domestic observer programs were started in 1987 in order to compensate for the loss of biological data usually collected from the joint venture fishery. The port sampling data collection procedures are described in Megrey (1987).

The overall pollock catch in the Gulf of Alaska in 1987 was 62,000 t--down 26% from 1986 (Table 1, Fig. 2). For the second consecutive year foreign fleets caught no pollock, except for a few taken incidentally in 1986 by the Japanese longline cod fishery. A time series of foreign catches is presented in Table 2. Joint venture fisheries took a total of 22,800 t in 1987, a drop of 64% from the 1986 level. Domestic catch increased for the third consecutive year to 39,200 t--up 84% from 1986. Domestic fisheries took 63% of the total 1987 gulf pollock harvest with the remaining 37% taken by joint venture fisheries. In total, 58% of the 1987 pollock harvest (36,026 t) was taken in the North Pacific Fisheries Management Council (NPFMC) Central Regulatory Area (Table 3).

Catch Categories

Foreign Fisheries

As in 1986, foreign fisheries received no catch allocation in 1987. Even though a small incidental catch was recorded in 1986 (114 t) no catch at all was taken in 1987 (Table 3). As mentioned above, this is the second consecutive year that no foreign nation took pollock in the Gulf of Alaska--a sharp contrast to past years when several foreign nations accounted for essentially all of the catch (Fig. 2).

Joint Venture Fisheries

The catch of pollock by joint venture fisheries in 1987 dropped sharply for the second consecutive year (Table 1). In contrast to the 1983-85 period, when harvest levels ranged from 100,000 to 200,000 t, the catch in 1987 came to only 22,800 t, or 37% of the total 1987 pollock harvest.

Table 1.--Catch of pollock (1,000 t) in the Gulf of Alaska by fishery category, 1977-88.

	Fishery category			
		Domestic		
Year	Foreign	JVP	DAP	Total
1977	117.8	--	0.2	118.0
1978	96.4	Tr	1.0	97.4
1979	103.2	0.6	2.0	105.8
1980	113.0	1.1	0.9	115.0
1981	130.3	16.9	0.6	147.8
1982	92.6	73.9	2.2	168.7
1983	81.4	134.1	0.1	215.6
1984	99.3	207.1	0.3	306.7
1985	31.6	237.9	15.4	284.9
1986	0.1	62.6	21.3	84.0
1987	0.0	22.8	39.2	62.0
1988*	0.0	Tr	19.8	19.8

*Through 10 Aug, 1988.

Tr = Trace (< 100 t).

Sources: Foreign and joint venture catches 1977-84--Berger et al. (1986); 1985-88--Pacific Fishery Information Network (PacFIN), Pacific Marine Fisheries Commission, Metro Center, Suite 170, 2000 SW. First Avenue, Portland, OR 97201. Domestic catches 1978-80--Rigby (1984); 1981-88--PacFIN.

JVP= joint venture processing.

DAP = domestic annual processing.

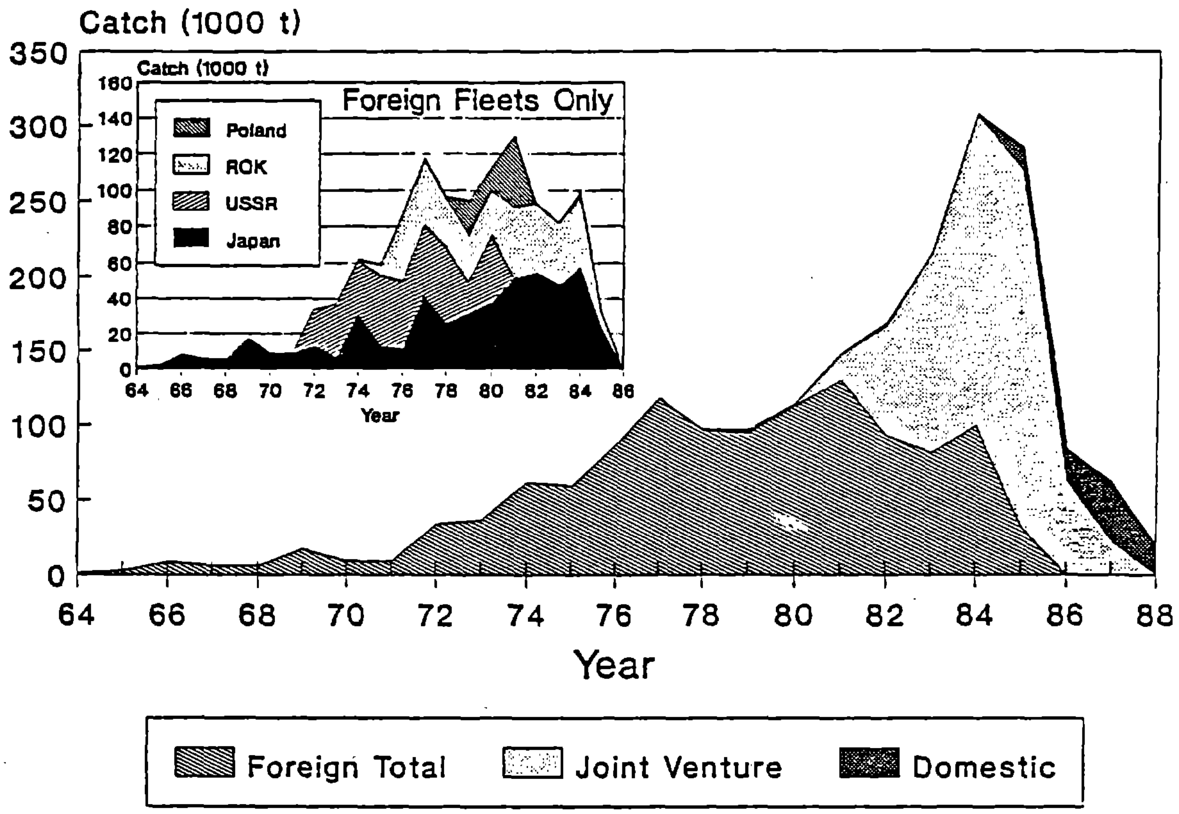

Figure 2.--Total catch of pollock in the western and central Gulf of Alaska by foreign, joint venture and domestic fisheries, 1964-87. Catches in 1988 are preliminary.

Table 2.--Catch of pollock (t) in the Gulf of Alaska by foreign nation, 1964-88.

Year	Japan	USSR	ROK	Poland	Mexico	Total
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	0		86,527
1977	41,170	39,570	35,838	1,256		117,834
1978	26,093	42,020	27,052	1,227		96,392
1979	31,920	17,300	25,739	19,551	8,677	103,187
1980	37,897	37,001	25,013	13,086	0	112,997
1981	51,885	0	38,552	39,887	0	130,324
1982	55,046	0	37,566	0	0	92,612
1983	47,725	0	33,633	0	0	81,358
1984	57,874	0	38,554	2,832	0	99,260
1985	22,937	0	8,650	0	0	31,587
1986	114(a)	0	0	0	0	114
1987	0	0	0	0	0	0
1988	0	0	0	0	0	0

Sources: 1964-76--personal communication with Jerald Berger, U.S. Foreign Fishery Observer Program, Northwest and Alaska Fisheries Center, National Marine Fisheries Service, NOAA, BIN C15700, 7600 Sand Point Way NE., Seattle, WA 98115 (catches reported by foreign nations themselves); 1977-84--Berger et al. (1986); 1985-&$--Pacific Fishery Information Network (PacFIN), Pacific Marine Fisheries Commission, Metro Center, Suite 170, 2000 SW. First Avenue, Portland, OR 97201.

Table 3.--Catch (t) of pollock in the Gulf of Alaska by fishery category and North Pacific Fisheries Management Council regulatory area, 1985-88.

Fishery category	Year	Regulatory area: Western	Central	Eastern	All areas
Foreign	1985	23,821	7,766	0	31,587
	1986	72	42	0	114
	1987	0	0	0	0
	1988*	0	0	0	0
JVP	1985	12,246	225,614	0	237,860
	1986	6,434	56,157	0	62,591
	1987	22,657	165	0	22,822
	1988*	0	75	0	75
DAP	1985	8,458	6,920	0	15,378
	1986	750	20,506	70	21,326
	1987	3,341	35,835	0	39,716
	1988*	415	19,281	64	19,760
Total	1985	44,525	240,300	0	284,825
	1986	7,256	76,705	70	84,031
	1987	25,998	36,000	0	61,998
	1988*	415	19,356	64	19,835

*Through 10 August 1988.

Source: Pacific Fishery Information Network (PacFIN), Pacific Marine Fisheries Commission, Metro Center, Suite 170, 2000 SW. First Avenue, Portland, OR 97201.

In 1987 joint venture and domestic fisheries took most of their catches from the Western and Central Regulatory Areas, respectively (Table 3).

Joint venture fisheries essentially took their entire harvest (99%) from the Western Regulatory Area. Only a very small percentage (165 t) was taken in the Central Regulatory Area, but this probably represents incidental catches (Table 3). This pattern contrasts the 1985 and 1986 seasons where most of the joint venture catch was taken in the Central Area.

Three types of joint venture fisheries took pollock in 1987:

1) Flatfish Joint Venture: Foreign vessels operating in the flatfish joint venture fisheries producing frozen products from catches delivered by U.S. fishing vessels.

2) Surimi Joint Venture: Foreign vessels operating in the roundfish joint venture fisheries producing surimi from the catches delivered by U.S. fishing vessels.

3) Freezer Joint Venture: Foreign vessels operating in the roundfish joint venture fisheries producing frozen products from the catches delivered by U.S. fishing vessels.

Three nations participated in the 1987 joint venture fisheries in the western and central Gulf of Alaska: Japan, the Republic of Korea (R.O.K.) and the People's Republic of China (P.R.O.C.). Essentially all of the 1987 joint venture catches (22,822 t) were taken in the fourth quarter from the Shumagin INPFC area (Table 4). Less than 1% of the total joint venture catch (97 t) was taken in the Central Regulatory Area during the third quarter (Table 4).

Surimi, freezer, and flatfish joint ventures accounted for 11,743 t (51%), 10,014 t (44%), 165 t (6%) of the total joint venture harvest, respectively (Table 5). As in years past, Japan was the primary harvester, taking 52% (11,908 t) of the total joint venture catch. Of Japan's joint venture catch, 11,743 t (99%) was taken by surimi joint ventures and the remaining 165 t (1%) was taken by flatfish joint ventures. In terms of total joint venture catch, R.O.K. followed with a harvest of 9,599 t, or 42% of the total joint venture catch. The R.O.K. participated only in freezer joint ventures, with this type of fishery accounting for their entire harvest. The P.R.O.C. followed in order with catches of 1,315, or 6% of the total joint venture catch. The P.R.O.C. only participated in freezer joint ventures.

Table 4.--Catch (t) of pollock in the Gulf of Alaska by fishery category, quarter, and International North Pacific Fisheries Commission regulatory area, 1987.

Area	Fishery category	Quarter 1	2	3	4	Total
Shumagin	DAP	620	399	1,635	687	3,341
	JVP	0	0	0	22,657	22,657
	Total	620	399	1,635	23,344	25,998
Chirikof	DAP	83	0	90	16	189
	JVP	0	0	1	24	25
	Total	83	0	91	40	214
Kodiak	DAP	6,333	1,855	7,456	20,002	35,646
	JVP	0	0	95	45	140
	Total	6,333	1,855	7,551	20,047	35,786
Total	DAP	7,036	2,254	9,181	20,705	39,176
	JVP	0	0	96	22,726	22,822
	Total	7,036	2,254	9,277	43,431	61,998

Source: Pacific Fishery Information Network (PacFIN), Pacific Marine Fisheries Commission, Metro Center, Suite 170, 2000 SW. First Avenue, Portland, OR 97201.

Table 5. --Catch of pollock, (t) by joint venture (JV) fisheries in the Gulf of Alaska by nation, fishery type, and International North Pacific Fisheries Commission statistical area, 1987.

		Fishery Type			
Nation	Area	Surimi JV	Freezer JV	Flatfish JV	Total
U.S.- R.O.K	Shumagin	0	9,599	0	9,599
	Chirikof	0	0	0	0
	Kodiak	0	0	0	0
	Total	0	9,599	0	9,599
U.S.- Japan	Shumagin	11,743	0	0	11,743
	Chirikof	0	0	25	25
	Kodiak	0	0	140	140
	Total	11,743	0	165	11,908
U.S.- P.R.O.C.	Shumagin	0	1,315	0	1,315
	Chirikof	0	0	0	0
	Kodiak	0	0	0	0
	Total	0	1,315	0	1,315
Total	Shumagin	11,743	10,914	0	22,657
	Chirikof	0	0	25	25
	Kodiak	0	0	140	140
	Total	11,743	10,914	165	22,822

Source: Personal communication with Jerald Berger, U.S. Foreign Fisheries Observer Program, Northwest and Alaska Fisheries Center, National Marine Fisheries Service, NOAA, BIN C15700, 7600 Sand Point Way NE., Seattle, WA 98115.

1987 Domestic Fisheries

As in 1986, the major element of the 1987 U.S. domestic fishery was a fleet of Kodiak-based catcher vessels that delivered their catches to shore-based processing plants on Kodiak Island. The domestic fleet was active during two periods in 1987. In the spring the fleet fished Shelikof Strait and in the fall they fished outside of Shelikof, concentrating their efforts on the east side of Kodiak Island (Fig. 3).

In 1987, domestic fisheries in the Gulf of Alaska harvested 39,200 t of pollock (Table 1) or 63% of the total pollock harvest. Most (35,861 t, 91%) of this catch was taken from the NPFMC Central Regulatory Area (Table 3) although a small fraction (3,341 t, 9%) was harvested from the NPFMC Western Regulatory Area. In terms of temporal distribution (Table 4), about 53% of the domestic catch (20,705 t) was taken in the fourth quarter. First, second, and third quarter domestic catches amounted to 7,036 t (18%), 2,254 (6%), and 9,181 (23%), respectively. Of the total domestic harvest, the spring fishery (Jan.-Apr.) took 8,395 (21%), while the fall fishery took 30,781 t (79%).

1988 Domestic Fisheries

Through 10 August 1988 the domestic fleet took 19,760 t of pollock (Table 3). Most of this amount was taken from Shelikof Strait in the NPFMC Central Regulatory Area. Figure 4 shows the areas within the strait where the domestic fisheries were active in the spring of 1988.

Length Composition

Joint Venture Fisheries

Estimates of length and age composition of pollock taken by the joint venture fisheries are based on data collected by U.S. observers. Nelson et al. (1981) described the sampling procedure used by observers to obtain length information and age structures, LaLanne (1979) described the procedures for determining the age of pollock from otoliths, and Kimura (1987) described the procedure for estimating the age composition of pollock catch.

Length frequency histograms of the 1987 pollock samples are presented by nation for the U.S.-R.O.K., U.S-Japan, and U.S.-P.R.O.C. joint venture fisheries in Figure 5. Overall, modal lengths ranged from 49 to 50 cm for males and 51 to 52 cm for females. There was a consistent 50 cm length mode for sexes combined. Modal lengths were fairly consistent across nation, perhaps reflecting the fact that all joint venture length frequency samples were taken in the same area (Shumagin) during

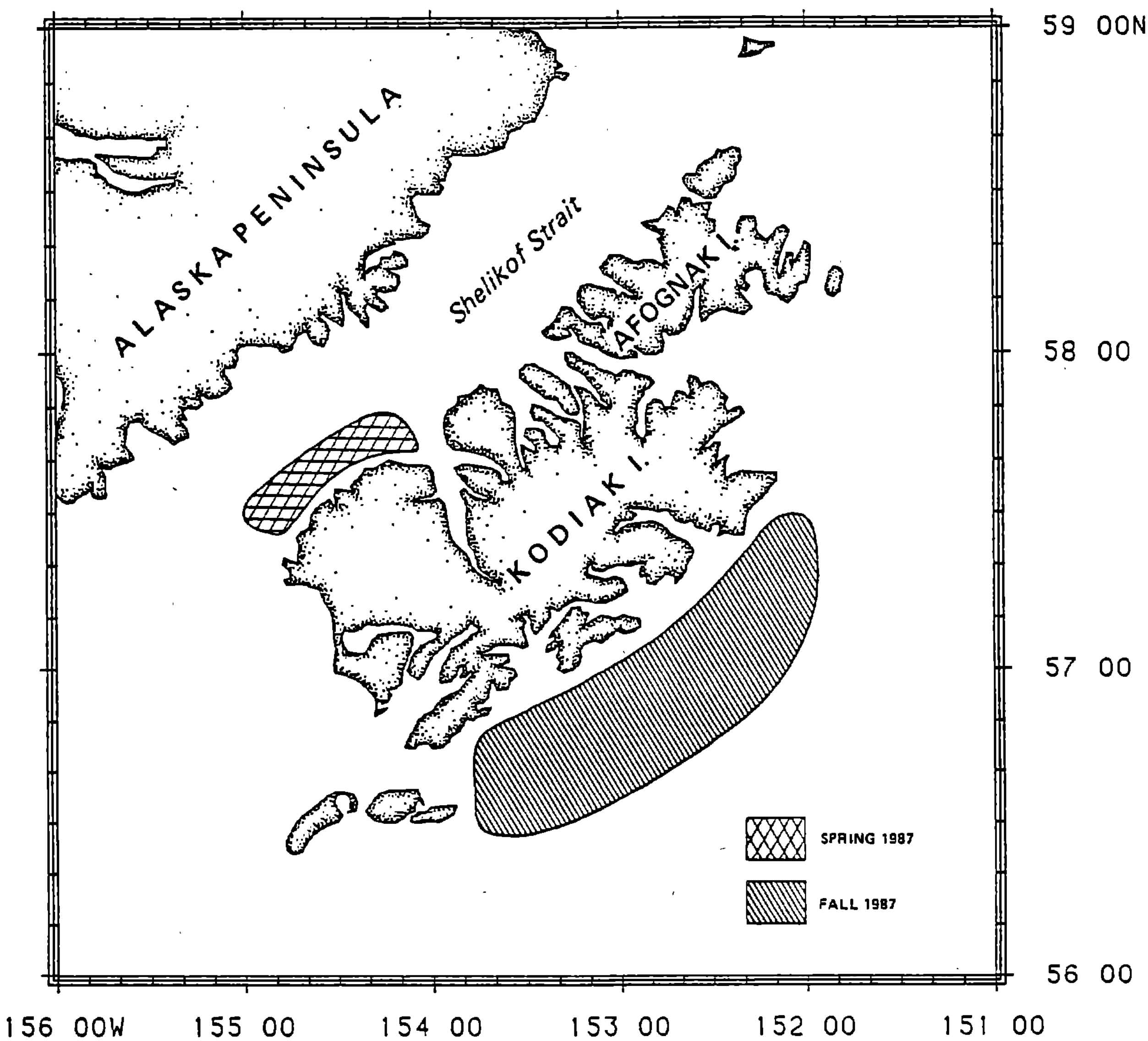

Figure 3. --Locations of domestic fishing activity in spring and fall of 1987.

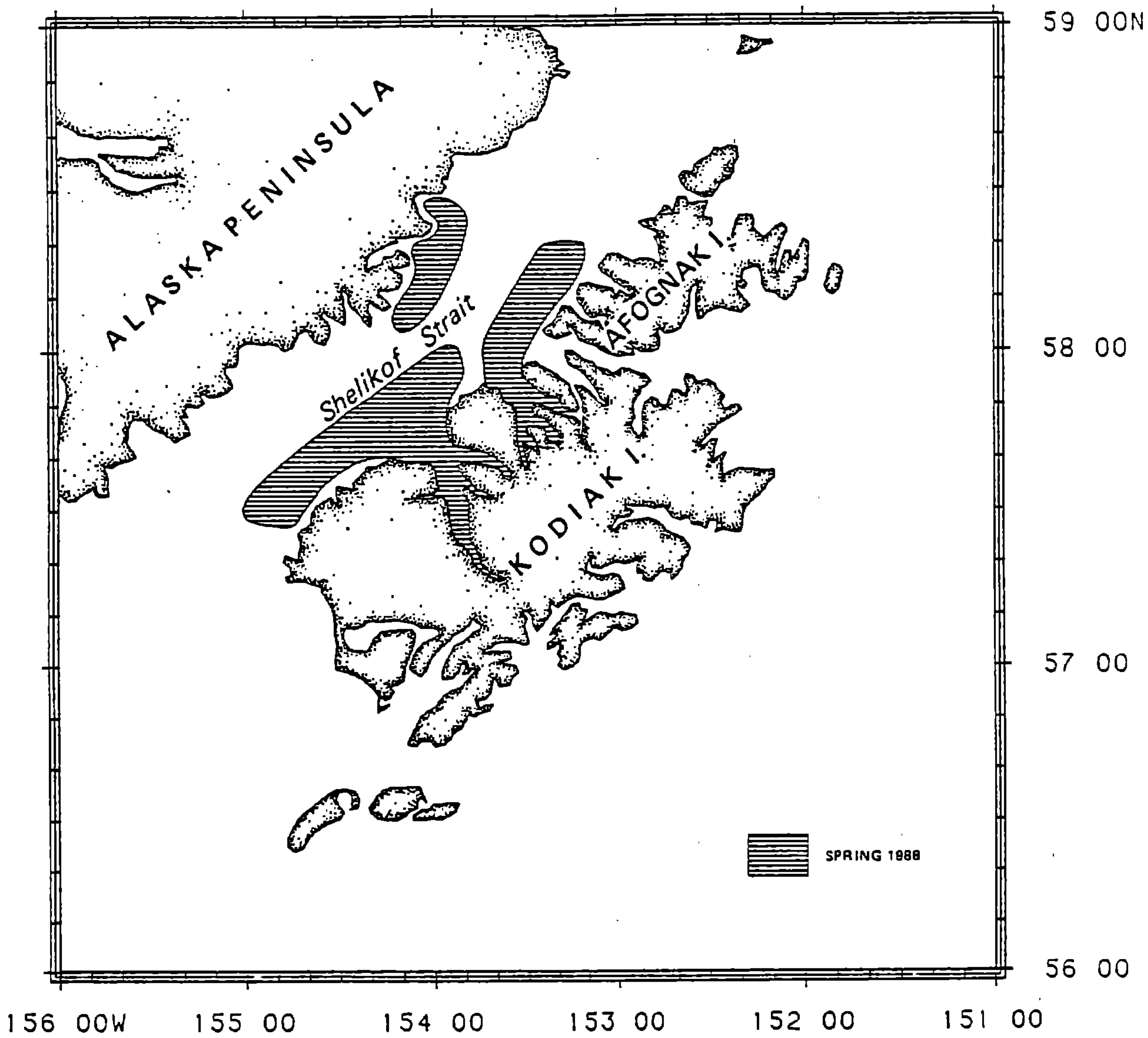

Figure 4. --Locations of domestic fishing activity in spring of 1988.

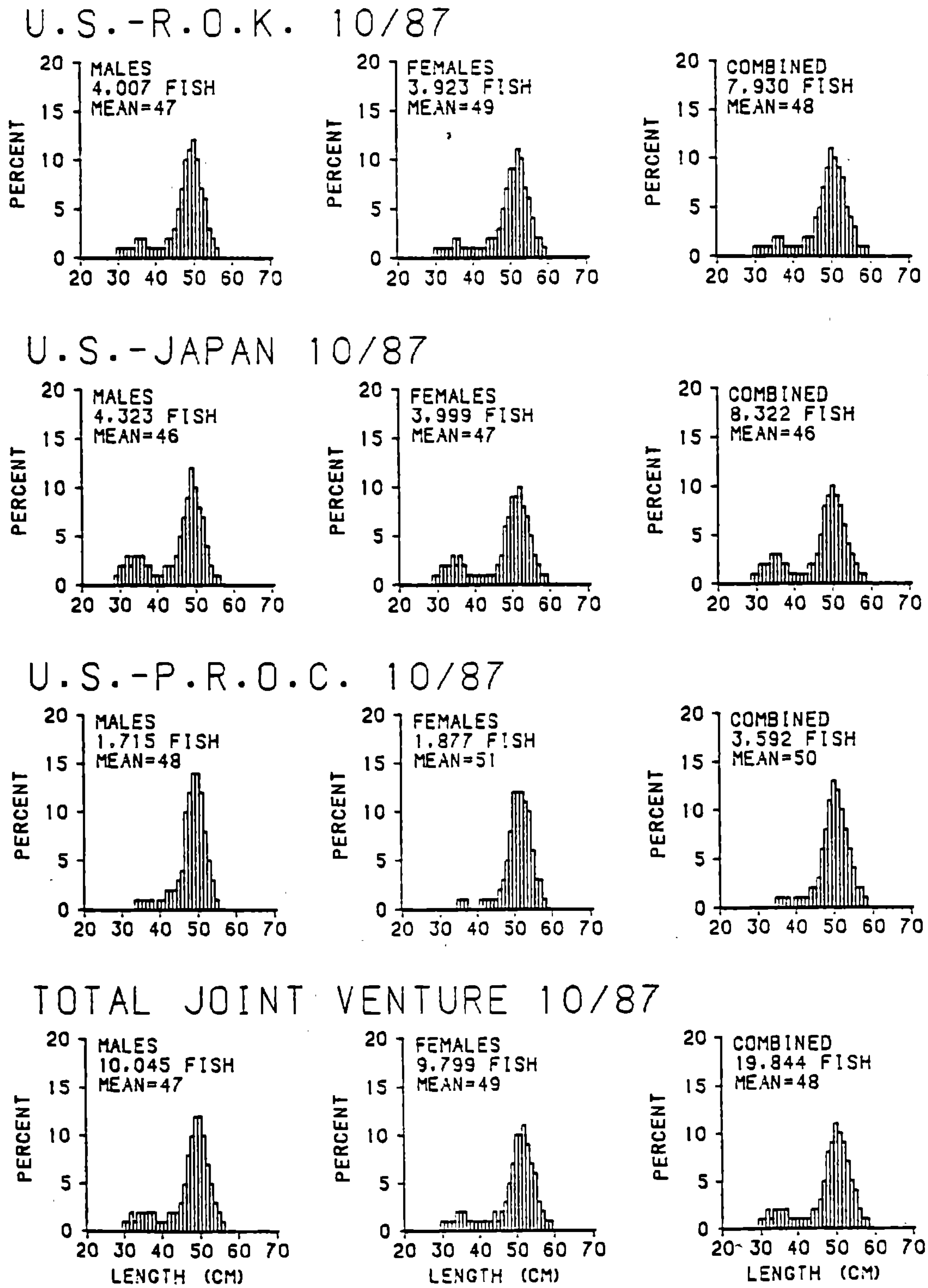

Figure 5. --Length frequency distributions (%) of pollock taken by joint venture fisheries of the Gulf of Alaska. All catches taken in the Shumagin INPFC statistical area in October 1987.

the same month (October). The slight increase in modes from 49 to 52 cm in 1987, relative to the 1986 modes of 45 to 51 cm, reflects the continued importance of the 1978 (g-year-old) year class in the catch (Table 6). Also modes in the 34 to 37 cm range represent the 1984 year class as 4-year-olds.

1987 Domestic Fisheries

Pollock length frequency histograms constructed from the 1987 spring and fall domestic fisheries port sample data are presented in Figures 6 and 7, respectively. The spring data were stratified with respect to the origin of the catch based on skipper interviews conducted by one of the port sampling team. In the spring fishery modal lengths ranged from 48 to 54 cm for males, from 52 to 54 cm for females, and from 48 to 54 cm for the sexes combined (Fig. 6). The increase in the sexes-combined mode from 47 to 48 cm in 1986 to 48-54 cm in 1987 plus the continued peaked shape of most of the histograms reflect the continued importance of the 1978 (g-year-old) and 1979 (8-year-old) year classes in the Shelikof fishery. Histograms from Shelikof Strait and the east side of Kodiak Island show substantial differences in shape. Histograms from the latter sample are much less peaked and have larger modes. To the extent that the catches from these two areas are true representations of the underlying populations, these data suggest that the age composition of the pollock stock on the east side of Kodiak Island is different from the age composition of the Shelikof stock.

Data from the 1987 fall domestic fishery (Fig. 7) are multimodal, with modes in the 30-32 cm, 42-43 cm, and 54-57 cm ranges. These length groups represent ages 2-3, 6, and 8-9-year-olds from the 1984-85, 1981, and 1978-79 year classes. The most notable difference between Figures 6 and 7 is a strong presence of small pollock from the fall domestic fishery in the length range of 28-32 cm. Pollock from this year class did not appear in the spring Shelikof catches nor did they appear in the spring catches from the east side of Kodiak Island.

1988 Domestic Fisheries

Pollock length frequency histograms from the 1988 spring domestic fishery are presented in Figure 8. These histograms were constructed from data collected by the port sampling team and the fall domestic observers. All of these data came from Shelikof Strait. The histograms are multimodal with modal lengths at 22 cm and ranging from 33-34 cm, 38-41 cm and 46-49 cm for males, and at 22 cm and ranging from 34-36 cm, and 46-54 for females. For combined sexes modal lengths appear at 22 cm and 49 cm (Fig. 8). When comparing Figure 8 with the 1987 Shelikof sample in Figure 6 several differences are apparent. First, in Shelikof Strait no small pollock were taken in 1987, whereas in 1988 fish from 20 to 40 cm length groups were well sampled. Second, the histograms from 1988 are much more dispersed relative to the 1987 histograms. Whether these data indicate true

Table 6.-- Catch (t and 1,000s of fish) of pollock by joint venture and domestic fisheries in the Gulf of Alaska by age, reporting area,* and season, 1987.

Age (yrs)	Shelikof reporting area, Jan.-Apr. Spring domestic fisheries t	nos.	Outside the Shelikof reporting area, May-Dec. Fall joint venture fisheries t	nos.	Fall domestic fisheries t	nos.	Domestic total t	nos.	Grand total t	nos.
1	0	0	0	0	0	0	0	0	0	0
2	0	0	2,687	2,995	5,384	5,831	5,384	5,831	8,071	8,826
3	39	40	1,945	2,168	10,912	11,818	10,951	11,858	12,896	14,026
4	558	576	1,007	1,122	5,818	6,300	6,376	6,876	7,383	7,998
5	914	944	2,297	2,560	3,130	3,390	4,044	4,334	6,341	6,894
6	2,279	2,352	2,199	2,451	1,507	1,632	3,786	3,984	5,985	6,435
7	1,131	1,168	3,831	4,270	1,609	1,742	2,740	2,910	6,571	7,180
8	987	1,019	2,306	2,570	559	605	1,546	1,624	3,852	4,194
9	2,221	2,294	5,455	6,080	1,456	1,577	3,677	3,871	9,132	9,951
10	166	171	757	644	406	440	572	611	1,329	1,455
11	100	103	338	377	0	0	100	103	438	480
Total	8,395	8,667	22,822	25,237	30,781	33,335	39,176	42,002	61,998	67,439

*See Megrey (1987) for a description of the Shelikof and non-Shelikof Reporting Areas.

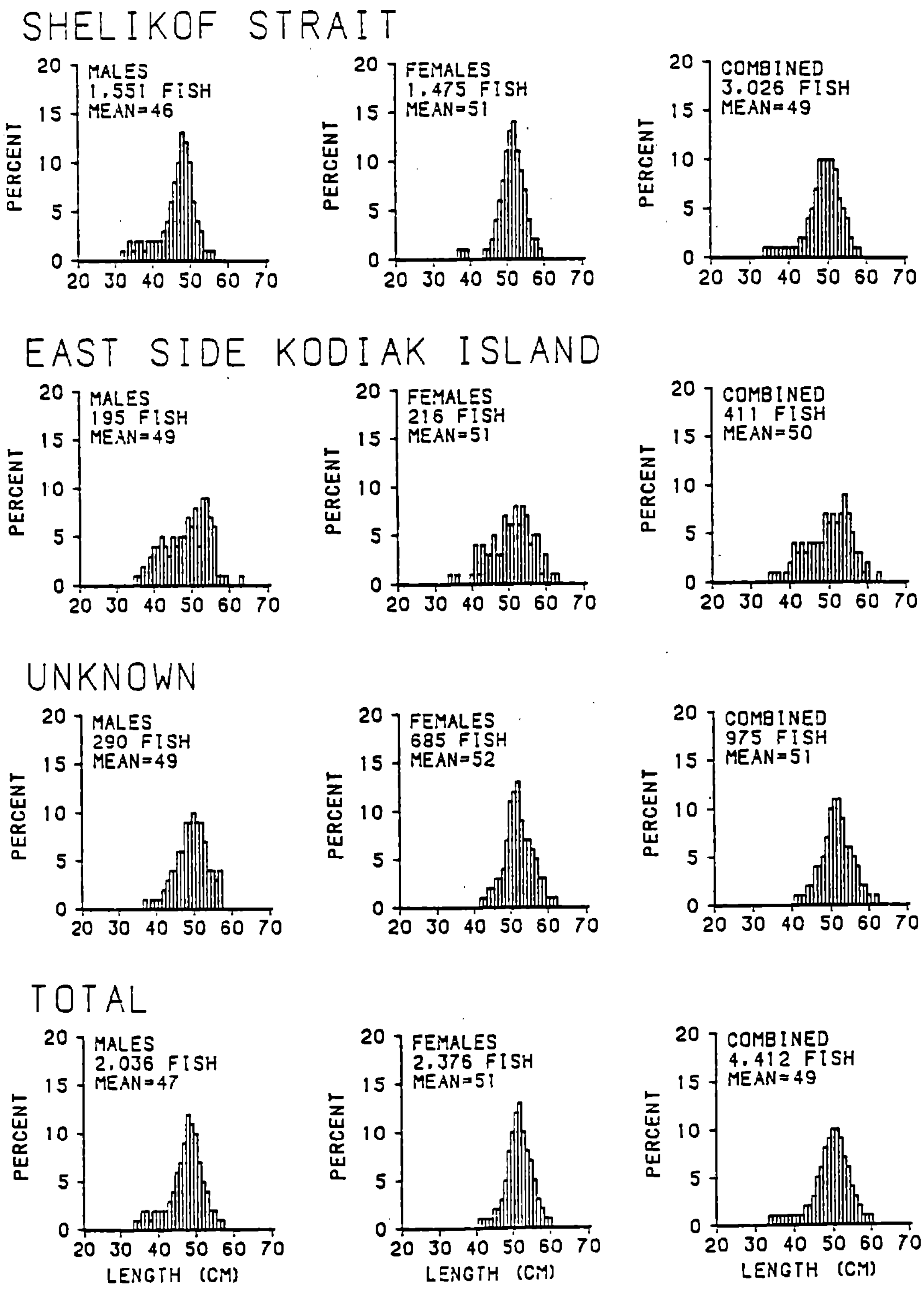

Figure 6.--Length frequency distribution (%) of pollock taken from inside and outside the Shelikof Strait reporting area. by domestic fisheries of the Gulf of Alaska during spring 1987. Data from 1987 port sample collections.

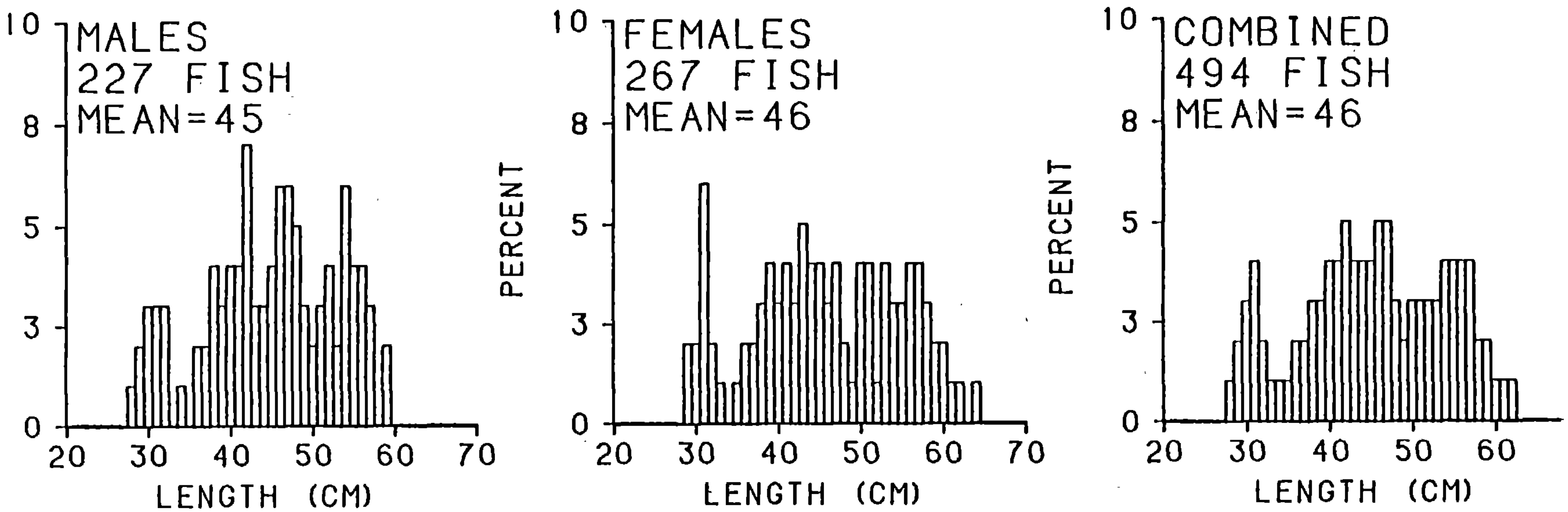

Figure 7.--Length frequency distribution (%) of pollock taken from outside the Shelikof Strait reporting area by domestic fisheries of the Gulf of Alaska during fall 1987.

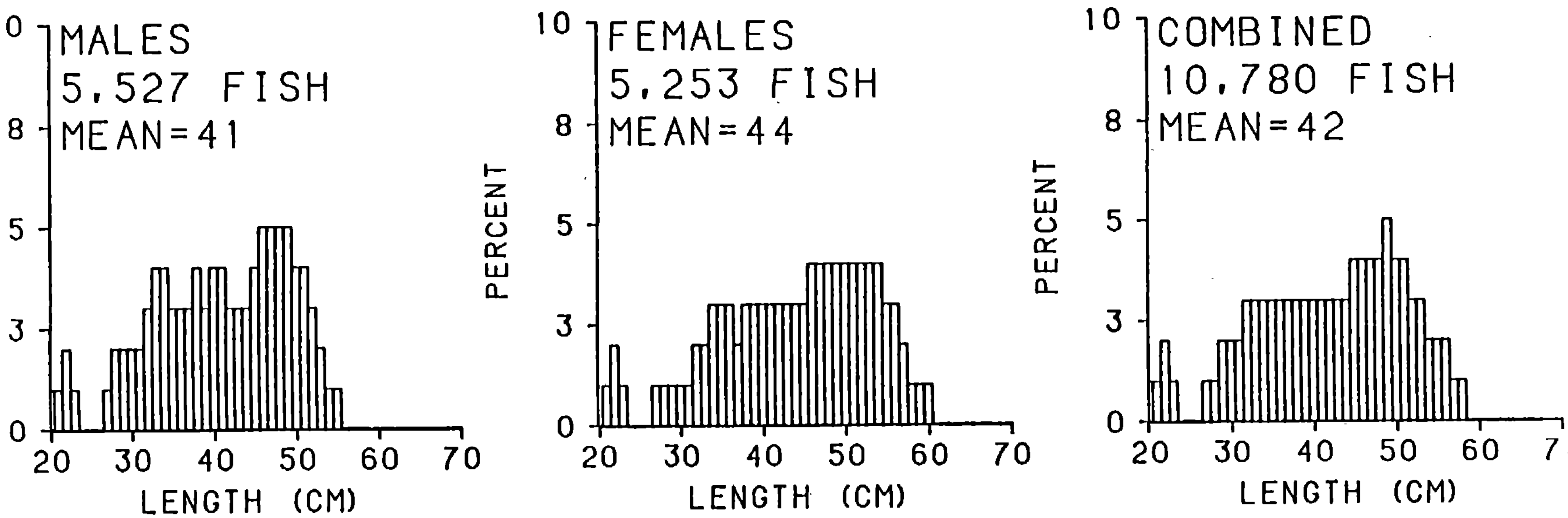

Figure 8.--Length frequency distribution (%) of pollock taken from the Shelikof Strait reporting area by domestic fisheries of the Gulf of Alaska during spring 1988.

differences in age composition again depends on the extent to which catches from these two periods are true representations of the underlying populations. Once again these data show the importance of the 1978 year class.

In the spring of 1988 there were two occasions in March where the catch of a domestic fishing vessel was sampled on the Shelikof Strait fishing grounds by a domestic observer and then sampled again by the port sampler once the catch was delivered. This double sampling of the catch was carried out specifically to address a question posed last year at the beginning of the port sample program as to whether the port sample was giving a true representation of the length composition of the catch. A potential problem concerning bias in the port sample length composition sample related to the timing of the sample relative to the offloading process was also raised.

A comparison of the length frequency histograms from the two samples for the two dates are presented in Figure 9. On the 3/3/88 sampling date, the port sample length frequency appears to have missed the 28-31 cm mode evident in the domestic observer sample and the port sample length frequencies seem to have well-defined modes in the 52 cm range compared to the domestic observer sample. On the 3/12/88 sampling date, length frequencies from both samples once again are not similar with respect to modes. Mean lengths are consistently smaller in the port sample. Presence of very small fish in the 20-21 cm length range are completely missing from the port sample. The port sample data (sexes combined) show a strong mode at 34 cm, whereas the domestic observer sample does not. Also the 30 cm mode evident in the domestic observer sample is missing in the port sample. Unfortunately, it is not possible to speculate as to why these differences exist because the time the port samples were taken during the offloading process is not known.

Age Compositon

Age composition estimates from the 1987 commercial fisheries and 1987 research surveys are presented in Figure 10. Panel A (Fig. 10) shows age composition estimates from the three 1987 commercial fishery components. Age composition estimates from the spring domestic fishery and the fall joint venture fishery were very similar with respect to the strong showing of the 1978 year class as 9-year-olds despite the wide geographic range of the catches. The 1981 year class as 6-year-olds made up almost 30% of the catch of the spring domestic fishery but that age group only contributed 10% to the catch of the joint venture fishery. There is a substantial difference in age composition of the catch taken by the fall domestic fishery and the spring domestic/fall joint venture fisheries. More young pollock were taken in the fall domestic fishery with the 1984 year class as 4-year-olds contributing almost 40% to the total catch. The 1985

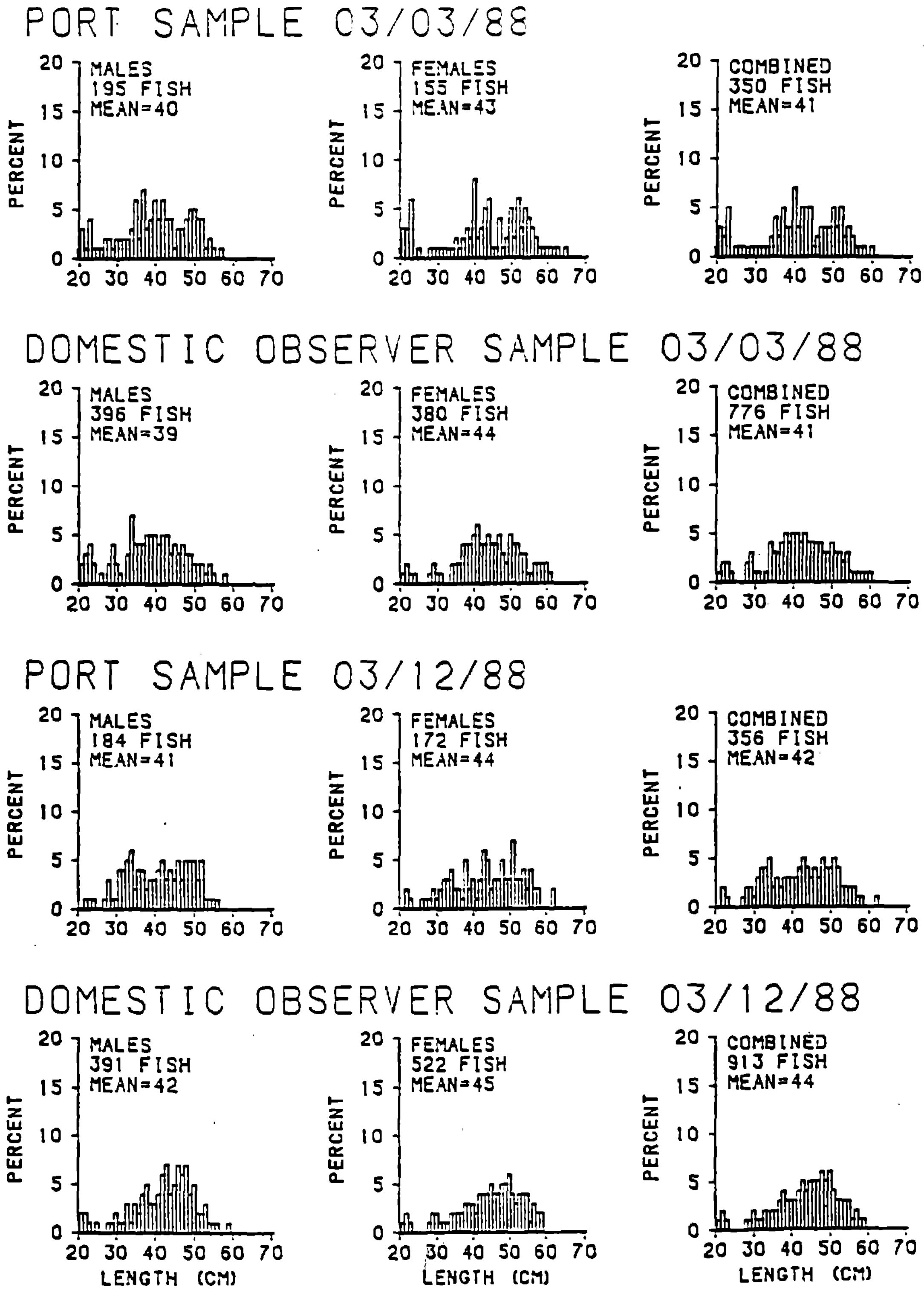

Figure 9.--Comparison of pollock length frequency distributions (%) sampled from the same fishing trip at two different times. Data collected on the Shelikof Strait fishing grounds by the North Pacific Fisheries Management Council (NPFMC) Pilot Domestic Observer Program and during dockside delivery on Kodiak Island by the NMFS Port Sample Data Collection Program during spring 1988.

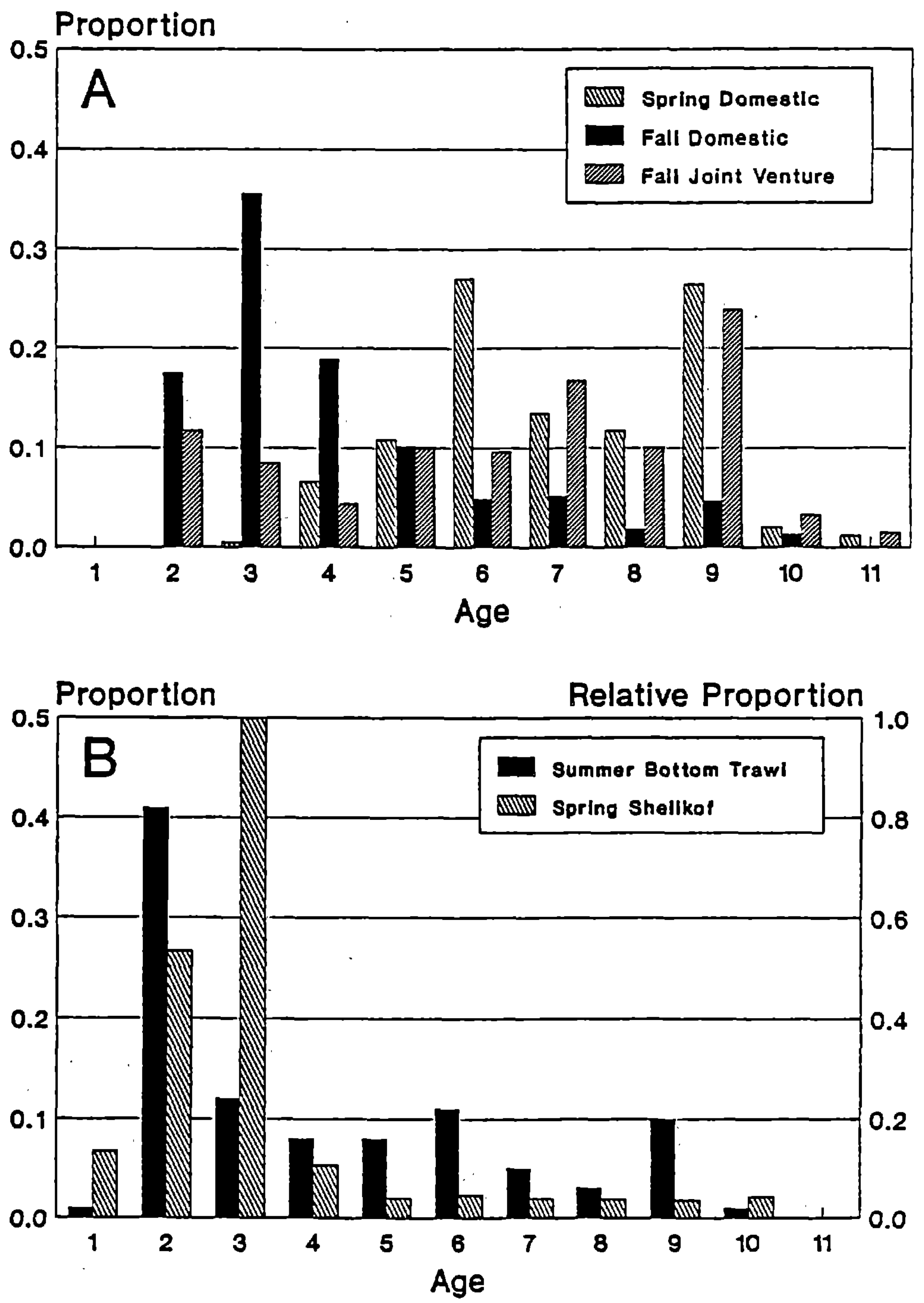

Figure 10.--Age. composition estimates of pollock taken in the commercial fisheries (panel A) and research surveys (panel B) from the Gulf of Alaska, 1987.

year class as 2-year-olds and the 1983 year class as 4-year-olds were also important. Very few older pollock were taken by the fall domestic fishery.

Panel B (Fig. 10) shows age composition estimates from the two 1987 research surveys, the spring Shelikof Strait hydroacoustic survey and the summer triannual bottom trawl survey. Recall that the hydroacoustic survey experienced a transducer malfunction in 1987 (Nunnallee 1987) so age composition estimates from this survey are available only on a relative scale (right side of figure). In the Shelikof survey the 1984 year class as 3-year-olds and the 1985 year class as 2-year-olds made up a significant portion of the catch, while in the bottom trawl survey the 1984 and 1985 year classes made up over 50% of the catch. The 1978 and 1981 year classes also showed up in the bottom trawl survey as 6- and 9-year-olds similar to the spring domestic and fall joint venture commercial fisheries.

Figure 11 shows age compositions derived from 1987 bottom trawl numerical abundance estimates. Abundance estimates are derived from weighted catches per unit effort. The dominance of the 2-year-old 1985 year class in the bottom trawl survey was evident throughout the entire Gulf of Alaska but less so in the Chirikof and Kodiak INPFC statistical areas. Also the 1984 year class as 3-year-olds was prevalent in all areas, but especially in the Kodiak, Yakutat, and Southeast INPFC statistical areas. Of lesser importance in the Shumagin, Chirikof, and Kodiak INPFC statistical areas, but still contributing from 10 to 20% to the catch, was the 1981 year class (6-year-olds) and the 1978 year class (9-year-olds).

It seems unusual to see so many 2-year-old pollock taken in the bottom trawl survey. Pollock are pelagic during their younger years and become more demersal as they age. Perhaps the strong showing of 2-year-olds in the 1987 bottom trawl survey is compelling evidence that the 1985 year class is strong.

The 1978-79 year classes have contributed significantly to the total Gulf of Alaska pollock catch (Fig. 12) since the time they recruited to the fishery. These year classes will have all but disappeared from the population in 1988.

CONDITION OF THE STOCK

Changes in Abundance Determined from' Age-structured Analysis

Data

The data set used in this year's analysis consists of estimates of pollock catch-at-age aggregated over all nations,

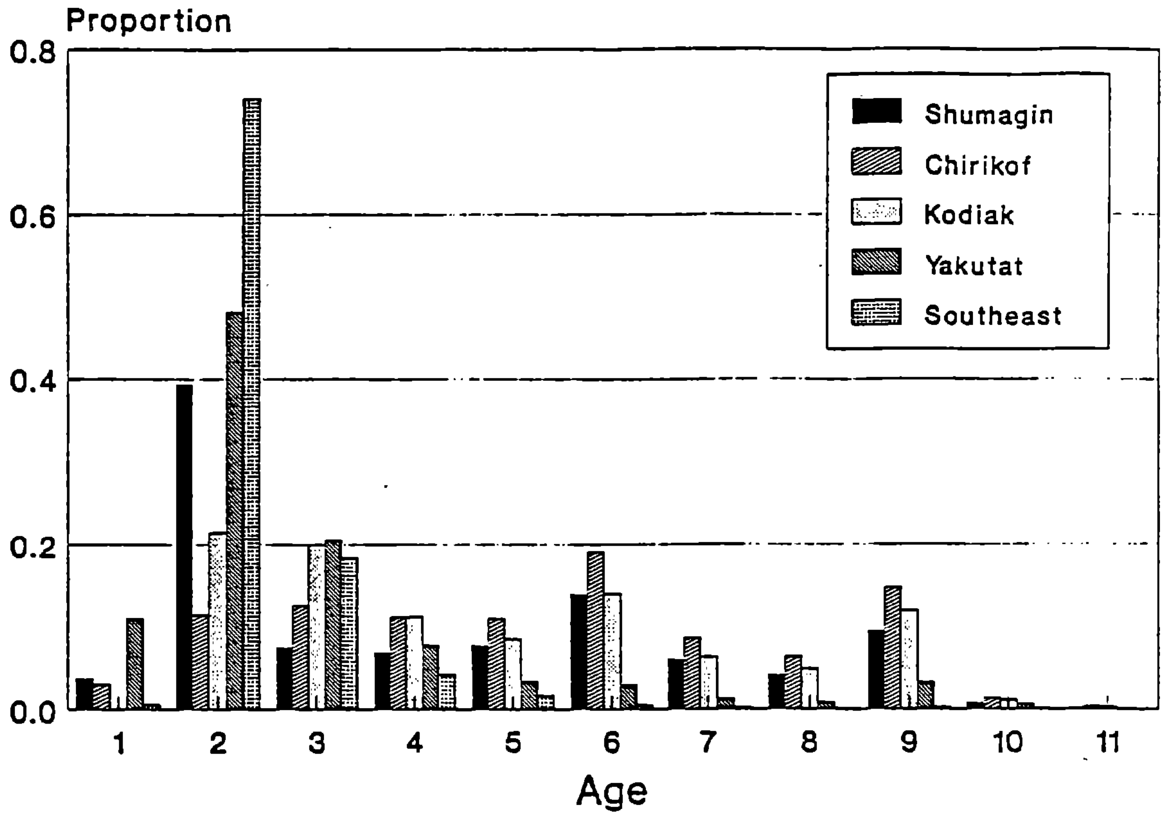

Figure 11.--Age composition estimates. of pollock taken in the 1987 Gulf of Alaska bottom trawl survey by INPFC statistical area.

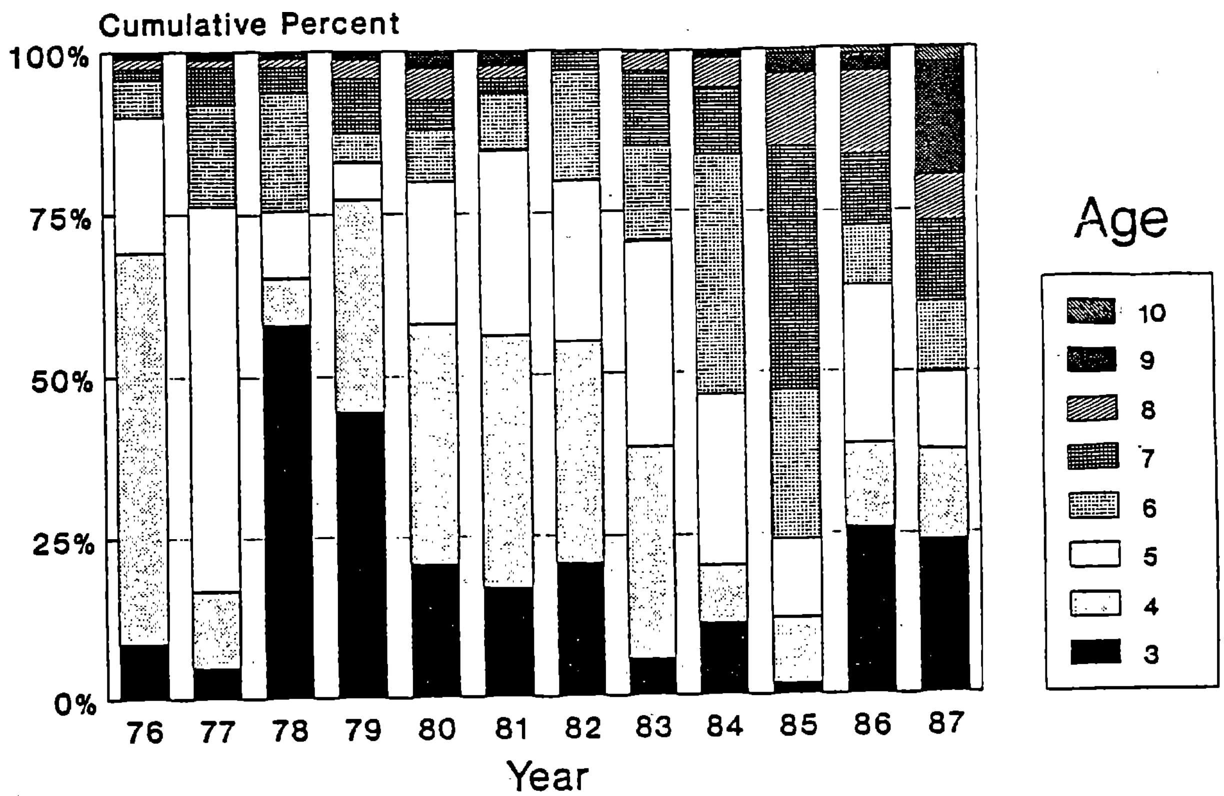

Figure 12.--Contribution of Gulf of Alaska pollock age groups (%) to the total catch, 1976-87.

vessel classes, and INPFC statistical areas for years 1976-87 (Table 7). Also fishery-independent data, consisting of hydroacoustic biomass estimates of the Shelikof Strait spawning pollock population for calendar years 1981, 1983, 1984, 1985, and 1986 (Nunnallee 1987), was incorporated into-the analysis. Since no absolute abundance estimate from the hydroacoustic survey is available for 1987, an alternative means is employed-to provide an approximate population biomass estimate. This will be described below. A single set of average weight-at-age values (Table 8) used in four previous analyses (Alton and Deriso 1983; Megrey 1985; Megrey and Alton 1987; Megrey 1987) were also used in this analysis.

Model Descriotion and Methods

The following description of the stock assessment model assumptions and methods is provided so that the reader can thoroughly evaluate the basic premises upon which the stock assessment was performed. These have been described elsewhere (Megrey 1987), but for the purposes of clarification I will also describe them here.

The CAGEAN separable nonlinear log catch model of Deriso et al. (1985) was applied to the all-nation catch-at-age data in order to estimate age-specific selectivities, fishing ortalities, and absolute estimates of population abundance. The assumptions of the stock assessment model are as follows: 1) Catch-at-age is modeled by a stochastic Baranov catch equation that incorporates a lognormal error random variable: 2) natural mortality is constant for all ages and years and is equal to 0.4; 3) selectivity-at-age trends are modeled with the selectivity model described below: 4) fishing mortality can be separated into an age-dependent factor and a year-dependent factor; 5) full recruitment fishing mortality parameters from the log catch model can differ from fishery-independent estimates of the same quantity by a lognormally distributed random variable; 6) catchability is constrained to be equal to an assumed value of 1.0; 7) the effort sum of squares weighting factor is fixed at an assumed value of 0.6; 8) the catch sum of squares weighting factor is fixed at an assumed value of 1.0; and 9) average weight-at-age does not change significantly over the 1976-87 time period. Bootstrap means are based on 50 bootstrap replications.

The selectivity model used in the analysis is similar to the one used last year (Megrey 1987). Because the fishery changed in 1982 from a foreign freezer trawler fishery using bottom trawls to a joint-venture fishery using midwater trawls the model is configured to annually partition age-specific selectivities into a pre-1982 (1976-81) group and a post-1982 (1982-87) group. For the pre-1982 group, selectivities are estimated for ages 3 to 6 over the period 1976-81. Ages 7 to 10 are assumed to be fully recruited (i.e., selectivity = 1.0) over the pre-1982 period so parameters for these selectivities are not estimated. For the

Table 7.--Estimated catch (1000's) of pollock by foreign trawl, joint venture, and domestic fisheries in the North Pacific Fisheries Commission Western and Central Regulatory Areas of the Gulf of Alaska, by age 1976-87.

	Year					
Age	1976	1977	1978	1979	1980	1981
3	13,562	7,676	111,332	76,305	30,514	33,106
4	94,005	18,821	13,819	55,977	54,838	75,760
5	32,137	92,616	19,338	9,669	31,910	54,959
6	8,997	24,204	34,446	7,661	11,586	16,861
7	2,515	8,990	7,684	14,473	6,787	4,630
8	2,515	1,823	2,669	4,951	7,150	3,770
9	1,561	795	1,488	1,591	2,914	3,744
10	1	1,105	548	708	925	687
Total	155,293	156,030	191,324	171,335	146,624	193,517

	Year					
Age	1982	1983	1984	1985	1986	1987
3	62,435	22,438	50,160	5,399	20,355	14,026
4	102,612	127,293	39,598	32,680	10,116	7,998
5	73,869	123,189	117,500	38,420	19,131	6,894
6	50,899	57,617	165,580	73,288	7,316	6,435
7	7,631	44,822	46,145	120,345	8,701	7,180
8	1,081	11,529	20,761	35,191	9,782	4,194
9	736	1,141	5,103	9,588	2,133	9,951
10	173	62	266	2,557	800	1,455
Total	299,436	388,091	445,113	317,468	78,334	58,133

Table 8.--Average weight-at-age values used as input data to the CAGEAN model, age-specfic selectivity coefficients estimated from the 1976-87 Gulf of Alaska pollock catch-at-age data set.

Age (years)	Weight-at-age (kg)	Estimated selectivity coefficient
3	0.417	0.33
4	0.565	0.66
5	0.637	1.00
6	0.686	0.98
7	0.760	0.68
8	0.839	0.43
9	0.872	0.28
10	0.855	0.06

post-1982 group, selectivities for ages 3 to 6 are constrained to be equal to the 1976-81 values, while selectivities for ages 7 to 10 are estimated from the period 1982-87.

In past analyses auxiliary data in the form of fishery-independent estimates of absolute population biomass from hydroacoustic surveys were used to calibrate the age-structured stock assessment results. This year, however, no estimate of absolute abundance from the 1987 hydroacoustic survey is available. The following procedure was carried out in order to provide a proxy value. Results of the 1987 bottom trawl survey are available and they indicate that in the western Gulf of Alaska (Shumagin, Chirikof and Kodiak INPFC statistical areas) the biomass of pollock ages 3-10 was 593,361 t (Eric Brown, Alaska Fisheries Science Center, 7600 Sand Point Way NE, Seattle, WA 98115. Pers. commun., 1988). In addition to this value, a 1987 hydroacoustic value can be extrapolated from earlier hydroacoustic results plus the new 1988 biomass estimate if we assume that 1) the unknown 1987 value falls between the known 1986 and 1988 values and 2) the rate of decline did not change over this period. With these assumptions the unknown 1987 value was approximated by fitting a straight line to the known data points and estimating the unknown data point. This procedure was carried out and weighted linear regression methods were applied to the hydroacoustic data using hydroacoustic biomass estimates, ages 3-10, as the dependent variable and year as the independent variable. The independent variable was scaled so that a value of 1 corresponded to calendar year 1981. Weighting factors were set inversely proportional to the variance of each annual hydroacoustic biomass values. In this way values estimated with high precision (low variance) have a large degree of influence on the fit and values with low precision (high variance) low influence. The data and estimated regression line are presented in Figure 13. The extrapolated 1987 hydroacoustic population biomass estimate was 484,430 t (Table 9).

To determine fishery-independent fishing mortality values the procedures suggested by Deriso et al. (1987) were applied to the data in Table 9. Fishery-independent population biomass estimates for ages 3 to 10 (Bh) were-used along with the catch biomass estimates for ages 3 to 10 (Bc) to calculate an annual full-recruitment exploitation fraction (p=Bc/Bh) for years 1981, 1983, 1984, 1985, 1986, and 1987. Hydroacoustic biomass values were used for all years except for 1987. The estimated population biomass values used for 1987 was 538,895 t, an average between the 1987 bottom trawl estimates (593,361 t) and the extrapolated 1987 hydroacoustic estimate (484,430 t). Annual catch biomass estimates were calculated using observed catch-at-age data (in numbers) multiplied by the average weight-at-age alues provided in Table 8. The calculated exploitation fractions, along with an estimate of natural mortality (M), were used to estimate the annual instantaneous full-recruitment fishing mortality rate (F) using the nonlinear equation:

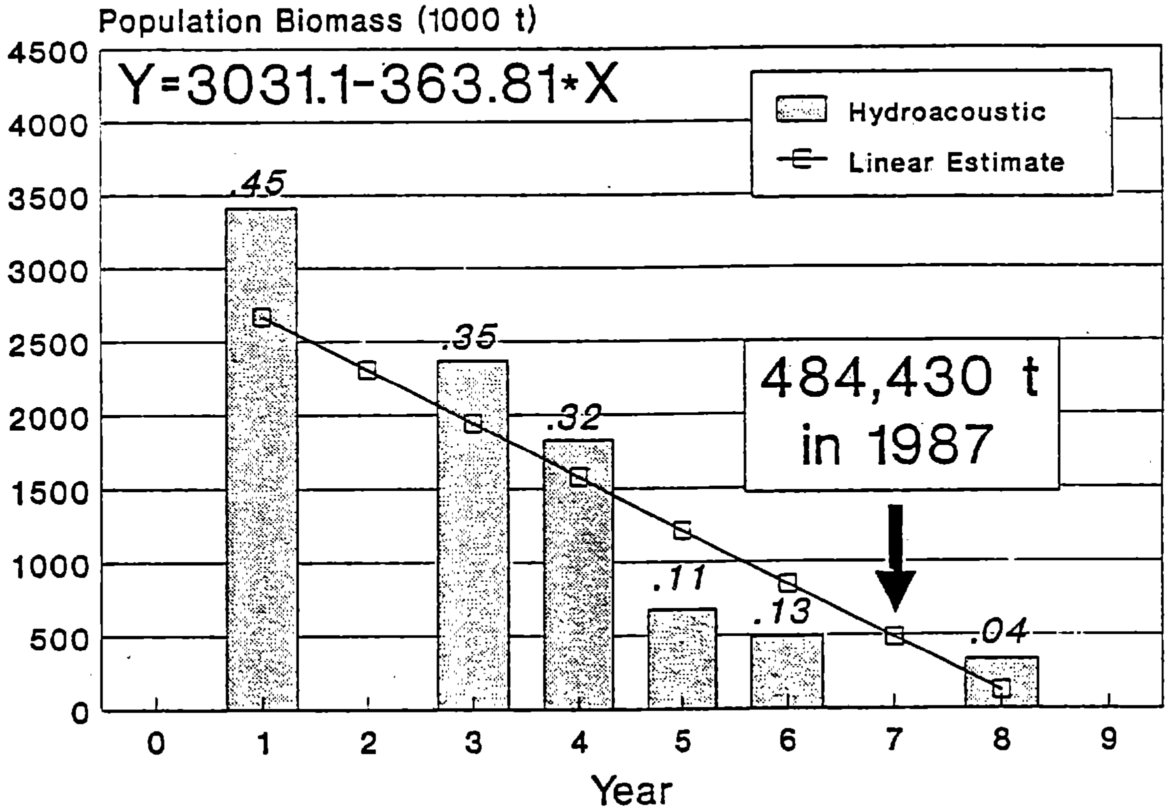

Figure 13.--Hydroacoustic population biomass estimates, 1981, 1983-86, and 1988 from Shelikof Strait, the estimated regression line, and the extrapolated '1987 population biomass value. Variance of annual population estimates are indicated above each bar.

Table 9.--Biomass estimates from different sources used to calculate fishery-independent estimates of full recruitment fishing mortality.

Year	Hydroacoustic biomass estimate (million t)	Catch estimate (t)	Exploitation fraction (μ)	Effective effort f (q=1.0)
1981	3.412	113,689	0.0333	0.0411
1982	--	--	--	--
1983	2.368	244,056	0.1031	0.1328
1984	1.829	289,096	0.1581	0.2111
1985	0.680	238,716	0.3511	0.5419
1986	0.492	48,871	0.0993	0.1283
1987*	0.539	38,127	0.0707	0.0895

*Average of extraploated 1987 hydroacoustic biomass estimate (484,430 t) and 1987 bottom trawl biomass estimate (593,361 t) for ages 3-10.

$$\mu = \frac{Bc}{Bh} = \frac{F}{F + M}\,[1-\exp(-F-M)] \qquad [1]$$

Equation [l] was solved for F given values of Bc, Bh, and M=0.4 with a Newton-Raphson root finding algorithm. Solutions for F from equation [l] were used as estimates of annual effective fully recruited fishing effort, which were then substituted into the auxiliary effort sums of squares term. Since the catchability coefficient were constrained to be equal to 1.0, these values correspond to alternative estimates of full-recruitment fishing mortality.

In this approach annual effective effort parameters estimated from the CAGEAN model can be different from values calculated from equation [l]. The degree of difference depends on how strongly the auxiliary effort sum of squares term is weighted (see equation 9, Deriso et al. 1985). Normally the auxiliary data should be restricted to only the age group(s) fully recruited to the fishery since the goal is to provide an alternate estimate of full-recruitment fishing mortality. However, to cover any uncertainty regarding age determination the analysis presented in this report used total population biomass estimates to calculate the auxiliary fishing mortality values from equation [l]. Because these calculations are based on biomass estimates that include age classes other than the fully recruited age class, the weighting factor for the effort auxiliary sum of squares term was set to 0.6. Adoption of this approach allows incorporation of the hydroacoustic biomass estimates into the catch-at-age analysis but weights the auxiliary data (fishing mortality values estimated from the hydroacoustic biomass) a little less than the primary data (catch-at-age).

The specific weighting factor value of 0.6 is slightly higher than last year when a value of 0.5 was used. One of the reasons that the influence of the fishery-independent auxiliary information in this year's analysis was adjusted slightly upwards relative to last year was because the catch in 1987 was the lowest on record. The corresponding exploitation fraction (Table 9) in 1987 is also very low (0.0707) indicating that the estimate of full recruitment instantaneous fishing mortality (0.0895) is no longer a significant component of total mortality. Note that the fraction of the total deaths in 1987 due to fishing (F/F+M) would be 0.18 using the values listed in Table 9. Compare this to 1985 when the fraction of total deaths due to fishing was 0.58. One of the critical assumptions regarding the validity of results from catch-at-age models is that fishing mortality is a significant mortality component. If it is not, then theoretically, abundance estimates do not accurately reflect the true dynamics of the underlying population. To compensate for this possible deficiency, the influence of the fishery-independent information was increased relative to the catch-at-age information.

Absolute Abundance

Estimates of total numerical abundance and population biomass are provided in Tables 10 and 11, respectively. A comparison of the annual trend in population biomass as estimated from the stock assessment, hydroacoustic and bottom trawl surveys is presented in Figure 14.

Results from the stock assessment indicate a continued decline in the abundance of pollock in 1987. Population abundance has been declining since 1983, after peaking in 1981 or 1982. Alton and Megrey (1986) forecasted that the 1986 biomass would be the lowest on record, but that there would be an upswing in 1987 because of the likelihood of strong recruitment of the 1984 year class. The reason for the continued decline in 1987 is due mainly to the fact that the 1984 year class has failed to recruit strongly to the exploitable population.

Estimates of the 1987 total population biomass from the catch-at-age analysis are slightly lower than the bottom trawl and extrapolated hydroacoustic estimate (Fig. 14). A comparison of these three estimates in 1984 also show differences. Results from just the bottom trawl survey also suggest a decline in population abundance has taken place between 1984 and 1987. In summary, the population is still low relative to historic levels but the rate of decline is showing evidence of leveling.

Estimates of age-specific selectivity coefficients are similar to results of last years analysis and are presented in Table 8.

Minimum sum of squares (MMSQ) estimates of total numerical abundance compare well with bootstrap estimates (Table 10). The MMSQ estimates are those values that minimize the objective function used in the catch-age analysis model (See equation 9 in Deriso et al. 1985). Bootstrap estimates are values generated-via the bootstrap resampling procedure (Efron 1982) as applied to the catch-age model (Deriso et al. 1985). Coefficients of variation (CV) for the bootstrap estimates range from 12 to 35% with low values associated with earlier years and the highest value associated with the most recent fishing year (1987). These values are quite lower than last year when CVs ranged from 27 to 51%.

The MMSQ estimates of total population biomass also compare well with bootstrap estimates (Table 11). Coefficients of variation (CV) for the bootstrap biomass estimates range from 12 to 33%. Similar to the numerical abundance estimates, low values are associated with earlier years and high values are associated

Table 10.--Abundance (billions) of the Gulf of Alaska pollock population ages 3 through 10 and the 3-year-old recruits by year class estimated from the application of the CAGEAN model to 1976-87 catch-at-age. The initial (minimum sum of squares estimate) was refined by the bootstrap method (see text) so that coefficients of variation (CV) could be computed.

	Population abundance			Recruit abundance	
	Minimum sum of squares	Bootstrap			
Year	estimate	Estimate	CV	Year class	3-year-old recruits
1976	1.63	1.63	12.0	1973	0.42
1977	1.35	1.35	12.2	1974	0.36
1978	2.31	2.40	17.4	1975	1.51
1979	3.59	3.70	20.3	1976	2.16
1980	4.26	4.43	16.9	1977	1.99
1981	5.57	5.91	15.3	1978	2.86
1982	4.95	5.21	15.3	1979	1.37
1983	3.47	3.66	15.2	1980	0.41
1984	2.32	2.46	16.9	1981	0.32
1985	1.27	1.36	21.5	1982	0.09
1986	0.73	0.80	28.5	1983	0.17
1987	0.57	0.64	35.3	1984	0.18

Table 11.--Biomass (million t) of the Gulf of Alaska pollock population ages 3 through 10 estimated from the application of the CAGEAN model to 1976-87 catch-at-age. The initial (minimum sum of squares estimate) was refined by the bootstrap method (see text) so that coefficients of variation (CV) and the 95% confidence intervals (CI) could be computed. For comparative purposes, the hydroacoustically determined estimates are also shown.

	Stock assessment				
		Bootstrap			Acoustic midwater trawl estimate
Year	Minimum sum of squares estimate	Estimate	CV	95% CI	
1976	0.900	0.897	12.1	0.69-1.42	--
1977	0.782	0.781	12.3	0.60-1.23	--
1978	1.156	1.195	16.1	0.83-1.77	--
1979	1.781	1.837	19.6	1.17-2.58	--
1980	2.214	2.302	17.4	1.54-3.33	--
1981	2.873	3.034	15.9	2.12-4.51	3.41
1982	2.790	2.940	15.7	2.07-4.38	--
1983	2.163	2.281	15.7	1.60-3.39	2.37
1984	1.523	1.613	17.5	1.08-2.33	1.83
1985	0.901	0.962	21.9	0.56-1.28	0.68
1986	0.501	0.548	28.7	0.25-0.63	0.49
1987	0.363	0.406	33.2	0.15-0.42	0.48*

* Extrapolated value (see text).

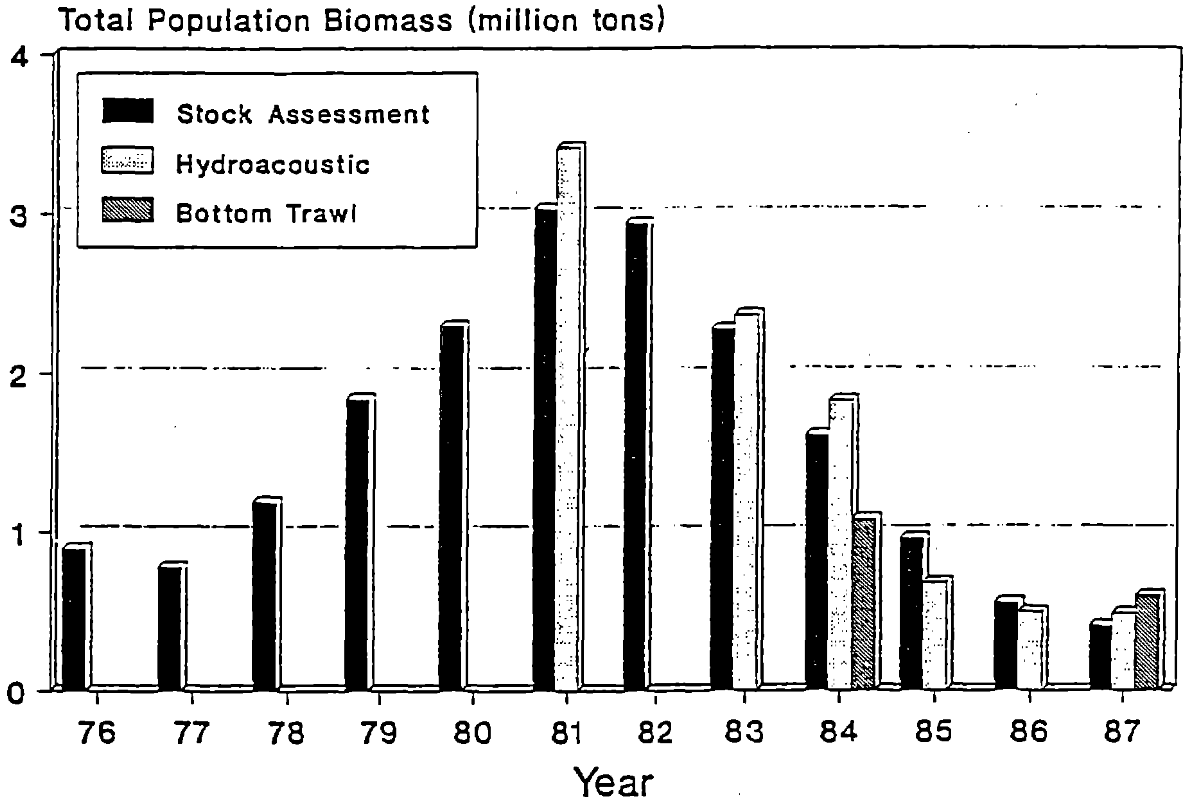

Figure 14. --Estimates of total pollock biomass (t) from 1) acoustic-trawl surveys in Shelikof Strait, 2) from bottom trawl surveys, and 3) from age-structured analysis using foreign; joint venture, and domestic fisheries data, 1976-87.

with the most recent fishing year (1987). Once again these are lower than last year when CVs ranged from 27 to 50%.

Current Exploitable Biomass

Estimates of biomass from the stock assessment are assumed to represent exploitable quantities since the age range used in the analysis includes all major exploitable age groups.

RECRUITMENT STRENGTHS

The trend in year class strength is given in Figure 15. Abundance estimates for the 1984 year class appear to be similar in magnitude to the weak 1980-83 year classes. No significant recruitment has taken place since the strong 1978 and 1979 year classes entered the fishery in 1981 and 1982. Since that time recruitment has been poor and recruitment levels have been low for 5 years, reaching a low (85.2 million) with the 1982 year class. The 1984 year class appears to be weak but this result should be viewed with caution since the estimate of 1984 year class abundance from the stock assessment is based on only one catch-at-age data point from the 1984 cohort, the catch of 3-year-olds in 1987. It is not known at this time whether 3-year-olds were fully available to the fishery in 1987. In addition, stock assessment parameter estimates associated with the most recent fishing year (1987) are the least accurate. At best the data from the apparently weak 1984 year class should be considered as preliminary until further data points from the 1984 cohort are added to the catch-at-age data set.

Information from the Shelikof acoustic/midwater trawl surveys in 1987 (Nunnallee 1987) and 1988 (Nunnallee and Williamson 1988, in this report) do not support the findings reported here with respect to strength of the 1984 year class. Estimates of year class strength from the acoustic/trawl surveys indicate that the 1984 year class recruited strongly based on relative abundance estimates. of 3-year-olds in 1987 and absolute abundance estimates of 4-year-olds in 1988.

Why the 1984 year class apparently did not recruit strongly to the commercial fishery in 1987 is not known. Perhaps it was due to the small catch taken by the domestic fisheries or because domestic, fishermen were trying to target more on older and larger pollock. Three-year-old fish are marginally useful to the domestic fishery because of their small size and because only a small percentage of this age group is mature. If an age group is not well represented in the catch relative to their actual proportion in the total population, then the stock assessment analysis cannot accurately estimate the true underlying abundance: this is particularly relevant with respect to the youngest age group in the exploitable population (the recruits).

BIOLOGICAL PARAMETERS

Even though the information is relatively dated, the most recent information regarding growth is reported in Hughes and Hirschhorn (1979). This information needs to be updated with a more recent growth analysis for Gulf of Alaska pollock.

Natural mortality is a difficult parameter to ascertain; however, in the Gulf of Alaska pollock stock a constant value of M = 0.40/yr has routinely been used. Megrey (1988) has recently investigated the validity of this assumption. Using three stock assessment models (Paloheimo 1980; Fournier and Archibald 1982; Deriso et al. 1985) and the methods of Alverson and Carney (1975) and Pauly (1980), he concluded that the assumption of a natural mortality rate of M = 0.40/yr was not unreasonable, especially in light of the high variability in the individual estimates.

Fecundity estimates as a function of length and weight are provided in Miller et al. (1986).

MAXIMUM SUSTAINABLE YIELD

Typically stock production or yield-per-recruit models are used to estimate maximum sustainable yield (MSY). Unfortunately, the lack of effort statistics in the Gulf of Alaska pollock fishery and the short time series of data available for analysis precludes application of analytic models that would permit estimation of MSY, F_{max} or $F_{0.1}$. A crude approximation of MSY is possible (Alverson and Pereyra 1969) but it requires an estimate of virgin biomass which in unavailable.

PROJECTIONS OF BIOMASS

The age-structured stock projection model used this year is the same model used in, four previous stock projection analyses (Alton and Rose 1985; Alton and Megrey 1986; Megrey and Alton 1987; Megrey 1987). The simulation modelling approach is preferred to the MSY approach in terms of evaluating management policy alternatives because the simulation model specifically addresses the unique features of the Gulf of Alaska fishery such as 1) temporal partitioning of the catch between two 6-month fishing seasons, 2) two major fleets with different selectivity characteristics, and 3) direct incorporation of biological features of the stock such as age-structure and growth. Until better biological information is made available, it seems that using the' simulation model to evaluate alternative management scenarios puts to the best use all available information. The model projects population biomass and age composition from an initial population given parameters for natural mortality, growth, age-specific selectivity, and schedules of catches and recruitment.

Projections of biomass (age 3-and-older fish) in Shelikof Strait for early 1988 and 1989 are given for six recruitment scenarios, three annual catch schedules, and three initial starting conditions. Normally, the initial population size used to begin the simulations is derived from the most recent hydroacoustic survey of Shelikof Strait. The reason for this approach hinges critically on the premise that the entire Gulf of Alaska pollock population migrates to Shelikof Strait in the spring of the year to spawn, and at this time the entire population present in Shelikof is assessed with the hydroacoustic survey. The unexpected very low abundance estimate from the 1988 hydroacoustic survey (Nunnallee and Williamson, this report) forces one to reexamine this assumption. In order to deal with the possibility that the Shelikof survey is only assessing a fraction of the gulfwide population, the projections this year will be initialized with three different starting population vectors. These vectors are the biomass estimates of age 3-10 fish and its age composition in numbers from the 1986 hydroacoustic survey, the 1987 bottom trawl survey, and the 1988 hydraacoustic survey. Catches from 1986 and 1987 are known and catches for 1988 are known or can be anticipated. The main benefit of carrying out the stock projections is to observe the effect of anticipated 1989 catch levels on the projected population in 1990.

Recruitment Schedule Calculations

Recruitment is defined as the number of 3-year-old fish present at the beginning of the year. Three recruitment levels (poor, average, and strong) were needed for the stock projection analysis. As a guide for assigning the different recruitment levels realisti values, age-3 abundance estimates from the updated catch-at-age analysis were used to estimate the three recruitment levels.

Recruitment estimates for the projections were derived by first grouping year class abundance estimates from the catch-at-age analysis according to whether they were from poor or strong year classes. In selecting poor and strong groupings the 1984 year class estimate was omitted from the calculation of poor and strong recruitment since this estimate is based on only one catch-at-age data point. Using Figure 15, 1973, 1974, 1980, 1981, 1982, and 1983 were judged to be poor year classes and the 1975 through 1979 year classes were judged to be strong. Poor and strong recruitment levels were calculated as the arithmetic mean of the abundance estimates for the year classes making up each respective group. Average recruitment level was calculated by taking the arithmetic average of all recruitment estimates (1973-84). Results of this procedure provide recruitment levels

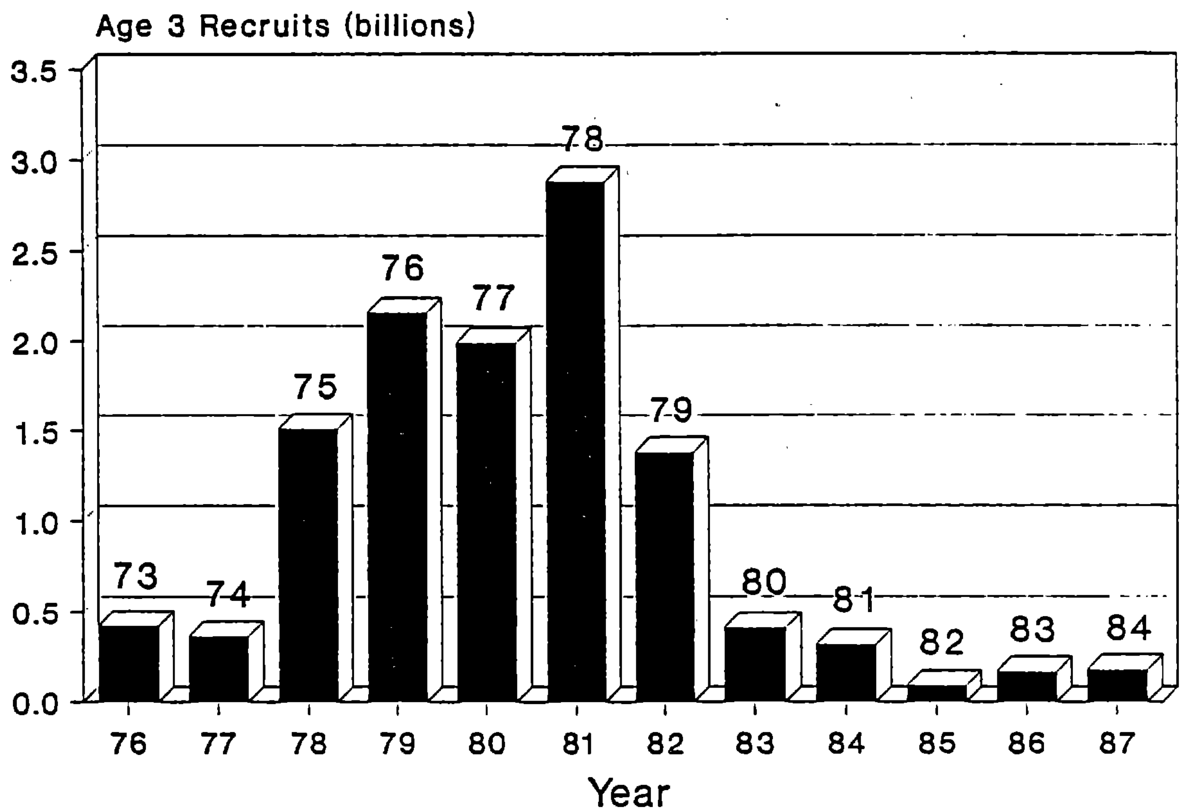

Figure 15.--Annual estimates of the number of 3-year-old recruits, as estimated-from age-structured analysis. Year classes are indicated above each bar.

at three levels: 0.3 billion fish for poor recruitment, 1.0 billion for average-recruitment, and 2.0 billion for strong recruitment. The levels for poor, average, and strong recruitment which have been used in three previous forecast exercises (Alton and Megrey 1986; Megrey and Alton 1987; Megrey 1987) are presented below:

Source	Analysis Year	Past recruitment levels (billions) Poor	Average	Strong
Alton and Megrey 1986	1985	0.5	1.0	1.5
Megrey and Alton 1987	1986	0.3	0.9	1.5
Megrey 1987	1987	0.3	0.9	1.7

The new levels described below reflect the results of the updated age-structured analysis described earlier. The recruitment schedules used in this analysis are:

Year	(Year class)	Recruitment scenario (age 3 population in billion fish) A	B	C	D	E	F
1986	1983	0.3	0.3	0.3	0.3	0.3	0.3
1987	1984	0.3	0.3	0.3	0.3	1.0	0.3
1988	1985	2.0	2.0	1.0	1.0	1.0	0.3
1989	1986	0.3	1.0	0.3	1.0	1.0	0.3
1990	1987	0.3	1.0	0.3	1.0	1.0	0.3

Recruitment schedules A-F all assume that recruitment of the 1983 year class in early 1986 is poor.

Even though the 1984 year class was observed in great abundance during the hydroacoustic-trawl surveys in 1985 as 1-year-olds, in 1986 as 2-year-olds, and on a relative basis in 1987 as 3-year-olds (Nunnallee 1987), they were not abundant in the 1988 hydroacoustic survey (Nunnallee and Williamson, in this report) nor in the 1987 commercial fishery. Therefore, schedules A-D and E reflect this lack of strong recruitment by representing the 1984 year class as poor. Schedule E has the 1984 year class as average just to cover the possibility that the year class is not poor but was just unavailable to the commercial fishery and hydroacoustic survey.

The 1985 year class is represented as strong in recruitment schedules A and B due to the fact that this year class has appeared to be strong in the 1987 hydroacoustic survey as 2-year-olds and as 3-year-olds in 1988 (Nunnallee and Williamson, in this report). Also this year class was extremely abundant throughout the entire Gulf of Alaska as indicated from the 1987 bottom trawl survey (Fig. 11). To cover the possibility that early looks at year class abundance are not accurate predictors of actual recruitment to the fishery, the 1985 year class is represented as average in schedules C-E, and as poor in schedule F.

Recruitment for the 1986 and 1987 year classes was set to the same level in each. recruitment schedule because the spawning abundance in these 2 years was very low (Table 11) and well below the minimum threshold spawning biomass of 768,000 t (Megrey and Alton 1987). Recruitment levels for the 1986 and 1987 year classes varied between poor (schedules A, C and F) and average (schedules B, D and E).

Schedule A is identical to B and C to D, except for the strength of the 1986 and 1987 year classes. The only difference between schedules A and C and B and D is the strength of the 1985 year class. Schedules B and D are identical except for the strength of the 1984 year class. In schedule B the 1984 year class is poor and average in schedule E. Schedules B and E are the most optimistic scenarios. Schedule F represents the most pessimistic outlook (the worst case scenario) since all year classes are represented as poor.

Catch Schedules

For each recruitment schedule three projections were made, each having a different annual catch schedule for 1989. These schedules begin with the known 1986 and 1987 catch and a preliminary estimate of the 1988 catch. The catch schedules are as follows:

	Catch scenario (1st half of year/2nd half of year) (1,000 t)			
Catch Schedule	**1986**	**1987**	**1988**	**1989**
1	63/21	39/23	20/0	0/0
2	63/21	39/23	20/0	12.5/12.5
3	63/21	39/23	20/0	25/25

Catch schedule 1 corresponds, to no annual harvest in 1989. Catch schedule 2 (25,000 t) provides a harvest level similar to the 1988 harvest level. Catch schedule 3 (50,000 t) provides a harvest level similar to the 1987 harvest level. In catch schedules 2 and 3 the annual harvest is split equally between the spring and fall fisheries.

Initial Population Vector Schedules

In order to deal with the possibility that the Shelikof survey is only assessing a fraction of the gulfwide population, the projections this year were initialized with three different starting population vectors. These vectors include information from three sources: the biomass estimates of age 3-10 fish and age composition in numbers from the 1986 hydroacoustic survey, the 1987 bottom trawl survey, and the 1988 hydroacoustic survey. These data are given below:

Data source	1986 Acoustic	1987 Bottom trawl	1988 Acoustic
Schedule	A	B	C
		Initial population (x1,000 fish)	
Age	Number	Number	Number
3	287,700	169,422	753,600
4	44,300	117,021	349,600
5	81,700	106,366	83,800
6	52,300	183,592	18,200
7	89,500	81,598	6,000
8	151,300	59,971	6,000
9	62,100	140,837	4,100
10	11,700	12,914	9,300
Total biomass (1000 t)	491,500	593,361	311,400

The specific catch and recruitment schedules used for projections based on different initial population vectors schedules differ with respect to the number of years included in the projection. For example, projections based on initial population vector schedule B (1987 bottom trawl survey) use recruitment and catch values only from years 1987-89. Similarly, a projection based- on initial population vector schedule C (1988 hydroacoustic survey) only uses recruitment and catch values from years 1988-89.

Projection Results

Projection results from using the various recruitment and catch schedules and the different initial population vector schedules are presented in Figure 16 (initial population vector schedule A), Figure 17 (initial population vector schedule B), and Figure 18 (initial population vector schedule C).

Initial Population Vector Schedule A

Using initial population vector schedule A (Fig. 16) the projected biomass in 1990 would be 935,000 t, 909,000 t, or 883,000 t if the 1985 year class is strong (scenario A), or

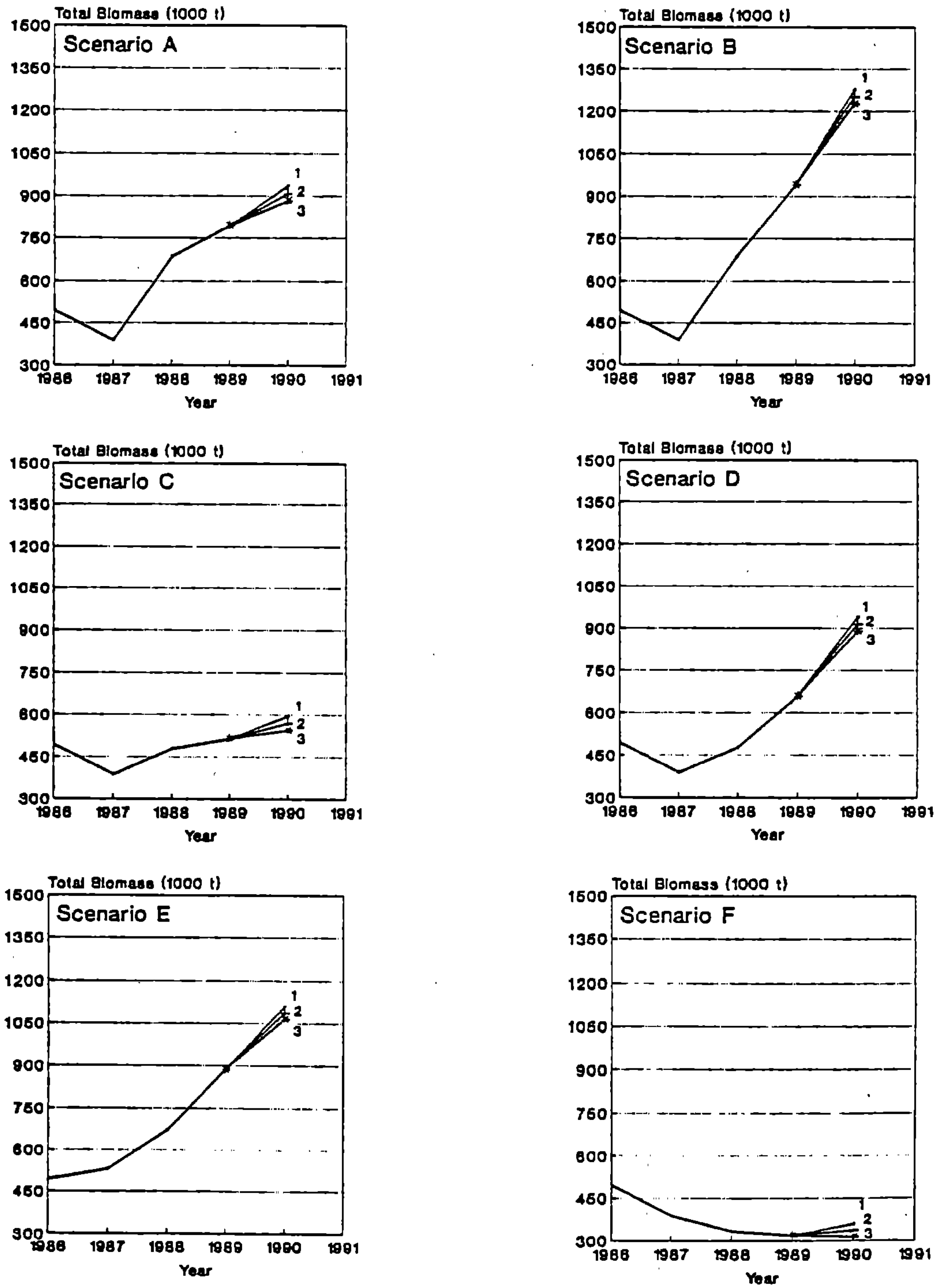

Figure 16. --Forecasts of total pollock biomass (ages 3-and-older) in Shelikof Strait (Jan.-Apr.) in 1986-90 given six likely recruitment scenarios (A-F) and three catch schedules (see text for description of recruitment and catch schedules). Projections were started with numerical population estimates from the 1986 hydroacoustic survey (initial population vector schedule A).

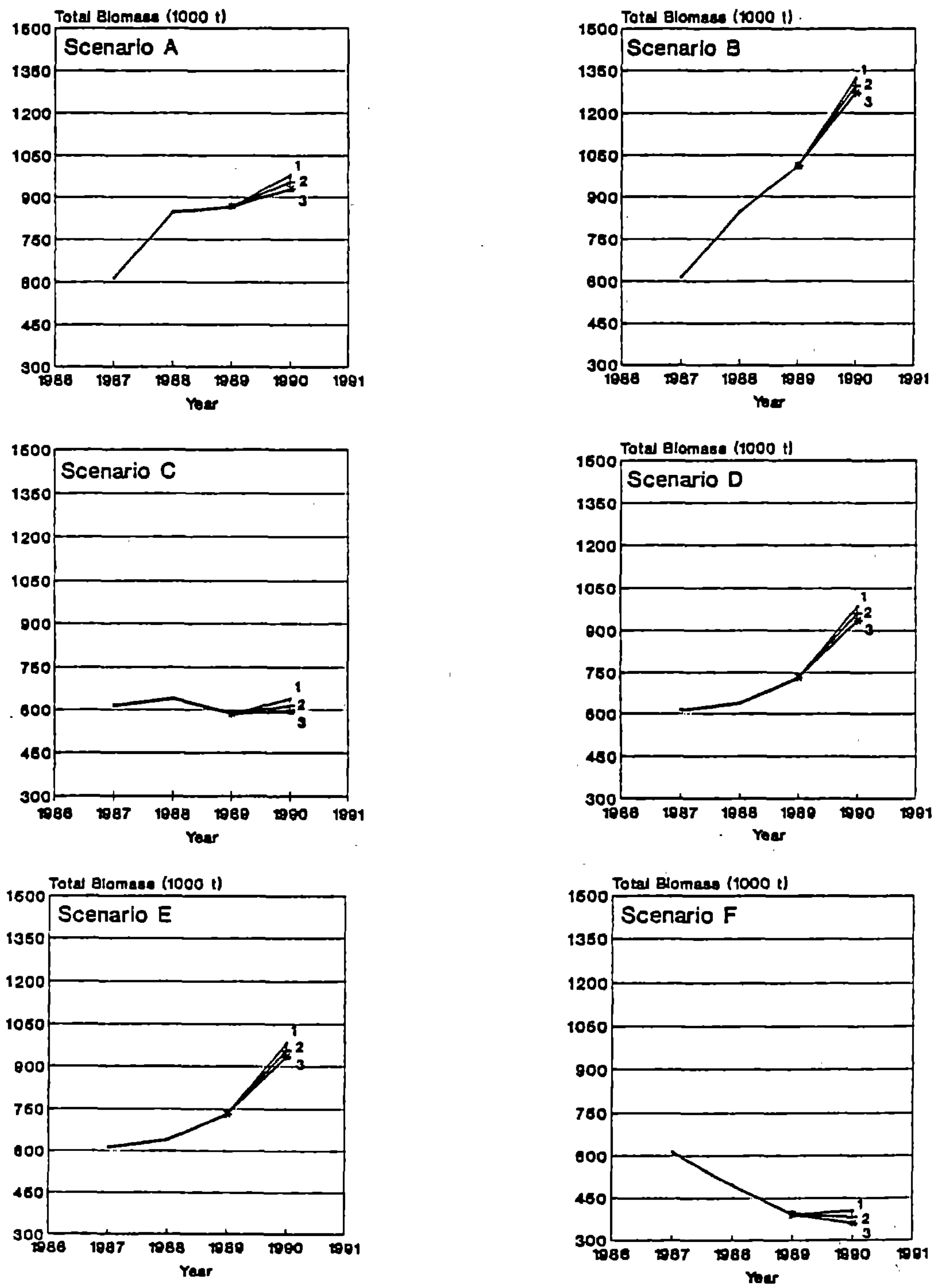

Figure 17. --Forecasts of total pollock biomass (ages 3-and-older) in Shelikof Strait (Jan.-Apr.) in 1987-90 given six likely recruitment scenarios (A-F) and three catch schedules (see text for description of recruitment and catch schedules). Projections were started with numerical population estimates from the 1987 bottom trawl survey (initial population vector schedule B).

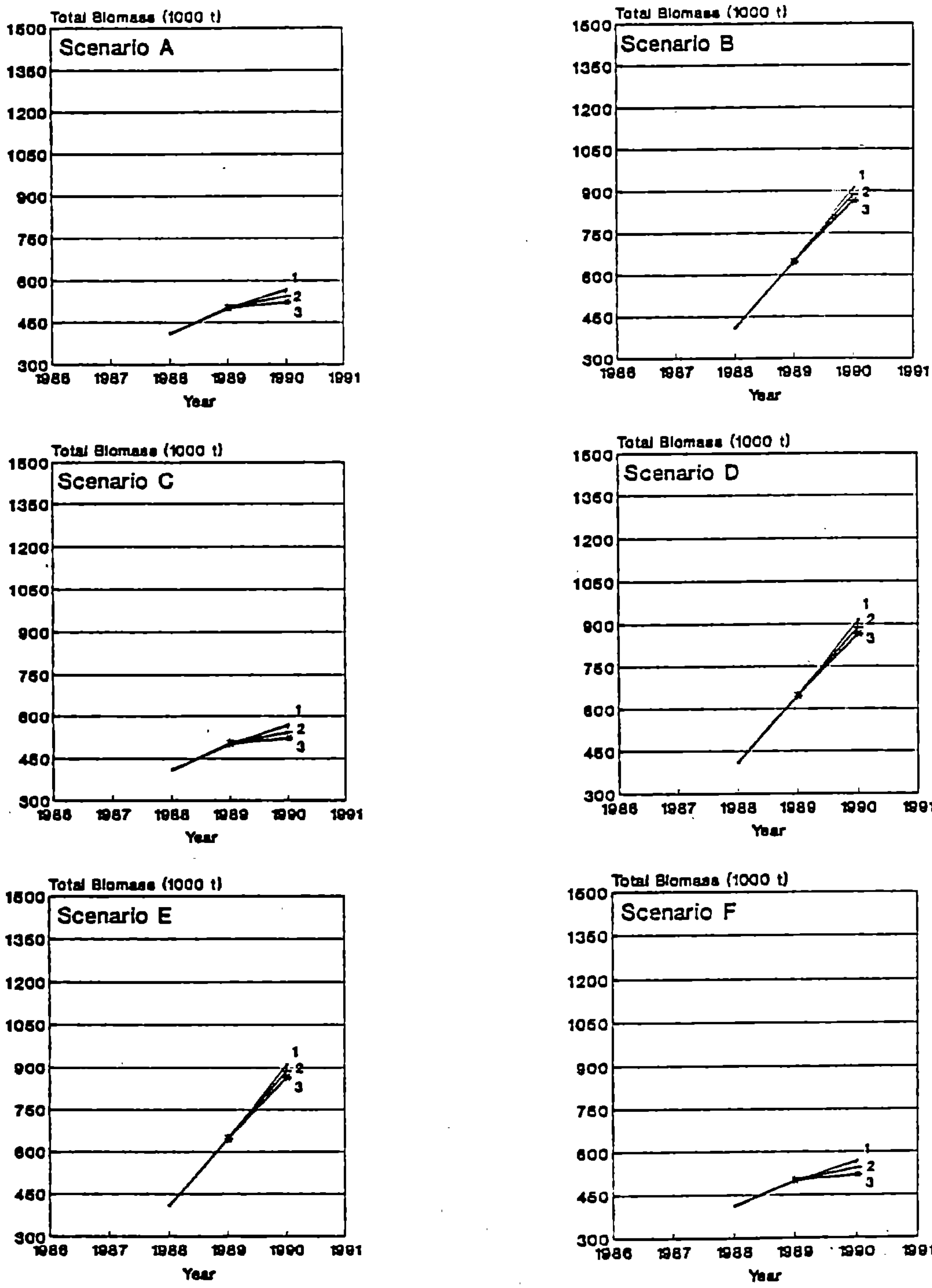

Figure 18.--Forecasts of total pollock biomass (ages 3-and-older) in Shelikof Strait (Jan.-Apr.) in 1988-90 given six likely recruitment scenarios (A-F) and three catch schedules. Projections were started with numerical population estimates from the 1988 hydroacoustic survey (initial population vector schedule C).

595,00 t, 571,000 t, or 546,000 t if the 1985 year class is average (scenario C), using catch schedules 1-3 respectively and assuming that the 1986 and 1987 year classes are poor. The projected biomass in 1990 would be 1,278,00 t, 1,252,000 t, or 1,227,000 t if the 1985 year class is strong (scenario B), or 938,00 t, 914,000 t, or 889,000 t if the 1985 year class is average (scenario D), using catch schedules l-3 respectively and assuming that the 1986 and 1987 year classes are average. The consequence of assuming the strength of the 1986 and 1987 year classes is poor or average, given the same 1983-85 year class strengths (compare scenarios A to B and C to D) amounts to about 343,000 t in the level of projected biomass, regardless of the harvest level.

Recruitment scenarios A and D resulted in very similar projected biomass levels. The two most optimistic recruitment scenarios projected population biomass levels in the range of 1,065,000 t (scenario E, catch schedule 3) to 1,278,000 t (scenario B, catch schedule 1). The model projected a 1987 biomass of 387,000 t if the 1984 year class was poor (scenarios A, B, C, D, and F) or 532,000 t if the 1984 year class was average (scenario E). If the 1983 and 1984 year classes were poor, then the projected biomass in 1988 was 332,000 t if the 1985 year class was poor (scenario F), 478,000 t if it was average (scenario C) and 686,00 t if it was strong (scenario A). The 1987 projected biomass level from scenario E is consistent with the 1987 bottom trawl population biomass estimate of 593,000 t.

Of particular interest is the projection from recruitment schedule F. This schedule is very similar to the most pessimistic recruitment schedule (E) from last year's projections (Megrey 1987) with respect to recruitment scenario (1983 year class is poor, the 1984 year class is strong, and year classes 1985-86 are poor), catch schedules (1988 catch schedules 1 through 3 are identical to catch schedules from last year) and initial population vector (the projections began using the 1986 hydroacoustic survey abundance estimates, initial population vector schedule A). Unlike last year's recruitment schedule E, the 1988 recruitment scenario F accurately reflects the fact that the 1984 year class recruited poorly to the commercial fishery in 1987. This run provides a comparison of the projected 1988 population biomass, starting from a known 1986 abundance level and using an updated recruitment scenario, to the 1988 hydroacoustic biomass estimate. The projected 1988 biomass level from this run was 332,000 t which is within 7% of the 1988 hydroacoustic estimate of 311,400 t.

Initial Population Vector Schedule B

Initializing the projection model with numerical population abundance estimates from the 1987 bottom trawl survey (initial population vector schedule B) produced projected biomass levels in 1987 of 612,000 t which is close to the estimated abundance of

593,000 t from the bottom trawl survey. Because the projections were started in 1987, scenarios D and E are identical since recruitment schedules for the 1988-90 years classes are the same.

Using initial population vector schedule B (Fig. 17) the projected biomass in 1990 would be 980,000 t, 954,000 t, or 929,000 t if the 1985 year class is strong (scenario A) or 640,000 t, 616,000 t, or 592,000 t if the 1985 year class is average (scenario C), using catch schedules l-3 respectively and assuming that the 1986 and 1987 year classes are poor. The projected biomass in 1990 would be 1,323,000 t, 1,297,000 t, or 1,272,000 t if the 1985 year class is strong (scenario B) or 983,000 t, 959,000 t, or 935,000 t if the 1985 year class is average (scenario D or E), using catch schedules l-3 respectively and assuming that the 1986 and 1987 year classes are average.

As in the earlier section, scenarios A and D resulted in very similar projected biomass levels. The two most optimistic recruitment scenarios projected population biomass levels in the range of 935,000 t (scenario D and E, catch schedule 3) to 1,323,000 t (scenario B, catch schedule 1). If the 1984 year class was poor, then the projected biomass in 1988 was 494,000 t if the 1985 year class was poor (scenario F), 639,000 t if it was average (scenario C) and 847,00 t if it was strong (scenario A). Even the most pessimistic scenario (F) projects higher 1988 population biomass levels (494,000 t) than those measured by the 1988 hydroacoustic survey by almost 100,000 t.

Initial Population Vector Schedule C

Initializing the projection model with numerical population abundance estimates from the 1988 hydroacoustic survey (initial population vector schedule C) produced projected biomass levels in 1988 of 409,000 t which is somewhat higher than the estimated abundance of 311,000 t from the 1988 hydroacoustic survey. Because the projections were started in 1988, scenarios A, C, and F are identical and B, D, and E are identical since the recruitment schedules for the 1989-90 year classes are the same.

Using initial population vector schedule C (Fig. 18) the projected biomass in 1990 would be 911,000 t, 887,000 t, or 864,000 t if the 1986-87 year classes are average (scenarios B, D, and E) or 567,00 t, 544,000 t, or 521,000 t if the 1986-87 year classes are poor (scenarios A, C, and F), using catch schedules l-3 respectively. The projected biomass in 1989 was 501,000 t if the 1986 year class was poor (scenario A, C, and F) or 646,000 t if it was average (scenario B, D, and E).

ACCEPTABLE BIOLOGICAL CATCH

Results from the projections are highly sensitive to the initial population vector and recruitment schedules.

Unfortunately, there is no compelling evidence to suggest which initial starting conditions are the "most correct." In fact, projection results are somewhat contradictory. Starting the projections from 1986 and assuming that an average 1984 year class produces projected 1987 biomass levels that are in agreement with the 1987 bottom trawl estimate. However, if we start the projections from 1986 and assume that both the 1984 and 1985 year classes are poor, then the projected 1988 biomass levels are in agreement with 1988 hydroacoustic estimates. Thus, according to the projections, the only way the population biomass level in 1988 could be as low as 300,000 t is if both the 1984 and 1985 year classes were below average. In no instance did projections predict population biomass levels as low as 300,000 t when initial population vector schedule B was used, even for the most pessimistic scenario. There does not seem to be a combination of initial population vector, catch, or recruitment schedules that provide projected population levels that are consistent with observed 1987 bottom trawl survey and 1988 hydroacoustic survey abundance estimates.

Before projection results can be used to recommend an ABC, we are forced to critically examine two crucial questions. The first concerns the relationship between the Shelikof Strait aggregations and the gulfwide pollock population. In the past, the working hypothesis was that pollock from the entire Gulf of Alaska migrated to Shelikof Strait in the spring of the year and that at this time total population abundance was assessed with the hydroacoustic survey. Results from the 1988 hydroacoustic survey force one to reconsider the premise of this hypothesis due to the fact that the abundance estimate is far lower than ever anticipated. Certainly one possible explanation would be that in 1988 all pollock did not return to Shelikof. The fact that in 1988 the Shelikof Strait aggregations were primarily immature fish (Nunnallee and Williamson, this. report) suggests that in 1988 the Shelikof Strait aggregations were not spawning aggregations. If they were not, then where were the mature pollock in the spring of 1988? This is not the first time that results, from the hydroacoustic survey did not agree with expectations. In 1985 there was a sharp decline in abundance between 1984 and 1985 when the hydroacoustically assessed biomass dropped from 1,840,OOO t to 700,000 t (Nelson and Nunnallee 1986). There was no explanation for the drop. The severity of the decline implied unusually large mortalities had taken place and that these were way out of line with expected population decreases. In retrospect, perhaps these age groups just did not return to Shelikof. Unfortunately, there is no information to determine what fraction of the gulfwide pollock population returns to Shelikof or if this fraction is a function of population density or if it varies by year.

The second question that must be asked is whether prerecruit abundance is related to recruitment abundance. The working assumption implicit in the projection analysis is that there is a direct correlation. The only year when the hydroacoustic surveys had an opportunity to detect a strong year class before it recruited to the fishery was in 1981 when the hydroacoustic survey saw the 1979 year class as 2-year-olds and the 1979 year class did indeed recruit strongly to the fishery. In 1986, the early look at what was then thought to be the strong 1984 year class did not correlate well with how the 1984 year class actually recruited to the fishery. So here again, there is not a good track record of predicting year class strength based on observed abundance of prerecruits. The implications of this discussion relate directly to the strength of the 1985 year class; early indications suggest that it is strong. However, this appraisal is based on prerecruit abundance estimates which have had mixed success. There is. the possibility that heavy predation is taking place. Stocks of cod and halibut, both potential predators of juvenile pollock, are at high levels of abundance.

These two disappointing results do not negate the usefulness of the projections. They do underscore the need to strike a balance between protecting the stock when abundance levels are low by reducing the ABC and maintaining a continuity in the time series of catch statistics so that stock assessments can continue. As long as the catch is sampled adequately and there are fishery-independent data sources with which to tune the assessment model, then stock assessments will provide usable information on underlying stock dynamics and abundance levels.

The ABC in 1989 should be conservative, given the uncertainties regarding the abundance of the 1984 year class and the fact that we cannot be sure-that the 1985 year class is strong. An ABC of 25,000 t in 1989, allocated to the domestic fishery, would permit a small harvest to take place and allow the domestic fishery operations to continue at levels similar to 1987 and 1986 levels. Also a small harvest would provide some fisheries catch information as long as the catches were well sampled for biological information. The projections demonstrate that even though the stock is at low levels of abundance, a small harvest between 25,000 and 50,000 t would have very little impact.

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PACIFIC COD

by

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and

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INTRODUCTION

In North American waters, Pacific cod (Gadus macroceohalus) occur on the continental shelf and upper slope from Santa Monica Bay, California (lat. 34°N) through the Gulf of Alaska, Aleutian Islands, and eastern Bering Sea to Norton Sound (Bakkala et al. 1981). Recently published information suggests that Gulf of Alaska, Bering Sea, and Aleutian Islands cod stocks- are genetically indistinguishable (Grant et al. 1987), and tagging studies have shown that cod move between the Gulf of Alaska, Bering Sea, and Aleutian Islands.[1] However, the relative number of cod that actually migrate and the regularity of the migrations are unknown; thus Gulf of Alaska cod stocks are managed as a separate unit.

CATCH HISTORY

Allocations

The optimum yield (OY) for Gulf of Alaska Pacific cod, which was replaced by target quota (TQ) in 1987 and total allowable catch (TAC) in 1988, has varied somewhat since the concept was adopted by the North Pacific Fishery Management Council (NPFMC). In 1977 OY was established at slightly less than the previous year's total catch. From 1978 to 1981, OY varied between 34,800 and 70,000 t, settling at 60,000 t in 1982. Prior to 1981 OY was assigned for "fishing years" rather than calendar years. In 1981 the OY was raised temporarily to 70,000 t and the fishing year was extended until 31 December to allow subsequent OYs to cover calendar years (Table 1). In 1986 OY was raised to 75,000 t, and to allow all of the total allowable level of foreign fishing (TALFF) to be taken from the NPFMC Western Regulatory Area, its geographic distribution was changed to 40, 44, and 16% from 28, 56, and 16% in the NPFMC Western, Central, and Eastern Areas,

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[1] Pers. commun., August 1987, Alan Shimada, Resource Assessment and Conservation Engineering Division, Northwest and Alaska Fisheries Center, National Marine Fisheries Service, NOAA, Bin C15700, 7600 Sand Point Way NE, Seattle, WA 98115.

Table 1.--Final allocations and catches (t) of Pacific cod in the Gulf of Alaska, by fishery category, 1980-87.

	Allocations[a]					Catch			
Year	OY/TQ/TAC	TALFF	DAP	JVP	Reserve	Foreign	Joint venture	DAP	Total
1980	60,000	53,442	4,058	2,500	0	34,245	466	612	35,323
1981[b]	70,000	63,634	5,167	1,199	0	34,969	58	1,061	36,088
1982	60,000	51,688	6,902	1,410	0	26,937	193	2,250	29,380
1983	60,000	50,936	5,312	3,752	0	29,777	2,426	4,198	36,401
1984	60,000	32,518	9,320	18,162	0	15,896	4,649	3,231	23,776
1985	60,000	10,200	30,360	7,640	11,800	9,086	2,266	2,954	14,306
1986	75,000	15,520	35,000	9,480	15,000	15,211	1,357	8,051	24,619
1987	50,000	0	48,000	2,000	0	0	1,978	29,150	31,128
1988[c]	80,000	0	68,950	11,050	0	0	942	24,415	25,357

[a]OY = optimum yield: TQ = target quota (1987 only): TAC = total allowable catch (1988 only); TALFF = total allowable level of foreign fishing: DAP = domestic annual processing: v = joint venture processing.

[b]"Fishing year" 1981 was extended to 14 months in order that subsequent fishing years would coincide with calendar years.

[c]Preliminary catch data as of 22 August 1988 from Pacific Fisheries Information Network (PacFIN), Pacific Marine Fisheries Commission, Metro Center, Suite 170, 2000 SW. First Avenue, Portland, OR 97201.

respectively. (The NPFMC Western Area is the International North Pacific Fisheries Commission (INPFC) Shumagin Statistical Area, the NPFMC Central Area combines the INPFC Chirikof and Kodiak Areas, and the NPFMC Eastern Area encompasses the INPFC Yakutat and Southeastern Areas.) The TQ was lowered to 50,000 t for 1987 to protect incidentally caught-and prohibited species, since direct catch observations could not be made.

Total initial allocations of Pacific cod for 1985 reflected a trend toward replacement of TALFF by domestic annual harvest (DAH). Initially, 1985 TALFF was 10,000 t, less than half of the 23,830 t allocated on 1 January 1984, and less than a third of the 32,518 t final allocation for 1984. Two hundred additional tons were allocated by the end of 1985. The 1986 TALFF increased to 15,520 t. None was allocated in 1987 and the proportion of DAH allocated by regulatory area was restored to near the pre-1986 levels at 27, 56, and 17% for the NPFMC Western, Central, and Eastern Areas, respectively.

Landings

After 1977 the importance of Pacific cod in Gulf of Alaska groundfish catches grew in response to one or two large year classes that recruited to the fishery in 1980-81. It increased initially as a foreign-dominated fishery: receded as TALFF allocations were reduced: and increased again as a domestic fishery. Growing from 2,257 metric tons (t) in 1977 to 36,401 t in 1983, the annual total catch dropped to 14,306 t in 1985, but grew to 31,128 t in 1987 (Table 1). The decreases in 1984 and 1985 were due mostly to reductions in TALFF. In 1984-86 the. Japanese voluntarily limited their longliners to the INPFC Shumagin and Chirikof Areas to avoid gear conflicts with domestic fishermen and were permitted to fish only in waters shallower than 350 m to reduce the incidental catch of sablefish (*Anoplopoma fimbria*).

Historically, the majority of Pacific cod catches came from the INPFC Shumagin and Chirikof Areas (Table 2). Foreign trawl catches of Pacific cod were usually incidental to directed fisheries for other species, and longlines harvested most of the TALFF cod allocations. In 1987 the vast majority of landings were taken from the INPFC Kodiak Area reflecting the absence of foreign fishing effort in the western gulf and an increase in domestic effort near the principal landing port of Kodiak. Most recently 69% of DAH catches were taken by trawls, longlines accounted for 28%, and hook and line and pots the rest.

As of the end of 1987, management of Gulf of Alaska Pacific cod stocks did not appear to have reached a critical point since the total harvest was well below TQ (Table 2). However, on a more localized basis, landings from the NPFMC Central Area approached the 33,000 t TQ (Table 3). Preliminary figures for the first 8 months of 1988 put harvest levels at about 26,000 t,

Table 2.--Catch (t) of Pacific cod in the Gulf of Alaska by International North Pacific Fisheries Commission (INPFC) statistical area, 1978-87.

INPFC area	Year									
	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
Shumagin	5,591	3,982	8,705	11,579	7,343	9,178	11,748	8,426	12,751	2,464
Chirikof	4,707	6,541	18,627	19,115	14,361	15,675	5,844	3,224	3,778	2,378
Kodiak	1,488	3,829	5,871	3,036	5,543	9,567	6,149	2,564	7,213	25,870
Shelikof	--	--	--	--	--	--	--	--	471	--
Yakutat	202	371	2,004	2,249	2,108	1,963	1	<1	222	30
South-eastern	174	147	116	109	25	18	34	92	185	386
Total	12,162	14,870	35,323	36,088	29,380	36,401	23,766	14,306	24,620	31,128

Sources: Foreign and joint venture catches--personal communication with Jerald Berger, U.S. Foreign Fisheries Observer Program, Northwest and Alaska Fisheries Center, National Marine Fisheries Service, NOM, 7600 Sand Point Way NE., Bin C15700, Building 4, Seattle, WA 98115, U.S. catches 1978-80--Rigby (1984), U.S. catches 1981-87--Pacific Fishery Information Network (PacFIN), Pacific Marine Fisheries Commission, Metro Center, Suite 170, 2000 SW. First Avenue, Portland, OR 97201.

Table 3.--Catch (t) of Pacific cod in the Gulf of Alaska, by North Pacific Fishery Management Council (NPFMC) regulatory area, 1978-87.

Regulatory area[a]	Year									
	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
Western	5,591	3,982	8,705	11,579	7,343	9,178	11,748	8,426	12,751	2,464
Central	6,195	10,370	24,498	22,151	19,904	25,242	11,993	5,788	11,462	28,248
Eastern	376	518	2,120	2,358	2,133	1,981	35	92	407	416
Total	12,162	14,870	35,323	36,088	29,380	36,401	23,776	14,306	24,620	31,128

[a]The NPFMC Western regulatory area -is the International North Pacific Fisheries Commission (INPFC) Shumagin statistical area, the NPFMC Central Area combines the INPFC Chirikof and Kodiak Areas, and the NPFMC Eastern Area encompasses the INPFC Yakutat and Southeastern Areas.

Sources: Foreign and joint venture catches--personal communication with Jerald Berger, U.S. Foreign Fisheries Observer Program, Northwest and Alaska Fisheries Center, National Marine Fisheries Service, NOM, 7600 Sand Point Way NE., Bin C15700, Building 4, Seattle, WA 98115; U.S. catches 1978-80--Rigby (1984); U.S. catches 1981-87--Pacific Fishery Information Network (PacFIN), Pacific Marine Fisheries Commission, Metro Center, Suite 170, 2000 SW. First Avenue, Portland, OR 97201.

a third of the total TAC. It is not likely that total 1988 DAB allocations will be harvested in any of the NPFMC regulatory areas.

CONDITION OF STOCKS

Relative Abundance

Japan-U.S. Cooperative Longline Survey

Although its geographic coverage has been distributed along the outer continental shelf and upper slope, results of the annual (1979-87) Japan-U.S. longline surveys suggest that in 1986 the relative number of Pacific cod in the gulf was about 66% of that found in 1979 and 1980, and that the relative population weight was only 55.3% of that found in 1979 (Teshima 1987). Yoshimura and Sasaki (1987) qualify this point by showing that the major decreases were limited to the INPFC Yakutat and Chirikof Areas and that catch rates increased in the INPFC Shumagin and Kodiak Areas. Indices of abundance catch per unit of effort (CPUE) derived from the Japanese-reported commercial longline fishery in the INPFC Shumagin and Chirikof Areas indicate that the cod population decreased 34 and 47%, respectively (Teshima 1987). Preliminary results of the 1987 survey show that CPUE continued to increase in the INPFC Shumagin Area, was up sharply in the INPFC Chirikof Area, but was down about a third in the INPFC Kodiak Area, which is where the bulk of the 1987 landings were harvested. Catch rates in the INPFC Yakutat Area were relatively high although only half of the magnitude found in the western gulf. Increases in relative abundance of cod in the western Gulf of Alaska and decreases in the INPFC Kodiak Area may reflect the concentration of landings from the latter area and diminished fishing effort in the former.

Generally, Japanese-reported longline catch statistics show a similar trend toward increasing Pacific cod CPUE from 1978 to 1985 and a small decrease between 1985 and 1986 (Teshima 1987).

U.S. Longline Survey in the Gulf of Alaska

During the summers of 1987 and 1988 the National Marine Fisheries Service (NMFS) conducted longline surveys occupying the same stations as the cooperative survey mentioned above. The only comparisons that can be made at this time are between the unweighted size compositions for Pacific cod sampled in the INPFC Shumagin and Chirikof Areas (Fig. 1). Basically, the two length frequencies are very similar, although the principal mode in the latter year's distribution shifted to the left about a centimeter (from 64 to 63 cm).

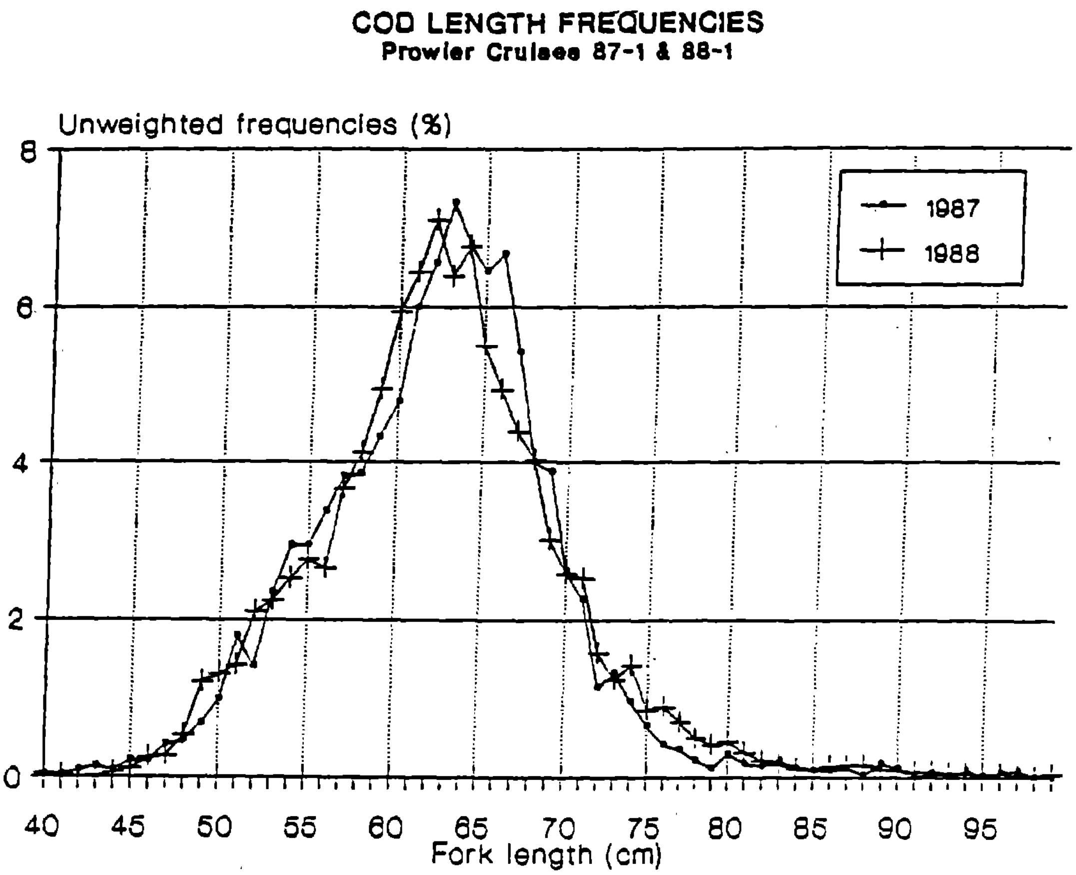

Figure l.--Unweighted length frequencies collected during the 1987 and 1988 U.S. longline survey, from the INPFC Chirikof and Shumagin statistical areas.

Absolute Abundance

The first U.S.-Japan cooperative Gulf of Alaska bottom trawl survey was conducted in 1984 and was followed by another in 1987. These were the most comprehensive trawl surveys ever completed in the region, having the general objective of determining the abundance, distribution, and biological condition of groundfish stocks in the central and western Gulf of Alaska on a triennial basis. To complement those surveys, others were conducted in the eastern Gulf of Alaska utilizing vessels chartered by the NMFS.

Catches of Pacific cod were standardized by vessel and gear-specific fishing power coefficients and adjusted to the most efficient trawl. The adjusted catches were used to calculate CPUE and biomass by INPFC area and 100 m depth interval. Complicating direct comparison of the survey results was the nonstandard nature of the Japanese sampling gear used in 1984 and 1987. In 1984, the Japanese trawl was more efficient at capturing cod than the U.S. trawl by a factor of about 1.7, so catches made by the U.S. trawl were adjusted accordingly. However, the Japanese trawl used in 1987 had different fishing characteristics and was less efficient at capturing cod than was its predecessor. Thus, if 1987 abundance estimates were calibrated to the 1987 Japanese trawl, they would be conservative relative to the 1984 estimates. Although this fact makes comparison of abundance estimates between the 2 years problematic, a valid comparison can be made by using the, CPUEs observed for the U.S. trawl during the 2 years to obtain a 1987 abundance estimate. This can be done by multiplying the 1984 abundance estimate (calibrated to the 1984 Japanese trawl) by the ratio of CPUEs observed for the U.S. trawl (1987 divided by 1984 CPUE). Using this procedure, the best estimate of total abundance was 627,679 t in 1984 and 627,710 t in 1987. Gear standardization was not a problem in the eastern Gulf of Alaska, but inadequate sample density and dispersed sample periods complicate between-survey comparisons. Abundance of Pacific cod in the eastern gulf was low during both years.

Current Exploitable Biomass

The U.S.-Japan cooperative Gulf of Alaska trawl surveys were designed to sample a broad part of the area where all ages and sizes of groundfish are found. Thus the surveys detected parts of stocks that had not yet recruited to the fisheries and the resultant estimated biomasses contain size categories not targeted by commercial vessels. Based on a 45 cm length at recruitment, 9% of Pacific cod biomass that was detected by the 1984 Gulf of Alaska cooperative trawl survey would be undersized, as compared to 11% in 1987. These calculations imply 1984 and 1987 exploitable biomass estimates of 571,188 t and 558,662 t, respectively. If the length at recruitment were 50 cm, these estimates would fall to 508,420 t and 520,999 t, respectively.

Results of stock reduction analysis (using a 45 cm recruitment length) project a 1989 exploitable biomass level of 498,044 t.

RECRUITMENT STRENGTHS

Determining the age of Pacific cod has proven to be a frustrating task: scale ages have been recognized as unsatisfactory since the early 1980s, the recently developed fin ray ageing technique has never been validated satisfactorily, and Gulf of Alaska samples have not been collected for production reading. Only this year has the ageing unit at the Northwest and Alaska Fisheries Center (NWAFC) identified otoliths as the preferred structure for ageing Pacific cod. Until samples can be gathered and production reading started, then, relative year class strengths can be estimated only by using ad hoc length-at-age assumptions to demarcate year class boundaries within observed length frequency distributions. To this end, it will be assumed here that lengths 1-20 cm correspond to age 0^+ fish, lengths 21-30 cm correspond to age 1^+ fish, lengths 31-40 cm correspond to age 2^+ fish, and lengths 41-50 cm correspond to age 3^+ fish.

Looking first at the size composition data from the 1984 U.S.-Japan cooperative bottom trawl survey, it can be seen that the 2' age group (1982 year class) was relatively abundant in the INPFC Shumagin Area (Fig. 2). In the INPFC Chirikof and Kodiak Areas, on the other hand, the 2^+ age group was not abundant. Cod from the 0^+ age group (1984 year class) were found as a component of relatively dense semipelagic schools along the edge of Shelikof Trough northeast of Chirikof Island and in lower Shelikof Strait near the Alaska Peninsula. The possibility of a relatively strong 1984 year class was investigated further in 1985 during a late summer trawl survey of juvenile groundfish in the Kodiak Island to Shumagin Island region. However, juvenile cod were rarely caught during the survey, which was largely exploratory in nature. A second trawl survey for juvenile groundfish was conducted in 1986 with similar results.

Turning to the 1987 cooperative trawl survey, the modes in the length frequency distributions indicate that the 2^+ age group (1985 year class) was relatively large (Fig. 3). In contrast, the 3^+ age group (1984 year class) does not appear to be unusually large. Based on the relative showings of the 1^+ age group during the two triennial surveys, it appears that the 1986 year class (as observed in 1987) might be small compared to the 1983 year class that was detected in 1984.

Comparisons of size compositions from the 1984 and 1987 cooperative trawl surveys show that the 1987 population was composed of slightly smaller fish, indicating a decline in abundance of the once-dominant year classes spawned in 1977 and 1978 (Figs. 2 and 3). The decline in the 1977-78 year classes is

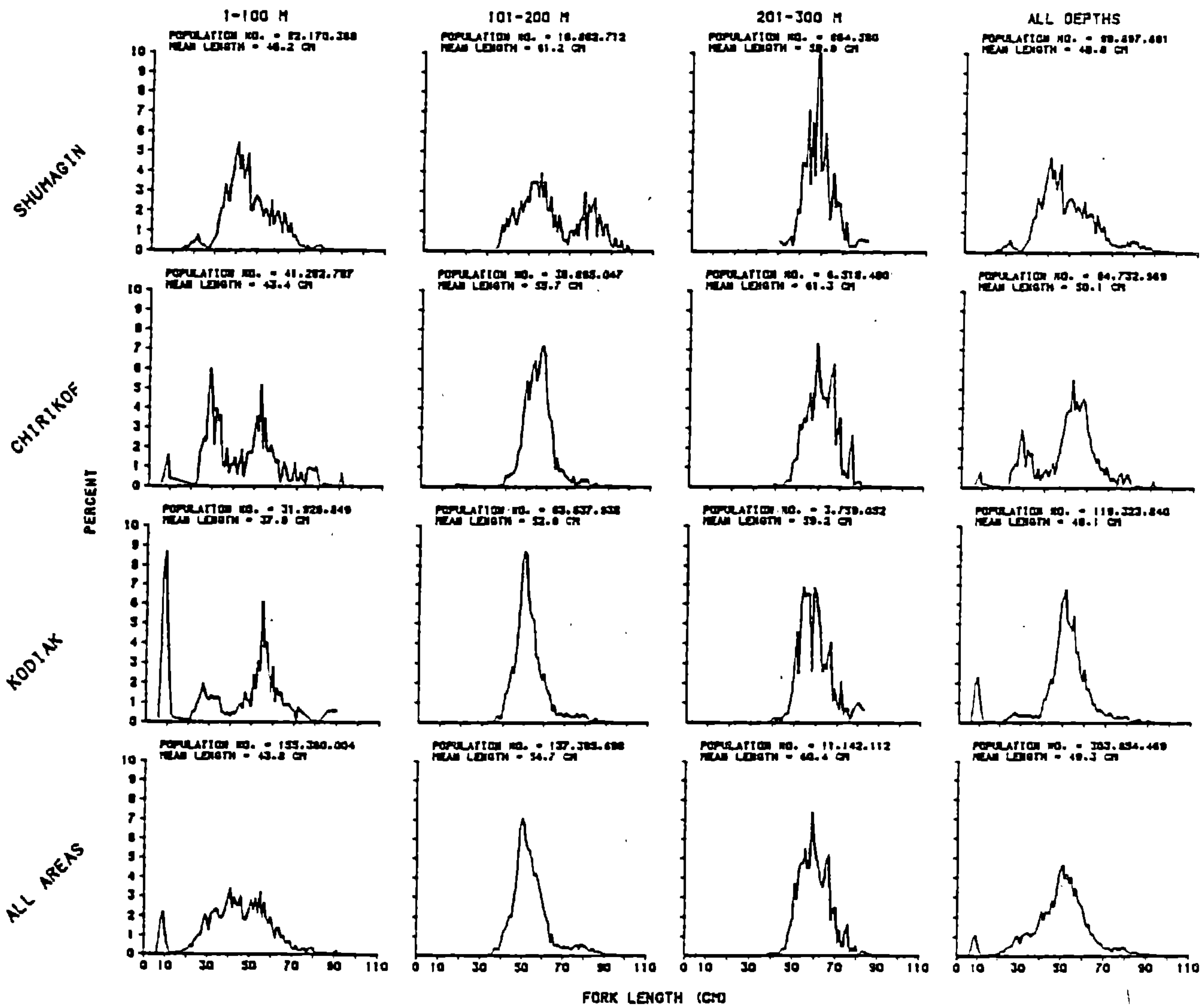

Figure 2.--All-vessel size compositions for Pacific cod sampled in the International North Pacific Fisheries Commission Shumagin, Chirikof, and Kodiak statistical areas during the 1984 U.S.-Japan cooperative bottom trawl survey of the central and western Gulf of Alaska, by 100 m depth stratum.

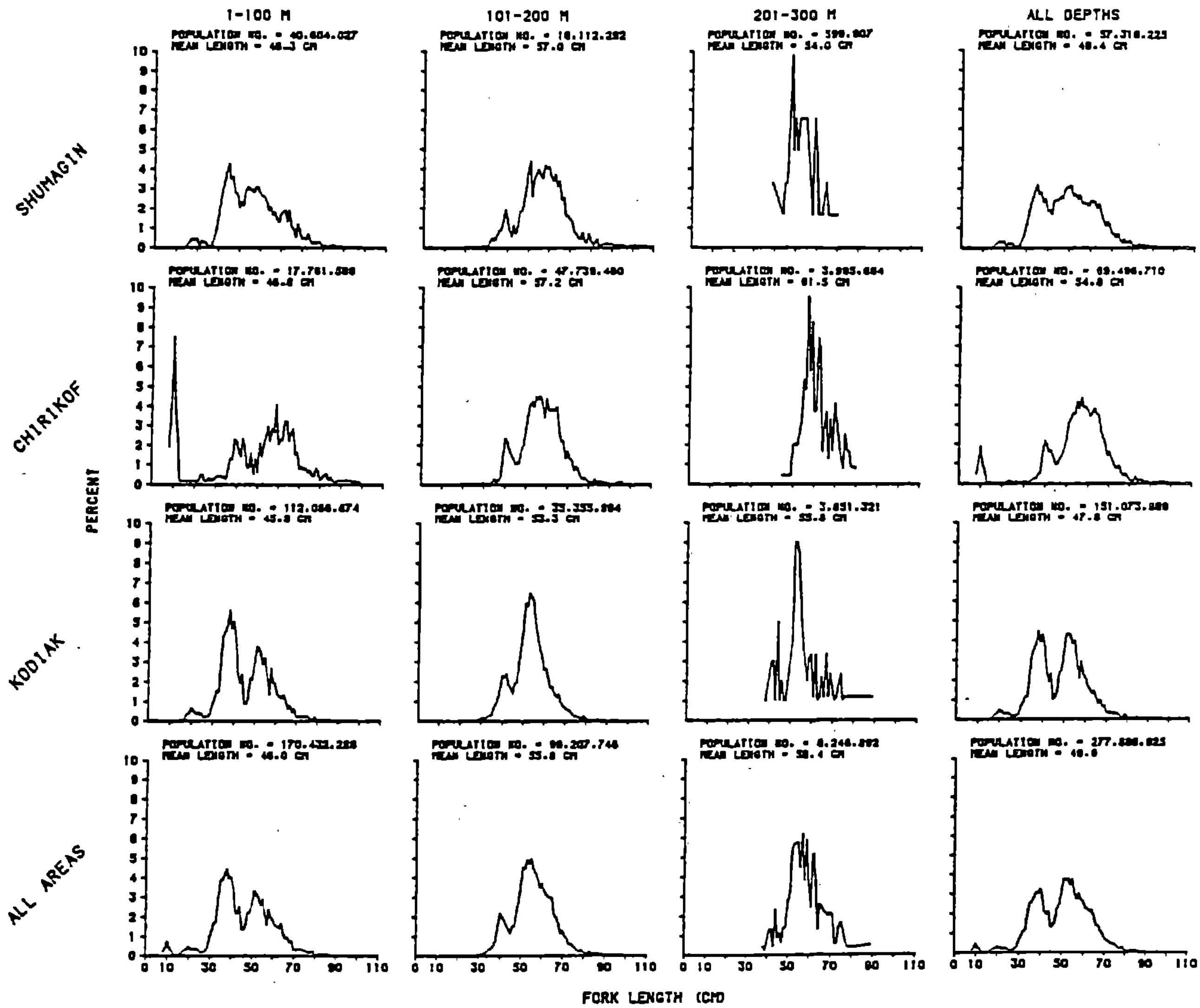

Figure 3.--All-vessel size compositions for Pacific cod sampled in the International North Pacific Fisheries Commission Shumagin, Chirikof, and Kodiak statistical areas during the 1987 U.S.-Japan cooperative bottom trawl survey of the central and western Gulf of Alaska, by 100 m depth stratum.

also borne out by size composition data from the Japanese longline fishery collected by the U.S. Foreign Fisheries Observer Program (Zenger and Blackburn 1987). In no case has recent recruitment approached the (presumed) levels of the 1977-78 year classes.

BIOLOGICAL PARAMETERS

Parameter values employed herein were based on estimates derived for the eastern Bering Sea stock of Pacific cod by Thompson (1988). Parameters specific to Gulf of Alaska cod stocks will be estimated as age-at-length data become available.

Natural Mortality, Age of Recruitment, and Maximum Age

Thompson (1988) estimated natural mortality at 0.29, although he noted that this value was lower than most previous estimates. The age of recruitment was set at 3 years. Although Thompson set maximum age at 8 years, this parameter is not utilized in the present assessment.

Length and Weight at Age

Thompson (1988) gave the following length-at-age and weight-at-length equations:

$$L(age) = 105.4*(1-\exp(-0.2367*(age-1.057))), \text{ and}$$

$$W(L) = 0.0061*L^{3.1635},$$

where L = length in cm, and W = weight in g. The above parameters were used in the present assessment to derive values for the Brody weight-at-age coefficients (rho and omega) of 1.0613 and -1.1489, respectively (Kimura 1985).

Historical Exploitation Rates

If the NWAFC trawl survey biomass estimates can be taken to represent mean annual biomass, then the instantaneous rate of fishing mortality can be estimated for each survey year by dividing catch (in biomass) by the exploitable portion of the survey biomass estimate. Assuming knife-edge recruitment at 45 cm, the exploitable biomass of the stock was 571,188 t in 1984 and 558,662 t in 1987. Given catches of 23,766 t in 1984 and 31,128 t in 1987, fishing mortality rates in those years were 0.042 and 0.056, respectively. These fishing mortality rates translate into exploitation rates of 3.6% and 4.7%, respectively.

MAXIMUM SUSTAINABLE YIELD

Although an estimate of maximum sustainable yield (MSY) is required by the Magnuson Fishery Conservation and Management Act (MFCMA), it should be- noted that the MSY concept might not be particularly useful for managing stocks which exhibit wide fluctuations in recruitment, as the Gulf Of Alaska Pacific cod stock appears to do. Nevertheless, MSY for this stock was estimated at 88,000-177,000 t by Low et al. (1979) and at 95,000-190,000 t by Zenger and Cummings (1983) based on various Gulf of Alaska groundfish surveys that were conducted in 1980 and 1981. Zenger and Blackburn (1987) utilized the Alverson and Pereyra (1969) equation to estimate MSY at 125,000 t, but the instantaneous natural mortality rate of 0.45 (Bakkala and Wespestad 1985) used in this analysis was probably too large. The Alverson-Pereyra method is also limited by its strong assumptions that the biomass level corresponding to MSY (B_{msy}) is' one-half the virgin level and that the fishing mortality rate corresponding to MSY (F_{msy}) is equal to the natural mortality rate.

To secure an alternative estimate of MSY, the method of stock reduction analysis (SPA) (Kimura and Tagart 1982; Kimura et al. 1984; Kimura 1985) was employed. The analysis assumed a Beverton-Halt (1957) stock-recruitment curve, which required the specification of a shape parameter A (Kimura 1988). The value of A can range from 0 (proportional recruitment) to 1 (constant recruitment).

Since there is no time series of stock-recruitment data for Gulf of Alaska Pacific cod, it was difficult to establish a value for A independently. However, it was possible to find a best estimate of this parameter by analyzing the SPA output that resulted from the full range of possible A values. The SRA was conducted by choosing tentative values for A, and finding the 1971 (presumed virgin) biomass and recruitment levels that, when subjected to the observed time series of catch data, resulted in a 1984 biomass level equal to the recruited portion (145 cm) of the 1984 survey biomass estimate (571,188 t). This procedure resulted in the output shown in Table 5.

Table 5.--output of stock reduction analysis under various values of the stock-recruitment parameter A.

A	B1	R1	MSY	B_{msy}	F_{msy}	U_{msy}
1.0	728,096	19,731	40,988	201,545	0.265	0.203
0.9	729,921	19,780	32,522	246,717	0.164	0.132
0.8	731,749	19,830	26,392	274,583	0.117	0.096
0.7	733,577	19,879	21,451	295,960	0.087	0.072
0.6	735,402	19,929	17,272	311,032	0.066	0.056
0.5	737,231	19,979	13,625	327,847	0.049	0.042
0.4	739,060	20,028	10,378	337,829	0.036	0.031
0.3	740,888	20,078	7,447	347,252	0.025	0.021
0.2	742,716	20,127	4,762	368,277	0.016	0.014
0.1	744,544	20,177	2,293	378,625	0.007	0.006
0.0	746,370	20,226	0	-	0.000	0.000

Bl = virgin biomass, Rl = virgin recruitment, MSY = maximum sustainable yield, B_{msy} = biomass at MSY, F_{msy} = fishing mortality rate at MSY, U_{msy} = exploitation rate at MSY.

Then, for each tentative A value, the projected 1987 biomass level was compared with the recruited portion of the 1987 survey biomass estimate (558,662 t). A weighting factor was then calculated, which was proportional to the reciprocal of the 1987 deviation squared. These weights were applied to the exploitation rates shown in Table 5 in order to obtain a weighted average exploitation rate, as shown in Table 6.

Table 6.--Calculation of weighted average exploitation rate, based on accuracy of 1987 biomass projection.

A	$d=B(87)-\hat{B}(87)$	$w=10^9/d^2$	wU_{msy}	
1.0	5,095	38.522	7.820	
0.9	8,150	15.055	1.987	
0.8	11,155	8.036	0.771	
0.7	14,110	5.023	0.362	
0.6	17,015	3.454	0.193	
0.5	19,870	2.533	0.106	
0.4	22,676	1.944	0.060	
0.3	25,434	1.546	0.032	weighted
0.2	28,143	1.263	0.018	average
0.1	30,805	1.054	0.006	exploit.
0.0	33,420	0.895	0.000	rate
Total		79.326	11.355/79.326 = 0.143	

It is interesting to note that the weighted average exploitation rate calculated above is nearly identical to the MSY exploitation rate calculated by Thompson (1988) for the eastern Bering Sea cod stock (U_{msy} = 0.145). The weighted average exploitation rate of 0.143 corresponds to an A value of 0.923, which in turn corresponds to the "best estimates" of MSY and related quantities in Table 7.

Table 7.--SRA "best estimate" output, based on weighted average exploitation rate.

A	B1	R1	MSY	B_{msy}	F_{msy}	U_{msy}
0.923	729,501	19,769	34,190	239,284	0.179	0.143

ACCEPTABLE BIOLOGICAL CATCH

The North Pacific Fishery Management Council (NPFMC) has demonstrated a preference for applying a constant exploitation rate strategy in managing the various stocks within the Gulf of Alaska groundfish complex. The NPFMC's Scientific and Statistical Committee has expressed a particular interest in exploitation rates corresponding to $F_{0.1}$, (Gulland and Boerema 1973), F_{msy}, F_{max} (i.e., the fishing mortality rate corresponding to the maximum yield per recruit), and F = M.

Because of potential ambiguities in interpreting $F_{0.1}$, and F_{max}, it may prove helpful to note the methodology used in this assessment. For $F_{0.1}$, two rates were calculated. The first ($F_{0.1a}$) was derived from the sustainable yield curve, which was generated using an A value of 0.923. The second ($F_{0.1b}$) was derived from the yield-per-recruit curve, which- was generated using an A value of 1 (i.e., constant recruitment). The same yield-per-recruit curve was used to derive F_{max}. This fact is noted here because some authors have derived F_{max} from a yield-per-recruit curve that incorporates density-dependent recruitment (e.g., Sissenwine and Shepherd 1987).

The original implementation of Deriso's delay-difference equation assumes that exploitation rate is represented by the term 1-exp(-F), implying that the entire catch is taken instantaneously at the start of the year (Deriso 1980). In contrast, the implementation used in SRA assumes the standard form for exploitation rate, implying a more realistic assumption of continuous harvesting. However, this requires that the weight-at-age parameters describe mean weight during the year, whereas Deriso's delay-difference equation is predicated on the assumption that the weight-at-age parameters describe weight at the start of the year. Despite this minor discrepancy, the standard exploitation rate shall be used here for consistency with the rest of the SPA results.

To determine acceptable biological catch (ABC), then, all that is required is to multiply projected 1989 exploitable biomass (498,044 t) by the exploitation rate corresponding to the desired F value. The complete set of F values (together with corresponding exploitation rates and ABC levels) is shown in Table 8. For comparison, sustainable yield and equilibrium exploitable biomass curves are shown in Figures 4 and 5, respectively, with the F values from Table 8 highlighted.

Table 8.--Selected fishing mortality (F) values with corresponding exploitation rates (U) and 1989 acceptable biological catch (ABC) levels.

	F	U	ABC
$F_{0.1a}$	= 0.125	0.102	50,800
$F_{0.1b}$	= 0.155	0.125	62,256
F_{msy}	= 0.179	0.143	71,220
F_{max}	= 0.265	0.203	101,103
F=M	= 0.290	0.220	109,570

$F_{0.1a}$ - Fishing mortality rate at which the slope of the sustainable yield vs. fishing mortality curve is one-tenth of the slope at the origin, assuming the best estimate of the stock-recruitment parameter A.

$F_{0.1b}$ - Fishing mortality rate at which the slope of the sustainable yield vs. fishing mortality curve is one-tenth the slope at the origin, assuming A = 0.

F_{msy} - Fishing mortality rate associated with maximum sustainable yield, assuming the best estimate of the stock-recruitment parameter A.

F_{max} - Fishing mortality rate associated with maximum yield per recruit, assuming A = 0.

F=M - Fishing mortality rate set equal to the natural mortality rate.

The NPFMC in the past has expressed a preference for utilizing an F_{msy}, harvest strategy. Furthermore, since the MFCMA states that MSY should be the starting point for calculation of OY, and since an F_{msy} harvest strategy should

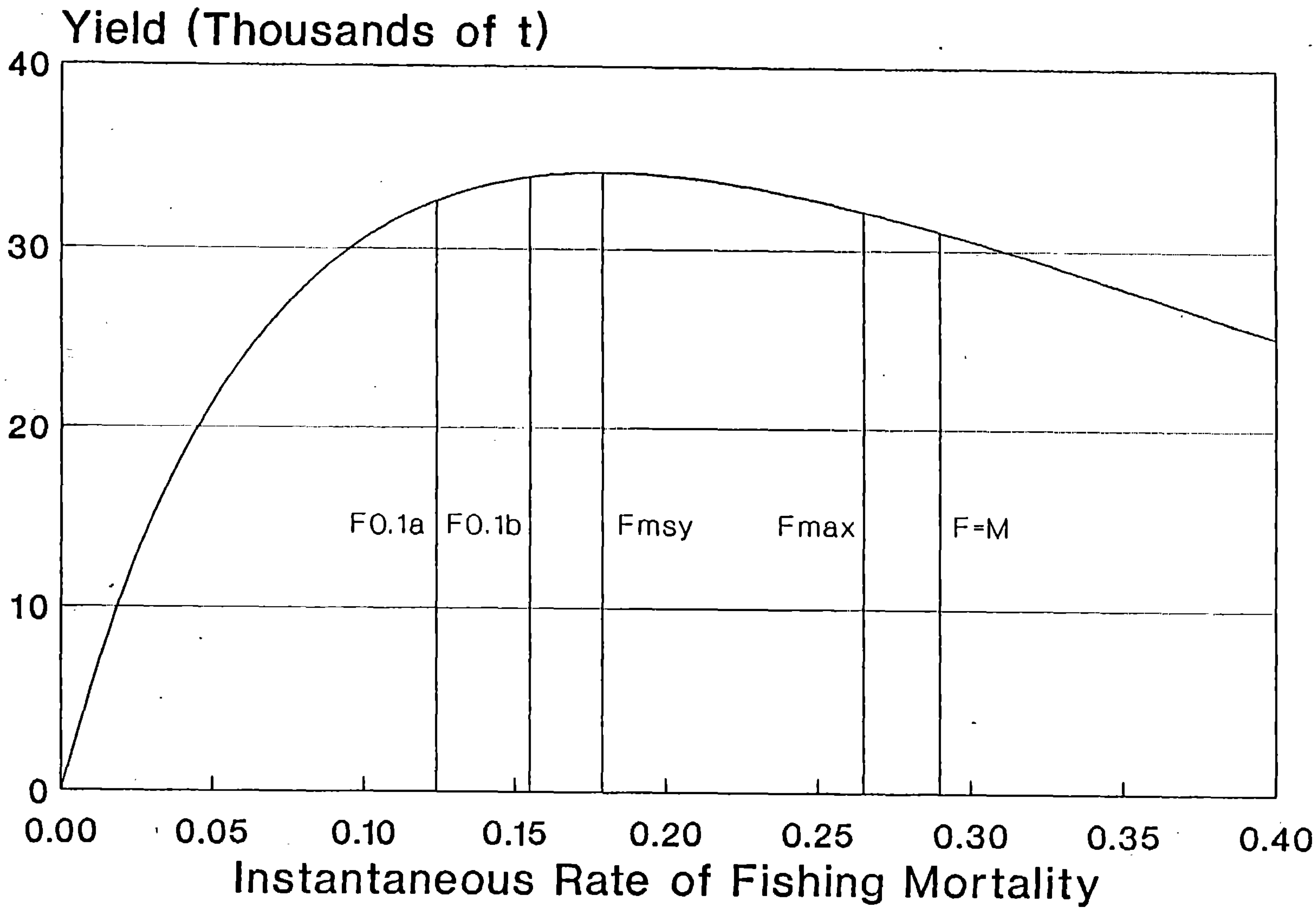

Figure 4.--sustainable yield of Pacific cod under various levels of fishing mortality.

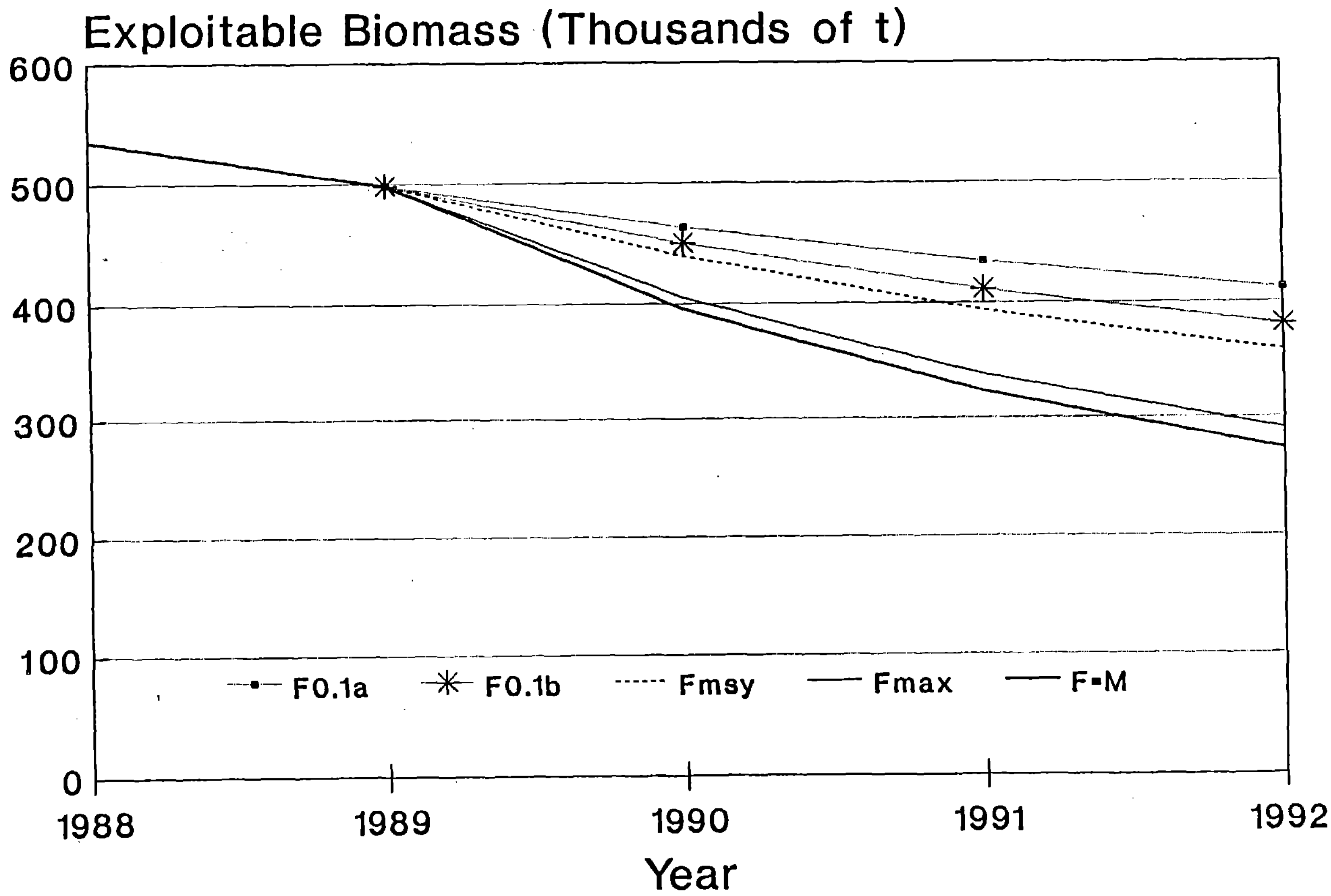

Figure 5. --Equilibrium biomass of Pacific cod under various levels of fishing mortality.

produce MSY, a reasonable recommendation for 1989 ABC would be the catch corresponding to F_{msy} (71,220 t).

BIOMASS PROJECTIONS

Model projections of exploitable biomass from SRA are given in Figure 6 for the years 1988-92 under each of the F values shown in Table 8. This figure indicates that the stock should continue to decline moderately from the recent high levels when exploited at a reasonable rate. Since these projections are based in part on a deterministic stock-recruitment relationship, they obviously would not reflect the impact of anomalously small or large year classes, should any enter the fishery during the next few years.

RESEARCH IN PROGRESS

Data collection for the second U.S. longline survey of the Gulf of Alaska has been completed. Data editing and analysis will follow this fall and winter. An important aspect of the analysis will be a comparison to the results of the Japan-U.S. cooperative longline survey. Indices of cod abundance and size composition data are extracted from the survey data.

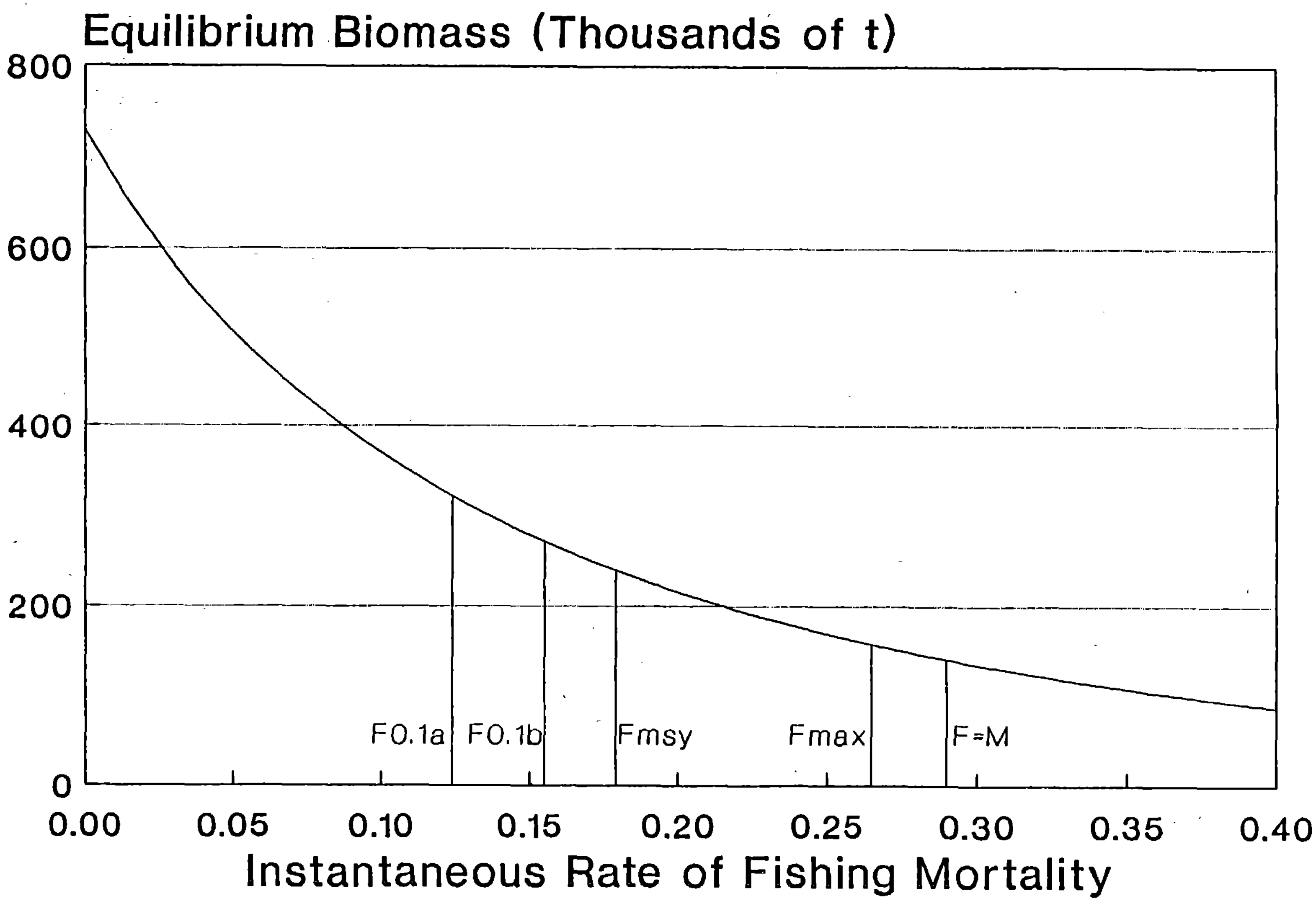

Figure 6.--Projected exploitable biomass of Pacific cod through 1992 under various levels of fishing mortality.

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SABLEFISH

by

Jeffrey T. Fujioka[1]

INTRODUCTION

The sablefish (Anoplopoma fimbria) resource in the northeastern Pacific Ocean extends from northern Mexico to the Gulf of Alaska, westward to the Aleutian Islands, and into the Bering Sea. This resource has been harvested by U.S. and Canadian fishermen since the early 1900s, but catches were relatively small and generally limited to areas near fishing ports from California to southeastern Alaska until expansion of foreign fleets began in the late 1950s.

CATCH HISTORY

Annual catches in the Gulf of Alaska averaged about 1,500 metric tons (t) in 1930-50, and exploitation rates remained low until the Japanese longline fleet expanded into the Gulf of Alaska. Catches rapidly escalated during the mid 1960s until the record all-nation catch from the Gulf of Alaska reached, 37,500 t in 1972 and averaged about 28,000 t in 1973-76.

Evidence of declining stock abundance led to significant fishery restrictions from 1977 to 1985, and total catches were reduced substantially. Catches in 1978-83 averaged 9,206 t in the Gulf of Alaska and have increased steadily since then to 26,325 t in 1987 (Table 1). In 1988, the reported landings have so far totaled 29,867 t (as of 22 October 1988).

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Table 1.--Annual catch (t) of sablefish in the Gulf of Alaska, 1977-88.

Year	Foreign	Domestic JVP	Domestic DAP	Total*
1977	15,961	0	1,179	17,140
1978	7,128	0	1,738	8,866
1979	6,885	18	3,447	10,350
1980	6,138	20	2,384	8,542
1981	7,976	0	1,941	9,917
1982	5,645	1	2,910	8,556
1983	4,966	275	3,761	9,002
1984	1,108	528	8,594	10,230
1985	38	226	12,215	12,479
1986	1	45	21,568	21,614
1987	0	180	26,145	26,325
1988	0	36	29,867	29,867

* Includes catches reported from inside waters of State of Alaska. Catch from EEZ waters for 1988 equals 28,363 t.
JVP = joint venture processing.
DAP = domestic annual processing.

CONDITION OF STOCKS

Relative Abundance

Since 1978 Japan and the United States have cooperated to survey sablefish in the Gulf of Alaska with longlines. The survey area is stratified by depth, and two indices of population abundance are computed: catch per effort in numbers weighted by respective strata areas to produce a relative population number (RPN) and catch per effort measured in weight multiplied by strata areas, to produce a relative population weight (RPW) (Sasaki 1986). Index values for the continental slope for depths 201-1,000 m are shown in Table 2 for the years 1979-88.

Table 2.--Index values (1,000's)- from the Japan-U.S. Cooperative Longline Survey as computed by Sigler (1988) for 1979-87, and preliminary values for 1988.

		Slope (201-1000 m)	
Area	**Year**	**RPN**	**RPW**
Gulf of Alaska	1979	223	651
	1980	203	537
	1981	255	671
	1982	365	987
	1983	347	953
	1984	369	1,011
	1985	467	1,456
	1986	471	1,437
	1987	428	1,370
	1988	483	1,503

RPW = Relative population weight.
RPN = Relative population number.

The population has increased significantly since 1979, with major increases occurring in 1982 and 1985. These increases have been attributed to recruitment and growth of the 1977 and 1980 year classes. The indices decreased slightly after 1985 and then increased again in 1988. This increase is in contrast to a decreased availability reported by some members of industry.

Absolute Abundance

Estimates of absolute biomass for the Gulf of Alaska are available from the 1984 and 1987 triennial trawl surveys. Recent information on the efficiency of nets used in the survey has revised the results previously reported for the 1984 survey. The total biomass estimate is revised upward from 536,400 to 577,463 t; however, the biomass deeper than 200 m has been revised downward approximately 24%. In 1987 the survey estimated total biomass at 443,800 t.

Exploitable Biomass

The biomass estimated for depths deeper than 200 m is considered to be exploitable biomass. Approximately 42% of total biomass during the 1984 trawl survey and 66% of the total during the 1987 survey was estimated to be deeper than 200 m.

Estimates of exploitable biomass for 1979 to 1988 are obtained by scaling estimates of relative biomass indices from the longline survey (201-1000 m RPWs) from 1979 to 1987 to estimates of absolute biomass. The estimates of absolute biomass used were 42% of the point estimate of the 1984 trawl survey, 42% of the lower confidence interval of the 1984 trawl survey, and 66% of the 1987 trawl survey biomass estimate. Values are further modified to include biomass from inside populations (this is necessary for analysis because catch data include catch from inside waters of southeast Alaska, an area not included in the EEZ and not part of the trawl survey) and to represent biomass at the beginning of the year by adding the annual catch that occurs between the beginning of the year and the time of the annual longline survey. The results scaled from the 1987 estimate are bracketed by the results scaled by the point estimate and the lower confidence interval from the 1984 survey (Table 3).

Table 3.--Estimates of exploitable biomass (1,000 t), 1979-88, based on estimate and lower confidence interval of the 1984 trawl survey, and the 1987 trawl survey. Values are adjusted to represent inside and outside waters of the Gulf of Alaska at the beginning of the calendar year.

	Scaled to trawl survey results		
Year	1984 Point est.	1984 Low est.	1987 Point est.
1979	177	127	157
1980	146	105	129
1981	182	130	161
1982	265	189	234
1983	257	183	227
1984	274	196	243
1985	396	284	351
1986	399	288	355
1987	387	282	345
1988	426	310	380

Catch at age analysis, adapted by Johnson and Quinn (1988) to Gulf of Alaska sablefish, provided estimates of exploitable biomass within the range above.

RECRUITMENT STRENGTHS

Increases in sablefish abundance since the late 1970s have been attributed to recruitment occurring mainly from the 1977 and 1980 year classes. Recruitment to the longline fishery occurred at approximately 5 years of age. Recruitment from other year classes through 1983 are thought to be of minor significance.

The length composition of samples taken in the 1986 Japan-U.S. cooperative longline survey indicated that the 1984 year class may be of above-average strength (Sigler 1988). Also, small (30-40 cm FL) sablefish, presumably 1984 year class, were more abundant than usual in inside waters of southeastern Alaska in 1985. Except for one small isolated bay, large concentrations of juvenile sablefish are not regularly seen. In 1981 abundant juveniles were observed in southeast Alaska, presumably of the 1980 year class, to which a significant recruitment in 1985 is attributed. Juveniles were also abundant during the summer of 1978 and 1979, corresponding to probable appearance of juveniles from the 1977 year class. Thus, the appearance of large numbers of juveniles in these waters may indicate a strong year class and recruitment in 1989 from the 1984 year class may be strong. However, a strong presence of this year class is not evident in 1988 sampling by Alaska Department of Fish and Game[2] in southeast Alaska or in the 1988 cooperative and domestic longline surveys[3]. Sablefish partially recruit to the survey area by age 4 and a strong year class would have been expected to be evident in the survey data.

BIOLOGICAL PARAMETERS

Natural Mortality, Age of Recruitment, and Maximum Age

A natural mortality rate of M = 0.10 is used in the yield analyses in this report. This compares to M = 0.22 estimated by Low et al. (1976) prior to the latest ageing techniques and M = 0.112 assumed by Funk and Bracken (1984). Johnson and Quinn (1988) used values of 0.10 and 0.20 in a catch at age analysis and noted that when M = 0.10 was used, estimated abundance trends agreed better with survey results.

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[2]Pers. commun., November 1988, Barry Bracken, Alaska Department of Fish and Game, P. 0. Box 667, Petersburg, AK 99833.

[3]Pers. commun., Dave Clausen, October 1988, Auke Bay Laboratory, Alaska Fisheries Science Center, NOAA, P.O. Box 210155, Auke Bay, AK 99821.

The average age of recruitment to the Gulf of Alaska slope where the longline fishery and survey takes place is considered to be 5 years. The maximum age of sablefish in the Gulf of Alaska is not determined: however, ages of 35 years have been read from samples from the trap survey. Canadian researchers report age determinations up to 55 years (McFarlane and Beamish 1983).

Length and Weight at Age

Von Bertalanffy equations for sablefish sampled from the Queen Charlotte Islands (McFarlane and Beamish 1983) are used to express length at age:

	females	males
Linf (asymptotic length)	**81.4**	**66.7**
K (Brody growth coefficient)	**0.249**	**0.290**
T(0) (length at time 0)	**-0.77**	**-1.07**

Following this equation a 5-year-old sablefish would be 62 cm and 55 cm in length for a female and male, respectively.

MAXIMUM SUSTAINABLE YIELD

Stock reduction analysis (SRA) was applied to the 1958-88 catch data. The time series of catch data was divided into two parts, 1958-78 and 1979-88, and SRA was applied to each part sequentially, linked with joint values for 1978 and 1979. The analysis was done in this way because no single model was found that was consistent with the biomass trend indicated by the longline survey, the catch history, and the assumption that the population decreased significantly from an unexploited equilibrium condition in 1958. The separate analyses allowed the 1979-88 part to be modified to follow estimates of 1979-88 exploitable biomass and provide an estimate of recruitment.

Both parts of the analysis assume the same natural mortality rate (M = O.lO), the same Schnute. (1985) growth parameters (rho = 0.80 and omega = 0.694) and the same age at recruitment (K = 5). Both parts are calibrated to the exploitable biomass level for 1979, B(79) = '177,000 t (scaled from the 1984 point estimate of biomass). The entire analysis was then repeated using B(79) = 127,000 t (scaled from the lower 95% confidence limit of the biomass estimate).

The analysis of the 1958-78 catches was done in the standard way, assuming a virgin biomass in 1958 and scaled to the 1979 biomass estimates. Beverton and Holt recruitment curves (see Kimura 1988) were used in this portion of the analysis, that is, A = 1.0 (constant recruitment), A = 0.889, and A = 0.480. Sustainable yields and equilibrium biomasses were computed using Schnute's (1985) form of the delay-difference equation (see

Kimura 1988). While virgin biomass, B(O), is relatively insensitive to the recruitment parameter chosen, maximum sustainable yield (MSY), B_{msy} (biomass that produces MSY), and F_{msy} (instantaneous fishing mortality rate at MSY) are highly sensitive to the recruitment parameter (A) chosen. A choice of MSY and F_{msy} from this portion of the analysis is highly dependent on the choice of the recruitment parameter.

For 1979-87, annual recruitment values R(i) are estimated by fitting biomass in the model, B(i), to annual estimates of exploitable biomass. The R(i)s obtained in this manner (and assumed by the model to be the actual recruitment) average 41,594 t when biomass is scaled to the point estimate and 33,077 t when biomass is scaled to the lower confidence limit.

The yields resulting from models assuming average constant recruitment of 41,594 t and 33,077 t can be computed using the Schnute (1985) delay-difference equation (Table 4). However, the model estimates that MSY occurs at 15% of virgin biomass. The population has actually never been estimated to be that low. The lowest biomass is estimated to have been during the years 1977-80, approximately 21-25% of virgin biomass (162,000 to 175,000 t for the biomass scaled to the point estimate or 114,000 to 125,000 t when scaled to the lower confidence level). The assumption of constant average recruitment may not hold when the biomass goes below these levels. Therefore, the model is truncated below the biomass levels estimated for 1977-80 (years which have produced successful year classes) and the maximum sustainable yield is considered to occur at these levels.

Table 4.--Results of stock reduction analysis from 1979 to 1988 scaled to the point estimate and lower confidence level of exploitable biomass as obtained from the 1984 trawl survey.

R(avg)	Virgin biomass	P	MSY	B_{msy}	F_{msy}	U_{msy}	$EY(F_{0.1})$
41,459	788,000	.54	42,000	175,000	0.29	0.240	36,900
33,077	626,000	.49	33,500	125,000	0.33	0.268	29,300

R(avg) - average recruitment estimated for 1979-88
P - B88/virgin biomass, B88 = 426,000 t, or 310,000 t
MSY - maximum sustainable yield
B_{msy} - biomass at MSY
F_{msy} - instantaneous fishing rate at MSY
U_{msy} - exploitation rate at MSY
$EY(F_{0.1})$ - equilibrium yield at $F_{0.1}$ (=.14)

An alternative to managing the population for MSY is to exploit the population at a level where the marginal increase in yield is one-tenth the marginal increase in a newly exploited population ($F_{0.1}$ policy). For an age of recruitment of 5 years and recruitment independent of biomass, this occurs when F = 0.14 (U = 0.124) and biomass, B($F_{0.1}$), is 37% of virgin biomass. For models estimated from the 1979-88 observations, $F_{0.1}$ management is more conservative than the truncated MSY level. Figures 1 and 2 summarize results from the 1979-87 analysis.

Environmental conditions may have been especially favorable during 1977-88, and the resulting yield estimates may be too high. Also note that the yields are long-term averages and that recruitment is not constant, but apparently quite low most of the time with occasional large year classes. For the 10 years from which the estimates are obtained, the model estimates that three of the years account for 75% of the total recruitment.

ACCEPTABLE BIOLOGICAL CATCH

All models indicate that current biomass is above B_{msy}. The 1979-88 point estimate results indicate that the stocks are being harvested at a level just below the long-term average equilibrium yield (EY) and that at current harvest levels the average population would be slightly higher. Alternatively, if it is assumed that the lower biomass estimate is correct, current harvest levels are slightly greater than EY and at current harvest levels the biomass will decrease slightly to a level where EY will increase to current harvest levels. The 1958-78 analysis estimated a virgin biomass that was less than the estimated current biomass, indicating that the recent recruitment has been unusually large and the population will decrease regardless of harvest levels.

Using the default definition of acceptable biological catch (ABC) as provided in the fishery management plan, an ABC can be computed using the estimates of population parameters just described. Because the current biomass is well above B_{msy}, this definition results in ABCs which are too high to provide practical management guidance for sablefish. If exploitation rate under an $F_{0.1}$ policy is applied to current biomass as determined from the point estimate, the ABC would be .124 x 426,000 t = 52,800 t, still rather high.

Acceptable Biological Catch Considerations

To examine risks stemming from the stochastic nature of the recruitment process and the random error in the biomass estimate, five harvest scenarios were examined in a pessimistic model that is scaled to the lower bound of the biomass estimate and has zero

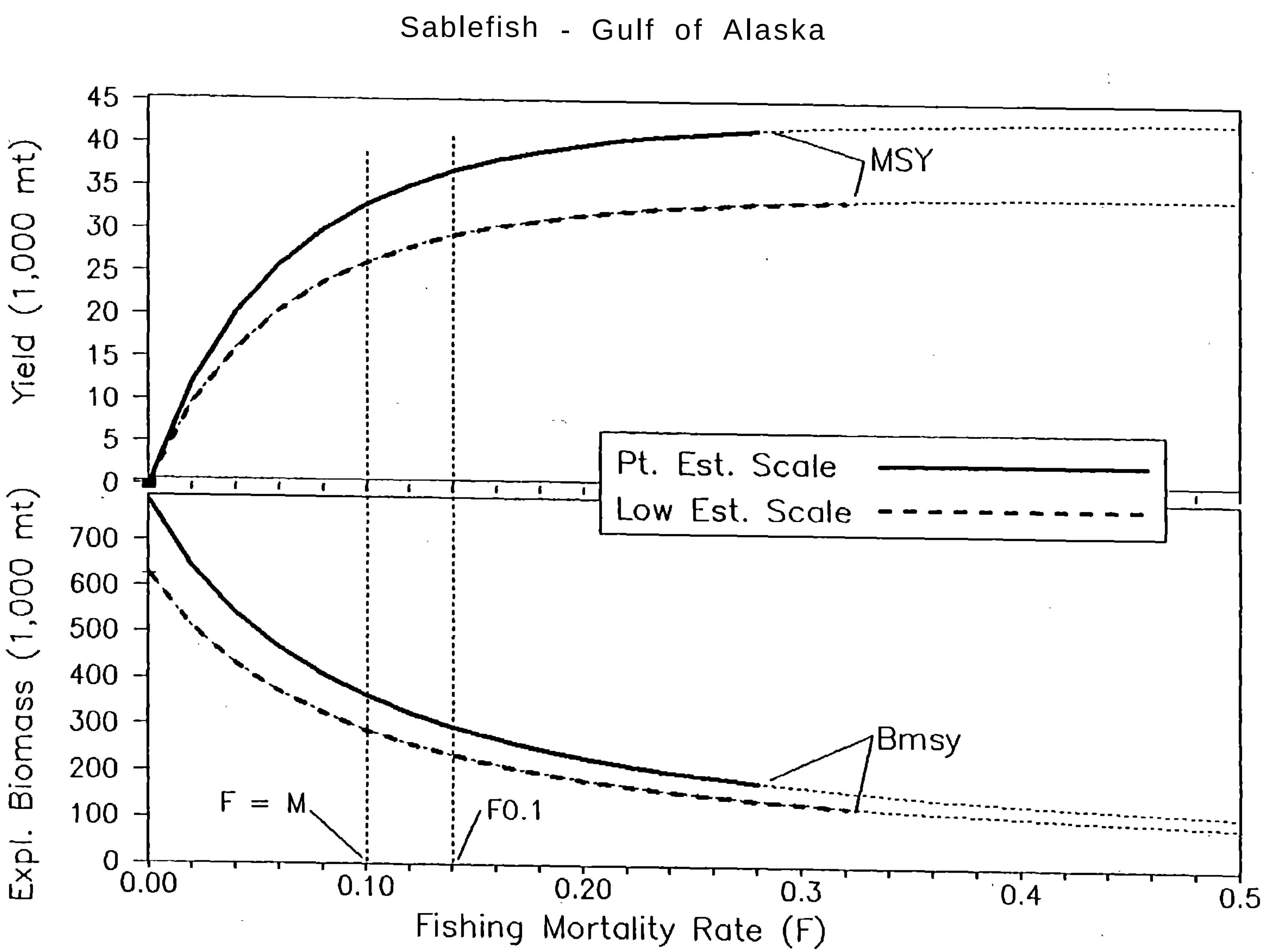

Figure 1.--Equilibrium yield and biomass as a function of fishing mortality rate (F), as estimated from stock reduction analysis scaled to the point estimate and the lower confidence interval of the 1984 biomass estimate.'

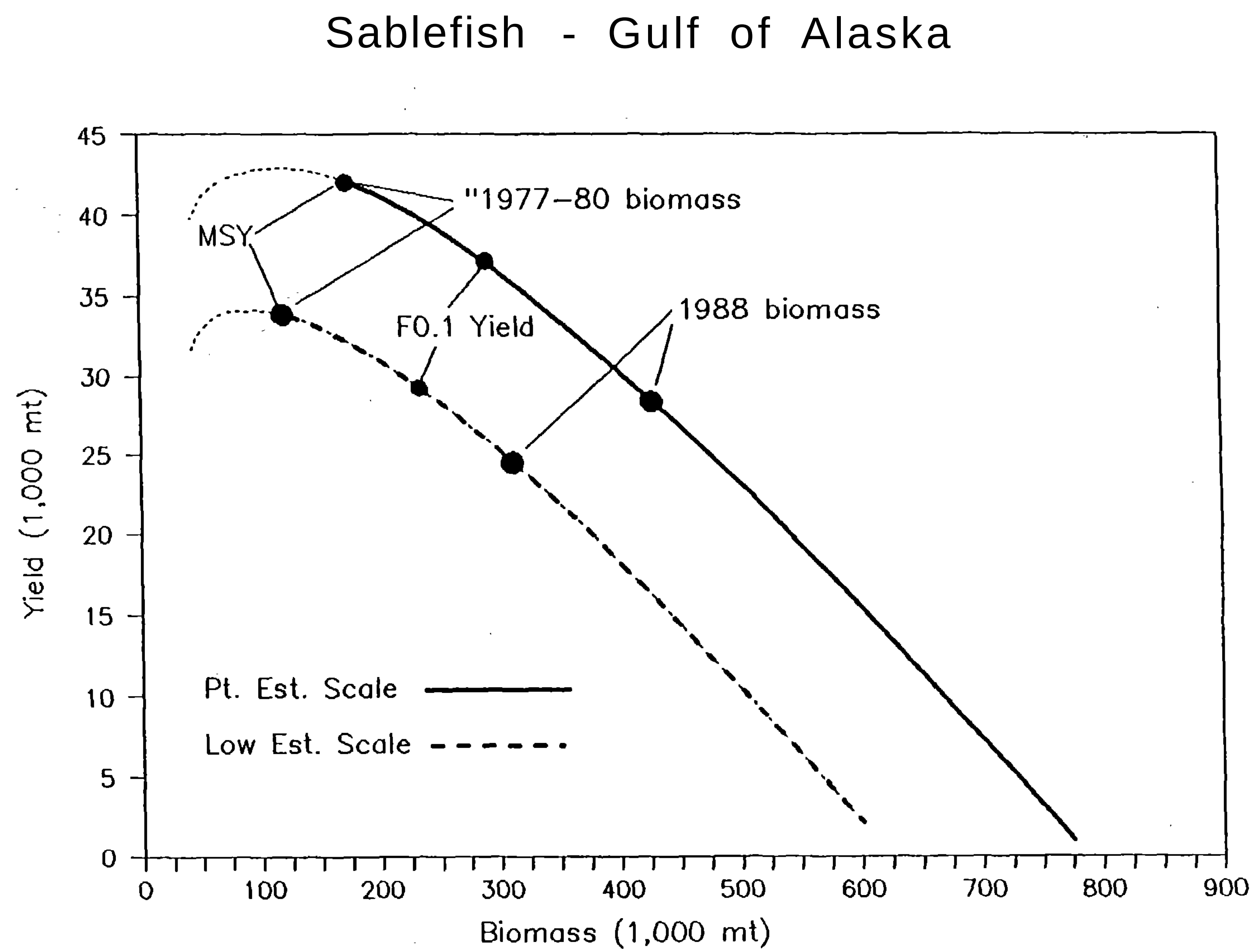

Figure 2. --Equilibrium yield as a function of biomass as estimated from stock reduction analysis scaled to the point estimate and the lower confidence interval of the 1984 biomass estimate.

recruitment through 1993. Confirmation of a strong 1984 year class has not materialized yet, and if it is weak, there is no indication another strong year class would recruit before 1993. The harvest scenarios compared include three constant harvest levels and two constant fishing rate policies: 20,000 t; 30,000 t; 40,000 t; $F_{0.1}$ exploitation rate X biomass (point. estimate scale): $F_{0.1}$ exploitation rate X biomass (lower confidence scale).

Examined under the pessimistic scenario, the model projects that at constant harvest levels of 20,000 t or less, the population would not decline to the low levels of abundance observed during 1977-80 until 1994 (Fig. 3), while a catch level of 30,000 t would decrease the population to the 1977-80 levels by the end of 1992. Catches of 40,000 t or greater applied each year would drive the population, by the end of 1992, below the 1977-80 levels.

When harvest levels are determined by multiplying the $F_{0.1}$ exploitation rate times the biomass estimated from the point estimate scale and applied in the pessimistic scenario, the population would be driven below the 1977-80 level by the beginning of 1992. If the biomass estimated from the lower confidence interval scale is multiplied by the $F_{0.1}$ exploitation rate to determine harvest levels, then the population would still be above the 1977-80 levels at the beginning of 1993 (Fig. 3).

These results indicate that for a pessimistic scenario of biomass and recruitment, a constant harvest level policy of 40,000 t and the $F_{0.1}$ harvest rate policy applied to the point estimate biomass scale would reduce the population too rapidly; therefore, these policies are not considered acceptable. A constant harvest of 20,000 t or a constant $F_{0.1}$ exploitation rate applied to the lower biomass scale would allow the population to remain above the 1977-80 level until 1993.

The 20,000 t and 30,000 t constant harvest level policies and the constant $F_{0.1}$ exploitation rate policy are compared in a scenario of lower confidence interva1 biomass scale but with average constant recruitment (Fig. 3). Because 20,000 t is well below equilibrium yield for current biomass, the population increases to higher levels where equilibrium yield decreases. At a constant catch level of 30,000 t, the population slowly decreases, eventually stabilizing slightly below the equilibrium biomass for the $F_{0.1}$ policy. Under the $F_{0.1}$ policy the population decreases more rapidly to the $F_{0.1}$ biomass with greater net harvest.

Under the $F_{0.1}$ exploitation rate policy, risk is acceptable in the pessimistic scenario, and in a constant recruitment scenario, the yield is greater than using acceptable constant harvest level policies. Therefore, it is recommended that the $F_{0.1}$ exploitation rate policy be applied to biomass determined using the lower confidence interval biomass scale projected to the beginning of 1989 assuming zero recruitment. A biomass of 276,700 t for 1989 is projected with the delay-difference equation assuming zero recruitment.- This value includes biomass for State of Alaska inside waters as explained in a preceding section and thus is adjusted to 249,030 t before applying the $F_{0.1}$ exploitation rate (0.124) to obtain an ABC of 30,880 t for the U.S. Exclusive Economic Zone.

It is noted that 30,880 t is greater than the equilibrium yield for the current biomass assuming average constant recruitment in the point estimate model. This is the proper strategy to apply to a population that is well above B_{msy} if the goal is to maximize yield.

Apportionment of Catch

Recent tagging studies demonstrate that movement of sablefish between areas is more significant than previously believed and that some size-specific movement may occur (Bracken 1982; Fujioka et al.' 1988). There has been some concern that an optimal apportionment strategy may exist that takes into account fish movement, as well as socioeconomic factors and differences in size or growth potential of fish residing in different areas and strata. As yet, there has been no quantitative evaluation of the effects of geographically concentrated harvests or estimates of an optimal geographic apportionment of the harvest. Until such an analysis is accomplished, the possibility continues to exist that an unapportioned or improperly apportioned gulfwide TAC could disrupt the distribution of the spawning stock or deplete a single aggregated spawning stock. However, the present apportionment scheme or moderate variations of it are not of concern. In 1988 the council apportioned the 28,000 t TAC amongst the NPFMC regulatory areas in proportion to the distribution of biomass in the 401-1,000 m slope and gully areas as estimated from the 1987 longline survey. The apportionment of RPW as estimated from the 1988 domestic longline survey are compared to last year's (the assessment for 1988) TAC apportionment:

	1988 RPW	1988 TAC apportionment
Western	0.16	0.145
Central	0.45	0.45
W. Yakutat	0.17	0.175
E. Yak/S.E.	0.22	0.23

Total Allowable Catch Considerations

In 1987 the North Pacific Fisheries Management Council (NPFMC) set the total allowable catch (TAC) below ABC. The NPFMC may wish to continue this policy to allow for possible underestimation of fishing mortality and overharvesting in the directed fishery. There has been recent concern that undocumented mortality and discards have increased due to highgrading because of bycatch trip limits in both the trawl and longline fisheries; use of crucifiers in the longline fisheries: discarding when prohibited species catch limits are reached: and increased losses during the directed fishery opening due to setting of excess amounts of gear and increased gear loss from entanglement.

The yield estimates reported here are influenced by reported catches from the years 1978 to 1988. The yield analysis compensates for consistently underestimated mortality, such that the estimates of sustainable yield have been reduced accordingly. However, if unreported mortality has increased recently and remains higher than average, the sustainable yield would be less than estimated.

Unreported mortality results in an effective fishing rate higher than assumed and the population response to the harvesting strategy would be misjudged. The sustainable yield estimates compensate for unreported mortality by underestimating recruitment, but this is not the case when projecting biomass response for given harvesting policies. This is especially clear when projecting biomass with zero recruitment, because there is no underestimated recruitment to compensate. Therefore, any unreported mortality that occurs during 1989 or later will decrease the population faster than projected. There is no current estimate of the amount of unreported mortality: however, if it was thought that a TAC of 25,000 t would generate an actual mortality of, for example, 30,000 t, the biomass trend labeled 30,000 t should be considered as shown in Figure 3.

It has been noted that the population decreased considerably in the early 1970s when reported catches averaged only 28,000 t. The amount of undocumented mortality during that period is not known any better than today's undocumented mortality is known.

The possibility is also noted that optimum management opportunities and economic yields may occur at harvest rates below those biologically acceptable.

BIOMASS PROJECTIONS

Figure 3 illustrates the preceding acceptable biological catch assessment, showing the estimated population trend over time as estimated by the 1979-87 longline survey, and as projected by the SRA model beyond 1987 at various catch levels. The population trends are shown for the two biomass scales (the point estimate and the lower confidence bound of the biomass) and the projected levels are estimated assuming average constant recruitment for the point estimate scale, and average and zero recruitment for the more pessimistic scale.

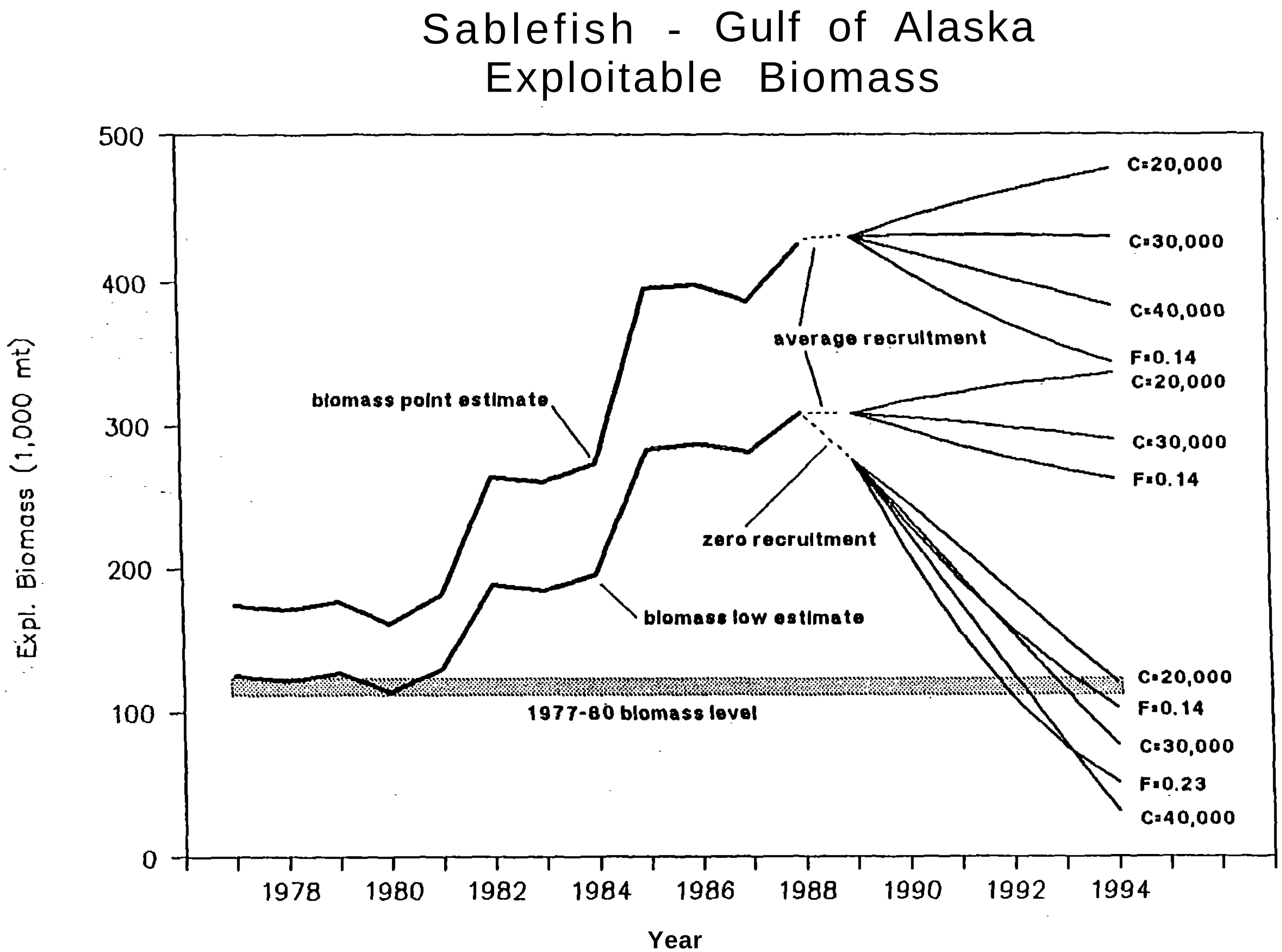

Figure 3. --Estimated population trend over time as estimated by the 1979-87 longline survey, and as projected by the stock reduction analysis model beyond 1987 at various catch levels (scaled to the point estimate and to the lower confidence bound of the biomass). The projected levels are estimated assuming average constant recruitment for the point estimate scale and zero recruitment for the more pessimistic scale.

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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 International North Pacific Fisheries Commission (INPFC) Kodiak, Chirikof, and Shumagin statistical areas at depths of 50-350 m.

The dramatic rise and decline of Atka mackerel in the Gulf of Alaska fishery suggests that this stock was situated at its extreme geographic range, an area which may only be populated during periods of favorable environmental conditions.

For management purposes, the stocks of Atka mackerel in the Gulf of Alaska have been considered separate and distinct from the stocks found in the eastern Bering Sea and Aleutian Islands.

CATCH HISTORY

After reaching an all time high of nearly 28,000 t in 1975, the catch of Atka mackerel in the Gulf of Alaska leveled off and remained stable near 20,000 t until 1978 (Table 1). Since that time, however, there has been a dramatic decrease in the catches in the Gulf of Alaska, first in the Kokiak INPFC area and then westward into the Chirikof and Shumagin Island areas (Table 2).

In the early years of the Atka mackerel fishery, foreign nations were the principal harvesters. Fleets from the Soviet Union initiated the fishery and dominated the catches until 1980. From 1981 until 1983, the Republic of Korea and Japan were the primary harvesters: and since 1984, the U.S. joint venture fisheries have been the primary harvesters, although the catches have been very small.

CONDITION OF THE STOCK

Relative Abundance

Because Atka mackerel are a densely schooling species and spend most of their adult life in proximity to the ocean floor,

Table 1.--Catch (t) of Atka mackerel (Pleurogrammus monopterygius) in the Gulf of Alaska, by fishery category, 1974-87. Optimum Yield (OY) also is included for the years 1977-1987.

	Nation								
Year	U.S.S.R.	Japan	R.O.K.	Mexico	Poland	J.V.	U.S.	Total	OY
1974	17,531	a	--	--	--	--	--	17,531	
1975	27,776	a	--	--	--	--	--	27,776	
1976	19,933	a	--	--	--	--	--	19,933	
1977	19,246	a	--	--	209	--	--	19,455	22,000
1978	18,387	1,136	63	--	--	--	--	19,586	24,800
1979	10,265	568	81	36	--	--	--	10,950	26,800
1980	10,473	1,896	736	57	--	--	--	13,162	28,700
1981	--	3,636	14,811	--	280	--	--	18,727	28,700[b]
1982	--	2,087	4,672	--	--	--	--	6,759	28,700
1983	--	2,806	8,664	--	--	790	--	12,260	28,700
1984	--	532	4	--	T	585	31	1,152	28,700
1985	--	Tr[c]	2	--	--	1,846	--	1,848	5,278
1986	--	--	--	--	--	4	--	4	5,278
1987	--	--	--	--	--	1	--	1	240[d]

a Reported in a category called "other species."

b Optimum yield for 1981 is sometimes given (elsewhere) as 33,484 t.

c Tr = Trace.

d For 1987, Gulf of Alaska species were managed by target quotas.

Sources: 1974-76: Forrester et al. (1983); foreign and joint venture catches 1977-84: Berger et al. (1986); foreign and joint venture catches 1985; personal communication with Jerald Berger, U.S. Foreign Fisheries Observer Program, Northwest and Alaska Fisheries Center, National Marine Fisheries Service, NOAA, 7600 Sand Point Way NE, BIN C15700, Building 4, Seattle, WA 98115; domestic catches: Pacific Fishery Information Network (PacFIN), Pacific Marine Fisheries Commission, 305 State Office Building, 1400 SW Fifth Avenue, Portland, OR 97201.

Table 2.--Catches (t) of Atka macherel (Pleurogrammus ~~monopterygius)~~ in the Gulf of Alaska, by fishery category and International North Pacific Fisheries Commission statistical area, 1974-87.

Year		Area					Total
		Shumagin	Chirikof	Kodiak	Yakutat	Southeastern	
1974	USSR	4,742	2,748	10,041	-	-	17,531
	Japan	-	-	-	-	-	[a]
							17,531
1975	USSR	2,132	743	23,688	1,213	-	27,776
	Japan	-	-	-	-	-	[a]
							27,776
1976	USSR	1,552	4,394	13,211	776[b]	-	19,933
	Japan	-	-	-	-	-	[a]
							19,933
1977	USSR	69	2,057	17,120	-	-	19,246
	Japan	-	-	-	-	-	[a]
	Poland	-	-	209	-	-	209
							19,455
1978	USSR	184	17,320	883	-	-	18,387
	Japan	243	265	338	125	165	1,136
	ROK	61	2	-	-	-	63
							19,586
1979	USSR	5	708	9,552	-	-	10,265
	Japan	322	8	227	11	-	568
	ROK	81	-	-	-	-	81
	Mexico	11	4	21			36
							10,950
1980	USSR	899	90	9,484	-	-	10,473
	Japan	35	179	1,511	171	Tr	1,896
	ROK	736	-	-	-	-	736
	Poland	48	9	-	-	-	57
							13,162
1981	Japan	699	1,331	1,369	212	25	3,636
	ROK	2,551	11,147	46	1,066	-	14,810
	Poland	221	59	-	-	-	280
							18,726
1982	Japan	1,922	77	87	1	-	2,087
	ROK	1,241	3,431	-	-	-	4,672
							6,759
1983	Japan	1,498	1,243	65	Tr	-	2,806
	ROK	1,096	7,568	-	-	-	8,664
	JV	789	-	1	-	-	790
							12,260
1984	Japan	476	56	Tr	-	-	532
	ROK	2	2	-	-	-	4
	Poland	-	-	Tr	-	-	Tr
	JV	578	2	5	-	-	585
	US	31	-	-	-	-	31
							1,152
1985	Japan	Tr	-	-	-	-	Tr
	ROK	2	-	-	-	-	2
	JV	1,843	3	Tr	-	-	1,846
							1,848
1986	JV	4	-	Tr	-	-	4
1987	JV	-	-	-	-	-	1

a Reported in a category called "other species."

Tr: Trace

Sources: 1974-76: Forrester et al. (1983); foreign and joint venture catches 1977-84: Berger et al. (1986); foreign and joint venture catches 1985: personal communication with Jerald Berger, U.S. Foreign Fisheries Observer Program, Northwest and Alaska Fisheries Center, National Marine Fisheries Service, NOAA, 7600 Sand Point Way NE, BIN C15700, Building 4, Seatle, WA 98115; domestic catches: Pacific Fishery Information Network (PacFIN), Pacific Marine Fisheries Commission, 305 State Office Building, 1400 SW Fifth Ave., Portland, OR 97201.

they are very difficult to assess with traditional bottom trawl or hydroacoustic surveys. The Atka mackerel's behavior characteristics, the changes in major harvesting fleets and gear, and the lack of effort statistics for the U.S. fishing operations make commercial catch per unit effort data (CPUE) meaningless.

Absolute Abundance

Biomass estimates of Atka mackerel in the Gulf of Alaska were obtained from National Marine Fisheries Service groundfish resource assessment surveys conducted in 1984 and 1987. During both surveys, the biomass estimates for Atka mackerel were extremely small, 36,000 t in 1984 and 33,000 in 1987. The Shumagin INPFC area contained over 98% of the total estimate both years. When the abundance of a fish stock becomes very low, it is extremely difficult to obtain a meaningful estimate of stock size with trawl surveys following random sampling techniques. No information on absolute abundance is available from other sources.

RECRUITMENT STRENGTHS

Since the decline of the commercial fishery, the National Marine Fisheries Service's resource assessment and international cooperative groundfish surveys have provided the only data available for evaluating the conditionof the Atka mackerel stocks in the Gulf of Alaska. During the most recent survey, 1987, the abundance was extremely low in most areas of the Gulf of Alaska; and only the Shumagin INPFC provided any biological samples. The size composition analysis indicates limited recruitment was present in the Shumagin area. A new incoming group of fish, mean size approximately 30 cm, was present: however, the group was relatively small when compared to the large-older portion of the stock (Figure 1).

BIOLOGICAL PARAMETERS

The abundance of Atka mackerel in the Gulf of Alaska has been so low that the resource assessment surveys have not provided adequate samples to establish recent estimates of biological parameters. Estimates are available, however, from Aleutian Island stocks and are reported by Kimura and Ronholt (1988).

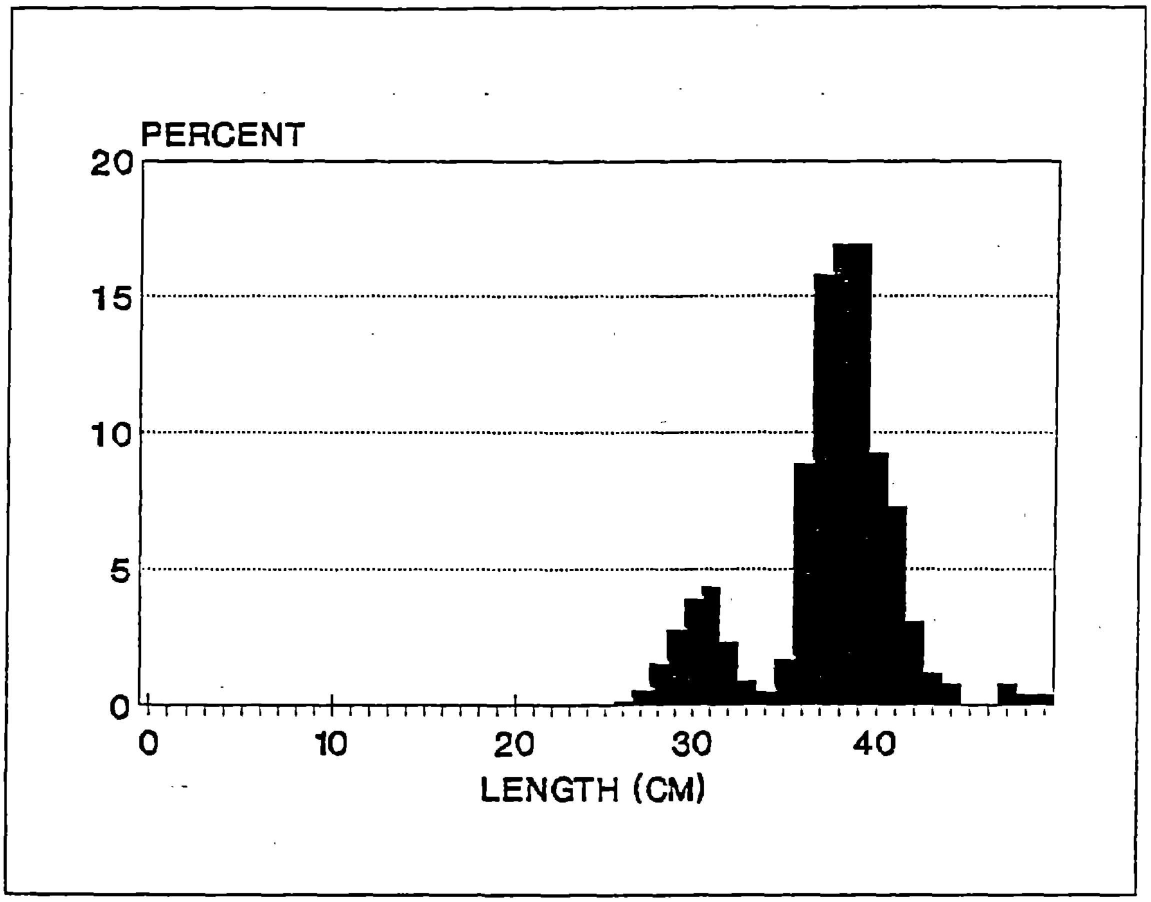

Figure 1.--Size composition of Atka mackerel in the Shumagin International North Pacific Fisheries Commission statistical area during the National Marine Fisheries Service resource assessment survey, June-August 1987.

MAXIMUM SUSTAINABLE YIELD AND BIOLOGICAL CATCH

No new data are available for estimating MSY or ABC (Ronholt 1988). Because of the low abundance and harvest of Atka mackerel, the North Pacific Fishery Management Council has combined this species into the other fish category for 1988.

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SLOPE ROCKFISH

by

David M. Clausen[1] and Jonathan Heifetz[1]

INTRODUCTION

At least 30 rockfish species of the genus Sebastes inhabit waters of the Gulf of Alaska (Eschmeyer et al. 1983), and many are commercially valuable. In 1988, the North Pacific Fishery Management Council (NPFMC) implemented a new management classification scheme for Sebastes rockfish in this region. Accordingly, Sebastes are now classified into three assemblages in the Gulf of Alaska based on habitat and distribution: demersal shelf rockfish, pelagic shelf rockfish, and slope rockfish. Separate quotas (total allowable catch) are assigned to each assemblage, rather than to individual species. Likewise, catch statistics are also reported by assemblage.

Slope rockfish are defined as those species of Sebastes that, as adults, inhabit waters of the outer continental shelf and continental slope of the Gulf of Alaska, generally in depths greater than 150-200 m. In contrast, shelf rockfish inhabit shallower, more inshore waters of the shelf. Based on these criteria, 18 species of rockfish are classified into the slope rockfish assemblage (Table 1). The assemblage is dominated by one species, Pacific ocean perch (Sebastes alutus), which has historically been the most abundant rockfish in this region and has provided most of the past commercial catch. The other species comprising the assemblage were compiled from catches reported by the foreign observer program in the Gulf of Alaska (Bracken and Ito 1986), and include all slope species encountered in this region.

Formerly (1979-87), Sebastes in the Gulf of Alaska were managed in just two groupings, the "Pacific ocean perch complex" and "other rockfish." The Pacific ocean perch complex consisted of Pacific ocean perch and four other species: northern (S. polyspinis), rougheye (S. aleutianus), shortraker (S. borealis), and sharpchin (S. zacentrus) rockfish. All other Sebastes rockfish were classified as "other rockfish." To avoid confusion, this old management classification is also listed in Table 1 for each species in the slope assemblage.

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[1]Auke Bay Laboratory, Northwest and Alaska Fisheries Center, National Marine Fisheries Service, NOAA, P.O. Box 210155, Auke Bay, AK 99821.

Table 1.--Species comprising the slope rockfish assemblage in the Gulf of Alaska.

Common name	Scientific name	Former management grouping (1979-87)
Pacific ocean perch	_Sebastes alutus_	P.O.P.* complex
Northern rockfish	_S. polyspinis_	P.O.P complex
Rougheye rockfish	_S. aleutianus_	P.O.P complex
Shortraker rockfish	_S. borealis_	P.O.P complex
Sharpchin rockfish	_S. zacentrus_	P.O.P complex
Harlequin rockfish	_S. variegatus_	Other rockfish
Redbanded rockfish	_S. babcocki_	Other rockfish
Greenstriped rockfish	_S. elongatus_	Other rockfish
Yellowmouth rockfish	_S. reedi_	Other rockfish
Darkblotched rockfish	_S. crameri_	Other rockfish
Aurora rockfish	_S. aurora_	Other rockfish
Blackgill rockfish	_S. melanostomus_	Other rockfish
Chilipepper	_S. goodei_	Other rockfish
Pygmy rockfish	_S. wilsoni_	Other rockfish
Shortbelly rockfish	_S. jordani_	Other rockfish
Splitnose rockfish	_S. diploproa_	Other rockfish
Stripetail rockfish	_S. saxicola_	Other rockfish
Vermilion rockfish	_S. miniatus_	Other rockfish

*P.O.P = Pacific ocean perch.

In this report, "Pacific ocean perch" refers to just a single species, _Sebastes alutus_, whereas "Pacific ocean perch complex" refers to the first five species listed in Table 1 and "slope rockfish" refers to all 18 species in Table 1.

CATCH HISTORY

Historical Overview

A Pacific ocean perch trawl fishery by the U.S.S.R. and Japan began in the Gulf of Alaska in the early 1960s (Fig. 1). This fishery developed rapidly, with massive efforts by the Soviet and Japanese fleets. Catches peaked in 1965, when a total of nearly 350,000 metric tons (t) was caught. This apparent overfishing resulted in a precipitous decline in catches in the late 1960s. Catches continued to decline in the 197Os, and by 1978 were only 8,000 t. A small domestic fishery began in 1977 and has continued since.

During these years, other slope rockfish species were probably caught along with Pacific ocean perch. However, catches of-these species remain unknown, since prior to 1978 catches for all _Sebastes_ species were usually reported as Pacific ocean perch.

Recent Catches

Detailed catch information for slope rockfish for the years 1977-88 are listed in Table 2. The reader is cautioned that actual catches of slope rockfish are only shown for 1988; for previous years, the catches listed are for the Pacific ocean perch complex, Pacific ocean perch alone, or all _Sebastes_ rock-fish, depending upon the year (see Footnote in Table 2). The acceptable biological catches and quotas in Table 2 are gulfwide values, but in actual practice the NPFMC has divided these into separate, annual apportionments for each of the three regulatory areas of the Gulf of Alaska.

Foreign fishing dominated the fishery from 1977 to 1984, and catches generally declined during this period. Most of the catch was taken by Japan (Carlson et al. 1986). Catches reached a minimum in 1985, after foreign trawling in the Gulf of Alaska was prohibited.

A domestic fishery first developed in 1985, and has expanded each year since. This fishery is composed of factory-trawlers that process the fish at sea for export to Japan. In 1987, the domestic fishery took its assigned quota (5,000 t), but in 1988 only 82% of the increased quota (16,800 t) was taken. This failure to reach the quota in 1988 was caused by a lack of fishing effort in the western regulatory area, where only 2,541 t of the 4,850 t apportioned to this area were caught.

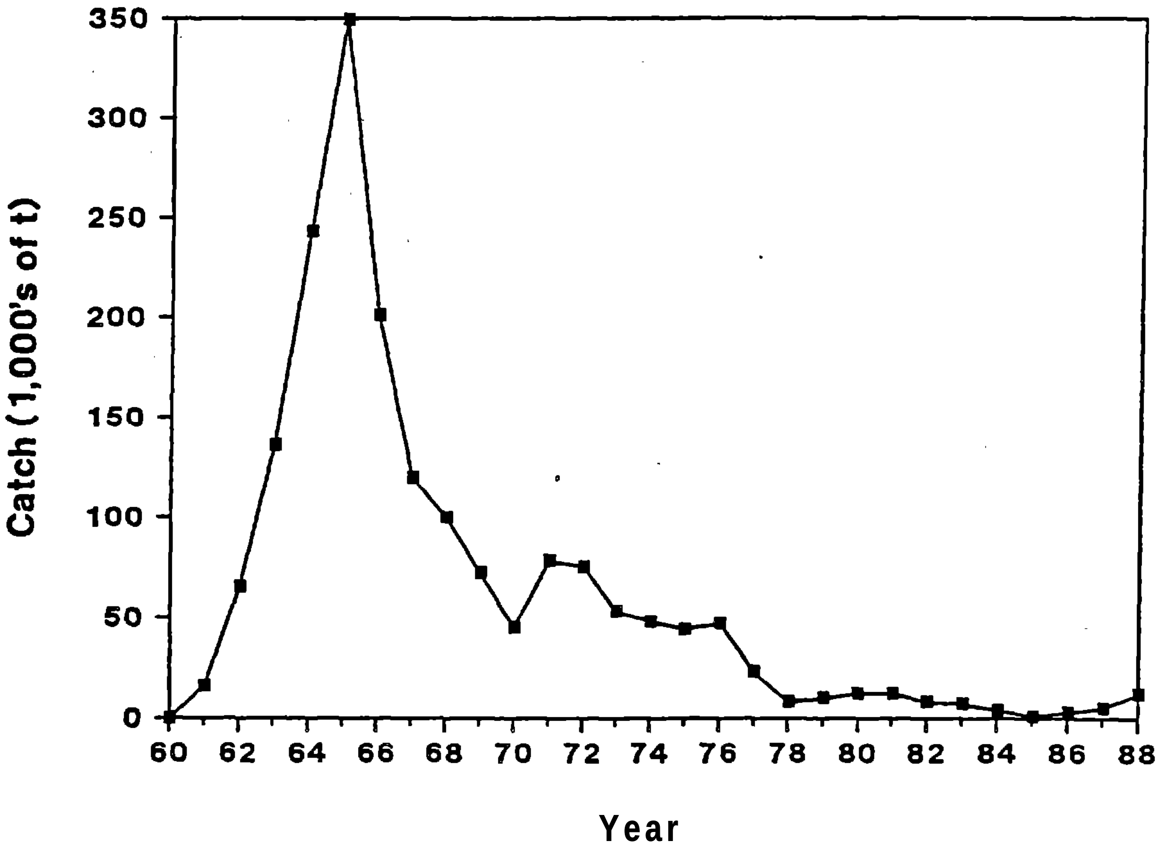

Figure l.--All-nation catch of Pacific ocean perch, _Sebastes alutus_, in the Gulf of Alaska, 1960-88. Data based on the following sources: 1960-63, Balsiger et al. (1985); 1964-84, Carlson et al. (1986); 1985-88, Table 2, this report. Some catches may have included other rockfish species besides Pacific ocean perch.

Table 2.--Catch[a] (t) of fish in the slope rockfish assemblage in the Gulf of Alaska, with gulfwide values of acceptable biological catch (ABC) and fishing quotas (t), 1977-88.

		Gulfwide					
	Fishery	Regulatory area				Management value[b]	
Year	category	Western	Central	Eastern	Total	ABC	Quota
1977	Foreign	6,282	6,166	10,993	23,441		
	U.S.	0	0	12	12		
	JV	-	-	-	-		
	Total	6,282	6,166	11,005	23,453	50,000	30,000
1978	Foreign	3,643	2,024	2,504	8,171		
	U.S.	0	0	5	5		
	JV	-	-	-	-		
	Total	3,643	2,024	2,509	8,176	50,000	25,000
1979	Foreign	944	2,371	6,434	9,749		
	U.S.	0	99	6	105		
	JV	1	31	35	67		
	Total	945	2,501	6,475	9,921	50,000	25,000
1980	Foreign	841	3,990	7,616	12,447		
	U.S.	0	2	2	4		
	JV	0	20	0	20		
	Total	841	4,012	7,618	12,471	50,000	25,000
1981	Foreign	1,233	4,268	6,675	12,176		
	U.S.	0	7	0	7		
	JV	1	0	0	1		
	Total	1,234	4,275	6,675	12,184	50,000	29,167
1982	Foreign	1,746	6,223	17	7,986		
	U.S.	0	2	0	2		
	JV	0	3	0	3		
	Total	1,746	6,228	17	7,991	50,000	11,475
1983	Foreign	671	4,726	18	5,415		
	U.S.	7	8	0	15		
	JV	1,934	41	0	1,975		
	Total	2,612	4,775	18	7,405	50,000	11,475
1984	Foreign	214	2,385	0	2,599		
	U.S.	116	0	3	119		
	JV	1,441	293	0	1,734		
	Total	1,771	2,678	3	4,452	6,944	11,475
1985	Foreign	6	2	0	8		
	U.S.	631	13	181	825		
	JV	211	43	0	254		
	Total	848	58	181	1,087	6,500	6,083

Table 2. --(Continued).

Year	Fishery category	Gulfwide: Regulatory area: Western	Central	Eastern	Total	Management value: ABC	Quota[b]
1986	Foreign	Tr	Tr	0	Tr		
	U.S.	642	394	1,908	2,944		
	JV	35	2	0	37		
	Total	677	396	1,908	2,981	10,500	3,702
1987	Foreign	0	0	0	0		
	U.S.	1,347	1,434	2,088	4,869		
	JV	108	4	0	112		
	Total	1,455	1,438	2,088	4,981	10,500	5,000
1988[c]	Foreign	0	0	0	0		
	U.S.	2,521	6,587	4,679	13,787		
	JV	0	4	0	4		
	Total	2,521	6,591	4,679	13,791	16,800	16,800

JV = Joint venture. Tr = Trace catches.

Sources: Catch: 1977-84, Carlson et al. (1986); 1985-88, Pacific Fishery Information Network (PacFIN), Pacific Marine Fisheries Commission, 305 State Office Building, 1400 S.W. 5th Avenue, Portland, OR 97201. ABC and Quota: 1977-1986 Karinen and Wing (1987); 1987, Clausen et al. (1988); 1988, pers. comm. with J. Fujioka, NMFS, Auke Bay Lab, P. O. Box 210155, Auke Bay, AK 99821.

[a]Catch defined as follows: 1977, all Sebastes rockfish for Japanese catch, and Pacific ocean perch for catches of other nations; 1978, Pacific ocean perch only; 1979-87, the 5 species comprising the Pacific ocean perch complex; 1988, the 18 species comprising the slope rockfish assemblage.

[b]Quota defined as follows: 1977-86, optimum yield; 1987, target quota; 1988, total allowable catch.

[c]Updated as of 3 February 1989.

CONDITION OF STOCKS

Relative Abundance

Japanese Catch and Catch per Unit Effort Data

The Japanese trawl fishery in the Gulf of Alaska provides detailed catch and effort information on Pacific ocean perch for the years 1964-84. The data in Figure 2 from the Japanese fishery indicate Pacific ocean perch stocks declined to extremely low levels by 1978. The total catch of Pacific ocean perch was down to about 5,000 t, the contribution of Pacific ocean perch to the Japanese all-species trawl catch had decreased to less than 15%, and the catch per unit effort (CPUE) had decreased to less than 0.2 t/h from nearly 5.8 t/h in 1965. Catch per unit effort data after 1978 indicate a severely depressed stock condition. This is supported by an analysis of Carlson et al. (1986) which used information from the U.S. foreign fishery observer program.

This time series of CPUE data ended in 1984 when Japanese trawl fisheries in the Gulf of Alaska were terminated. Similar CPUE data have not been available from the domestic trawl fishery.

Japan-U.S. Cooperative Longline Survey

The Japan-U.S. cooperative longline survey provides the only current relative abundance data on slope rockfish in the Gulf of Alaska. This survey has been conducted annually since 1979 and encompasses the continental slope of all five International North Pacific Fisheries Commission statistical areas of the gulf. Detailed CPUE information from this survey is available for *Sebastes* species combined. However, in each year's survey, an estimated 90-95% of the rockfish catch in depths more than 200 m has consisted of just two species, rougheye rockfish and shortraker rockfish. Sasaki and Teshima (1988) computed relative population numbers (RPNs) for rockfish in the Gulf of Alaska for each year of the survey. The RPN is an index of relative abundance consisting of CPUE by depth stratum weighted by size (km^2) of the depth stratum. On an areal basis, the rockfish RPNs at depths greater than 200 m, indicating combined abundance of rougheye and shortraker rockfish, show large annual variation (Table 3). The gulfwide RPNs are less variable. Without associated confidence intervals, these results are difficult to interpret and no consistent trends are apparent. These data suggest that abundance of rougheye and shortraker rockfish remained stable during this time period.

The longline survey data in Table 3 show that the rockfish RPN was consistently higher in the eastern Gulf of Alaska than in the central and western areas. Each year of the survey (except

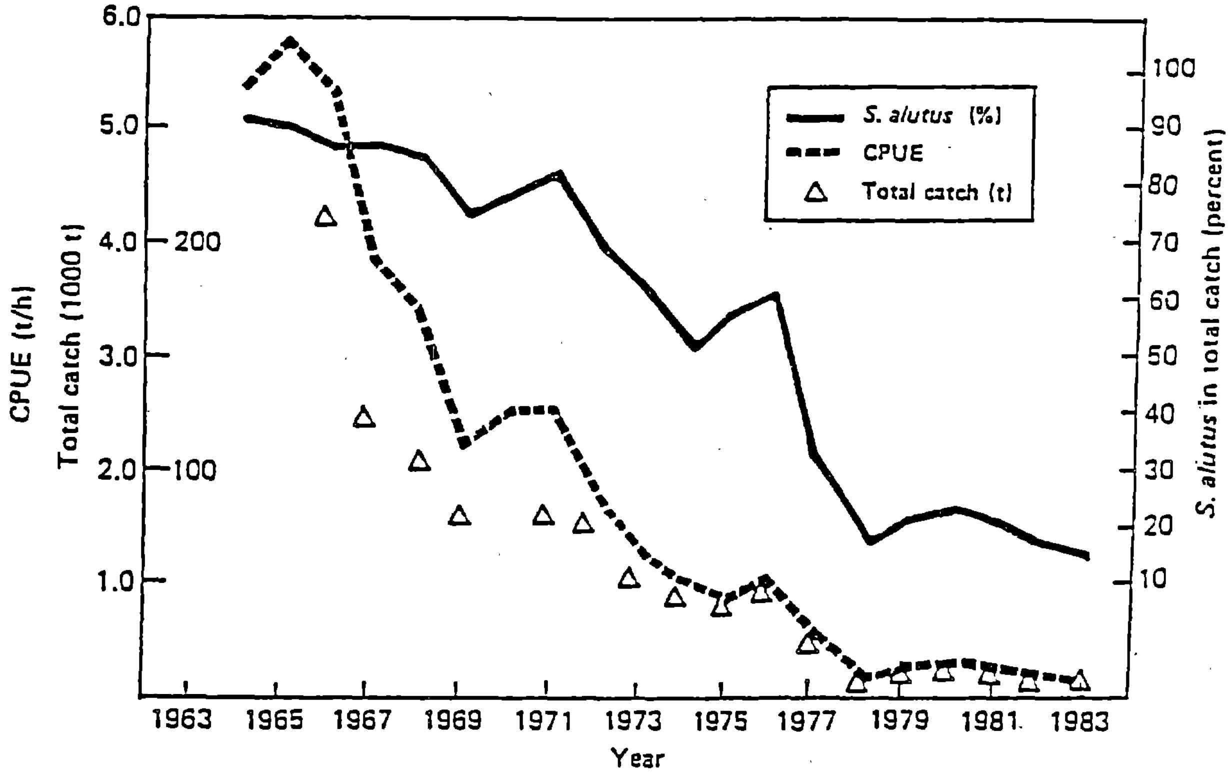

Figure 2. --Catch, percentage of the all-species catch, and catch per unit effort (CPUE) of Pacific ocean perch; Sebastes alutus, in the Japanese trawl fishery in the Gulf of Alaska, 1964-83. (Figure adapted from Carlson et al. 1986).

Table 3.--Relative population number (RPN) of rockfish caught in the Gulf of Alaska in the Japan-U.S. cooperative longline survey, 1979-1987. Includes information from depth strata more than 200 m.

Year	Area[b] Shumagin	Chirikof	Kodiak	Yakutat	Southeastern	Gulfwide (all areas combined)
1979	931	657	1,251	2,330	2,341	7,510
1980	1,083	2,285	1,476	2,765	2,409	10,018
1981	576	1,185	1,545	1,578	1,536	6,420
1982	454	411	1,202	1,796	1,368	5,231
1983	361	1,203	2,055	2,331	2,403	8,353
1984	432	304	665	2,164	2,362	5,927
1985	276	645	1,440	2,868	2,199	7,428
1986	466	805	2,086	2,984	1,597	7,938
1987	589	1,414	2,278	2,624	2,441	9,346
Mean	574	990	1,555	2,382	2,073	7,575
% of mean	7.6	13.1	20.5	31.4	27.4	100.0

[a]Data from Sasaki and Teshima (1988).
[b]International North Pacific Fisheries Commission statistical area.

1981) the RPN for the eastern gulf (Yakutat and Southeastern areas) comprised over half the gulfwide RPN. Averaged over survey years, the Yakutat and Southeastern areas contain 58.9% of the gulf RPN. These data indicate that rougheye and shortraker rockfish are most abundant in the eastern Gulf of Alaska.

Absolute Abundance

Comprehensive triennial trawl surveys were conducted in the Gulf of Alaska in 1984 and 1987. These surveys covered all areas of the gulf and provide much information on slope rockfish, including estimates of absolute abundance (biomass). Results of the most recent survey in 1987 will be discussed first in some detail, followed by a comparison with 1984 results. For a discussion of the methodology of these surveys, see Brown (1986); for a detailed presentation of the 1984 survey results concerning slope rockfish, see Clausen et al. (1988).

1987 Triennial Trawl Survey

Biomass estimates from the 1987 survey showed Pacific ocean perch to be the most abundant species in the slope rockfish assemblage, with 44.7% of the gulfwide biomass (Table 4). Five other slope rockfish species were also caught in abundance. In descending order of gulfwide biomass, these five species included: northern rockfish, harlequin rockfish, sharpchin rockfish, rougheye rockfish, and shortraker rockfish. All other species in the assemblage accounted for only 0.3% of the gulf-wide biomass. On a regional basis, Pacific ocean perch was the predominant species in three areas: Shumagin, Chirikof, and Yakutat. In the Kodiak area, northern rockfish had the highest biomass, and in Southeastern, sharpchin was most important. The overall biomass estimate for the entire assemblage was 789,580 t, and the 95% confidence interval was 605,163-973,997 t.

Detailed discussion on each of the six important species of slope rockfish follows.

Biomass estimates of Pacific ocean perch in 1987 were highest in the Shumagin area, followed by Kodiak, Southeastern, Chirikof, and Yakutat (Table 5). The gulfwide biomass estimate was 352,736 t, and the 95% confidence interval was 213,282-492,189 t. In all areas, biomass was concentrated in the 101-200 m and 201-300 m depth strata. Highest CPUEs were in the 201-300 m stratum, except for Shumagin where 101-200 m was greatest.

Northern rockfish biomass was distributed primarily in the central and western gulf, with highest values in Kodiak followed by Shumagin -and Chirikof (Table 6). Biomass was very low in Yakutat, and no fish were caught in Southeastern. The gulfwide biomass estimate was 172,619 t, and the 95% confidence interval was 75,841-269,396 t. Northern rockfish were generally distributed at depths shallower than Pacific ocean perch with

Table 4. --Estimated biomass (t) of species in the slope rockfish assemblage, based on results of the 1987 triennial trawl survey of the Gulf of Alaska. Biomass estimates were adjusted to the most efficient trawl used in the survey.

Area[a] and species	Biomass (t)	Percent of total assemblage biomass for area
Shumagin		
Pacific ocean perch	145,710	64.0
Northern rockfish	60,550	26.6
Rougheye rockfish	3,988	1.8
Shortraker rockfish	3,248	1.4
Sharpchin rockfish	3,223	1.4
Harlequin rockfish	10,726	4.7
Redbanded rockfish	19	Tr
Other species[b]	77	Tr
Total (all species combined)	227,541	100.0
Chirikof		
Pacific ocean perch	43,731	49.7
Northern rockfish	22,112	25.2
Rougheye rockfish	7,812	8.9
Shortraker rockfish	12,879	14.6
Sharpchin rockfish	14	Tr
Harlequin rockfish	969	1.1
Redbanded rockfish	395	0.4
Other species[b]	1	Tr
Total (all species combined)	87,913	100.0
Kodiak		
Pacific ocean perch	75,550	30.5
Northern rockfish	88,497	35.8
Rougheye rockfish	22,214	9.0
Shortraker rockfish	17,775	7.2
Sharpchin rockfish	36	Tr
Harlequin rockfish	42,740	17.3
Redbanded rockfish	215	0.1
Other species[c]	193	0.1
Total (all species combined)	247,220	100.0

Table 4.--(Continued).

Area[a] and species	Biomass (t)	Percent of total assemblage biomass for area
Yakutat		
Pacific ocean perch	35,543	45.7
Northern rockfish	1,460	1.9
Rougheye rockfish	10,734	13.8
Shortraker rockfish	8,543	11.0
Sharpchin rockfish	11,587	14.9
Harlequin rockfish	9,376	12.0
Redbanded rockfish	525	0.7
Other species[b]	45	Tr
Total (all species combined)	77,813	100.0
Southeastern		
Pacific ocean perch	52,201	35.0
Northern rockfish	0	0.0
Rougheye rockfish	8,479	5.7
Shortraker rockfish	5,257	3.5
Sharpchin rockfish	55,295	37.1
Harlequin rockfish	27,068	18.1
Redbanded rockfish	406	0.3
Other species[b]	388	0.3
Total (all species combined)	149,094	100.0
Gulfwide, all areas combined		
Pacific ocean perch	352,736	44.7
Northern rockfish	172,619	21.9
Rougheye rockfish	53,225	6.7
Shortraker rockfish	47,702	6.0
Sharpchin rockfish	70,155	8.9
Harlequin rockfish	90,879	11.5
Redbanded rockfish	1,560	0.2
Other species[b]	704	0.1
Total (all species combined)	789,580	100.0

Tr = Trace catches.
[a]International North Pacific Fisheries Commission statistical areas.
[b]Includes pygmy rockfish, yellowmouth rockfish, greenstriped rockfish, darkblotched rockfish, and splitnose rockfish.

Table 5.--Estimated biomass, mean catch per unit effort (CPUE), and mean size of Pacific ocean perch, Sebastes alutus based on results of the 1987 triennial trawl survey of the Gulf of Alaska.

Area[a]	Depth (m)	No. of trawl hauls	hauls with POP[b]	CPUE (kg/km^2)	Biomass (t)	Mean length (cm)	Mean weight (kg)
Shumagin							
	1-100	106	33	348.3	15,449	20.7	0.18
	101-200	55	31	7,840.3	113,965	31.1	0.46
	201-300	7	7	5,871.3	16,070	36.0	0.72
	301-500	5	1	89.1	225	-	0.89
	501-700	3	0	0.0	0	-	-
	701-1000	2	0	0.0	0	-	-
	All depths	178	72	2,141.4	145,710	28.9	0.41
Chirikof							
	1-100	55	10	314.6	8,359	21.5	0.19
	101-200	118	46	925.0	21,968	35.3	0.69
	201-300	17	9	1,164.9	13,397	36.2	0.72
	301-500	5	2	4.5	7	-	0.46
	501-700	4	0	0.0	0	-	-
	701-1000	4	0	0.0	0	-	-
	All depths	203	67	639.6	43,731	29.1	0.46
Kodiak							
	1-100	58	5	9.7	383	21.2	0.17
	101-200	149	61	1,209.6	52,232	34.4	0.60
	201-300	22	14	1,968.8	22,730	36.9	0.71
	301-500	8	5	66.5	197	-	0.66
	501-700	6	1	5.0	8	-	0.67
	701-1000	1	0	0.0	0	-	-
	All depths	244	86	739.0	75,550	34.8	0.62
Yakutat							
	1-100	14	0	0.0	0	-	-
	101-200	63	26	134.5	3,853	21.9	0.22
	201-300	21	18	6,431.5	31,347	33.2	0.52
	301-500	11	6	115.8	343	39.4	0.85
	501-700	3	0	0.0	0	-	-
	701-1000	0	-	-	-	-	-
	All depths	112	50	657.6	35,543	31.0	0.45
Southeastern							
	1-100	1	0	0.0	0	-	-
	101-200	20	5	157.6	1,556	28.8	0.31
	201-300	15	14	9,608.0	48,377	35.4	0.68
	301-500	10	7	786.4	2,268	39.0	0.88
	501-700	2	0	0.0	0	-	-
	701-1000	0	-	-	-	-	-
	All depths	48	26	2,313.7	52,201	35.1	0.67
All Gulf - All Areas Combined							
	1-100	234	48	185.4	24,191	21.0	0.18
	101-200	405	169	1,613.3	193,574	31.8	0.50
	201-300	82	62	3,696.1	131,921	35.2	0.65
	301-500	39	21	234.5	3,041	39.1	0.86
	501-700	18	1	1.0	8	-	0.67
	701-1000	7	0	0.0	0	-	-
	All depths	785	301	1,118.8	352,736	30.8	0.48

[a]International North Pacific Fisheries Commission statistical areas.
[b]Pacific ocean perch.

Table 6.--Estimated biomass, mean catch per unit effort (CPUE), and mean size of northern rockfish, Sebastes polyspinis, based on results of the 1987 triennial trawl survey of the Gulf of Alaska. Biomass and CPUE were adjusted to the most efficient trawl used in the survey.

Area[a]	Depth (m)	No. of trawl hauls	Hauls with Northern	CPUE (kg/km^2)	Biomass (t)	Mean length (cm)	Mean weight (kg)
Shumagin							
	1-100	106	41	935.3	41,494	29.3	0.43
	101-200	55	32	1,308.2	19,015	34.9	0.67
	201-300	7	4	14.9	41	-	-
	301-500	5	0	0.0	0	-	-
	501-700	3	0	0.0	0	-	-
	701-1000	2	0	0.0	0	-	-
	All depths	178	77	889.8	60,550	30.6	0.48
Chirikof							
	1-100	55	14	372.3	9,895	30.7	0.51
	101-200	118	44	510.7	12,128	35.2	0.72
	201-300	17	3	7.7	89	-	0.48
	301-500	5	0	0.0	0	-	-
	501-700	4	0	0.0	0	-	-
	701-1000	4	0	0.0	0	-	-
	All depths	203	61	323.4	22,112	32.8	0.61
Kodiak							
	1-100	58	13	93.9	3,715	27.1	0.36
	101-200	149	41	1,962.8	84,757	32.6	0.66
	201-300	22	5	1.4	17	-	0.58
	301-500	8	0	0.0	0	-	-
	501-700	6	1	4.8	7	-	0.53
	701-1000	1	0	0.0	0	-	-
	All depths	244	60	865.6	88,497	32.3	0.64
Yakutat							
	1-100	14	0	0.0	0	-	-
	101-200	63	4	51.0	1,460	38.0	0.62
	201-300	21	0	0.0	0	-	-
	301-500	11	0	0.0	0	-	-
	501-700	3	0	0.0	0	-	-
	701-1000	0	-	-	-	-	-
	All depths	112	4	27.0	1,460	38.0	0.62
Southeastern							
	1-100	1	0	0.0	0	-	-
	101-200	20	0	0.0	0	-	-
	201-300	15	0	0.0	0	-	-
	301-500	10	0	0.0	0	-	-
	501-700	2	0	0.0	0	-	-
	701-1000	0	-	-	-	-	-
	All depths	48	0	0.0	0	-	-
All Gulf - All Areas Combined							
	1-100	234	68	422.3	55,104	29.3	0.43
	101-200	405	121	978.1	117,361	33.3	0.67
	201-300	82	12	4.1	146	-	0.58
	301-500	39	0	0.0	0	-	-
	501-700	18	1	1.0	7	-	0.53
	701-1000	7	0	0.0	0	-	-
	All depths	785	202	547.5	172,619	31.7	0.57

[a]International North Pacific Fisheries Commission statistical areas.

essentially all the biomass in depths less than 200 m. Highest CPUE was in the 101-200 m depth stratum.

Rougheye rockfish biomass was highest in Kodiak, followed by Yakutat, Southeastern, Chirikof, and Shumagin (Table 7). The gulfwide biomass estimate was 53,225 t, and the 95% confidence interval was 40,465-65,985 t. Rougheye rockfish were distributed deeper than Pacific ocean perch and northern rockfish, with highest biomass and CPUE in the 301-500 m depth stratum in all areas.

Shortraker rockfish biomass was highest in the Kodiak and Chirikof areas, with lesser amounts in Yakutat, Southeastern, and Shumagin (Table 8). The gulfwide biomass estimate was 47,702 t, and the 95% confidence interval was 16,002-79,402 t. Biomass and CPUE were distinctly concentrated in the 301-500 m depth stratum, with few fish caught outside of this depth range. Thus, rougheye and shortraker rockfish cohabitate the same depths in the Gulf of Alaska, 301-500 m, as previously noted by Clausen et al. (1988) in the 1984 triennial survey.

Sharpchin rockfish biomass was almost entirely in the eastern gulf, with 79% of the gulfwide biomass coming from the Southeastern area (Table 9). The gulfwide biomass estimate was 70,155 t, and the 95% confidence interval was 9,192-131,117 t. Highest biomass and CPUE were in the 201-300 m stratum.

Harlequin rockfish biomass was greatest in the Kodiak and Southeastern areas, and less in Shumagin, Yakutat, and Chirikof (Table 10). The gulfwide biomass estimate was 90,879 t, and the 95% confidence interval was 37,461-144,296 t. Highest biomass and CPUE in the central and western gulf were in the 101-200 m stratum, whereas in the eastern gulf they occurred at depths more than 200 m.

Fish size has an important effect upon their marketability and value and can induce fishermen to target upon larger fish. Thus, a comparison of fish size by species in the slope rockfish assemblage is worthwhile (Tables 5-10). If only adult fish at depths where they are vulnerable to commercial exploitation are considered, shortraker rockfish are the largest in size among the six important species in the assemblage. Next in size is rougheye rockfish, followed by Pacific ocean perch and northern rockfish, with the latter two species nearly equal in size. Sharpchin and harlequin rockfish are much smaller in size and may have a lower market value and be less desirable to fishermen.

<u>Comparison of Trawl Surveys in 1987 and 1984</u>

Results for slope rockfish from the 1987 triennial trawl survey are compared in Table 11 with the 1984 trawl survey results.. A note of caution is neccesary since specific comparisons of the actual biomass estimates listed in the table may be invalid because of standardization problems between the

Table 7.--Estimated biomass, mean catch per unit effort (CPUE), and mean size of rougheye rockfish, *Sebastes aleutianus*, based on results of the 1987 triennial trawl survey of the Gulf of Alaska. Biomass and CPUE were adjusted to the most efficient trawl used in the survey.

Area[a]	Depth (m)	No. of trawl hauls	Hauls with rougheye	CPUE (kg/km^2)	Biomass (t)	Mean length (cm)	Mean weight (kg)
Shumagin							
	1-100	106	2	0.7	32	-	0.37
	101-200	55	19	39.6	576	34.4	0.68
	201-300	7	7	121.5	333	-	0.84
	301-500	5	4	1,205.5	3,047	44.9	1.53
	501-700	3	0	0.0	0	-	-
	701-1000	2	0	0.0	0	-	-
	All depths	178	32	58.6	3,988	43.2	1.20
Chirikof							
	1-100	55	5	4.0	106	-	0.82
	101-200	118	57	87.2	2,072	45.0	0.78
	201-300	17	14	206.2	2,371	39.2	1.12
	301-500	5	5	1,993.9	3,255	45.6	1.44
	501-700	4	1	4.1	8	-	1.61
	701-1000	4	0	0.0	0	-	-
	All depths	203	82	114.2	7,812	43.9	1.09
Kodiak							
	1-100	58	6	23.9	946	-	0.64
	101-200	149	63	95.3	4,115	32.5	0.65
	201-300	22	20	361.7	4,176	38.5	0.92
	301-500	8	8	3,974.4	11,764	43.7	1.43
	501-700	6	1	535.9	831	-	1.51
	701-1000	1	1	111.0	382	-	1.69
	All depths	244	99	217.3	22,214	39.0	1.04
Yakutat							
	1-100	14	0	0.0	0	-	-
	101-200	63	41	63.0	1,804	27.3	0.36
	201-300	21	14	453.1	2,208	33.5	0.73
	301-500	11	10	2,268.0	6,721	41.8	1.28
	501-700	3	0	0.0	0	-	-
	701-1000	0	-	-	-	-	-
	All depths	112	65	198.6	10,734	36.2	0.81
Southeastern							
	1-100	1	0	0.0	0	-	-
	101-200	20	0	0.0	0	-	-
	201-300	15	4	8.4	42	-	0.26
	301-500	10	8	2,851.1	8,224	47.2	1.73
	501-700	2	1	211.1	212	-	2.19
	701-1000	0	-	-	-	-	-
	All depths	48	13	375.8	8,479	47.2	1.69
All Gulf - All Areas Combined							
	1-100	234	13	8.3	1,084	-	0.64
	101-200	405	180	71.4	8,567	33.9	0.58
	201-300	82	59	255.8	9,130	36.5	0.89
	301-500	39	35	2,545.6	33,012	44.3	1.47
	501-700	18	3	134.5	1,051	-	1.61
	701-1000	7	1	45.9	382	-	1.69
	All depths	785	291	168.8	53,225	40.2	1.06

[a]International North Pacific Fisheries Commission statistical areas.

Table 8:--Estimated biomass, mean catch per unit effort (CPUE), and mean size of shortraker rockfish, Sebastes borealis, based on results of the 1987 triennial trawl survey of the Gulf of Alaska. Biomass and CPUE were adjusted to the most efficient trawl used in the survey.

Area[a]	Depth (m)	No. of trawl hauls	Short-raker present	CPUE (kg/km^2)	Biomass (t)	Mean length (cm)	Mean weight (kg)
Shumagin							
	1-100	106	0	0.0	0	-	-
	101-200	55	5	25.9	377	-	2.03
	201-300	7	2	32.2	88	-	4.65
	301-500	5	5	1,054.5	2,666	56.8	2.90
	501-700	3	2	58.6	118	-	0.87
	701-1000	2	0	0.0	0	-	-
	All depths	178	14	47.7	3,248	56.8	2.58
Chirikof							
	1-100	55	0	0.0	0	-	-
	101-200	118	3	3.0	71	-	4.43
	201-300	17	1	0.4	5	-	1.41
	301-500	5	5	7,734.5	12,628	69.9	6.61
	501-700	4	2	92.3	175	-	2.99
	701-1000	4	0	0.0	0	-	-
	All depths	203	11	188.4	12,879	69.9	6.48
Kodiak							
	1-100	58	2	4.2	166	-	-
	101-200	149	12	7.7	331	-	1.05
	201-300	22	7	175.7	2,028	67.3	4.93
	301-500	8	8	4,706.6	13,932	61.6	4.22
	501-700	6	3	850.3	1,318	-	2.33
	701-1000	1	0	0.0	0	-	-
	All depths	244	32	173.9	17,775	62.2	3.84
Yakutat							
	1-100	14	0	0.0	0	-	-
	101-200	63	0	0.0	0	-	-
	201-300	21	2	17.9	87	-	4.56
	301-500	11	8	2,853.3	8,456	63.5	3.46
	501-700	3	0	0.0	0	-	-
	701-1000	0	-	-	-	-	-
	All depths	112	10	158.0	8,543	63.5	3.47
Southeastern							
	1-100	1	0	0.0	0	-	-
	101-200	20	0	0.0	0	-	-
	201-300	15	1	152.8	770	74.7	8.66
	301-500	10	5	1,063.0	3,066	63.5	4.14
	501-700	2	2	1,413.8	1,421	57.6	2.96
	701-1000	0	-	-	-	-	-
	All depths	48	8	233.0	5,257	62.0	4.01
All Gulf - All Areas Combined							
	1-100	234	2	1.3	166	-	-
	101-200	405	20	6.5	779	-	1.50
	201-300	82	13	83.4	2,978	68.6	5.45
	301-500	39	31	3,142.0	40,747	63.5	4.37
	501-700	18	9	388.2	3,032	57.6	2.45
	701-1000	7	0	0.0	0	-	-
	All depths	785	75	151.3	47,702	63.4	4.10

[a]International North Pacific Fisheries Commission statistical areas.

Table 9:-Estimated biomass, mean catch per unit effort (CPUE), and mean size of sharpchin rockfish, Sebastes zacentrus, based on results of the 1987 triennial trawl survey of the Gulf of Alaska. Biomass and CPUE were adjusted to the most efficient trawl used in the survey.

Area[a]	Depth (m)	No. of trawl hauls	Sharp-chin present	CPUE (kg/km^2)	Biomass (t)	Mean length (cm)	Mean weight (kg)
Shumagin							
	1-100	106	0	0.0	0	-	-
	101-200	55	1	221.7	3,223	32.4	0.39
	201-300	7	0	0.0	0	-	-
	301-500	5	0	0.0	0	-	-
	501-700	3	0	0.0	0	-	-
	701-1000	2	0	0.0	0	-	-
	All depths	178	1	47.4	3,223	32.4	0.39
Chirikof							
	1-100	55	0	0.0	0	-	-
	101-200	118	2	0.6	14	-	0.18
	201-300	17	0	0.0	0	-	-
	301-500	5	0	0.0	0	-	-
	501-700	4	0	0.0	0	-	-
	701-1000	4	0	0.0	0	-	-
	All depths	203	2	0.2	14	-	0.18
Kodiak							
	1-100	58	0	0.0	0	-	-
	101-200	149	7	0.8	36	-	0.20
	201-300	22	0	0.0	0	-	-
	301-500	8	0	0.0	0	-	-
	501-700	6	0	0.0	0	-	-
	701-1000	1	0	0.0	0	-	-
	All depths	244	7	0.4	36	-	0.20
Yakutat							
	1-100	14	0	0.0	0	-	-
	101-200	63	12	60.9	1,746	22.1	0.17
	201-300	21	9	2,018.9	9,840	25.6	0.34
	301-500	11	1	0.4	1	-	-
	501-700	3	0	0.0	0	-	-
	701-1000	0	-	-	-	-	-
	All depths	112	22	214.4	11,587	24.8	0.30
Southeastern							
	1-100	1	0	0.0	0	-	-
	101-200	20	6	877.1	8,658	23.2	0.19
	201-300	15	14	9,262.0	46,635	26.7	0.29
	301-500	10	2	0.5	1	-	-
	501-700	2	0	0.0	0	-	-
	701-1000	0	-	-	-	-	-
	All depths	48	22	2,450.8	55,295	25.9	0.27
All Gulf - All Areas Combined							
	1-100	234	0	0.0	0	-	-
	101-200	405	28	114.0	13,677	24.2	0.22
	201-300	82	23	1,582.3	56,475	26.5	0.30
	301-500	39	3	0.2	3	-	-
	501-700	18	0	0.0	0	-	-
	701-1000	7	0	0.0	0	-	-
	All depths	785	54	222.5	70,155	25.9	0.28

[a]International North Pacific Fisheries Commission statistical areas.

Table 10.--Estimated biomass, mean catch per unit effort (CPUE), and mean size of harlequin rockfish, *Sebastes variegatus*, based on results of the 1987 triennial trawl survey of the Gulf of Alaska. Biomass and CPUE were adjusted to the most efficient trawl used in the survey.

Area[a]	Depth (m)	No. of trawl hauls	Harlequin present	CPUE (kg/km^2)	Biomass (t)	Mean length (cm)	Mean weight (kg)
Shumagin							
	1-100	106	12	10.4	460	-	0.14
	101-200	55	7	706.2	10,265	30.5	0.48
	201-300	7	0	0.0	0	-	-
	301-500	5	0	0.0	0	-	-
	501-700	3	0	0.0	0	-	-
	701-1000	2	0	0.0	0	-	-
	All depths	178	19	157.6	10,726	30.5	0.44
Chirikof							
	1-100	55	2	30.1	800	21.3	0.16
	101-200	118	8	7.1	169	-	0.33
	201-300	17	0	0.0	0	-	-
	301-500	5	0	0.0	0	-	-
	501-700	4	0	0.0	0	-	-
	701-1000	4	0	0.0	0	-	-
	All depths	203	10	14.2	969	21.3	0.18
Kodiak							
	1-100	58	6	120.9	4,782	16.5	0.07
	101-200	149	30	878.5	37,937	21.5	0.16
	201-300	22	4	1.8	21	-	0.28
	301-500	8	0	0.0	0	-	-
	501-700	6	0	0.0	0	-	-
	701-1000	1	0	0.0	0	-	-
	All depths	244	40	418.0	42,740	20.4	0.14
Yakutat							
	1-100	14	2	36.6	594	14.8	0.05
	101-200	63	10	70.8	2,029	27.6	0.33
	201-300	21	4	1,384.0	6,745	27.3	0.29
	301-500	11	2	2.8	8	-	-
	501-700	3	0	0.0	0	-	-
	701-1000	0	-	-	-	-	-
	All depths	112	18	173.5	9,376	23.6	0.22
Southeastern							
	1-100	1	0	0.0	0	-	-
	101-200	20	6	1,362.5	13,450	24.1	0.19
	201-300	15	10	2,703.2	13,611	23.8	0.19
	301-500	10	3	2.5	7	-	-
	501-700	2	0	0.0	0	-	-
	701-1000	0	-	-	-	-	-
	All depths	48	19	1,199.7	27,068	24.0	0.19
All Gulf - All Areas Combined							
	1-100	234	22	50.9	6,636	16.5	0.08
	101-200	405	61	532.2	63,850	22.7	0.19
	201-300	82	18	570.9	20,377	24.7	0.21
	301-500	39	5	1.2	15	-	-
	501-700	18	0	0.0	0	-	-
	701-1000	7	0	0.0	0	-	-
	All depths	785	106	288.3	90,879	22.1	0.17

[a]International North Pacific Fisheries Commission statistical areas.

two surveys. These problems are 1) In the central and western gulf, Japanese vessels provided most of the fishing effort in both 1984 and 1987, and in each year the vessels used different trawl gear. No fishing power comparisons are available between these two gears. 2) Subareas in the eastern gulf in 1984 were not sampled with widespread coverage.; instead, survey effort was concentrated in two index areas. This results in uncertainty of the biomass estimates in 1984 in the eastern gulf (Clausen et al. 1988).

With these caveats in mind, some general comparisons can be made between results of the two surveys. The Japanese trawl used in 1984 is considered more efficient at catching rockfish than the Japanese trawl used in 1987. Thus, the biomass estimates for slope rockfish in 1987 are believed to be conservative relative to the biomass estimates in 1984. If we assume this to be true, Table 11 indicates that biomass for Pacific ocean perch, rougheye rockfish, and shortraker rockfish. may have remained stable between 1984 and 1987, whereas biomass increased sharply for northern, sharpchin, and harlequin rockfish. The increases for sharpchin and harlequin rockfish are particularly large, expanding from low biomasses in 1984 to relatively large biomasses in 1987. It should be noted, that even with these large increases, none of the changes in biomass were statistically significant because of the large variability inherent in bottom trawl survey catches of slope rockfish.

Results from the two surveys were used to compare Pacific ocean perch biomass and CPUE between 1984 and 1987 in two smaller areas of the eastern Gulf of the Alaska, the Yakutat Canyon, and Cape Ommaney index sites (Table 12). This analysis was done because there were no standardization problems between the two surveys at these two sites. In each survey, only U.S. vessels with standardized trawl gear were used at these two sites, and the sites were both sampled with reasonably good coverage each year. Table 12 shows there was no significant difference in biomass at either site between 1984 and 1987. Moreover, the point estimates of CPUE and biomass are nearly identical between years at each site. These data indicate that absolute abundance of Pacific ocean perch at the index sites was unchanged between 1984 and 1987.

The increase in biomass estimates for northern, sharpchin, and harlequin rockfish in 1987 resulted in a changed species composition of the slope rockfish assemblage (Table 11). In the 1984 survey, Pacific ocean perch were the dominant species, with the other species less important. In 1987, Pacific ocean perch comprised less than half the assemblage biomass (44.7%), and northern, sharpchin, and harlequin rockfish included a larger proportion than before.

The relative species composition of slope rockfish appears to have changed even more when compared with the 1960s.

Table 11. --Comparison of- biomass estimates for the slope rockfish assemblage in the 1984 vs. 1987 triennial trawl surveys. Values listed are for the entire Gulf of Alaska, combining data from all areas.

Species	Biomass (t)		Percentage of assemblage biomass	
	1984	1987	1984	1987
Pacific ocean perch	370,673	352,736	63.5	44.7
Northern rockfish	75,731	172,619	13.0	21.9
Rougheye rockfish	74,368	53,225	12.7	6.7
Shortraker rockfish	53,661	47,702	9.2	6.0
Sharpchin rockfish	5,989	70,155	1.0	8.9
Harlequin rockfish	1,777	90,879	0.3	11.5
Redbanded rockfish	1,194	1,560	0.2	0.2
Other species	449	704	0.1	0.1
Total (all species combined)	583,842	789,580	100.0	100.0

Table 12.--Comparison of 1984 vs. 1987 Pacific ocean perch, *Sebastes alutus*, catch per unit effort (CPUE) and biomass for Yakutat Canyon and Cape Ommaney index sites. Sites were sampled during the 1984 and 1987 triennial trawl surveys in the Gulf of Alaska. Catches from 1984 were standardized to the polyethylene northeastern trawl used in the 1987 survey.

Year	No. of trawl hauls	CPUE (kg/km^2)	Biomass (t)	95% Confidence interval of biomass
		Yakutat Canyon Index Site[a]		
1984	75	1,561.2	17,033	998-33,069
1987	30	1,860.4	20,298	0-41,018
		Cape Ommaney Index Site[b]		
1984	73	3,510.9	32,694	8,764-56,624
1987	26	3,443.7	32,068	265-63,871

[a]140°00'-142°00' W. longitude, 101-500 m depth.

[b]55°00'-56°30' N. latitude, 101-500 m depth.

Westrheim (1970) reported that in trawl surveys of the Gulf of Alaska in 1963-66, Pacific ocean perch comprised more than 90% of the rockfish catch at all depths, far greater than in either the 1984 or 1987 surveys. Westrheim and Tsuyuki (1971) also found that northern rockfish appeared to be a minor component of the rockfish community in the Gulf of Alaska in the 1960s whereas this species was abundant in recent surveys. Harlequin rockfish were not taxonomically described until 1971 and were unreported from the 1960s surveys.

The reasons for the apparent large increase in abundance of sharpchin and harlequin rockfish between 1984 and 1987 are unclear. Given the slow growth rates of all rockfish species, it seems improbable that the increase could result from the sudden appearance of successful year classes. (However, there is evidence of an abundant year class of harlequin rockfish in some areas of the gulf in 1987--see Recruitment Strengths Section.) Likewise, it is unlikely that the fish migrated into the Gulf of Alaska from other areas of the northeast Pacific Ocean. Research conducted prior to 1984 indicated these fish to be abundant. In a 1978 trawl survey of the Southeastern area, harlequin rockfish were reported to be the most abundant rockfish species, with sharpchin rockfish nearly as abundant as Pacific ocean perch (Feldman and Rose 1981). This suggests that both species in 1984 may have been present in some abundance in the Gulf of Alaska, but for reasons unknown were not available to the survey at that time. Clearly, more research into the biology and population dynamics of these two species is needed.

Comparison Between 1987 Trawl Survey and 1979-87 Longline Survey

The trawl survey results can be compared with the Japan-U.S. Cooperative Longline Survey in regards to the geographic abundance of rougheye and shortraker rockfish (Table 13). Both surveys show that in the Shumagin area, the abundance of the two species is proportionately low. However, the two surveys differ when other areas are compared. The trawl survey indicates most of the biomass is in the Chirikof and Kodiak areas, contrasting with the longline survey results where most of the biomass was found in the eastern gulf (Yakutat and Southeastern areas).

This difference in biomass among certain areas may be explained by the inability of the trawl survey to adequately sample the 301-500 m depth-stratum (where most shortraker and rougheye rockfish are caught) in the eastern Gulf of Alaska. Much of this stratum along the continental slope in the eastern gulf was either untrawlable or marginally trawlable with the gear used in the survey. This may have caused rougheye and shortraker biomass in the eastern gulf to be underestimated. In contrast, the longline survey had no problem sampling these rough bottom areas. Thus, the longline survey results may better indicate the actual geographic distribution of rougheye and shortraker rockfish biomass in the gulf.

Table 13.--Rougheye and shortraker rockfish, *Sebastes aleutianus* and *S. borealis*, abundance in the Gulf of Alaska compared between the 1987 triennial trawl survey and the Japan-U.S. cooperative longline survey.

		Area[a]				
Survey	Unit	Shumagin	Chirikof	Kodiak	Yakutat	Southeastern
Trawl	% biomass[b]	7.2	20.5	39.6	19.1	13.6
Longline	% RPN[c]	7.6	13.1	20.5	31.5	27.4

[a]International North Pacific Fisheries Commission statistical area.

[b]biomass for rougheye and shortraker rockfish combined.

[c]RPN = relative population number for rockfish in depths >200 m averaged over the years 1979-87; may include a small number of rockfish other than rougheye and shortraker rockfish.

Current Exploitable Biomass

Current exploitable biomass for slope rockfish in the Gulf of Alaska is estimated at 702,191 t (Table 14). This estimate is derived from the gulfwide biomass estimate in the 1987 trawl survey of 789;580 t, excluding the 87,389 t in the l-100 m depth stratum. The l-100 m depth stratum was removed from the estimate because most slope rockfish in this stratum are small juvenile fish younger than the age of recruitment, and thus are not considered exploitable. Gulfwide mean weight of Pacific ocean perch in l-100 m was only 0.18 kg (Table 5) and mean age of these fish was 3.5 years (see Fig. 9 later in this report). This age is much younger than the recruitable age of 9 years for Pacific ocean perch (Table 15 later in this report).

RECRUITMENT STRENGTHS

Information on recruitment strength of slope rockfish in the Gulf of Alaska are currently based on two sources, both from the 1987 trawl survey: length-frequency distributions of the six important species in the assemblage, and age compositions for Pacific ocean perch.

Length Frequency Distributions

Length-frequency distributions for Pacific ocean perch show distinct modes of small fish at approximately 20 cm length in all areas of the gulf except Kodiak (Fig. 3). This indicates a possible successful year class of fish over a wide area of the gulf. The graphs further demonstrate the increasing size of Pacific ocean perch with depth.

For the remaining five. major species in the assemblage, there is little evidence of abundant year classes except for harlequin rockfish and possibly rougheye rockfish (Figs. 4-8). An obvious mode of small harlequin rockfish is seen at around l7-18 cm in both the Kodiak and Yakutat areas, perhaps indicating a strong year class. Small modes of fish can also be distinguished in the graphs for rougheye rockfish at 23-25 cm in Shumagin, Kodiak, and Southeastern. No discernible modes are seen in the figures for northern, shortraker, or sharpchin rockfish. The graphs for shortraker rockfish show almost no fish less than 40 cm, indicating young of this species probably reside in a habitat inaccessible to the trawl gear used in the survey.

Age Composition of Pacific Ocean Perch

Age compositions of Pacific ocean perch from the 1987 trawl survey are shown in Figure 9 for the Gulf of Alaska. Ages ranged

Table 14.--Exploitable biomass of slope rockfish in the Gulf of Alaska, based on results of the 1987 triennial trawl survey.

	Area			
	Western	Central	Eastern	Total
Shallow slope rockfish				
Pacific ocean perch	130,261	110,539	87,744	328,544
Northern rockfish	19,056	96,999	1,460	117,515
Harlequin rockfish	10,265	38,127	35,850	84,242
Sharpchin rockfish	3,223	50	66,850	70,123
Other	88	802	1,198	2,088
Total shallow slope rockfish	162,893	246,517	193,102	602,512
Deep slope rockfish				
Rougheye rockfish	3,956	28,974	19,213	52,143
Shortraker rockfish	3,248	30,488	13,800	47,536
Total deep slope rockfish	7,204	59,462	33,013	99,679
Total slope rockfish	170,097	305,979	226,115	702,191

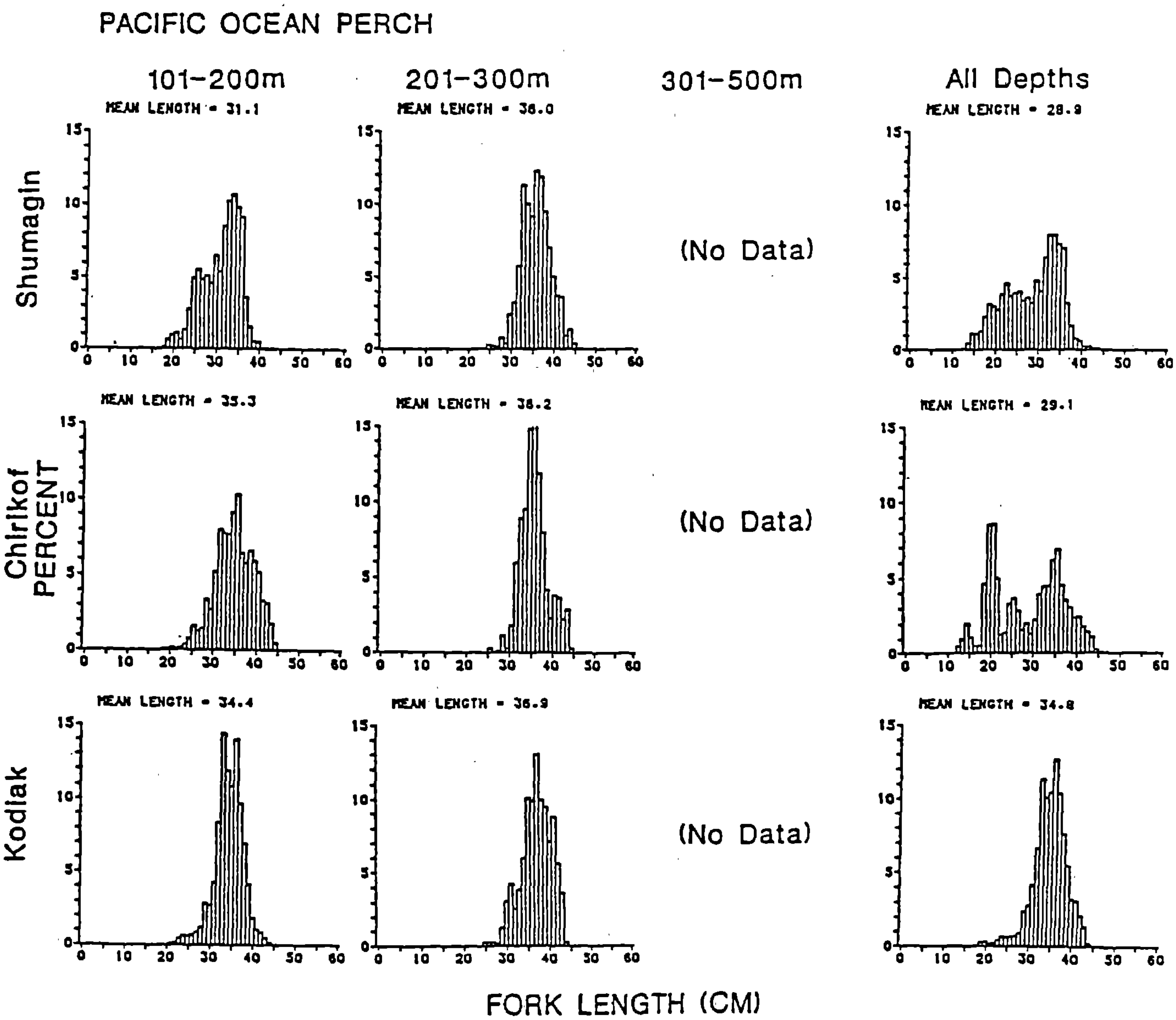

Figure 3. --Length frequency distributions of the estimated population of Pacific ocean perch, Sebastes alutus, in the Gulf of Alaska. Distributions are based on results of the 1987 triennial trawl survey, and are shown by depth stratum and International North Pacific Fisheries Commission statistical area.

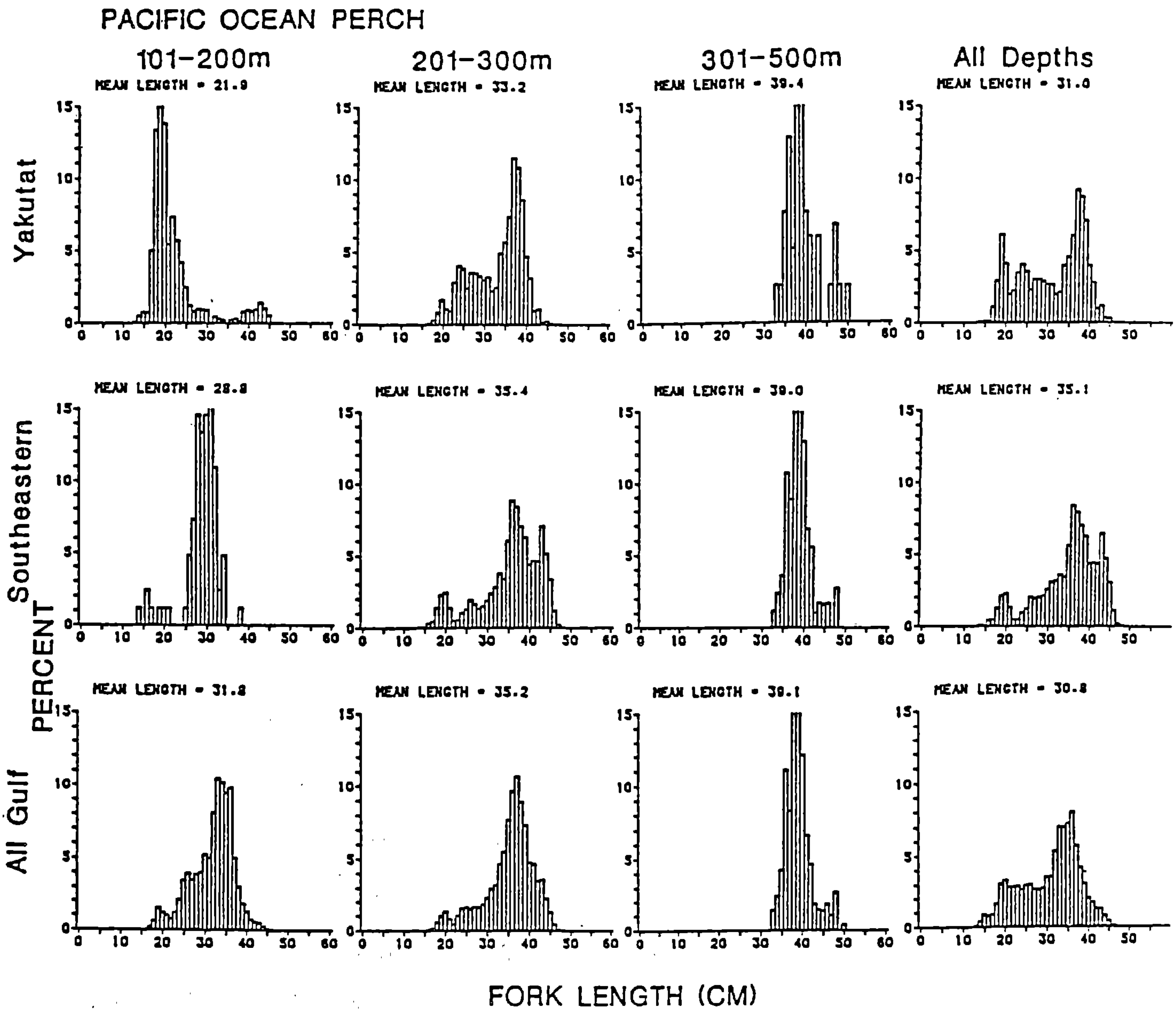

Figure 3.--(Continued).

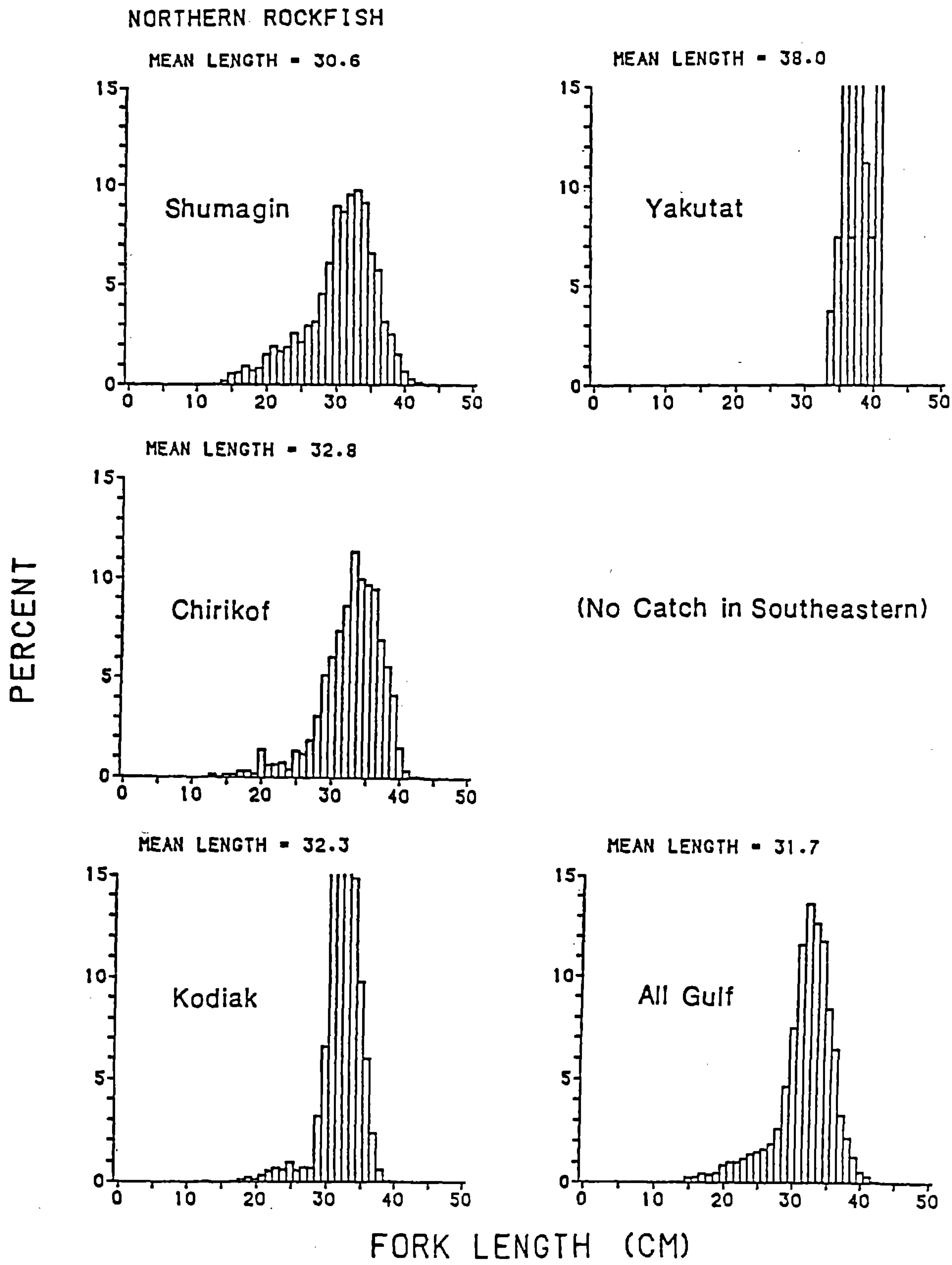

Figure 4.--Length frequency distributions of the estimated population of northern rockfish, Sebastes polyspinis, in the Gulf of Alaska. Distributions are based on results of the 1987 triennial trawl survey and are shown by International North Pacific Fisheries Commission statistical area.

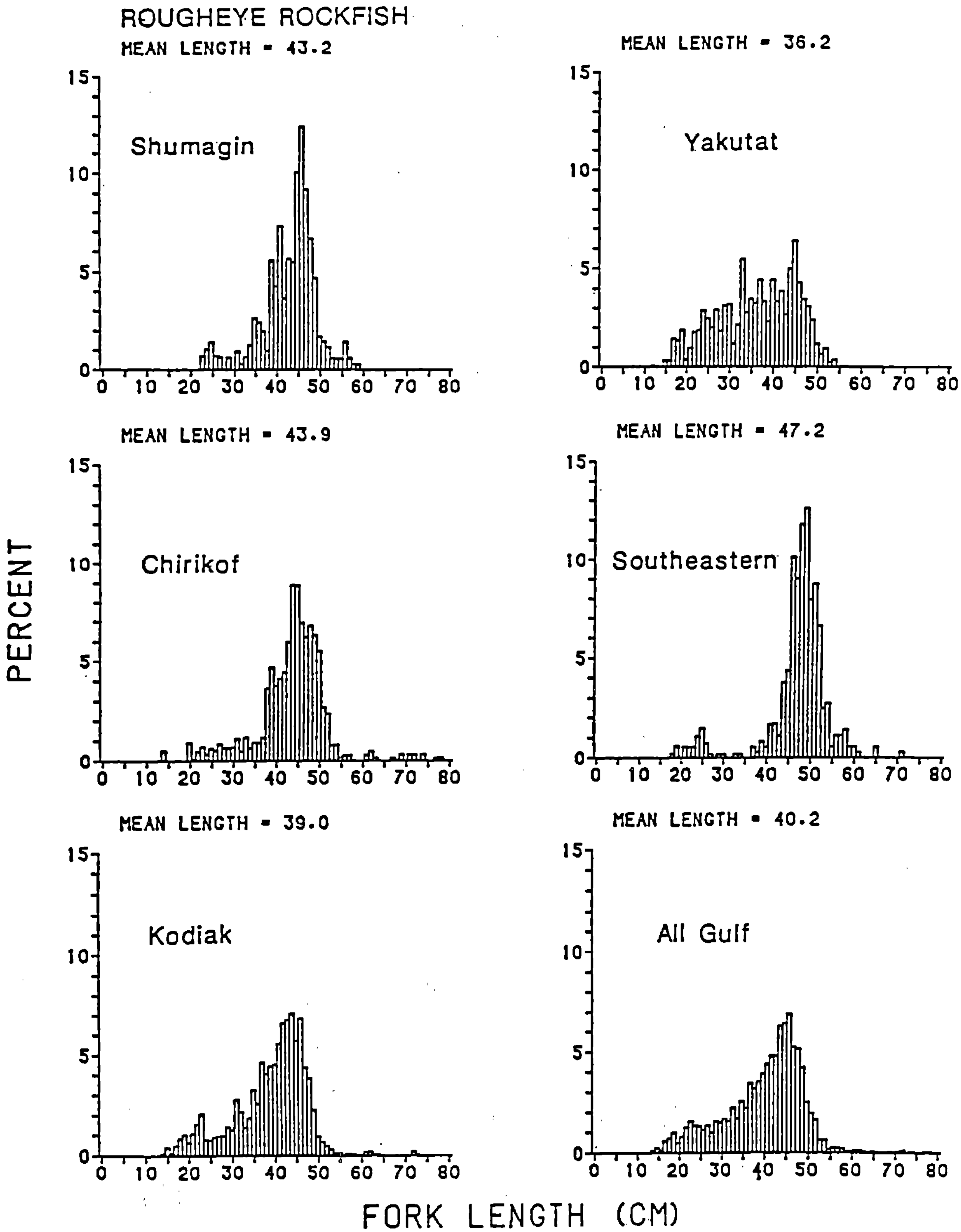

Figure 5.--Length frequency distributions of the estimated population of rougheye rockfish, Sebastes aleutianus, in the Gulf of Alaska. Distributions are based on results of the 1987 triennial trawl survey and are shown by International North Pacific Fisheries Commission statistical area.

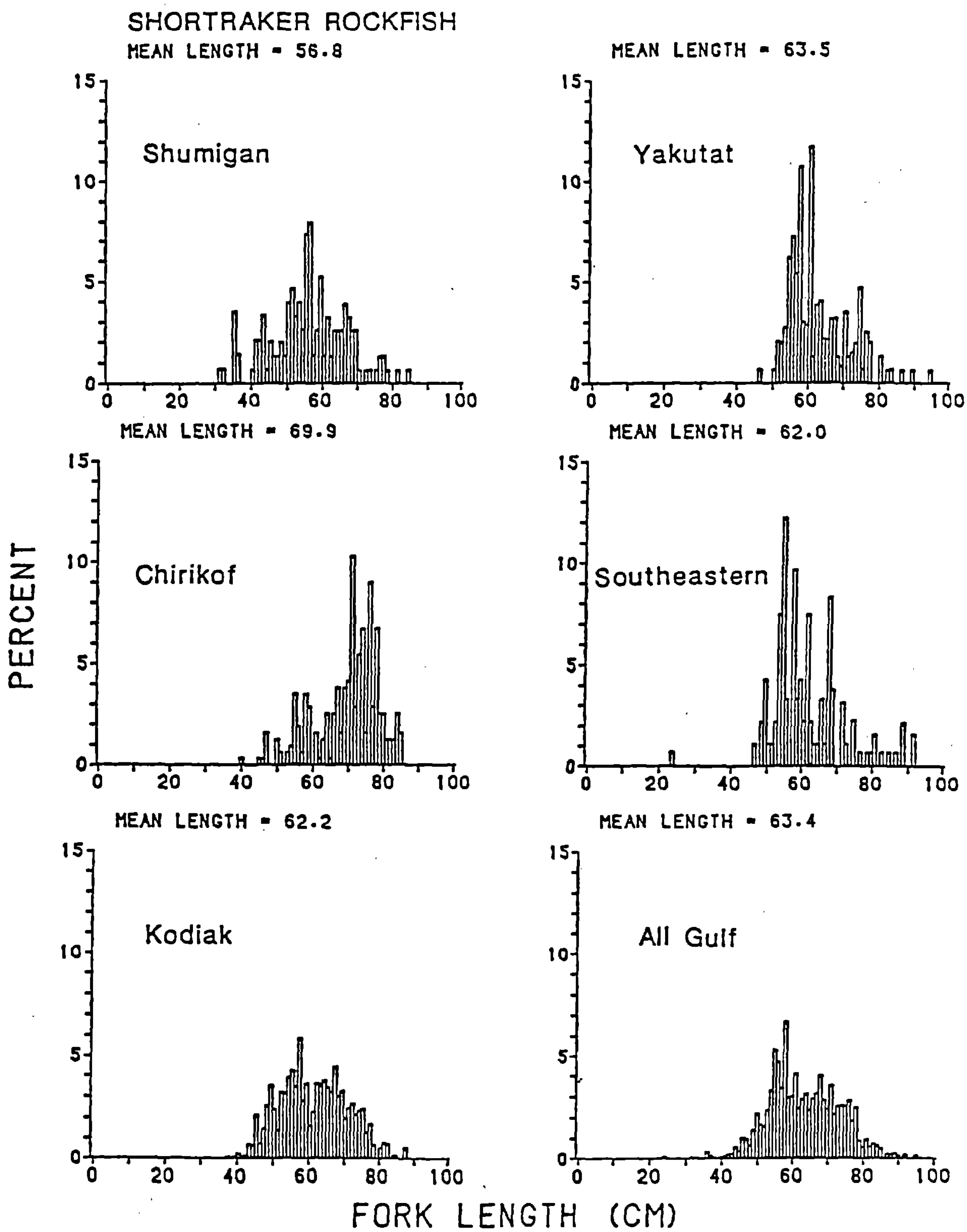

Figure 6.--Length frequency distributions of the estimated population of shortraker rockfish, Sebastes borealis, in the Gulf of Alaska. Distributions are based on results of the 1987 triennial trawl survey and are shown by International North Pacific Fisheries Commission statistical area.

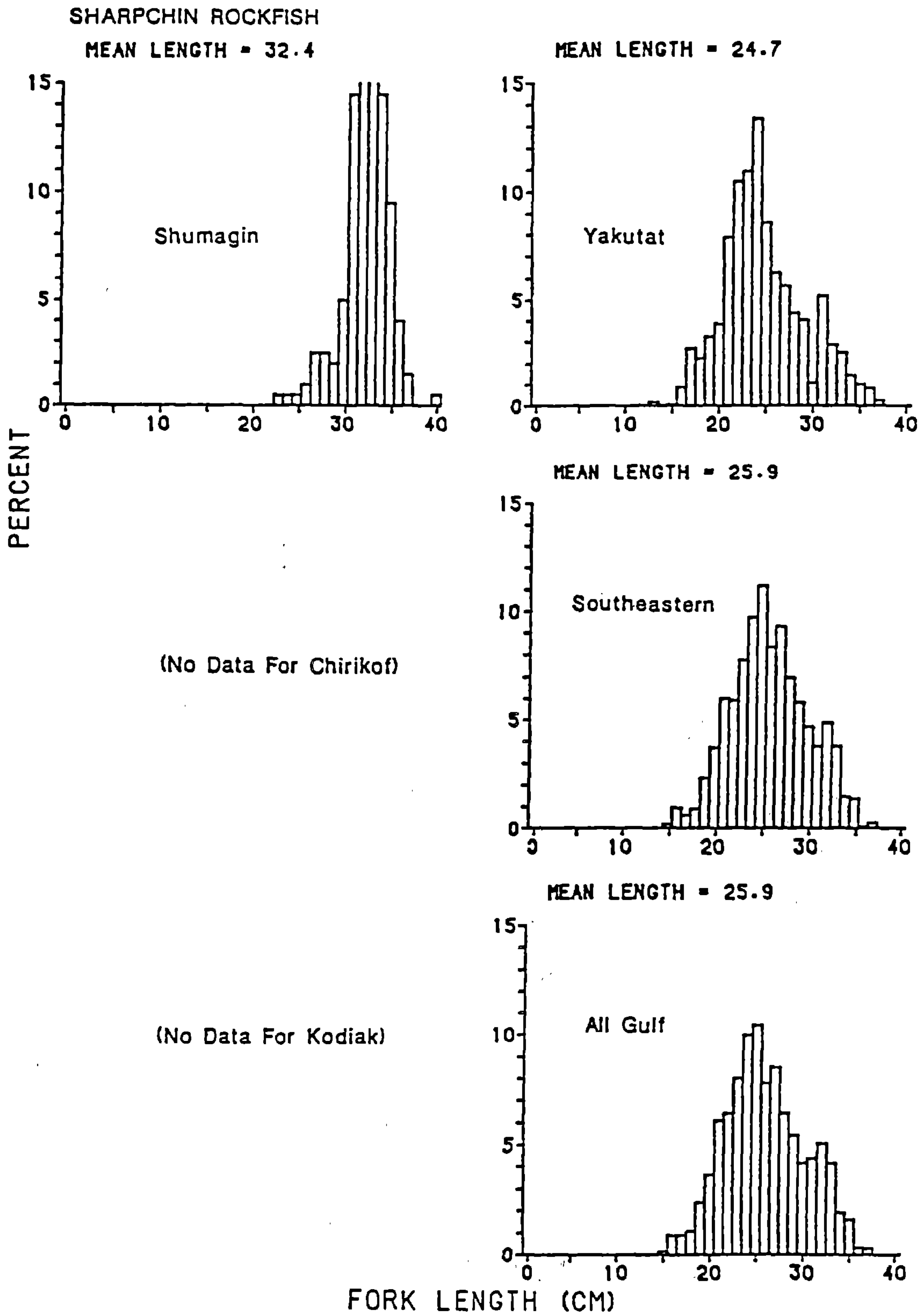

Figure 7.--Length frequency distributions of the estimated population of sharpchin rockfish, Sebastes zacentrus, in the Gulf of Alaska. Distributions are based on results of the 1987 triennial trawl survey and are shown by International North Pacific Fisheries Commission statistical area.

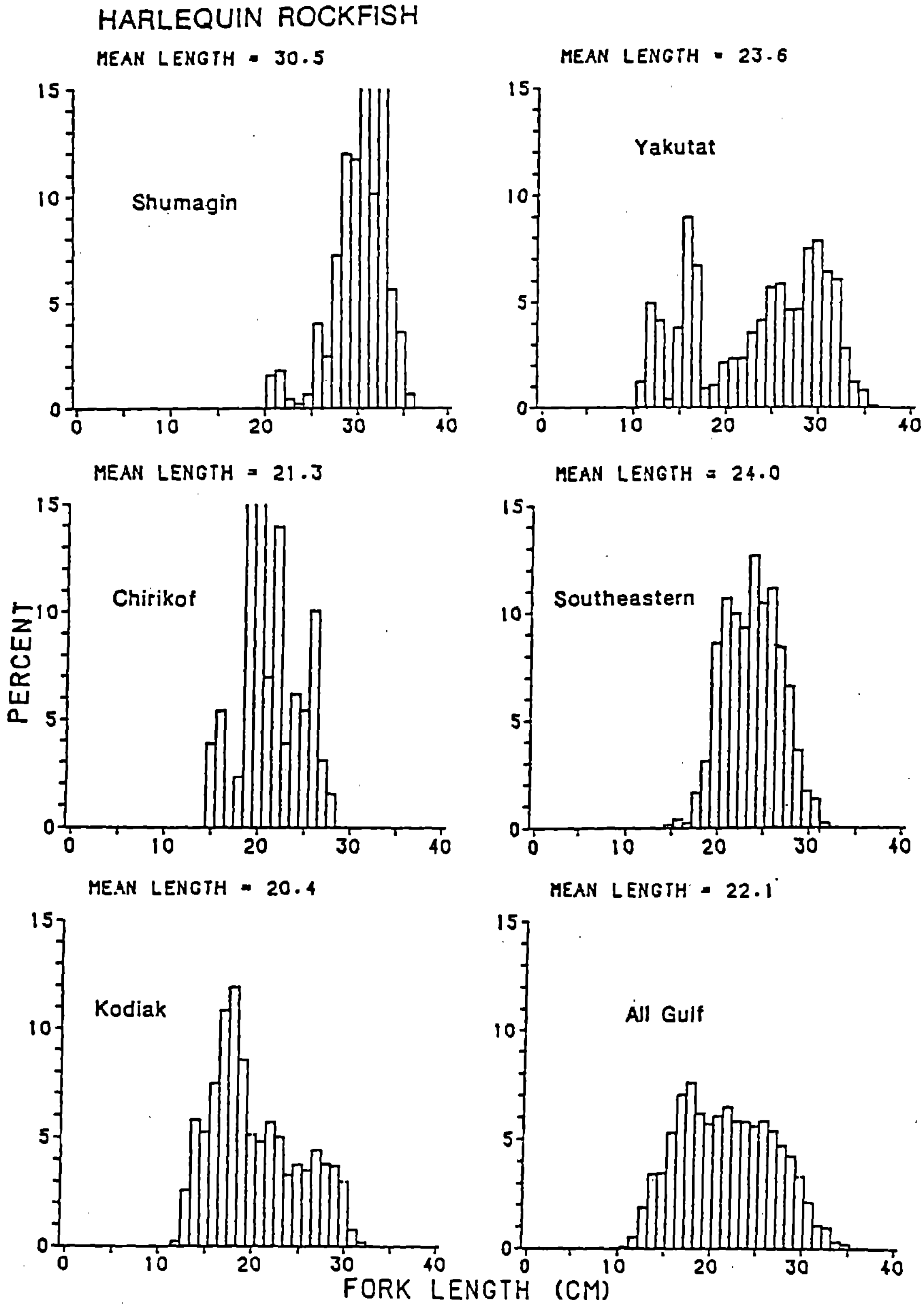

Figure 8.--Length frequency distributions of the estimated population of harlequin rockfish, Sebastes variegatus in the Gulf of Alaska. Distributions are based on result; of the 1987 triennial trawl survey and are shown by International North Pacific Fisheries Commission statistical area.

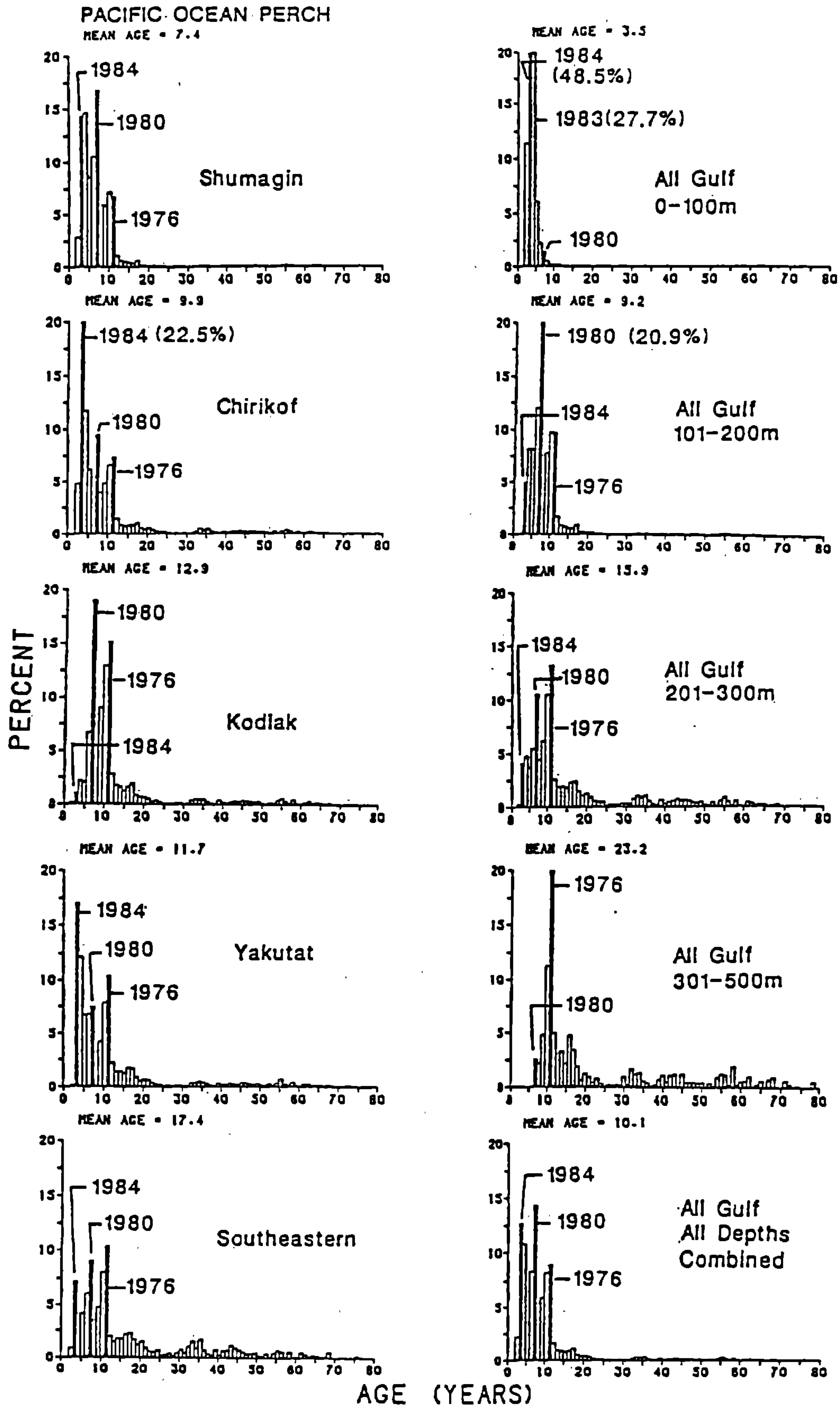

Figure 9.--Age composition of the estimated population of Pacific ocean perch, Sebastes alutus, in the Gulf of Alaska, based on otoliths collected in the 1987 triennial trawl survey. Dark bars identify three prominent year classes: 1976 (age 11); 1980 (age 7); and 1984 (age 3).

from 2 to 78 years (n = 1,824 fish aged), and were determined using the "break and burn" method of ageing otoliths. These ages were used to develop a gulfwide age-length key, which was then used to estimate the age composition of Pacific ocean perch populations in the gulf.

Three prominent year classes can be identified in areas across the gulf: 1976 (age ll), 1980 (age 7), and 1984 (age 3). The 1977 and 1983 year classes also appear relatively strong in some areas. The 1976 year class is evident in all areas except Shumagin; 1980 is strong everywhere except Yakutat; and 1984 is absent only in Kodiak. Since 1976 there is evidence of a number of successful year classes of Pacific ocean perch in the gulf.

Previous investigations have also identified a strong 1976 year class in the Gulf of Alaska (Carlson et al. 1986; Clausen et al. 1988) and in the Aleutian Islands (Ito 1987). Identifiable modes of small fish at 24 cm seen in the 1984 trawl survey in the Yakutat and Southeastern areas (Clausen et al. 1988) probably correspond to the 1980 year class. Similarly, the modes of young Pacific ocean perch at 20 cm noted in the 1987 survey (discussed in the section above) are likely from the 1984 year class.

The success of these year classes indicates future stock condition of the Pacific ocean perch may be improving. The age compositions (Fig. 9) show a long period of weak year classes in the years previous to 1976. The resulting years of poor recruitment may have delayed recovery of Pacific ocean perch populations after they were overfished in the 1960s and early 1970s.

BIOLOGICAL PARAMETERS

Natural Mortality, Maximum Age,, and Age at Recruitment

Using the sectioned break and burn method of determining age from otoliths, Archibald et al. 1981, Nelson and Quinn 1987, and others determined mortality rates, maximum age, and age of recruitment for some species of slope rockfish (Table 15). Age samples collected in the 1984 and 1987 trawl surveys are currently being analyzed to provide further information on these parameters.

Length and Weight at Age

Length and weight at age for slope rockfish are shown in Table 16.

Table 15. --Instantaneous rate of natural mortality, maximum age, and age of recruitment for slope rockfish. Area indicates location of study: British Columbia (BC), Gulf of Alaska (GOA), Aleutians (AL).

Species	Natural mortality rate	Maximum age	Age of recruit-ment	Area	Refer-ence
Pac. ocean	0.04-0.06	77	-	BC	1
perch	0.02-0.08	77	-	BC	1
	-	78	-	GOA	2
	-	98	-	AL	3
	-	-	9	GOA	4
Northern	-	43	-	GOA	2
Rougheye	0.03-0.04	68	-	BC	1
	0.01-0.02	72	-	BC	1
	0.04	95	30	GOA	5,6
Sharpchin	0.05	46	-	BC	1
Yellowmouth	0.06	41	-	BC	1
Darkblotched	0.07	48	-	BC	1

1) Archibald et al. 1981; 2) Unpublished data Auke Bay Laboratory; 3) Ito 1987; 4) Kimura et al. 1984; 5) Nelson and Quinn 1987; 6) Nelson 1986.

Table 16.--Von Bertalanffy parameters and length-weight coefficients for some species of slope rockfish. Length-weight coefficients are for the relationship $w = aL^b$ where W = weight in kg and L = length in cm.

Species	Length-weight coefficients a	b	t_0	k	L_∞ (cm)	Reference
Pacif. ocean perch	1.54×10^{-5}	2.96	-8.22	0.088	44.8	1,2
	—		-5.22	0.126	42.6	1
Northern	1.63×10^{-5}	2.98	1.95	0.301	36.2	3
Rougheye	—		-4.21	0.050	54.7	4
Sharpchin	—		-2.12	0.095	34.9	1

1) Archibald et al. 1981; 2) Ito 1982; 3) Unpublished data Auke Bay Laboratory, P.O. Box 210155, Auke Bay AK 99821; 4) Nelson 1986.

MAXIMUM SUSTAINABLE YIELD

Stock Reduction Analysis

To determine potential yield for slope rockfish, generalized stock reduction analysis (SRA) (Kimura et al. 1984; Kimura 1985) was applied to Pacific ocean perch. Results of SRA were then applied to other slope rockfish assuming that growth, mortality, and stock condition were similar for all species. In the future, this analysis may be improved when information on biological parameters becomes available for the other species.

Input data required for SRA used in this analysis: estimated annual catches of Pacific ocean perch from 1961 to 1987 (Table 17): rate of instantaneous natural mortality (M = 0.05; from Archibald et al. (1981) estimate of rate of total instantaneous mortality (Z) of lightly exploited stocks of Pacific ocean perch): Schnute (1985) growth model parameters (rho = 0.931, omega = 0.82; Kimura 1985); age of recruitment (k = 9 years: Kimura 1985); current exploitable biomass = 328,544 t (point estimate from Table 14) and 190,627 t (lower confidence interval).

The SRA was performed using three Beverton-Holt stock recruitment levels ranging from constant recruitment (A = 1.0) to 70% of virgin recruitment at 50% of virgin biomass (A = 0.6). The various recruitment scenarios and estimates of exploitable biomass were necessary for the analysis because of the uncertainty regarding Pacific ocean perch exploitable biomass and recruitment relationships.

Assuming that the stock was unexploited in 1960, the results of SRA estimated that virgin biomass ranged from 1,460,OOO to 1,640,OOO t and current biomass is 12 to 25% of virgin biomass (Table 18 and Fig. 10). Values of maximum sustainable yield (MSY) are quite variable and depend on the corresponding recruitment model. Except for the constant recruitment model (A = l.O), current exploitable biomass is well below biomass that produces MSY. The constant recruitment model fit to the lower 95% confidence bounds of 1987 exploitable biomass produced no solution to the SRA equations; catch would have had to exceed biomass. For the constant recruitment model fit to the point estimate of 1987 biomass, SRA implied that catch was greater than 90% of exploitable biomass in some years. Thus, the constant recruitment model is probably unrealistic and estimates of MSY from the other models are more reasonable. In these other models, MSY ranges from 12,900 to 25,500 t and exploitation rates at MSY (U) range from 0.021 to 0.057. The relationship between yield, exploitable biomass, and instantaneous rate of fishing mortality (F) is shown in Figure 11.

Table 17.--Estimated catch of Pacific ocean perch, *Sebastes alutus*, in the Gulf of Alaska, 1961-87.

Year,	Catch (t)	Year	Catch (t)
1961	16,000	1975	50,400
1962	65,000	1976	45,500
1963	136,300	1977	21,600
1964	243,400	1978	8,000
1965	348,600	1979	8,300
1966	200,800	1980	10,800
1967	120,000	1981	10,500
1968	100,200	1982	5,400
1969	72,600	1983	2,821
1970	44,900	1984	2,752
1971	77,500	1985	800
1972	77,600	1986	2,200
1973	56,400	1987	3,500
1974	51,000		

Sources: 1961-82 from Balsiger et al. (1985); 1983-87 estimated from catch composition in foreign observer reports (Nelson et al. 1983; Berger et al. 1984, 1985).

Table 18.--Results of Gulf of Alaska stock reduction analysis for Pacific ocean perch.

Recruit. coeff.	Virgin biomass	P	MSY	B_{msy}	F_{msy}	U_{msy}	$F_{0.1}$
Lower conf. limit 1987 expl. biomass (B87) = 190,627 t							
1.000	(No solution - catch exceeds biomass)						
0.889	1,460,000	0.13	24,400	429,600	0.060	0.057	0.040
0.600	1,546,500	0.12	12,900	607,100	0.022	0.021	0.017
Point est. 1987 expl. biomass (B87) = 328,545 t							
1.000	1,419,000	0.25	34,200	230,600	0.165	0.148	0.060
0.889	1,527,000	0.21	25,500	449,000	0.060	0.057	0.040
0.600	1,640,000	0.20	13,700	643,700	0.022	0.021	0.017

P = B87/virgin biomass.

MSY = Maximum sustainable yield.

B_{msy} = Biomass which produces MSY.

F_{msy} = Instantaneous fishing mortality rate at MSY.

U_{msy} = Exploitation rate at MSY.

$F_{0.1}$ = Level of F where the marginal increase in yield due an increase in F is 10% of the marginal increase in yield at F=O.

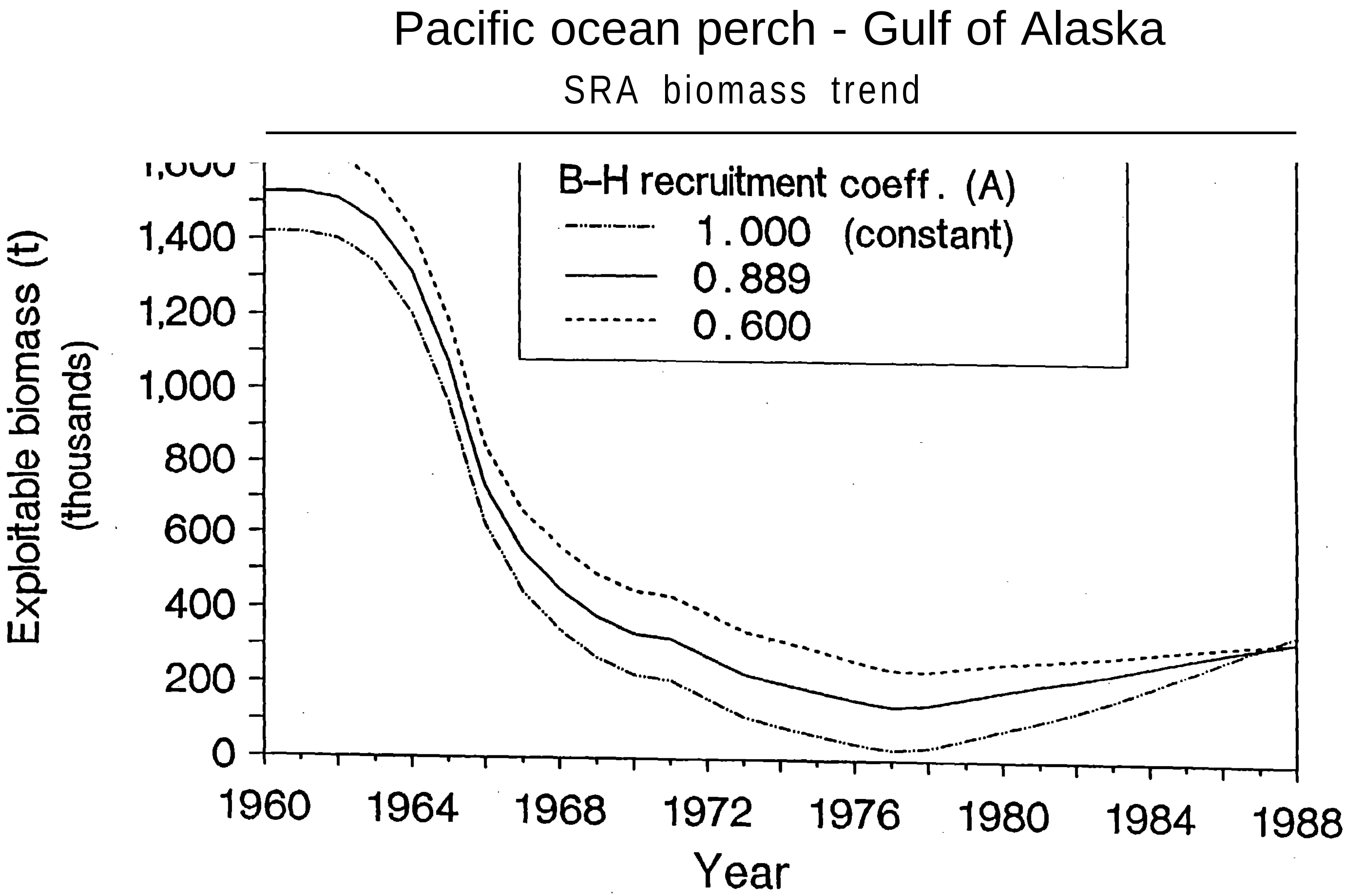

Figure 10.--Exploitable biomass of Pacific ocean perch in the Gulf of Alaska, 1960-88, based on stock reduction analysis (SRA).

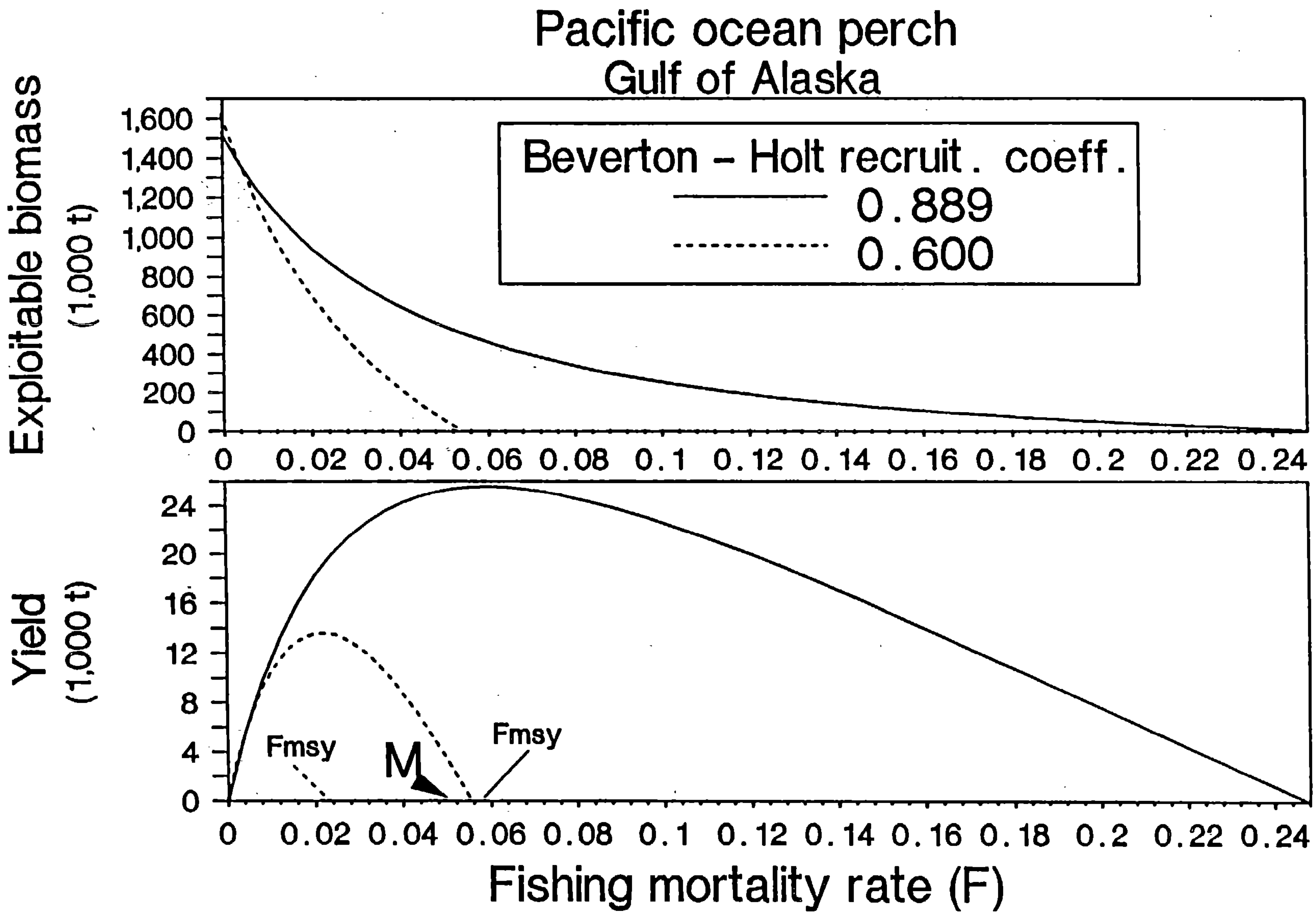

Figure 11.--Equilibrium yield and exploitable biomass as a function of instantaneous rate of fishing mortality (F) for Pacific ocean perch in the Gulf of Alaska based on SRA fit to the point estimate of 1987 exploitable biomass.

ACCEPTABLE BIOLOGICAL CATCH

Pacific Ocean Perch

Multiplying MSY exploitation rates (U_{msy},) by the point estimate of current exploitable biomass gives a range of ABC for Pacific ocean perch in the Gulf of Alaska of 6,898 to 18,727 t. Because of the uncertainty of the stock recruitment relationship, a conservative ABC, near the lower end of the range, is recommended to assure U_{msy} is not exceeded.

Slope Assemblage

An ABC for the slope assemblage can be determined-by assuming that all species are similar to Pacific ocean. perch in productivity and stock condition. By using the same exploitation rates used for Pacific ocean perch, a range of ABC can-be computed for each species. in the assemblage by multiplying U_{msy} (0.021 to 0.057) by the estimates of current exploitable biomass in Table 14. This results in ABCs apportioned to each species in the same proportion as that estimated for their exploitable biomass. A range of ABC for the slope assemblage (including Pacific ocean perch) estimated by summing the individual species ABCs gives an ABC of 14,746 to 40,025 t.

The method described above assumes that the fishery harvests the assemblage ABC in proportion to the abundance estimated for each species of the slope assemblage from the 1987 trawl survey. If this assumption is not met, overexploitation of some species of slope rockfish may result. Such overexploitation may occur if the fishery targets or avoids certain species in the assemblage. Although there is no information on the current species composition in the catch, the foreign fishery for Pacific ocean perch mostly occurred at depths greater than 200 m (Balsiger et al. 1985). Fishing at such depths would occur if the fishery targets on the largest and most valuable fish in the assemblage (shortraker and rougheye rockfish and larger Pacific ocean perch; Fig. 12).

To determine effects of targeting, exploitable biomass of deep slope rockfish (rougheye and shortraker rockfish) was projected for three fishing strategies, two estimates of exploitable biomass, and two catch levels (Fig. 13). The three fishing strategies were 1) no targeting (species composition in the catch is proportional to 1987 exploitable biomass), 2) targeting at depths greater than 200 m (species composition in the catch is the same as species composition at depths greater than 200 m in the 1987 trawl survey), and 3) targeting at depths greater than 300 m (species composition in the catch is the same as species composition at depths greater than 300 m in the 1987 trawl survey). The starting point for the projections was the point estimate of 1987 exploitable biomass for deep slope rockfish (99,679 t) and the lower 95% confidence limit of 1987

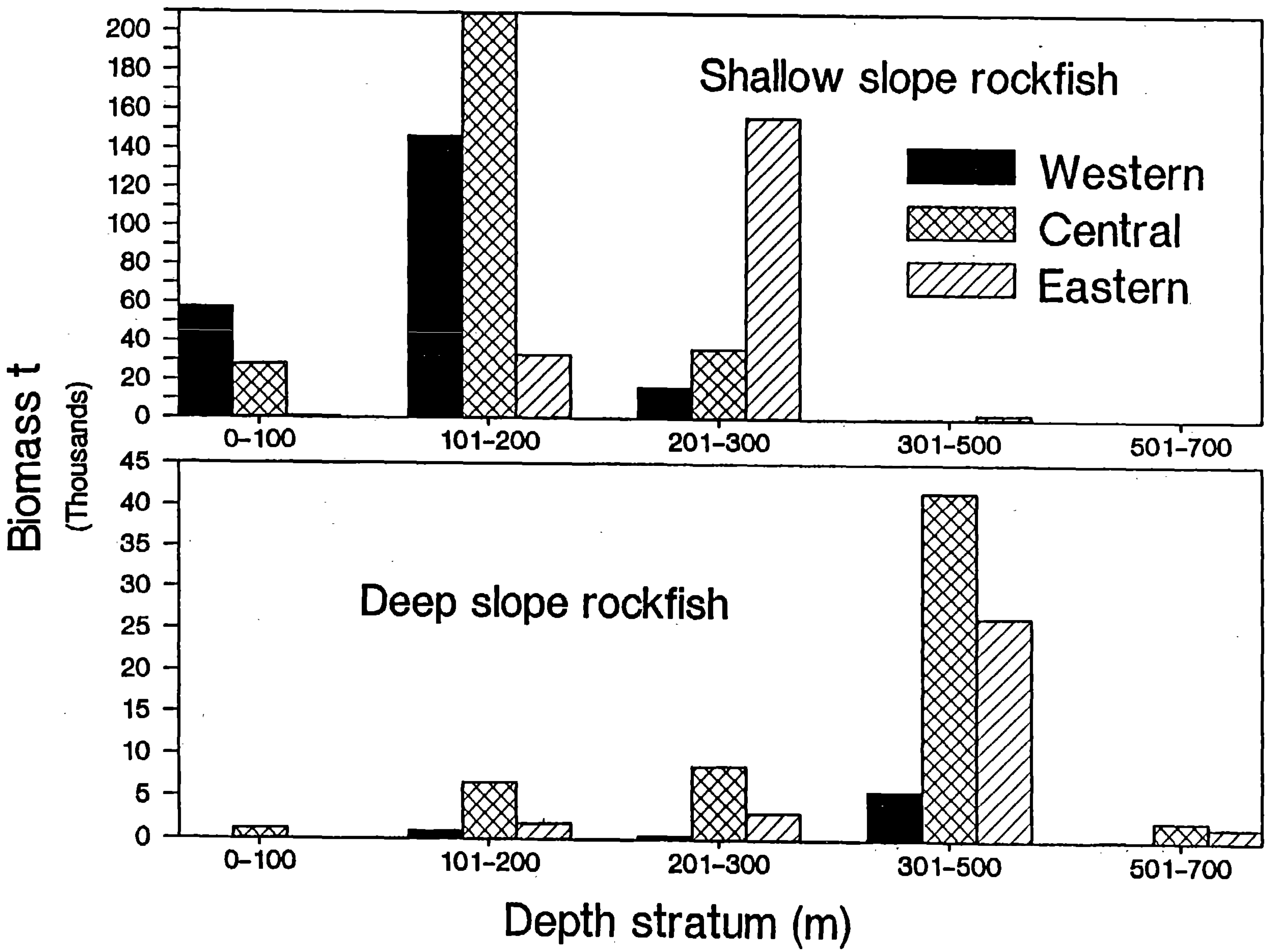

Figure 12.--Depth distribution of deep slope rockfish and shallow slope rockfish in the western, central, and eastern Gulf of Alaska based on the 1987 triennial trawl survey. Deep slope rockfish refers to rougheye and shortraker rockfish and shallow slope rockfish refers to all other species of slope rockfish.

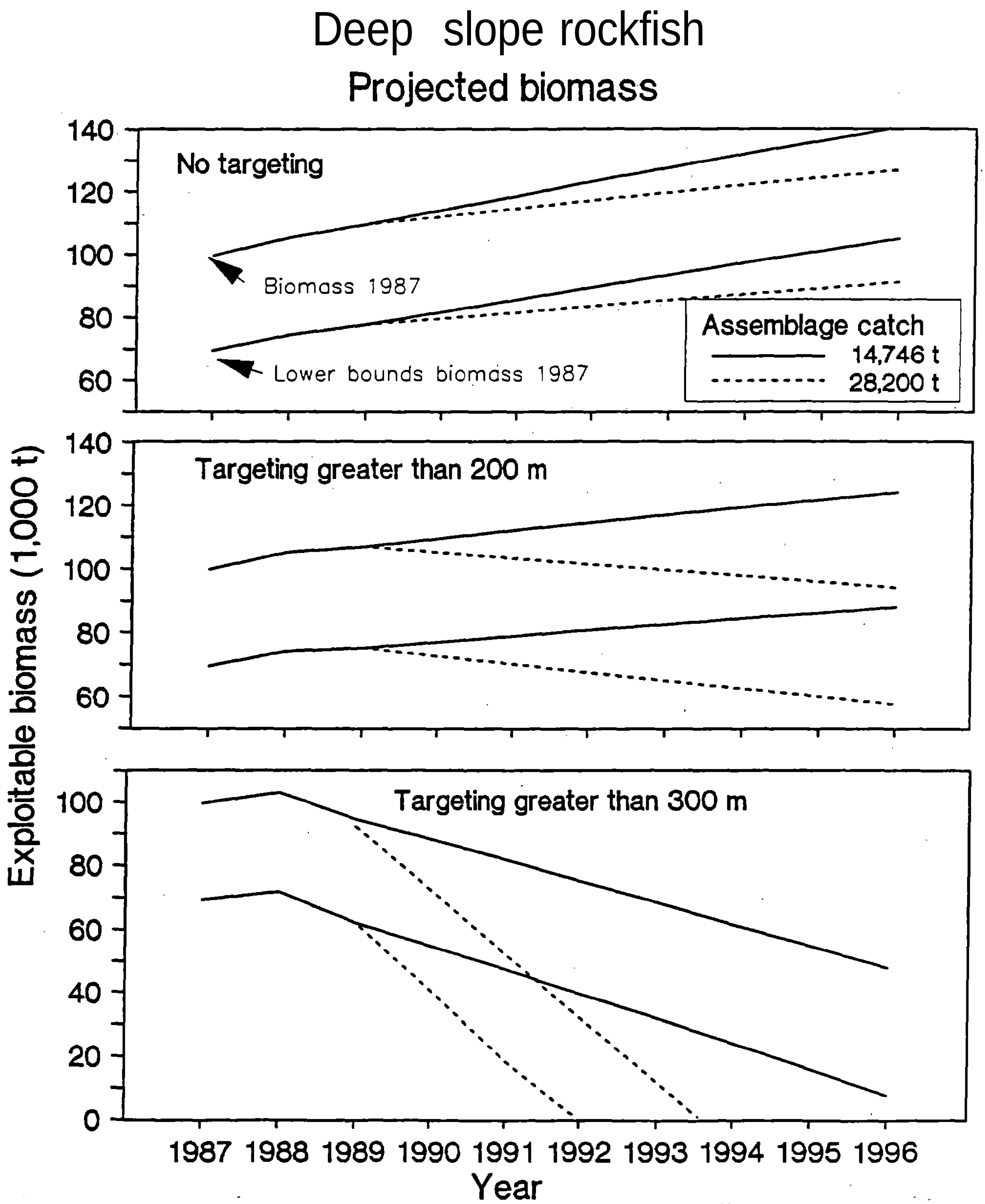

Figure 13.--Projected biomass of deep slope rockfish in the Gulf of Alaska for three fishing strategies, two estimates of exploitable biomass, and two catch levels.

exploitable biomass for deep slope rockfish (69,546 t). The two catch levels corresponded to assemblage catches of 14,746 and 28,200 t. The 14,746 catch level corresponds to a conservative U of 0.021. The 28,200 catch level corresponds to a observative F = M exploitation rate (0.040). For simplicity, deep slope rockfish were assumed to be similar to Pacific ocean perch in productivity. Recruitment was scaled to recruitment from the SRA model for Pacific ocean perch under Beverton-Holt recruitment with A = 0.889. These assumptions are probably optimistic with regard to productivity of deep slope rockfish.

With targeting, the model projects that an assemblage exploitation rate of 0.040 (catch = 28,200 t) causes the exploitable biomass of deep slope rockfish to decline (Fig. 13). Targeting causes increased exploitation rates of deep slope rockfish because a greater proportion of the assemblage catch is composed of deep slope rockfish (Table 19). For example, in the moderate targeting scenario (>200 m), an assemblage catch of 28,200 t results in exploitation rates of deep slope rockfish of 0.081 to 0.115 which are higher than the range of U_{msy} values determined from SRA (0.021 to 0.057). In contrast, a catch of 14,746 t results in exploitation rates of deep slope rockfish of 0.042 to 0.059 which are generally within the range of U_{msy} values determined from SRA.

Based on these considerations, a catch of 14,746 t is recommended for slope rockfish for 1989. This ABC will minimize possible overexploitation of deep slope rockfish and should allow other species to increase towards B_{msy}. Apportionment of the recommended ABC to each management area in the same proportion as exploitable biomass from the triennial trawl survey gives ABCs of 3,572 t for the Western, 6,426 t for the Central, and 4,748 t for the eastern Gulf of Alaska (Table 20).

Table 19.--Projected exploitation rates of deep slope rockfish for 1989 as estimated by the stock reduction analysis model.

Assemblage Catch (t)	Effective exploitation rate: No targeting (P = 0.14)	Targeting >200 m (P = 0.30)	Targeting >300 m (P = 0.96)
Point estimate model			
14,746	0.020	0.042	0.153
28,200	0.037	0.081	0.293
Lower confidence interval model			
14,746	0.028	0.059	0.232
28,200	0.052	0.115	0.445

P = Proportion of assemblage catch composed of deep slope rockfish.

Table 20.--Recommended slope rockfish acceptable biological catch (t) for management areas in the the Gulf of Alaska, 1989.

Species	Management area Western	Central	Eastern	Total
Shallow slope rockfish				
Pacific ocean perch	2,735	2,321	1,843	6,899
Northern rockfish	400	2,037	31	2,468
Harlequin rockfish	216	801	753	1,770
Sharpchin rockfish	68	1	1,404	1,473
Other	2	17	25	44
Total shallow slope rockfish	3,421	5,177	4,056	12,654
Deep slope rockfish				
Rougheye rockfish	83	608	403	1,094
Shortraker rockfish	68	640	290	998
Total deep slope rockfish	151	1,248	693	2,092
Total slope rockfish	3,572	6,425	4,749	14,746

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THORNYHEADS

by

Pierre K. Dawson and Herbert H. Shippen

INTRODUCTION

The shortspine thornyhead (*Sebastolobus alascanus*) inhabits deep waters from 92 to 1,460 m from the Bering Sea to Baja California. Thornyheads are abundant throughout the Gulf of Alaska and are commonly taken in bottom trawls from resource assessment surveys. Since 1980, the shortspine thornyhead resource has been managed as a unit in the Gulf of Alaska.

While in the past the species was not ordinarily the target of fisheries, today thornyheads are one of the most valuable of the rockfish species and are sought after. However, they are also taken in trawl and longline fisheries aiming at other species. According to Alverson et al. (1964), fishes commonly associated with thornyheads are arrowtooth flounder (*Atheresthes stomias*), Pacific ocean perch (*Sebastes alutus*), sablefish (*Anoplopoma fimbria*), rex sole (*Glyntocephalus zachirus*), Dover sole (*Microstomus pacificus*), shortraker rockfish (*Sebastes borealis*), rougheye rockfish (*Sebastes aleutianus*), and grenadiers (family Macrouridae).

CATCH HISTORY

As an element of the deepwater community of demersal fishes, thornyheads have been fished in the northeastern Pacific Ocean since the late 19th century, when commercial trawling by U.S. and Canadian fishermen began. In the mid-1960s Soviet fleets arrived in the eastern Gulf of Alaska (Chitwood 1969), where they were soon joined by vessels from Japan and the Republic of Korea.

Thornyhead catches have been reported in a variety of ways. There are no records of the catches of thornyheads in these early fisheries. The first data began to accrue as part of the U.S. Foreign Fisheries Observer Program in 1977, when the catch in the Gulf of Alaska (as a whole) was estimated at 1,163 t (Wall et al. 1978). From 1980 on, the observer program has generated annual estimates of the foreign catch of thornyheads by International North Pacific Fisheries Commission (INPFC) statistical area. Since 1983 the observer program has also estimated the catches of thornyheads in the joint venture fisheries. Finally (in 1984 for the first time), thornyheads were identified as a separate entity in the U.S. domestic catch statistics (Table 1).

The catches of thornyheads in the Gulf of Alaska declined markedly in 1984 and 1985 because of restrictions on foreign fisheries imposed by U.S. management policies. In 1985 the U.S. catch surpassed the foreign catch for the first time. U.S. catches of thornyheads have continued to increase with the 1988 year-to-date catch being the highest on record. Not represented in the catches are thornyheads that are discarded as bycatch in the U.S. longline fishery, a fishery that has rapidly expanded since 1983.

CONDITION OF THE STOCKS

Relative Abundance

Several factors complicate the management of thornyheads. First, the population structure of the thornyheads has not been defined. As a matter of practical convenience, those thornyheads inhabiting the Gulf of Alaska are managed as a single stock, independent of those in the Bering Sea-Aleutian region or the region to the south. Second, because of the incidental nature of the thornyhead harvest, catch and catch per unit effort (CPUE) of thornyheads are often functions of fisheries directed at the target species rather than at thornyheads themselves.

Trawl Surveys

Resource assessment surveys provide some information about changes in relative abundance of thornyheads over time. Results of bottom trawl surveys in 1979, 1981, and 1984 (expressed in kilograms of catch per square kilometer (kg/km^2)) are summarized in Tables 2 and 3. Comparisons are severely hampered by the lack of samples from deepwater areas which, according to Alverson et al. (1964), are the domicile for the greater part of the thornyhead population. Even in the shallower regions, however, there are no well-defined trends in the relative abundance of thornyheads.

Longline Surveys

Longline surveys have been-conducted jointly by the United States and Japan in the Gulf of Alaska each year since 1979 to ascertain the abundance level and length composition of important groundfish species in the depths from 101 to 1,000 m. For each species, Sasaki and Teshima (1988) used the catch rate, the area, and the size composition of samples from each depth stratum to determine the relative population number (RPN) and weight (RPW) for the depth stratum. The RPNs and RPWs for the various depth

Table 1.--Catch (t) of thornyheads in the Gulf of Alaska by International North Pacific Fisheries Commission statistical area and fishery category, 1980-88.

Year	Nation	Area: Shumagin	Chirikof	Kodiak	Yakutat	South-eastern	Total
1980	Japan	129	197	391	355	144	1,216
	ROK	99	-	-	33	-	132
	U.S.S.R.	1	0	2	-	-	3
	Total	229	197	393	388	144	1,351
1981	Japan	203	138	235	365	179	1,120
	ROK	154	27	27	12	-	220
	Total	357	165	262	377	179	1,340
1982	Japan	134	135	326	64	-	659
	ROK	32	12	19	65		128
	Total	166	147	345	129	-	787
1983	Japan	148	191	287	53	-	679
	ROK	10	3	20	4	-	37
	JV	12	0	1	-	-	13
	Total	170	194	308	57	-	729
1984	Japan	47	53	59	-	-	159
	ROK	3	2	-	-	-	5
	Poland	-	0	1	-	-	1
	JV	18	0	1	-	-	19
	U.S.	9	0	1	2	12	24
	Total	77	55	62	2	12	208
1985	Japan	4	0	0	-	-	4
	JV	2	3	4	-	-	9
	U.S.	6	5	17	29	12	69
	Total	12	8	21	29	12	82
1986	JV	1	-	-	-	-	1
	U.S.	322	8	274	85	24	713
	Total	323	8	274	85	24	714
1987	JV	20	-	-	-	-	20
	U.S.	526	91	880	344	102	1943
	Total	546	91	880	344	102	1963
1988*	U.S.	427	374	551	556	100	2008

Sources: Foreign and joint venture catches: personal communication with Jerald Berger, U.S. Foreign Fisheries Observer Program, Northwest and Alaska Fisheries Center, National Marine Fisheries Service, NOAA, BIN C15700, Building 4, 7600 Sand Point Way NE, Seattle, WA 98115.
U.S. catches: Pacific Fishery Information Network (PacFIN), Pacific Marine Fisheries Commission, 305 State Office Building, 1400 SW. Fifth Avenue, Portland, OR 97201.
* Catches reported through August 1988.

Table 2.--Thornyhead catch per unit effort (kg/km^2) by area and depth in resource assessment surveys by bottom trawl in the International North Pacific Fisheries Commission's Shumagin, Chirikof, and Kodiak statistical areas of the Gulf of Alaska, 1979, 1981, and 1984.*

	Area								
	Shumagin			Chirikof			Kodiak		
Depth (m)	1979	1981	1984	1979	1981	1984	1979	1981	1984
101-200	37	-	28	26	-	47	55	165	79
(No. sta.)	(20)	(0)	(76)	(22)	(0)	(83)	(25)	(5)	(136)
201-300	2,613	-	2,896	864	-	574	1,416	5,852	927
(No. sta.)	(23)	(0)	(23)	(32)	(0)	(35)	(43)	(7)	(49)
301-500	-	-	2,507	2,657	-	3,289	1,160	4,019	2,523
(No. sta.)	(0)	(0)	(17)	(15)	(0)	(11)	(5)	(5)	(20)
501-700	-	-	2,338	-	-	2,252	-	-	1,875
(No. sta.)	(0)	(0)	(15)	(0)	(0)	(10)	(0)	(0)	(15)
701-1,000	-	-	1,151	-	-	3,274	-	-	2,275
(No. sta.)	(0)	(0)	(5)	(0)	(0)	(6)	(0)	(0)	(6)

*To make the 1979 and 1981 survey results comparable to those of 1984, the 1979 and 1981 results have been converted from kg/h to kg/km^2 by assuming a towing speed of 3 knots during sampling, a trawl opening width of 18.3 m, and a fishing power coefficient of 1.00 in 1979 and 1981 as compared to 3.66 in 1984. The latter figure (3.66) was derived by means of comparative tests between U.S. and Japanese trawls as part of the 1984 U.S.-Japan cooperative bottom trawl survey of- the central and western Gulf of Alaska (Brown 1986).

Table 3.--Thornyhead catch per unit effort (kg/km^2) by area and depth in resource assessment surveys by bottom trawl in the International North Pacific Fisheries Commission's Yakutat and Southeastern statistical areas of the Gulf of Alaska, 1979, 1981, and 1984.*

	Area					
	Yakutat			Southeastern		
Depth (m)	1979	1981	1984	1979	1981	1984
101-200	-	66	16	267	92	58
(No. sta)	(0)	(37)	(55)	(1)	(39)	(37)
201-300	190	1,091	700	1,940	2,053	1,277
(No. sta)	(7)	(41)	(32)	(5)	(36)	(39)
301-500	-	4,688	3,002	4,051	1,826	2,424
(No. sta)	(0)	(15)	(12)	(9)	(6)	(11)
501-700	-	-	2,504	-	-	14,579
(No. sta)	(0)	(0)	(3)	(0)	(0)	(1)
701-1000	-	-	1,409	-	-	-
(No. sta)	(0)	(0)	(1)	(0)	(0)	(0)

* To make the 1979 and 1981 survey results comparable with those of 1984, the 1979 and 1981 results have been converted from kg/h to kg/km^2 by assuming a towing speed of 3.0 knots during sampling, a trawl opening width of 18.3 m, and a fishing power coefficient of 1.00 in 1979 and 1981 as compared with 3.66 in 1984. See Brown (1986) regarding the derivation of the figure 3.66.

strata (201-1,000 m for thornyheads) were summed to obtain the following gulfwide totals:

Year	RPN	RPW
1979	9875	5696
1980	11823	6726
1981	12723	6793
1982	6840	4254
1983	6893	4148
1984	5291	3115
1985	7532	4362
1986	5411	3401
1987	5071	3294

In general, the stock had declined by 1984 to less than one-half of what it had been in the plateau years of 1980-81. The index has stayed low since 1984 except for a brief increase in 1985. The average RPW of the last 3 years is only 57% of the average of the first 3 years of the index.

Absolute Abundance

1984 Biomass Survey

The 1984 U.S.-Japan cooperative bottom trawl survey of the central and western Gulf of Alaska and the complementary National Marine Fisheries Service bottom trawl survey in the eastern Gulf of Alaska yielded the first information about the standing stock of thornyheads in the region. Most tows were in waters where bottom depths were less than 700 m, although there were some tows at depths over 700 m. Standing stock within the areas surveyed was estimated at 123,005 t--75,350 t in the central and western portion of the gulf and 47,655 t in the eastern gulf (Table 4). The 95% confidence interval on this -biomass is 105,277 to 140,728 t. This is an increased amount from the level reported in Shippen (1987), and represents finalized results from the Yakutat and Southeastern regions provided by D. Clausen, (Alaska Fisheries Science Center, Natl. Mar. Fish. Serv., NOAA, P.0. Box 210155, Auke Bay, AK 99821).

1987 Biomass Survey

The 1987 preliminary biomass estimate is presented in Table 5. In both the 1984 and 1987 biomass estimates, the catch rate is multiplied by the area swept to generate catch per unit area of the bottom. That figure is then extrapolated to the area of the bottom within the region. Relative catch rates at similar stations are compared between the different vessels and gears involved in the survey. The gear with the highest relative catch rate becomes the reference standard and coefficients are derived that adjust the relative catches of the other gears to match the reference. Unfortunately the 1984 reference gear was not present

Table 4.--Estimated standing stock (t) of thornyheads in the Gulf of Alaska in 1984, by International North Pacific Fisheries Commission statistical area and depth stratum. (Based on bottom trawl surveys by U.S. and Japanese research vessels.)

Depth (m)	Area: Shumagin	Chirikof	Kodiak	Yakutat	Southeastern
	Number of stations (top) and standing stock (bottom)				
1-100	106	43	70	11	-
	0	0	0	11	0
101-200	76	83	136	55	37
	362	1,047	3,191	455	595
201-300	23	44	40	32	39
	7,399	6,169	9,622	3,417	6,609
301-500	17	11	20	12	11
	5,916	5,016	6,975	8,877	7,067
501-700	15	10	15	3	1
	4,387	3,989	2,711	3,376	14,101
701-900	5	6	6	1	0
	2,013	9,231	7,322	3,147	-
Total	242	197	287	114	88
	20,077	25,452	29,821	19,283	28,372
Grand Total	123,005 t				

95% confidence interval = 105,277-140,728 t

Table 5.--Estimated standing stock (t) of thornyheads in the Gulf of Alaska in 1987, by International North Pacific Fisheries Commission statistical area and depth stratum. (Based on preliminary results from bottom trawl surveys by U.S. and Japanese research vessels. Biomass is scaled-to the most efficient-trawl.) Results are- not directly comparable with 1984 (see text for explanation).

Depth (m)	Area				
	Shumagin	Chirikof	Kodiak	Yakutat	South-eastern
	Number of stations (top) and standing stock (bottom)				
1-100	106 0	55 0	58 0	14 0	1 0
101-200	55 301	118 109	149 680	63 335	20 78
201-300	7 7,463	17 8,100	22 7,039	21 2,905	15 2,666
301-500	5 15,309	5 7,936	8 6,311	11 4,313	10 4,371
501-700	3 5,962	4 8,210	6 2,034	3 3,029	2 1,904
701-1000	2 1,349	4 6,716	1 1,550	0 --	0 --
Total	178 30,384	203 31,071	244 17,614	112 10,582	48 9,019
Grand Total	98,670 t				

95% confidence interval = 72,232-125,110 t in 1987 so the biomass estimates of the 2 years are not directly comparable. Despite the problem of comparability, the 1987 biomass estimate is the best estimate available of current biomass. The total estimated biomass of thornyheads in the Gulf of Alaska in 1987 is 98,671 t with a 95% confidence interval of 72,232 to 125,110 t.

Current Exploitable Biomass

The best estimate of current exploitable biomass is derived from the 1987 trawl survey with a point estimate of 98,671 t for the entire gulf and a 95% confidence interval of 72,232 to 125,110 t.

RECRUITMENT STRENGTHS

There are no data on this topic. Miller (1985) suggests that there is substantial variation in year class success in her aged sample from the southeastern region taken in 1982.

BIOLOGICAL PARAMETERS

Natural Mortality, Age of Recruitment and Maximum Age

Miller (1985) estimated thornyhead natural mortality by the Ricker (1975) procedure to be 0.07. Miller (1985) also determined the age at recruitment to be 16 years old and the oldest thornyhead found was 62 years old.

Length and Weight at Age

Samples collected in 1982 in the southeastern region of the gulf have provided the only age information available on thornyheads. Parameters estimated from this collection are given below:

Von Bertalanffy Growth Equation:

$$\text{length (cm standard length)} = L_\infty \; (1-\exp(-k(\text{Age}-t_0)))$$
$$L_\infty = 48.3$$
$$k = .025$$
$$t_0 = -6.94$$

Length to weight conversion:

$$\text{weight (kg)} = a(\text{length(cm)})^b$$
$$a = 1.6\text{x}10^{-6}$$
$$b = 3.29$$

MAXIMUM SUSTAINABLE YIEID

From the time the first fishery management plan for groundfish in the Gulf of Alaska went into effect in 1979, maximum sustainable yield (MSY) for thornyheads has arbitrarily been set at 3,750 t. That MSY figure is 3.8% of the 1987 total estimated biomass in the Gulf of Alaska.

Yield per Recruit Analysis

Based on data from Miller (1985), a yield per recruit analysis was undertaken. This technique uses the Beverton-Halt yield equation to calculate the yield available from a given cohort over its fishable lifespan as a function of mortality, growth, and size at recruitment to the fishery (Ricker 1975). Since nothing is known about the stock-recruitment relationship of thornyheads, a conservative approach was taken and an $F_{0.1}$ value was calculated (Gulland and Boerema 1973). Rather than maximizing the yield per recruit, the $F_{0.1}$ figure represents a fishing mortality for which the corresponding marginal yield is 10% of the marginal yield at the origin. The analysis is shown in Figure 1. The calculated $F_{0.1}$ value equals 0.075 (whereas the F_{max} value equals 0.29). This fishing mortality rate reduces the equilibrium biomass to 35% of the unexploited biomass. The analysis is relatively insensitive to changes in the age at recruitment. Reducing the age at recruitment from 16 to 10 does not change the $F_{0.1}$ level.

Yield per Recruit with Constraints on the Biomass Level

Using a combination of yield per recruit analysis and an assumption from the parabolic surplus yield model (Schaefer 1954), an F_{msy} level can be determined. The assumptions are as follows:

1. Recruitment is constant.
2. The biomass of the recruited portion of the population at MSY equals one-half of the virgin biomass of the fish of recruitment age.
3. F and M are both independent of year and age.

Then the following equations can be solved for F_{msy}:

$$B_{msy} = R \int_{t_r}^{t_l} \exp[-(F_{msy}+M)(t-t_r)]\ W_t\ dt \qquad (1)$$

$$B_{\infty} = R \int_{t_r}^{\infty} \exp[-M(t-t_r)]\ W_t\ dt \qquad (2)$$

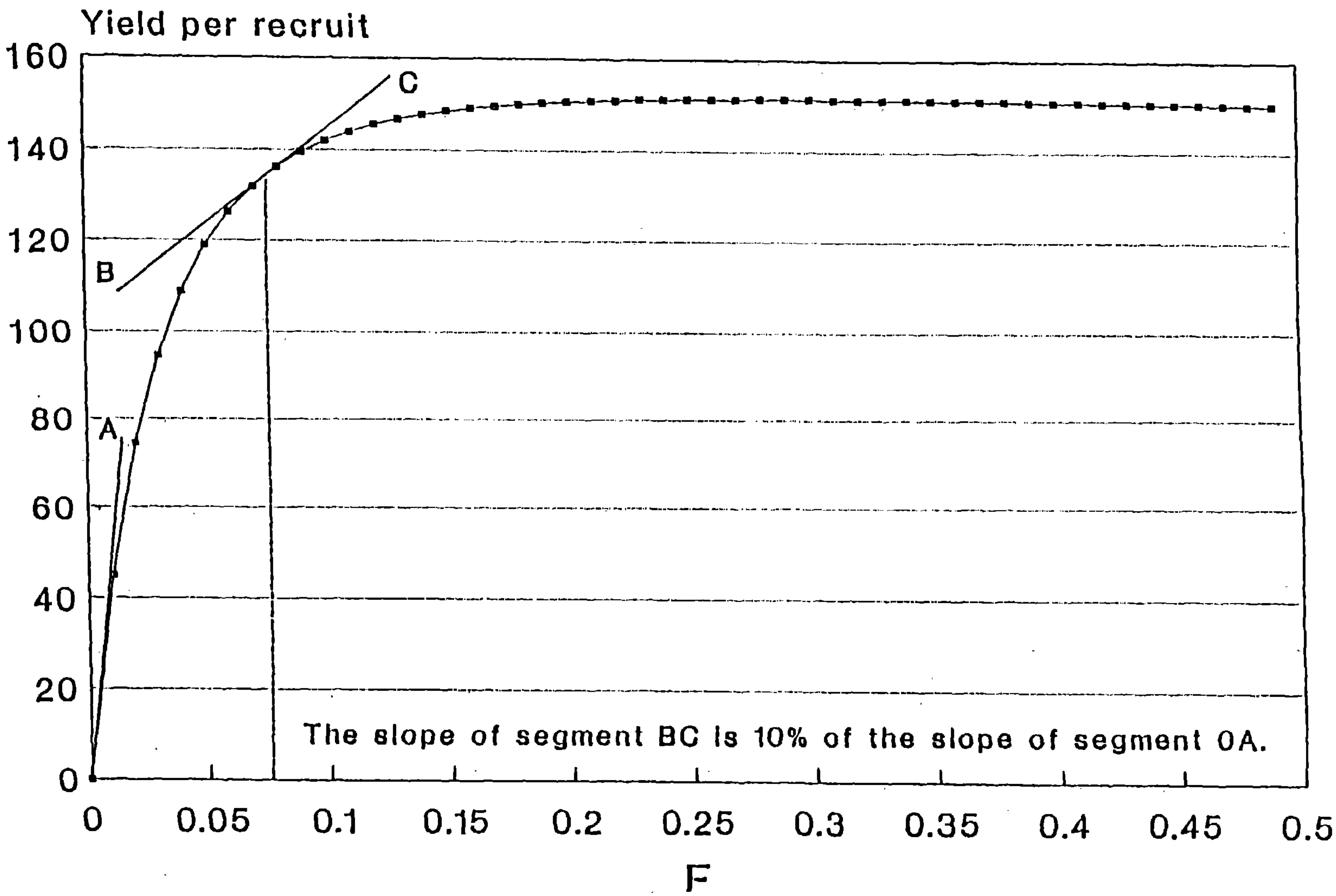

Figure 1.--Plot of yield per recruit versus $\bar{F}$ for thornyheads in the Gulf of Alaska. The $F_{0.1}$ value corresponds to the point on the curve whose slope is 10% of the slope at the origin. (In this case $F_{0.1} = 0.075$), Age at recruitment is 16 years.

$$B_{msy}/B_{\infty} = .5 \qquad (3)$$

where: R = number of recruits to the population

w_t = weight-at-age

t_r = age-at-recruitment

t_1 = oldest age in the fishery

M = instantaneous rate of natural mortality

F = instantaneous rate of fishing mortality

B_{∞} = unexploited biomass

Using data from Miller (1985) of M = 0.07, t_r = 16 and W_t, the calculated F_{msy} value equals 0.05. The effect of changing the age-at-recruitment is shown in Figure 2. Lowering the age at recruitment lowers the F_{msy} level. An age-at-recruitment of 10 results in a decrease in F_{msy} to 0.035.

A current annual potential yield can be determined by multiplying the MSY fishing mortality by the mean exploitable biomass. If the 1987 biomass estimate is assumed to be the mean exploitable biomass for the year then the range of F_{msy} from 0.035 to 0.05 results in potential yields ranging from 3,453 to 4,934 tons.

Maximum Sustainable Yield Assuming Various Stock-Recruitment Relationships

Even if the stock-recruitment relationship for thornyheads is unknown, a range of possible MSYs can be calculated given a range of possible stock-recruitment relationships. Two possible relationships were chosen: a Beverton-Holt stock-recruitment relationship in which the relative recruitment is 90% of virgin, recruitment when the parent biomass has been reduced to 50% of virgin levels, and a Beverton-Halt relationship in which the recruitment is reduced to 80% of virgin recruitment when the parent biomass has been reduced to 50% of the virgin level (Fig. 3) (Kimura 1988). Those two relationships represent relatively robust and nonrobust stock-recruitment scenarios. Where the actual relationship for thornyheads lies is unknown. Combining the Beverton-Halt yield equation with the stock-recruitment relationship results in portraits of equilibrium biomass and yield levels (Fig. 4). The analysis was run again with an age-at-recruitment of 10 years instead of 16 years to investigate the sensitivity of the model to a different age-at-recruitment (Fig. 5).

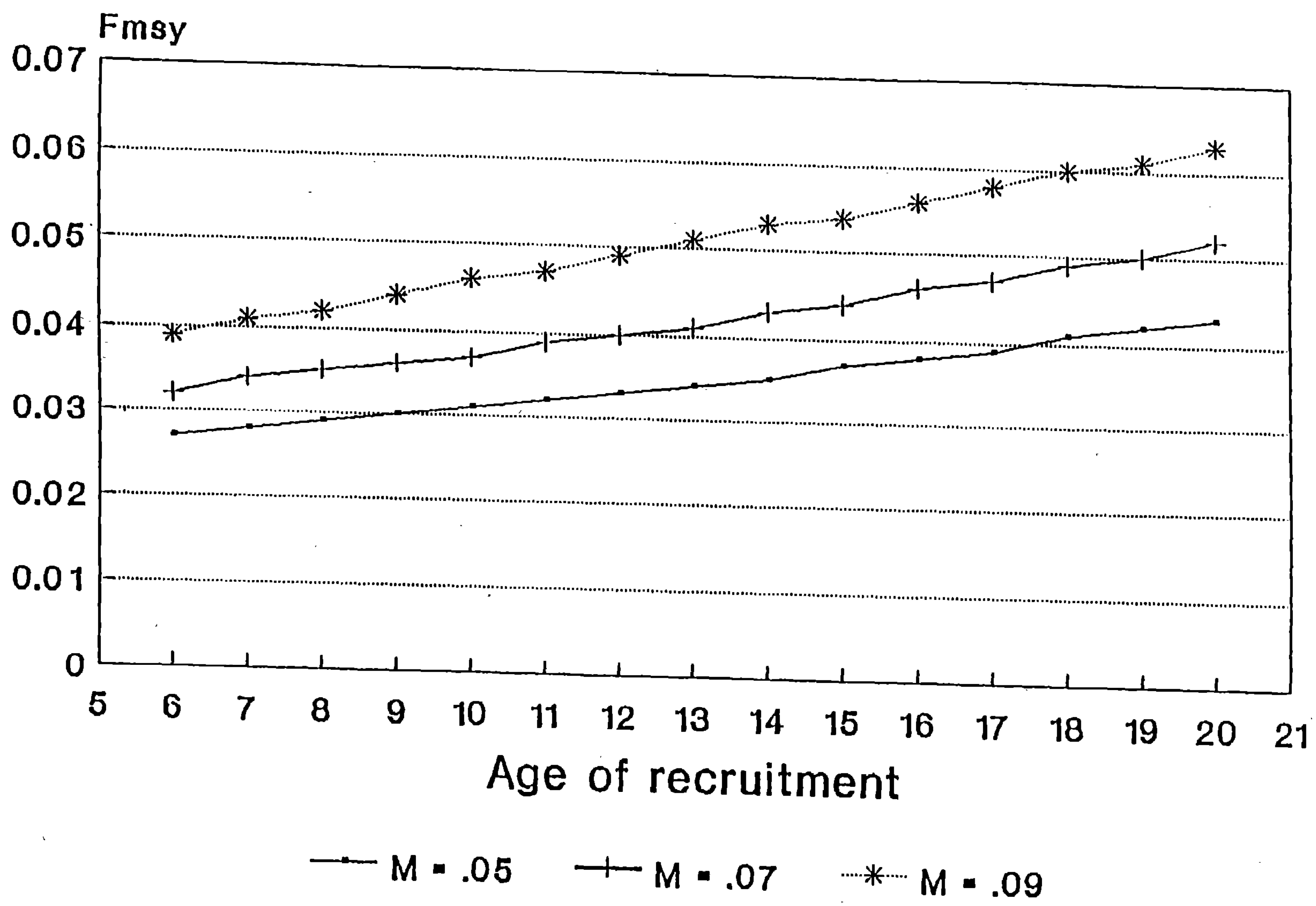

Figure 2.--Plot of F_{msy} as a function of M and age at recruitment for shortspine thornyheads.

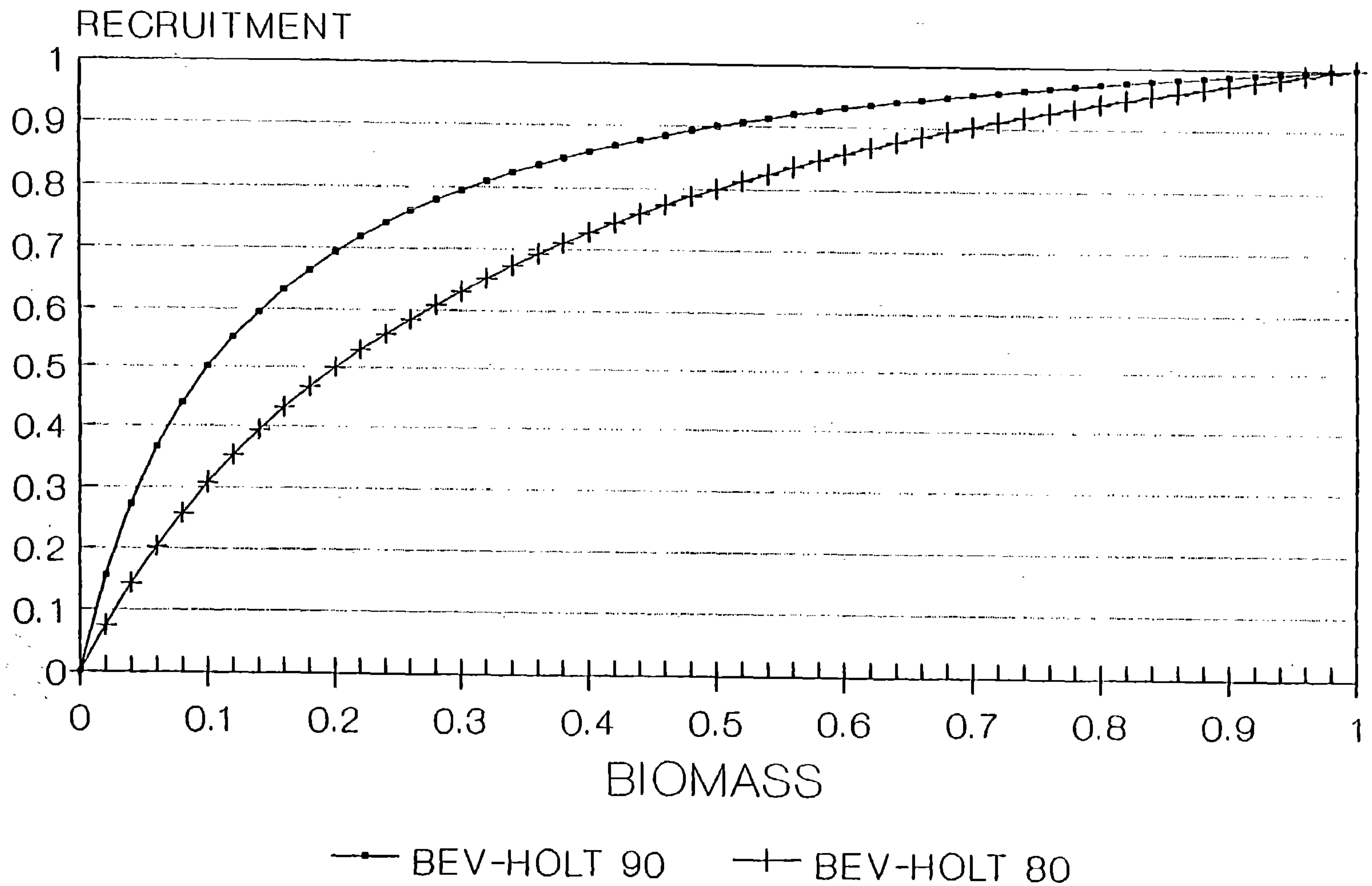

Figure 3.--The relationship between shortspine thornyhead biomass and recruitment. Shown is a Beverton-Holt stock-recruitment relationship of 90% of maximum recruitment at 50% of maximum biomass, and a Beverton-Holt relationship of 80% of maximum recruitment at 50% of maximum biomass.

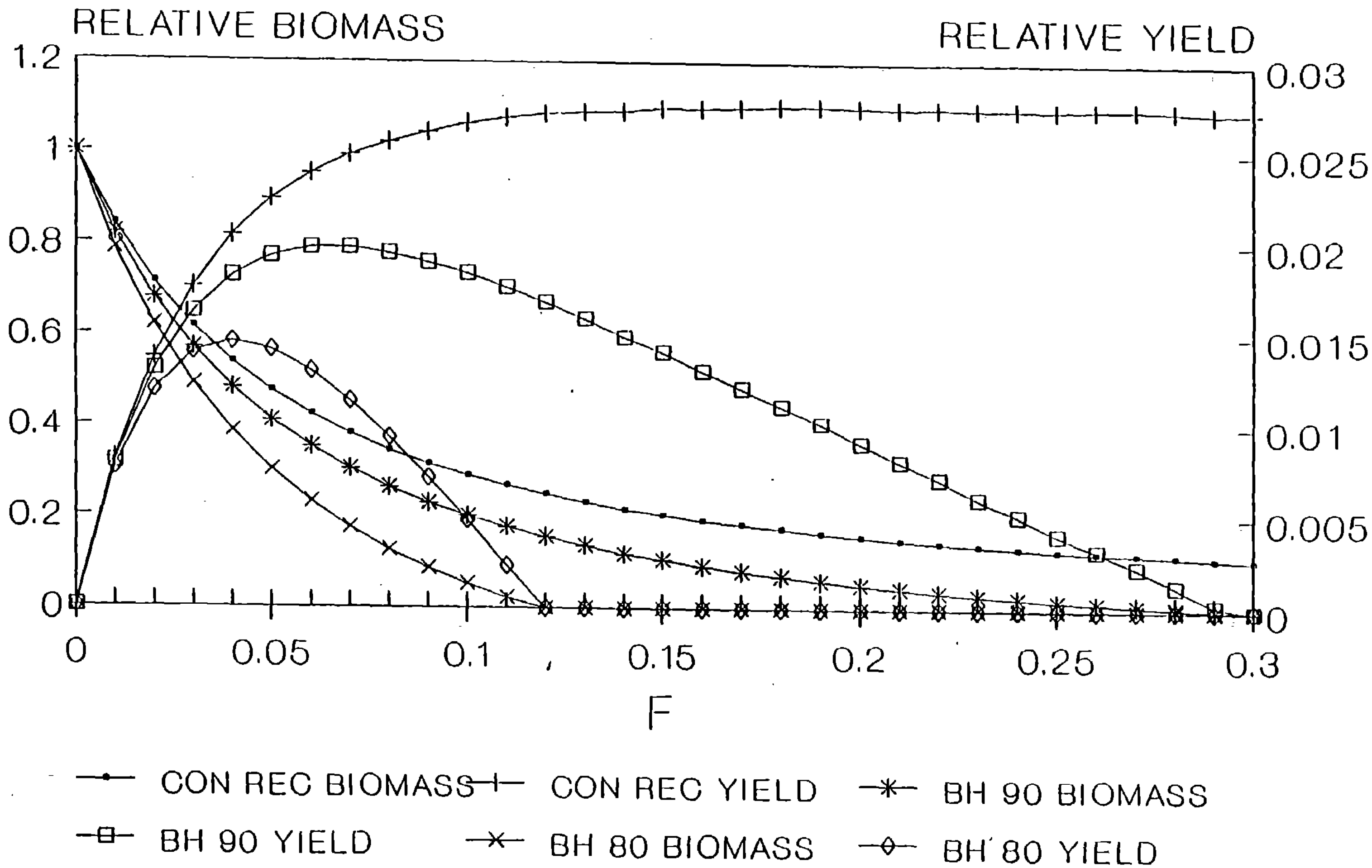

Figure 4.--Plot of thornyhead equilibrium yield and biomass versus F for constant recruitment (con rec), a Beverton-Holt stock-recruitment relationship of 90% of maximum recruitment at 50% of maximum biomass (bh 90), and a Beverton-Holt relationship of 80% of maximum recruitment at 50% of maximum biomass (bh 80). The age at-recruitment is 16 years.

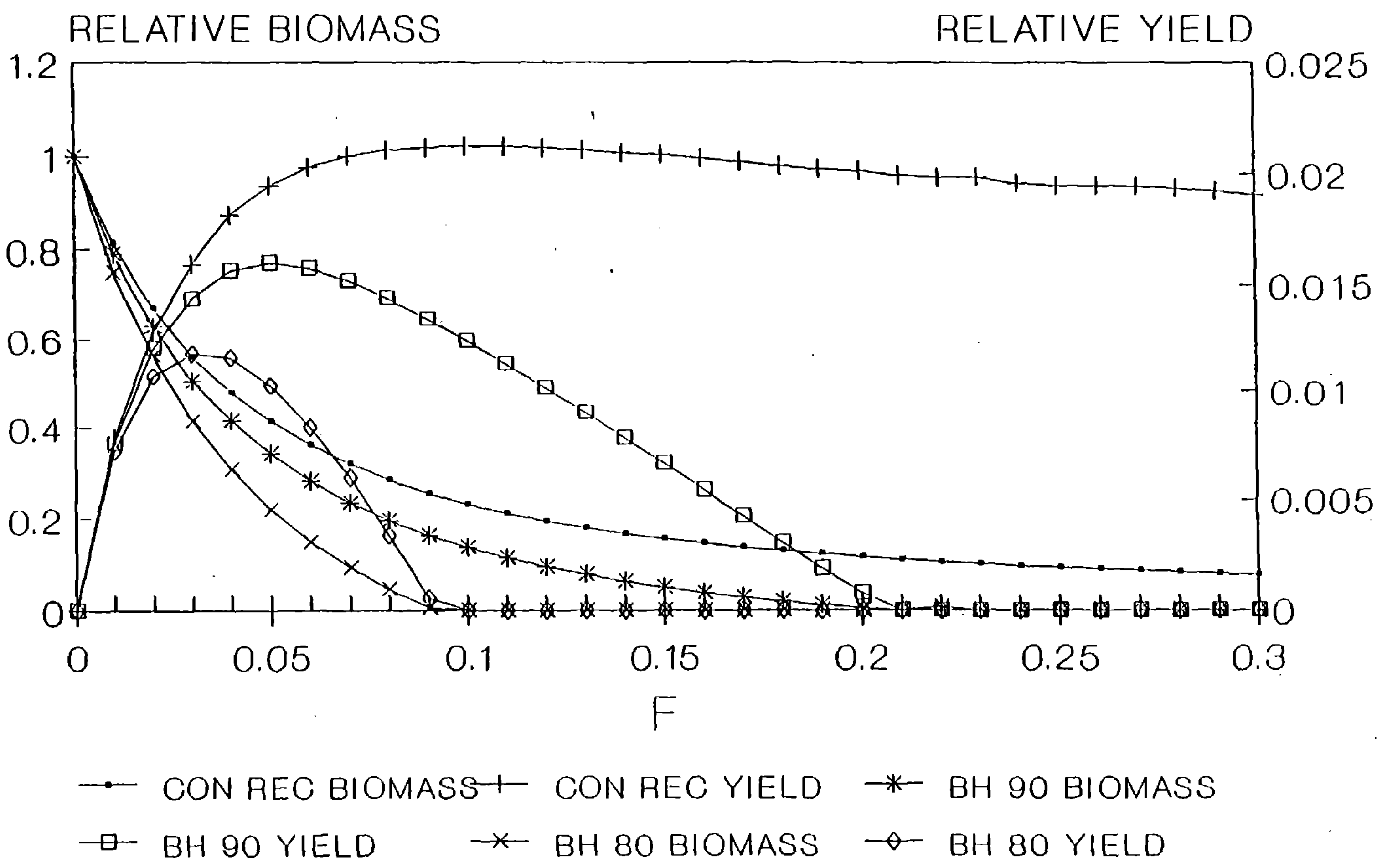

Figure 5. --The same plot as Figure 4 except the age-at-recruitment is 10 years.

The results show that yields are quite sensitive to the stock-recruitment relationship and less sensitive to the age-at-recruitment. Under the Beverton-Holt, 50-90 relationship, the maximum sustainable yield occurs at an F of 0.065 and 0.05 for an age-at-recruitment of 16 and 10 years, respectively. F values of 0.30 and 0.21 drive the population to zero. With the 50-80 stock-recruitment relationship, maximum sustainable yields are obtained at an F of 0.04 and 0.03 for the two recruitment ages. The population is driven to extinction at F values of 0.12 and 0.1.

The range of current annual potential yields is quite similar to that derived from the constrained biomass model above. In this case the range is from 2,960 to 6,414 tons.

ACCEPTABLE BIOLOGICAL CATCH

In the past, acceptable biological catch (ABC) has been set equal to the MSY level of 3,750 t. Given that the value is within the bounds of model predictions above, there is no overwhelming reason to change that value for ABC. However, there are some points of concern in the present situation. Both the 1984 and 1987 trawl surveys took place during periods when the abundance of thornyheads was low according to the longline surveys. While the relationship between the longline abundance indices and the trawl biomasses is uncertain, the decline in those longline indices during a period of time when the reported catches have only been a fraction of the ABC, indicates that the current ABC may not be sustainable. To complicate matters even further, the catch data are clouded by the unreported discarded bycatch in the U.S. longline fishery.

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PELAGIC SHELF ROCKFISH

by

David M. Clausen[1] and Jonathan Heifetz[1]

INTRODUCTION

The pelagic shelf rockfish assemblage in the Gulf of Alaska includes five species of *Sebastes* rockfish (Table 1). This assemblage is one of the three new management groups for *Sebastes* in the gulf which were implemented in 1988 by the North Pacific Fishery Management Council. The other two management groups are slope rockfish and demersal shelf rockfish. Pelagic shelf rockfish can be defined as those species of *Sebastes* that inhabit waters of the continental shelf of the Gulf of Alaska, and that typically exhibit a midwater, schooling behavior. In contrast, demersal shelf rockfish, although inhabiting similar areas of the continental shelf, are found near bottom.

Gulfwide, dusky rockfish are the most important species in the assemblage. The centers of abundance of the other four species lie to the south of the Gulf of Alaska, off Canada and the U.S. west coast. Black and yellowtail rockfish have been reported as locally abundant in Southeastern Alaska (Rosenthal et al. 1982).

The taxonomy of dusky rockfish is unclear. Although only one species has been officially described, two morphologically distinct types have been observed in the Gulf of Alaska: an inshore, shallow water, dark-colored variety; and a lighter-colored variety found in deeper water offshore (Field 1984). This has led some investigators to suggest that these two varieties may be separate species, although no conclusive studies have been made. In the remainder of this report, most of the discussion on dusky rockfish will concern the offshore, light-colored variety, since most information is available from offshore trawl surveys.

CATCH HISTORY

Catches of pelagic shelf rockfish in the Gulf of Alaska are only available for 1988, the first year when catch statistics

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Table 1.--Species comprising the pelagic shelf rockfish assemblage in the Gulf of Alaska.

Common name	Scientific name	Former management grouping (1979-87)
Dusky rockfish	_Sebastes ciliatus_	Other rockfish
Black rockfish	_S. melanops_	Other rockfish
Widow rockfish	_S. entomelas_	Other rockfish
Blue rockfish	_S. mystinus_	Other rockfish
Yellowtail rockfish	_S. flavidus_	Other rockfish

were collected for this assemblage. These data are listed in Table 2 below.

Table 2.--Pelagic shelf rockfish catches (metric tons) in the Gulf of Alaska, updated 3 February 1989.

	Regulatory area				Gulfwide management value	
Year	Western	Central	Eastern	Total	ABC[a]	Quota[b]
1988	240	465	184	888	3,300	3,300

Source: Pacific Fishery Information Network (PacFIN), Pacific Marine Fisheries Commission, 305 State Office Building, 1400 S.W. 5th Avenue, Portland, OR 97201.

[a]Acceptable biological catch.
[b]Quota = total allowable catch (TAC).

There were no reported foreign or joint venture catches of pelagic shelf rockfish in 1988, so the catches listed in Table 2 are entirely domestic (i.e., domestic annual production (DAP)). Approximately 84% of the 1988 catch was taken in trawls, with the remainder caught on longlines or other hook and line gear. The total catch (888 t) was much less than the assigned quota (3,300 t).

Catches of pelagic shelf rockfish for years previous to 1988 cannot be determined. Any of these rockfish caught in trawls would have been reported in the "other rockfish" group (an older management classification used before 1988) along with species now placed in either the slope or shelf demersal groups.

Small numbers of pelagic shelf rockfish have been reported in the Southeastern Alaska rockfish longline fishery. Bracken and O'Connell (1987) found that in past years these species comprised less than 4% weight of the landings in this fishery.

CONDITION OF STOCKS

There is little information on condition of stocks for pelagic shelf rockfish. Traditional resource assessment surveys using bottom trawls have likely underestimated the abundance of these midwater fish. Furthermore, no comprehensive off-bottom surveys of rockfish in the Gulf of Alaska have been conducted.

Relative Abundance

The only data on relative abundance of pelagic shelf rockfish in the Gulf of Alaska come from a survey conducted in nearshore waters of Southeastern Alaska in 1980-81. In this survey, midwater jigging in localized areas was used to evaluate potential rockfish resources (Rosenthal et a1. 1982). The survey indicated that three species of pelagic shelf rockfish composed over half the catch: black, yellowtail, and dusky rockfish, in descending order of abundance. 'In comparison,-longlines set nearby on the bottom caught very few of these fish. The survey indicated that pelagic shelf rockfish may be a latent, under-utilized resource in Southeastern Alaska:

Absolute Abundance

Comprehensive triennial trawl surveys were conducted in the Gulf of Alaska in 1984 and 1987. These surveys provide estimates of biomass for pelagic shelf rockfish. However, fish living in midwater were not sampled in these surveys because the surveys used bottom trawls exclusively.

The 1987 trawl survey indicated that dusky rockfish were the most abundant fish in the assemblage (Table 3). Dusky rockfish comprised more than 99% of the gulfwide assemblage biomass, with three other species (black, widow, and blue rockfish) caught in very small amounts. The total combined biomass estimate was 164,352 t, with 95% confidence intervals of 39,449-289,255 t.

Dusky rockfish biomass were primarily in the Kodiak area, followed by Shumagin, Yakutat, Chirikof, and Southeastern (Table 4). The gulfwide biomass estimate was 163,188 t, and the 95% confidence interval was 35,738-290,638 t. Highest values of both catch per unit effort (CPUE) and biomass were in the 101-200 m depth stratum. Largest individual catches were at stations located on offshore banks, often more than 40 nmi from land (Stark et al. 1988).

The 1987 survey results showed dusky rockfish was the third most abundant rockfish species in the Gulf of Alaska. Only Pacific ocean perch (S. _alutus_) and northern rockfish (S. _polyspinis_) had higher estimates of biomass, with 352,736 t and 172,619 t, respectively.

Abundance of dusky rockfish appears to have increased in the Gulf of Alaska when compared with the 1984 triennial trawl survey. The 1984 survey estimated a gulfwide biomass for dusky rockfish of 37,313 t, far less than the 1987 biomass. The increase is not statistically significant due to the wide confidence intervals around these estimates.

Localized trawl surveys in the gulf prior to 1984 show even lower catch rates for dusky rockfish.' In 1979, CPUE for dusky

Table 3.--Biomass estimates for species in the pelagic shelf rockfish assemblage, based on results of the 1987 triennial trawl survey of the Gulf of Alaska. Biomass estimates were adjusted to the most efficient trawl used in the survey.

Species	Biomass (metric tons) by area*					All gulf
	Shumagin	Chirikof	Kodiak	Yakutat	Southeastern	
Dusky rockfish	28,247	9,237	106,536	18,070	1,097	163,188
Black rockfish	196	137	684	0	0	1,018
Widow rockfish	0	0	0	47	96	143
Blue rockfish	1	0	2	0	0	3
Total	28,444	9,374	107,222	18,117	1,193	164,352

*International North Pacific Fisheries Commission statistical areas.

Table 4.--Estimated biomass, mean catch par unit effort (CPUE), and mean size of dusky rockfish, *Sebastes ciliatus*, based on results of the 1987 triennial trawl survey of the Gulf of Alaska. Biomass and CPUE were adjusted to the most efficient trawl used in the survey.

Area[a]	Depth (m)	No. of trawl hauls	Hauls with dusky	CPUE (kg/km^2)	Biomass (t)	Mean length (cm)	Mean weight (kg)
Shumagin							
	0-100	106	23	122.1	5,416	41.6	0.92
	101-200	55	18	1,566.9	22,776	42.8	1.40
	201-300	7	2	20.5	56	-	1.35
	301-500	5	0	0.0	0	-	-
	501-700	3	0	0.0	0	-	-
	701-1000	2	0	0.0	0	-	-
	All depths	178	43	415.1	28,247	42.7	1.27
Chirikof							
	0-100	55	9	37.4	995	-	1.06
	101-200	118	49	330.8	7,839	41.7	1.34
	201-300	17	6	35.0	403	-	1.21
	301-500	5	0	0.0	0	-	-
	501-700	4	0	0.0	0	-	-
	701-1000	4	0	0.0	0	-	-
	All depths	203	64	135.1	9,237	41.7	1.29
Kodiak							
	0-100	58	13	72.8	2,881	33.8	0.70
	101-200	149	68	2,398.0	103,554	39.0	1.05
	201-300	22	5	8.8	102	-	1.13
	301-500	8	0	0.0	0	-	-
	501-700	6	0	0.0	0	-	-
	701-1000	1	0	0.0	0	-	-
	All depths	244	86	1,042.0	106,536	38.8	1.03
Yakutat							
	0-100	14	0	0.0	0	-	-
	101-200	63	20	508.0	14,553	42.2	1.21
	201-300	21	8	721.6	3,517	42.3	1.20
	301-500	11	0	0.0	0	-	-
	501-700	3	0	0.0	0	-	-
	701-1000	0	-	-	-	-	-
	All depths	112	28	334.3	18,070	42.2	1.21
Southeastern							
	0-100	1	0	0.0	0	-	-
	101-200	20	2	48.3	477	-	1.42
	201-300	15	2	123.2	620	-	1.34
	301-500	10	0	0.0	0	-	-
	501-700	2	0	0.0	0	-	-
	701-1000	0	-	-	-	-	-
	All depths	48	4	48.6	1,097	-	1.37
All Gulf - All Areas Combined							
	0-100	234	45	71.2	9,292	36.7	0.85
	101-200	405	157	1,243.5	149,198	39.9	1.12
	201-300	82	23	131.6	4,698	42.3	1.22
	301-500	39	0	0.0	0	-	-
	501-700	18	0	0.0	0	-	-
	701-1000	7	0	0.0	0	-	-
	All depths	785	225	517.6	163,188	39.8	1.10

[a]International North Pacific Fisheries Commission statistical areas.

rockfish averaged less than 5 kg/h in the central and western Gulf (Ronholt 1980). Similarly, during the years 1963-71, median catch rates for dusky rockfish in the Gulf were 4.5 kg/h (Westrheim 1973). For comparison, the 1987 gulfwide CPUE of dusky rockfish, 517.6 kg/km^2 (Table 3), can be converted to an equivalent CPUE of 76 kg/h. This indicates abundance of dusky rockfish is now much greater than in these earlier surveys.

The abundance of dusky rockfish in the 1987 trawl survey suggests that the validity of the pelagic shelf assemblage should be examined. The assemblage certainly seems appropriate for black, yellowtail, and inshore dusky rockfish in the Southeastern area, where Rosenthal et al. (1982) found these fish residing off bottom. However, the large catches of dusky rockfish in the 1987 survey were all from demersal, offshore catches, which may indicate that offshore dusky rockfish behave differently than. those inshore. Perhaps the offshore fish might be better classified as a demersal species. Clearly, more research is needed on these offshore dusky rockfish to determine if they are taxonomically separate from the inshore variety and if their distribution and behavior tends to be more demersal than those inshore.

Current Exploitable Biomass

Current exploitable biomass for pelagic shelf rockfish in the Gulf of Alaska is estimated at 164,352 t from results of the 1987 trawl survey.

RECRUITMENT STRENGTHS

Length frequency distributions of dusky rockfish from the 1987 trawl survey show no apparent year classes of young fish (Fig. 1). Size of dusky rockfish were similar in all areas of the gulf, except Kodiak, where fish averaged slightly smaller. Very few fish less than 35 cm length were taken during the survey, indicating that either younger dusky rockfish may not be available to the survey's trawl gear, or they may be absent during the time of the survey (June-August) in the area sampled.

BIOLOGICAL PARAMETERS

Natural Mortality, Age of Recruitment, and Maximum Age

The only information on mortality rates and maximum age of pelagic shelf rockfish in the Gulf of Alaska comes from the studies of Rosenthal et al. (1982) and Field (1984). These studies were on black, yellowtail, and dusky rockfish in near-

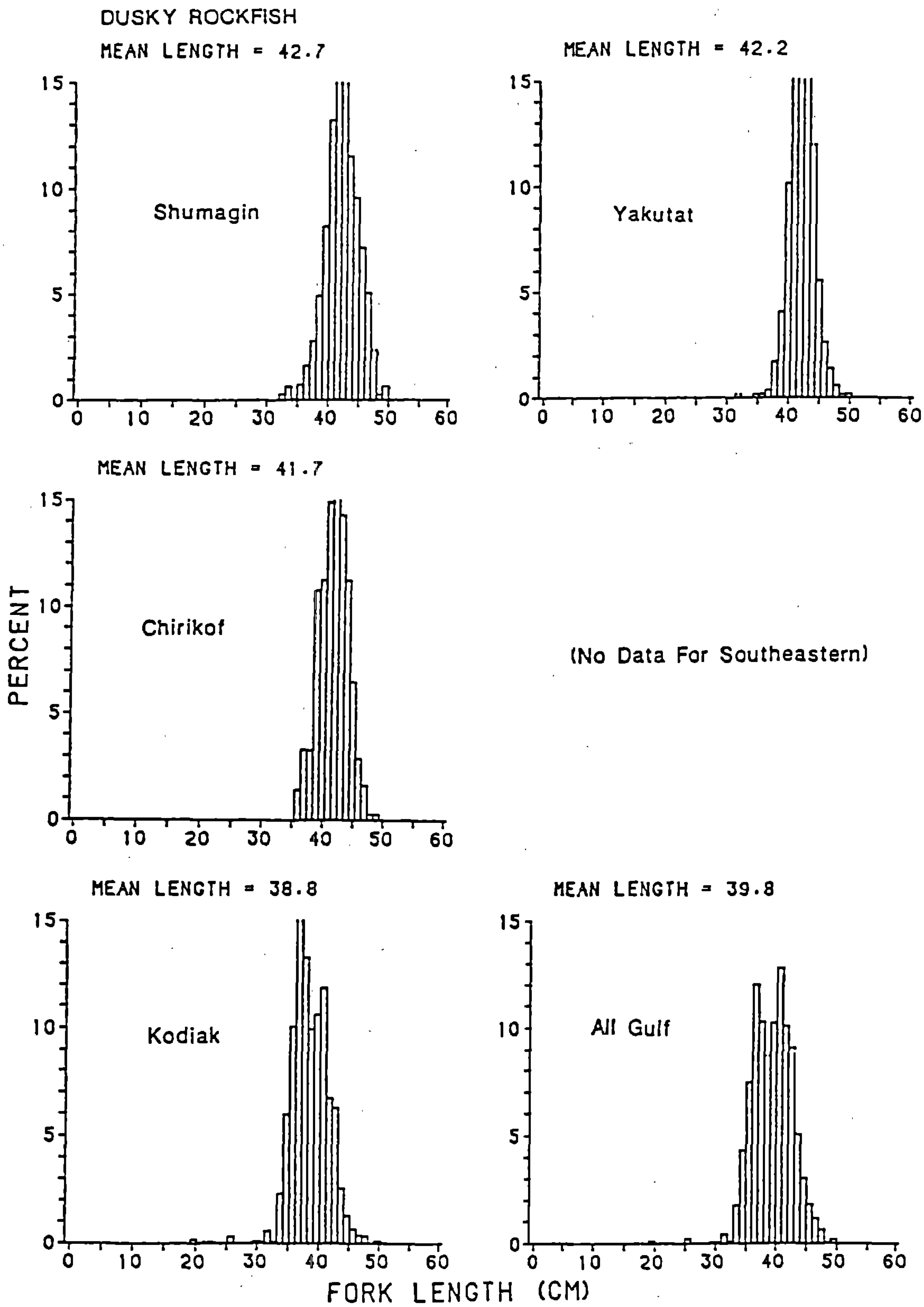

Figure 1. --Length frequency distributions of the estimated population of dusky rockfish, _Sebastes ciliatus_, in the Gulf of Alaska. Distributions are based on results of the 1987 triennial trawl survey and are shown by International North Pacific Fisheries Commission statistical areas.

shore areas of Southeastern Alaska and the results are summarized in Table 5. Unfortunately, the studies were based on surface age determinations of otoliths, a technique that is now believed to be inaccurate for rockfish species. For comparison, estimates of natural mortality rates-and maximum ages of yellowtail and widow rockfish in-British Columbia (Archibald et al. 1981) are also included in Table 5. In the Field study' (1984), the currently accepted break-and-burn technique was- used for age determination.

There is no information on age of recruitment for any of the pelagic shelf species.

Length and Weight at Age

No information on length and weight at age is currently available for pelagic shelf rockfish in the Gulf of Alaska.

MAXIMUM SUSTAINABLE YIELD

Information is not yet available to provide an estimate of maximum sustainable yield of pelagic shelf rockfish in the Gulf of Alaska.

ACCEPTABLE BIOLOGICAL CATCH

Acceptable biological catch (ABC) of pelagic shelf rockfish can be estimated in a similar manner to that used to estimate ABCs for slope rockfish (see Slope Rockfish report in this document). If one assumes that pelagic shelf rockfish are comparable to slope rockfish in growth, mortality, and stock condition, then the exploitation rate used for slope rockfish would be applicable to pelagic shelf rockfish. Multiplying F_{msy} = 0.02 (the value resulting from the most conservative recruitment parameter) by the estimate of current biomass gives a recommended ABC of 3,300 t (164,352 x 0.02) for pelagic shelf rockfish in the Gulf of Alaska. The conservative recruitment parameter was used because there is no information describing the stock-recruitment relationship for these species. In addition, the estimate of exploitable biomass has very broad confidence limits, suggesting a relatively high risk of overexploitation if a higher exploitation rate is used.

Apportioning this ABC to each management area in the same proportion as that estimated from the 1987 triennial trawl survey results in an ABC of 550 t in the Western area, 2,350 t in the Central area, and 400 t in the Eastern area.

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Table 5.--Instantaneous rate of natural mortality and maximum age for pelagic shelf rockfish. Area indicates location of study: Southeastern Alaska (SE) and British Columbia (BC). Ages in Southeastern Alaska were determined using surface readings of otoliths; ages in British Columbia was determined using the break-and-burn technique.

Species	Mortality rate	Maximum age	Area
Dusky rockfish	0.17	33	SE
Black rockfish	0.28	33	SE
Yellowtail rockfish	0.35	25	SE
Yellowtail rockfish	0.06-0.14	52	BC
Widow rockfish	0.05	59	BC

DEMERSAL SHELF ROCKFISH

by

Barry E. Bracken[1]

INTRODUCTION

Rockfishes of the genus _Sebastes_ are found in nearshore waters and along the continental slope of the northeast Pacific Ocean. Fishes in the demersal shelf rockfish assemblage include 10 species of nearshore rockfishes in Alaskan waters (Table 1).

Table 1.--Rockfish which are included in the demersal shelf rockfish assemblage in the Gulf of Alaska.

Common name	Scientific Name
Bocaccio	_Sebastes paucispinis_
Canary rockfish	_S. pinniger_
China rockfish	_S. nebulosus_
Copper rockfish	_S. caurinus_
Quillback rockfish	_S. maliger_
Rosethorn rockfish	_S. helvomaculatus_
Silvergray rockfish	_S. brevispinis_
Tiger rockfish	_S. nigrocinctus_
Yelloweye rockfish	_S. ruberrimus_
Redstripe rockfish	_S. proriger_

Prior to 1987 demersal shelf rockfish were grouped with the "other rockfish" complex for fisheries management. However, in 1987 the nearshore or shelf rockfish component was identified as a separate management group from the "other rockfish" category. In the Southeast Outside District (east of 137°W long.), shelf rockfish has been divided into two management groups, demersal and pelagic, based on behavior and habitat. Pelagic shelf rockfish are a minor component of the nearshore longline fishery and are not currently a target species.

This report summarizes the available information on the biology of demersal shelf rockfish and on the shore-based rockfish fishery in the southeastern Gulf of Alaska, including the internal waters of South&astern Alaska.

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CATCH HISTORY

Demersal shelf rockfish have been landed incidentally in catches of other groundfish fisheries in Southeastern Alaska since the turn of the century. Some bycatch was also landed by foreign trawlers targeting on slope rockfish in the eastern gulf during the 1960s and through the mid-1970s. In 1979 a small shore-based rockfish fishery began in Southeastern Alaska. This fishery targets primarily on the nearshore bottom-dwelling. component of the rockfish complex. This directed fishery expanded from 160 t landed in 1982 to 1,225 t landed in 1987 (Table 2).

Table 2.--Reported landings of demersal shelf rockfish from domestic fisheries in Southeastern Alaska, 1982-87.

Year	Gulf of Alaska (East of 137°) Directed landings	Incidental landings	Total landings
1982	160	79	239
1983	291	103	394
1984	736	62	798
1985	665	38	703
1986	900	110	1,010
1987	1,034	174	1,208

Source: Alaska Department of Fish and Game fish ticket database.

The peak catch of demersal shelf rockfish reported from the Southeastern region was 1,208 t in 1987. However, this number should be considered an estimate since reporting requirements make analysis of species composition from fish ticket records somewhat unreliable. This is because the database include landings of "unspecified red rockfish" and "unspecified rockfish" which may include species from other assemblages as well as demersal shelf rockfish. Data used in this report include only landings reported by vessels using hook and line gear (longlines, jigs, troll). Catch is listed by calendar year to be consistent with the International North Pacific Fisheries Commission (INPFC) report format, however, the State of Alaska manages the demersal shelf rockfish fishery based on a season which begins on 1 October and continues into the next calendar year. Although there may also be some bycatch of demersal shelf rockfish in the eastern gulf trawl fishery for slope rockfish, no attempt was made to include these data since species composition information from the domestic trawl fishery are not available.

The Alaska Department of Fish and Game (ADF&G) has divided Southeastern Alaska into five areas for rockfish management (Fig. 1). These areas represent the general geographic separation of the fleets from the various Southeastern ports, although ranges have begun to overlap as fishing pressure increases. The target fishery for demersal shelf rockfish has expanded rapidly both in terms of landings and areas of catch. The fishery first developed in Sitka with the majority of landings coming from the Central Southeast Outside area (CSEO). By 1986 Ketchikan became the major port of landing with 41% of the 'directed catch in Southeastern Alaska landed from the Southern Southeast Inside (SSEI) management area. In 1987 the fishery expanded to the Southern Southeast Outside area (SSEO) with 31% of the directed harvest reported from this area (Fig. 2).

Over 99% of the 1987 demersal shelf rockfish harvest was landed on longline gear. A total of 368 vessels reported rockfish landings on miscellaneous finfish permits during 1987.

A 600 t harvest limit was established for demersal shelf rockfish in the CSEO management area for the 1985 season by the North Pacific Fishery Management Council and the Alaska Board of Fisheries at a joint meeting in the fall of 1984. This harvest limit was based upon the anticipated 1984 harvest from both the state and federal waters in the CSEO area. This limit was intended to place a cap on rockfish harvests from that area until an appropriate yield level could be established. The 600 t anticipated harvest level was not reached and only 521 t were actually landed. during 1984.

In 1987 the harvest limit (optimum yield, OY) for demersal shelf rockfish harvest was set at 1,250 t for the Southeast Outside District. This limit was based upon an extrapolation which expanded the 600 t established for the CSEO area in 1984 to the remainder of the Southeast Outside District using a habitat comparison technique (Bracken 1986).

Based on fisheries performance indicators and available biological information, the total allowable catch (TAC) limit for demersal shelf rockfish was reduced to 660 t in the Southeast Outside District for 1988. The TAC is divided by ADF&G between the three outside management areas for in-season management.

CONDITION OF STOCKS

Analysis of commercial catch and effort data is difficult to interpret because of the dynamic nature of the fishery. Changes

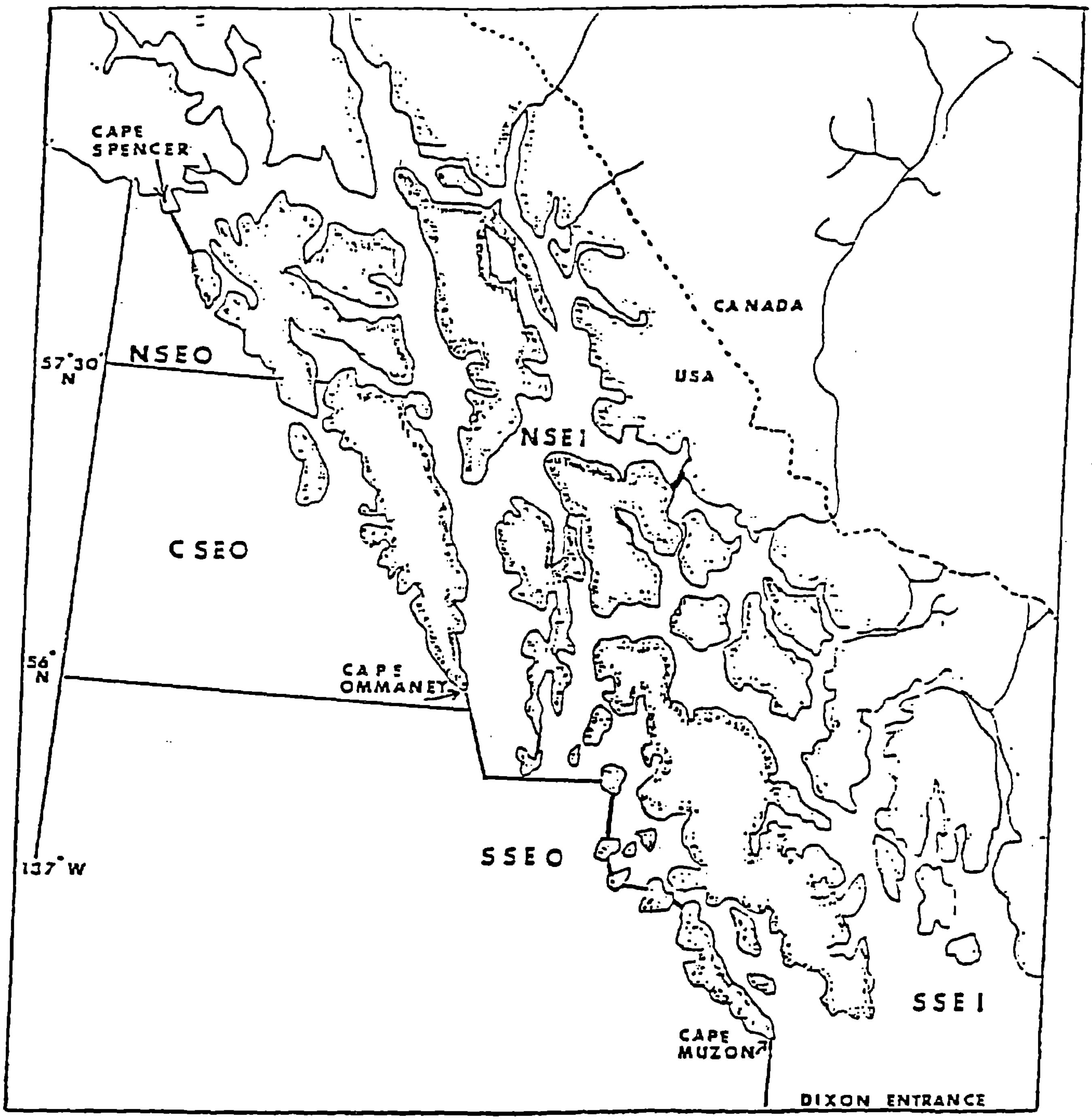

Figure l.--The Southeastern Alaska coastline showing Alaska Department of Fish and Game groundfish management areas. Management areas are as follows: NSEO = north southeast outside area, NSEI = north southeast inside area, CSEO = central southeast outside area, SSEO = south southeast outside area, and SSEI = south southeast inside area.

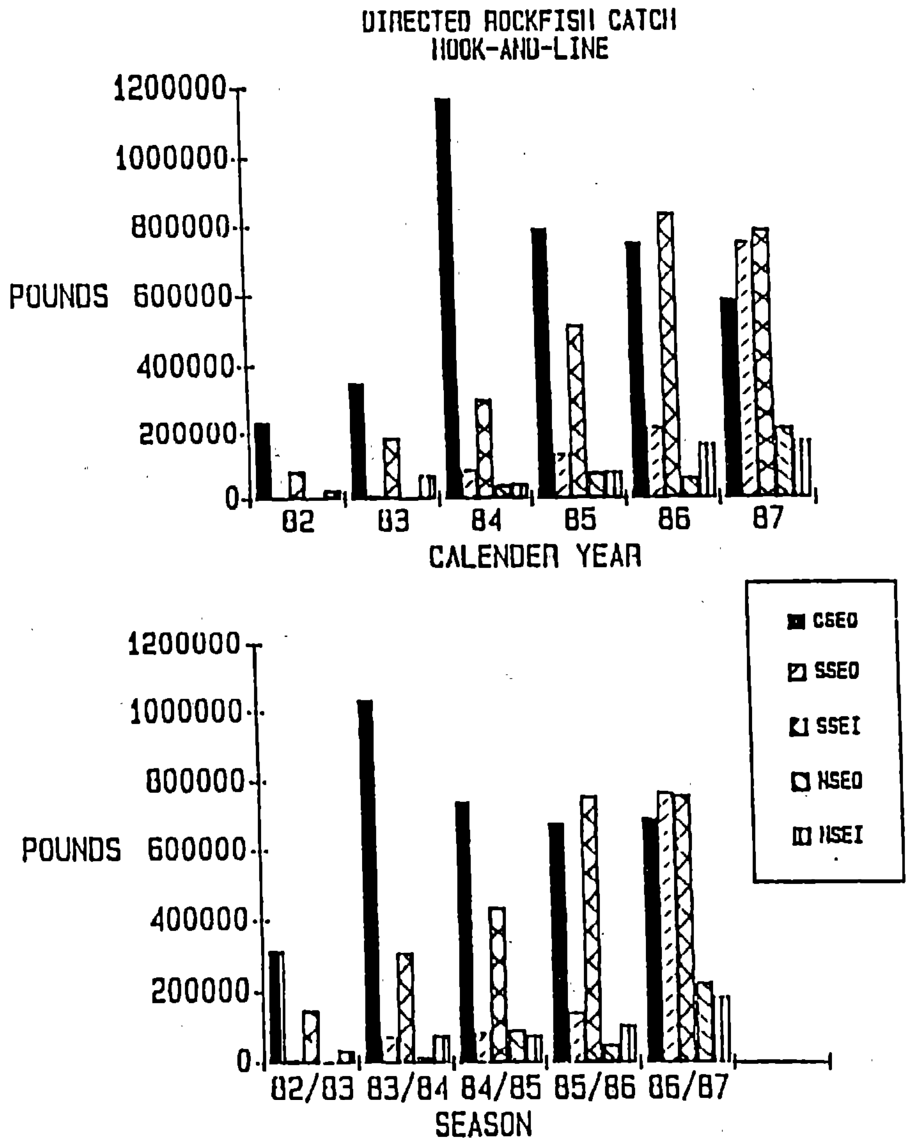

Figure 2. --Directed rockfish catch (hook and line gear) for southeastern Alaska by management areas, in round weight. Management areas are as follows; NSEO = north southeast outside area, NSEI = north southeast inside area, CSEO = central southeast outside area, SSEO = south southeast outside area, and SSEI = south southeast inside area.

in market demand, gear technology, and skipper proficiency, and rapid turnover in the fleet confounds concise analysis. Additionally, since demersal shelf rockfish are reef oriented and the longline fleet very mobile, using catch per unit effort (CPUE) data as an indicator of stock condition tends to underestimate the true level of stock decline (Francis 1985; Bracken and O'Connell 1987). Nonetheless, fishery performance indicators point to a decline in demersal shelf rockfish stocks in the CSEO area and may indicate reductions in the other management areas as well.

Relative Abundance

As stated earlier, the percentage of the total Southeast rockfish harvest taken in the CSEO area has declined dramatically since the peak harvest in 1984. More significant is the fact that the actual harvest from this area has decreased as well, from 521 t in 1984 to 247 t in 1987, a decline of 52%. It is important to note that the harvest level in this area was unrestricted during that time period and that rockfish markets remained strong throughout the region. During this period of declining catch levels in the CSEO area, the Sitka fleet moved progressively further from port to maintain productive fishing (Fig. 3). Similar shifts in- effort have occurred in the two southern management areas as well. Given the 4-day limit on delivery from the first day of fishing and the additional costs associated with lost fishing time and fuel consumption as the vessels travel further from port, this progressive expansion to more distant fishing grounds is considered to be a strong indication that the productivity nearer the ports has declined to the point where fishing is no longer profitable.

Catch per unit effort is measured in terms of pounds per landing. It is difficult to make definitive statements regarding CPUE as the fishery is in a constant state of change. Between 1983 and 1985 there was a shift from "j-hooks" to "circle hooks" (Bracken and O'Connell 1986). Although no direct comparison experiments have been implemented for this fishery, the increase in efficiency of circle hooks was estimated to be two times that of j-hooks in the halibut fishery (IPHC 1987). Change in skipper performance is hard to quantify and there is a high turnover rate in this fishery. Only 14% of the vessels that landed demersal shelf rockfish in 1987 had also participated in the 1982 fishery. Also changes in fishing grounds obscure actual declines in stock as CPUE may remain fairly constant areawide, while localized depletion has occurred. Declines in average CPUE have occurred in the three most productive rockfish management areas in Southeastern Alaska (Bracken and O'Connell 1986). While inconclusive these declines are cause for concern.

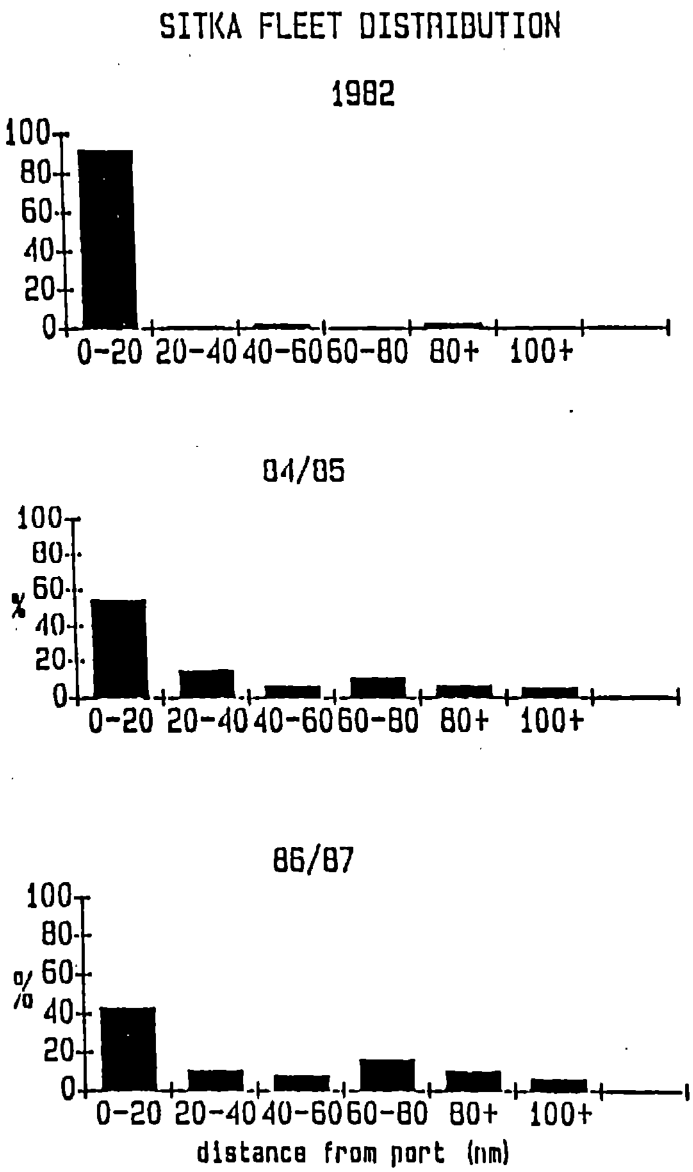

Figure 3. --Distribution of- vessels fishing rockfish from Sitka by year.

Absolute Abundance

A S-year annual survey began in 1987 to assess the demersal shelf rockfish stock in CSEO. The initial project involved testing of various sampling designs and therefore no estimates of relative or absolute abundance are expected from this project for several years.

Current Exploitable Biomass

No biomass estimates are currently available for demersal shelf rockfish in the Gulf of Alaska. Preliminary ageing of key species indicates that most fish do not recruit to the fishery in Southeastern Alaska until they are at least 25 to 35 years of age (see recruitment section). Early life- history information is lacking and it is unclear whether the younger fish are not present or are not available to the gear being used. Work conducted by Rosenthal et. al. (1982) suggests that there is a spacial separation by size and that the younger fish may be in depths shallower than normally fished.

Demersal shelf rockfish, being long-lived and slow-growing, are "k" selective (Adams 1980; Archibald et al. 1981; Gunderson 1980). These types of fishes are very susceptible to over-exploitation and are slow to recover once driven below the level of sustainable yield (Francis 1985; Leaman and Beamish 1984). Therefore appropriate rates of exploitation are assumed to be very low.

RECRUITMENT STRENGTHS

Length frequency and age distributions for yelloweye rockfish from commercial catch and research survey data are shown in Figures 4 and 5, respectively. Length frequency data show a strong mode at the 55 to 60 cm range. Age distribution shows several peaks with initial recruitment to the fishery occurring at between 30 and 35 years in the 1984 commercial catch data and at 25 years in the 1987 CSEO survey data. Further recruitment details appear in the following section.

BIOLOGICAL PARAMETERS

Biological information is collected from the commercial catch through a port sampling program. Species composition and length, sex, and stage of maturity information is recorded and otoliths taken when possible. Shelf rockfish appear to stratify

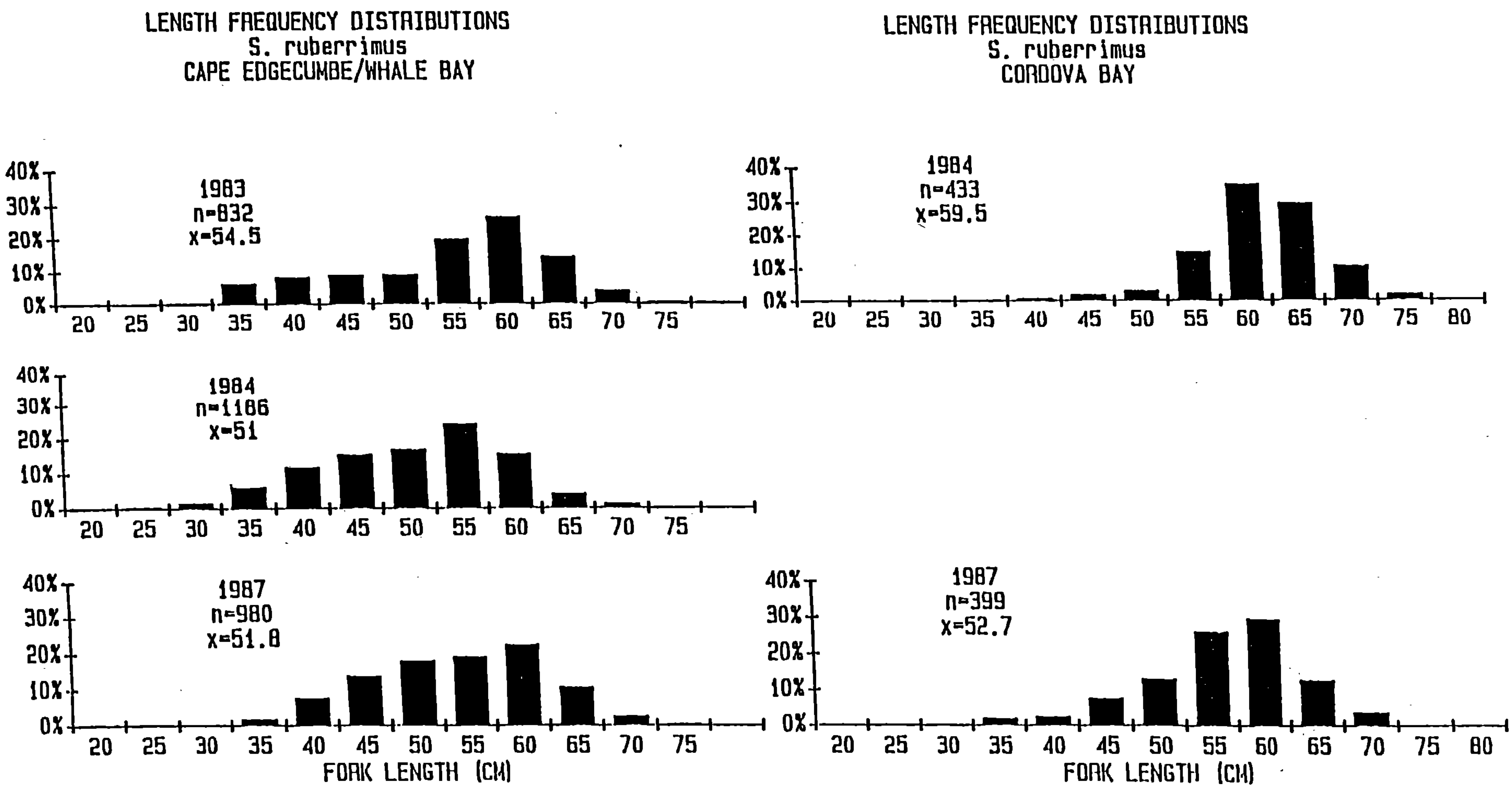

Figure 4.--Length frequency distributions for yelloweye rockfish (<u>Sebastes ruberrimus</u>) sampled from the commercial fishery.

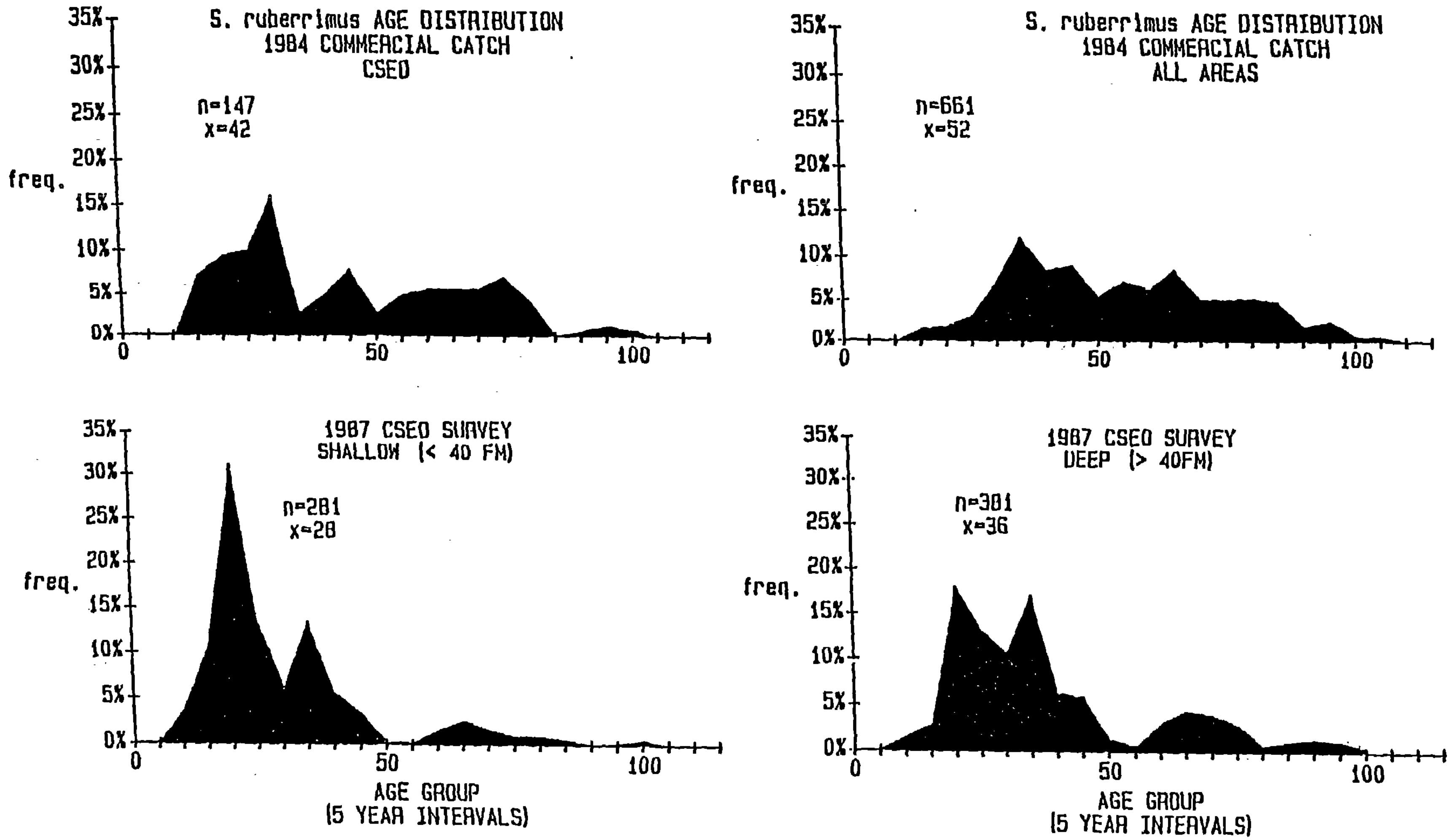

Figure 5.--Age distributions for yelloweye rockfish ~~(Sebastes~~ ruberrimus) from commercial catch and research survey samples (bleak-and-burn technique).

by depth, both in terms of species composition and size and age structure within species. The smaller fish are generally found in shallower water (Rosenthal et al. 1982). Commercial landings are usually composed of fish from several depth zones; consequently, no attempt has been made to analyze length frequency by depth from the commercial landings.

Yelloweye rockfish is the primary target species for this fishery, accounting for at least 67% of the catch by weight (unspecified red rockfish accounts for another 4.5%). Quillback rockfish is also important in terms of numbers of fish landed accounting for 21% of the pounds landed.

Detailed biological parameters are presented only for yelloweye rockfish in this report although other demersal shelf rockfish are known to have similar life history characteristics.

Length frequency distributions for yelloweye from two heavily fished areas in Southeastern Alaska show a decline in average length over time (Fig. 4). The yearly distributions for Cape Edgecumbe (CSEO) are not directly comparable with the distribution from Cordova Bay (SSEI) at any given point in time as the SSEI fishery did not develop until 1984, 2 years later than the fishery in the CSEO area. Part of this, change in average length may be due to increased market acceptance of small fish as the fisheries developed. Interview information reveals that some small fish were discarded at sea in the early years of the fishery, particularly in the SSEI area, although no figures are available on the extent of this practice. Increased fishing pressure is likely to be the cause of at least some of the observed decline in the average length. For example, data collected from the CSEO area in 1981 yields mean lengths for yelloweye rockfish of 55.9 cm for the commercial catch (n = 2,183) and 59.2 for the survey samples (jigging machines, n = 80) (Rosenthal et al. 1982) compared to 51.8 cm for the commercial catch in the same area in 1987 (Fig. 4).

Sagittal otoliths are collected for ageing. The break-and-burn technique is used for distinguishing annuli (Chilton and Beamish 1983). Age distribution from the commercial catch during 1983 and 1984 represents ages of 13 to 114 years with the first strong mode at about 35 years (Fig. 5). When age data from the CSEO area are plotted separately, the average age and first strong mode decrease compared to the age data from all areas combined. This variation may be due to both differences in landed catch between areas (at sea discard of small fish in the southern areas) and differences in fishing pressure between areas prior to 1984. Age distribution from the otoliths collected during the 1987 CSEO research cruise shows a distinctly different age distribution with the first strong mode occurring between 20 and 25 years followed by a lesser mode at 35 to 40 years. These data suggest that the older year classes are being removed from the population.

Von Bertalanffy growth parameters calculated from the 1984 commercial catch data are shown in Tables 3 and 4. For further information on age and growth refer to O'Connell and Funk (1987).

Table 3.--Growth parameters for S. ruberrimus in Southeastern Alaska.

Sex	L_inf	k	t_0	n
Male	64.628	.04798	-2.9985	257
Female	62.145	.05892	-3.3101	310

L_inf = asympototic length.
k = growth coefficient.
t_0 = length at time zero.
n = sample size.

Table 4.--Length-weight relationships (cm-kg) for yelloweye rockfish in Southeastern Alaska calculated from the equation $W = aL^b$.

Sex	a	b	n
male	.000023827	2.932887377	169
female	.000015348	3.056191748	108
gravid female	.000004348	3.396210000	63

a, b = parameters of the nonlinear fit of length-weight data.
n = sample size.

Mortality estimates were calculated using catch curve analysis on the 1984 commercial catch data (Ricker 1975). The southern area data were used as this stock was considered to be less heavily exploited in 1984. Mortality estimates were also calculated using Hoenig's formula: In Z = 1.44-.984 In (t_{max}) where t_{max} is the maximum age (Pauly and Murphy 1982). These values are shown in Table 5.

Table 5.--Natural mortality estimates for S. ruberrimus in Southeastern Alaska.

Method	Sex	M (estimate)
Catch curve	**male**	**.037**
	female	**.034**
Hoenig's	**both**	**.039 (t_{max} = 115)**

Demersal shelf rockfish are classified as ovoviviparous although recent work indicates that some species may be viviparous (Boehlert and Yoklavich 1984; Boehlert et al 1986). Rockfish have internal fertilization with several months separating copulation, fertilization, and parturition. Within this lo-species complex, parturition occurs from February through September with the majority of fish extruding larvae in late winter and spring. Yelloweye rockfish extrude larvae over an extended time period with peak period of parturition occurring in April and May (O'Connell and Funk 1987).

MAXIMUM SUSTAINABLE YIELD

Information is not available to provide a direct estimate of maximum sustainable yield (MSY) for demersal shelf rockfish in Southeastern Alaska.

ACCEPTABLE BIOLOGICAL CATCH

Information is not available to provide an estimate of acceptable biological catch (ABC). However, since fisheries performance indicators show continued declines at the current harvest level of approximately 600 t in the Southeast Outside District, it appears that the current harvest is above the annual recruitment level. Therefore, it is assumed that the ABC is below 600 t in that area.

BIOMASS PROJECTIONS

Declines in average size and age distribution of key rockfish species at current levels of harvest suggest that the current levels are not sustainable. Unless harvests are reduced, it is likely that the demersal shelf rockfish stocks will continue to decline in the Southeastern area.

The Alaska Department of Fish and Game manages this fishery under a provision in the Gulf of Alaska Groundfish fisheries management plan. They submitted a proposal for harvest reductions to the Alaska Board of Fisheries for consideration at their January 1989 meeting. The suggested harvest limits in the directed fishery for the Southeast Outside District will be 300 t to 420 t which represents a range of from 50 to 70% of the 1988 directed harvest of approximately 600 t.

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FLATFISH

by

Thomas K. Wilderbuer and Eric S. Brown

INTRODUCTION

The "flatfish" species complex is managed as a unit in the Gulf of Alaska and includes, the major flatfish species inhabiting the region with the exception of Pacific halibut (Hipposlossus stenolepis). The major species, which comprised 97% of the 1988 domestic flatfish catch and account for 98% of the current biomass, are arrowtooth flounder (Atheresthes stomias), flathead sole (Hippoglossoides elassodon), rock sole (Lepidopsetta bilineata), rex sole (Glyptocephalus zachirus), Dover sole (Microstomus pacificus), yellowfin sole (Limanda aspera), and starry flounder (Platichthys stellatus).

This report describes the catches taken from 1978 through 1988 and presents information on the status of these stocks and their potential yield from data obtained during the 1984 and 1987 Gulf of Alaska trawl surveys.

CATCH HISTORY

In recent years, the fishery for flatfish in the Gulf of Alaska has undergone dramatic changes. Until 1981, the fishery took around 15,000 t per year, almost all of which was taken by foreign vessels which were targeting on other species (Table 1). After 1981, the catches decreased to a low of 2,552 t in 1986 before increasing to 9,925 in 1987.

With the cessation of foreign fishing in 1986, joint venture fishing began to account for the majority of the catch. In 1987 the gulfwide flatfish catch increased nearly fourfold to 9,925 t. The joint venture fisheries accounted for nearly all of the increase--going from 961 t in 1986 to 7,707 t in 1987 (from 38 to 73% of the gulfwide catch). The domestic fishery nearly doubled (1,586 t in 1986 vs. 2,718 t in 1987) but took a smaller percentage of the total flatfish catch (down from 60% in 1986 to 27% in 1987). With respect to the total yield of 554,739 t (estimated later in this report) the resource remains lightly harvested.

In 1987 the International North Pacific Fisheries Commission (INPFC) Kodiak statistical area continued to produce more than

Table 1.--Catch (t) of flatfish in the Gulf of Alaska, by International North Pacific Fishery Commission statistical area and fishery category, 1978-87

Fishery category	Shumagin	Chirikof	Kodiak	Yakutat	Southeastern	Total
Foreign						
1978	2,538	2,482	3,830	2,955	2,536	14,341
1979	2,817	618	4,408	3,290	2,341	13,474
1980	3,022	976	5,909	4,095	1,495	15,497
1981	3,224	3,653	2,106	3,308	2,153	14,444
1982	1,412	2,898	4,618	58	0	8,986
1983	2,020	4,235	3,224	51	0	9,530
1984	603	1,349	1,081	0	0	3,033
1985	115	54	1	0	0	170
1986	56	15	0	0	0	71
1987	0	0	0	0	0	0
Joint venture						
1978	5	0	0	0	0	5
1979	7	0	62	1	0	70
1980	11	106	92	0	0	209
1981	0	18	0	0	0	18
1982	6	12	0	0	0	18
1983	171	62	2,459	0	0	2,692
1984	566	224	2,658	0	0	3,448
1985	324	570	1,553	0	0	2,447
1986	302	66	593	0	0	961
1987	2,073	1,133	4,001	0	0	7,207
Domestic						
1978	6	4	82	0	760	852
1979	0	1	54	7	322	384
1980	0	0	46	0	94	140
1981	0	0	77	0	327	404
1982	0	0	71	0	203	274
1983	0	0	88	0	351	439
1984	5	10	236	0	181	432
1985	10	0	254	12	185	461
1986	362	8	766	123	150	1,409
1987	184	1,900	1,811	40	493	2,718
Total						
1978	2,549	2,486	3,912	2,955	3,296	15,198
1979	2,824	619	4,524	3,298	2,663	13,928
1980	3,033	1,082	6,047	4,095	1,589	15,846
1981	3,224	3,671	2,183	3,308	2,480	14,866
1982	1,418	2,910	4,689	58	203	9,278
1983	2,191	4,297	5,771	51	351	12,661
1984	1,174	1,583	3,975	0	181	6,913
1985	449	624	1,808	12	185	3,078
1986	720	89	1,359	123	150	2,441
1987	2,257	1,323	5,812	40	493	9,925

half the flatfish catch from the Gulf of Alaska. The joint venture fishery landed 56% of its catch in the Kodiak area targetting on rock sole on the continental shelf east of Kodiak Island. Furthermore, 67% of the smaller (1,586 t) domestic harvest was from the Kodiak statistical area.

The changing makeup of the gulf fisheries has also affected the composition of the flatfish catch. Whereas the foreign and joint venture catches have always tended to feature the deep-water species described by Rose (1986), the domestic effort had previously focused on the shallow-water group. Observer sampling of the Kodiak-based domestic flatfish fishery in 1988 (Alaska Dept. Fish and Game) indicates the catch composition has changed. This is reflected in the species composition of the observed 1988 flatfish catch (Table 2) where the domestic catch contained 90% deep-water species (exclusive of the unspecified "other" flatfish).

The joint venture catch in 1987 targetted on the shallow-water species group. Observers of the Foreign Fisheries Observer Program sampling this fishery in the Kodiak statistical Area reported that rock sole was the major component of the catch (Janet Wall, Northwest and Alaska Fisheries Center, 7600 Sand Point Way NE, BIN C15700, Seattle, WA 98115. Pers. commun., March 1988.) As the domestic fishery assumes a larger role in the Gulf of Alaska flatfish catch, more removals are expected from the deep-water species group, which accounted for 80% of the estimated gulf flatfish biomass as estimated in 1987.

CONDITION OF STOCKS

Relative-Abundance

Because the Gulf of Alaska flatfish species have usually been taken incidentally in target fisheries for other species, catch per unit of effort (CPUE) from commercial fisheries seldom reflect trends in abundance for these species. It is therefore necessary to use research vessel survey data to assess the relative abundance of these stocks. Comparative CPUE data between the 1984 and 1987 Gulf of Alaska triennial bottom trawl surveys are available from catch data standardized to the trawl common to both surveys: the U.S. noreastern trawl. Standardized CPUE (kg/km^2) from the central and western Gulf of Alaska are as follows:

Species	1984	1987
Arrowtooth flounder	2,946	4,066
Flathead sole	746	793
Rock sole	540	1,263
Yellowfin sole	316	210

Table 2.--Composition of the Gulf of Alaska flatfish catch by species from the 1988 domestic catch (information from 86 observer trips aboard Kodiak-based vessels, 58 trips targetting on deep-water species and 28, trips targetting on shallow-water species).

	Catch weight sampled (kg)	Percent
Deep-water species		
Arrowtooth flounder	128,492	49.9
Flathead sole	22,679	8.8
Rex sole	31,915	12.4
Dover sole	73,429	28.5
Others[a]	1,177	0.5
All deep-water	257,692	100.0
Shallow-water species		
Rock sole	28,528	43.1
Butter sole	1,931	2.9
Starry flounder	574	0.9
Lemon sole	64	0.1
Others[b]	35,032	53.0
All shallow-water	66,129	100.0

[a] Includes rock sole (0.4%), and butter sole (0.02).

[b] Includes arrowtooth flounder (35.0%), Dover sole (6.5%) , rex sole (8.7%), and flathead sole (2.8%).

Rock sole abundance, and to a lesser extent arrowtooth flounder, indicate a major increase in exploitable population density between survey years with a decrease for yellowfin sole;

Absolute Abundance

The principal source of information for evaluating the condition of flatfish stocks in the Gulf of Alaska is the series of triennial bottom trawl surveys. Estimates of flatfish biomass from the 1987 cooperative U.S. -Japan demersal trawl survey are given in Table 3. For the survey the apportionment of sampling stations on the shelf and slope followed the methods of the shelf portion of the 1984 survey (Brown 1986). There were, however, key refinements. Based on the 1984 survey results, new subareas were developed with respect to fish abundance and sampling densities within the subareas were allocated proportional to the variances encountered during the previous survey. Finally, a special word of caution is appropriate regarding the 1987 survey. Results from the l-100 m depth interval in the eastern portion of the survey area (an area characterized by a narrow, irregular, and generally untrawlable bottom) were based on a single sampling station.

The 1987 Gulf of Alaska bottom trawl survey biomass estimates indicate that the flatfish resource remains stable with a slight increase (approx. 3%) over 1984 (2,110,854 t in 1987 to 2,056,808 t in 1984). Seven species resulted in biomass increases from 1984 while five species declined. The largest increases were for Dover, rex, and rock sole with the largest decreases estimated for flathead sole and yellowfin sole.

Biomass estimates were calculated by standardizing survey CPUE to the trawl most efficient at capturing each species during the survey. With the exception of rock sole, all flatfish catch rates were standardized to the Japanese trawl in 1984 which was not used in 1987. The common trawl used both survey years, the U.S. polypropylene trawl, was found to be the most efficient trawl in 1987 for all flatfish species. Consequently, the biomass estimates generated on the basis of the 1987 survey are the best available, but are conservative relative to the 1984 estimates, which were based on catches adjusted to the more efficient Japanese trawl.

Current Exploitable Biomass

The exploitable biomasses are assumed to be the same as the survey biomasses from 1987 since the nonexploitable component of the survey biomass is small. The Japanese trawl used during the 1984 survey was a commercial flatfish trawl, and although it was more efficient than the 1987 survey trawls, it provided nearly the same size composition as resulted from the 1987 trawl survey.

Table 3.--Biomass estimates (t) for Gulf of Alaska flatfish, based on the 1987 bottom trawl survey, by North Pacific Fishery Management Council regulatory area and species (percentages of the grand total are in parentheses).

	Area				
	Western	Central	Eastern	Total	(%)
Deep-water species					
Arrowtooth flounder	158,547	829,468	156,227	1,144,242	(54)
Flathead sole	45,256	140,706	32,313	218,275	(10)
Rex sole	17,754	84,436	14,140	116,330	(5)
Dover sole	18,215	163,181	25,618	207,014	(10)
Others	76	61	0	137	(<1)
All deep-water	239,848	1,217,852	228,298	1,685,998	(80)
Shallow-water species					
Rock sole	110,848	211,105	893	322,846	(15)
Yellowfin sole	30,326	23,044	0	53,370	(3)
Butter sole	4,605	14,738	593	19,936	(<1)
Starry flounder	4,689	7,504	2,520	14,713	(<1)
Others	1,922	5,800	6,269	13,991	(<1)
All shallow-water	152,390	262,191	10,275	424,856	(20)
All flatfish	392,238	1,480,043	238,573	2,110,854	(100)

RECRUITMENT STRENGTHS

Age. determinations were made for samples of arrowtooth flounder and flathead sole collected during the 1984 survey and for rock sole and yellowfin sole collected during the 1987 survey (Fig. 1). Age samples for arrowtooth flounder and rock sole indicate that the 1979 and 1980 year classes have been strong. Examination of the size composition from the 1987 survey suggests continued recruitment to the stock. Age composition of rock sole and yellowfin sole also indicates the continued presence of juvenile fish in survey catches. Given the similarities in biomass estimates between survey years, it is assumed that average recruitment has occurred for these species to maintain their present stock size.

BIOLOGICAL PARAMETERS

Natural Mortality, Age at Recruitment, and Maximum Age

A catch curve analysis (Ricker 1975), using the age composition as a synthetic cohort (Fig. 2), was used to estimate mortality rates, average recruitment, and age selectivity of the survey effort in past assessments (Rose 1987; Rose and Wilderbuer 1988). While this method is effective if recruitment and mortality are not too variable, it may result in biased estimates if either variable has an increasing or decreasing trend, or if older ages were not accounted for from an age sample. Natural mortality rates (M) resulting from this analysis were unrealistically high, ranging from 0.30 for arrowtooth flounder males to 0.86 for flathead sole females. Since natural mortality and growth estimates are an integral part of yield and allowable catch calculations, they were re-examined for this assessment.

The estimation of natural mortality rates for Gulf of Alaska flatfish species was analyzed using the methods of Alverson and Carney (1975), Pauly (1980), and Hoenig (1983). These methods correlate M with life history parameters such as growth and maximum age (Alverson and Carney); growth, maximum length, and mean water temperature during the life of the fish (Pauly); and the maximum age attained by a species (Hoenig). Estimates of natural mortality are as follows:

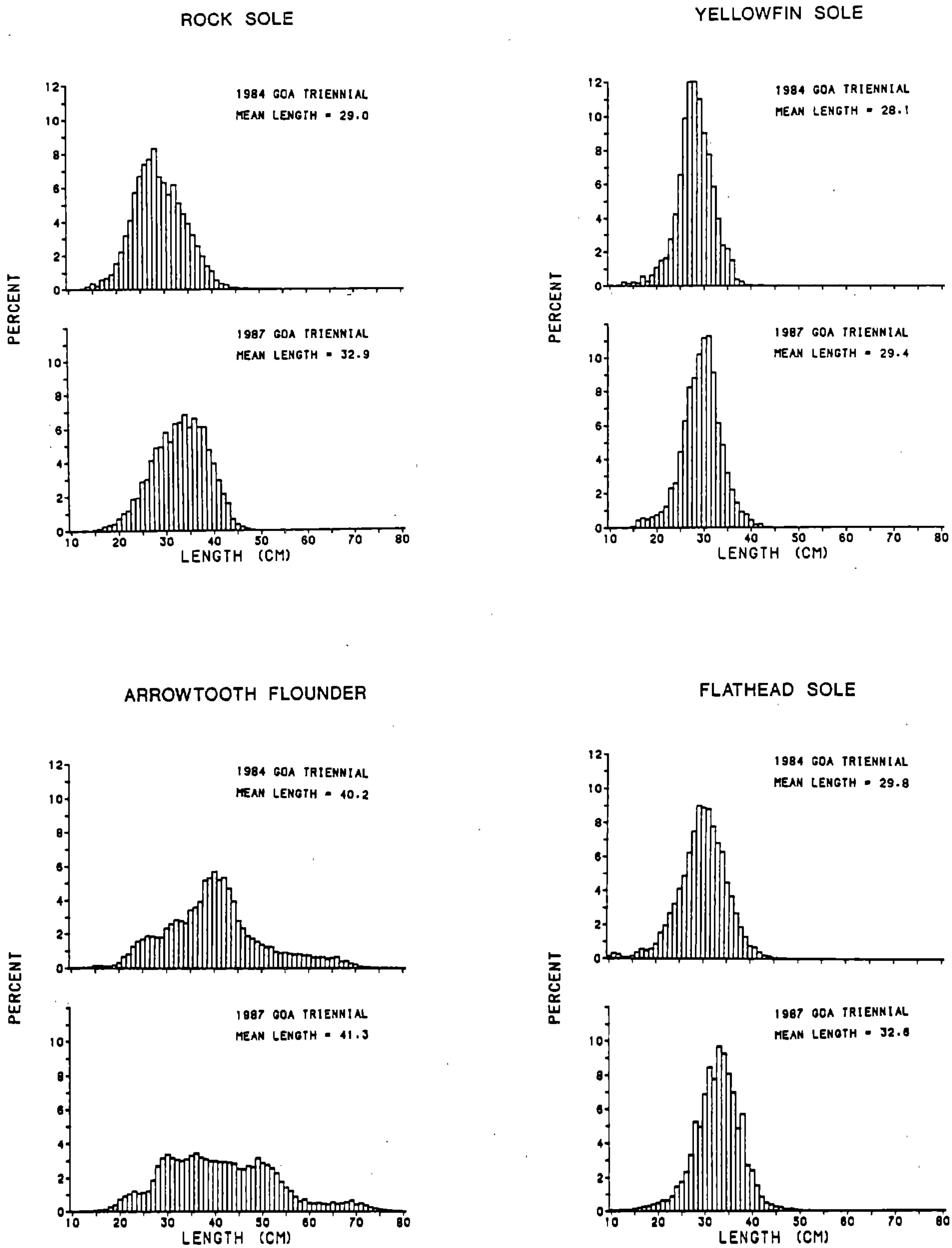

Figure 1.--Size composition of Gulf of Alaska flatfish estimated from the 1984 and 1987 triennial bottom trawl surveys.

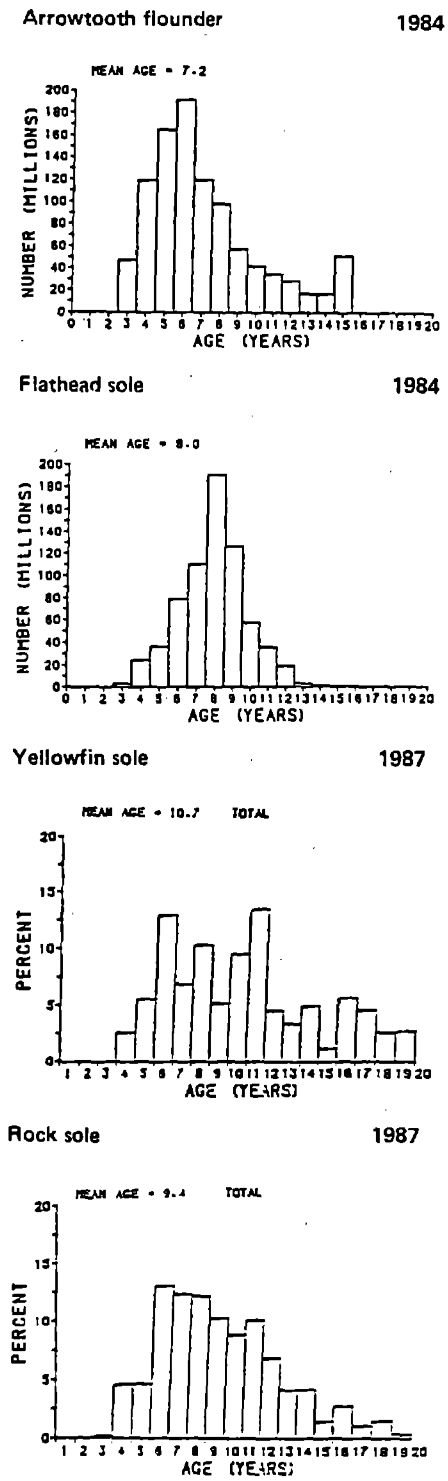

Figure 2.--Age composition of Gulf of Alaska flatfish estimated from age structures collected from the 1984 and 1987 Gulf of Alaska triennial trawl surveys.

Species	Alverson and Carney	Pauly	Hoenig
Flathead sole	0.11	0.51	0.32
Rock sole	0.09	0.27	0.21
Yellowfin sole	0.11	0.26	0.21
Arrowtooth flounder	0.22	0.21	0.32

These values are much lower than those which resulted from the catch curve analysis and are consistent with M values used in other flatfish assessments which used values ranging from 0.20 to 0.22 (Fargo 1988; Walters and Wilderbuer 1989; Forrester and Thompson 1969; Bakkala and Wilderbuer 1989). Accordingly, values for the instantaneous natural mortality rate of Gulf of Alaska flatfish species used for this assessment are 0.20 for flathead, rock and yellowfin sole, and 0.22 for arrowtooth flounder. Mortality rates and recruitable ages are summarized in Table 4.

Length and Weight at Age

The following values for the parameters in the von Bertalanffy age-length relationship were found from the latest ageing data:

Species	Source	L_{inf} (cm)	K	t_0
Arrowtooth flounder	1984 survey			
males		46.5	0.20	-0.16
females		73.3	0.15	0.24
combined		59.6	0.17	0.04
Flathead sole	1979 Kodiak*			
males		27.3	0.58	0.12
females		32.5	0.39	-0.36
combined		29.9	0.49	-0.24
Rock sole	1987 survey			
males		31.7	0.36	0.73
females		41.6	0.21	0.38
combined		38.8	0.21	0.02
Yellowfin sole	1987 survey			
males		32.8	0.19	-2.24
females		38.2	0.14	-2.18
combined		34.0	0.18	-1.82

* C. R. Rose, 1981. Distribution and growth of flathead sole (Hipposglossoides elassodon). M.S. Thesis, Univ. of Washington, Seattle, 59 p.

Table 4.--Estimates of natural mortality, growth (von Bertalanffy k) and age of recruitment for the major Gulf of Alaska flatfish species.

Species	Natural mortality	Growth	Age at recruitment
Arrowtooth flounder	0.22	0.17	3
Flathead sole	0.20	0.49	4
Rock sole	0.20	0.21	4
Yellowfin sole	0.20	0.18	4

The following parameters have been calculated for the length (cm)-weight (g) relationship: $w = a * L^b$ (both sexes combined).

Species	a	b
Flathead sole	.004056	3.2374
Rock sole	.009984	3.0468
Arrowtooth flounder	.003915	3.2232
Yellowfin sole	.006678	3.1793

MAXIMUM SUSTAINABLE YIELD

The growth, mortality, and age composition estimates described above were used on two analyses to estimate potential yields of the key gulf flatfish stocks. The initial analysis from Gulland (1971) used growth, mortality, and size-at-capture parameters (Table 5) to estimate the ratio of virgin biomass to maximum sustainable yield (MSY). In this analysis, the traditional production model concept of MSY occurring at half the stock level of virgin biomass (Schaefer 1957) was adjusted by considering the ratio of the size at first capture to maximum size and the ratio of natural mortality to the growth coefficient (coefficient from von Bertalanffy growth equation). Since flatfish abundance is currently at high levels, the 1987 triennial survey biomass estimates (Table 3) were used to represent virgin biomass.

Rock sole values of the ratio of size at first capture to maximum size and the ratio of natural mortality to the growth coefficient were used to calculate MSY values for flatfish in the "others" category used in Table 5. Recalculation of the natural mortality rates of gulf flatfish from the previous assessment (Rose and Wilderbuer 1988) causes the total flatfish MSY derived from this method to decline from 477,853 t to 121,447 t.

ACCEPTABLE BIOLOGICAL CATCH

The data were also used in a Beverton and Holt (1957) yield per recruit analysis to examine the effect of different levels of fishing mortality (F) on yield. This analysis projected the yield of a cohort through its lifetime at each value of F using the imputes of asymptotic weight, natural mortality, age at recruitment, and a growth parameter (von Bertalanffy k). For this' analysis, survey selectivities were used to estimate the age at recruitment, which may vary from the size at entry in the commercial fishery. A comparison of survey and fishery size

Table 5.--Maximum sustainable yield estimates* (t) for selected Gulf of Alaska flatfish, based on the 1987 bottom trawl survey, by North Pacific Fishery Management Council regulatory area and species (percentages of the grand total are in parentheses).

	Area				
	Western	Central	Eastern	Total	(%)
Deep-water species					
Arrowtooth flounder	8,720	45,620	8,592	62,932	(52)
Flathead sole	3,439	10,694	2,456	16,589	(13)
Others	1,207	10,774	1,691	13,692	(11)
All deep-water	13,366	67,088	12,739	93,193	(76)
Shallow-water species					
Rock sole	7,316	13,933	59	21,308	(18)
Yellowfin sole	2,123	1,613	0	3,736	(3)
Others	740	1,851	619	3,210	(3)
All shallow-water	10,179	17,397	678	28,254	(24)
All flatfish	23,545	84,485	13,417	121,447	(100)

* Calculated from the method of Gulland (1971).

compositions indicated that this was a reasonable approximation, although the survey did catch a slightly higher proportion of smaller individuals.

With the exception of flathead sole, the yield per recruit analysis indicates that values of F_{max} occur for Gulf of Alaska flatfish at low levels of F (Fig. 3). The fact that these species begin reproduction after first entry into the fishery makes such high exploitation for flathead sole (F_{max} = 5.5) dangerous from the perspective of recruitment. While no spawner-recruit information is available to fully evaluate this danger, it is clear that if spawners are reduced to a low enough level, recruitment will suffer.

One management alternative to harvesting under conditions of F_{max} is the $F_{0.1}$ approach described by Gulland and Boerema (1973). This rule of thumb determines the fishing mortality where the marginal yield is one-tenth of the original CPUE in a very lightly exploited stock. This represents a compromise between a fishery which would maintain a better spawning stock and mean size. These F values from the yield per-recruit analysis and the natural mortality estimates can be used to estimate the proportion of a stock which would be harvested annually under this strategy from the formula:

$$\frac{Y}{B} = \frac{F}{F + M} \quad 1 - e^{-(F + M)}$$

where Y = yield, B = biomass, and F and M are fishing and natural mortality, respectively. The resulting values are as follows:

Species	F_{max}	$F_{0.1}$	$U@F_{max}$	$U@F_{0.1}$
Arrowtooth flounder	0.3	0.17	0.24	0.14
Flathead sole	5.5	0.34	0.96	0.26
Rock sole	0.5	0.20	0.36	0.16
Yellowfin sole	0.4	0.19	0.30	0.16

With the exception of flathead sole, the recommended F for Gulf of Alaska flatfish is F_{max} since the stocks are considered to be near virgin biomass levels. In the case of flathead sole, however, the exploitation rate at F_{max} is clearly unrealistic

(due to the k value obtained from the age analysis for this species, see Table 4). The $F_{0.1}$ value is therefore the default harvest level for flathead sole.

The exploitation rates were then multiplied by the 1987 biomass estimates to determine the current potential yield (acceptable biological catch) under conditions of an F_{max} fishery for arrowtooth flounder, rock sole, and yellowfin sole, and an

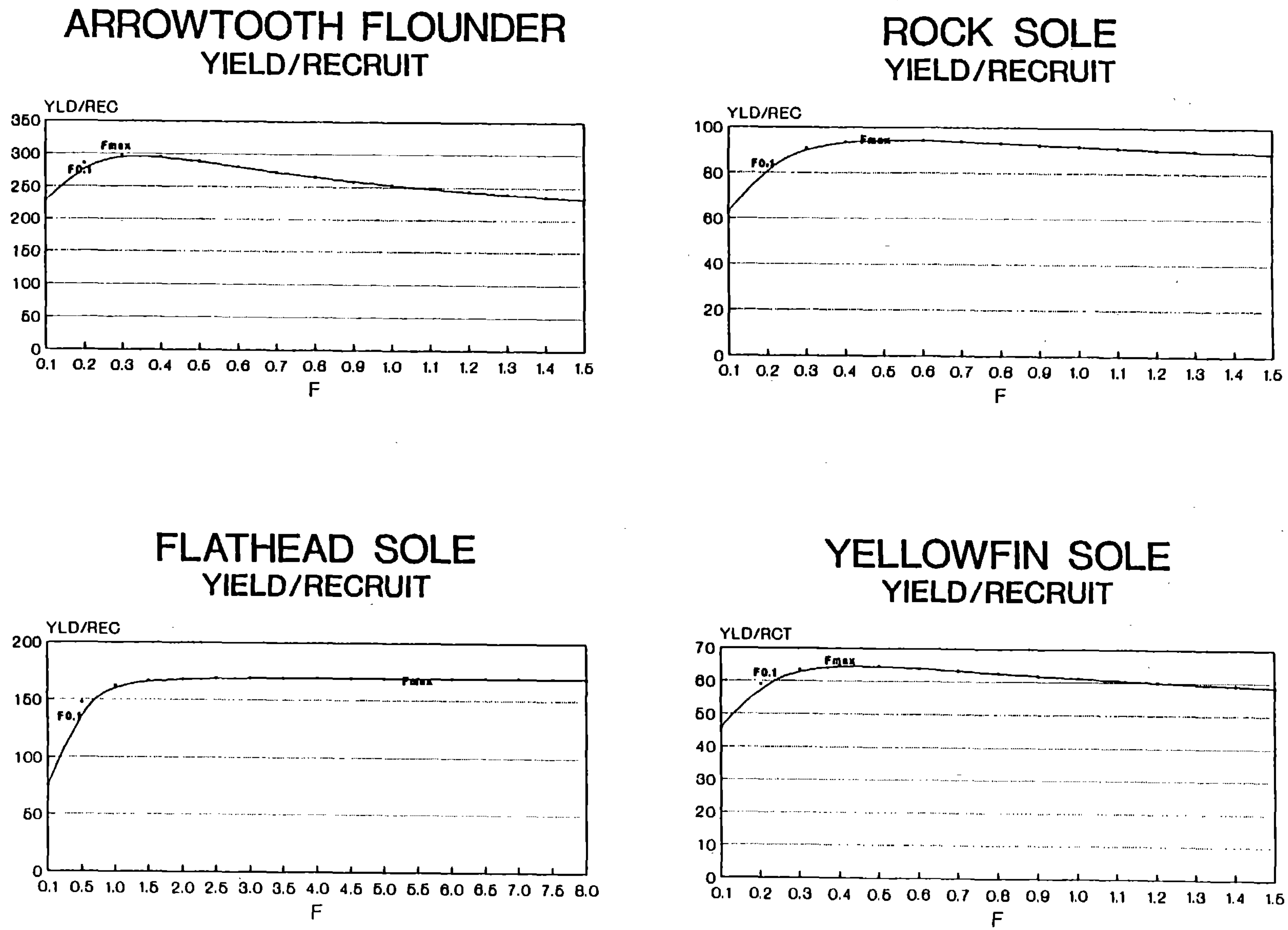

Figure 3.--Yield per recruit of arrowtooth flounder, rock sole, flathead sole, and yellowfin sole at various levels of fishing mortality. Fishing mortality at F_{max} and $F_{0.1}$ are indicated.

$F_{0.1}$ fishery for flathead sole (Table 6). The 1989 ABC recommendation is 554,700 t for the flatfish complex. This ABC is a reduction from the previous estimates due to the recalculation of natural mortality rates.

Due to the overlapping distributions of these species, it is not at all certain that they could all be fished at an optimum level simultaneously. Also, the fishery is likely to be limited by the potential for high by-catches of Pacific halibut.

BIOMASS PROJECTIONS

Exploitable biomass through 1995 is projected using the delay difference equation (Deriso 1980). This model incorporates growth, natural mortality, recruitment, and 2 years of biomass estimates to predict future biomass (Fig. 4). Exploitable biomass is predicted under harvest strategies of F_{max}, $F_{0.1}$ and $F=0$. Recruitment biomass is assumed constant during the projected years and was approximated from the 1987 Gulf of Alaska trawl survey biomass as follows:

Arrowtooth flounder	fish less than 29 cm	21,100 t
Rock sole	fish less than 21 cm	903 t
Flathead sole	fish less than 24 cm	2,880 t
Yellowfin sole	fish less than 25 cm	1,950 t

Table 6.--Acceptable biological catch (ABC) (t) of selected flatfish in the Gulf of Alaska, based on estimates from the 1987 bottom trawl survey with stocks at current levels under conditions of an F_{max} fishery for arrow-tooth flounder, rock sole, yellowfin sole, and "others," and an $F_{0.1}$ fishery for flathead sole. Presented by North Pacific Fishery Management Council regulatory area (percentages of the grand total are in parentheses).

	Area				
	Western	Central	Eastern	Total	(%)
Deep-water species					
Arrowtooth flounder	38,051	199,072	37,494	274,617	(50)
Flathead sole	11,767	36,584	8,401	56,752	(10)
Others	8,650	59,442	9,542	77,634	(14)
All deep-water	54,468	295,098	55,437	409,003	(74)
Shallow-water species					
Rock sole	39,905	75,998	140	116,043	(21)
Yellowfin sole	9,098	3,084	0	12,128	(2)
Others	4,038	10,095	3,378	17,511	(3)
All shallow-water	53,041	89,177	3,518	145,736	(26)
All flatfish	111,509	384,275	58,955	554,739	(100)

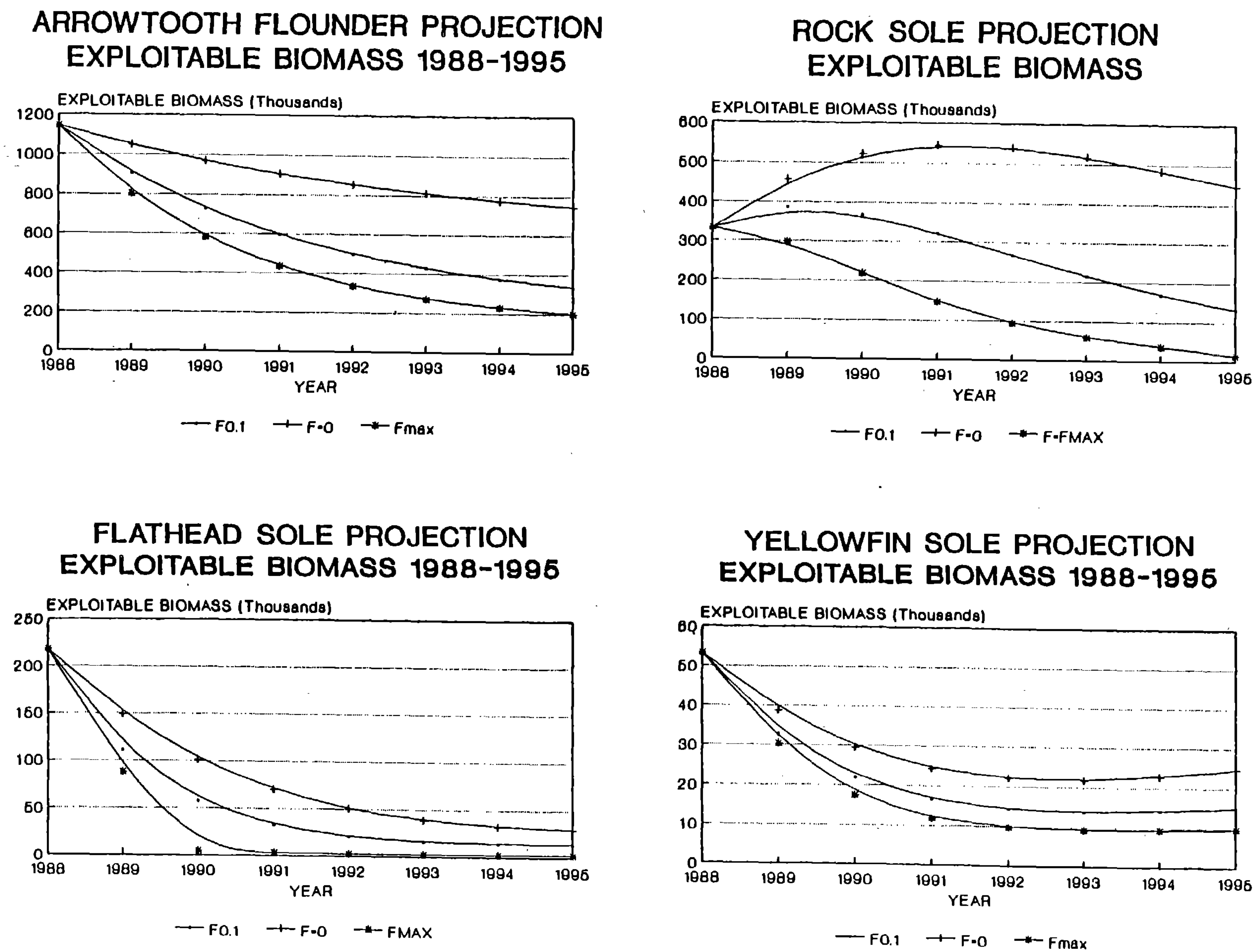

Figure 4.--Projections of exploitable biomass (t) for arrowtooth flounder, rock sole, flathead sole, and yellowfin sole based on three harvest strategies (F_{max}, P_{0-l}, and F = 0).

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SQUID

by

Thomas K. Wilderbuer

INTRODUCTION

Squid species, including *Berryteuthis magister*, *Berryteuthis anonychus*, and *Gonatus* spp., are distributed throughout the Gulf of Alaska. These species display a pelagic to bentho-pelagic vertical distribution and are commonly caught in midwater and bottom trawls. Currently of minor economic importance, squid species are managed as a single group in the Gulf of Alaska.

CATCH HISTORY

Gulf of Alaska squid are taken as by-catch by fisheries in pursuit of other species. Catches have averaged just 347 t for the years 1978-88 (Table 1), most of which has been taken by foreign fleets fishing in the central and western gulf. Catches by joint venture fisheries are insignificant and there have been no reported catches of squid by the U.S. domestic fishery. The total catch of squid has decreased sharply since 1981 as fishing by foreign nations has decreased.

CONDITION OF STOCK AND MAXIMUM SUSTAINABLE YIELD

The abundance and potential yield of squid in the Gulf of Alaska have not been evaluated through research findings. However, catches of squid by commercial vessels and research vessels, and their occurrence in the stomachs of fish and marine mammals, indicate a large standing stock. Maximum sustainable yield is intuitively believed to be greater than 5,000 metric tons (t). Accordingly, optimum yield (OY) has been set at 5,000 t (North Pacific Fishery Management Council 1987).

Table 1.--Catch (t) of squid in the Gulf of Alaska, by fishery category, 1978-88.

Year	Foreign total	U.S. joint venture	Total catch	OY/TAC
1978	322	---	322	2,000
1979	425	---	425	5,000
1980	841	Tr	841	5,000
1981	1,135	Tr	1,135	5,000
1982	278	16	294	5,000
1983	267	4	271	5,000
1984	120	5	125	5,000
1985	6	7	13	5,000
1986	0	7	7	5,000
1987	--	4	4	5,000
1988*	--	35	35	5,000

*Catches through 20 August 1988.'
Tr = Trace.
TAC = total allowable catch.
Sources: 1978-84--Berger et al. (1986); 1985-85--personal communication with Jerald Berger, U.S. Foreign Fisheries Observer Program, Northwest and Alaska Fisheries Center, National Marine Fisheries Service, NOAA, 7600 Sand Point Way NE, BIN C15700, Building 4, Seattle, WA 98115; 1986-88 Pacific Fishery Information Network (PacFIN), Pacific Marine Fisheries Commission, 305 State Office Building, 1400 SW Fifth Avenue, Portland, OR 97201.

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OTHER SPECIES

by

Richard L. Major

INTRODUCTION

The fishes or groups of fishes in the "other species" category are currently of little economic value to the fisheries of the Gulf of Alaska. Although the groups making up the other species category--sculpins (family Cottidae), skates and sharks (class Chondrichthys), smelts (family Osmeridae), and octopuses (order Octopoda) --are not the target objects of the present fisheries, they are regularly taken as by-catch. Nonetheless, with an eye to the ecological importance and potential economic importance of fishes in the other species category, it is instructive to examine the available information pertaining to their condition. Although this assessment is essentially unchanged from Major (1988), it is repeated here for the sake of completeness of the Gulf of Alaska status of stocks document.

CATCH HISTORY

Because of the relative unimportance of the fishes in the other species category, there have been no special studies directed at assessing their condition. Therefore, commercial catch data provide virtually the only opportunity to appraise the current status of the stocks. The catch data themselves, however, are not straightforward. Catches of the groups making up the other species category were not recorded in the U.S. domestic fishery until 1987. Furthermore, Japan included Atka mackerel (*Pleurogrammus monopterygius*) in their 1977 catch, and their 1979 catch included shortspine thornyhead (*Sebastolobus alascanus*). Similarly, rattails and grenadiers (family Macrouridae) have been in and out of the other species category. It was not until 1981 that the makeup of the other species category stabilized in its present form.

Catches since 1981 are as follows (in metric tons (t)):

	Fishery Category			
Year	Foreign	Joint venture	Domestic	Total
1981	7,112	33	--	7,145
1982	2,049	301	--	2,350
1983	2,255	391	--	2,646
1984	576	1,268	--	1,844
1985	97	2,246	--	2,343
1986	146	255	--	401
1987	--	178	75	253
1988*	--	99	515	614

*Catches through 20 August 1988.

It is clear that the total catch of other species remains at a low level. Because the magnitude of the catches and their distribution among the component foreign,, joint venture, and domestic fisheries are largely shaped by regulatory- decree, the catches offer little real insight as to the condition of the other species group. Because the catches have been relatively small over the years, however, it is intuitively unappealing to project the stocks as being less than stable.

CONDITION OF THE STOCK

Species Composition

It is worthwhile to note the similarity in species composition between the 1984 commercial catch and the samples taken by the 1984 U.S.-Japan cooperative bottom trawl survey of the central and western Gulf of Alaska (which, together with a complementary survey in the eastern gulf, is also referred to as the triennial survey). Expressed in terms of the major groups making up the other species category, composition was as follows (commercial catch first, then survey catches in parentheses): sculpins 50% (41%), skates 20% (32%), smelts 16% (9%), sharks 11% (16%), and octopuses 4% (2%). Excluded from the computations is a disproportionately large catch of eulachon (smelts; *Thaleichthys pacificus*), taken by the U.S.-Japan joint venture for walleye pollock (*Theragra chalcogramma*) in Shelikof Strait. This gives rise to the precaution that bottom trawls are generally a poor tool with which to sample smelts--mainly because the species of this family primarily inhabit pelagic waters. It must be assumed, therefore, that the abundance of this family is substantially underestimated.

Although the triennial survey was repeated in 1987, the composition of the other species category recorded in that survey cannot be compared with the composition of the foreign or joint venture fisheries because the latter fisheries had been eliminated or reduced to a low level by 1987.

Absolute Abundance and Exploitable Biomass

The 1987 U.S.-Japan cooperative bottom trawl survey did, however, provide data with which to generate biomass estimates for a few bottom-dwelling species or groups of species that were taken in fair numbers[1]. Estimates are as follows:

Species	Biomass (t)
Skates	
Unidentified	47,430
Sharks	
Spiny dogfish (*Squalus acanthias*)	9,225
Salmon shark (*Lamna ditropis*)	13,504
Pacific sleeper shark (*Somniosus pacificus*)	1,267
Sculpins	
Myoxocephalus spp.	400
Yellow Irish Lord (*Hemilepidotus jordani*)	13,672
Bigmouth sculpin (*Hemitripterus bolini*)	10,429
Darkfin sculpin (*Malacocottus zonurus*)	859
Spinyhead sculpin (*Dasycottus setiger*)	142
Total	96,928

It is important to emphasize, for reasons of later discussion, that the so-called "absolute" biomass estimate does not include smelts (which could make up a large element in the other species category), octopuses, and many sculpins.

MAXIMUM SUSTAINABLE YIELD, EQUILIBRIUM YIELD AND TOTAL ALLOWABLE CATCH

The maximum sustainable yield, equilibrium yield, and total allowable catch (TAC) have not been estimated for the other species

[1] Eric Brown, Northwest and Alaska Fisheries Center, National Marine Fisheries Service, NOAA, 7600 Sand Point Way NE, Seattle, WA 98115. Pers. commun., April 1988.

category because of the dearth of information. Rather, the North Pacific Fishery Management Council, according to the terms of the Fishery Management Plan (FMP) for the Gulf of Alaska Groundfish Fishery, sets the TAC at 5% of the sum of the TACs for the other eight species categories (squid are not included). Using this procedure, the 1988 TAC was set at 12,426 t. Considering that 12,426 t is only 13% of the bare minimum current biomass estimated above (and probably a much lower percentage of the real biomass), the procedure called for in the FMP does not jeopardize the well-being of the other species category. The population, in fact, could probably sustain a higher harvest rate, providing that the weaker elements in the multispecies complex were not thereby imperiled.

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Results of Acoustic-Midwater Trawl Surveys for Walleye Pollock in Shelikof Strait, Alaska, in 1988

by

Edmund P. Nunnallee and Neal J. Williamson

INTRODUCTION

The annual acoustic-midwater trawl survey of the walleye pollock (*Theragra chalcogramma*) population in Shelikof Strait, Alaska, was conducted using the National Oceanic and Atmospheric Administration (NOAA) ship *Miller Freeman*. Echo integrator-midwater trawl survey passes were made through the strait during 11-19 March and 20-27 March. The series was comparable to those conducted in 1981 and 1983-87 (Nunnallee 1987). The major objective of the survey was to provide data for estimation of the age and length specific biomass and population of the off-bottom component of the pollock stock near the time of spawning in the strait.

Estimates of age and size specific population and biomass and other selected biological observations are presented for the 1988 survey. Similar estimates from previous survey years are presented for reference and for comparison where applicable.

SURVEY METHODS

Acoustic data were collected with a 38 Khz echo sounder and a digital echo integrator interfaced to a computer system for storage and subsequent analysis. The echo sounder's transducer was housed in a dead weight body that was towed from the stern of the ship at an average depth of about 18 m. The acoustic system was calibrated after the cruise period. Biological samples were collected and echo sign was identified using a midwater rope trawl (NET Systems Inc., No. 864) equipped with 45 fathom bridles, 5 m steel otter doors, 600 and 1200 lb tom weights and 3.2 cm mesh cod end liner. The trawl was also equipped with a cable (third wire) netsounder system. Vertical mouth openings ranged from 12 to 18 fathoms.

Survey operations were conducted 24 hours per day along parallel tracklines which extended between the 50 fathom depth contours of the strait (Fig. 1). Each pass through the survey area was run from near Chirikof Island to near Foul Bay. The average distance between adjacent transects was about 7.5 nmi. Average vessel speed was 9 kn. Echo integrator estimates of fish density were obtained along each transect at l-minute intervals for each of up to 400 contiguous 1 m depth intervals between 5 m

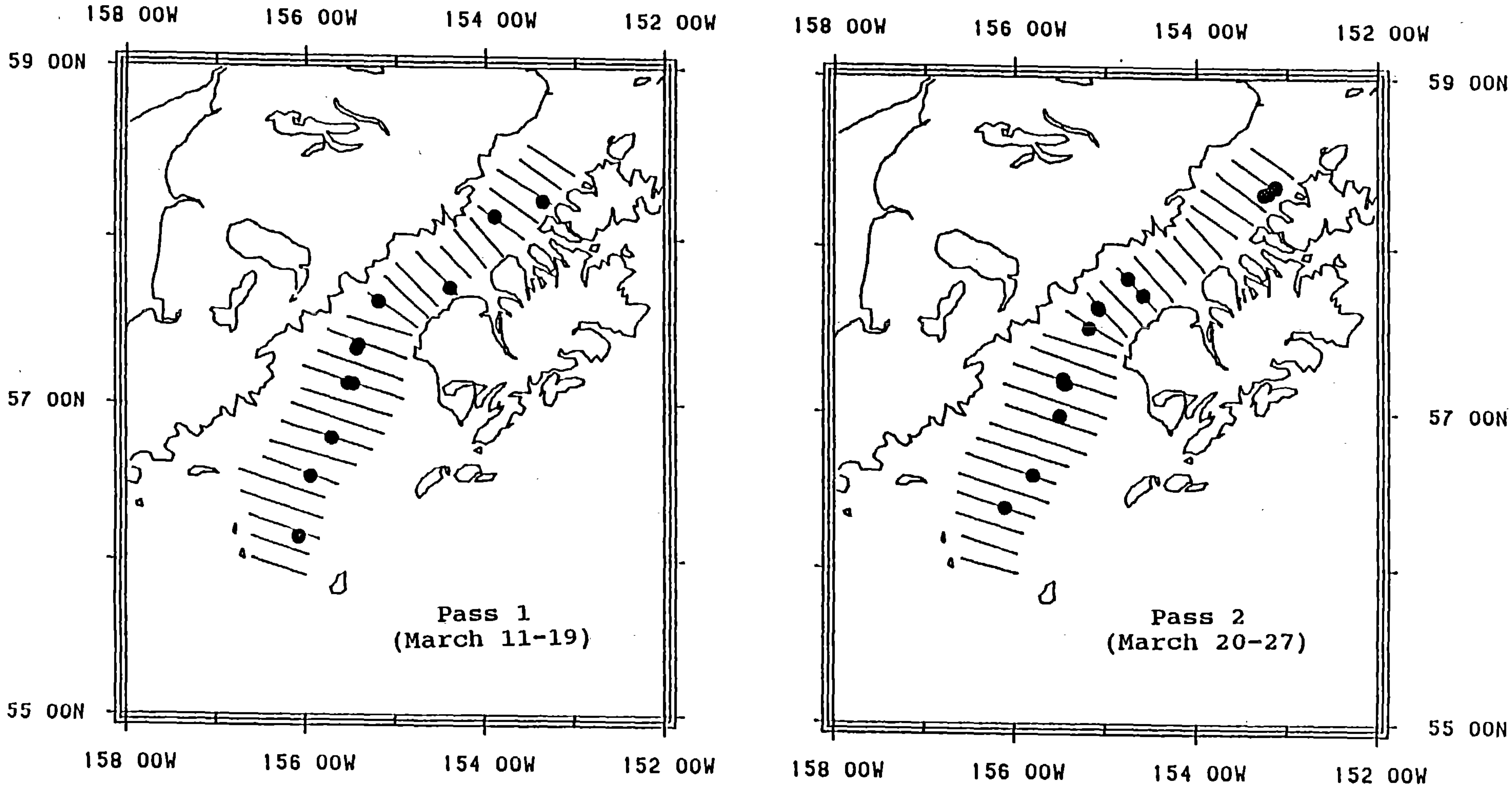


Figure 1.--Acoustic survey tracklines and midwater trawl stations, 1988 Shelikof Strait pollock survey.

below the transducer and the seabed. Echo integration data were collected to within about 3 m of the seabed.

Midwater trawl hauls were made during each pass through the survey area to provide data on the biological composition of the pollock stock and other midwater species. The distribution, of trawl stations was roughly proportional to the occurrence of echo sign. Individual trawl durations depended on the time required to capture an adequate amount of the target echosign required for a biological sample, as judged by interpretation of the netsounder echo trace. Average trawling speed was about 3 kn. Standard on-deck catch sorting and enumerating procedures were used to provide estimates of weight and numbers by species for each haul. Each catch was either sorted completely or, if it exceeded about 2,000 lb, was subsampled and then sorted to determine species composition. Pollock length (by sex) data were collected from random catch subsamples from each haul. Individual weight, sex, maturity and length data, and otoliths were collected from stratified length subsamples from, most hauls.

RESULTS

Sampling Effort and Species Composition in Trawl Catches

Trackline distances for survey pass 1 and 2 amounted to 1,505 km (813 nmi) and 1,608 km (868 nmi), respectively. Twenty-six midwater trawl hauls were completed during the survey (Table 1). The frequency of occurrence in trawl hauls and the total catch of each species taken are shown in Table 2. The catch weight of species other than pollock amounted to only 7.6% of the total; 4.3 % of the total was eulachon (_Thaleichthys pacificus_). It has not been possible to determine for any of the Shelikof Strait surveys (1981 & 1983-1988) whether the proportion of the catch represented by eulachon is a true reflection of the eulachon population size or is an artifact of the aimed trawling sampling technique. Eulachon have consistently been found near bottom and when taken in trawl catches were associated with the lower layer of pollock echosign. Discussion of catch quantities other than pollock are included only to indicate the degree of contamination in the assessment of the pollock population.

Biomass and Population Size and Age Compositions

The estimated biomass and population of 2 year and older pollock in Shelikof Strait during the 1988 survey was 324,800 t and 1,349.6 millions, respectively. Age specific population and biomass estimates for 1988 and all previous survey years are given in Table 3, population estimates by year class are given in Table 4 and annual biomass estimates for all survey years are given in Table 5. In addition, plots of estimated total annual

Table 1.--Midwater trawl haul station and catch data for the 1988 Shelikof Strait pollock survey.

Haul no.	Date	Equil. hour	Equil. duration (min)	Start position Lat.(N)	Start position Long.(W)	Average depth (fm) (footrope/ bottom)	Catch (lb) Pollock	Catch (lb) Eulachon	Catch (lb) Other species
3	3/11	11	12	56 09	156 05	127/134	1719	15	49
4	3/13	13	3	56 32	155 57	141/143	365	25	9
5	3/16	18	31	57 07	155 29	96/148	134	1	Tr
6	3/16	20	6	57 08	155 32	135/149	1083	103	525
7	3/17	13	4	57 37	155 12	79/153	806	0	4
8	3/18	13	6	58 08	153 54	103/114	737	0	6
9	3/18	23	3	58 13	153 22	105/115	587	42	6
10	3/20	01	33	57 42	154 24	77/120	2082	7	23
11	3/20	06	3	57 21	155 25	82/146	390	1	0
12	3/20	06	7	57 20	155 26	126/146	824	12	24
13	3/20	10	2	56 46	155 43	136/158	540	401	13
14	3/21	03	16	56 23	156 03	131/148	605	63	47
15	3/21	15	29	56 35	155 48	80/142	464	65	7
16	3/22	04	2	56 59	155 30	146/142	1672	290	14
17	3/22	20	1	57 12	155 28	136/148	659	19	3
18	3/22	21	23	57 11	155 28	55/146	951	0	3
19	3/23	04	6	57 11	155 26	55/144	1338	1	0
20	3/23	14	11	56 31	155 11	128/141	1327	85	33
21	3/23	21	30	57 38	155 04	56/145	659	0	0
22	3/24	04	30	57 39	155 05	66/147	562	6	4
23	3/24	16	11	57 49	154 45	127/139	774	55	5
24	3/24	22	40	57 43	154 35	64/121	554	46	15
25	3/26	01	10	57 22	153 08	45/129	2948	1	21
26	3/26	06	3	58 22	153 08	45/118	905	0	1
27	3/26	00	5	58 19	153 15	48/107	1977	0	Tr
28	3/27	04	1	58 20	153 12	45/111	2185	0	1

Hauls 1 and 2 were made outside of Shelikof Strait.
= trace amount (< 0.5 lb.).
Equilibrium Equil.) hour is the nearest hour to when the trawl first reached its desired depth.

Table 2.--Frequency of occurrence and total catch by species in 26 midwater trawl hauls made during the 1988 Shelikof Strait pollock survey.

Species	Frequency No.	Frequency %	Total catch lb.	Total catch %
Walleye pollock (*Theragra chalcogramma*)	26	100.0	26,902	92.6
Eulachon (*Thaleichthys pacificus*)	19	73.1	1237	4.3
Pacific herring (*Clupea harengus pallasii*)	11	42.3	19	.1
Smooth lumpsucker (*Aptocyclus ventricosus*)	9	34.6	50	.2
Squid (unidentified)	9	34.6	17	.1
Chinook salmon (*Oncorhynchus tshawytscha*)	9	34.6	51	.2
Arrowtooth flounder (*Atheresthes stomias*)	8	30.8	43	.2
Pacific cod (*Gadus macrocephalus*)	7	26.9	89	.3
Flathead sole (*Hippoglossoides elassodon*)	5	19.2	5	Tr
Jellyfish (Unidentified)	5	19.2	9	Tr
Rougheye rockfish (*Sebastes aleutianus*)	2	7.7	18	.1
Shrimp (*Pandalus* sp.)	2	7.7	3	Tr
Pink salmon (*Oncorhynchus gorbuscha*)	1	3.8	2	Tr
Salmon shark (*Lamna ditropis*)	1	3.8	500	1.7
Big skate (*Raja binoculata*)	1	3.8	103	.4
Starry flounder (*Platichthys stellatus*)	1	3.8	1	Tr
Rock sole (*Lepidopsetta bilineata*)	1	3.8	1	Tr
Salmon (unidentified)	1	3.8	1	Tr
	Total		29,051	

Tr = Trace (<.05 %)

Table 3.--Pollock population and biomass estimates by age (ages ≥2), determined from 1981 and 1983-88 Shelikof Strait acoustic-midwater trawl surveys.

Survey year	Age 2	3	4	5	6	7	8	9	10	11	12
					Estimated Numbers (millions of fish)						
1981	3,704.6	1,490.7	888.5	3,480.1	1,464.1	258.6	151.2	115.7	31.4	3.5	0.0
1982						No survey					
1983	757.8	325.7	1,410.0	1,270.3	761.7	648.4	145.2	19.5	11.9	4.1	1.9
1984	74.2	258.9	231.1	700.9	1,045.0	464.8	239.8	42.1	3.7	0.0	0.9
1985	218.6	92.4	194.9	111.5	214.0	269.2	103.5	26.0	2.9	1.5	0.6
1986	1,993.1	287.7	44.3	81.7	52.3	89.5	151.3	62.1	11.7	1.8	0.0
1987	*	*	*	*	*	*	*	*	*	*	*
1988	115.3	753.6	349.6	83.8	18.2	6.0	6.0	4.1	9.3	1.8	1.9
					Estimated Biomass (1,000 t)						
1981	350.6	375.0	339.4	1,509.0	756.1	177.3	115.8	111.0	27.9	3.2	0.0
1982						No survey					
1983	58.9	103.9	570.7	700.8	497.2	360.6	105.1	17.3	12.1	4.8	1.6
1984	8.0	64.1	105.5	405.8	710.5	333.8	169.8	34.8	4.9	0.0	0.9
1985	22.4	27.1	99.8	67.9	157.2	217.0	86.6	21.5	2.9	1.9	0.6
1986	129.5	60.0	18.6	62.3	44.8	81.8	148.4	62.4	13.2	2.6	0.0
1987	*	*	*	*	*	*	*	*	*	*	*
1988	7.9	140.6	99.0	33.7	9.7	5.9	6.5	4.7	11.3	2.4	3.1

* No estimates available for 1987.

Table 4.--Pollock population estimates (millions) by year class and age (ages ≥ 2), determined from 1981 and 1983-88 Shelikof Strait acoustic-midwater trawl surveys.

	Year class																	
Age	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
2											3704.6	*	757.8	74.2	218.6	1993.1	#	115.3
3										1490.7	*	325.7	258.9	92.4	287.7	#	753.6	
4									888.5	*	1410.0	231.1	194.9	44.3	#	349.6		
5								3480.1	*	1270.3	700.9	111.5	81.7	#	83.8			
6							1464.1	*	761.7	1045.0	214.0	52.3	#	18.2				
7						258.6	*	648.4	464.8	269.2	89.5	#	6.0					
8					151.2	*	145.2	239.8	103.5	151.3	#	6.0						
9				115.7	*	19.5	42.1	26.0	62.1	#	4.1							
10			31.4	*	11.9	3.7	2.9	11.7	#	9.3								
11		3.5	*	4.1	0.0	1.5	1.8	#	1.8									
12	0.0	*	1.9	0.9	0.6	0.0	#	1.9										

* No survey in 1982.
# No estimates available for the 1987 survey.

Table 5.--Summary of annual biomass estimates of age 2 and older pollock in Shelikof Strait for surveys conducted in 1981 and 1983-88.

Year	($t \times 10^6$)	Interval ($t \times 10^6$)	Source of estimates
1981	3.77	2.86 to 4.67	Mean of ests., pass 1 & 2
1982	-	-	No survey conducted in 1982
1983	2.43	1.69 to 3.13	Mean of ests., pass 1 & 2
1984	1.84	1.21 to 2.47	Mean of ests., pass 1, 2 & 3
1985	0.70	0.50 to 0.91	Mean of ests., pass 1, 2 & 3
1986	0.62	0.37 to 0.87	Mean of ests., pass 1, 2 & 3
1987	-	-	No ests. available for 1987
1988	0.33	0.23 to 0.42	Mean of ests., pass 1 & 2

biomass and annual age, and size specific populations are shown in Figure 2, 3 (ages >2), and 4 (all ages), respectively.

The estimated pollock biomass in Shelikof Strait during the 1988 survey is the lowest of any of the survey years and the population estimate is lowest of all years except 1985. The reason for these unexpectedly low numbers is unclear but may be the result of 1) a large proportion of the fish not having been available to the survey, or 2) an actual decrease in the population having occurred.

Areal Distribution and Maturity Composition

Separation of the areal distributions of the immature (non-spawning) and mature components of the pollock population in Shelikof Strait was ambiguous during the 1988 survey due to large numbers of nonspawning (2- to 5- year old) fish at all depths. Two layers of echosign were found in most areas but each contained fish of all ages. The upper layer contained mostly younger fish (age 2-4). The size composition in the lower layer was similar but also included some smaller and some larger fish (age 1 and age 5-12). There was no obvious environmental factor that accounted for the vertical stratification. The size and age compositions of the layers remained consistent throughout the survey period. The heaviest aggregations of pollock were found at about the same latitudes as in previous years, but were located more toward the east side of the strait. The only aggregationof large, mature pollock that was identified (by a commercial fishing vessel) was located near Cape Ugat, very near the east side. During previous survey years much of the pollock echosign was found in the central and western part of the strait, mostly in the deeper trenches near the west side.

Echosign of l-year-old pollock (1987 year class) was found in the most southerly part of the survey area and small numbers occurred in all but one of the trawl haul catches from the lower layer of echosign; no age-l pollock were taken in upper layer catches. No attempt was made to conduct a detailed survey of the extent of age-l pollock since little is known about their distribution or movements in the strait and their assessment is questionable at best. The thickness and extent of the layer, as indicated by echograms, were similar to those of the 1986 year class as we observed it during the 1987 survey.

The maturity composition of age-4 and older female pollock during the 1988 survey (Tables 6 and 7) indicated lower percentages of spawning and spent females during the last 10 days of March than during any previous survey period and likely indicates a late peak spawning period for 1988. No mature 3-year-old female pollock were seen during the survey period.

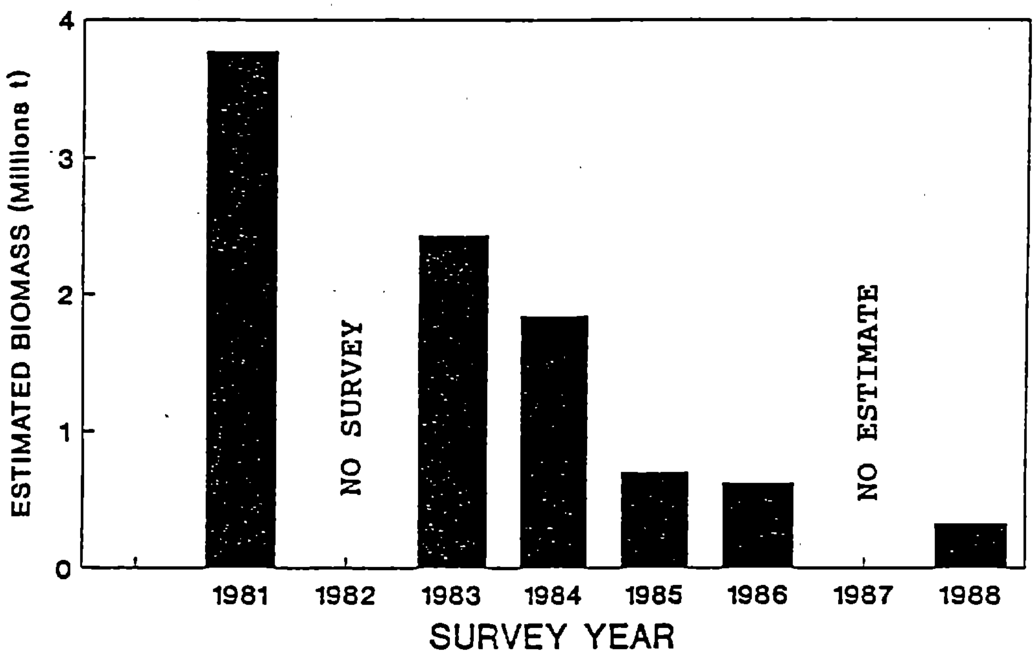


Figure 2.--Total estimated annual biomass of the Shelikof Strait pollock population during the 1981 and 1983-88 surveys.

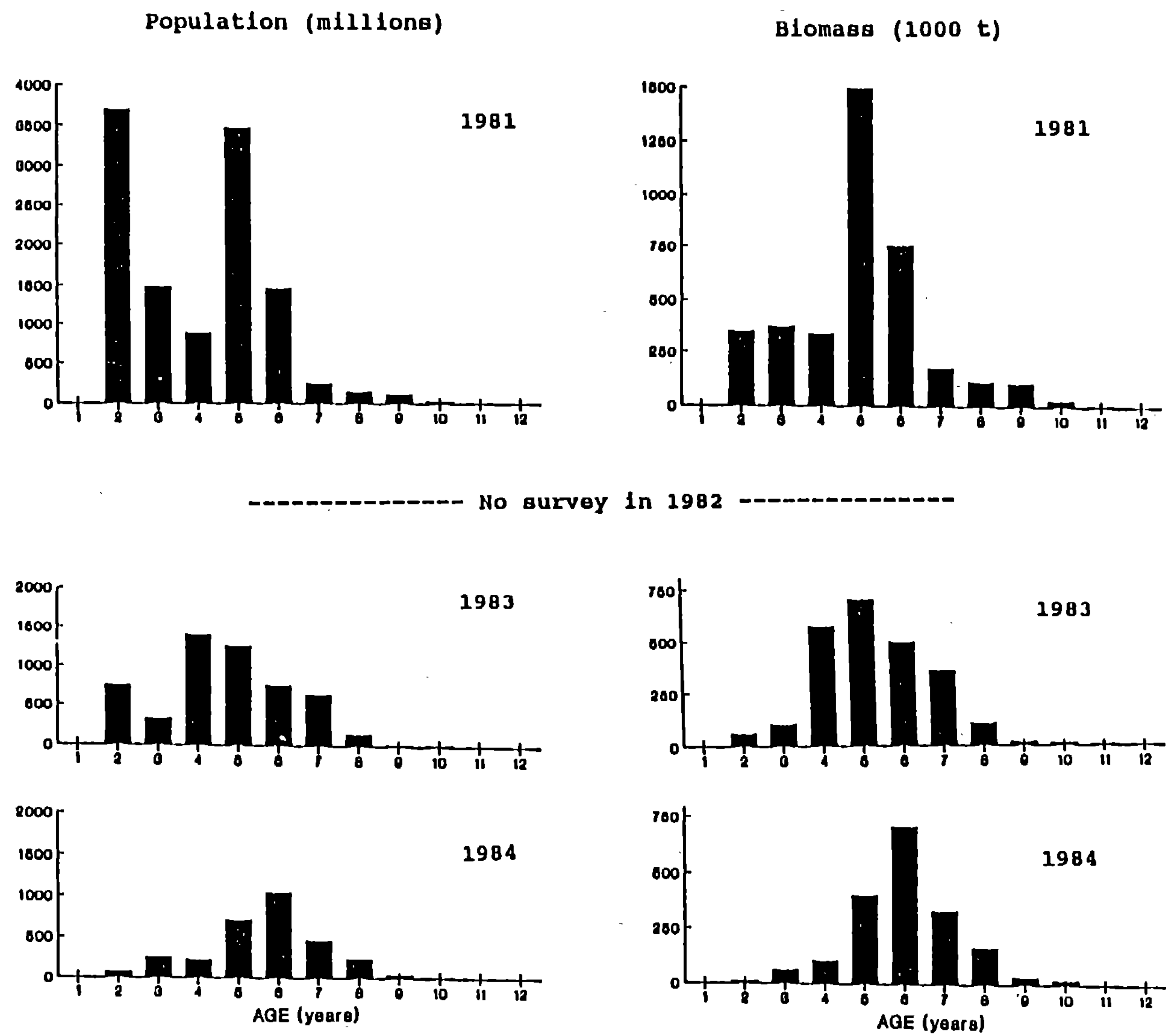


Figure 3. --Annual pollock age-specific population and biomass estimates (ages >2) for Shelikof Strait surveys conducted in 1981 and 1983-88.

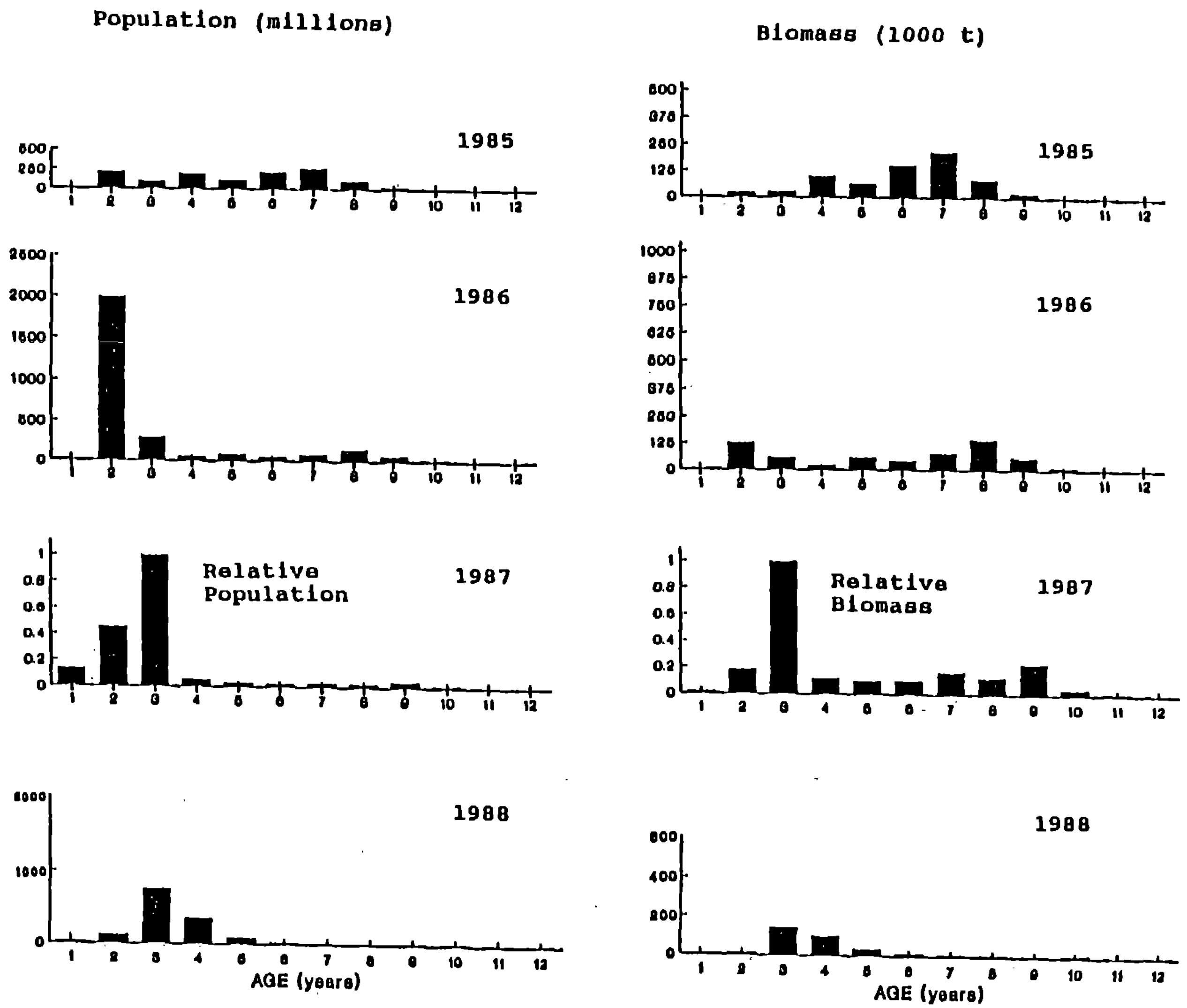


Figure 3.--(cont.) Annual pollock age-specific population and biomass estimates (ages ≥ 2) for Shelikof Strait surveys conducted in 1981 and 1983-88.

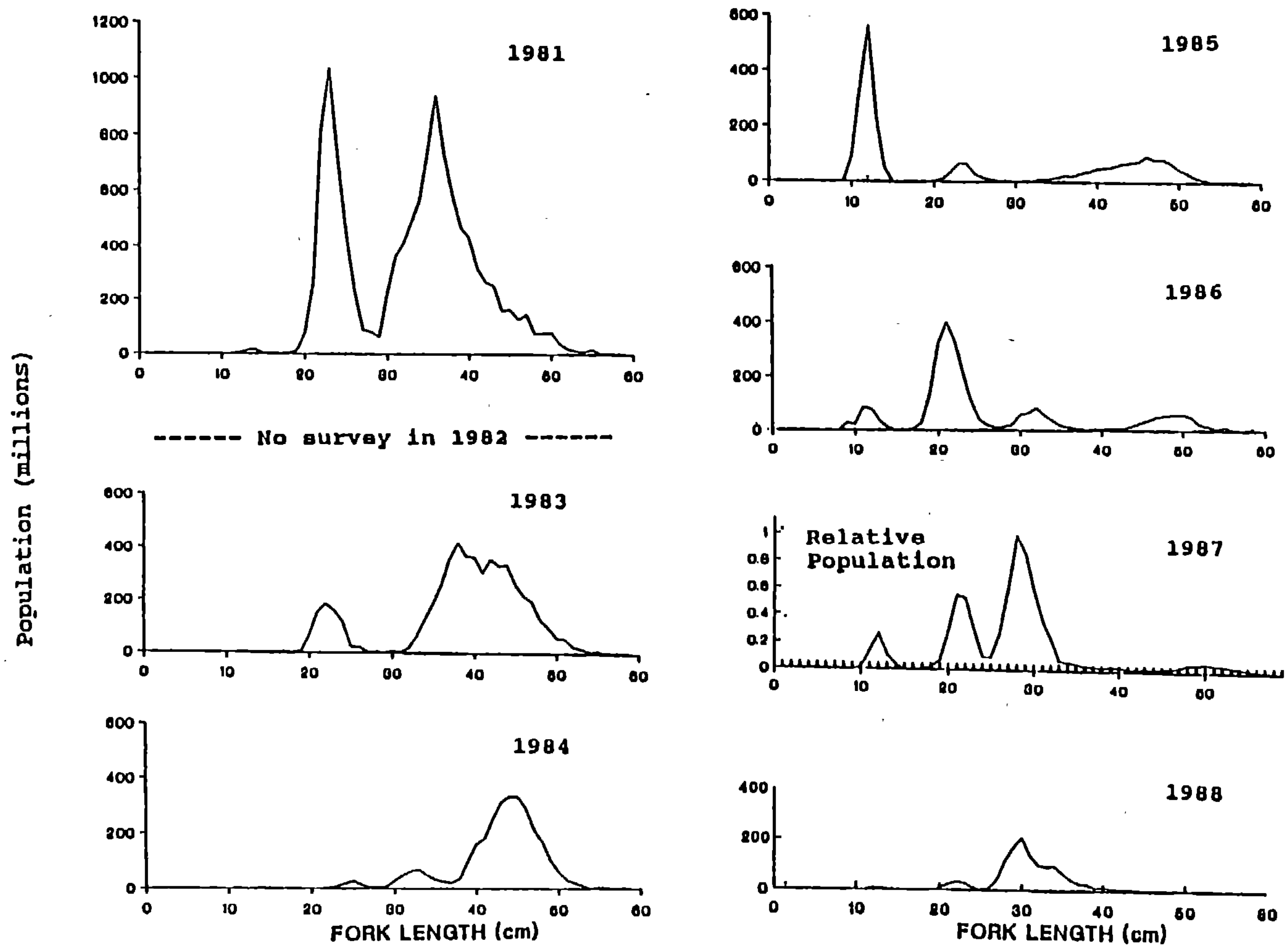


Figure 4.--Annual pollock length-specific population estimates (all ages) for Shelikof Strait surveys conducted in 1981 and 1983-88.

Table 6.--Observed percentages of spawning female pollock at age in Shelikof Strait during surveys conducted in March 1983-88.

	Year					
Age	1983	1984	1985	1986	1987	1988
2	0.0	0.0	1.0	0.0	0.0	0.0
3	74.5	30.8	26.0	3.3	1.2	0.0
4	79.0	61.3	45.5	10.5	10.6	20.9
5	96.3	95.3	52.0	86.1	34.0	17.6
6	96.7	99.0	89.8	90.2	76.9	60.6
7	97.7	100.0	99.2	95.9	88.5	66.7
8	93.8	99.2	99.2	100.0	95.0	100.0
9	100.0	100.0	100.0	100.0	99.1	85.7
10	100.0	100.0	100.0	100.0	100.0	94.4
11	100.0	100.0	100.0	100.0	100.0	100.0
12	100.0	100.0	100.0	100.0	100.0	100.0

Table 7.--Percentage maturity corn compositions for age-4 and older female pollock sampled during 1983-88 Shelikof Strait acoustic-' midwater trawl survey passes.

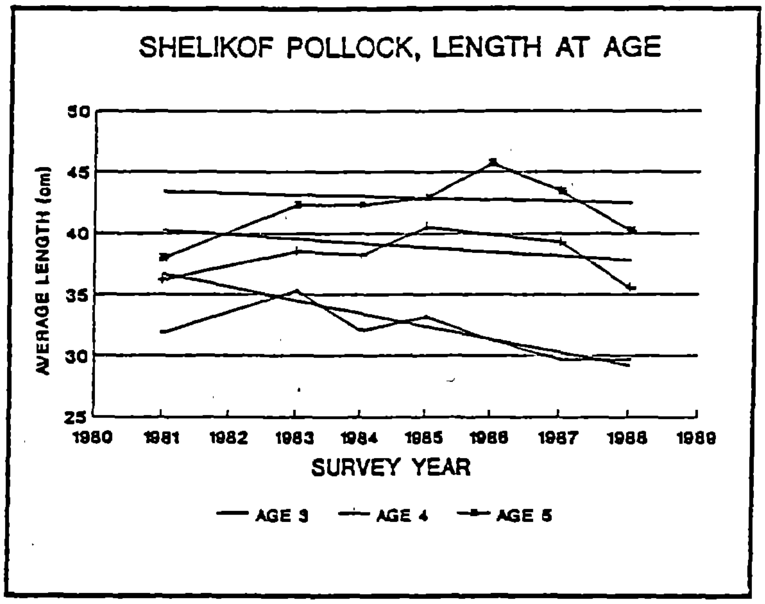
Year	Survey pass No. and period		Maturity stage					Sample size
			Immature	Developing	Mature	Spawning	Spent	
1983	1	March 6-15	0.0	8.6	90.8	0.5	0.0	371
	2	March 16-19	0.0	9.7	87.3	2.2	0.8	361
	3	April 6-12	0.0	11.7	6.6	13.1	68.6	137
1984	1	March 1-9	1.5	8.0	90.5	0.0	0.0	274
	2	March 9-16	0.0	5.1	92.9	1.5	0.4	467
	3	March 16-18	*	*	*	*	*	*
	4	March 22-25	0.0	3.1	55.3	37.5	4.1	291
	5	April 1-7	0.0	0.4	14.4	29.2	56.0	250
1985	1	Feb. 21-28	0.0	12.1	87.9	0.0	0.0	190
	2	March 1-9	0.0	29.3	70.7	0.0	0.0	242
	3	March 14-20	0.0	22.3	71.5	6.2	0.0	130
	4	March 21-28	0.0	13.2	58.7	21.4	6.7	341
1986	1	March 5-12	0.0	18.8	80.2	1.0	0.0	192
	2	March 13-21	0.0	17.4	73.4	9.2	0.0	109
	3	March 22-30	0.6	9.2	62.4	16.2	11.6	173
1987	1	March 12-17	0.0	47.1	52.9	0.0	0.0	140
	2	March 18-25	0.0	9.8	87.7	1.2	1.2	163
	3	March 25-29	0.0	14.8	77.4	3.5	4.3	115
1988	1	March 11-19	0.0	60.2	38.1	0.0	1.7	181
	2	March 20-27	0.0	59.2	39.8	0.0	1.0	98

* Maturity data were not collected for this survey pass.

DISCUSSION

The 1984 and 1985 year classes were by far the most abundant during the March survey period. Their combined population and biomass contributed 82 and 73% of the 1988 totals, respectively. The 1984 year class strongly dominated the population during the 1985-87 surveys. During the 1988 survey, however, the 1985 year class population was estimated to be more than twice as abundant as the 1984 year class. The 1985 year class did not appear to be exceptionally large during the 1986 or 1987 surveys and this apparent shift in year class dominance in 1988 was unexpected. A possible but unsupported hypothesis is that since the 1984 year class is only about 21% mature (Table 6), a large portion of the population was not in the strait and was under-represented in the survey area. The apparent population decline of the 1984 year class from 1986 to 1988 amounts to about 82.5% total mortality over the 2-year period (no population estimate for 1987), or an instantaneous mortality rate of 0.87. These calculations should be viewed with caution, however, since they are necessarily based on the 1986 population estimate of the 1984 year class at age 2. Reliable estimation of the abundance of age-2 pollock in Shelikof Strait has proven to be difficult (Table 3).

The assumption was made during the first few years of the Shelikof Strait survey series that the abundance of pollock in the strait during March represented a large portion of the total population in the central and western gulf area. Exploratory surveys were conducted in 1983 during late February-early March from near Unimak Pass to Shelikof Strait and on the southeastern and eastern side of Kodiak Island. Further investigations were made during 1984 early March in Amatuli Trench (East of Kodiak Island) and in Prince William Sound. No significant aggregations of spawning pollock were found in any of these areas, supporting to some degree the assumption that much of the pollock in the central and western gulf spawned in Shelikof Strait during that time. This assumption has become more and more questionable during the last 3 years as the proportion of the population in the strait represented by mature fish has become increasingly smaller. The population in Shelikof Strait during March has changed from mainly a spawning to a nonspawning aggregation. In addition, the size (length and weight) at age of pollock this year was considerably less than during the early years of the survey series (Fig. 5). Nearly 75% of the 3-year-old and 80% of 4-year-old female pollock in Shelikof Strait were mature during the 1983 survey.' In contrast, none of the 3-year-old and only about 21% of the 4-year-old females were mature in 1988 (Table 6). The nonspawning portion of the population in 1988 amounted to 90.7%. The average individual size and weight of pollock have also decreased since 1983. The average size of 3-year-old fish in 1983 was about 35 cm; in 1988 they were a little less than 30 cm in length. Likewise, average weight of 3-year-old fish have decreased from about 300 g in 1983 to less than 200 g in 1988.



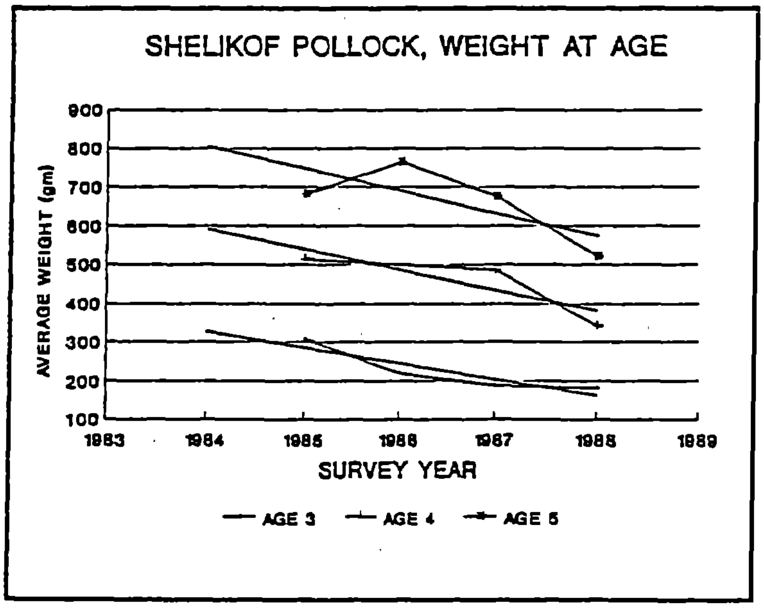


Figure 5. --Average lengths and weights at age of Shelikof Strait pollock showing a consistent trend in decreasing size and weight over the last several survey years. Straight lines indicate predicted values (from linear regressions).

Some of this apparent decrease in average weight may be attributable to the change in maturity over the period since gravid fish can weigh more than similar-size immature individuals. Similar but less obvious trends can be seen for older fish. No data are available on environmental factors that could account for reduced growth and maturation rates of the indicated magnitude. It is not known whether the apparent slower growth of the fish over the last several years is a factor in their reduced rate of maturation at age.

The changes in growth rate and age at maturity of the Shelikof Strait pollock population may indicate that the March survey results for 1986-88 have been, year-by-year, becoming less comparable to those from previous years. In addition, it is not known whether the biological characteristics or abundance of immature (nonpawning) pollock within the strait during March is a reliable index of the central and western population in general.

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ASSESSMENT OF GULF OF ALASKA SABLEFISH BASED ON THE JAPAN-U.S. COOPERATIVE LONGLINE SURVEY, 1987

by

Michael F. Sigler[1]

INTRODUCTION

In 1978, the Fisheries Agency of Japan and the U.S. National Marine Fisheries Service (NMFS) began a cooperative longline survey along the continental slope of the Gulf of Alaska to assess the abundance of sablefish (Anoplopoma fimbria) and Pacific cod (Gadus macrocephalus). The initial purpose of the survey was to supplement relative abundance data from the then shrinking Japanese commercial longline fishery. The first year of the survey was experimental and the data could not be used for population assessment purposes. Since 1979, the survey has been conducted annually in the Gulf of Alaska. The survey was expanded in 1980 to include the Aleutian Islands region and again in 1982 to include the eastern Bering Sea. This report, however, will present results and analysis only for the Gulf of Alaska portion of the survey. The longline survey currently is the primary method of determining' annual changes in sablefish abundance in the Gulf of Alaska. Survey results are used by the North Pacific Fishery Management Council (NPFMC) to determine the acceptable biological catch (ABC) and the total allowable catch (TAC), and to allocate the harvest among the regulatory areas of the Gulf of Alaska.

Sablefish abundance in the Gulf of Alaska doubled from 1979 to 1986 (Sasaki 1987; Sigler 1987); this increase was statistically significant (Sigler 1987). The main increases in abundance were from 1980 to 1982 and from 1984 to 1985. The strong 1977 year class (Sasaki 1982; McFarlane and Beamish 1983; Funk and Bracken 1984) probably was responsible for the first increase (Sigler and Fujioka 1988). The second increase probably was due to recruitment of a strong 1980 year class (Sigler and Fujioka 1988) and increased availability of large fish (Fujioka 1987; Johnson and Quinn 1987).

This report updates- previous analyses of the longline survey results. In this report, relative population numbers (RPN, an

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index of relative abundance in numbers), relative population weights (RPW, an index of relative abundance in weight), and length compositions are computed for sablefish in the Gulf of Alaska from the results of the 1987 longline survey. In addition, the statistical significance of annual changes in the RPNs from 1986 to 1987 are evaluated.

SURVEY METHODS

The Gulf of Alaska portion of the Japan-U.S. cooperative longline survey covered five International North Pacific Fisheries Commission (INPFC) statistical areas: Shumagin, Chirikof, Kodiak, Yakutat, and Southeastern (Fig. 1). Each year a total of 47 stations were sampled by longline using a Japanese commercial longline vessel chartered by the Japan Fisheries Agency. One station was sampled each day and covered depths from approximately 100 to 1,000 m. The longline was 16 km long and consisted of 160 hachis (the Japanese word for "skate" or length of longline); each hachi was 100 m long with 45 hooks attached (baited with squid). Soak time, the time between setting and retrieval, varied from 3 hours at the beginning of the longline gear to 7 or 8 hours at its end. Sablefish caught were tallied by depth and hachi as the longline was brought aboard, then weighed and measured to the nearest centimeter fork length. Most of the sablefish were also sexed, but some *were* tagged and released without sexing. Detailed survey methods are described in Sasaki et al. (1983).

RELATIVE POPULATION INDICES

The survey area for the longline survey was the upper continental slope (Fig. 2); survey stations were spaced approximately equidistantly along the length of the upper continental slope. The extensive continental shelf and numerous gullies of the Gulf of Alaska were not sampled.. Thus, computations of sablefish relative abundance in this report, with one necessary exception noted later, have been confined to the area surveyed, the upper continental slope.

Relative population numbers were calculated for the upper continental slope to index annual changes in sablefish abundance. Catch data were divided into nine strata based on 100 m depth increments (Table 1) because of differences in the sablefish catch rate by depth. The number of sablefish caught per hachi were calculated for each stratum of a station, and the resultant values within each statistical area were averaged. As in Sasaki (1985) , the mean number of sablefish caught per hachi for each stratum in a statistical area. was multiplied by the stratum's areal size (Table 2). The resultant RPNs were summed across

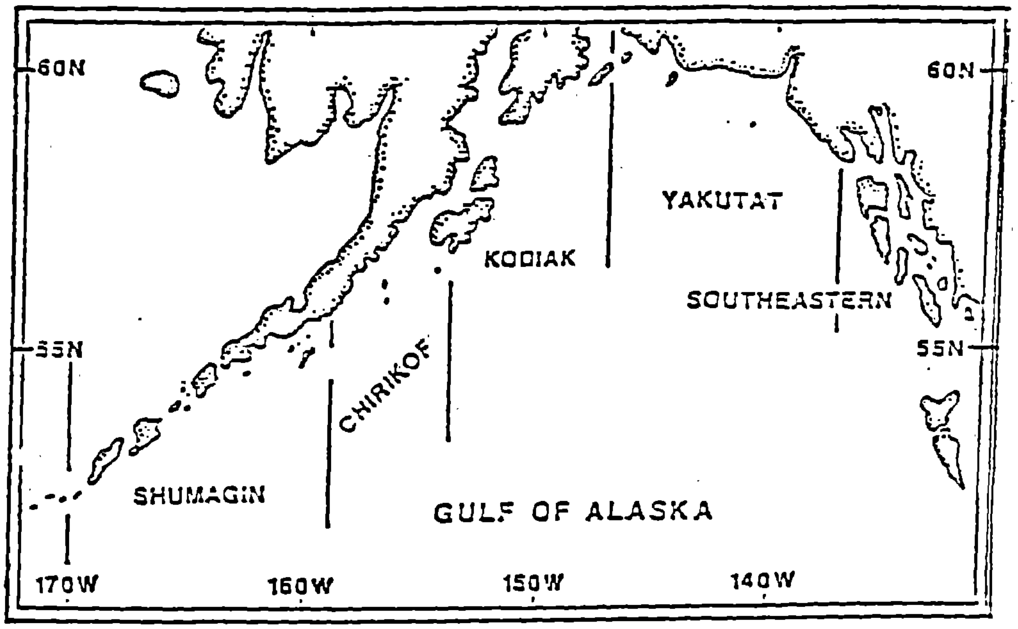

Figure 1.--International North Pacific Fisheries Commission statistical areas sampled during the Gulf of Alaska portion of the Japan-U.S. cooperative longline survey, 1979-87.

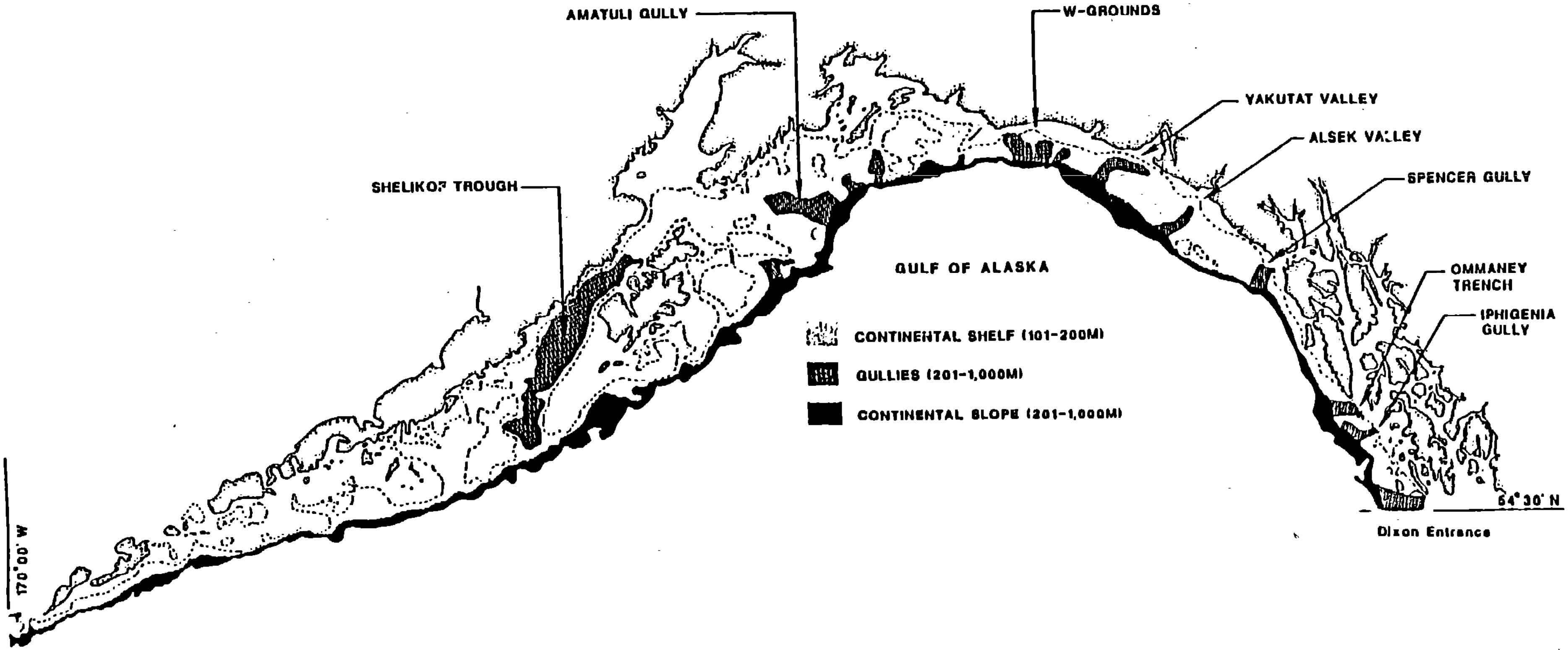

Figure 2.--The Gulf of Alaska by depth and topography showing location of the upper continental slope, gully areas, and the continental shelf.

Table 1.--Number of stations sampled by year, International North Pacific Fisheries Commission (INPFC) area, and depth during the Japan-U.S. cooperative longline survey, 1979-87.

Year	Depth (m)	INPFC area Shumagin	Chirikof	Kodiak	Yakutat	Southeast
1979	101-200	7	4	6	6	2
	201-300	7	5	7	10	5
	301-400	7	5	8	11	6
	401-500	7	5	9	11	6
	501-600	6	4	9	11	6
	601-700	6	4	8	11	5
	701-800	6	4	7	11	5
	801-900	5	1	4	9	4
	901-1,000	4	1	2	4	1
1980	101-200	9	5	8	7	4
	201-300	10	6	8	10	6
	301-400	10	6	8	10	8
	401-500	10	6	9	10	8
	501-600	10	5	9	10	7
	601-700	9	5	9	9	7
	701-800	6	4	8	9	7
	801-900	6	2	3	7	4
	901-1,000	5	1	2	6	1
1981	101-200	9	6	7	8	1
	201-300	10	6	9	11	9
	301-400	10	6	9	11	9
	401-500	10	6	9	11	9
	501-600	10	6	9	11	9
	601-700	9	4	9	11	9
	701-800	7	2	7	11	9
	801-900	6	1	5	7	7
	901-1,000	2	0	1	2	1
1982	101-200	9	5	7	10	4
	201-300	9	6	9	11	9
	301-400	10	5	9	11	8
	401-500	10	6	9	11	8
	501-600	10	5	9	11	8
	601-700	10	5	9	11	8
	701-800	9	4	8	11	7
	801-900	7	4	6	9	6
	901-1,000	3	3	5	8	3

Table 1.--Continued.

Year	Depth (m)	INPFC area Shumagin	Chirikof	Kodiak	Yakutat	Southeast
1983	101-200	9	5	7	8	3
	201-300	10	6	9	11	9
	301-400	10	5	9	11	8
	401-500	10	6	9	11	8
	501-600	10	5	9	11	8
	601-700	9	5	9	11	7
	701-800	8	4	8	11	7
	801-900	5	4	4	10	7
	901-1,000	2	0	1	5	2
1984	101-200	10	7	7	8	2
	201-300	10	7	9	11	9
	301-400	10	6	9	11	8
	401-500	10	6	9	11	8
	501-600	10	5	9	11	8
	601-700	8	5	8	11	8
	701-800	7	5	6	10	8
	801-900	3	0	3	7	5
	901-1,000	0	0	0	6	1
1985	101-200	9	6	6	7	1
	201-300	10	7	8	11	9
	301-400	10	6	9	11	8
	401-500	10	6	9	11	7
	501-600	10	6	9	11	8
	601-700	9	5	9	11	8
	701-800	7	4	9	10	8
	801-900	4	4	4	11	6
	901-1,000	0	0	0	5	2
1986	101-200	9	5	7	7	2
	201-300	10	6	9	11	9
	301-400	10	6	9	11	8
	401-500	10	6	9	11	8
	501-600	10	6	9	11	8
	601-700	10	4	9	11	8
	701-800	10	3	8	11	8
	801-900	5	2	7	11	8
	901-1,000	1	1	3	5	1

Table 1. --Continued.

Year	Depth (m)	INPFC area				
		Shumagin	Chirikof	Kodiak	Yakutat	Southeast
1987	101-200	8	5	7	8	2
	201-300	10	6	9	11	9
	301-400	10	6	9	11	9
	401-500	10	6	9	11	8
	501-600	10	6	9	11	8
	601-700	9	6	9	11	8
	701-800	7	5	9	11	8
	801-900	4	2	6	9	8
	901-1,000	0	1	2	3	3

Table 2.--Areal sizes (km^2) of the upper continental slope and gully areas in the Gulf of Alaska by International North Pacific Fisheries Commission area and depth (m).

	INPFC Area				
Depth (m)	Shumagin	Chirikof	Kodiak	Yakutat	Southeast
Upper continental slope					
201-400	4,001	2,350	3,106	2,988	1,781
401-600	2,269	1,766	2,255	1,666	822
601-800	1,629	1,955	1,923	1,470	1,006
801-1,000	1,248	2,012	2,296	1,489	1,165
201-1,000	9,147	8,083	9,580	7,613	4,774
Gully areas					
201-400	0	9,968	9,454	3,939	5,602
401-600	0	0	0	50	548
601-800	0	0	0	50	0
801-1,000	0	0	0	0	0
201-1,000	0	9,968	9,454	4,039	6,150

Sources: Shumagin, Chirikof, and Kodiak areas and Yakutat area from 147-144 degrees longitude: (Pers. commun., E. Brown, 1985. Northwest and Alaska Fisheries Center, NOAA, RACE Division, 7600 Sand Point Way NE, Seattle, WA 98115); Yakutat area from 144 to 137 degrees longitude and Southeastern area: (R. Haight, NWAFC, Auke Bay Laboratory, P.O. Box 155, Auke Bay AK 99821 Pers. commun., April 1988).

strata to calculate an RPN for each statistical area, and these RPNs were summed across statistical areas to calculate an RPN for the Gulf of Alaska.

Length compositions were computed for the upper continental slope by strata and statistical area to examine sablefish size structure. For depths 201-1,000 m, an RPN weighted length frequency for each stratum in an area was constructed by allocating the stratum's RPN to each centimeter increment of the stratum's length frequency distribution based on the relative *numbers* of fish caught at that length increment. For depths lOl-200 m, a sablefish catch per hachi weighted length frequency was computed for each area by the same procedure used to compute the RPM weighted length frequencies. Sablefish catch per hachi values were used instead of RPNs because only a small fraction of the area at depths 101-200 m was surveyed (depths less than 200 m generally are part of the continental shelf).

Relative population weights were computed for the upper continental slope to assess the relative biomass of sablefish by strata and statistical area. A sablefish length-weight equation

$$W = 2.99 \times 10^{-6} \times L^{3.30}$$

for the Gulf of Alaska (Sasaki 1985) was applied to the RPN weighted length frequencies for depths 201-1,000 m to compute RPW weighted length frequencies for each stratum in a statistical area. These weighted length frequencies were summed across length to calculate RPWs by stratum and statistical area.

Relative population weights were extrapolated for gully areas in the Gulf of Alaska. Gully areas were not sampled in the. longline survey, but RPWs were estimated because of the management importance of having estimates of sablefish relative biomass for these areas. Gully areas in the Gulf of Alaska include Shelikof Trough, Amatuli Gully and three small, unnamed gullies close to Amatuli Gully, the W-grounds, Yakutat Valley, Alsek Valley, Spencer Gully, Ommaney Trench, Iphigenia Gully, and Dixon Entrance (Fig. 2).

The RPWs for the gully areas were estimated using areal size estimates for gully areas (Table 2) and catch-and-length information from three sources: 1) Japan-U.S. cooperative longline survey; 2) the domestic longline-survey (Sigler and Zenger in prep.); and 3) experimental longline research in 1987 aboard the R/V John N. Cobb. Shelikof Trough was sampled during the domestic longline survey and Spencer Gully and Ommaney Trench were sampled during the experimental longline research. Catch rates from the domestic longline survey and the experimental longline research, which used similar longline gear, were corrected to the catch rates from the Japan-U.S. cooperative longline survey based on a comparison of the catch rates from the two longline surveys (Sigler and Zenger in prep.). The resultant catch rates and the length compositions from the domestic longline survey and experimental longline research were used to compute RPWs for Shelikof Trough, Spencer Gully, and Ommaney Trench. RPWs for the remaining unsampled gully areas, Amatuli Gully and three nearby gullies, the W-grounds, Yakutat Valley, Alsek Valley, Iphigenia Gully, and Dixon Entrance were based on slope catch rates and length compositions for the statistical area from the Japan-U.S; cooperative longline survey.

Relative population weights extrapolated for the gully areas were combined with the RPWs computed for the upper continental slope to determine relative biomasses for each North Pacific Fishery Management Council (NPFMC) management area. Separate relative biomasses were determined for the NPFMC areas because of the management importance of estimating the relative biomass of sablefish by NPFMC area. The RPW for the Yakutat INPFC area was allocated to the West and East Yakutat areas based on the area at the depths examined. The RPW for the East Yakutat area was then combined with the RPW for the Southeastern area to produce an RPW for the East Yakutat-Southeastern NPFMC area.

STATISTICAL METHODS

The bootstrap method (Efron 1982; Efron and Tibshirani 1986) was applied to test the statistical significance of annual changes in RPNs. The bootstrap method was used to test the null hypothesis that the difference $RPN_{i',k} - RPN_{i,k} = 0$: where i = year (1979-86), i' is any later year, and k = statistical area (Shumagin, Chirikof, Kodiak, Yakutat, and Southeastern). An approximate confidence interval was computed for the difference using the bootstrap method, and then the statistical significance of the difference was evaluated based on the location of the confidence interval relative to zero. If the 95% confidence interval for the difference did not include zero, then the null hypothesis was rejected, and the annual change in the RPN was considered statistically significant. The computation of the RPN and the test of the statistical significance of annual changes of the RPN are described in more detail in Sigler and Fujioka (1988).

SURVEY AREA

Estimates of sablefish relative abundance in this report generally were confined to the upper continental slope, whereas previous estimates of sablefish relative abundance from the longline survey (Sasaki 1987; Sigler 1987) included the upper continental slope, the continental shelf, and gully areas. The inclusion of these unsurveyed areas, the continental shelf and gully areas, in previous computations of the RPN resulted in an apparent overestimate of the RPN at lOl-1,000 m in 1985 (Sigler 1987). Thus, computation of estimates of sablefish relative abundance in this report generally were limited to the upper continental slope.

Areal size measurements of the Gulf of Alaska by National Marine Fisheries Service (NMFS) scientists (Table 2) used in this report are different from areal size measurements used in previous reports (Sasaki 1987; Sigler 1987). Measurements in this report include a breakdown of area into upper continental slope and gullies which were previously unavailable. This increased detail allowed computation of separate indices of relative abundance for the upper continental slope and gullies. Previous areal size measurements were compared to those used in this report to determine if they are markedly different (Table 3). Areal depths at 201-400 m in the Chirikof, Kodiak, Yakutat, and Southeastern areas and for depths 401-600 m in the Southeastern area are markedly larger for the two previous reports because of gullies in these areas and depths (e.g., Shelikof Trough). In the remainder of the Gulf of Alaska, the areal size estimates generally are similar because they cover the same area, the upper continental slope. There are a few notable differences, for example, Shumagin area at depths 601-800 m, and one surprisingly large difference, Kodiak area at depths 401-600 m. Possible reasons for these differences are errors in determining location of contours, measuring areal sizes, and the use of different scale charts which would give different levels of detail of the bathymetry.

TRENDS IN ABUNDANCE

Relative population numbers for the upper continental slope of the Gulf of Alaska decreased significantly (9%: $p = 0.05$) from 1986 to 1987 (Tables 4-5, Fig. 3). Although the RPN dropped, sablefish abundance in 1987 still was nearly double the abundance in 1979. A preliminary analysis using the RPN weighted length frequencies for 1986 and 1987 indicated that low recruitment in 1987 may account for the drop from 1986 to (1987. The RPN declined in all areas of the Gulf of Alaska except the Chirikof area which remained about the same. The decreases in the Shumagin and Kodiak areas followed decreases from 1985 to 1987. The decreases from 1985 to 1987 in these two areas were statistically significant (Sigler 1987).

Annual changes in the RPW for the upper continental slope generally paralleled the annual change in the RPN (Fig. 4). However, from 1986 to 1987 the RPW for the Gulf of Alaska decreased only 5% (Table 6), whereas the RPN decreased 9%. This difference between RPN and RPW could indicate that weight increases due to growth of individual fish partially compensated for decreased numbers of fish in the population.

Table 3.--Comparison of areal sizes (km^2) used in this report to areal sizes (km^2) used in previous reports (Sasaki 1987; Sigler 1987).

INPFC area	Depth (m)	A	B
Shumagin	201-400	4,001	3,870
	401-600	2,269	2,250
	601-800	1,629	1,940
	801-1,000	1,248	1,680
Chirikof	201-400	2,350	16,440
	401-600	1,766	1,620
	601-800	1,955	2,150
	801-1,000	2,012	2,450
Kodiak	201-400	3,106	16,190
	401-600	2,255	3,270
	601-800	1,923	2,300
	801-1,000	2,296	2,300
Yakutat	201-400	2,988	9,740
	401-600	1,666	2,240
	601-800	1,470	1,420
	801-1,000	1,489	1,350
Southeastern	201-400	1,781	7,490
	401-600	822	1,340
	601-800	1,006	990
	801-1,000	1,165	1,260

A = Areal sizes used in this report; these include the upper continental slope of the Gulf of Alaska.

B = Areal sizes used in Sasaki (1987) and Sigler (1987); these include the upper continental slope and gully areas of the Gulf of Alaska. Sasaki (1987) used areal sizes expressed in tens of square kilometers to compute relative population number (RPN), whereas Sigler (1987) used areal sizes expressed in square kilometers to compute RPN, with the result that RPN estimates from the two reports will differ by an order of magnitude.

Table 4.--Relative population numbers (RPNs) of sablefish (Anoplopoma fimbria) for the upper continental slope of the Gulf of Alaska. Japan-U.S. cooperative longline survey, 1979-87.

Statistical	Depth (m)				
area/year	201-400	401-600	601-800	801-1,000	201-1,000
Gulf of Alaska					
1979	83,739	61,021	44,120	33,898	222,778
1980	93,030	41,770	40,653	27,703	203,156
1981	105,420	78,603	47,073	23,627	254,723
1982	146,639	94,262	75,949	47,701	364,551
1983	149,533	89,618	75,396	32,869	347,416
1984	147,415	97,540	77,463	46,252	368,670
1985	161,191	128,844	100,190	77,037	467,262
1986	162,668	135,238	108,808	63,984	470,698
1987	143,006	115,854	109,191	59,490	427,540
Shumagin					
1979	15,370	13,475	5,465	2,665	36,975
1980	20,325	7,457	4,200	2,552	34,534
1981	28,848	16,471	4,706	1,028	51,053
1982	54,929	20,072	7,254	2,714	84,969
1983	62,431	25,955	8,361	897	97,644
1984	59,957	25,134	8,205	663	93,959
1985	67,227	35,391	15,403	2,833	120,854
1986	57,633	34,540	14,572	1,822	108,567
1987	44,453	29,146	12,424	2,029	88,052
Chirikof					
1979	21,041	15,382	9,944	5,584	51,951
1980	19,469	8,220	6,983	4,175	38,847
1981	19,582	15,247	6,746	0	41,575
1982	30,563	20,993	19,000	8,952	79,508
1983	26,632	16,516	20,197	6,892	70,237
1984	28,496	25,764	21,699	6,669	82,628
1985	35,873	24,617	16,816	6,897	84,203
1986	37,322	24,979	19,489	15,262	97,052
1987	33,550	22,400	24,094	17,779	97,823

Table 4. --Continued.

Statistical area/year	Depth (m) 201-400	401-600	601-800	801-1,000	201-1,000
Kodiak					
1979	19,842	14,604	9,233	12,743	56,422
1980	19,790	10,440	9,582	3,773	43,585
1981	16,870	18,251	10,511	6,624	52,256
1982	20,440	22,542	19,422	12,665	75,069
1983	27,068	23,256	18,848	8,386	77,558
1984	26,599	22,546	20,522	14,630	84,297
1985	25,881	32,903	27,248	37,996	124,028
1986	27,066	33,002	26,881	12,902	99,851
1987	24,875	24,443	27,844	15,889	93,051
Yakutat					
1979	15,903	9,721	9,075	3,995	38,694
1980	18,487	7,892	9,625	7,821	43,825
1981	21,365	18,524	12,281	5,577	57,747
1982	25,751	20,425	17,794	10,426	74,396
1983	20,381	13,397	14,015	6,057	53,850
1984	19,343	14,884	14,014	9,658	57,899
1985	17,001	23,157	23,545	15,224	78,927
1986	22,300	28,540	29,622	19,131	99,593
1987	25,153	26,506	26,615	9,370	87,645
Southeastern					
1979	11,583	7,839	10,403	8,911	38,736
1980	14,959	7,761	10,263	9,382	42,365
1981	18,755	10,110	12,829	10,398	52,092
1982	14,956	10,230	12,479	12,944	50,609
1983	13,021	10,494	13,975	10,637	48,127
1984	13,020	9,212	13,023	14,632	49,887
1985	15,209	12,776	17,178	14,087	59,250
1986	18,347	14,177	18,244	14,867	65,635
1987	14,974	13,359	18,214	14,422	60,969

Table 5.--Statistical significance of annual changes in relative population numbers (RPN's) of sablefish for the upper continental slope of the Gulf of Alaska. Japan-U.S. cooperative longline survey, 1979-87.

	1980	1981	1982	1983	1984	1985	1986	1987
				Gulf of Alaska				
1979	o	+	+	+	+	+	+	+
1980		+	+	+	+	+	+	+
1981			+	+	+	+	+	+
1982				o	o	+	+	+
1983					o	+	+	+
1984						+	+	+
1985							o	o
1986								-
				Shumagin				
1979	o	o	+	+	+	+	+	+
1980		o	+	+	+	+	+	+
1981			+	+	+	+	+	+
1982				o	o	+	+	o
1983					o	o	o	o
1984						o	o	o
1985							o	-
1986								0
				Chirikof				
1979	o	o	+	+	+	+	+	+
1980		o	+	+	+	+	+	+
1981			+	+	+	+	+	+
1982				o	o	o	+	+
1983					o	o	+	+
1984						o	o	o
1985							o	o
1986								o

Table 5. --Continued.

	1980	1981	1982	1983	1984	1985	1986	1987
				Kodiak				
1979	-	o	+	+	+	+	+	+
1980		o	+	+	+	+	+	+
1981			+	+	+	+	+	+
1982				o	o	+	+	+
1983					o	+	+	o
1984						+	o	o
1985							o	-
1986								o
				Yakutat				
1979	o	+	+	+	+	+	+	+
1980		+	+	o	+	+	+	+
1981			+	o	o	+	+	+
1982				-	-	o	+	o
1983					o	+	+	+
1984						+	+	+
1985							+	o
1986								o
				Southeastern				
1979	o	+	+	o	+	+	+	+
1980		o	o	o	o	+	+	+
1981			o	o	o	o	+	o
1982				o	o	o	+	o
1983					o	o	+	o
1984						o	+	o
1985							o	o
1986								o

RPN values between years were considered significant if the 95% confidence intervals of the annual differences (from bootstrapping) did not include zero. The symbols used are defined as follows:
+ signifies a significant increase in RPN;
- signifies a significant decrease in RPN;
o signifies no significant change.

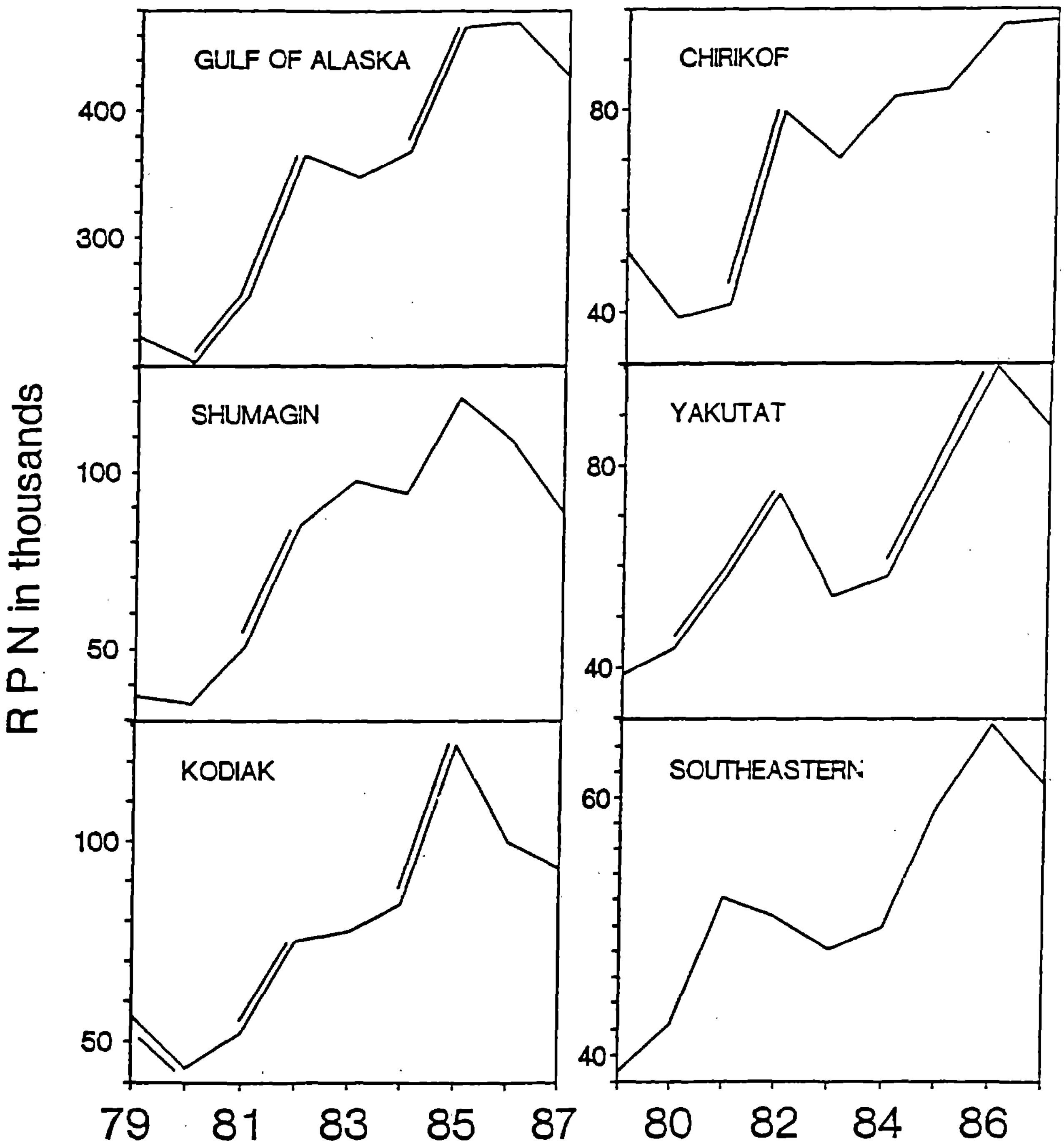

Figure 3.--Relative population number (RPN) of sablefish for the upper continental slope at depths 201-1,000 m in the Gulf of Alaska (Shumagin, Chirikof, Kodiak, Yakutat, and Southeastern areas) from the Japan-U.S. cooperative longline survey, 1979-87. Double lines (═══) indicate a statistically significant annual change.

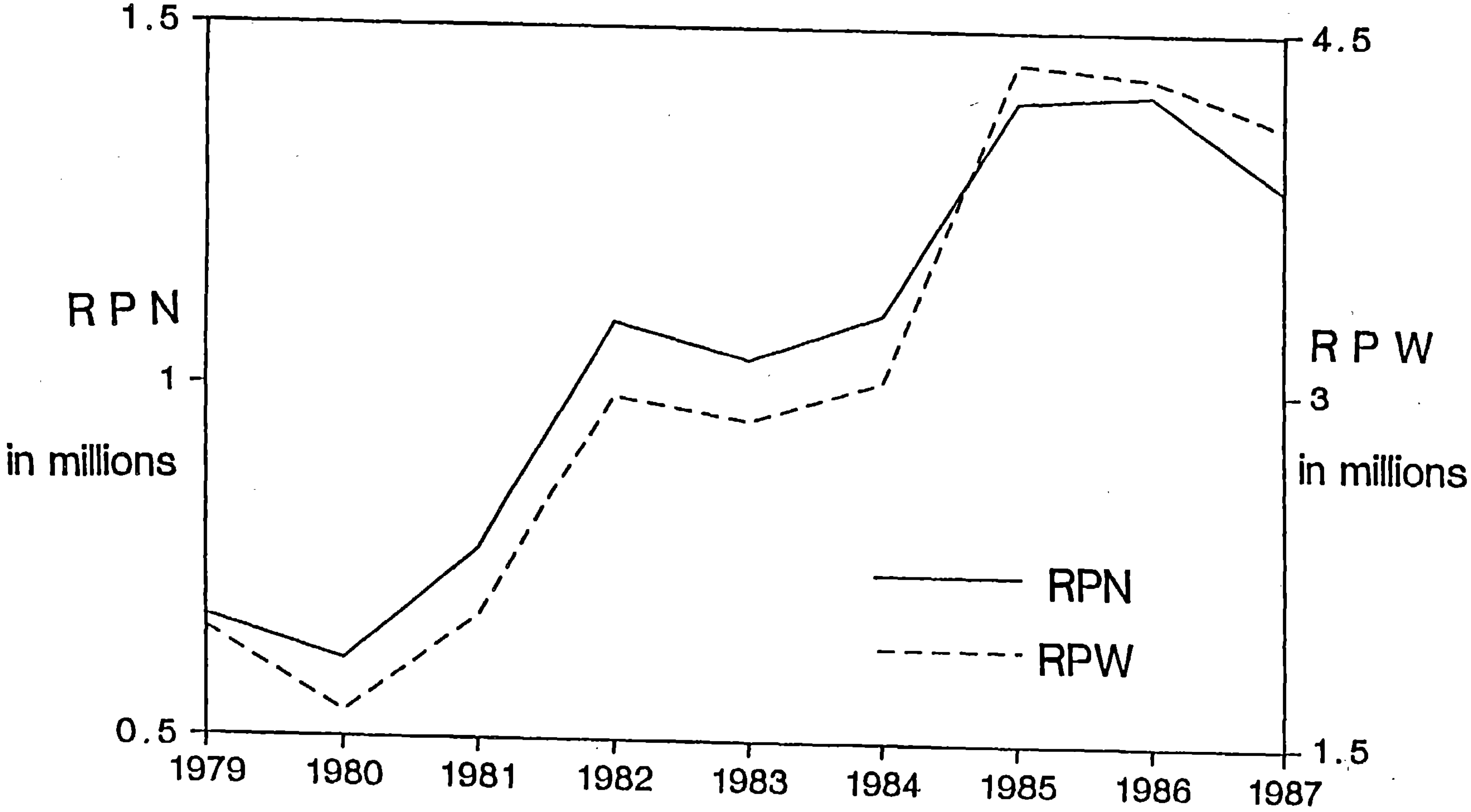

Figure 4.--Relative population number (RPN) and relative population weight (RPW) of sablefish for the upper continental slope at depths 201-1,000 m in the Gulf of Alaska from the Japan-U.S. cooperative longline survey, 1979437.

Table 6.--Relative population weights (RPWs) of sablefish (*Anoplopoma fimbria*) for the upper continental slope of the Gulf of Alaska. Japan-U.S. cooperative longline survey, 1979-87.

Statistical area/year	Depth (m) 201-400	401-600	601-800	801-1,000	201-1,000
Gulf of Alaska					
1979	225,978	187,544	129,232	108,377	651,131
1980	212,560	112,441	123,045	88,592	536,638
1981	260,210	198,832	132,837	79,324	671,203
1982	350,101	249,094	222,686	164,994	986,875
1983	398,414	236,393	209,945	108,166	952,918
1984	408,094	267,733	220,098	115,263	1,011,188
1985	474,298	382,282	320,502	278,624	1,455,706
1986	469,289	414,391	348,120	204,945	1,436,745
1987	438,352	368,108	365,366	197,856	1,369,682
Shumagin					
1979	34,351	41,321	17,131	8,095	100,898
1980	49,341	23,055	14,562	8,588	95,546
1981	63,372	44,794	16,333	3,547	128,046
1982	128,552	57,519	25,107	10,163	221,341
1983	166,623	74,781	27,104	3,014	271,522
1984	166,866	75,782	26,664	2,218	271,530
1985	194,746	106,711	50,371	8,021	359,849
1986	162,000	108,550	48,213	3,656	322,419
1987	138,789	92,337	42,355	5,583	279,064
Chirikof					
1979	52,600	48,072	29,776	18,883	149,331
1980	49,474	24,049	22,696	13,863	110,082
1981	43,892	35,019	17,581	0	96,492
1982	75,102	53,223	56,279	28,608	213,212
1983	66,910	42,031	58,115	21,143	188,199
1984	76,007	68,205	60,642	0	204,854
1985	106,720	72,450	47,431	19,673	246,274
1986	118,828	79,505	58,365	38,267	294,965
1987	106,295	76,114	84,437	53,688	320,534

Table 6. --Continued.

Statistical area/year	Depth (m) 201-400	401-600	601-800	801-1,000	201-1,000
Kodiak					
1979	57,675	44,089	27,587	40,135	169,486
1980	45,903	25,860	30,995	13,122	115,880
1981	38,634	45,345	32,116	24,551	140,646
1982	50,541	52,825	55,724	45,490	204,580
1983	70,186	50,949	47,369	26,260	194,764
1984	69,959	54,013	53,878	35,002	212,852
1985	80,088	91,220	90,665	146,751	408,724
1986	76,385	95,446	87,691	43,937	303,459
1987	72,520	71,536	90,712	55,936	290,704
Yakutat					
1979	52,218	30,634	25,950	12,809	121,611
1980	39,069	19,447	26,040	25,846	110,402
1981	58,905	44,432	30,036	17,140	150,513
1982	57,522	54,139	48,155	36,073	195,889
1983	55,812	36,539	37,037	20,779	150,167
1984	55,947	41,579	40,836	33,009	171,371
1985	47,762	72,534	78,990	54,295	253,581
1986	57,860	85,577	95,031	67,919	306,387
1987	76,582	84,307	88,059	33,224	282,172
Southeastern					
1979	29,134	23,428	28,788	28,455	109,805
1980	28,773	20,030	28,752	27,173	104,728
1981	55,407	29,242	36,771	34,086	155,506
1982	38,384	31,388	37,421	44,660	151,853
1983	38,883	32,093	40,320	36,970	148,266
1984	39,315	28,154	38,078	45,034	150,581
1985	44,982	39,367	53,045	49,884	187,278
1986	54,216	45,313	58,820	51,166	209,515
1987	44,166	43,814	59,803	49,425	197,208

BIOMASS DISTRIBUTION

In 1987, the RPWs for the upper continental slope for the Shumagin, Chirikof, Kodiak, and Yakutat areas were approximately the same, with a smaller RPW for the Southeastern area (Table 6). This pattern issimilar to that seen in 1986, although the area with the largest RPW changed from the Shumagin area in 1986 to the Chirikof area in 1987.

In 1986, the NPFMC used the survey's RPW values to allocate sablefish catch quotas to NPFMC management areas in the Gulf of Alaska. The RPW values used were for depths 401-1,000 m for the upper continental slope and gully areas, where most of the commercially exploitable biomass of sablefish is found. The 1987 RPW values for depths 401-1,000 m for the upper continental slope and gullies were very similar to the 1986 values (Table 7a). The RPW for the Central NPFMC area was again largest and was greater than the combined total of the second (East Yakutat-Southeastern) and third (West Yakutat) largest RPWs. Notable differences between 1986 and 1987 were the decrease in the relative size of the RPW for the West Yakutat area and the increase in the relative size of the RPW for the East Yakutat-Southeastern area.

Relative population weights were also computed for depths 201-400 m for the upper continental slope and gully areas because of the management importance of knowing the relative biomass of sablefish by NPFMC area at these depths. The relative size of the RPWs by NPFMC area changed when depths from 201 to 400 m were included in the computations (Table 7b,c). In particular, relative sizes of RPWs for the Western and Central areas were much larger for 201-1,000 m than for 401-1,000 m. The relative size of the RPW for the Western area was markedly larger because the upper continental slope in this area is relatively large at depths 201-400 m. The relative size of the RPW for the Central area was also much larger when the area for the upper continental slope and gully areas from 201 to 400 m were included in the computation since these depths include the large Shelikof Trough area and other gullies east of Kodiak Island.

LENGTH COMPOSITIONS

Sablefish length compositions by sex for the upper continental slope were similar for all INPFC areas and depths in 1987 (Figs. 5-8). This is in contrast to 1986, when the Southeastern area had relatively more large fish than other areas of the Gulf of Alaska (Sigler 1987). Modes were present from 46 to 55 cm FL for males and from 46 to 58 cm FL for females in the Yakutat area at 201-400 m and from 49 to 59 cm FL for females in the Southeastern area at 201-400 m (Fig. 6). The modes in the Yakutat area at 201-400 m in 1987 were similar to the modes seen there in 1986.

Table 7a. --Relative population weights (RPWs) of sablefish (*Anoplopoma fimbria*) for the upper continental slope and gully areas for depths 401-1,000 m by North Pacific Fishery Management Council management area, expressed as a percentage of the RPW for the Gulf of Alaska at the same depth and topography. Japan-U.S. cooperative longline survey, 1986-87.

Management area	Year 1986	1987
Western	15.0	14.5
Central	44.0	44.8
W. Yakutat	20.0	17.5
E. Yakutat/ Southeastern	21.0	23.2

Table 7b. --Relative population weights (RPWs) of sablefish (*Anoplopoma fimbria*) by North Pacific Fishery Management Council management area, depth, and topography, expressed as a percentage of the RPW for the Gulf of Alaska by the same depth and topography. Japan-U.S. cooperative longline survey, 1987.

Management area	A	B	C
Western	14.5	19.9	12.6
Central	44.8	43.6	52.5
W. Yakutat	17.5	15.3	13.4
E. Yakutat/ Southeastern	23.2	21.2	21.5

A = upper continental slope 401-1,000 m and gully areas 401-1,000 m.
B = upper continental slope 201-1,000 m and gully areas 401-1,000 m.
C = upper continental slope 201-1,000 m and gully areas 201-1,000 m.

Table 7c.--Relative population weights (RPWs) of sablefish (*Anoplopoma fimbria*) by North Pacific Fishery Management Council management area, depth, and topography. Japan-U.S. cooperative longline survey, 1987.

Management area	A	B	C
Western	140,275	279,064	279,064
Central	432,423	611,238	1,163,515
W. Yakutat	168,631	214,677	295,975
E. Yakutat/ Southeastern	223,407	298,109	477,089
Gulf of Alaska	964,736	1,403,088	2,215,642

A = upper continental slope 401-1,000 m and gully areas 401-1,000 m.
B = upper continental slope 201-1,000 m and gully areas 401-1,000 m.
C = upper continental slope 201-1,000 m and gully areas 201-1,000 m.

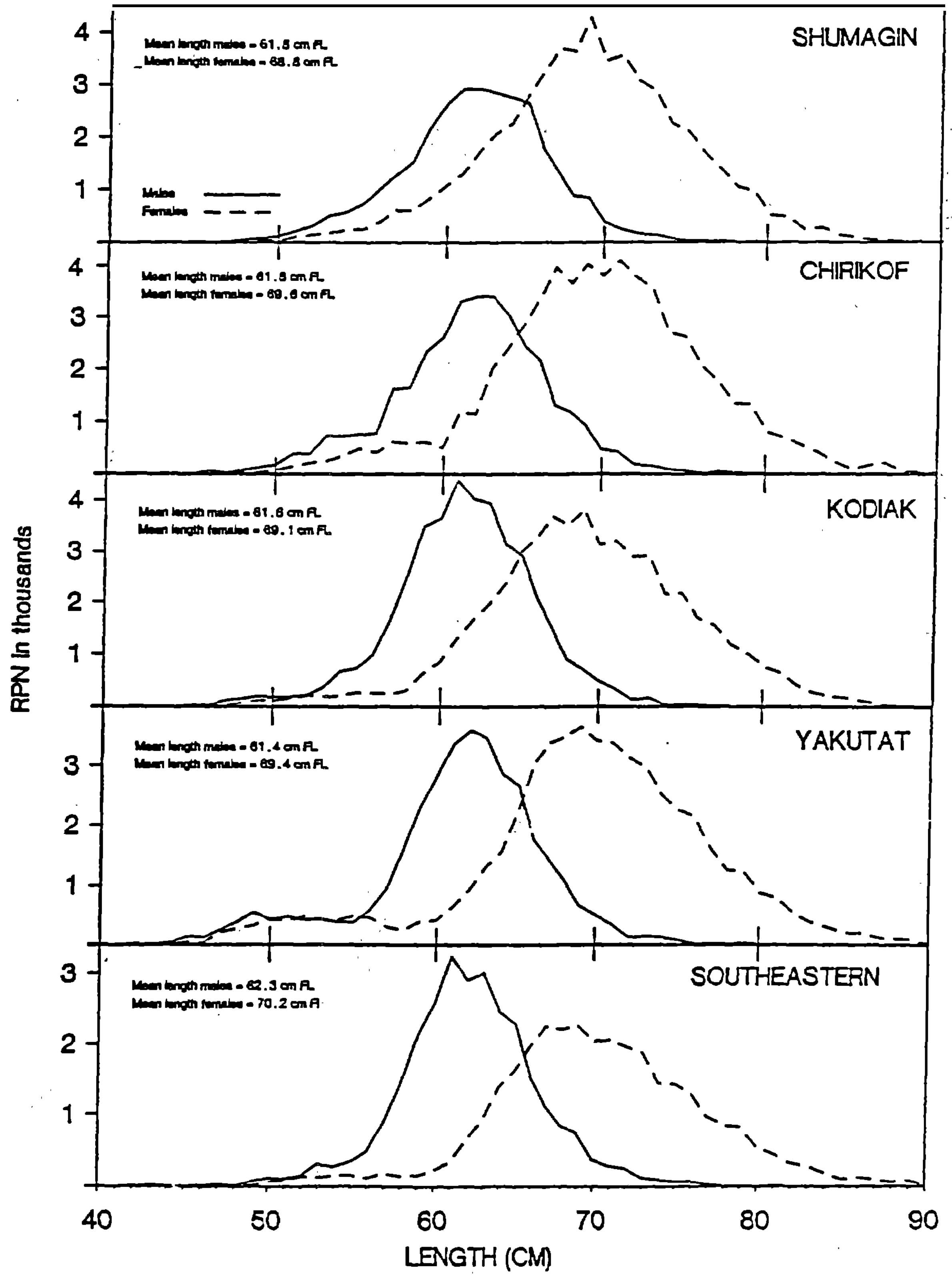

Figure 5.--Relative population number (RPN) weighted length frequencies of sablefish of the upper continental slope at depths 201-1,000 m shown for the Shumagin, Chirikof, Kodiak, Yakutat, and Southeastern International North Pacific Fisheries Commission areas. Japan-U.S. cooperative longline survey, 1987.

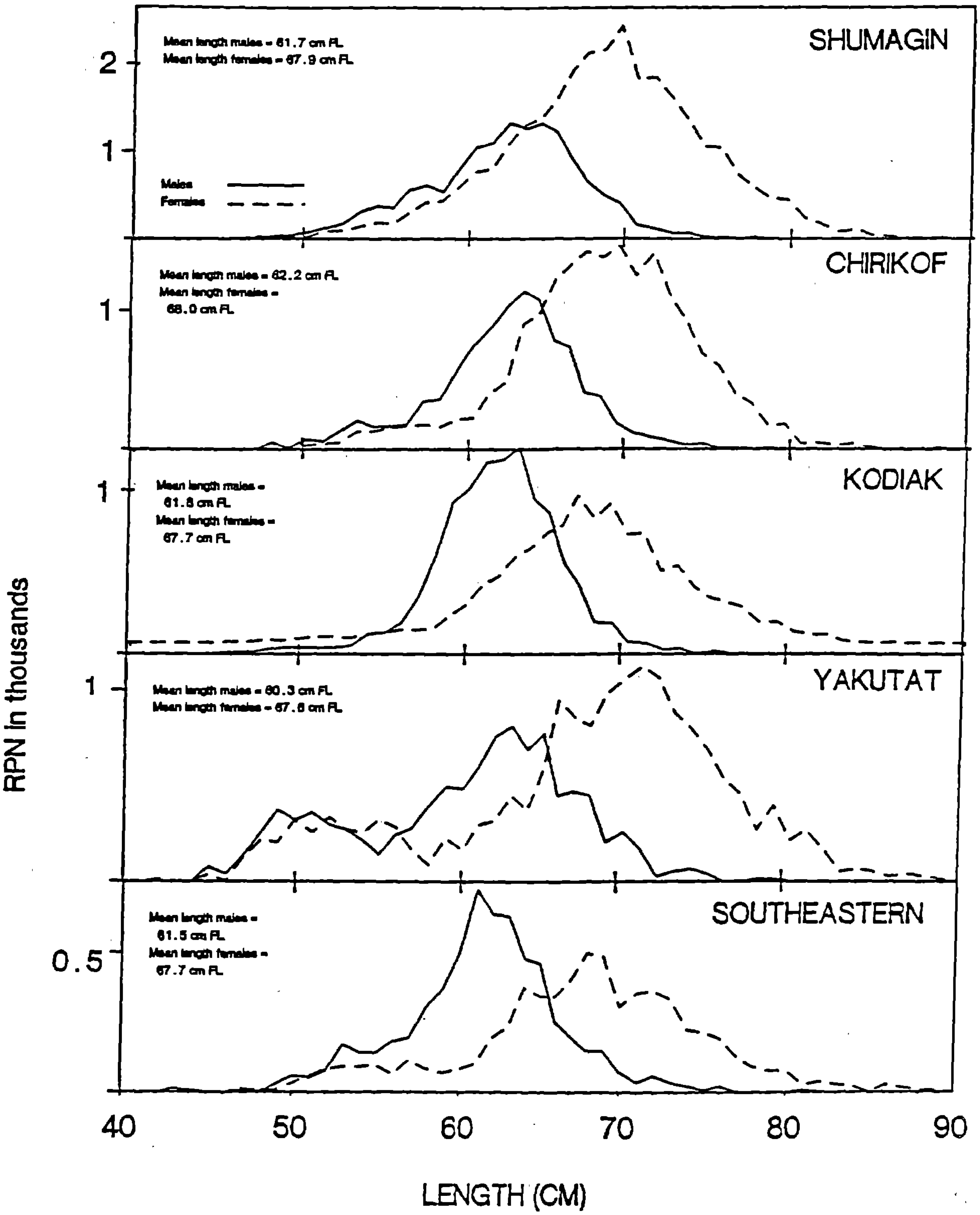

Figure 6. --Relative population number (RPN) weighted length frequencies of sablefish of the upper continental slope at depths 201-400 m shown for the Shumagin, Chirikof, Kodiak, Yakutat, and Southeastern International North Pacific Fisheries Commission areas. Japan-U.S. cooperative longline survey, 1987.

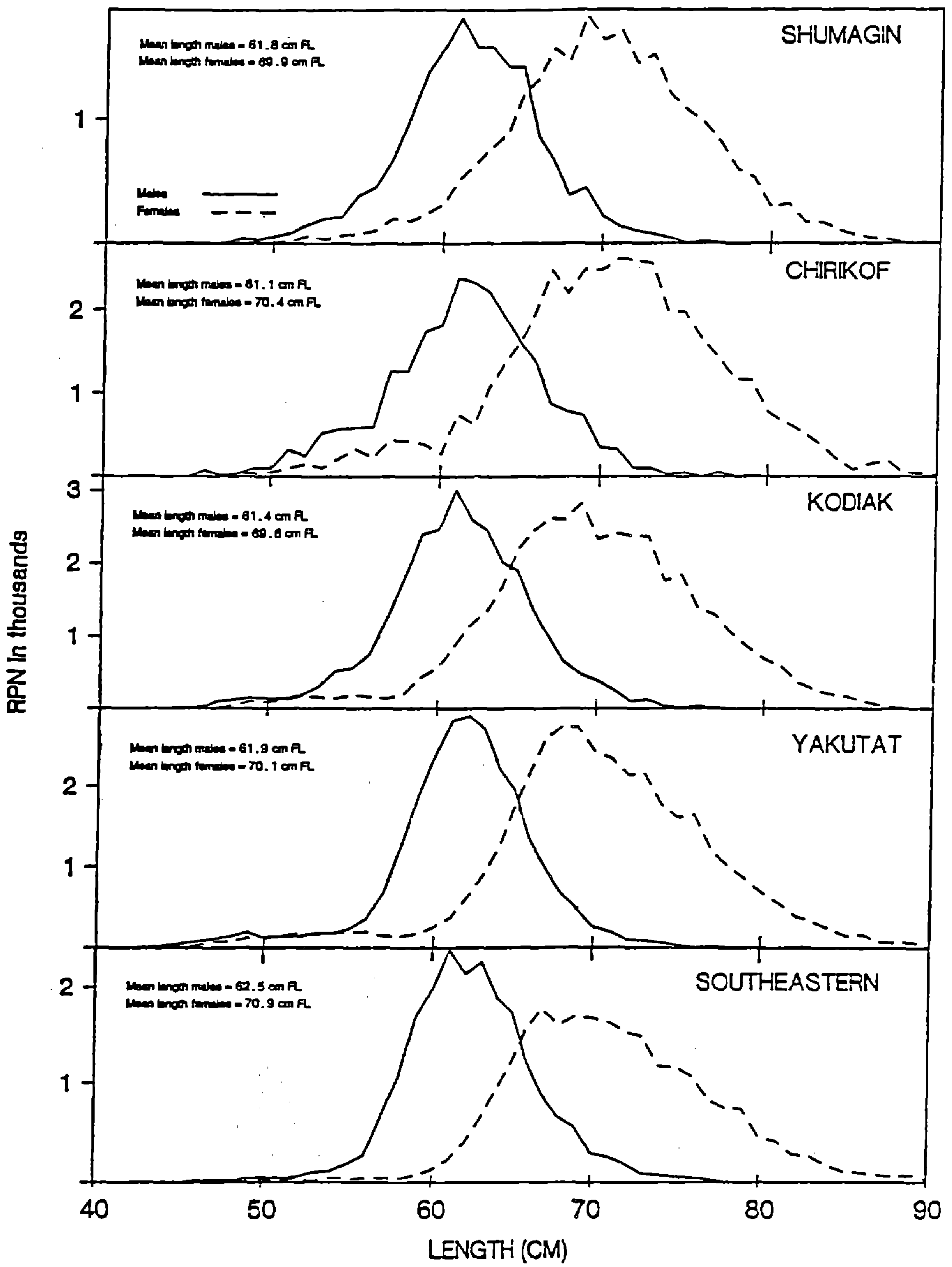

Figure 7.--Relative population number (RPN) weighted length frequencies of sablefish of the upper continental slope at depths 401-1,000 m shown for the Shumagin, Chirikof, Kodiak, Yakutat, and Southeastern International North Pacific Fisheries Commission areas. Japan-U.S. cooperative longline survey, 1987.

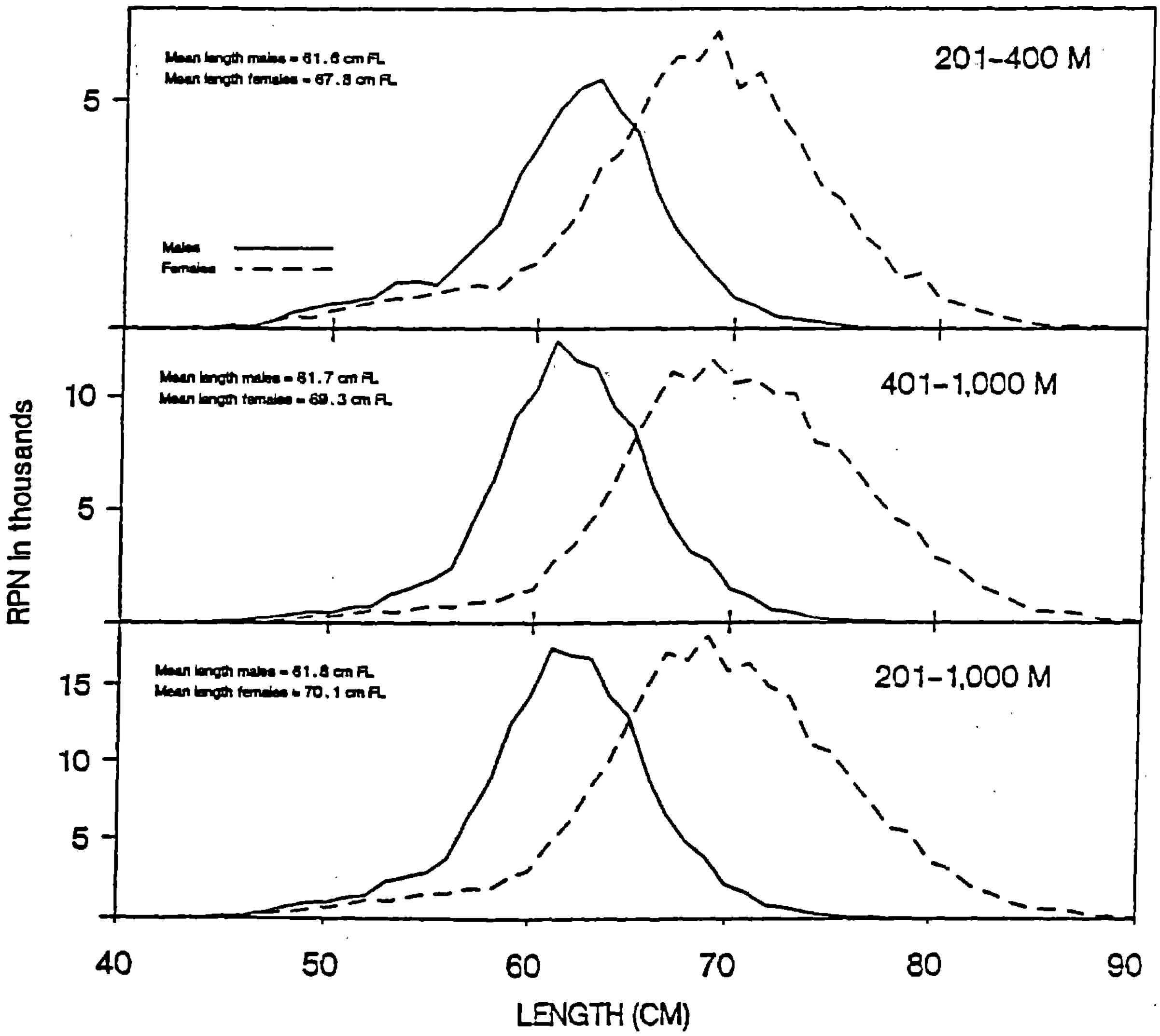

Figure 8. --Relative population number (RPN) weighted length frequencies of sablefish of the upper continental slope at depths 201-1,000, 201-400, and 401-1,000 m of the Gulf of Alaska. Japan-U.S. cooperative longline survey, 1987.

YEAR CLASS STRENGTH

Sablefish recruiting to the survey area first appear at depths 101-200 m, and strong year classes are distinguishable in the length compositions- at these depths. The length compositions from 1979 to 1986 have been used previously to document the strong 1977 and 1980 year classes (Sigler and Fujioka 1988). Modes at depths 101-200 m at 45-47 cm FL in the Chirikof and Kodiak areas in 1986 and at 55 cm FL in the Shumagin, Chirikof, Yakutat, and Southeastern areas in 1987 (Fig. 9) may be due to a strong 1984 year class. Modes at 51-54 cm FL in the Shumagin, Yakutat, and Southeastern areas for depths 101-200 m also were observed in the domestic longline survey (Sigler and Zenger in prep.). The reason for the difference in modal lengths between the cooperative longline survey and the domestic longline survey is unknown. The modal length at 55 cm FL from the cooperative longline survey in 1987, however, is larger than any reported for sablefish 3+ years of age (McFarlane and Beamish 1983; Sasaki 1985; Kastelle[2]). The prospect of an above average 1984 year class has been previously noted for both the Gulf of Alaska (Sigler 1987) and the eastern Bering Sea (McDevitt 1987). This year class is expected to primarily recruit to the fishery in 1989.

Recruitment of the strong 1977 and 1980 year classes probably was responsible for large RPN increases from 1981 to 1982 and 1984 to 1985, respectively (Sigler and Fujioka 1988). In the years preceding each of these increases, 1980 to 1981 and 1983 to 1984, the RPN also increased (Fig. 3). These increases were probably due to partial recruitment of the 1977 and 1980 year classes, respectively. If this pattern of recruitment repeats itself, then the strong 1984. year class will partially recruit in 1988 and primarily recruit in 1989. Instead of declining as it did from 1986 to 1987, sablefish abundance may decrease only slightly or remain about the same from 1987 to 1988 and increase from 1988 to 1989 as a result of this recruitment.

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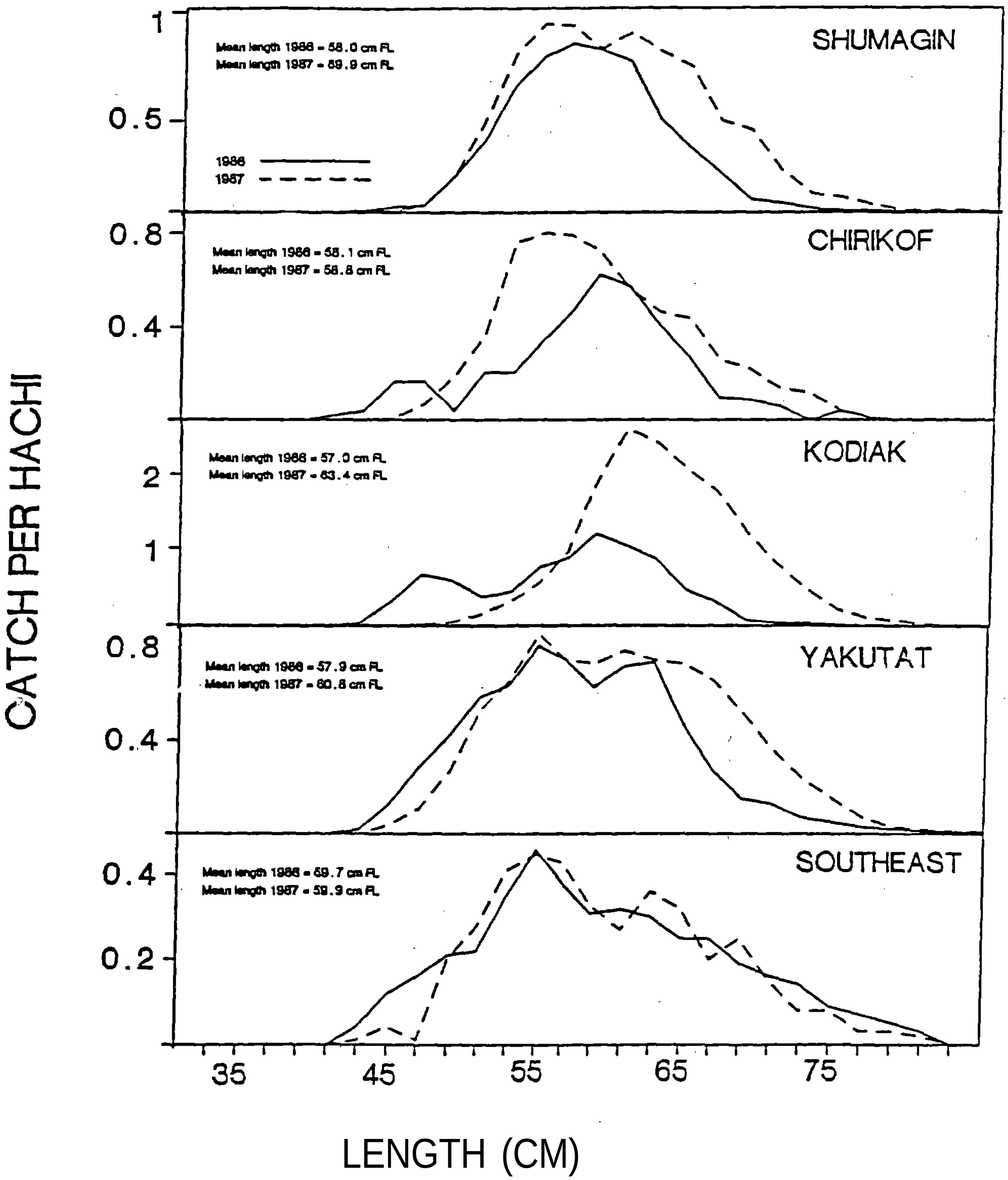

Figure 9.--Catch per hachi weighted length frequencies of sablefish of the upper continental slope at depths 101-200 m shown for the Shumagin, Chirikof, Kodiak, Yakutat, and Southeastern International North Pacific Fisheries Commission areas. Japan-U.S. cooperative longline survey, 1986-87.

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U.S. RESEARCH SURVEYS CONDUCTED IN 1988
AND PLANNED FOR 1989 IN THE NORTHEAST PACIFIC OCEAN

by

Lael L. Ronholt

U.S. RESEARCH-GULF OF ALASKA IN 1988

Resource Assessment

Walleye pollock

Juveniles--During August-September 1988, Northwest and Alaska Fisheries Center (NWAFC) scientists from the Resource Assessment and- Conservation Engineering Division (RACE) completed a hydroacoustic/trawl resource assessment survey of the juvenile walleye pollock (*Theragra chalcogramma*) in the western Gulf of Alaska aboard the chartered vessel *Alaska*. Approximately 2,500 miles of trackline were surveyed from Unimak Pass to Kodiak Island. Target verification sampling was conducted with a 61 foot high opening shrimp trawl equipped with a small mesh liner.

Hydroacoustic--From 6 to 9 March 1988, RACE Division scientists conducted an echo integration/midwater trawl survey of spawning walleye pollock in Shelikof Strait. Two replicate surveys were made using the NOAA ship Miller Freeman. Biological data collected included size, sex, weight, and age and maturity composition. Temperature and salinity profiles were obtained at selected locations using expendable bathythermograph probes (XBT) or conductivity, temperature, and depth (CTD) profilers.

Sablefish

Longline survey--Scientists from the NWAFC RACE Division and Auke Bay Laboratory (ABL) completed the second annual longline survey of the upper continental slope of the Gulf of Alaska aboard the chartered research vessel *Prowler*. During July-September 1988, the 47 traditional longline stations from the Islands of Four Mountains to Dixon Entrance were sampled along with 12 new stations located in gullies throughout the Gulf of Alaska.

Juveniles--During March-April 1988, the NOAA ship Murre II was used to conduct a juvenile sablefish survey on the inside waters of Southeastern Alaska. During October-November 1988, ABL scientists will conduct another survey for juvenile sablefish throughout the inshore waters of Southeastern Alaska aboard the NOAA ship *John N. Cobb*.

Survey Support Studies

Sablefish

During March and May-August 1988, ABL scientists conducted several experiments aboard the NOAA ship John N. Cobb. They assessed the relative effects of different baits. (herring and squid) and also gangion length on the catch rates of the sablefish longline gear to compare catch rates of two-different sizes of circle hooks. Also, sablefish were tagged for age validation using oxytetracycline injections and sonic tags used to determine the movements of sablefish in Southeastern Alaska.

Rockfish

From May to August 1988, scientists from ABL used the NOAA ship John N. Cobb to conduct a hydroacoustic study of the Pacific ocean perch populations off Southeastern Alaska and sampled selected rockfish species for life- history data. A manned submersible was also used in conjunction with the NOAA ship John N. Cobb to study the behavior of Pacific ocean- perch.

Egg and Larvae Studies

During April-June 1988, ichthyoplankton surveys focusing on the early life history of walleye pollock were conducted aboard the NOAA ship Miller Freeman. Specific objectives were to 1) estimate the magnitude of the spawning stock in Shelikof Strait, 2) relate the distribution of eggs and larvae to oceanographic conditions, and 3) trace the drift and assess the feeding condition of larvae. This research was part of the Fisheries-Oceanography Coordinated Investigations (FOCI), a NOAA research program through NWAFC and the Pacific Marine Environmental Laboratory (PMEL), to investigate causes of recruitment variation in economically important fish and shellfish populations.

Oceanography

ABL scientists conducted an oceanographic, study of the Sitka Eddy area off Southeastern Alaska during May-August 1988 aboard the NOAA ship John N. Cobb.

COOPERATIVE RESEARCH-GULF OF ALASKA 1988

Longline Survey

During May-September 1988, a U.S. -Japan cooperative longline survey for sablefish (*Anoplopoma fimbria*) and associated species was conducted throughout the Aleutian Islands, Bering Sea, and the Gulf of Alaska aboard the chartered Japanese research vessel Tomi Maru No. 88. Scientific operations were planned by scientists at the Far Seas Fisheries Research Laboratory, Shimizu, Japan and implemented by scientists from the Japan Marine Fisheries Resource Research Center (JMARC) and the NWAFC RACE Division and ABL.

Eggs and Larvae

A cooperative U.S.-U.S.S.R. ichthyoplankton survey was conducted in the central Gulf of Alaska aboard the Soviet research vessel Darwin from March to May 1988: The survey was coordinated with the NWAFC and PMEL FOCI research program.

U.S. RESEARCH-WEST COAST

The NWAFC in cooperation with the Southwest Fisheries Center (SWFC) completed sampling to study the distribution, abundance, and spawning of sablefish and Dover sole (*Microstomus pacificus*) off the Washington-California coasts during November-December of 1988 aboard the NOAA ship Miller Freeman. Bottom trawl and ichthyoplankton samples were collected to determine the pattern of spawning as a function of time, area, depth, size, and age. These data will be used to establish the feasibility of estimating spawning stock abundance with egg production methods. Other objectives were to obtain an area-swept abundance estimate and data on size and age at first maturity, determine fecundity and proportion of active oocytes as a function of size and age at first maturity, determine fecundity and proportion of active oocytes as a function of size and age, tag juvenile sablefish in a continuing study of movements, and describe the upper slope species complex and changes in components and behavior related to depth and season. Standard measurements of physical oceanographic parameters will also be collected.

A sablefish abundance indexing survey was conducted off California and southern Oregon during October-November 1988. The survey is part of a series of surveys alternating annually between the northern and southern portions of the west coast aimed at monitoring long-term changes in relative abundance. Rectangular traps were set at depths of 150-700 fathoms at nine index sites and were fished in a standardized manner to obtain comparable measures of catch per unit effort (CPUE). Biological data were collected and sablefish were double tagged to determine the rate of tag loss and to study fish movements by size and age.

PLANNED U.S. RESEARCH-GULF OF ALASKA 1989

Resource Assessment

Walleye pollock

During March 1989, an echo integration-midwater trawl survey of the spawning pollock concentration in Shelikof Strait is scheduled aboard the NOAA ship Miller Freeman.

Sablefish

Longline survey--From July to September 1989, the NWAFC RACE Division and ABL are anticipating conducting the third annual longline survey for sablefish and associated species of the Gulf of Alaska. The survey, which will require chartered longline vessels, may be extended into the Bering Sea and the Aleutian Islands.

Juveniles--ABL scientists will use the NOAA ship John N. Cobb to conduct a survey to determine the distribution and abundance of juvenile sablefish and to study sablefish. reproduction.

Survey Support Studies

Sablefish

Scientists from ABL will continue to study short-term movements of sablefish in Icy Strait using sonic tags to verify the effectiveness of oxytetracycline injections for validating sablefish ageing techniques. Also, a hooking mortality study will be implemented.

Rockfish

ABL scientists plan to continue their hydroacoustic studies of Pacific ocean perch (Sebastes alutus) off Southeastern Alaska utilizing the NOAA ship John N. Cobb.

Oceanography

A continuation of the oceanographic survey of Sitka Eddy is planned by ABL scientists also using the NOAA ship John N. Cobb.

Fisheries-Oceanographic Coordinated Investigations

FOCI will again conduct support investigations designed to elucidate the recruitment mechanisms of commercially important fish and shellfish. Field research will continue and several cruises are planned during April-June using the NOAA ship Miller

Freeman to trace the development, distribution, drift, and feeding condition of eggs and larvae of walleye pollock.

PLANNED U.S. COOPERATIVE RESEARCH-GULF OF ALASKA 1989

During March-May 1989, cooperative U.S.-U.S.S.R. ichthyoplankton surveys are planned for the central Gulf of Alaska utilizing Soviet research vessels. These surveys will be coordinated with the Alaska Fisheries Science Center and PMEL FOCI program.

PLANNED RESEARCH-WEST COAST 1989

Resource Assessment

The fifth in a series of triennial bottom trawl-hydroacoustic surveys of important groundfish species off the coast of Washington, Oregon, and California will be conducted during July-September 1989. The target species will be Pacific whiting (*Merluccius productus*) but catch and biological data will also be collected from a wide range of groundfish species. The data will become a part of a comprehensive time series database started in 1977 to monitor long-term trends in west coast groundfish populations.

A sablefish abundance indexing survey will be conducted off the Washington and northern Oregon coasts during September-October 1989. Traps will be set at 5-6 depths between 150-700 fathoms at 8 index sites. Traps on longlines will be fished in a standardized method to obtain comparable measures of CPUE. Sex, age, and length frequency data will be collected and the ongoing sablefish tagging- program to study population movements will be continued: the program will include double tagging for estimating tag loss.

Hydroacoustic

During July-August 1989, an echo integration-midwater trawl survey of the Pacific whiting off the west coast is scheduled aboard the NOAA ship *Miller Freeman.*

Sablefish

During February-March 1989, the NWAFC and SWFC plan a second cooperative survey to investigate the reproductive biology and the egg and larval distributions of Dover sole and sablefish in the Washington-California coastal waters. Survey plans include, the use of the NOAA ship *David Starr Jordan.*