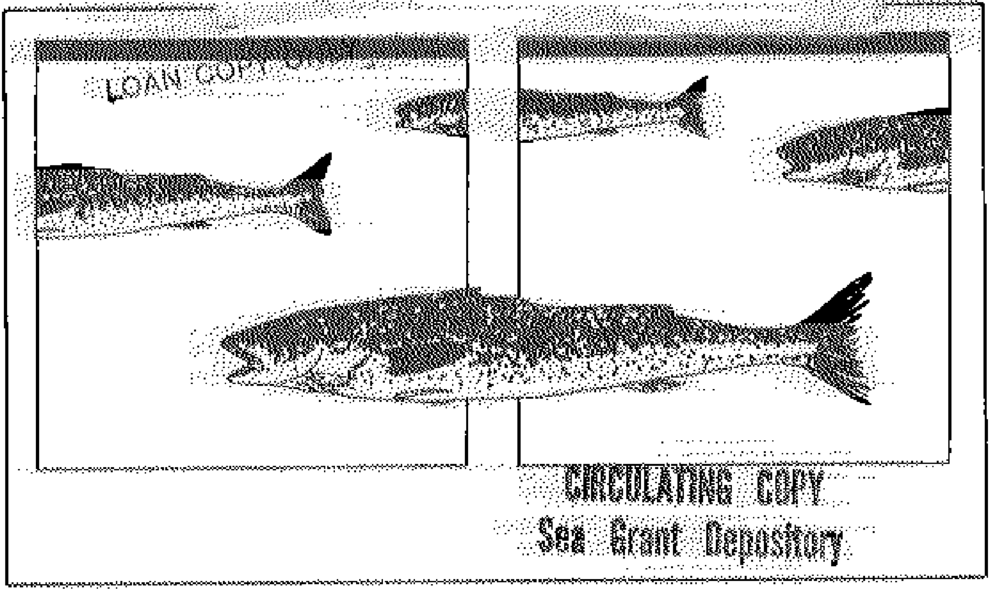

Proceedings of the International Sablefish Symposium

March 29-31, 1983
Anchorage, Alaska

University of Alaska
August 1983

Alaska Sea Grant Report 83-8

Alaska Sea Grant College Program
University of Alaska
Fairbanks, Alaska 99701

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Brenda R. Melteff
Symposium Coordinator

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Acknowledgments

The program for this international symposium was structured by a program planning committee whose members are:

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Introduction

The International Sablefish Symposium is the second in the Univesity of Alaska's Lowell Wakefield Fisheries Symposia Series. The first in the series was the International Symposium on the Genus *Chionoecetes* held in May 1982.

The sablefish (*Anoplopoma fimbria*) is becoming commercially more important although relatively little is known about its biology. In order to properly manage the species, available knowledge needs to be gathered and areas for future research need to be identified. This symposium provided the forum for reporting available information in the five technical sessions. In addition, two workshops were held; one on Stock Assessments of the Future and the other on the Need for Future Tagging Studies.

This proceedings includes the technical papers presented. An appendix containing the summaries of the two workshops will be published as soon as preparation of the material is completed.

Session I

Overview of the Commercial Fishery and Management Regime

Management strategies for the sablefish fishery off the coast of Alaska

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Sablefish off the coast of Alaska in the U.S. Fishery Conservation Zone (3-200 miles) are managed under two groundfish fishery management plans (FMP) developed by the North Pacific Fishery Management Council (Council), and approved and implemented by the Secretary of Commerce under the provisions of the Magnuson Fishery Conservation and Management Act of 1976 (16 U.S.C. 1801 et seq.).

Both FMPs are designed to achieve the following broad goals in order to meet the requirements of the Magnuson Act:

1. Promote conservation while providing for the optimum yield from the Region's groundfish resource in terms of: providing the greatest overall benefit to the nation with particular reference to food production and recreational opportunities; avoiding irreversible or long-term adverse effects on fishery resources and the marine environment; and insuring availability of a multiplicity of options with respect to the future uses of these resources.

2. Promote, where possible, efficient use of the fishery resources but not solely for economic pruposes.

3. Promote fair and equitable allocation of identified available resources in a manner such that no particular group acquires an excessive share of the privileges.

4. Base the plan on the best scientific information available.

In this context, the term "optimum yield" is generally considered to be a quota, which is prescribed as such on the basis of the maximum sustainable yield for the fishery, modified by any relevant economic, social, or ecological factors. Although "maximum sustainable yield" is not defined in the Magnuson Act, it is defined in the FMPs as an average, over a reasonable length of time, of the largest catch which can be taken continuously from a stock under current environmental conditions.

In the management regime of each groundfish FMP, there are four objectives which the groundfish management strategies are to fulfill. In order of priority, they are:

1. Provide for rational and optimal use, in a biological and socioeconomic sense, of the region's fishery resources as a whole;

2. Minimize the impact of groundfish fisheries on prohibited species and continue the rebuilding of the Pacific halibut resource;

3. Provide for the opportunity and orderly development of domestic groundfish fisheries, consistent with (1) and (2) above; and

4. Provide for foreign participation in the groundfish fishery; consistent with the three objectives above, to take the portion of the . . .[quota]. . . not utilized by domestic fishermen.

Additionally, the Council has specified that in the Gulf of Alaska, the objective of the sablefish management regime is to promote the development of the domestic sablefish fishery Gulf-wide. Sablefish is the only groundfish for which there is a specific management objective.

Various management strategies to fulfill the above objectives are in effect for the sablefish resource off Alaska. These include time/area closures, gear restrictions, and quotas.

Although these same strategies are in effect for all groundfish managed under the FMPs and their effect in another groundfish fishery may carry over to the sablefish fishery, I will only discuss them in terms of their direct effect on the sablefish fishery and resource.

<u>Quotas</u>

The most important strategy in terms of its effect on the fishery and resource is the establishment of quotas, or OY. Due to the depressed condition of the sablefish resource in the Bering Sea/Aleutian Islands area and in the Gulf of Alaska, OY has been set below the current equilibrium yields (EY) to promote stock rebuilding. Current EYs and OYs are shown in Table 1. This strategy is designed to fulfill the broad goal of promoting conservation, and the objective of promoting domestic fishery development.

Sablefish OYs are distributed to specific areas of the Bering Sea-North Pacific areas. Figure 1 shows the areas in the Gulf of Alaska and the Bering Sea/Aleutian Islands area. The distribution is based on past resource assessment surveys (example, Low, 1977), the impression that sablefish are not particularly migratory (Wespestad, et al., 1978), and that OYs for different areas would prevent overfishing on localized stocks by distributing fishing effort.

In the Bering Sea/Aleutian Islands area, the Western and Central Gulf of Alaska, and in the West Yakutat area, the sablefish OY is apportioned between the domestic and foreign fishery. The domestic fishery has priority to the resource. The domestic apportionment is divided into fish caught by U.S. fishermen and processed by U.S. processors (DAP) and fish caught by U.S. fishermen and processed by foreign processors (JVP). DAP has priority over JVP. In additon, 20% of the OY in the Gulf of Alaska and 10% of the OY in the Bering Sea/Aleutian Islands is withheld as a reserve for unexpected domestic fishery expansion. Table 2 shows current estimates of DAP, JVP, Reserves, and the allowable level of foreign fishing, TALFF. There is no foreign fishing for sablefish in the East Yakutat and Southeast areas.

Gear Restrictions

There are gear restrictions in the sablefish fishery for both foreign and U.S. fishermen. Foreign fishermen may use only longline gear for directed sablefish fishing in all waters off Alaska. Sablefish may be taken incidentally to other directed fishing by foreign trawlers.

The Council has amended the domestic management regime to prohibit the use of sablefish pots east of 140°W longitude to Cape Addington. As of this writing, this regulation has not been approved by the Secretary of Commerce and is not yet in effect.

Time/Area Closures

There are no established time/area closures for the domestic sablefish fishery. The Council has written emergency closure authority for conservation reasons into the FMPs. This authority was used to close the domestic sablefish fishery in the Southeast area in 1982 when the quota had been caught before the end of the fishing year (January 1 to December 31), and in 1983 to close the East Yakutat and Southeast areas.

There are a number of time/area closures in the waters off Alaska applicable to the foreign fisheries. Most of these apply to the foreign trawl fisheries. All of them are designed to either control the foreign incidental catch of prohibited species (Pacific halibut, Tanner crab, king crab, salmonids) or to separate the U.S. and foreign fleets during the U.S. halibut or crab fisheries.

Only the prohibition on foreign fishing East of 140°W longitude is, in part, specifically to prevent foreign sablefish fishing in the area. Figures 2 and 3 show the foreign fishery time/area closures in the waters off Alaska.

Effectiveness of Management Strategies

A reading of the goals of the FMP, the objectives of the groundfish management regime, and the sablefish management objective clearly shows that the Council is committed to U.S. domination in the sablefish fishery off Alaska.

It is difficult to objectively assess the success of sablefish management strategies in fulfilling this commitment, and an in-depth analysis is outside the scope of this presentation. However, if the extent of the U.S. participation in the sablefish fishery is examined, shown in Table 3 as percent of total harvest, it appears that in the Gulf of Alaska the U.S. share has remained fairly stable.

In order for the sablefish resource to be fully utilized by the U.S. fishery, it may be necessary to consider other management strategies than those presented here. New information on the growth, natural mortality, reproductive capacity, and stock structure-migration will help to fashion those strategies. It will also be necessary to know more about the market structure and the economics of the sablefish fishery.

Table 1
Sablefish Equilibrium Yield (EY) and Optimum Yield (OY)

Area	EY	OY
Bering Sea	4,200 mt	3,500 mt
Aleutian Islands	1,800	1,500
Western Gulf of Alaska	3,737	2,100
Central Gulf of Alaska	6,838	3,800
West Yakutat	3,760	1,680
East Yakutat	1,135-1,510	850-1,135
Southeast*	1,290-2,580	970-1,435

*Includes State of Alaska waters

Sources:

Resource Assessment Document for Bering Sea-Aleutian Islands Groundfish, unpl. manuscript, North Pacific Fishery Management Council, July 1983

Stauffer, Gary D., unpl. manuscript, Draft of 1983 I.N.P.F.C. Report

North Pacific Fishery Management Council, 1983

Table 2
Apportionment of Sablefish OY in 1983

Area	OY	DAP	JVP	Reserves	TALFF
Bering Sea	3,500 mt	500	200	350	2,450
Aleutian Islands	1,500	500	200	150	650
Western Gulf of Alaska	2,100	100	170	420	1,410
Central Gulf of Alaska	3,800	1,000	220	760	1,820
West Yakutat	1,680	530	0	336	814
East Yakutat	850-1,135	850-1,135	--	--	--
Southeast	970-1,435	970-1,435	--	--	--

Source: North Pacific Fishery Management Council, 1983

Table 3
Recent Foreign and U.S. Sablefish Harvests off Alaska (MT)

	1977	1978	1979	1980	1981	1982
Bering Sea/ Aleutian						
U.S.	0	0	0	44	180	315
Foreign	3826	1960	2170	2438	2955	2698
TOTAL	3826	1960	2170	2482	3135	3003
% U.S.	0	0	0	1.8	5.7	10.5
Gulf of Alaska						
U.S.	1676	2590	3344	3149	2547	2756
Foreign	15,446	6350	5882	5193	7216	4817
TOTAL	17,122	8940	9226	8342	9763	7573
% U.S.	9.8	29.0	36.2	37.7	26.1	36.4

Sources:

Resource Assessment Document for Bering Sea-Aleutian Islands Groundfish, unpl. manuscript, North Pacific Fishery Management Council, July 1983

Nelson, R., et al., 1983, "Summary of Provisional Foreign and Joint Venture Groundfish Catches (metric Tons) in the Northeast Pacific Ocean and Bering Sea, 1982

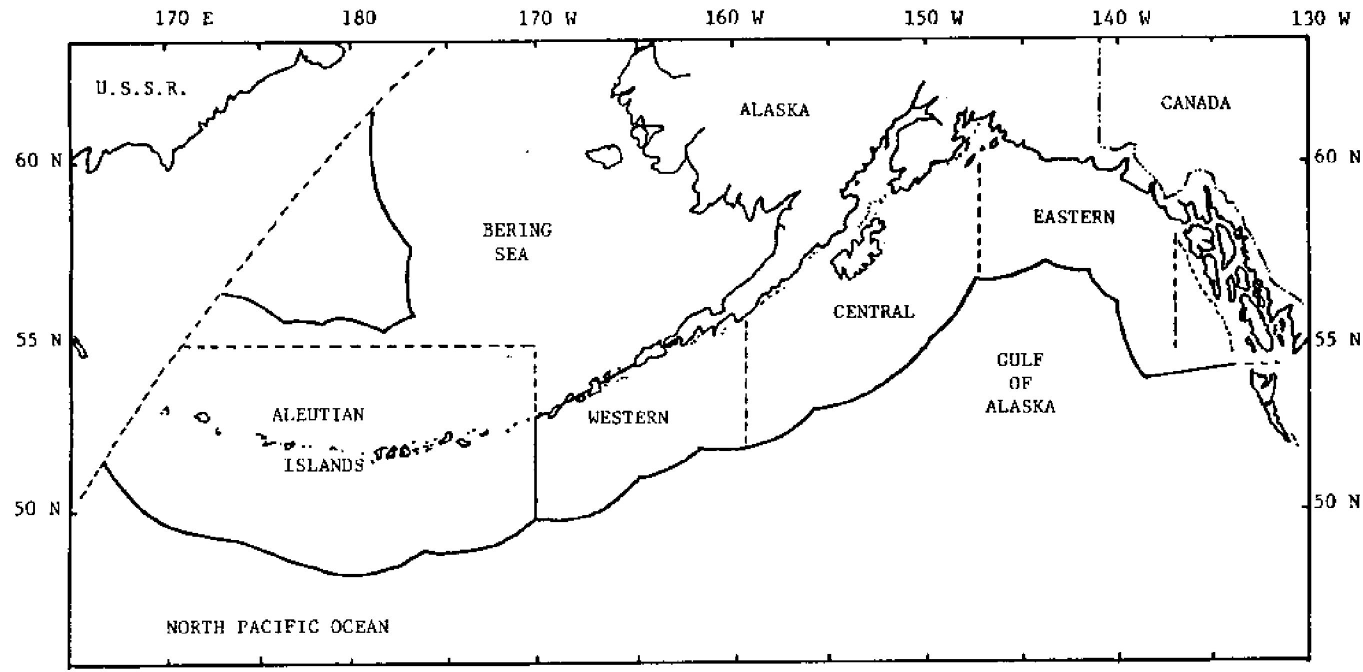


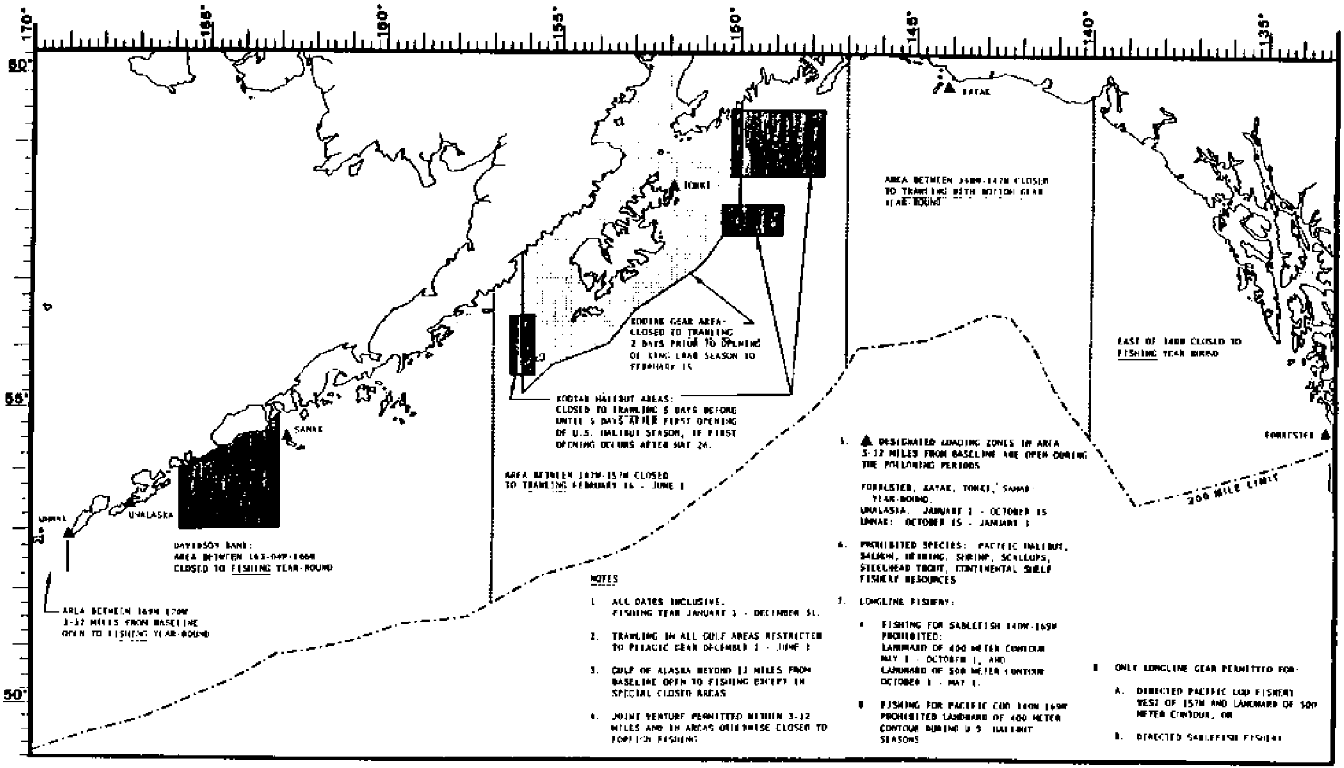
Figure 1
Quota Management Areas in the Bering Sea/Aleutian Islands Area and the Gulf of Alaska

Figure 2

1982 Foreign Fishing Regulations

GULF OF ALASKA

PREPARED BY:
NATIONAL MARINE FISHERIES SERVICE
LAW ENFORCEMENT
JUNEAU, ALASKA
MAY 1982



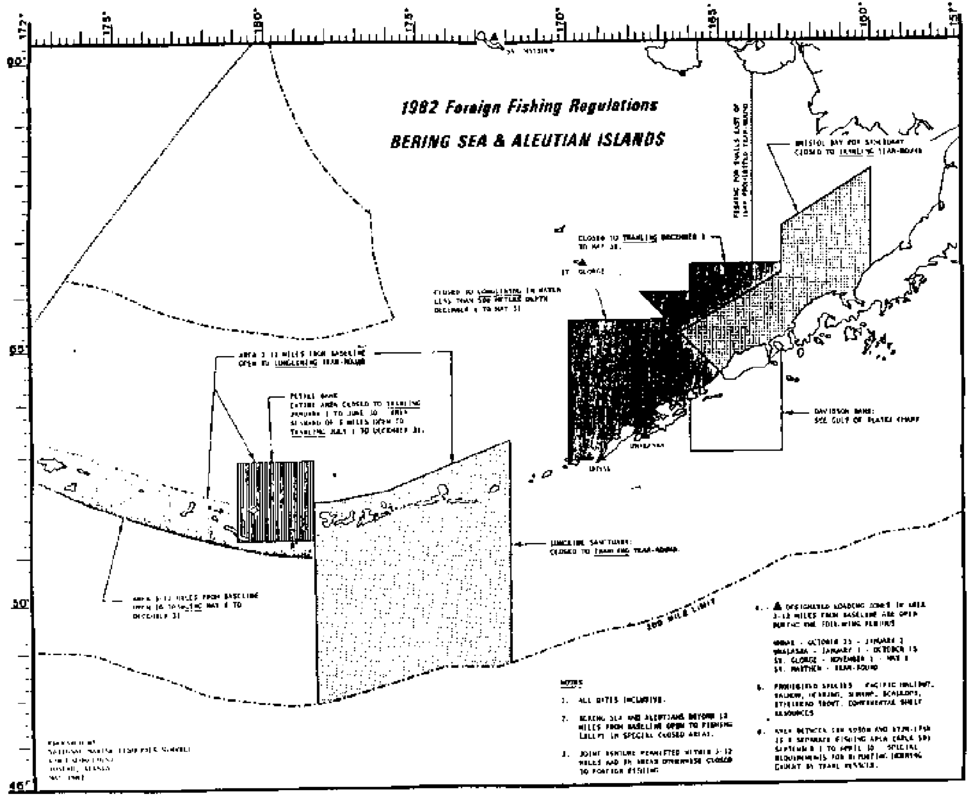

1982 Foreign Fishing Regulations
BERING SEA & ALEUTIAN ISLANDS
200 MILE LIMIT
NOTES

Figure 3

REFERENCES

Alaska Department of Fish & Game, 1977-81, In-season groundfish domestic catch report, IN, Stauffer, Gary D., 1983.

Low, Loh-Lee, 1977, "Status of the Sablefish Resource in the Bering Sea and Northeastern Pacific Ocean through 1977," submitted to the International North Pacific Fisheries Commission by the U.S. National Section, Northwest and Alaska Fisheries Center, National Marine Fisheries Service, 2725 Montlake Blvd. E., Seattle, WA 98112.

Nelson, R., J. Wall, J. Berger, B. Gibbs, 1983, "Summaries of Provisional and Joint Venture Groundfish Catches (Metric Tons) in the Northern Pacific Ocean and Bering Sea, 1982," National Marine Fisheries Service, Northwest and Alaska Fisheries Center, 2725 Montlake Blvd. E., Seattle, WA 98112.

North Pacific Fishery Management Council, 1981, Fishery Management Plan for the Gulf of Alaska Groundfish Fishery, Incorporates Amendments 1 through 9, P.O. Box 103136, Anchorage, AK 99510.

North Pacific Fishery Management Council, 1981, 1982, 1983, Minutes of various Council meetings, P.O. Box 103136, Anchorage, AK 99510.

North Pacific Fishery Management Council, 1979, Fishery Management Plan for the Groundfish Fishery in the Bering Sea/Aleutian Islands Area, P.O. Box 103136, Anchorage, AK 99510.

Stauffer, Gary D., 1983, unpl. manuscript, "Sablefish," Draft of paper for the International Pacific Fisheries Commission, Northwest and Alaska Fisheries Center, National Marine Fisheries Center, 2725 Montlake Blvd. E., Seattle, WA 98112.

Wespestad, V.G., K. Thorson, S. Mizroch, "Movement of Sablefish (Anoplopoma fimbria) in the Northwest Pacific Ocean as Determined by Tagging Experiments (1971-1977)," Northwest and Alaska Fisheries Center, National Marine Fisheries Service, 2725 Montlake Blvd., E., Seattle, WA 98112.

Overview of the fishery and management strategy for sablefish (*Anoplopoma fimbria*) off the west coast of Canada

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Abstract

Early and recent history of the sablefish fishery off Canada, trends in stock abundance as reflected by catch/effort data, and stock assessments and management rationale are reviewed.

Introduction

The importance of the sablefish fishery in the Canadian zone has increased steadily since the extension of Canada's fishery jurisdiction zone in 1977. It is the purpose of this report to present an overview of the fishery, fishery statistics, and management strategy for sablefish off Canada. This report summarizes the current management strategy, however, recent information on the biology, abundance, and stock delineation of sablefish may indicate that strategies should be re-evaluated.

Methods

Material for this report was summarized from Department of Fisheries and Oceans annual reports, International North Pacific Fisheries Commission statistical yearbooks, and groundfish stock assessment documents produced by staff at the Pacific Biological Station. Unpublished sources of data are cited in the text or text tables.

Discussion

History of the Sablefish Fishery in Canada

Early history (summarized from Ketchen and Forrester 1954). The first fishery for sablefish in British Columbia was carried out on a small scale by the Indians of the Queen Charlotte Islands. However, because sablefish inhabit deeper waters there was little incentive for the development of an extensive fishery.

The first commercial fishery for sablefish in Canadian waters occurred late in the nineteenth century and was carried out by specially equipped longline vessels. The establishment of a market was hampered, however, by abundant supplies of salmon. Between 1910 and 1915, salmon production decreased and the rising demand for salted sablefish gave incentive for development of the fishery. Landings of sablefish rose from close to 2000 t in 1913 to almost 6000 t in 1917 but declined in following years, reaching their lowest levels, during the depression of the 1930s (Table 1). In the late 1930s and early 1940s there was an improvement in the fishery due to a shortening of the halibut season and an increased demand for fish liver products, particularly vitamin A. The fishery was also aided by an increased demand for food fish early in World War II. Landings hit a peak of 1895 t in 1949 but abruptly dropped in subsequent years with the development of synthetic vitamin A in 1950 (Table 1; Fig. 1).

Recent history. From 1951-1971 catches by Canadian fishermen in the Canadian zone were fairly stable, averaging about 400 t/year (Tables 2 and 3). It should be noted that fish landed at British Columbia ports may have been caught outside the Canadian zone. It was not until 1951 that the portion of the catch made in areas such as Alaska could be separated from the total landings. Prior to that time this was not possible due to the methods used in recording catch data.

Heavy exploitation of sablefish off the Pacific coast of North America did not start until the late 1960s when Japan increased the size of its distant water longline fleet. In 1968 the Japanese fleet began fishing sablefish as a target species on an experimental basis. They increased their effort substantially in 1969 and 1970 and the catch of 5142 t in 1970 was the largest made during their years in the Canadian zone (Table 4). The largest proportion of their catch was taken off the Queen Charlotte Islands. Total catch by the Japanese fleet fluctuated between 2900 t and 4700 t from 1971 to 1975 and tapered off in following years, due to self-imposed catch limits for the northeastern Pacific and the quotas created by the declaration of a 200-mile fishery zone by Canada in 1977.

The USSR and the Republic of Korea (R.O.K.) also fished off the Pacific coast of North America but to a lesser extent off British Columbia than did Japan. There is little information on catches made by the USSR prior to 1973 but it is known that they removed 6 and 65 t of sablefish incidental to their trawl catches in 1973 and 1974, respectively (Ketchen, 1977). The R.O.K. was engaged in a longline fishery targeting on sablefish from 1974 to 1977 and in 1975 and 1976 was a strong competitor with Japan (Table 4).

As of January 1, 1977, Canada declared a 200-mile fishery conservation zone. The total allowable catch (TAC) of sablefish for the Canadian zone was set at 5,000 t for 1977. It was estimated that Canada and the United States would not require more than 1500 t and as a result 3500 t of the 5000 t TAC was considered as surplus. Quotas of 3000 t and 500 t were allotted to Japan and the Republic of Korea, respectively. From 1978 to the present the TAC for the Canadian zone was reduced to 3500 t, with Japan being allotted 2200 t in 1978, 1000 t in 1979, and 200 t in 1980. Since 1980, Japan has not fished sablefish in the Canadian zone.

Table 1. Sablefish landings in the Canadian zone, 1913-1950 (round weight, tonnes).[a]

Year	Vancouver[b]	Charlotte[c]	Total
1913			1988
1914			3209
1915			2441
1916			4312
1917			5956
1918	1013	1026	2039
1919	446	270	716
1920	743	1011	1754
1921	774	609	1383
1922	843	450	1293
1923	727	408	1135
1924	786	452	1238
1925	406	611	1017
1926	343	362	705
1927	578	540	1118
1928	610	301	911
1929	729	313	1042
1930	746	378	1124
1931	337	60	397
1932	280	156	436
1933	208	205	413
1934	206	229	435
1935	348	311	659
1936	208	282	490
1937	396	516	912
1938	342	234	576
1939	403	214	617
1940	319	629	948
1941	348	840	1188
1942	277	558	835
1943	591	835	1426
1944	844	675	1519
1945	734	694	1428
1946	411	1208	1619
1947	346	559	891
1948	364	1119	1483
1949	691	1204	1895
1950	290	358	648

[a]Fishery Statistics of Canada. Converted from dressed weight to round weight by a factor of 1.5.

[b]Listed as District 1 or South Coast and District 3 or Fraser.

[c]Listed as District 2 or North Coast.

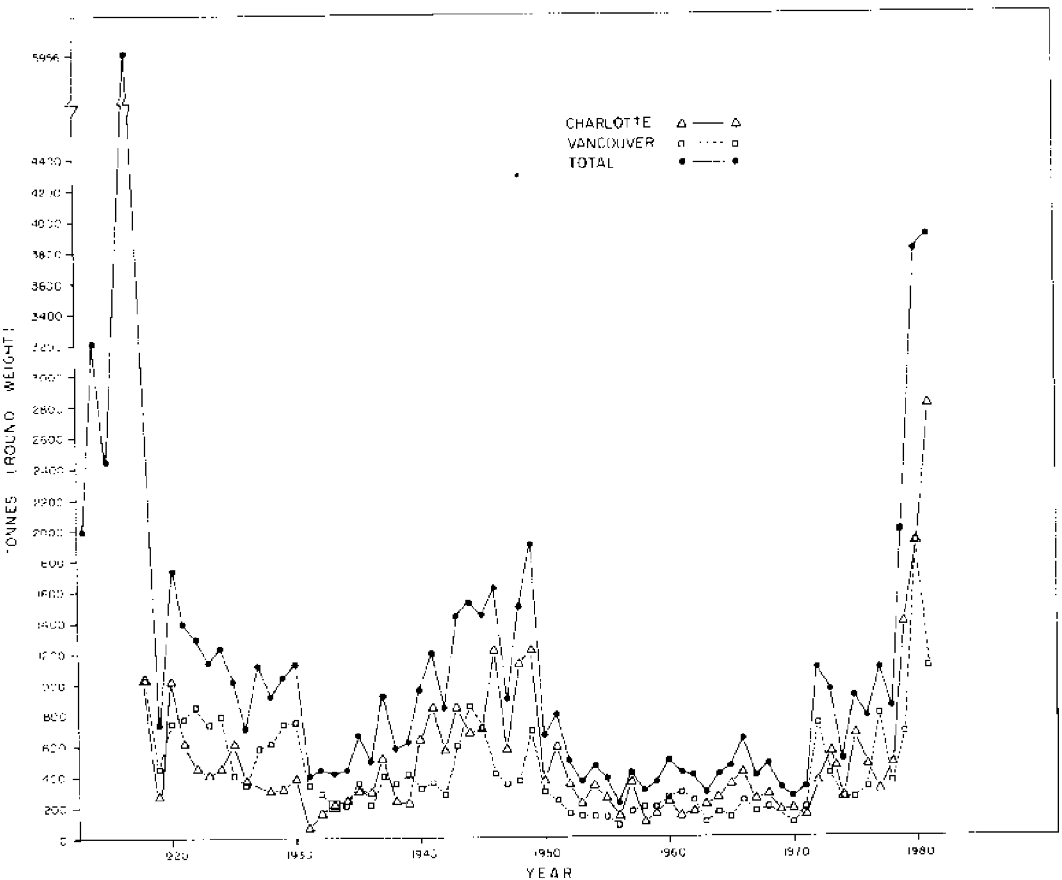

Fig. 1. Canadian landings of sablefish, 1913-1981 (landings prior to 1951 include fish caught in Alaska).

Table 2. Canadian sablefish catches, by gear, in the "Vancouver" zone, 1951-1981 (round wt., metric tons).[a]

	Gear type								
	Longline		Trawl		Trap		Other[b]		
Year	Wt.	%	Wt.	%	Wt.	%	Wt.	%	Total
1951	196.1	(89.8)	21.8	(9.9)			0.5	(0.2)	218.4
1952	115.1	(78.3)	31.3	(21.3)			0.6	(0.4)	147.0
1953	129.4	(94.6)	6.3	(4.6)			1.1	(0.8)	136.8
1954	103.7	(80.8)	24.3	(18.9)	0.3	(0.2)			128.3
1955	115.5	(89.3)	13.9	(10.7)					129.4
1956	48.3	(60.8)	31.1	(39.2)					79.4
1957	123.6	(74.8)	41.2	(25.0)	0.3	(0.2)			165.1
1958	78.6	(41.2)	111.4	(58.4)	0.6	(0.3)			190.6
1959	143.8	(72.5)	54.6	(27.5)					198.4
1960	208.9	(80.9)	49.2	(19.1)					258.1
1961	198.1	(69.4)	87.4	(30.6)					285.5
1962	152.5	(64.4)	83.2	(35.1)			1.1	(0.5)	236.8
1963	64.5	(76.0)	20.4	(24.0)					84.9
1964	108.4	(71.6)	42.9	(28.4)					151.3
1965	54.0	(44.1)	68.5	(55.9)					122.5
1966	127.2	(55.9)	100.3	(44.1)					227.5
1967	55.7	(34.4)	106.3	(65.6)					162.0
1968	68.4	(35.9)	122.3	(64.1)					190.7
1969	18.2	(12.5)	126.8	(87.3)			0.3	(0.2)	145.3
1970	12.0	(14.8)	69.3	(85.2)					81.3
1971	14.6	(8.1)	166.7	(91.9)					181.3
1972	100.3[c]	(13.7)	632.7	(86.3)					733.0
1973	3.2	(0.8)	50.9	(12.5)	353.4	(86.7)	Tr		407.5
1974	2.3	(0.9)	83.7	(33.6)	161.5	(64.8)	1.8	(0.7)	249.3
1975	2.3	(0.9)	200.3	(81.8)	41.5	(16.9)	0.9	(0.4)	245.0
1976	41.7	(13.3)	224.8	(71.5)	47.6	(15.1)	0.1	(0.1)	314.2
1977	27.3	(3.5)	688.4	(87.1)	68.9	(8.7)	5.9	(0.7)	790.5
1978	18.2	(5.1)	89.9	(25.4)	239.5	(67.7)	6.4	(1.8)	354.0
1979	118.3	(17.5)	143.4	(21.2)	409.8	(60.5)	6.0	(0.9)	677.5
1980	69.1	(3.6)	106.8	(5.6)	1722.5	(90.6)	3.0	(0.2)	1901.4
1981	94.8	(8.6)	140.2	(12.8)	862.4	(78.6)			1097.4

[a]Can. Dept. Fish., British Columbia Catch Statistics, 1951-1971 (converted from dressed weight to round weight by a factor of 1.5). Fish. Res. Board Can. Catch and effort statistics of the Canadian groundfish fishery of the Pacific coast, 1972-1981.

[b]Includes troll and handline.

[c]Includes longline, handline, and others.

Table 3. Canadian sablefish catches, by gear, in the "Charlotte" zone, 1951-1981 (round wt., metric tons).[a]

	Gear type								
	Longline		Trawl		Trap		Other[b]		
Year	Wt.	%	Wt.	%	Wt.	%	Wt.	%	Total
1951	576.7	(99.8)	1.3	(0.2)					578.0
1952	338.1	(99.2)	2.7	(0.8)					340.8
1953	206.2	(99.2)	1.7	(0.8)					207.9
1954	328.6	(99.4)	2.1	(0.6)					330.7
1955	243.5	(99.8)	0.6	(0.2)					244.1
1956	124.5	(95.4)	6.0	(4.6)					130.5
1957	342.0	(98.3)	5.9	(1.7)					347.9
1958	88.5	(93.5)	6.2	(6.5)					94.7
1959	154.5	(98.3)	2.7	(1.7)					157.2
1960	214.4	(93.2)	15.7	(6.8)					230.1
1961	123.2	(92.1)	10.6	(7.9)					133.8
1962	125.2	(80.4)	30.5	(19.6)					155.7
1963	157.8	(77.9)	44.5	(22.0)			0.2	(0.1)	202.5
1964	166.1	(66.9)	82.2	(33.1)			0.1	-	248.4
1965	139.2	(41.8)	193.4	(58.1)			0.3	(0.1)	332.9
1966	198.5	(48.6)	209.4	(51.3)			0.2	(0.1)	408.1
1967	197.2	(85.8)	32.6	(14.2)			0.1	(0.1)	229.9
1968	223.9	(82.1)	33.7	(12.4)			15.1	(5.5)	272.7
1969	144.1	(86.9)	21.4	(12.9)			0.3	(0.2)	165.8
1970	130.1	(73.2)	47.2	(26.5)			0.5	(0.3)	177.8
1971	108.4	(82.7)	22.7	(17.3)					131.1
1972	299.4	(84.3)	55.8	(15.7)					355.2
1973	116.6	(21.6)	31.7	(5.9)	392.4	(72.6)			540.7
1974	39.0	(16.1)	38.1	(15.7)	165.6	(68.2)			242.7
1975	149.9	(22.7)	82.0	(12.4)	427.9	(64.9)			659.8
1976	47.7	(10.4)	154.2	(33.7)	255.8	(55.9)			457.7
1977	49.8	(16.9)	98.3	(33.4)	145.7	(49.4)	0.9	(0.3)	294.7
1978	39.0	(8.2)	40.4	(8.5)	395.1	(83.0)	1.4	(0.3)	475.9
1979	158.7	(11.7)	133.1	(9.8)	1067.6	(78.5)			1359.4
1980	179.7	(9.5)	226.7	(12.0)	1488.3	(78.6)			1894.7
1981	284.8	(10.2)	92.9	(3.3)	2412.6	(86.5)			2790.3

[a]Can. Dept. Fish. British Columbia Catch Statistics, 1951-1971 (converted from dressed weight to round weight by a factor of 1.5). Fisheries Research Board of Canada Catch and effort statistics of the Canadian groundfish fishery of the Pacific coast, 1972-1981.

[b]Includes troll, handline, and sunken gillnet (1968 only).

Table 4. Sablefish catch (t) by nation (all fishing gears) in INPFC areas "Vancouver" and "Charlotte", 1964-1981.

Calendar year	Canada[a]			U.S.A.[b]			Japan[c]		
	Charl.	Vanc.	Total	Charl.	Vanc.	Total	Charl.	Vanc.	Total
1964	248	151	399	40	43	83			
1965	333	123	456	40	52	92			
1966	408	228	636	39	56	95	164	10	174
1967	230	162	392	49	16	65	381	808	1189
1968	273	191	464	29	36	65	1870	520	2390
1969	166	145	311	26	17	43	2533	2187	4720
1970	178	81	259	21	83	104	3980	1162	5142
1971	131	181	312	11	150	161	2180	870	3050
1972	355	733	1088	19	563	582	2784	1452	4236
1973	541	408	949	20	62	82	2143	807	2950
1974	243	249	492	33	194	227	2084	1782	3866
1975	660	245	905	12	529	541	3286	1416	4702
1976	458	314	772	25	448	473	2628	866	3494
1977	295	791	1086	42	529	571	1818	1143	2961
1978	476	354	830	Tr	948	948	1339	764	2103
1979	1359	678	2037	17	1219	1236			1112[d]
1980	1895	1901	3796	10	307	407			199
1981	2790	1097	3887						

Calendar year	U.S.S.R.[e]			R.O.K.[e]			TOTAL
	Charl.	Vanc.	Total	Charl.	Vanc.	Total	
1964							482
1965							548
1966							905
1967							1646
1968							2919
1969							5074
1970							5505
1971							3523
1972							5906
1973		6	6				3981
1974		65	65		129	129	4779
1975				207	1056	1263	7411
1976						2335	7074
1977						186[d]	4804
1978							3881
1979							4385
1980							4402
1981							3887

[a]Canada Dept. Fisheries, B.C. Catch Statistics, 1965-1971, and Fish. Res. Board Can. Catch and effort statistics of the Canadian groundfish fishery of the Pacific coast (1972-1981).

[b]Ketchen (1977) until 1973, from INPFC Statistical Yearbooks, 1974-1979 (1979 preliminary) and from PMFC data series, 1980.

Table 4 (cont'd).

[c]INPFC Statistical Yearbooks, 1964-1978, and from fishing log books for 1979-1980.

[d]Best estimate of catch using fishing log books plus observer information. These figures differ from previously published estimates (Ketchen 1980) as a result of a change in conversion rates.

[e]Ketchen (1977).

In Canada, the sablefish fishery has traditionally been carried out by longlining and trawling. The effort expended by the longline fleet has been closely linked to the fluctuations of the halibut fishery. Most longline vessels targeted on sablefish only after the halibut season closed. As the halibut season was shortened over the years more boats turned to sablefish, particularly when they were allowed to retain incidental catches of halibut after that season had closed. From 1951 to 1972 longliners accounted for the largest portion of domestic sablefish landings, especially in the "Charlotte" area (Table 3; Fig. 2). In the "Vancouver" area trawl landings surpassed landings by other gear types from the mid-sixties until 1977 (Table 2).

In 1973, longline landings dropped sharply with the introduction of traps to the fishery (Tables 2 and 3; Fig. 2). The trap fishery has been most successful off the west coast of the Queen Charlotte Islands, accounting for about 70% of the sablefish landings from that area from 1973 to 1981. In 1980 there were restrictions put on Canadian participation in the halibut fishery in U.S. waters and this resulted in an increased number of vessels landing sablefish and also some changes in gear from longline to trap. Since 1980, trap-caught sablefish have accounted for approximately 80 to 90% of landings from both areas.

The increase in trawl landings in the "Vancouver" area may be partly attributed to a reduction in the minimum size limit. In 1945, a minimum size limit of 5 lb. (2.3 kg) dressed, head-on (approximately 63 cm FL) was imposed for economic reasons and in 1948 it was amended to 4.5 lb. (2.0 kg) dressed, head-off (Ketchen and Forrester, 1954). In 1965 the minimum size was reduced to 2.5 lb. (1.1 kg) dressed, head-off (approximately 54 cm FL). This regulation remained in effect until November 1970 when a large number of undersized sablefish were landed by special permit to test a specialty market for small sablefish. In July 1972 the minimum size regulation was waived for three months, on an experimental basis, and there was a corresponding sharp increase in trawl landings of sablefish (Table 2). A downward shift in the sizes of fish landed was evident, as fish that would normally have been discarded were kept (unpub. data). In October 1972 the size limit was reinstated and has remained in effect since that time. In 1977 it was redefined as the equivalent size of 4 lb. (1.8 kg) round weight (approximately 55 cm FL).

In 1981, license limitation was implemented in an attempt to control effort directed towards sablefish. There are currently 49 sablefish or "K" licenses in the fishery of which 16 are longline and 31 are trap vessels. Two licenses have not been identified by gear.

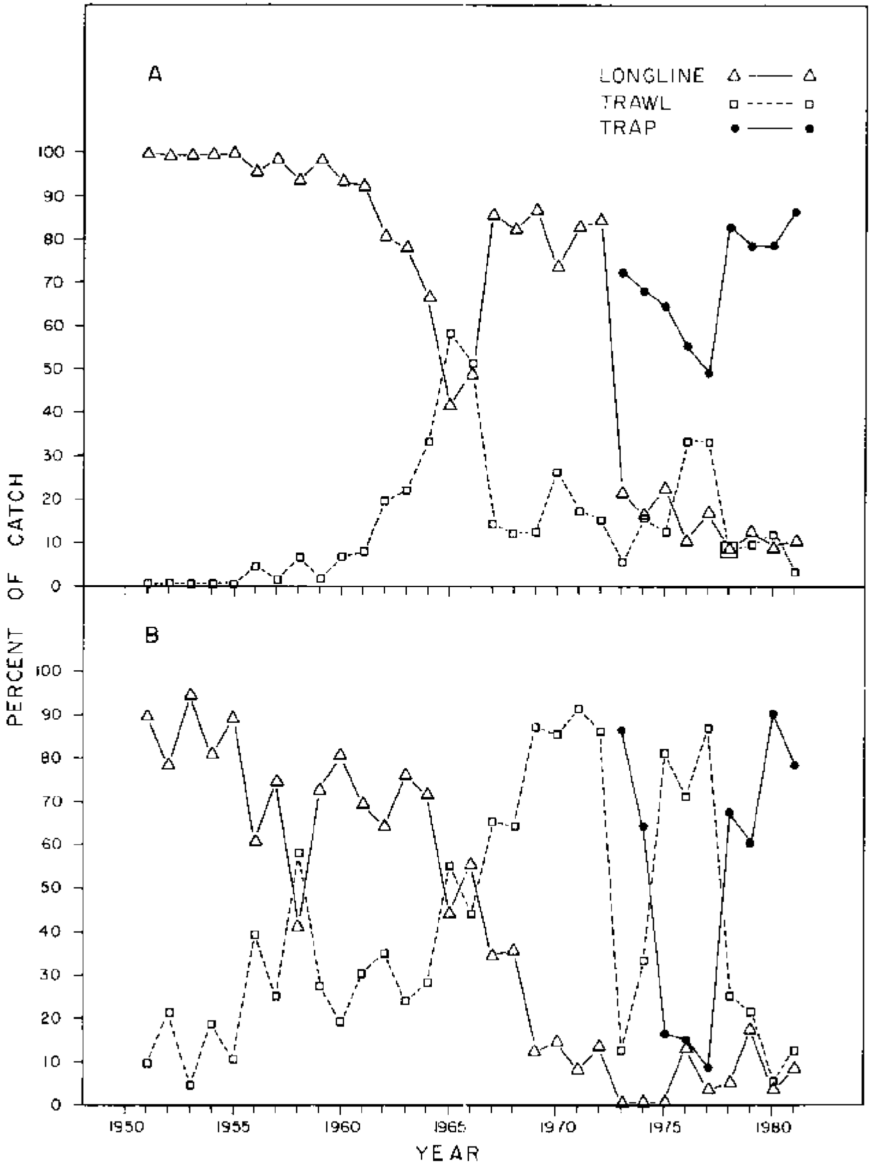

Fig. 2. Percent catch of sablefish by major gear type in the Canadian fishery (1951-1981) A. Charlotte zone and B. Vancouver zone.

Trends in CPUE

Japan. Catch-per-unit-effort for the Japanese longline fishery is defined as catch in metric tons per 10 hachi (t/10 hachi). One hachi of longline gear is approximately 100 m long and contains an average of 40 hooks but the number of hooks may vary between 33 and 53 (information from observers aboard longliners in 1977, 1978, and 1979). Since the Japanese freeze a dressed product, their estimate of total catch was obtained by multiplying the dressed product weight by 1.333, a recovery rate of 75%. However, calculations made by Canadian observers indicated that the recovery rate is closer to 65%; that is the dressed, head-off weight should be multiplied by 1.538. Reported total catches would therefore be lower than actual total catches by approximately 15%. Of course, if these conversion factors have not changed since the beginning of the fishery, CPUE data will not be affected.

The use of 10-hachi units to measure fishing effort could misrepresent effort if longer "soak-time" times are used. Soak-time is the period of time, usually in hours, that the gear is left in the water and is actually fishing. The use of boat-days, the number of calendar days spent fishing, might reduce the dependence on soak-time, however, a boat-day unit ignores the problem of increased efficiency by setting more hachi per day or more hooks per hachi. Since the possibility of setting

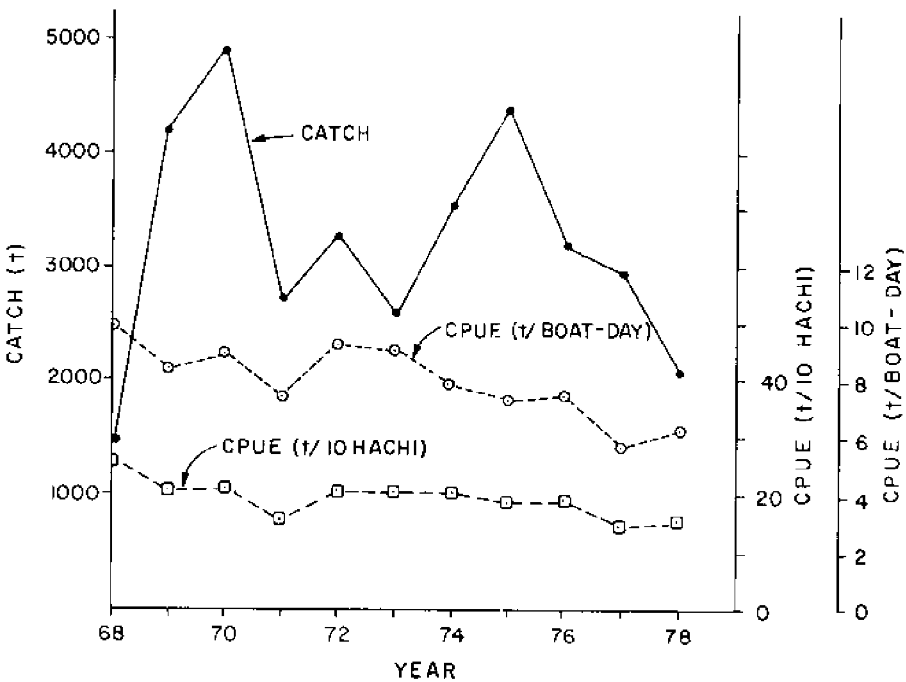

Fig. 3. Trends in catch and CUPE for the Janpanese longline fishery for sablefish in Canadian waters (48°00' - 54°39') 1968-1978).

more hachi per day is thought to have a greater effect than longer "soak-time", effort calculated as 10-hachi units is thought to be more accurate. The CPUE using boat-days has been calculated for the whole coast for comparison (Fig. 3).

The Japanese catches (Table 5; Fig. 3) show an initial decline from 1968 to 1971 in CPUE from 0.261 t per 10-hachi to 0.162 t per 10-hachi. CPUE then remained relatively steady from 1972 to 1976 ranging from 0.194 to 0.210 t per 10-hachi. During 1977, CPUE dropped by 24% to 0.147 t per 10-hachi and 1978 CPUE was only slightly higher at 0.162 t per 10-hachi. (If a correction for the 1977 and 1978 catches for the discrepancy in recovery rates is made, the drop in CPUE in 1977 is only 13% to 0.170 t per 10-hachi.)

Table 5. Sablefish catch (t) and effort (10-hachi) statistics for Japanese longline fishery in Canadian waters (48°00'-54°30'N lat.), 1968-78.

Calendar year	Catch (t)	Effort (10-hachi)	CPUE (t/10-hachi)
1968[a]	1,454	5,573	0.261
1969	4,224	22,412	0.207
1970	4,919	22,886	0.215
1971	2,721	16,774	0.162
1972	3,491	16,831	0.207
1973	2,585	12,367	0.209
1974	3,527	16,765	0.210
1975	4,433	22,807	0.194
1976	3,209	16,519	0.194
1977[b]	2,982(3,440)[c]	20,260	0.147(0.170)[c]
1978	2,091(2,405)[c]	13,396	0.162(0.180)[c]
1968-78 average	3,240	16,781	0.197

[a]1968-76 statistics from U.S. National Marine Fisheries Service computer printouts.

[b]1977 and 1978 statistics from fishing log books.

[c]Catch and CPUE corrected for change in recovery rates reported by observers on board vessels.

A similar pattern of change in CPUE is seen in the Queen Charlotte Islands-Dixon Entrance area, Sub-zone 5-5, (Table 6; Fig. 4), where CPUE declined from 1968 to 1971 from 0.289 t per 10-hachi to 0.180 t per 10-hachi. During 1972-75, CPUE was relatively consistent, varying between 0.194 t per 10-hachi and 0.202 t per 10-hachi. A drop in CPUE in 1976 to 0.184 t per 10-hachi precedes the drop in 1977 to 0.140 t per 10-hachi. However, there was an increase in CPUE in 1978 to 0.162 t per 10-hachi.

Table 6. Sablefish catch (t) and effort (10-hachi) statistics for Japanese longline fishery in the Queen Charlotte Islands-Dixon Entrance area, Sub-zone 5-5 (52°00'-54°30'N lat.), 1968-78.

	Total for Sub-zone 5-5			Block with the largest catch (033540)		
Year[a]	Catch (t)	Effort (10-hachi)	CPUE (t/10-hachi)	Catch (t)	Effort (10-hachi)	CPUE (t/10-hachi)
1968[b]	1,142	3,954	.289	478	1,532	.312
1969	1,490	6,650	.224	580	2,128	.273
1970	1,549	7,229	.214	708	2,971	.238
1971	1,472	8,164	.180	786	4,484	.175
1972	2,080	10,284	.202	1,221	5,996	.204
1973	1,327	6,589	.201	752	3,731	.202
1974	1,151	5,875	.196	694	3,559	.195
1975	1,610	8,284	.194	935	4,759	.196
1976	1,259	6,850	.184	717	4,098	.175
1977[c]	737	5,246	.140	377	2,743	.138
1978	555	3,424[d]	.162	219[e]	1,363[e]	.161

[a]Calendar year.

[b]1968-76 data from U.S. Nat. Marine Fish. Serv. computer printouts.

[c]1977 and 1978 data from Japanese log books.

[d]One log book unavailable, therefore, effort estimated.

[e]Catch and effort in this block probably higher -- missing information from one log book.

The pattern of catch and effort in Queen Charlotte Sound, Sub-zone 5-4, and off Vancouver Island, Sub-zones 5-1, 5-2, and 5-3 was different from Sub-zone 5-5 (Table 7, 8; Fig. 4). In the former areas CPUE is almost as high between the years 1972 and 1976 as the initial high CPUEs in 1969 and 1970. However, there were low CPUEs in 1971 and in 1977. The increase in CPUE in 1978 from the low of 1977 is less pronounced in these areas than in the Queen Charlotte Islands-Dixon Entrance area.

Canada. Accurate catch and effort statistics for the Canadian trap fishery were unavailable until 1977 when a concerted attempt was made to collect this information. The change from Canadian rectangular traps to Korean conical traps around 1978 further complicated the situation in that the change-over was so complete that we have very little information to standardize the two types of traps.

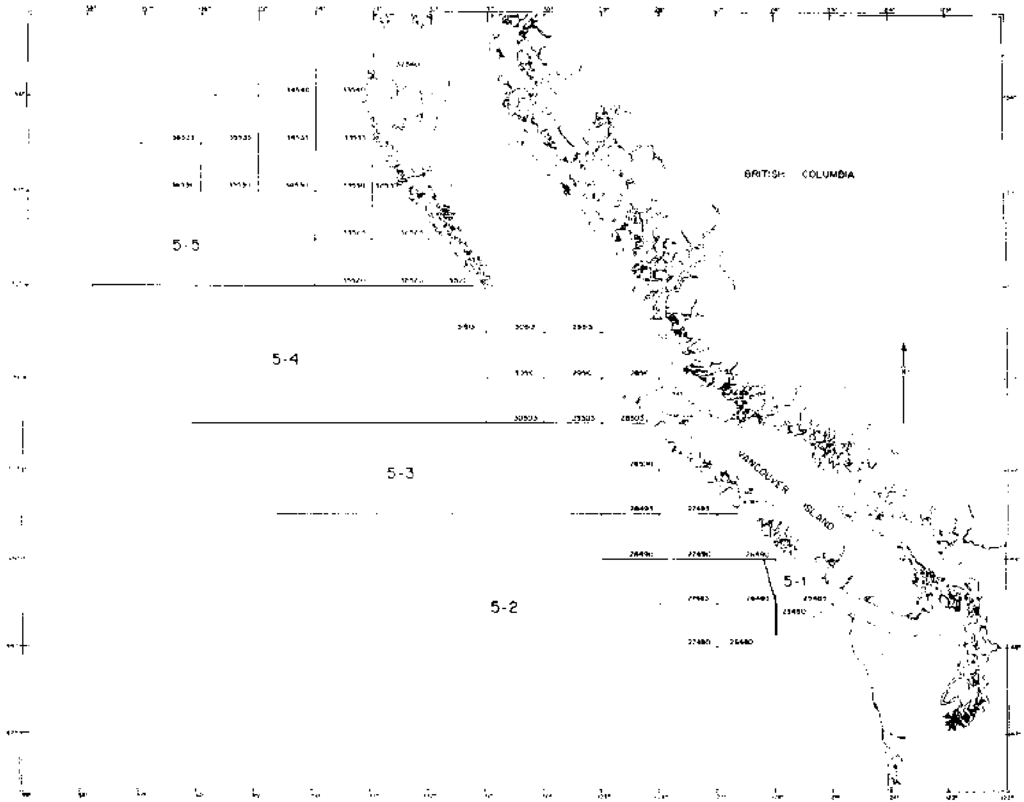

Fig. 4. Locations of blocks referred to in Japanese catch and effort records. Numbers refer to the longitude and latitude of the southeast corner of each block.

Table 7. Sablefish catch (t) and effort (10-hachi) statistics for Japanese longline fishery adjacent to Queen Charlotte Sound, Sub-zone 5-4 (50°30'-52°00'N lat.), 1968-78.

	Total for Sub-zone 5-4			Block with the largest catch					
				Catch (t)					
Year[a]	Catch (t)	Effort (10-hachi)	CPUE (t/10-hachi)	029510	029503	030510	030513	Effort (10-hachi)	CPUE (t/10-hachi)
1968[b]	73	466	.157	22	-	-	-	189	.116
1969	765	3,700	.207	-	-	246	-	1,051	.234
1970	2,310	10,756	.215	-	-	886	-	3,988	.222
1971	655	4,458	.147	-	-	-	338	1,843	.183
1972	585	2,503	.234	-	-	-	295	1,140	.259
1973	460	2,156	.213	-	178	-	-	872	.204
1974	820	3,755	.218	-	-	-	268	1,172	.229
1975	1,444	7,397	.195	-	-	-	405	2,051	.197
1976	1,126	5,327	.211	-	-	-	741	3,382	.219
1977[c]	1,081	7,342	.147	-	-	-	423	2,761	.153
1978	765	4,924	.155	-	-	-	304	1,954	.155

[a]Calendar year.

[b]1968-76 data from U.S. Nat. Marine Fish. Serv. computer printouts.

[c]1977 and 1978 data from Japanese log books.

Table 8. Sablefish catch (t) and effort (10-hachi) statistics for Japanese longline fishery in the Vancouver Island Area, Sub-zones 5-1, 5-2 and 5-3 (48°00'-50°30'N. lat.), 1968-78.

Year[a]	Total for Sub-zones 5-1,2,3			Block with the largest catch						
				Catch (t)						
	Catch (t)	Effort (10-hachi)	CPUE	028500	027493	027490	026483	025480	Effort (10-hachi)	CPUE
1968[b]	239	1,153	.207	-	102	-	-	-	466	.219
1969	1,969	10,062	.196	-	796	-	-	-	4,367	.182
1970	1,060	4,901	.216	455	-	-	-	-	1,858	.245
1971	594	4,152	.143	-	-	-	200	-	1,264	.158
1972	826	4,044	.204	-	191	-	-	-	826	.231
1973	798	3,622	.220	-	-	-	211	-	943	.224
1974	1,556	7,135	.218	-	-	-	-	411	1,893	.217
1975	1,379	7,126	.194	-	-	371	-	-	1,903	.195
1976	824	4,342	.190	267	-	-	-	-	1,295	.206
1977[c]	1,164	7,672	.152	-	-	-	308	-	1,942	.158
1978	771	5,048[d]	.162	-	238[e]	-	-	-	1,445[e]	.165

[a]Calendar year.

[b]1968-76 data from U.S. Nat. Marine Fish. Serv. computer printouts.

[c]1977 and 1978 data from Japanese log books.

[d]One log book unavailable, therefore, effort estimated.

[e]Catch and effort in this block probably higher--missing information from one log book.

The CUPE data for 1978 are incomplete and probably not representative of the annual catch and CPUE for Korean traps. The coast-wide CPUE from 1979 to 1982 is similar and has varied from 14.8 to 17.4 kg/trap (Table 9, Fig. 5). There has been considerable variation between and within areas (Table 9). The first quarter (January to April) landing statistics have been included for comparison (Table 10, Fig. 5) showing the substantial increases in catch made in this quarter since 1980. In the Vancouver area both catch and CPUE declined by 50 and 30% in 1981 and 1982 respectively, from 1980 levels. At this time, the decline in CPUE in this area is attributed to new participants entering the fishery and is not a reflection of declining abundance. In the Charlotte area CPUE has remained relatively stable with substantial increases in both catch and effort (Table 9), in 1981 and 1982.

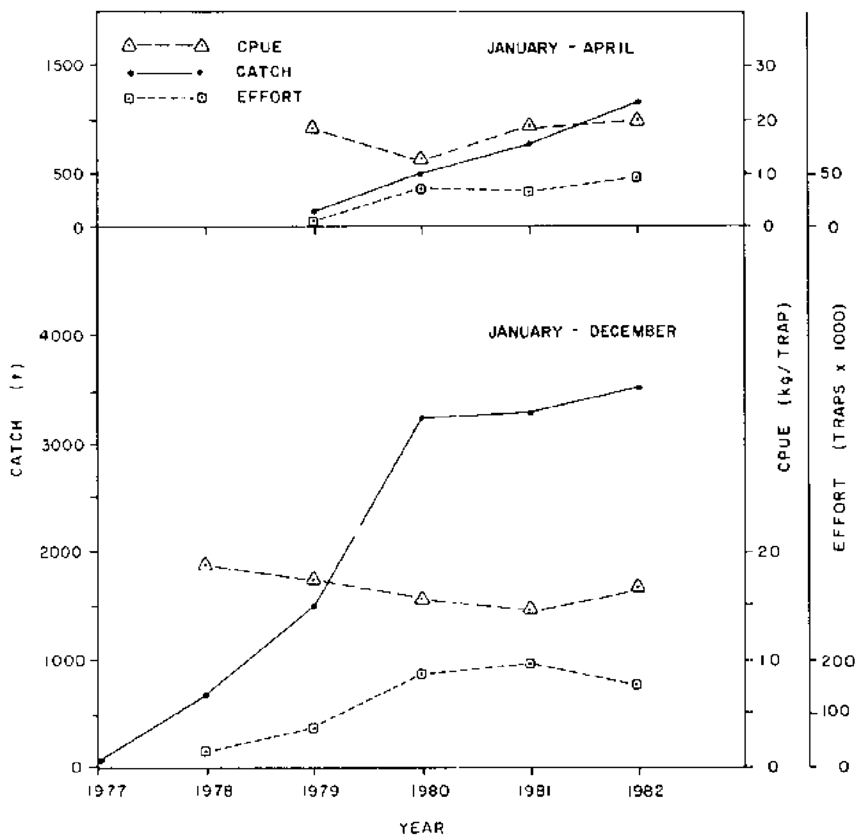

Fig. 5. Trends in catch and CPUE for the Canadian trap fishery for sablefish in Canadian waters, 1977-1982.

Table 9. Reported sablefish catch (round weight) and effort statistics for the Canadian trap fishery by INPFC Areas - Vancouver and Charlotte, 1978-1982.

	Vancouver			Charlotte			Total		
Year	Catch (tonnes)	Effort (traps)	CPUE (kg/trap)	Catch (tonnes)	Effort (traps)	CPUE (kg/trap)	Catch (tonnes)	Effort (traps)	CPUE (kg/trap)
1978	141.3	5,603	15.3	404.8	23,127	17.5	545.3	28,730	18.9
1979	409.8	18,687	13.9	1067.6	52,531	18.1	1477.4	71,218	17.4
1980	1722.5	80,312	15.0	1488.3	91,873	15.7	3210.8	172,185	15.4
1981	862.5	72,947	10.3	2412.6	125,885	17.4	3275.1	198,827	14.8
1982	947.2	43,560	11.8	2559.8	111,085	18.7	3507.0	154,645	16.8

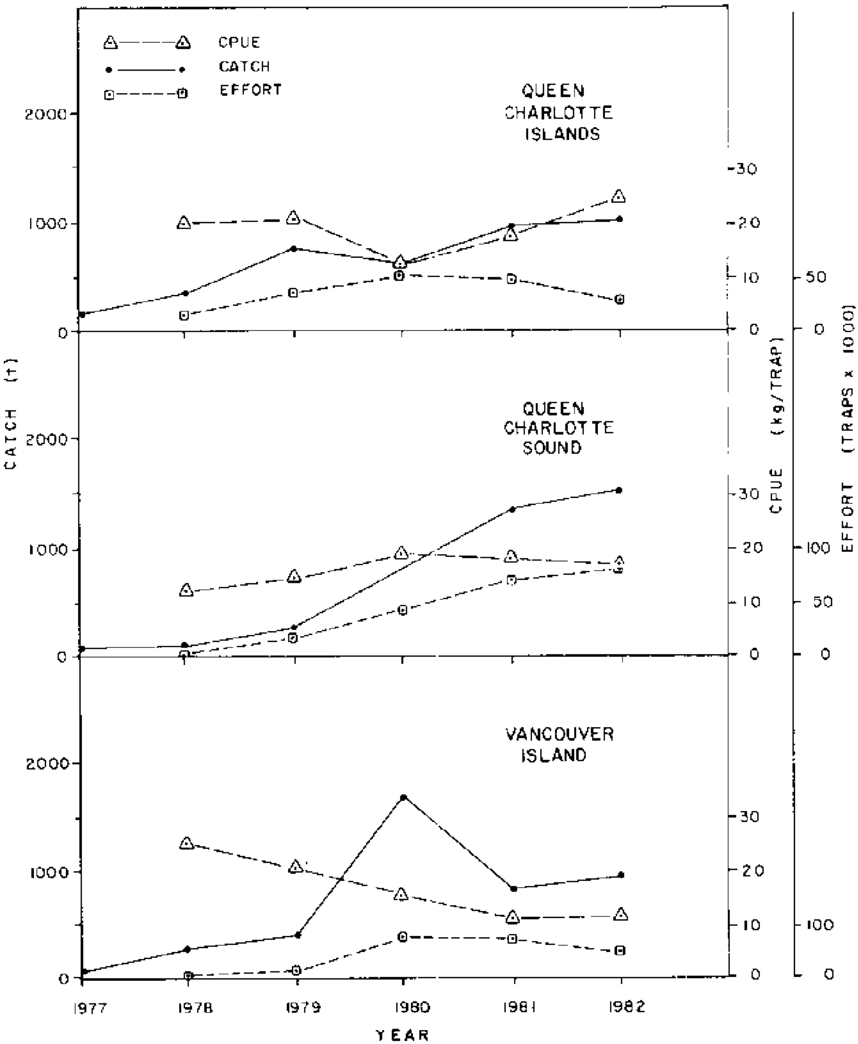

Fig. 6. Trends in catch and CPUE for the Canadian trap fishery for sablefish in the major fising areas, 1977-1982.

Table 10. Sablefish total trap catch and CPUE estimates for January 1-April 10 and for all months combined for the three major fishing areas[a] during 1977-1982.

	Vancouver Island				Queen Charlotte Sound				Queen Charlotte Islands			
	1st Qtr.		All Qtrs.		1st Qtr.		All Qtrs.		1st Qtr.		All Qtrs.	
Year	T.L.[b] (t)	CPUE kg/trap	T.L. (t)	CPUE kg/trap	T.L. (t)	CPUE kg/trap	T.L. (t)	CPUE kg/trap	T.L. (t)	CPUE kg/trap	T.L. (t)	CPUE kg/trap
1977	-	-	53.6		-	-	17.3	-	-	-	128.6	-
1978	-	-	141.3	25.2	-	-	77.6	11.6	-	-	326.4	20.1
1979	15.1	-	392.0	14.1	-	-	281.3	14.0	163.4	18.3	759.7	20.9
1980	275.7	16.9	1714.1	15.0	31.3	8.6	797.2	15.5	193.1	9.9	682.8	13.5
1981	240.3	12.5	860.6	10.3	198.7	22.4	1359.1	17.9	342.3	24.2	991.9	18.5
1982	222.0	13.0	942.2	11.8	369.1	16.8	1511.2	16.8	556.6	30.9	1033.7	25.0

[a]Vancouver Island = Statistical Areas 3C and 3D
Queen Charlotte Sound = Statistical Areas 5A, 5B, and 5C
Queen Charlotte Islands Statistical Areas 5E

[b]T.L. = Total Landing

In the Charlotte area, two major fishing grounds are monitored (Table 10). In Queen Charlotte Sound (Table 10, Fig. 6) landings increased by approximately 71% in 1981 and 90% in 1982 from 1980 levels as a result of an 85% increase in effort during these years. CPUE in this area has remained relatively constant (Table 10), ranging from 14.0 to 18.5 kg/trap from 1977 to 1982. Off the west coast of the Queen Charlotte Islands (Table 10, Fig. 6) landings increased by approximately 47% in 1981 and 1982 over the 1980 level, despite declining effort (Table 9, Fig. 6). It is unknown at this time if the dramatic increase in CPUE in 1982 is an error in reporting or due to the particular vessels involved in the fishery in that area.

Review of Stock Assessments

American scientists in 1979 used two methods to fit the sablefish catch and effort data from the Japanese longline fishery to a general production model. They indicate from tagging observations that there may be a number of biological stock units. However, defining these stocks was considered to be difficult so an analysis by geographical regions was used. Their results for the longline fishery off Canada produced a MSY of 5,155 t/yr using the method of Fox (1970) and a MSY of 5,800 t/yr using the method of Rivard and Bledsoe (1973, personal communication) (Table 11).

Initially, Canadian scientists used two methods to estimate MSY (Westrheim, 1980). The first method is the same as that used by U.S. and Japanese scientists. It involves a regression of CPUE on the average fishing effort over a number of preceding years (K), which ideally should be equal to the average length of time an individual of a year-class is vulnerable to the fishery (Gulland, 1961); the second is a dynamic, stochastic version of the Schaefer model (Schnute, 1977).

Using Gulland's (1961) linear regression model, estimates of MSY using catch-per-10-hachi and catch-per-boat-day range between 3,200 and 4,100 t/yr (Table 11). Results generated by the modified Schaefer model produced estimates ranging from 5,200 to 6,200 t/yr.

An estimated total effort for all-nation catches for the whole coast was calculated by applying the Japanese longline CPUE to all other catches of sablefish (i.e., catches by different gear types). The results of Gulland's linear regression model using this estimated total effort in both 10-hachi and boat-day units ranged from 4,600 to 4,800 t/yr.

Recent analysis using new age estimates indicated that the range in MSY may be greatly reduced (Table 11). Deriso's (1980) model produced an estimate of 2,200 t/yr while preliminary analysis incorporting age and fecundity data (unpub.) gave a range of MSY of 3,200 to 4,000 t/yr.

In summary, stock assessments prior to 1981 were based on analysis of the Japanese longline fishery from 1968-1978. Estimates of MSY ranged from 3,400 to 6,100 t/yr. Recent analysis using new age composition data indicate previous estimates may have been too high.

Table 11. Summary of estimated ranges of predicted MSY.

	MODEL TYPE	MSY (t/yr)
American	-Exponential surplus yield (assuming Gompertz Growth function)	5155
	-Pella Tomlinson stock production model	5800
Canadian	-Gulland's Linear Regression (Japanese Catch)	3200-4100
	-Gulland's Linear Regression (All-nation Catch)	4600-4800
	-Schaeffer	5200-6200
	-Deriso	2200
	-Sablefish Dynamic Pool	3200-4000

Management

When Canada extended its fishery jurisdiction zone in 1977 and assumed responsibility for management in its zone, little was known about the biology or fishery for sablefish. Initially, a quota of 5,000 t was established for 1977. This was reduced to a more conservative quota of 3,500 t in 1978, based upon analysis of Japanese longline catch and effort data from 1968-1978.

Biological information collected from 1977-1982 indicates that the 3500 t quota may not be conservative and may be close to the sustainable yield. In addition, there is the concern that management to a fixed quota generally results in an overrun of the quota. For example, during 1980, 1981, and 1982 the quota was exceeded by approximately 500 t (14%) annually. Also, fish captured by lost gear cannot be accounted for. At present, we do not have an estimate of the number of traps lost annually, however, reports from fishermen suggest that it is substantial. Non-reporting is not considered to be serious, however, there may be a small amount of sablefish caught which is not reported or which is not included in the landings until after the quota has been reached. In view of these concerns, it may be necessary to re-examine our management strategies. In other words, although the quota may be sustainable, it may be necessary to recommend lower quotas because of the lack of rigid control over the actual landings.

Effective management of sablefish has been limited by a general lack of biological information. As mentioned, recent evidence indicates the quota may not be conservative. New ageing information has shown that sablefish are much older than previously thought (Beamish and Chilton, 1982), with the majority ranging from 4-35 years of age. This represents a substantial decrease in mortality rates and a corresponding increase in the length of time a cohort is available to the fishery. It is also evident that strong year-classes are an important component of the stock and that the fishery is supported by these strong year-classes (McFarlane and Beamish a, this symposium). It has been estimated that the biomass of the strong 1977 year-class may be equal to the adult component of the stock (McFarlane and Beamish b, this symposium). The strategy for exploiting strong year-classes has not been developed, however, the desirability of increased fishery pressure on these year-classes, coupled with the concurrent increase in mortality of older year-classes, is questionable. The presence of older fish in the population and hence the longer reproductive life span may be necessary for maintaining the stock, particularly in times of poor environmental conditions.

Tagging studies have shown that juvenile fish rearing in the inside waters (Queen Charlotte Sound, Hecate Strait, and mainland inlets) move northward into the United States zone off Alaska (Beamish and McFarlane, this volume). If this northward movement is a coastwide phenomena in the northeast Pacific Ocean, as evidenced by Bracken (1982) and Sasaki (1982), then a Canadian fishery for juveniles in these inside waters would impact on the U.S. fishery off Alaska. However, the intensive fishery for juveniles being conducted off the coasts of Washington, Oregon, and California clearly indicates that the management strategy in these areas is to exploit strong year-classes when they occur. This fishery may be seriously affecting recruitment to the Canadian zone, making it difficult to justify conservation of migratory juveniles rearing in the Canadian zone but recruiting to the U.S. fishery.

These tagging studies (Beamish and McFarlane, this volume) have identified discrete stocks of adult sablefish off areas such as the northwest coast of Vancouver Island, Queen Charlotte Sound, the west coast of the Queen Charlotte Islands, as well as major inlets. The major recruitment to these stocks is from outside the particular area (Beamish and McFarlane, this symposium) and excessive effort in these areas without compensating recruitment may result in a localized depletion. If monitoring programs indicate excessive effort and reduction in CPUE in an area, it will be necessary to set quotas by discrete areas as a precautionary measure.

In addition, stocks present off the west coast of the Queen Charlotte Islands and in the Southeastern area of Alaska have a higher percentage of interchange than other areas (Beamish and McFarlane, this symposium). The greater southward movement of adult fish from the Southeastern area may partially compensate for the northward movement of juveniles.

In summary, new age information indicates that the time series of catch and effort data is not sufficient to allow the use of general production modelling. Biological characteristics such as longevity, strong year-classes, and stock boundaries have been identified and must be considered when evaluating exploitation strategies. It appears that at present we do not have the required assessment tools for adequate management of this species. For this reason, we recommend a very conservative management strategy until the implications of the new biological information have been assessed and the responses of the stocks to the fishery are more clearly understood.

Acknowledgments

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References

Beamish, R. J. and D. E. Chilton. 1982. Preliminary evaluation of a method to determine the age of sablefish (Anoplopoma fimbria). Can. J. Fish. Aquat. Sci. 39: 277-287.

Beamish, R. J. and G. A. McFarlane. 1983. Summary of results of the Canadian sablefish tagging program. (This symposium).

Bracken, B. 1982. Sablefish (Anoplopoma fimbria) migration in the Gulf of Alaska based on gulf-wide tag recoveries, 1973-1981. Alaska Dept. of Fish & Game Informational Leaflet No. 199: 24 p.

Deriso, R. B. 1980. Harvesting strategies and parameter estimation for an age-structured model. Can. J. Fish. Aquat. Sci. 37: 268-282.

Fox, W. W., Jr. 1970. An exponential surplus-yield model for optimizing exploited fish populations. Trans. Amer. Fish. Soc. 99(1): 80-83.

Gulland, J. A. 1961. Fishing and the stocks of fish at Iceland. U.K. Min. Agric. Fish. Food, Fish Invest. (Ser. 2) 23(4): 52 p.

Ketchen, K. S. 1977. A summary of foreign and domestic fisheries for groundfish off the west coast of Canada. Fish. Res. Board Can. MS Rep. 1423: 35 p.

Ketchen, K. S. Editor. 1980. Assessment of groundfish stocks off the west coast of Canada. Can. Data Rep. Fish. Aquat. Sci. 185: 213 p.

Ketchen, K. S. and C. R. Forrester. 1954. The sablefish fishery of British Columbia. Bull. Pacific Mar. Fish. Comm. 3: 58-72.

McFarlane, G. A. and R. J. Beamish. 1983a. Biology of adult sablefish (Anoplopoma fimbria) in waters off western Canada. (This symposium.)

1983b. Preliminary observations on the juvenile biology of sablefish (Anoplopoma fimbria) in waters off the west coast of Canada. (This symposium.)

Sasaki, J. 1982. Condition of sablefish stocks in the North Pacific. (Document submitted to the International North Pacific Fisheries Commission.) 17 p. Fisheries Agency of Japan, Tokyo, Japan 100.

Schnute, J. 1977. Improved estimates from the Schaefer production model: theoretical considerations. J. Fish. Res. Board Can. 34(5): 583-603.

Westrheim, S. J. Editor. 1980. Assessment of groundfish stocks off the west coast of Canada in 1979 and recommended total allowable catches for 1980. Can. Data Rep. Fish. Aquat. Sci. 208: 265 p.

Management strategies for sablefish off California, Oregon, and Washington

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Introduction

The Pacific Coast Groundfish Plan for the management of the California, Oregon and Washington groundfish fishery was approved by the Department of Commerce in January 1982. The stated objectives of that fishery management plan are:

(A) Promote the availability of quality seafood to the consumer.

(B) Promote rational and optimal use, in the biological, social and economic senses, of the regions fishery resources as a whole.

(C) Provide a favorable climate for existing domestic commercial and recreational groundfish fisheries within the limitations of other objectives and guidelines. When change is necessary, institute the regulation which accomplishes the change while minimizing disruption of current domestic fishing practices, marketing procedures, and environment.

(D) Provide for the orderly development of domestic groundfish fisheries, including new fisheries consistent with (B) and (C) above, at the expense of foreign participation.

(E) Provide for foreign participation in the fishery consistent with (B), (C), and (D) above, to take that portion of the optimum yield not utilized by domestic fisheries.

(F) Prevent over fishing of stocks which can be managed as a unit, including rebuilding those stocks which are now depleted.

(G) Minimize gear conflicts among users.

(H) Recognizing the multispecies nature of the fishery, establish a concept of managing by species and by gear, or by groups of interrelated species.

(I) Attain an information flow on the status of the fishery and the fishery resource which allows for informed management decisions as the fishery occurs.

Strategies

Strategies for the achievement of these objectives are presented in the plan. The Pacific Council's managment strategy contrasts sharply with the North Pacific Council's quota management strategy and efforts to replace foreign catch with domestic catch as discussed by Jeffrey Povolny. No foreign fishing has been allowed for sablefish since 1976. The Pacific Council is seeking alternatives to total cessation of fishing while recognizing the need to keep the total catch within bounds. Most groundfish species are not given a numerical OY but are managed by points of concern and gear restrictions. Sablefish is one of five species given a numerical OY because there is a directed fishery for this species. The specific management measure selected for sablefish is a trip limit to be implemented when annual landings reach 95% of the OY. A trip limit rather than a total prohibition of landings was selected to minimize discards while discouraging targeting. The trip limit is to equal the percent sablefish in trawl landings containing sablefish, but not exceeding 30% of any load. A trip limit of 3,000 pounds was imposed 27 October 1982 after the OY had been exceeded. This regulation allowed trawlers to continue fishing as long as they shoveled over any sablefish in excess of the trip limit, but made set gear fishing unprofitable for the remainder of the year. Trap Fishermen had no alternate fishery to turn to and were very upset by what seemed to them to be a clear act of favoritism to trawlers. Many longline fishermen felt the same.

Some members of the Groundfish Task Group,formed at the Council's December 1982 meeting,felt a quota or season would have to be along the entire coast or fishing would continue in closed areas and be delivered in adjacent open areas, and would shut down processing plants in closed areas. The Pacific coast groundfish fishery depends upon the fresh fish market in which an interruption in supply results in a loss of market. A five day per month closure was suggested as a solution to this interruption of supply problem but management costs become too high with several short closures per year. Some fishermen called for extending the trip limit through March 1983 and beginning the fishing year, for the purpose of accumulating landings, on April 1, 1983 so there would be a reduced chance of having to institute a trip limit during the fall when weather is still good. They hoped any trip limit necessary would be instituted in the winter. This suggestion did not have enough support to be adopted but other measures were taken to resolve complaints resulting from the 1982 trip limits.

Given the expanding sablefish markets, the knowledge that trawlers have been catching and dumping sablefish for over 20 years for lack of markets, and the need to minimize disruption of existing fisheries, the Task Group recommended that the council's management strategy be composed of one or more of the following components: trip limits set,such that OY is not exceeded in the calendar year; a minimum size limit and/

or an incidental catch limit of small sablefish to discourage targeting on the younger fish. The Council selected an incidental catch allowance of sablefish less than 22 inches total length north of Point Conception as the method that would cause the least disruption of existing fisheries. A 22 inch size limit is expected to reduce trawl landings. An incidental catch allowance of short fish is expected to minimize discards while discouraging targeting on small sablefish. Boats may land up to 333 fish, one thousand pounds or ten percent by weight of the sablefish aboard. It is hoped that this size limit will reduce landings sufficiently to eliminate the need for a trip limit at the end of the season and more evenly balance between trawlers and set gear fishermen the burden for keeping landings within the OY.

The plan directs the team to continuously monitor the fishery and report to the council whenever information available indicates a change in harvest guidelines is needed to meet plan objectives. The team is to base recommended adjustments to OY on the same points of concern used to base recommendations for restrictions on the harvest of non OY species. These points of concern are:

1. Exploitable biomass or spawning biomass is below a level expected to produce MSY for the species/species complex under consideration;

2. Recruitment is substantially below replacement level;

3. Fishing mortality rate exceeds that required to take ABC for the calendar year;

4. Catch for the calendar year is projected to exceed the best current estimate of ABC; or

5. Any other abnormality in the biological characteristics of the species/species complex is discovered, such as changes in age composition, size composition and age at maturity.

The team will recommend the management measure that will both relieve the stress and achieve the plan objectives if it determines that the identified point of concern truly indicates biological stress.

The total coastwide OY was set at 13,400 mt when the groundfish plan was adopted based on 1977 NMFS rockfish survey data indicating a sablefish biomass of 15,200 mt in water shallower than 250 fms. Distributional studies (Alverson et al., 1964 and Low, 1977) indicated 75% of the exploitable biomass lies deeper than 250 fms. This adjustment produces a total biomass estimate of 60,800 mt. An instantaneous natural mortality rate of .22 was accepted and applied to the formula MSY = MB produced the 13,400 mt estimate. The plan warns the reader that the survey was not designed to sample sablefish but this is the best available estimate. The plan calls for annual adjustments and permits adjustments at any time. The council may raise the OY by 30% each year and they did raise the 1982 OY to 17,420 mt at the December 1982 meeting, causing some to jokingly suggest that the Council's strategy was to keep the OY greater than the expected domestic annual harvest. There is no lower limit to an OY adjustment. A separate OY of 2,500 mt, that is part of the total OY, was established for Monterey Bay because of severe declines in CPUE and size of fish landed. This OY was not increased.

Speculations on Status of Stock

There is little precision in current estimates of stock status because catches have been well below MSY throughout most of the fishery's history on most fishing grounds. The exploitation rate increased so rapidly in the Monterey area where MSY was exceeded that MSY can't be estimated with any precision. I expect the MSY of grounds fished primarily from Monterey Bay ports to be near 1,000 mt per year and near 20,000 mt in the Washington to California region if sablefish densities are similar coast wide. The current OY is very close to this range. Annual increases of 30% are too great for precise estimation of MSY before it is severely exceeded. Annual increases, 5% or less, will permit calculation of an F, giving maximum economic return and given the considerable price differential paid for large fish, economic return is maximized at harvest rates well below MSY and well before points of concern one to four are reached. Only point five, an abnormality in biological characteristics as change in age or size composition and age at maturity, occurs before economic loss.

The history of the U.S sablefish fishery in the Gulf of Alaska, 1906-1982

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Introduction

The U.S. sablefish fishery is one of the oldest fisheries in Alaska and landing documents exist back to 1906. Acutal harvest probably occurred as early as the late 1800's since historic records show that the fishery was well established by 1907.

Much of the historic Alaskan catch and effort information exists as loose notes that have been accumulated over time and it is impossible to assign credit to the authors of most of the material. This report is a summary of known information on the fishery.

Harvest

Before 1913 all landings were incidental to the halibut fishery and annual harvests did not exceed 200 tons until 1916. In 1916, the market name was changed from blackcod to sablefish to improve market demand. Catch exceeded 700 tons during 1917 and 1918 and then dropped below 400 tons until 1923. After 1924 the landings declined until 1935. Fluctuations were apparently related to market demand for fish and fish liver for Vitamin A manufacture during the war years.

The harvest fluctuated wildly after 1947 according to market demand and cold storage holdings with one or two years of high harvest which saturated the market, followed by a sharp decline until the fish on hand were sold. The general trend, however, was one of decline until the late 1960's with the average annual harvest from 1966-1970 the lowest since the depression era slump of 1931-1935.

Gear

Until 1948 sablefish were fished with conventional halibut gear modified slightly to fish deep water. The first inovation in the fishery occurred in 1948 when a vessel named the Wolverine introduced smaller hooks placed at 9-foot intervals rather the 13- 18-foot spacing of halibut gear. A temporary increase in catch per skate was noted in both inside and outside fisheries after that introduction.

In recent years hooks as small as 6/0 spaced at 3-foot intervals are being used. Several automated systems have entered the fishery since 1979.

Pot gear was first allowed in 1970 and by 1973 a fairly large fishery was established in the southern inside area and Dixon Entrance. That gear type averaged over 33% of the total harvest from 1973-1975. Since 1979 pot gear has been responsible for less than 5% of the total harvest.

Management Areas

Southeastern Alaska has historically been separated into inside and outside waters with the approximate division between these waters occurring at the surf line. For state management, the Yakutat area extends from Cape Fairweather to Cape Suckling. However, the Yakutat INPFC area extends from 137° W. longitude to 147° W. longitude. Adult sablefish are generally fished in depths greater than 200 fathoms and so most offshore catches are beyond three miles, outside of state jurisdiction.

Southeastern Alaska is further separated into management districts, numbered progressively from 1 through 16 from south to north. Although these districts did not go into effect until the late 1960's, the areas represented are based on historic management.

The southern inside area includes districts 1-8 excluding district 4 on the outer coast of Prince of Wales Island. The northern inside area includes districts 9-15 excluding sections 13A and B along the outer coasts of Baranof and Chichigof Islands.

Fishery Monitoring

Vessel logs were maintained in the sablefish fishery starting in 1932. Data was collected and summarized by the Fish and Wildlife Service through 1949 and then transferred to the Alaska Territorial Fisheries Board in 1950.

In the inside fishery which up to that time was generally confined to the northern area; pounds per skate declined steadily from 1932 until 1960 when the logbook program was discontinued.

The catch per unit of effort (CPUE) in the outside area off Southeastern fluctuated more, possibly in response to the more sporadic fishery in that area, but still a general declining trend in pounds per skate was observed.

Average size of fish declined steadily in the fishery as well as numbers of fish per skate. Data from the inside area is more complete and a decline in average size from 8 pounds in 1935 to 6.3 pounds in 1946 was observed. Data from the outside fishery is not as complete, but average weight declined from 7.3 pounds in 1935 to 6.5 pounds by 1946.

No monitoring of fishery performance occurred from 1960 to 1978 when an attempt was made by National Marine Fisheries Service (NMFS) and Alaska Longline Fishermen's Association (ALFA) to introduce a cooperative logbook program. The program was voluntary and returns were not actively solicited and so the program produced little useful material.

The Alaska Department of Fish and Game (ADF&G) began a port sampling - skipper interview program in 1981. Although the program concentrated on catches from the northern inside area fishery, data from the offshore fisheries was also collected. Catch per skate in the offshore fishery so far this year is 52.5 pounds based on a 150 hook skate and the average dressed weight is 5.4 pounds. Catch per skate in the northern inside area was 88.5 during the 1982 season and average weight was 5.5 pounds. Pounds per hook rather than pounds per skate are now used for comparison. Current data does indicate that declines in CPUE and average fish size have continued to date.

Regulations

Regulations have had an impact on the Alaskan sablefish fishery and a regulation review is necessary to fully understand the fishery.

The first regulations were imposed in 1945. A memo discussing management action from L.N. Kolleen of Fish and Wildlife Service, dated April 10, 1950 cited a 55% decline in pounds per skate between 1937 and 1944 and a decline in average weight from 8 pounds in 1934 to 6.5 pounds by 1944 as justification for shortening the season in 1945 to decrease fishing intensity. Further justification was given: To "afford protection to the stocks during the winter spawning period" and to "reduce the destruction of halibut taken inadvertantly on sablefish gear during the early spring period", the 1945 season was shortened by 2.5 months with a closure imposed for all areas from December 1st of one year until March 15th of the next year. It is unclear from the memo whether the action went into effect in December 1944 or December 1945.

The closed period was extended until May 1 in the 1947 season. Although that action called for a four month closure in reality it effected a longer closure. Since the May 1 sablefish opening was concurrent with halibut openings at that time and the same fleet was involved in both fisheries, the directed sablefish fishery did not start until after the Area II halibut closure. This restricted the fishery to the summer and fall seasons. It was noted that the incidental catch of halibut declined significantly as a result of this action, but the catch per skate of sablefish continued to decline.

The December 1 to May 1 closure remained in effect for all districts through 1962 when additional restrictions were imposed. In that year all waters of northern Southeastern including the outer coast of

Baranof and Chichigof were open only from August 15 to October 15. Those regulations remained in effect until 1970 when the northern Southeastern season changed to September 15 through November 15 and pot gear was allowed as legal gear. Sablefish were allowed as incidental catch in longline and trawl fisheries for other species up to 10% by weight of each landing in 1968.

In 1972, the closures were relaxed somewhat and in the northern area the season was extended by 15 days, to September 1 through November 15. All other districts were open from April 1 through December 30. The season was the same in 1973, however, a quota of 1,000,000 was adopted for the northern area and the season was to be closed if the quota was reached prior to the November 16 closing date. The incidental catch allowance was increased to 20% in 1972.

The 1976 season in the southern Southeastern districts including the outer coast of Prince of Wales Island was shortened to June 15 to November 15. The southern and northern outside areas were both opened to year-round fishing by emergency order in 1977 "In order to allow U.S. fishermen to harvest sablefish off the coast of Southeastern Alaska in competition with foreign effort".

The incidental catch allowance was abolished in 1978 because it was being abused and sablefish became a prohibited species in U.S. fisheries for other species. In 1979 the northern area quota was reduced to 850,000 pounds to reflect the removal of the outer coast from the quota area.

Guideline harvest ranges were established for both the southern and northern areas in 1980. The northern area range was 500,000 to 900,000 pounds and the southern area range was 125,000 to 500,000 pounds. These ranges were established by computing average annual harvest over the previous ten years and allowing two standard deviations from the mean to determine a range.

Fishery performance is monitored in-season and a cutoff date announced according to indicators in the fishery. Also in 1980 vessels entering the northern fishery were required to register within 72 hours of the start of fishing operations.

Minor changes were introduced in 1982 including lowering the lower end of the northern area guideline harvest level from 500,000 to 300,000 pounds and the restriction of the area north of Cape Addington to longline gear.

The Alaska Board of Fisheries passed a regulation to go into effect in 1983 closing the outside districts from January 1 through March 15. The north Pacific Fisheries Management Council has not endorsed a parallel proposal for Federal waters and unless action is taken prior to next year, management problems are expected.

The Fish and Wildlife Service and Alaska Territorial Board of Fisheries had control of fisheries regulations until statehood. The regulations in place in 1959 were continued by the Alaska Board of Fisheries. Although the offshore quota did not technically apply to waters beyond three miles, very little fishing occurred prior to the May 1 opening and less than 150 m.t. round weight cummulative harvest was reported landed prior to May 1 for all years from 1969 through 1976. Most of that limited harvest came from Dixon Entrance. It was not until 1977 that the outer coast of Southeast Alaska was open to year-round fishing.

After statehood federal regulations did not become an important issue until the passage of the Magnuson Fisheries Conservation and Management Act (MFCMA) in 1976. With the act in place, fishermen began to request relief from competition with foreign longline fleets in the southeastern area. Ironically, it was an agreement by the Japanese North Pacific Longline-Gillnet Association to voluntarily withdraw from the area east of Yakutat Bay and not Federal action that gave the needed relief. That action went into effect in July 1978 and the U.S. offshore fishery expanded rapidly over the next few years. That closure was enforced by a Federal regulation in 1979.

Emergency order closures were imposed in the northern inside area in 1973, 1979, 1981 and 1982. In 1982 the outside southeastern areas including both State and Federal waters were closed by joint action for the first time ever on August 2nd. The southern inside area was also closed for the first time in 1982 on September 30th.

It is apparent that over time regulations have had a significant impact on the U.S. harvest of sablefish in the Southeastern area and will continue to effect harvest levels and distribution of effort in the future.

Distribution of Harvest

Distribution of harvest has been effected by markets, regulations, and stock conditions. Up until the mid-1940's most of the U.S. sablefish harvest came from the inside northern area. After 1940 catch per skate had declined in the inside areas to the point much of the effort moved offshore. By 1944, 32% of the catch was reported from outside areas and between 1945 and 1953, 58% of the harvest was from outside areas. With declining effort most of the fishery again occurred in the inside areas between 1960 and 1977.

One anonymous report stated that low harvests from 1968 to 1971 were the result of a lack of effort due to low prices, bad weather, and fishermen remaining in the fall salmon fishery or expanding king crab fishery. By the time the market recovered in 1972 the Japanese fishery was fully established offshore and the U.S. and Canadian fisheries were effectively displaced. Stock abundance decreased in the northern inside areas by the end of the 1972 season, indicating that stocks had not recovered during the four years of low harvest, or were being influenced by the intense foreign fisheries offshore.

Information that is available indicates that U.S. harvest in the Yakutat area was never large in proportion to the harvest in the Southeastern area, but that some fishing occurred as far west as Middleton Island as early as the 1920's.

From 1973 through 1975, 33% of the total U.S. harvest came from the southern inside areas which represented a new fishery. There was very little effort in the offshore areas until 1978 when the Japanese fleet withdrew. Since 1978 the proportion of offshore harvest has increased steadily. In 1982, 48% of the total U.S. Eastern Gulf harvest was from the offshore Southeastern area, 26% from the Yakutat area, 19% from the northern inside area and 7% from the southern inside area.

Impact of Foreign Fishing

Canadian fishery.

The first foreign fishery to enter Alaskan waters was the Canadian longline fishery which reported landings off Southeastern Alaska as early as the late 1920's.

For the period between 1951 and 1953 the Canadian catch from Southeastern Alaskan waters averaged approximately 45% of annual Canadian landings (Ketchen & Forrester, 1954), or about 600 m.t. per year.

Although Canadian effort was reported as far west as Middleton Island, most of the effort was restricted to the Southeastern area and in 1951 and 1952 IPHC statistical area 16 off Cape Ommaney yielded the largest catch of any area fished by Canada. The CPUE off Southeastern Alaska was also the highest in the Canadian fishery (Ketchen & Forrester, 1954).

Canadian catch data from Alaska is lacking between 1953 and 1969. However, by 1969 the Canadian fishery in Alaska declined and the harvest averaged less than 25 m.t. between 1969 and 1978, the last year of Canadian harvest in Alaska. It is assumed that in the later years of the fishery most of the landings were incidental to the halibut fishery rather than a directed effort.

Japanese fishery.

The Japanese longline fishery entered Southeastern Alaska in 1968 and over 6349 m.t. were harvested that first year. The fishery peaked in 1972 at 9301 m.t. and then began to decline. The average annual harvest for the 10 years of the Japanese fishery off Southeastern exceeded 6350 m.t. The 1977 harvest was less than 60% of the 10 year average.

U.S. fishermen were being regulated because of observed declines in CPUE at average harvests of less than 2000 m.t. between 1945 and 1965 and could not compete effectively with the intense year-round effort of the Japanese high seas fleet. Canadian effort in Alaskan waters after 1969 may have been effected by the Japanese fishery as well.

Summary

The sablefish fishery is one of the oldest in the State. It has been impacted by markets, declining stock abundance, regulations and the presence of foreign fleets in or adjacent to areas of harvest.

The fishery is again expanding and since 1979 has approached historic levels. Recent landings in Seward and Kodiak are encouraging and slow but steady expansion of the U.S. fishery into other areas is expected. The rate of expansion will depend on the same factors that have influenced the fishery in the past.

<u>Bibliography</u>

Ketchen, K.S. and C.R. Forrester, 1954. The sablefish fishery of British Columbia. Pac. Marine Fish. Commission Bulletin 3, pp. 58-72.

Session II

Age and Growth

Growth of sablefish in Southeastern Alaska

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Introduction

A well defined relationship among age, length, and weight is a prerequisite for accurately determining optimal yield and for understanding the life history strategy of the Gulf of Alaska sablefish population. Early attempts to determine maximum sustained yields for Gulf of Alaska sablefish (Low et al, 1976; Low and Wespestad, 1979; Anon., 1978) were based on stock production models which require no explicit formulation of growth. The fit of these models to the available catch and effort data was poor since the data represented an aggregation of growth, mortality, recruitment, and harvest processes and encompassed wide temporal and spatial variation in catch rates, harvests, and effort, with unknown amounts of migration among areas. More accurate prediction of optimal yield requires explicit formulations of growth, mortality, recruitment, and harvest processes and the temporal, spatial, and age structure of the population. Recent sablefish modeling efforts (Balsiger and Terry, 1981; Funk, 1983) have included explicit growth submodels, but have been hampered by the lack of available data from the Gulf of Alaska area for estimating the parameters of the growth models.

Early studies of sablefish growth in British Columbia (Kennedy and Pletcher, 1968), Oregon (Pruter, 1954), and the Bering Sea (Saski et al, 1975) indicated that sablefish were a relatively fast-growing and shortlived species. Recently, Beamish and Chilton (1982) reported a considerably different impression of sablefish growth using the "break-and-burn: otolith reading technique. They describe a species with very rapid initial growth, but very slow growth upon reaching maturity, with many members of the population surviving to very old ages. These newer, slower growth rates have a profound impact on the yield that can be obtained from sablefish stocks on a sustained basis. They also point to a radically different life history strategy from that described in earlier studies.

This paper describes sablefish growth from Southeastern Alaskan waters and compares the growth pattern to published values from other areas. Unfortunately, the methods of age determination have varied widely among sablefish growth studies so that observed differences in growth among areas could be attributed to differences in aging technique as well as actual difference in growth. Preliminary results of this study of growth of sablefish in Southeastern Alaska were previously reported in Bracken (1981).

Methods

Sablefish otoliths were collected from four sites in Southeastern Alaska for age determination (Figure 1). The sablefish ranged from 22 to 80 cm fork length and were aged with surface reading techniques. An allometric growth model was fit to log-transformed lengths-at-age using least squares regression. An investigation of the effects of the

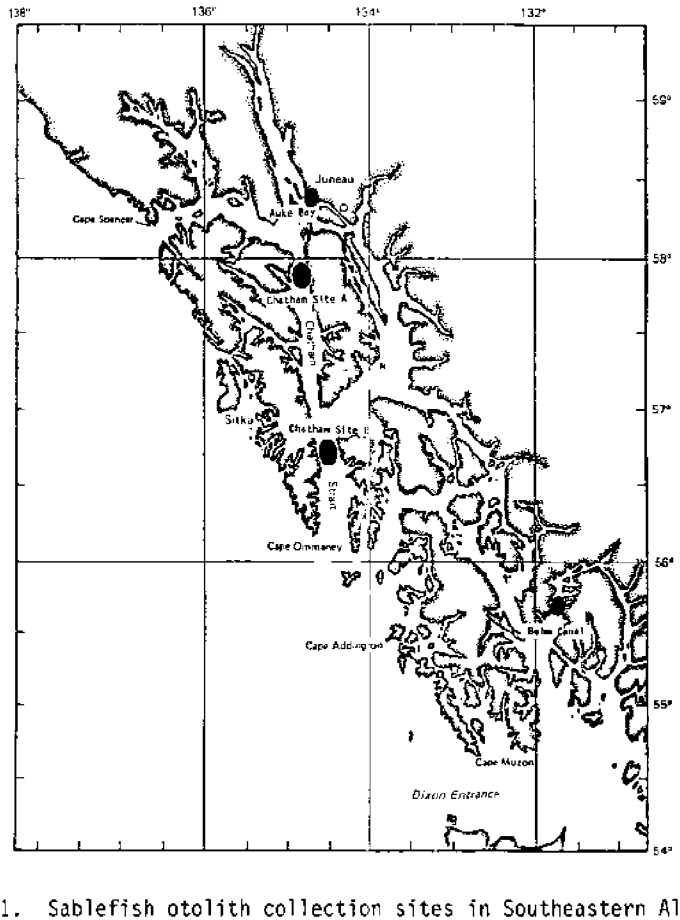

Figure 1. Sablefish otolith collection sites in Southeastern Alaska.

logarithmic transformation showed that the assumptions required for least squares procedures were satisfied by the log-transformed data. The log-transformed allometric model fit the data as well as the von Bertalanffy model in most cases and was used for comparing growth curves because of its simple, linear form.

Sablefish length-at-age data from northern British Columbian waters were also examined and compared to the data from Southeastern Alaska. The methods used to collect these data are described in Beamish and Chilton (1982). Data from the sample sites described as "west coast of the Queen Charlotte Islands" and "inlets east of Queen Charlotte Sound" in Beamish and Chilton (1982) are pooled together and are referred to as "northern British Columbia." These samples are pooled together to approximate the spatial variation in sablefish growth in all northern British Columbian waters. Beamish and Chilton (1982) describe the otolith "break-and-burn" technique used to determine the ages of these specimens.

Results

Variation in growth among sites within Southeastern Alaska.

Adult sablefish captured at Chatham Strait site A, Chatham Strait site B, and at the Behm Canal site were compared for differences in growth. The sample of sablefish from Auke Bay consisted only of smaller juveniles and could not be directly compared with samples from the other sites. Analysis of covariance (ANCOVA) techniques were used to compare growth data from the three sites using the linear, log-transformed allometric model. Variances among the three sites were not found to be heteroscedastic for males or females, using Barlett's test of homogeneity of variance. For male sablefish there is no significant difference in slope (parameter b of the allometric model) of log-transformed allometric models fitted independently through the growth data from the three sites (Figure 2). Intercepts (parameter a of the allometric model) are significantly different ($p < .005$). Growth was fastest at the Behm Canal site and slowest at Chatham Strait site A.

For female sablefish there was also no significant difference in the slopes of the three independent regressions (Figure 3). Intercepts were significantly different ($p < .005$). As for males, growth was fastest at the Behm Canal site and slowest at Chatham Strait site A.

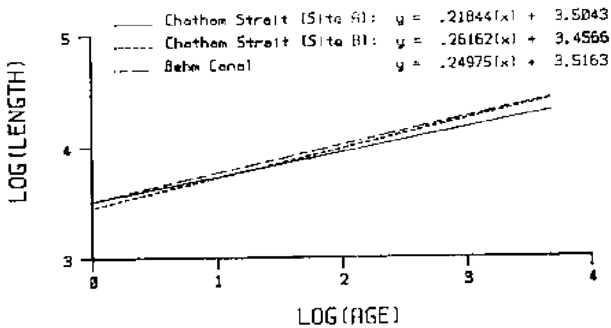

Figure 2. Log-transformed allometric growth models fit to male sablefish length-at-age data from sites within Southeastern Alaska.

Comparison of Southeastern Alaska and northern British Columbia data.

Growth data from all four Southeastern Alaskan sample sites were pooled together and compared with data pooled together from the two sample sites in northern British Columbia. The amount of variability found among the sample sites in Southeastern Alaska is assumed to approximate the magnitude of the variance component among all sites within northern British Columbia. Variances between the two areas were not found to be heteroscedastic for males or females, using an F ratio test for homogeneity of variance. Slopes of the log-transformed allometric model fitted through the growth data from each area were very highly significantly different ($p < .001$) for both males (Figure 4) and females (Figure 5).

The untransformed length-at-age data and fitted models are shown for males and females in Figures 6 and 7 respectively. The Southeastern Alaskan data clearly describes much slower growth at early ages. The differences between the growth curves for the two areas decreases with age. The Southeastern Alaskan lengths lag behind the British Columbian lengths by two to three years of growth. The northern British Columbian data describes a species with very rapid initial growth and relatively little growth beyond age six or seven.

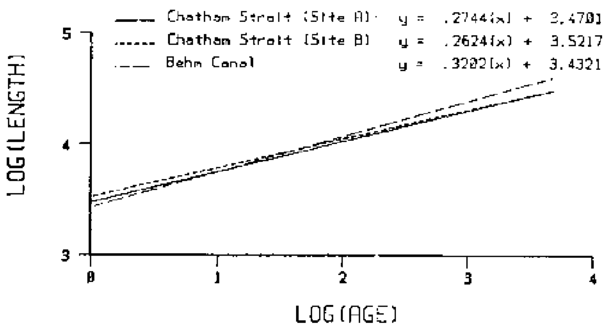

Figure 3. Log-transformed allometric growth models fit to female sablefish length-at-age data from sites within Southeastern Alaska.

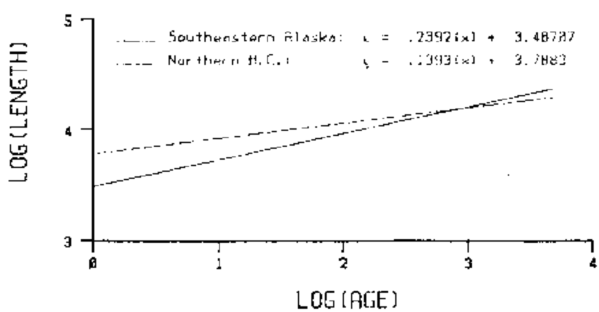

Figure 4. Log-transformed allometric models comparing male sablefish growth in Southeastern Alaska and northern British Columbia.

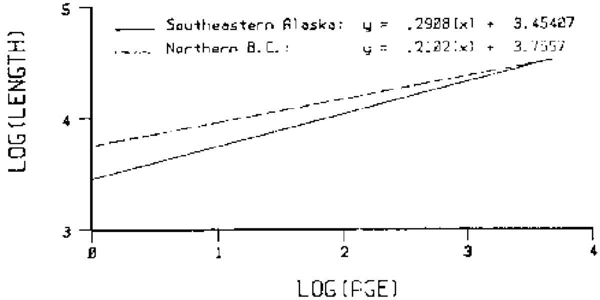

Figure 5. Log-transformed allometric models comparing female sablefish growth in Southeastern Alaska and northern British Columbia.

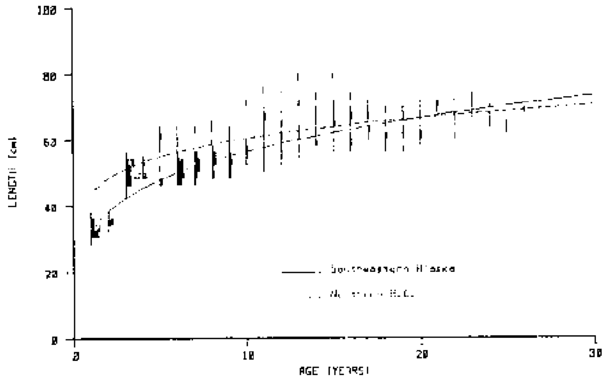

Figure 6. Comparison of length-at-age observations and fitted allometric models for northern British Columbia and Southeastern Alaska male sablefish.

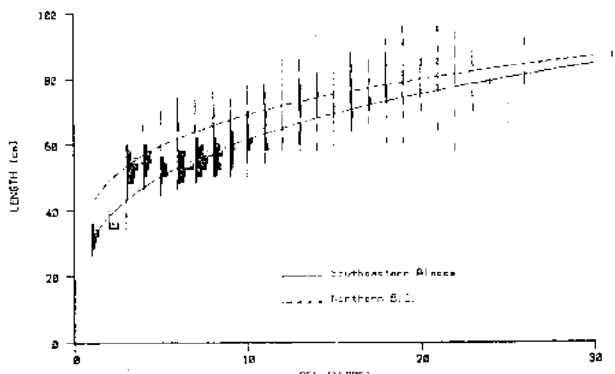

Figure 7. Comparison of length-at-age observations and fitted allometric models for northern British Columbia and Southeastern Alaska female sablefish.

Discussion

Sablefish growth in both northern British Columbia and Southeastern Alaska is characterized by an initial period of fast growth, followed by slower asymptotic growth. The change in the rate of growth appears to be rather abrupt and coincides with the approximate age of sexual maturity. This relatively rapid transition from fast to slow growth is probably indicative of fundamental changes in physiology and behavior associated with the onset of sexual maturity. A change in rate of growth at sexual maturity is well established in other species and separate growth curves are often fit to data before and after the age of sexual maturity (e.g., Somerton, 1979). For sablefish (Low et al, 1976) obtained better fits of the von Bertalanffy model by partitioning sablefish length-at-age data into two size groups, although the size categories did not correspond to the age of sexual maturity. However, a single growth expression is often desirable for simplicity in modeling applications, even though the fit may be less precise.

The Southeastern Alaskan sablefish length-at-age data describe slower initial growth compared to the northern British Columbia data. It is not possible to determine from the length-at-age data whether the observed differences in sablefish growth between Southeastern Alaska and northern British Columbia are due to differences in aging technique or to actual differences in growth in the two areas. The fact that the differences among sites within Southeastern Alaska were relatively minor, though significant, should imply that similar relatively minor differences in growth would be expected between Southeastern Alaska and northern British Columbia. Analysis of growth from following length-frequency modes indicates that surface reading may have overestimated ages. This is unusual since surface-read otolith ages are normally less than "break-and-burn" read ages (Beamish and Chilton, 1982). However, the surface-read data from Southeastern Alaska also produced fewer older aged fish than in British Columbia. This indicates that larger fish may have been underaged. A review of the surface aging techniques suggests that two extra annuli could have counted, one at the focus and one at the outside edge of the otolith. Adjusting the Southeastern Alaskan ages downward by two years brings the fitted growth curve much closer to the British Columbian curve. This type of error along with underaging of older surface-aged fish is one possible explanation for the observed differences in the length-at-age data between Southeastern Alaska and northern British Columbia. The observed differences could also be due to actual differences in growth rate between the sizes. Double reading of otoliths using both aging techniques on the same otolith are essential in order to determine whether the observed differences in length-at-age data are due to aging error or to actual variation in the rate of growth.

Acknowledgements

Sandy McFarlane of the Pacific Biological Station, Canada Department of Fisheries and Oceans, graciously provided sablefish growth data from northern British Columbia. Ruth Mandapat of the Washington Department of Fisheries Aging Laboratory read the Southeastern Alaskan otoliths. Phil Rigby donated vessel time for capturing the Auke Bay sample of juvenile sablefish.

Literature Cited

Anonymous. 1978. Report of the meeting between U.S. and Japanese scientists for the exchange of information on the condition of fishery stocks in the Bering Sea and northeastern Pacific. U.S. Dept. of Commerce, NOAA, NMFS, NWAFC, Seattle, WA (unpubl.).

Beamish, R.J. and D.E. Chilton. 1982. Preliminary Evaluation of a method to determine the age of sablefish (Anaplopoma fimbria). Can. J. Fish. Aquat. Sci. 39:277-287.

Bracken, B.E. 1981. Interim report on the results of sablefish tagging experiments in Southeastern Alaska 1979-1981. AK Dept. Fish and Game, Juneau, Alaska 20 pp. (unpubl. manuscr.).

Funk, F.C. 1983. A spatially compartmented model for sablefish populations in the eastern Gulf of Alaska. AK Dept. Fish and Game, Juneau, AK (manuscr. in prep.).

Kennedy, W.A. and F.T. Pletcher. 1968. The 1964-1965 sablefish study. Fish. Res. Bd. Can. Tech. Rep. 74:24p.

Low, L.L. and V. Wespestad. 1979. General production models on sablefish in the north Pacific. Unpubl. manuscr. 16 p. Northwest and Alaska Fish. Cent., NMFS, NOAA, 2725 Montlake Blvd. E., Seattle, WA 98112. (Submitted to Int. North Pac. Fish. Comm. by the U.S. Natl. Section).

Low, L.L., G. Tanonaka, and H.H. Shippen. 1976. Sablefish of the northeastern Pacific Ocean and Bering Sea. Northwest and Alaska Fishery Center processed report, NMFS, Seattle, WA 115 p.

Pruter, A.T. 1954. Age and growth of the Oregon sablefish, Anoplopoma fimbria. Bull. Pac. Mar. Fish. Comm. 3:122-128.

Sasaki, T., L.L. Low, and K.N. Thorson. 1975. Sablefish (Anaplopoma fimbria) resources of the Bering Sea and northeastern Pacific Ocean. NMFS, NOAA, Northwest and Alaska Fish. Center, Seattle, WA. Unpubl. manuscr. (cited in Low et al, 1976).

Somerton, D.A. 1979. Fitting straight lines to Hiatt growth diagrams: a re-evaluation. J. Cons. int. Explor. Mer. 39(1):15-19.

Terry, J. and J.B. Balsiger. 1981. A simulation model for sablefish in the Gulf of Alaska. U.S. Dept. of Commerce, NOAA, NMFS, NWAFC. Seattle, WA (unpubl. manuscr.).

Zenger, H.E. 1981. Relative abundance and size composition of sablefish in coastal waters of Southeast Alaska, 1978-1981. NOAA Tech. Mem. NMFS F/NWC- 20, 42pp.

Biology of adult sablefish *(Anoplopoma fimbria)* in waters off western Canada

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Abstract

Adult sablefish are abundant along the west coast of British Columbia at depths exceeding 200 m and are most abundant between 600 and 800 m.

Spawning takes place at depths greater than 300 m and no appreciable spawning migration occurs. Length and age at 50% maturity is approximately 58 cm and age 5 for females and 52 cm and age 5 for males. Sex ratio of the catch appeared biased and varied between areas, however, for all areas combined the male:female ratio was 1:3 during the spawning season and 1:1.5 during all other sampling periods.

In Canadian waters sablefish fed predominately on rockfish, Pacific herring and squid. A very preliminary estimate of biomass using the tag-recapture data was approximately 37,000 t.

Growth curves, expressed in terms of the von Bertalanffy equation, show that growth is similar between areas. However, differences in size and sex ratio may indicate the presence of discrete stocks of slower growing fish. In all areas, less than 10% of the males and greater than 55% of the females are larger than 70 cm. There was considerable variation between and within areas and years and average size in the fishery varies depending on capture location and sex ratio.

Mean annual growth of mature fish ranged from 0.17-0.26 cm for males and 0.55-0.66 cm for females. Corroboration was obtained from recaptured tagged sablefish.

No size segregation by depth interval for adult sablefish has been observed in the Canadian zone. The majority of fish in the fishery range from 4 to 35 years of age, however, some sablefish reach an age of

55 yr. Growth of males was reduced before that of females and both males and females continued to live for long periods during which little growth occurred. The importance of longevity remains to be determined, however, it may be an adaptive feature for maintaining the population, particularly in times of unfavorable environmental conditions.

Strong year-classes are an important component of the stock. Strong year-classes occurred in 1977, in the late 1960s, the late 1950s or early 1960s, and the early 1950s. The strong 1977 year-class may be as large as the total adult biomass in the Canadian zone.

Introduction

Sablefish have been exploited off Canada since the late nineteenth century, however, intensive exploitation did not occur until the late 1960s when the Japanese fished off the Canadian coast outside of Canada's 12-mile territorial limit. As Canadian effort in this fishery was minimal there was little effort expended on studies concerned with the biology of sablefish. After extension of the fishery jurisdiction zone to 200 miles (1977), responsibility for management of the resource and interest by the domestic fleet resulted in increased research effort being allocated to sablefish. This report summarizes our current knowledge of the biology of adult sablefish in the Canadian zone (Fig. 1).

Methods

Material for this report was assembled from research studies conducted by the Pacific Biological Station between 1977 and 1982, and from commercial trap catches collected by vessel observers. Commercial catch data were taken from Department of Fisheries and Oceans annual reports (Smith, 1978, 1979, 1980, 1981; Leaman, 1982).

Fishing, tagging and sampling methods are described in Beamish et al. (1978, 1979, 1980, 1983). Representative lots of sablefish were sampled for length, sex, maturity, weight and age determination. Stomach contents were examined from sablefish captured in sunken gill nets in 1979 and trawl nets in 1980. Sablefish were measured for fork length to the nearest centimeter, and beginning in 1980 measured to the nearest millimeter.

Age was determined from broken, polished and burnt otoliths as described by Beamish and Chilton (1982). Growth was assessed from otolith readings and length increments of recaptured tagged sablefish.

Tag release and recapture data were used to estimate the biomass of the fishable sablefish in waters off the west coast of the Queen Charlotte Islands, the west coast of Vancouver Island and Queen Charlotte Sound. The procedure makes use of an adaptation to the simple Petersen method. Only sablefish measuring >55 cm in length at the time of tagging and released from domestic trap vessels were considered. Sablefish injected with oxytetracycline were excluded to eliminate biases in population estimates that would have resulted from unnaturally high mortality rates in injected fish (Beamish et al., 1979). Population estimates were not calculated for the year of release to allow time for tagged sablefish to mix with the untagged stock components. Tag releases during July 1977, May-June 1978 and June 1979 and recoveries to December 31, 1981 were used in the analysis of the stock off the west coast of the Queen Charlotte

Islands. Off the west coast of Vancouver Island only releases from 1979-1980 were considered. During 1979, tag releases were concentrated off the southwest coast and in 1980 off the northwest coast of the Island. Estimates were calculated separately and combined for the two areas. For Queen Charlotte Sound, releases during March 1980 and subsequent recaptures to December 1981 were used in the estimates.

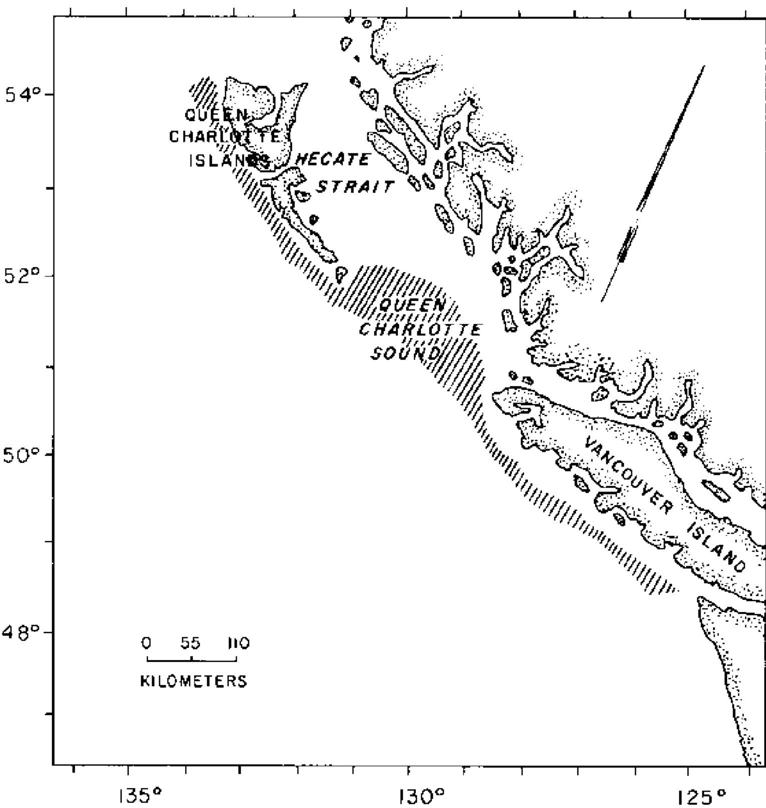

Fig. 1. General distribution of adult sablefish off the west coast of Canada.

The annual rate of tag loss was estimated directly as the proportion of the total single to total double-tag recoveries for all double-tag releases in Canadian waters during 1977-80 and recoveries to December 1981. Tag loss showed no trend and the annual rate of loss is estimated at approximately 7.5%. For this analysis it was assumed that all tag losses occurred immediately following tagging.

Two estimates of annual survival were calculated, one from tag release-recovery data and the other from age composition of the commercial trap catch.

Annual rate of survival was estimated from tag release and recovery data using a modification of a maximum-likelihood procedure developed separately by Seber (1970) and Robson and Young (1971). The model assumes survival is independent of age and allows for year-specific recovery and survival rates. Survival rates were also calculated as the slope of the regression of the descending right limb of the catch curve from data collected from the commercial trap fishery.

The estimate of annual survival rate calculated from the catch curve was based on age data collected for sablefish prior to the more recent high levels of exploitation. In the absence of fishing mortality, estimates of annual survival calculated from tag release-recovery data closely approximated the survival rate estimated from the slope of the catch curve. Non-reporting and tagging mortality are considered to be low. Fishermen were extremely cooperative and as captured fish are handled individually any tagged fish is likely to be reported along with accurate recovery information. Tagging mortality was considered low and was assumed to occur immediately following tagging.

Rate of emigration was calculated from domestic trap recoveries within Canadian waters. Recoveries were grouped by year and recapture area. Recoveries were standardized by fishing effort. The rate of emigration was calculated by dividing the number of tag recoveries from areas other than the release area by the total number of standardized recoveries.

Numbers of sablefish were estimated by dividing the annual landed catch by the mean weight of sablefish in the commercial catch. The mean weight per fish was estimated from the length-weight relationship, $Wt(kg) = 1.4 \times 10^{-6} L(cm)^{3.5025}$ and calculated for length frequency data collected during the tagging cruises.

Results and Discussion

Geographical distribution

Adult sablefish range along the Pacific coast of North America, from northern Mexico to the Gulf of Alaska and Aleutian Islands and along the edge of the continental shelf in the Bering Sea to the coasts of Siberia, Kamchatka and northern Japan. The largest concentrations are found in the Gulf of Alaska between Queen Charlotte Sound and the Shumagin Islands (Low et al., 1976). Juvenile sablefish are generally located in shallow inshore waters at depths <200 m.

Adult sablefish are abundant along the entire west coast of British Columbia at depths exceeding 200 m. Tagging studies (Beamish and McFarlane, this symposium) indicate that most adult sablefish are recovered close to the release area. As of December 31, 1981, 88.7% of the 6,337 recoveries were made within 200 km of the release area. There was substantial movement by a small number of fish (Beamish and McFarlane, this symposium).

Sablefish are also present on seamounts. An exploratory longline set made June 3, 1979 on Bowie seamount (unpub. data) indicated that sablefish were present but not in appreciable quantities. A total of 294 hooks were set between 256-457 m and of the 38 fish captured, 14 (37%) were sablefish. Commercial catches by Japanese longline vessels fishing in 1973 and 1977 on Bowie seamount (U.S. Nat. Mar. Fish. Serv. computer printouts-SM762) indicated that catch per unit effort (CPUE) of 0.12 t/10 hachi in 1977 and 0.20 t/10 hachi in 1973 were similar to CPUE values obtained by Japanese longliners fishing the more traditional grounds (0.14 t/10 hachi and 0.20 t/10 hachi) in 1977 and 1973, respectively.

A research survey conducted in 1979 on the Gulf of Alaska seamounts indicated that sablefish were abundant on all seamounts surveyed (NOAA, 1979).

Bathymetric distribution

Sablefish have been reported at depths of 1900 m (Kodolov, 1976), and 2740 m (Beamish et al., 1979). Trawl surveys along the Pacific coast of North America indicate that 93% of the exploitable biomass is confined to the continental slope from 200-1000 m (Low et al., 1976). Trawl surveys off Washington and Oregon, indicated sablefish were most abundant between 350 and 800 m (Heyamoto and Alton, 1965). Shippen (1972) reported trap catches were highest between 250 and 450 m and declined steadily from 500-900 m.

A summary of commercial trap catches off the west coast of British Columbia from 1979-1981 (Table 1) indicated sablefish were abundant between 400-1830 m. There was no apparent trend between total catch and depth range. Catches were consistently high between 600-800 m. Catches increased in deeper waters (>800 m) during summer and fall, probably a reflection of cessation of spawning (Mason et al., this symposium).

Similarly, CPUE varied without trend in relation to either depth or season. Analysis of catch rate by vessel (unpub. data) indicated that the variation observed in the commercial trap catch rates was probably a reflection of fleet distribution.

Table 1. Commercial trap catches of sablefish by depth, season and year off the west coast of Canada.

		Jan-Apr		May-Aug		Sept-Dec[a]	
Year	Depth (m)	Total catch (t)	Kg/trap (mean)	Total catch (t)	Kg/trap (mean)	Total catch (t)	Kg/trap (mean)
1979	0-199	0	0	0	0	0.02	0.3
	200-399	0	0	2.8	4	21.7	10
	400-599	33.2	24	12.7	15	65.7	14
	600-799	113.5	17	331.9	19	139.3	23
	800-1830	16.8	20	231.4	19	252.5	16
1980	0-199	0	0	0	0	0	0
	200-399	3.7	5	98.6	29	4.2	9
	400-599	76.9	6	127.6	13	163.1	13
	600-799	293.7	19	1050.5	19	370.7	17
	800-1830	116.6	14	91.0	9	330.0	18
1981	0-199	0	0	0	0	0	0
	200-399	7.5	10	235.5	23	72.3	13
	400-599	410.2	21	304.8	10	242.0	10
	600-799	206.0	19	571.8	13	105.7	13
	800-1830	50.9	11	395.3	20	348.6	16

[a]The sablefish fishery closed on December 1 and October 4 in 1980 and 1981, respectively.

Previous studies have reported an increase in the size of sablefish with depth, especially within the interval from surface to 200 m (Phillips, 1954; Heyamoto and Alton, 1965; Kennedy and Pletcher, 1968). Shippen (1972) reported an increase in the average size of both sexes to 450 m and a decrease for males and females at depths exceeding 450 and 650 m, respectively. No change in the size distribution of trawl-caught sablefish was apparent in the Bering Sea between 200 and 900 m (Kulikov, 1965). No size segregation by depth interval in the commercial catch has been observed in the Canadian zone (Table 2).

Spawning biology

Sablefish spawn from January to March along the entire Pacific coast at depths exceeding 300 m. Fertilization is external and the eggs incubate bathypelagically (Mason et al., this symposium). Studies conducted during 1980 and 1981 indicated that all adult sablefish spawn annually. There was no appreciable spawning migration.

Mean length and age at 50% maturity were calculated for samples collected during 1980 and 1981 (Mason et al., this symposium). During 1980 the mean size of males and females varied little among localities (Table 3). Females were larger than males (56.8 cm and 52.5 cm, respectively). Mean ages at maturity were 4.8 for males and 5.1 for females indicating that 50% of males and females spawned for the first time at age 5.

Another survey of age and size at maturity was conducted during November-December 1981 (Beamish et al., 1983). The later survey produced larger mean lengths for females at 50% maturity, and males maturing at a somewhat younger age (Table 4).

The discrepancies in size and age at maturity between the two studies and among sampling areas probably reflects real variation and sampling error both in the field and in the ageing laboratory. For example, we know that sablefish grow very slowly in a particular area off the west coast of Vancouver Island (Beamish and Chilton, 1982), and that generally, faster growing marine fish tend to mature at younger ages (Beacham, 1982; 1983). The method of age determination is difficult (Beamish and Chilton, 1982) and ageing errors cannot be discounted. In 1981, larger members of the 1977 year-class matured and were recruited into the fishable stock. The inclusion of these fish in the 1981 sample tends to reduce average age at maturity and, since they were larger than 60 cm, to increase the average size at maturity. Thus, we have combined the 1980 and 1981 samples, resulting in average length and age at 50% maturity of 58.3 cm and 5.2 yr for females and 52.8 cm and 4.8 yr for males (Table 5).

Presently, a large year-class (1977) is being recruited into the fishery. Approximately 50,000 of these fish were tagged and released as juveniles. The recovery of tagged fish from 1981 to 1983 may reveal any tendency for fish to mature at larger sizes in northern latitudes and any variation in age at maturity associated with area of residency.

Sex ratio

Male:female ratios of sablefish collected during prespawning and spawning periods in 1980 and 1981 (mid-November to mid-March) were 1:3. During

Table 2. Length (cm) distribution by depth throughout the year.

Year	Depth (m)	Jan-Apr Range	Jan-Apr $\bar{x}$ (n)	May-Aug Range	May-Aug $\bar{x}$ (n)	Sept-Dec Range	Sept-Dec $\bar{x}$ (n)
1978	0-199	-		-		-	
	200-399	-		-		54-103	74.1 (63)
	400-599	-		48-99	68.8 (4805)	-	
	600-799	-		44-100	68.4 (5772)	-	
	>800	-		49-100	69.4 (261)	60-92	73.3 (59)
1979	0-199	-		-	-	-	
	200-399	-		49-91	69.0 (336)	-	
	400-599	-		40-96	65.9 (3092)	-	
	600-799	-		40-100	62.6 (10,842)	-	
	>800	-		43-94	63.5 (1446)	-	
1980	0-199	-		-		-	
	200-399	43.2-51.6	47.1 (8)	-		-	
	400-599	43.7-100.0	64.9 (580	-		-	
	600-799	40.3-115.0	64.9 (6254)	-		-	
	>800	40.9-120.0	66.8 (2499)	-		-	
1981	0-199	-		-		-	
	200-399	-		-		46.1-96.0	61.6 (424)
	400-599	40.5-95.2	59.9 (1482)	43.5-99.1	66.8 (677)	41.1-97.0	62.8 (2033)
	600-799	42.7-93.0	62.3 (1283)	41.7-109.7	67.8 (2227)	43.5-93.0	59.9 (1744)
	>800	43.7-89.1	66.6 (338)	-		48.4-81.2	60.3 (208)

all other periods, the male to female ratio was 1:1.5 (Mason et al., this symposium). There was considerable variability among samples. For example, the sex ratio of 1138 fish sampled in June 1980 off the Queen Charlotte Islands was 64% male, while in 1981 at the same time and location, the ratio of a 300 fish sample was 66% female. Samples collected from the Queen Charlotte Islands, Queen Charlotte Sound, and Vancouver Island during November and December 1981, were predominantly female, 64%, 78%, and 81% respectively. Samples collected from Queen Charlotte Sound in fall 1980 showed the male to female ratio to be almost 1:1. Research samples of juvenile sablefish (McFarlane and Beamish, this symposium) contained 50% males and females. It is probable that the sex ratio of the stock is equal and the bias towards females is a reflection of the fishery selecting larger fish.

Table 3. Sablefish length and age at 50% maturity for four cruises in January-March, 1980.

	Length at 50% maturity		Average age at 50% maturity	
Area	♂ (n)	♀ (n)	♂ (n)	♀ (n)
Queen Charlotte Is (52°N.-U.S. border)	52.8 (396)	56.6 (1035)	4.5 (248)	4.8 (774)[a]
Queen Charlotte Sd (50°50'N-52°N)	51.3 (226)	57.5 (349)	5.8 (81)	6.0 (158)[a]
Vancouver Is (N) (49°30'N-50°50'N)	55.6 (64)[a]	62.0 (95)[a]	6.5 (36)[a]	6.0 (52)[a]
Vancouver Is (S)	52.3 (233)	56.0 (604)	4.0 (65)	5.3 (187)[a]
Weighted mean	52.5 (919)	56.8 (2083)	4.8 (430)	5.1 (1171)
Mean	53.0 (4)	58.0 (4)	5.2 (4)	5.5 (4)

[a]Not determined by probit analysis.

Table 4. Sablefish length and age at 50% maturity for November-December, 1981.

	Length at 50% maturity		Average age at 50% maturity	
Area	♂ (n)	♀ (n)	♂ (n)	♀ (n)
Queen Charlotte Is (52°N-U.S. border)	51.6 (240)	61.2 (393)[a]	4.2 (163)	5.6 (276)
Queen Charlotte Sd (50°50'N-52°N)	54.6 (99)	63.4 (702)	4.9 (60)[a]	4.7 (493)[a]
Vancouver Is (N) (49°30'N-50°50'N)	53.1 (92)	61.7 (415)	3.8 (48)	4.6 (234)
Weighted mean	52.6 (431)	62.4 (1510)	4.3 (271)	4.9 (1003)
Mean	53.1 (3)	62.1 (3)	4.3 (3)	5.0 (3)

[a]Not determined by probit analysis.

Table 5. Sablefish length and age at 50% maturity for combined samples in 1980-1981.

Area	Length at 50% maturity		Average age at 50% maturity	
	♂ (n)	♀ (n)	♂ (n)	♀ (n)
Queen Charlotte Is (52°N-U.S. border)	52.6 (636)	56.6 (1428)	4.6 (411)[a]	5.1 (1050)
Queen Charlotte Sd (50°50'N-52°N)	51.9 (325)	60.4 (1051)	5.6 (141)	5.6 (650)
Vancouver Is (N) (49°30'N-50°50'N)	53.1 (156)	61.4 (510)	3.5 (84)	4.5 (286)
Vancouver Is (S)	52.3 (233)	56.0 (604)	4.0 (65)	5.3 (187)
Weighted mean	52.4 (1350)	58.3 (3593)	4.8 (701)	5.2 (2173)
Mean	52.3 (4)	58.6 (4)	4.5 (4)	5.1 (4)

Table 6. Stomach contents of adult sablefish captured in sunken gillnets, August 1979 and bottom trawl, 1980.

	Sunken gillnets		Bottom trawl	
No. examined	78		1,131	
No. empty	40		821	
Food Item	Volume (cc)	%	Volume (cc)	%
Pacific herring	-		866	24
Rockfish (sp)	500	61	40	1
Myctophid	5	1	-	
Unidentified fish remains	119	15	828	24
Squid	31	4	1389	39
Jellyfish	75	9	-	
Shrimps	27	3	19	<1
Octopus	-		31	<1
Crab	15	2	50	1
Euphausiids	-		62	2
Amphipods	-		80	2
Other	46	5	175	5
Total	818	100	3,540	100

Feeding

A study of the stomach contents of sablefish recovered from traps may be biased because it may be argued that only fish that require food will go into the trap. Therefore, we have examined stomach contents of sablefish captured in sunken gillnet and bottom trawl catches.

Table 7. Food items observed in sablefish stomachs.

	PELAGIC OR NECTOBENTHIC	DEMERSAL OR BENTHIC	BATHYPELAGIC
Fishes	walleye pollock	arrowtooth flounder	rattails
	(*Theragra chalcogramma*)	(*Atheresthes stomias*)	(*Coryphaenoides* spp.)
	Pacific herring	Greenland turbot	deepsea smelts
	(*Clupea harengus pallasi*)	(*Reinhardtius hippoglossoides*)	(*Leuroglossus stilbius*)
	capelin	Pacific halibut	(*Bathylagus* spp.)
	(*Mallotus villosus*)	(*Hippoglossus stenolepis*)	anglemouth
	Pacific saury	skates	(*Cyclothone atraria*)
	(*Cololabis saira*)	(*Raja* spp.)	lanternfishes
	Pacific hake	rockfishes	(*Diaphus theta*)
	(*Merluccius productus*)	(*Sebates* spp.)	(*Stenobrachius* spp.)
	sandlance	(*Sebastolobus* spp.)	(*Tarletonbeania crenularis*)
	(*Ammodytes hexapterus*)	eelpouts	northern pearleye
	sablefish	(*Lycodes* spp.)	(*Benthalbella dentata*)
	(*Anoplopoma fimbria*)	sculpins	Pacific viperfish
	rainbow smelt	(*Triglops* spp.)	(*Chauliodus macouni*)
	(*Osmerus mordax dentex*)	(*Icelus* spp.)	
		(*Malacocottus zonurus*)	
		poachers	
		(Agonidae)	
		smooth lumpsucker	
		(*Aptocyclus ventricosus*)	
Invertebrates	Scyphozoa	Hydroidea	
	Actinaria	Polychaeta	
	Ctenophora	Echiurida	
	Calanoida	Sipunculida	
	Euphausiacea	Isopoda	
	Pandalidae	Gammaridea	
	Chaetognatha	Decapoda	
		Gastropoda	
		Bivalvia	
		Octopoda	
		Echinoidea	
		Asteroidea	
		Holothuroidea	

Of the 78 sablefish examined from gillnet catches off the Queen Charlotte Islands in 1979 (Beamish et al., 1980) 38 stomachs contained food items. Fish remains were dominant (76%) of which the majority (61% by volume) were rockfish (Table 6). During 1980 (Beamish et al., 1983) 821 (72%) of the 1131 stomachs examined from sablefish captured in trawl nets were empty. In stomachs which contained prey items fish or unidentified fish remains were dominant (49%) (Table 6). The dominant food items were Pacific herring (Clupea harengus) (24%) and squid (38%). These samples clearly show that the majority of the sablefish had not fed. The absence of food in the stomachs of sablefish is a common observation in the commercial fishery, and may explain why sablefish are so easily trapped.

In other studies, sablefish have been reported to feed on a wide variety of organisms depending on the season and location and the relative availability of prey (Shubnikov, 1963; Kodolov, 1976). Items observed in sablefish stomachs, compiled mainly from research conducted in the Bering Sea (Shubnikov, 1963; Kodolov, 1976), is presented in Table 7. In the Bering Sea, fishes, cephalopods and coelenterates comprise most of the diet whereas along the coast of North America, fishes, cephalopods and shrimps predominate and coelenterates appear to be much less important (Kodolov, 1976).

Biomass estimate

Although the tagging program was not designed to estimate population size, biomass was determined to provide an approximate estimate. Population estimates were calculated from an adaption of the simple Petersen equation,

$$N(ij)=M(j)(1-L)(1-m)(S^{**}(i-1))(r(i,j)(C(i) \;/\; R(i,j)\;\;(1+a)$$

where: N = population estimate of sablefish in year i from releases in year j; M = number of tagged sablefish released in year j; L = rate of tag loss; m = rate of tagging mortality; S = annual survival rate; r = the proportion of tagged sablefish released in year j and recaptured in water of the same area in year i; C = landed catch in numbers of sablefish in year i; R = number of recaptures in year i from releases in year j; a = rate of non-reporting.

The ability of the Petersen model to produce reliable estimates of population is dependent on the accuracy with which the individual parameters in the equation can be determined. Estimates of tag loss, survival, and the rate of emigration were calculated as separate components to the Petersen equation. Non-reporting of tag recaptures and tagging mortality had to be estimated. Values used in this analysis are as follows: L (rate of tag loss) = 0.075; S (survival rate) = 0.53; r (rate of emigration) = 0.01-0.08; a (rate of non-reporting) = 0.1; m (rate of tagging mortality = 0.1.

The estimated total biomass for the Canadian zone was 36,593 t for 1981. Confidence limits were estimated for specific areas, however, lack of data in other areas precluded estimating confidence limits for the whole coast.

Age and growth

The oldest age determined to date for sablefish is 55 yr, however, the majority of fish range from 4 to 35 yr (Fig. 2). The average age of the samples was 20.2, 12.7 and 16.5 years in 1979, 1980, and 1981, respectively. The average age of males (19.5, 12.8, and 16.4 yr) was similar to that of females (21, 12.5, and 16.6 yr). The decrease in average age for 1980 and 1981 is due to the presence of the strong 1977 year-class in the fishery.

Juvenile sablefish show spectacular growth in length during the first year, after which growth is slower (McFarlane and Beamish, this symposium). Males and females show similar lengths up to the age of 4 after which females are significantly larger (t-test, $p<0.05$) at given ages (McFarlane and Beamish, this symposium).

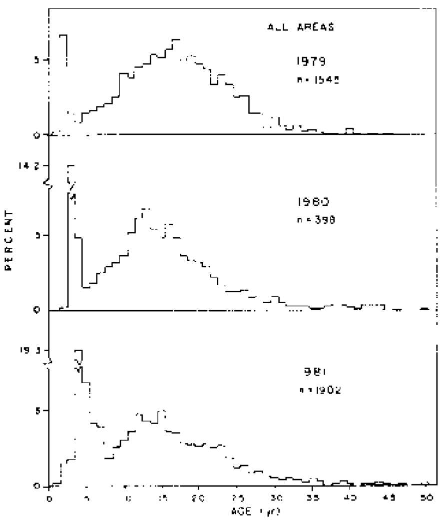

Fig. 2. Age composition of trap-caught sablefish (sexes combined) present in the commercial catch off Canada, 1979-1981.

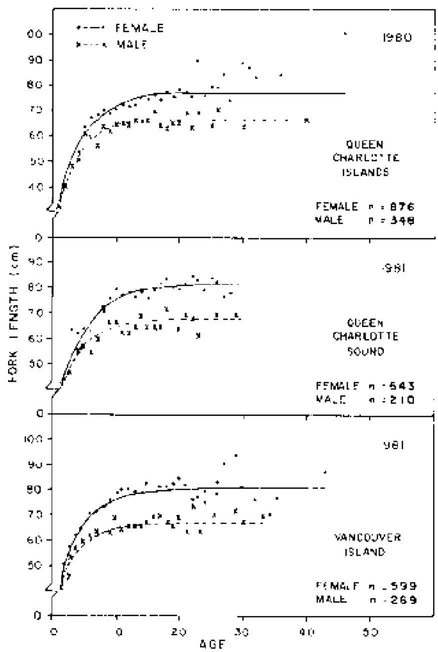

Fig. 3. Growth curves of sablefish stocks off the west coast of British Columbia in 1980 and 1981. Von Bertalanffy parameters are presented in Table 8.

Growth of mature fish is constant and relatively rapid to about age 10 (Fig. 3). Growth in length for males is greatly reduced after age 12 or 13 and for females after age 15 (Fig. 3). Females attain larger sizes than males and both males and females continue to live for long periods during which little growth occurs. The von Bertalanffy constants L_∞, K and t_0 are presented in Table 8

Table 8. Von Bertalanffy parameters for curves fitted to the mean length at age data for sablefish by area presented in Fig. 3. L_∞ values given in cm. Mean lengths from the 1977 year-class at age 1, 2, and 3 years old were included in calculating von Bertalanffy parameters.

Area	Year	Month sampled	Sex	No. of observations	von Bertalanffy parameters t_0	k	L_∞
5E	1980	Jan-Feb	M	348	-0.79	0.338	65.9
			F	876	-0.932	0.263	76.2
			T	1,224	-0.93	0.269	74.3
5A-5B	1981	Nov	M	210	-1.07	0.290	66.7
			F	643	-0.77	0.249	81.4
			T	853	-0.86	0.243	80.1
3C-3D	1981	Nov	M	269	-0.67	0.350	66.4
			F	599	-0.41	0.317	79.8
			T	868	-0.45	0.322	76.4

Mean annual growth of mature sablefish based on otolith ages, ranges from 0.17 to 0.26 cm for males and 0.55 to 0.66 cm for females. Measurement of tagged and recovered sablefish corroborates this low rate of annual growth (Table 9). As reported previously (Beamish et al., 1980), if all measurements from tagging are used there has been a net decrease in some length groups. The absence of a net increase is related to shrinkage during freezing. If fish were measured immediately upon recovery without freezing then there was a definite trend to a net increase in length with time (Table 10). If only fresh measurements are considered, the mean annual increment for males (0.47 cm), as expected, is less than for females (0.80 cm). Combining samples by time at liberty rather than age can bias the results if unequal numbers of younger faster growing fish are recovered. However, at this time we wanted to show only that sablefish grow very slowly, corroborating estimates obtained from age analysis.

The length-weight relationship is exponential (Fig. 4 & 5). The seasonal relationships were:

$$W = 1.4 \times 10^{-6}(FL)^{3.5025} \quad \text{(Summer)}$$

$$W = 2.9 \times 10^{-6}(FL)^{3.2973} \quad \text{(Winter-post spawning)}$$

Calculated weights at length for the winter, post-spawning period are approximately 15% lower than the summer length-weight relationship, reflecting the release of the gonadal products.

Stock structure and strong year-classes

Size composition of sablefish from the commercial catch from 1979 to 1982 ranged from 30 to 104 cm off the Queen Charlotte Islands, 38 to 104 cm

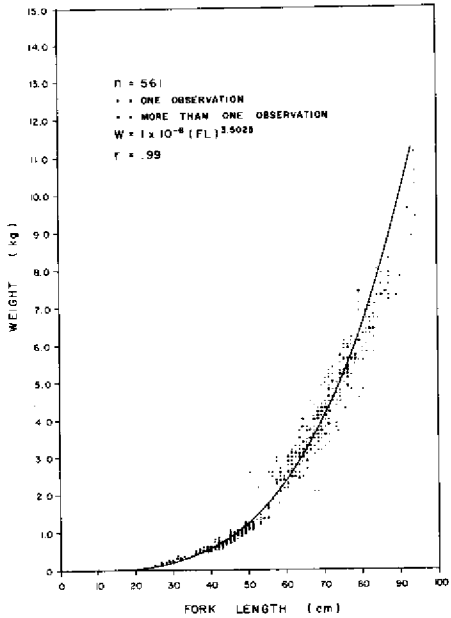

Fig. 4. Relationship between fork length and round weight for sablefish caught during summer and fall 1979. Trawl-caught juvenile sablefish from Queen Charlotte Sound and Hecate Strait combined with trap-caught fish from the west coast of the Queen Charlotte Island.

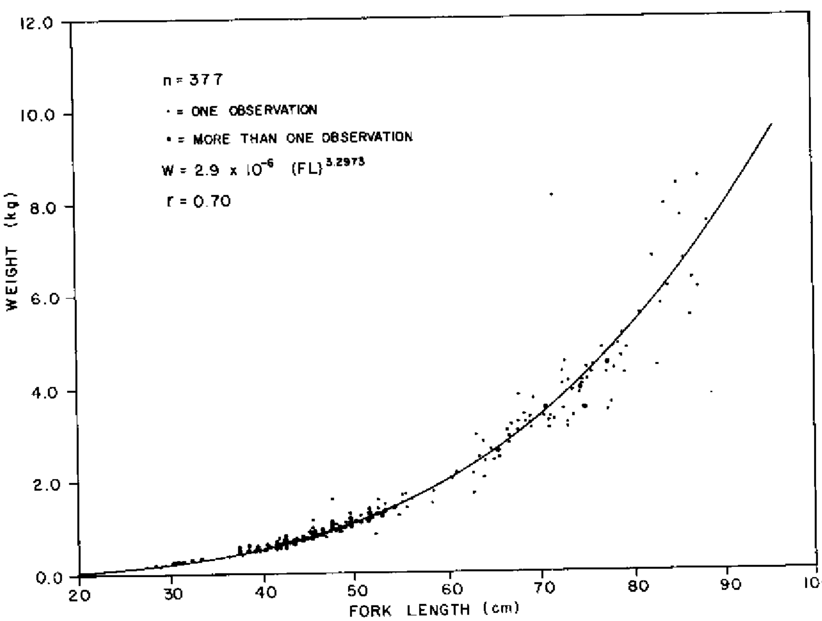

Fig. 5. Relationship between fork length and round weight for sablefish captured during winter 1981 (post-spawning). Trawl-caught juveniles from Queen Charlotte Sound and Hecate Strait combined with trap-caught fish from the west coast of the Queen Charlotte Islands.

Table. 9. Average growth of recovered sablefish.

	All recovered sablefish			Only sablefish measured in fresh condition by fisheries staff		
Years after tagging	Average growth (cm)	S.D.	n	Average growth (cm)	S.D.	n
0	-0.63	2.14	820	0.99	2.91	51
0.5	-0.25	1.95	1324	0.52	1.81	138
1.0	-0.51	2.30	1490	0.43	2.63	38
1.5	-0.53	2.33	425	0.99	2.81	19
2.0	-0.62	2.40	328	0.61	1.54	36
2.5	-0.62	2.97	83	-0.18	0.87	11
3.0	-0.99	2.77	128	6.1	5.88	5
3.5	-1.5	0.71	2	-	-	-

Table 10. Average growth (cm) of recovered sablefish with release length greater or equal to 60 cm, and measured in fresh condition by fisheries staff. (Includes recoveries up to December 31, 1981.)

Number of growing seasons[a] at large	$\bar{x}$ annual increment	$\bar{x}$ growth	S.D.	n
Males				
1	0.48	0.47	1.7	28
2	0.16	0.31	1.0	21
3	0.76	2.27	2.0	3
$\bar{x}$ annual increment	0.47			
Females				
1	0.54	0.54	1.6	58
2	0.44	0.87	3.3	45
3	0.95	2.86	2.1	5
4	1.39	5.56	6.6	5
5	0.80	4.00	4.9	2
$\bar{x}$ annual increment	0.80			

[a]Growing season taken as June to September.

off Queen Charlotte Sound and 38 to 114 cm off the west coast of Vancouver Island. The mean lengths of males and females in the samples have increased steadily since 1979 (Table 11). At this time it is not known whether the increase in mean length can be attributed to a shift in areas fished by commercial vessels. The reduced mean length of both males and females in the 1982 samples off the west coast of Vancouver Island is probably a reflection of the heavier recruitment of the 1977 year-class to this area in 1982 (McFarlane and Beamish, this symposium).

As mentioned, females attain larger sizes than males. For all areas and years, less than 10% of the males and more than 55% of the females were larger than 70 cm. In samples from some areas less than 1% of the males were larger than 70 cm compared to 58% of the females.

Table 11. Size composition of sablefish catches sampled at sea, including discards, by area and year.

Year		Queen Charlotte Islands		Queen Charlotte Sound		West Coast Vancouver Island	
		M	F	M	F	M	F
1979	Range in length (cm)	-	-	-	-	40-73	46-89
	Mean Length (cm)	no samples		no samples		55.5	66.8
	n					604	653
1980	Range in length (cm)	41-81	30-104	42-74	44-98	42-82	41-97
	Mean length (cm)	60.4	69.4	55.1	62.8	58.6	67.3
	n	396	1035	239	417	439	534
1981	Range in length (cm)	43-88	41-101	43-80	49-104	46-91	43-114
	Mean length (cm)	61.1	70.1	60.8	72.6	62.0	70.5
	n	545	849	437	1081	474	1589
1982	Range in length (cm)	44-89	43-104	38-85	47-102	38-86	40-103
	Mean length (cm)	62.3	72.2	62.2	72.3	59.5	67.5
	n	496	654	1408	2378	887	1795

During late 1977, a large number of young-of-the-year sablefish appeared in Hecate Strait, Queen Charlotte Sound and the mainland inlets and reports of their abundance continued in 1978, 1979, and 1980 (McFarlane and Beamish, this symposium). This strong year-class has been reported from all areas of the northeast Pacific Ocean (Balsiger, 1982).

Age frequencies for male and female sablefish sampled in 1980 and 1981 (Fig. 6 & 7) indicated the presence of strong year-classes in 1977, the late 1960s and the early 1960s. These strong year-classes could not be identified in age composition data from the commercial catch for males and females combined (Fig. 2). A simple reconstruction of cohort strength for age frequencies of females corrected for natural mortality (M) of 0.1 (Table 12) indicated that strong year-classes occurred in the late 1960s, the late 1950s/early 1960s and the early 1950s. We recognize that there are problems associated with the assumptions used to estimate cohort strength, such as the use of a constant natural mortality

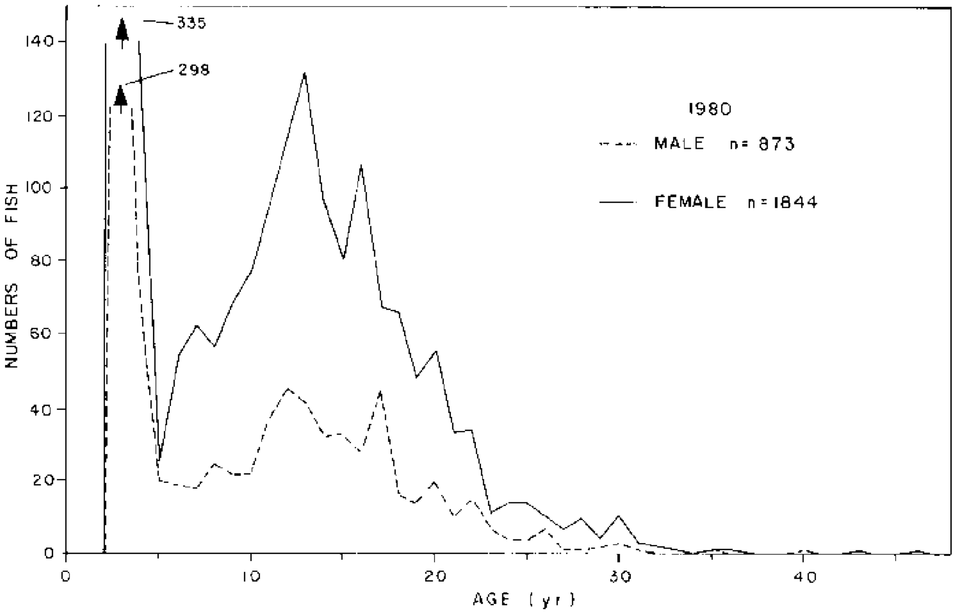

Fig. 6. Age frequency for trap-caught male and female sablefish from the commercial fishery and research tagging cruises off the west coast of British Columbia.

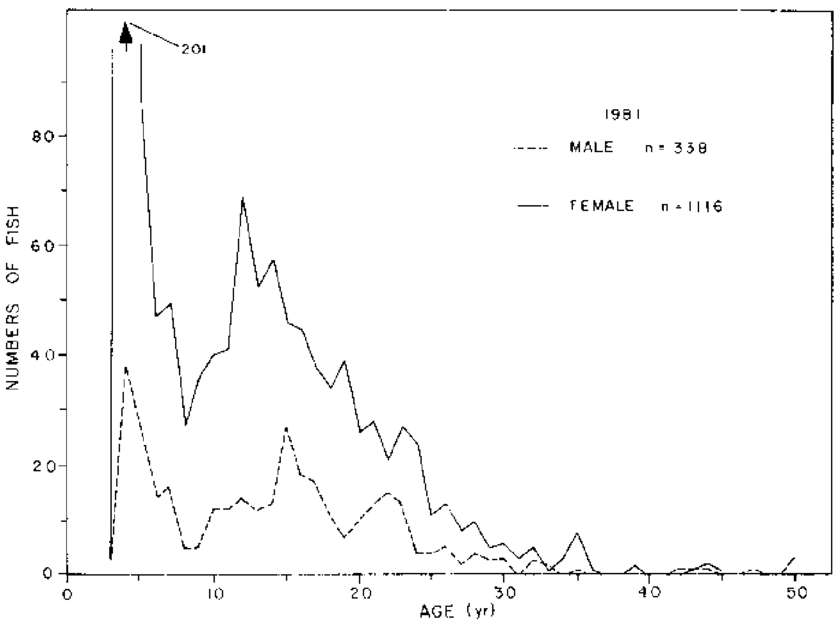

Fig. 7. Age frequency for trap-caught male and female sablefish from the commercial fishery off the west coast of British Columbia, 1981.

rate that is influenced by year-class strength, the application of this rate without consideration of the history of the fishery, the small numbers of older fish in the samples, and ageing errors. However, because of the large number of age groups in the fishery, and the fact that there has been no indication that a fishery targeted on any particular year-class, the comparison is useful in determining relative year-class strength.

Table 12. Relative year-class strength of female sablefish captured off the Queen Charlotte Islands in 1980 and 1981. Numbers at age corrected for natural mortality (0.1).

	1980			1981		
Year-class	Age	n	n corrected for natural mortality	Age	n	n corrected for natural mortality
1975	5	10	11	6	11	12
74	6	23	28	7	16	20
73	7	30	41	8	15	21
72	8	31	47	9	12	18
71	9	36	61	10	8	14
70	10	41	77	11	14	26
69	11	48	100	12	52	109
68	12	61	142	13	24	56
67	13	86	222	14	53	137
66	14	54	155	15	24	69
65	15	34	108	16	32	102
64	16	56	198	17	22	78
63	17	27	106	18	20	79
62	18	26	113	19	21	92
61	19	24	117	20	18	87
60	20	17	92	21	26	140
59	21	9	54	22	14	84
58	22	10	67	23	17	113
57	23	2	15	24	16	118
56	24	6	49	25	6	49
55	25	4	37	26	11	101
54	26	4	41	27	8	81
53	27	1	11	28	10	113
52	28	2	26	29	4	50
51	29	0	-	30	6	84
50	30	2	28	31	6	93
49	31	1	17	32	5	86
48	32	1	19	33	1	64

Anecdotal information from fishermen and a study of the relative abundance of juvenile sablefish in the diet of Pacific cod (*Gadus macrocephalus*) captured in inside waters (Fig. 8; Westrheim and Harling, 1983) indicated that juveniles were abundant in the late 1970s, the late 1960s, and the late 1950s, or early 1960s. These reports corroborate the approximate years of strong year-classes determined from the age reconstructions.

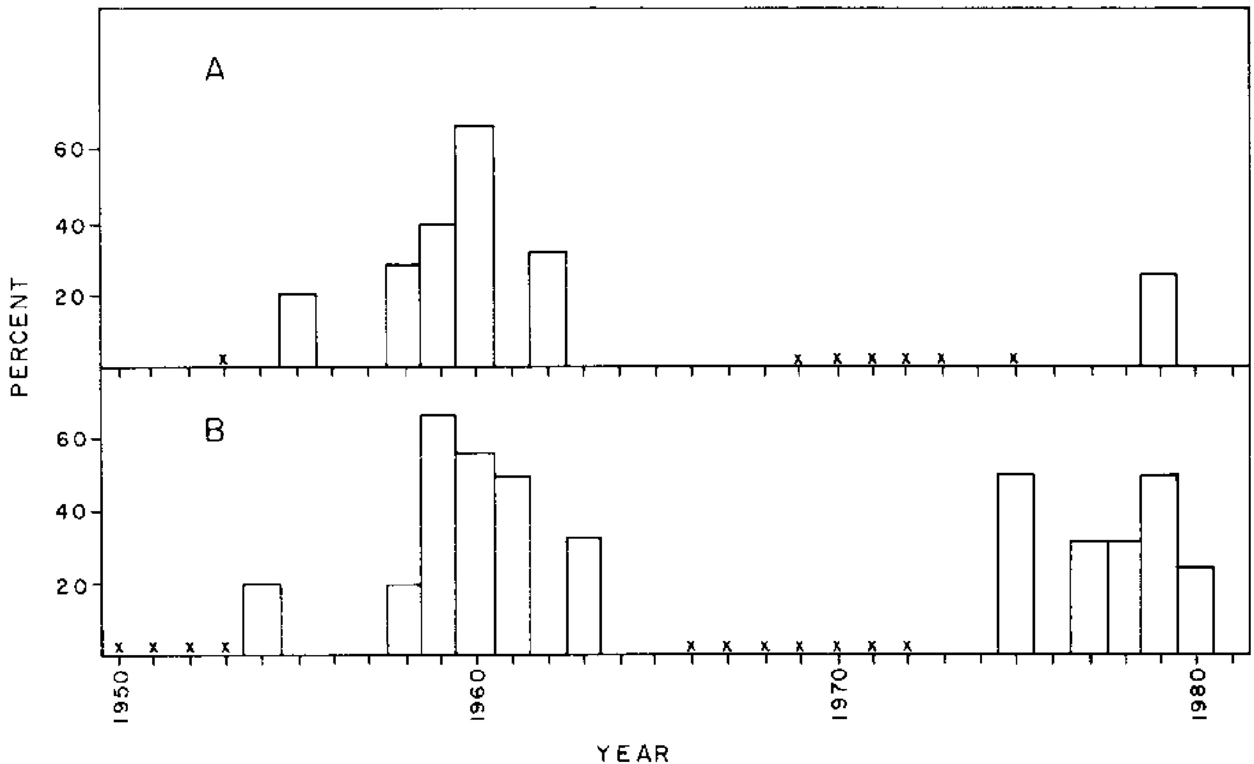

Fig. 8. Incidence (%) of sablefish in Pacific cod stomach samples from: A. Northern Hecate Strait and B. North-central Hecate Strait, by year 1950-1980 (x = no samples taken). Data from Westrheim and Harling (1983 in press).

Bailey (1981) related the development of strong year-classes in Pacific hake (Merluccius productus) to the presence of strong onshore currents (Ekman transport) during the spawning period and Mysak et al. (1982) have demonstrated a relationship between interannual baroclinic waves and fish populations in the northeast Pacific Ocean. It is beyond the scope of this paper to discuss the mechanisms causing strong year-classes, however, there is little doubt that oceanographic conditions contribute to the success of some year-classes.

The importance of a large number of age groups for sablefish is unknown. It is possible that the ability to live to older ages permits sablefish to survive in an environment where food may be scarce and where recruitment is limited for extended periods.

In contrast to mature individuals, actively growing juveniles are found in inshore shallower waters, where food resources are greater. In the offshore waters, after maturation, growth is reduced. It is probable that most energy, surplus to maintenance requirements is used for reproduction. The extension of the reproductive life probably is an adaptation to surviving in the deeper offshore areas, particularly in times of unfavorable environmental conditions. It appears that under conditions of limited recruitment the stability of the populations may depend on maintenance of the age structure in the population. It also appears that the success of any year-class is dependent on its ability to move into areas of high productivity.

Acknowledgments

Many people contributed directly or indirectly to this report. In particular, the assistance of K. Best, A. Cass, and R. Scarsbrook is appreciated. The authors sincerely appreciate the cooperation of fishermen who provided valuable advice and assistance and allowed us to accompany them on commercial fishing trips and sample the catch for biological information. Mr. S. J. Westrheim kindly reviewed the manuscript.

References

Bailey, K. M. 1981. Larval transport and recruitment of Pacific hake (Merluccius productus). Mar. Ecol. Prog. Ser. 6: 1-9.

Balsiger, J. W. 1982. Sablefish. In J. Balsiger (ed). Condition of groundfish resources of the Gulf of Alaska in 1982. Unpubl. Rep. 198 p. Northwest and Alaska Fisheries Center, Nat. Mar. Fish. Ser. Seattle, Wa.

Beacham, T. D. 1982. Some aspects of growth, Canadian exploitation, and stock identification of Atlantic cod (Gadus morhua) on the Scotian Shelf and Georges Bank in the Northwest Atlantic Ocean. Can. Tech. Rep. Fish. Aquat. Sci. 1069: 43 p.

Beacham, T. D. 1983. Variability in median size and age at sexual maturity of cod (Gadus morhua) on the Scotian Shelf in the Northwest Atlantic Ocean. (In press).

Beamish, R. J., C. Wood, and C. Houle. 1978. A summary of sablefish tagging studies conducted during 1977. Fish. Mar. Sci. Data Rep. 77: 103 p.

Beamish, R. J., C. Houle, C. Wood, and R. Scarsbrook. 1979. A summary of sablefish tagging and exploratory trapping studies conducted during 1978 by the Pacific Biological Station. Can. Data Rep. Fish. Aquat. Sci. 162: 113 p.

Beamish, R. J., C. Houle, and R. Scarsbrook. 1980. A summary of sablefish tagging and biological studies conducted during 1979 by the Pacific Biological Station. Can. MS Rep. Fish. Aquat. Sci. 1588: 194 p.

Beamish, R. J. and D. Chilton. 1982. A preliminary evaluation of a method to determine the age of sablefish (Anoplopoma fimbria). Can. J. Fish. Aquat. Sci. 39: 277-287.

Beamish, R. J. and G. A. McFarlane. 1983. Summary of results of the Canadian sablefish tagging program. (This symposium).

Beamish, R. J., G. A. McFarlane, R. J. Scarsbrook, A. Cass, D. Chilton, W. Shaw, K. Best, and I. Barber. 1983. A summary of sablefish tagging and biological studies conducted during 1979 by the Pacific Biological Station. Can. MS Rep. Fish. Aquat. Sci. (In press).

Heyamoto, H. and M. S. Alton. 1965. Distribution, abundance and size of sablefish found in deep water off the mouth of the Columbia River. Commer. Fish. Rev. 27(2): 1-8.

Kennedy, W. A. and F. T. Pletcher. 1968. The 1964-65 sablefish study. Fish. Res. Board Can. Tech. Rep. 74.

Kodolov, L. S. 1976. Details of biology and distribution of blackcod (Anoplopoma fimbria Pall) Izv. Tikhookean. Nauchno-Issled. Inst. Rybn. Khoz. Okeanogr. 100: 19-42.

Kulikov, M. Yn. 1965. Vertical distribution of sablefish (Anoplopoma fimbria) on the Bering Sea continental slope - English trans. in Soviet Fish. Invest. in the northeast Pacific, Part IV: 157-161.

Leaman, J. E. 1982. Catch and effort statistics of Canadian groundfish fishery on the Pacific coast in 1981. Can. Tech. Rep. Fish. Aquat. Sci. 1124: iv + 90 p.

Low, L. L., G. K. Taronaka, and H. H. Shippen. 1976. Sablefish of the northeast Pacific Ocean and Bering Sea - Northwest and Alaska Fisheries Center processed report - Nat. Mar. Fish. Serv. Seattle, Wa.

Mason, J. E., R. J. Beamish, and G. A. McFarlane. 1983. Sexual maturity, fecundity and spawning of sablefish off the west coast of Canada. (abstract only, this symposium).

McFarlane, G. A. and R. J. Beamish. 1983. Preliminary observations on the juvenile biology of sablefish (Anoplopoma fimbria) in waters off the west coast of Canada. (This symposium).

Mysak, L. A., W. W. Hsieh, and T. R. Parsons. 1982. On the relationship between interannual baroclinic waves and fish populations in the northeast Pacific. Bio. Oceanogr. 2: 63-103.

NOAA, National Marine Fisheries Service Cruise Results. 1979. Cruise No. 79-1, Gulf of Alaska Seamount Survey. 13 p.

Phillips, J. B. 1954. The sablefish fishery of California 1) History and research. Pac. Mar. Fish. Comm. Bull. 3: 5-38.

Robson, D. S. and W. D. Young. 1971. Statistical analysis of reported tag-recaptures in the harvest from an exploited population. Biometrics Unit, Cornell University, Ithaca, New York. BV-369-M-15 p.

Seber, G. A. F. 1970. Estimating time-specific survival and reporting rates for adult birds from band returns. Biometrika 57: 313-318.

Shippen, H. H. 1972. Progress report on sablefish studies by the U.S. National Marine Fisheries Service 1971-72. Northwest and Alaska Fisheries Center processed report. Nat. Mar. Fish. Serv. Seattle, Wa.

Shubnikov, D. A. 1963. Data on the biology of sablefish of the Bering Sea. Trans by Israel Program Sci. Trans. 1968 in Soviet fish invest. in the northeast Pacific. Part I: 287-296.

Smith, J. E. 1978. Catch and effort statistics of the Canadian groundfish fishery on the Pacific coast in 1977. Fish. Mar. Serv. Tech. Rep. 835: 85 p.

Smith, J. F. 1979 Catch and effort statistics of the Canadian groundfish fishery on the Pacific coast in 1978. Fish. Mar. Serv. Tech. Rep. 891: 62 p.

Smith, J. F. 1980. Catch and effort statistics of the Canadian groundfish fishery on the Pacific coast in 1979. Can. Tech.Rep. Fish. Aquat. Sci. 961: 90 p.

Smith, J. F. 1981. Catch and effort statistics of the Canadian groundfish fishery on the Pacific coast in 1980. Can. Tech. Rep. Fish. Aquat. Sci. 1032: 90 p.

Westrheim, S. J. and W. H. Harling. 1983. Principal prey species and periodicity of their incidence in stomachs of trawl-caught Pacific cod (Gadus macrocephalus), rock sole (Lepidopsetta bilineata), and petrale sole (Eopsetta jordani) landed in British Columbia, 1950-80. Can. MS Rep. Fish. Aquat. Sci. 1681: 38 p.

Age and growth of sablefish landed in Eureka, California: A comparison of conventional surface age assignments with sectioned otolith assignments

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Abstract

Sablefish were sampled at Eureka fish processing plants and while on board a commercial Eureka-based trawling vessel during 1979 and 1980. Conventional surface aging methods, applied to scales and whole otoliths, revealed that females grew more rapidly than males, and that size at age for Eureka-landed sablefish is greater than for more northern stocks. We observed seasonal changes in proportions of sablefish showing newly-formed annuli on scales and otoliths; this may suggest that apparent surface annuli do correspond to annual events.

A sample of 28 whole otoliths from previously surface-aged fish was sent to the Pacific Biological Station for age assignments using the burnt section otolith method. Eighteen of 23 female specimens had age assignments by both techniques that were within ± 2 years of one another. Remaining female specimens had greater discrepancies, but there was no obvious trend of discrepancy with fish size or conventional age assignment. Serious discrepancies (18-24 years) were found for three of five male specimens, but discrepancies for two intermediate-sized males were 0 and 2 years. Conventional age assignments appear to be reasonably sound for females, at least up to 80 cm, but are probably seriously in error for slower-growing males if otolith section ages are valid.

Based on the apparent correlation of age discrepancies with time of capture, and upon the apparent dramatic variation in male size at age in otolith section ages, we speculate that the Eureka fishery may harvest more than one sablefish stock and that a migratory slower-growing stock may enter the fishery in late fall. We hope to investigate the plausibility of this speculation in future work.

Introduction

Although nearly one-third of all sablefish (Anoplopoma fimbria) caught by trawl gear off California, Oregon and Washington in the past decade have been landed in the port of Eureka, California, little scientific effort has been devoted to characterization of local harvests. The primary objectives of the research described in this paper were to: 1) compare the reliability of aging sablefish from scales and whole otoliths; 2) determine the most appropriate back-calculation procedures; 3) generate conventional Von Bertalanffy growth curve parameter estimates for both male and female sablefish; and 4) using these parameter estimates, derive estimates of natural mortality rates (M). Research objectives thus involved a conventional age and growth assessment for sablefish landed in Eureka, California; to our knowledge, no previous assessment of this nature has been conducted for Eureka-landed sablefish.

While realizing our primary objectives, we secured a draft of a now-published paper by Beamish and Chilton (1982) concerning assessment of sablefish age through examination of burnt sections of otoliths. After our study was completed, we sent a sample of 28 whole otoliths to the Pacific Biological Station to contrast our conventional age assignments with their otolith section age assignments. Discrepancies between age assignments by the two techniques were of sufficient interest that we felt their presentation at the International Sablefish Symposium would be of general interest; hence this brief paper.

Materials and Methods

Sample collections.

Sablefish scales and otoliths were collected by two methods: 1) sampling commercial landings at local fish processing plants; and 2) sampling catches at sea while on board a commercial Eureka-based trawling vessel. Most of the specimens used for aging purposes were collected at sea, because market samples did not provide a large range of sablefish sizes (and presumably ages). Market samples were obtained weekly or biweekly from September through November, 1979. Samples at sea were collected during June through August, 1980, and in November, 1980.

Market samples were selected from standard 1000 pound capacity boxes by sytematically selecting every other fish until two plastic buckets, each holding about 80 pounds of sablefish, were collected. A total of 404 fish were sampled at the markets in this manner, of which 101 had been dressed. Dressed fish were measured from the origin of the first dorsal fin to the center of the forked tail; these measurements were later converted to fork length using the conversion factor reported by Phillips (1954). Whole fish were dissected to determine sex, weighed to the nearest ounce when time permitted, and fork lengths recorded in whole centimeters following Holden (1974). Otolith pairs (sagittae) and scales were removed from all sampled whole fish. Scales were removed from the base of the first dorsal fin (Pruter 1954; Sasaki 1971) from both sides of the body. In addition, groups of scales from different regions of the body were removed from a single fish to determine which region provided scales which were most easily read (see Sasaki 1971; and Figure 1).

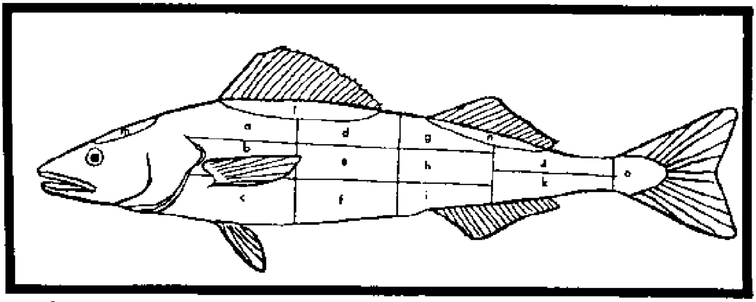

Figure 1. Depiction of regions of the body from which scales were removed to evaluate scale readability. Actual scale measurements and age assignments are based on scales removed from region 1, immediately below the first dorsal fin.

Sampling at sea was conducted using an otter trawl with a 4 1/2 inch (11 cm) stretched mesh cod-end liner. Incidentally harvested sablefish were sorted from target species; the largest and smallest fish were purposively selected to expand size range among collected fish. Intermediate-sized sablefish were selected randomly. The total number of fish sampled at sea was 1957; scales and otoliths were collected from 1364 fish. Sex of fish was determined by dissection, and measurements of body length were made as for market sampling. Fishing areas ranged from just south of Eureka (latitude 40°41'N) to Cape Sebastian, Oregon (latitude 42°14'N), at depths ranging from 40 to 430 fathoms, but most sampling took place between 300 and 400 fathoms (Figure 2).

Sample preparation, age determination, and data analyses.

Scales. Scales, which had previously been stored in dry coin envelopes, were soaked in detergent solution for 12-24 hr prior to mounting and reading. Usually six non-regenerated scales per fish were read. Scales were mounted on slides, examined on a microfiche reader at a usual magnification of 24x, and annuli and scale radii measurements (from the focus to the anterior margins and to the outer edges of annular marks) taken from the anterior field of long elongated scales (see Pruter 1954). Scale measurements were made for at least three readable scales for each fish; later a series of measurements from a single fish was used for back-calculation purposes, based on a subjective assessment of scale feature clarity.

Approximately 15 fish per 5 cm body length intervals for each sex were randomly selected for age determination; for length groups for which total samples were less than 15, all fish were included and sample sizes always exceeded six fish with one exception: only two fish over 91 cm were collected. Fish sizes ranged from 32 to 97 cm. Conventional criteria for detection of annular marks were used to establish annuli, and ages were assigned following LaLane (1979) and Williams and Bedford (1973).

In addition, the proportion of fish exhibiting newly-formed annuli for the above samples was recorded by sampling period in order to determine the approximate time of apparent annulus formation; only mature fish ranging from about 45 to 75 cm fork length were used for this determination.

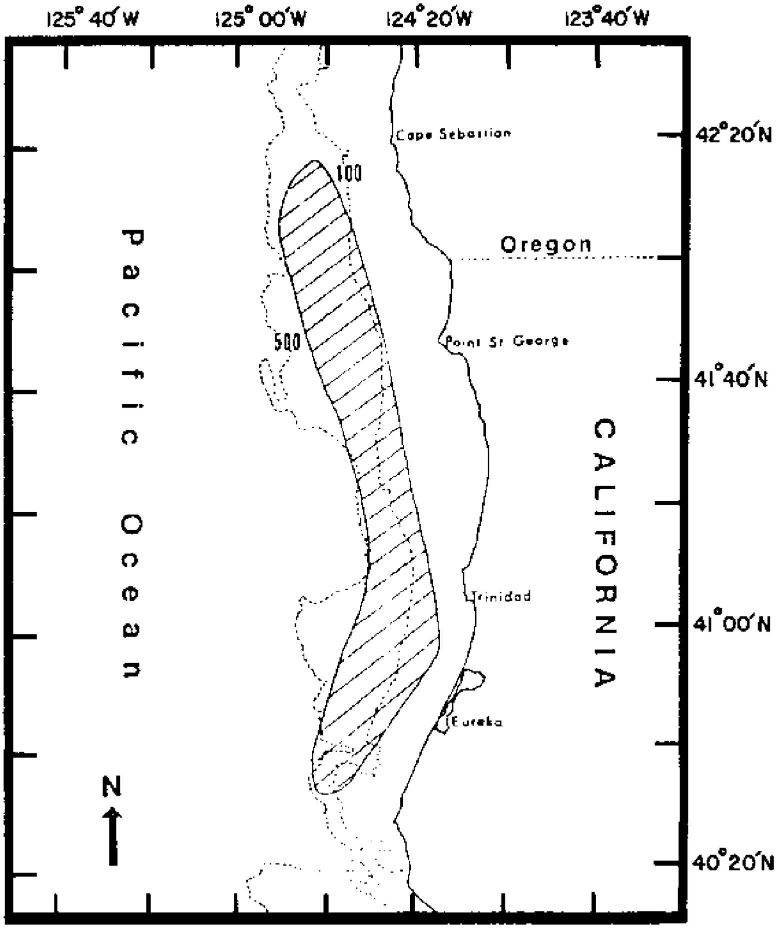

Figure 2. Approximate sablefish collection area off northern California and southern Oregon (hatched area). Dotted lines show 100 and 500 fathom isobars.

Otoliths. Fifteen males and fifteen females per 5 cm body length intervals were selected randomly for age determinations and otolith measurements, as for scales. Not all fish selected for aging using otoliths were also aged using scales; for certain individuals, ages could not be reliably assessed by one technique. Otolith and scale age determinations were jointly made on a total of 189 female and 174 male sablefish. Otoliths were soaked in 70% ethyl alcohol for several days before reading, and were examined under a dissecting microscope at 7-12x magnification over a black background using reflected light. Counts of hyaline zones were used as the basis for age assignments. Of a pair of otoliths (right and left sagittae), either one was read at least twice and the more confident readings were used for back-calculations. Measurements were taken from the focus to the anterior margin of annuli and otoliths using an ocular micrometer, and were all scaled to 7x magnification.

Data analyses. Allometric length-weight relationships were derived for males and females separately, and for combined sexes, using approximately five randomly selected fish per 5 cm body length interval. Both linear and non-linear body length-scale radius and body length-otolith radius relationships were fit by linear least-squares regression, sometimes requiring log transformation of data. Back-calculations were carried out using three distinct methods for comparison: 1) Lea's formula (Lea 1910); Fraser and Lee's formula (Fraser 1916; Lee 1920); and 3) Monastyrsky's formula (Monastyrsky 1930).

Possible differences between age determinations from otoliths and scales, and between calculated mean lengths at age for both males and females were examined through paired t-tests. Calculated mean length at age data were used to fit Von Bertalanffy equations using standard procedures (Ricker 1975). Based on calculated Von Bertalanffy growth parameters, the instantaneous natural mortality rate (M) for sablefish was estimated following techniques presented in 1) Alverson and Carney (1975) and Taylor (1958); and in 2) Pauly (1980).

Contrasting conventional surface ages with burnt-section otolith ages.

In June of 1982, a sample of whole otoliths from 28 sablefish ranging in length from 55 to 87 cm was sent to Dr. R.J. Beamish, Director, Fisheries Research Branch, Pacific Biological Station, Nanaimo, B.C., for age assessment by the otolith section method (see Beamish and Chilton 1982). Conventional surface otolith ages had been previously determined (Maeda 1982) for all of these specimens. Doris Chilton, Supervisor of the Aging Lab, kindly agreed to age these specimens for us using the burnt section method; results of these contrasting age assignments are presented below.

Results

Sex ratios, sizes at maturity and length-weight relations.

In both market samples and in November 1980 collections at sea, male:female sex ratio was approximately 2:1. The smallest sexually mature sablefish observed had fork lengths of 43 cm (males) and 49 cm (females). Weights of fish ranged from 339 g (FL 32 cm) to 4653 g (FL 75 cm) for males, and from 339 g (FL 34 cm) to 9136 g (FL 91 cm) for females. The combined sexes allometric length-weight relation was

$W = 0.213 \times 10^{-5} L^{3.248}$; where W=weight in grams; L = FL in mm

Relationships for the two sexes were nearly identical. Comparison of Fulton's condition factors (in $W = CL^3$) showed a significant change in condition factors with increasing fish size, but no difference between sexes. Condition factors for juvenile sablefish (1+ and 2+) were significantly smaller than for older fish.

Age determination and age assignments.

Readability. Long elongated scales from the base of the first dorsal fin were found most easily read, although other regions of the body (regions a,b,c,d,h and n on Figure 1) had scales with relatively clear apparent annular marks. Aging of females by both otoliths and scales was generally easier and presumably reflected differences in growth rates between sexes. Assigned ages (those judged reliable) as determined from scales and otoliths ranged from 1+ to 18+ and from 1+ to 17+ respectively.

Paired-sample t-test statistics, computed between otolith- and scale-determined ages for both males and females for which ages had been determined by both techniques, failed to indicate a significant difference between age assignments for either sex. T-tests also revealed that lengths at capture of ages 1+ and 2+ males and females were not significantly different. Beyond age 2+, females were larger than males.

Annulus formation. The percentage of fish with newly-formed annuli on scale margins was lowest (5%) in the beginning of August and then increased through October when the proportion reached a high of 44% (Figure 3); the proportion was about 43% in late November. Examination of otoliths revealed a similar trend. Although these results are hardly conclusive, and did not cover all months of the year, there does appear to be a strong seasonality to apparent annulus formation; the proportion of fish showing plus growth did correspond to likely periods of greatest seasonal growth.

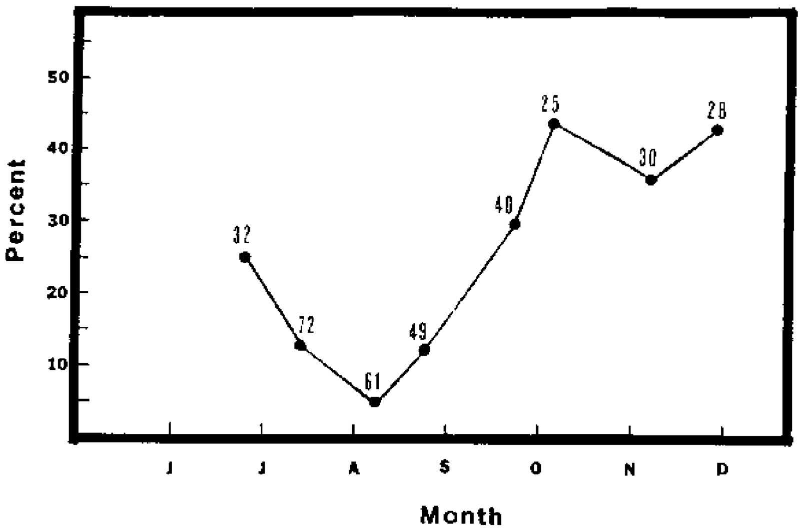

Figure 3. Percentage of sablefish scales with newly-formed annuli on the margin by different sampling periods, northern California, 1979-1980. Samples from September through early November were obtained by market sampling in Eureka, California, during 1979. Samples from June through August and in late November were obtained by bottom trawling during 1980. Sample sizes above points.

Back-calculations and derived growth patterns.

Body length-scale radius and -otolith radius relationships. Linear models adequately described body length-scale radius and body length-otolith radius relationships for both sexes and for combined sexes. Reduction of unexplained variation achieved through the use of non-linear models was small and estimates of b (in $L = aS^b$) were usually close to 1. Based on a combined sex sample size of 276 fish, the correlation coefficient for the linear model applied to scales was 0.9143; for otoliths, based on 286 fish, the linear model correlation coefficient was 0.8977.

Probably because the intercepts for the linear models were fairly small (about 10 cm for scales and about -5 cm for otoliths), back-calculations computed by all three of the techniques used were similar for scales; however, the non-linear (Monastyrsky's) back-calculation method applied to otoliths resulted in apparent serious negative bias for older ages, especially when compared to the results for scales. Maeda (1982) concluded that use of Lea's formula for scales and Fraser and Lee's formula for otoliths gave most reliable results, and that these results compared favorably with collections of fish which exhibited no plus growth at capture.

Von Bertalanffy growth curves and mortality rate estimates. Growth of males, as determined from back-calculations, was considerably slower than of females (Figure 4). Differences in size at age were obvious as early as age three. Von Bertalanffy growth curve parameter estimates reflected this obvious difference. Predicted ultimate lengths for males and females, based both on scales and otoliths, were about 72 and 87 cm respectively. Predicted lengths at age agreed favorably with back-calculated lengths at age (Table 1).

Using Pauly's technique, and assuming an average temperature at 200 fathoms of 5.5°C, instantaneous natural mortlaity rate (M) was estimated to be 0.19 . Alverson and Carney's (1975) method, which does not rely on mean environmental temperature, gave M=0.25. This figure has previously been assumed appropriate for sablefish (Low et al. 1976).

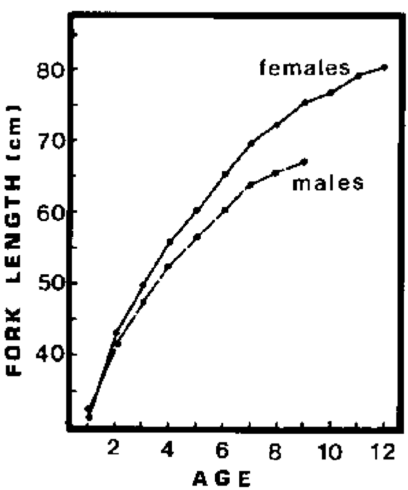

Figure 4. Mean back-calculated fork lengths at age by Fraser and Lee's method for male and female sablefish collected in northern California, 1979-1980. Based on reading of whole otoliths.

Table 1. Observed (back-calculated) and predicted (based on fitted Von Bertalanffy equations) fork lengths at age for male and female sablefish landed in Eureka, California, 1979-1980, based on surface ages read from scales.

	Males		Females	
Age	Observed (cm)	Predicted[a]	Observed (cm)	Predicted[b]
1	29.6	29.1	30.0	29.5
2	39.8	39.0	40.9	38.9
3	46.4	46.6	47.9	46.8
4	51.6	52.5	53.6	53.4
5	56.0	56.9	58.4	59.0
6	60.0	60.4	62.8	63.6
7	63.7	63.0	67.3	67.5
8	65.7	65.0	71.0	70.7
9	66.6	66.5	73.8	73.4
10	67.4	67.7	76.3	75.7
11	----	68.6	78.4	77.6
12	----	69.3	79.3	79.2
13	----	69.9	79.4	80.6

[a] $\hat{l}_t = 71.62\ (1 - e^{-.2657(t+0.9642)})$

[b] $\hat{l}_t = 87.43\ (1 - e^{-.1777(t+1.3128)})$

Comparison of conventional surface ages with otolith section ages

Of the 28 whole otoliths which were sent to the Pacific Biological Station for comparison of age assignments, 23 were from females and five were from males. Age discrepancies among females were not alarming. Among the female samples, ages were in agreement in 10 cases and were within ± 2 years in an additional eight cases, giving a total of 18 out of 23 cases for which age assignments were judged to be in essential agreement. There was no clear pattern of discrepancies with size of female or with conventional surface age assignment. For example, an 86 cm female aged by Maeda (1982) as 17+ had the same otolith section age assignment, but a 62 cm fish aged by Maeda as 6+ had an otolith section age assignment of about 30. For this latter fish, Doris Chilton observed that otolith features were similar to those encountered with slow-growing males; it is possible that this individual was incorrectly coded as a female.

Among the male specimens for which comparative age assignments were available, discrepancies were very large in three of five cases. Two 55 cm specimens for which Maeda had obtained surface ages of 5+ and 6+ had otolith section ages of ≈ 23 and 30+. A 67 cm specimen aged by Maeda as 6+ had an otolith section age assignment of 29+. However, two intermediate-sized males of 63 and 66 cm which Maeda had aged at 6+ and 7+ had otolith section ages of 6+ and 9+. The full tabulation of comparisons, including dates of capture, is presented in Table 2.

Table 2. Comparison of conventional surface age assignments with burnt section otolith age assignments for sablefish landed in Eureka, California, 1979-1980.

Females

Collection Date	Fork Length (cm)	Surface Age[a]	Section Age[b]	Difference (Section - Surface)
08-20-80	61	5+	5+	0
11-06-79	62	6+	≈30[c]	≈ +24
07-02-80	66	6+	7+	+1
07-17-80	67	7+	8+	+1
07-02-80	68	7+	7+	0
07-02-80	69	7+	7+	0
07-02-80	71	6+	6+	0
07-02-80	72	10+	9+	-1
07-02-80	73	8+	7+	-1
11-06-79	73	7+	7+	0
08-20-80	74	7+	12+	+5
07-02-80	74	10+	11+	+1
07-02-80	75	10+	12+	+2
07-02-80	76	9+	7+	-2
08-13-80	77	12+	12+	0
07-02-80	77	10+	10+	0
07-02-80	78	12+	12+	0
06-27-80	79	11+	12 ?[d]	0
08-13-80	80	9+	14+	+5
06-27-80	85	9+	21+	+12
07-02-80	86	12+	14+	+2
07-02-80	86	17+	17+	0
07-17-80	87	25+?[e]	31+	+6 ?

Males

Collection Date	Fork Length (cm)	Surface Age[a]	Section Age[b]	Difference (Section - Surface)
11-26-80	55	5+	≈23	≈+18
11-06-79	55	6+	30+	+24
07-02-80	63	6+	6+	0
08-13-80	66	7+	9+	+2
08-20-80	67	6+	29+	+23

[a] From Maeda (1982), based on whole otoliths.

[b] Based on burnt-section otolith reading, Pacific Biological Station, personal communication.

[c] Pacific Biological Station comment: "looks like a slow-growing male"

[d] Pacific Biological Station comment: "annulus on edge?"

[e] Surface age as determined by Maeda (1982) judged unreliable.

Discussion

It is unfortunate that such a small sample of specimens was sent to the Pacific Biological Station for comparison of age assignments by conventional surface and otolith section methods, particularly of males for which discrepancies were greatest. Had we suspected that the pattern of discrepancies would be so bizarre, we would probably have sent more specimens. As it was, however, Pacific Biological Station staff kindly performed the age assessments for us at no cost and we were reluctant to impose upon the Station for a larger sample.

Nevertheless, the small sample used for comparison does seem to strongly implicate very serious errors in age assignments for male sablefish based on conventional surface aging methods applied to both scales and whole otoliths. Discrepancies among female age assignments, at least for fish less than perhaps 80 cm, were a bit less disconcerting and lacked obvious trends with female size or conventional age assignment. We have tentatively concluded that ages of fast-growing females may be fairly reliably assessed by conventional surface methods, but that conventional methods may seriously fail when applied to slower-growing males or to slow-growing stocks of sablefish. This conclusion presumes that otolith section ages are valid.

There are some intriguing features of the discrepancies which were found in the small sample used for comparison of age assignments, and it is difficult to resist the temptation to speculate as to the possible causes for the observed pattern of discrepancies. At the risk of embarrassing ourselves with questionable inferences, but in the spirit of promoting discussion at this Symposium, we have not resisted the temptation to speculate. Careful scrutiny of Table 2 shows that three of the four specimens for which aging discrepancies were greatest were collected during the month of November (two males and one female, perhaps a misclassified male). Among the entire sample of 28 otoliths sent to the Pacific Biological Station, there were only four specimens which had been collected in November; remaining specimens were collected primarily during June through August. There were no absolute discrepancies in excess of two years for those specimens which were collected on 07-02-80; yet these specimens constituted fully 50% of the entire constrast sample.In addition, among the three male specimens which were collected during July and August, ages were in close agreement in two cases. These three fish, aged by Maeda as 6+, 7+, and 6+, but by otolith section as 6+, 9+, and 29+, had lengths of 63, 66, and 67 cm respectively. The other two male specimens, collected in November, aged by Maeda as 5+ and 6+ but by otolith section as ≈23 and 30+, both had lengths of 55 cm. Thus, agreement among males was best for intermediate-sized fish.

The above two general observations — that aging discrepancies may be correlated with time of capture, and that aging discrepancies for slower-growing males do not seem nicely related to male size — prompt us to speculate that the aging discrepancies may, at least in part, result from the existence of mixed and migratory stocks of sablefish, with widely differing growth rates, which are jointly harvested in the Eureka fishery.

Although the above speculation appears to diverge from conventional wisdom concerning sablefish stock mixing (e.g. the Monterey, California, fishery, is believed to be based on a single local stock; see PFMC 1982), one is hard pressed to resolve the pattern of age discrepancies without conjuring up an hypothesis which involves multiple local stocks in the Eureka fishery. Alternative hypotheses, for example that growth rates among males within the same stock are rather exceptionally variable, seem far less tenable, although certainly possible. Although our speculation of the existence of multiple local stocks rests on a near dismally small sample in which the importance of time of capture is confounded by fish sex, we intend to pursue study of this possibility in future research. We plan to contrast discrepancies between conventional surface and otolith section age assignments with time of capture and with meristic/morphometric and perhaps electrophoretic measurements of sampled fish. Should age discrepancies be highly correlated with characteristics indicative of distinct races of fish and with time of capture, then at least some of the reasons for the aging discrepancies may be resolved. We also hope to learn, from information presented at this Symposium, whether results from recent sablefish tagging can shed any light on these issues.

Finally, our conventional age assignments, regardless of their validity for slower-growing sablefish, do suggest that Eureka-landed sablefish grow more rapidly than more northern stocks, and that local stocks also exhibit strong sexual dimorphism of growth. It is our understanding that sexual dimorphism of growth is also striking among many rockfishes. Since for sablefish female growth is more rapid than male growth, an intensive fishery would probably selectively remove the faster-growing females at a greater rate than the slower-growing males. Thus females, which are presumably of greater reproductive importance for eventual sablefish recruitment, would likely be reduced in numbers and biomass to a far greater extent than would would be so for males. Surprisingly, the problem of optimal harvest strategies in the face of strong sexual dimorphism of growth seems to have received little attention. Our naive impression is that size limits should be set such that the female stock is less likely to be severely impacted. This, coupled with the (usually) increasing economic value of sablefish with increasing size, would argue for a size limit which probably exceeds the effective size limit now imposed through mesh size regulation and/or market conditions. However, an increased size of harvest would also result in an underharvest of the slower-growing males which have lower reproductive value to stocks.

Maeda's (1982) and other observations (Alverson et al. 1964) of roughly 2:1 male:female sex ratios in trawl catches may be indicative of the effectively greater harvest rates which are applied to females. Alternatively, the predominance of males in our samples may be a reflection of migration of females away from males during certain times of the year. For example, Beamish (1980) suggested that females may undergo an early fall migration to depths as great as 1,000-1,500 fathoms and he reported October catches at these depths which were 92% female. Perhaps the long-term solution to effective management of sablefish stocks, in light of strong sexual dimorphism of growth, lies in a thorough understanding of this kind of migratory behavior coupled with corresponding sex-targeted fisheries.

Acknowledgements

We extend our sincere thanks to the International Sablefish Symposium sponsors for supporting our presentation of this brief paper at the Symposium, and to R.J. Beamish and D. Chilton for providing us with otolith section ages for those specimens which we sent to the Pacific Biological Station. We also extend thanks to Dennis Forbes, captain, and the crew of the Eureka-based vessel the "Midnight Sun" for allowing Maeda to collect sablefish on board the vessel, for allowing this at no cost, and for their kindness and cooperation in our research.

Literature Cited

Alverson, D.L., A.T. Pruter, and L.L. Ronholt. 1964. A study of demersal fishes and fisheries of the Northeastern Pacific Ocean. H.R. MacMillan lectures in fisheries, U.B.C., Vancouver. 190 pp

Alverson, D.L. and M.J. Carney. 1975. A graphic review of the growth and decay of population cohorts. J. Cons. Int. Explot. Mer 36:133-143.

Beamish, R.J. and D.E. Chilton. 1982. Preliminary evaluation of a method to determine the age of sablefish (Anoplopoma fimbria). Can. J. Fish Aquat. Sci. 39: 277-287.

Beamish, R.J., C. Houle, and R. Scarsdale. 1980. A summary of sablefish tagging and biological studies conducted during 1979 by the Pacific Biological Station. M.S. Rept. Can. Fish. Aquat. Sci. No. 1588. 194 pp

Fraser, C.M. 1916. Growth of the spring salmon. Trans. Am. Fish. Soc., Seattle, for 1915: 29-39.

Holden, M.J. 1974. Manual of fisheries science, Part 2, methods of resource investigation and their application. FAO Fish. Tech. Pap. Revision 1, NO. 115. 215 pp

LaLane, J.J. 1979. The validity and consistency of age determinations from otoliths of Pacific pollock (Theragra chalcogramma). Inter. N. Pac. Fish. Comm. Ann. Rep. 1977:99-107.

Lea, E. 1910. On the methods used in herring investigations. Publs. Circonst. Cons. Perm. Int. Explor. Mer No. 53. 174 pp

Lee, R.M. 1920. A review of the methods of age and growth determination by means of scales. Fish. Invest., London, Ser. II 4(2). 32 pp

Low, L.L., G.K. Tanonaka, and H.H. Shippen. 1976. Sablefish of the Northeastern Pacific Ocean and Bering Sea. NW and Alaska Fish. Center Processed Rept. 79-3. 75 pp

Maeda, R. 1982. Aging of sablefish, Anoplopoma fimbria, from otoliths and scales: an evaluation of readability, reliability and derived growth patterns. M.S. thesis, Fisheries, Humboldt State U., Arcata, CA. 124 pp

Monastyrsky, G.N. 1930. Methods of determining growth in length of fishes by their scales. Trudy nauch. Inst. ryb. Khoz. 5(4): 1-44.

PFMC. 1982. Fishery management plan and environmental impact statement for the California, Oregon and Washington groundfish fishery. Pac. Fish. Manag. Council, Portland, Or.

Pauly, D. 1980. On the interrelationships between natural mortality, growth parameters, and mean environmental temperature in 175 fish stocks. J. Cons. Int. Explor. Mer 39: 175-192.

Phillips, J.B. 1954. The sablefish fishery in California. Pac. Mar. Fish. Comm. Bulletin 3: 5-22.

Pruter, A.T. 1954. Age and growth of the Oregon sablefish, Anoplopoma fimbria. Pac. Mar. Fish. Comm. Bulletin 3:121-128.

Ricker, W.E. 1975. Computation and interpretation of biological statistics of fish populations. Fish. Res. Board Can. Bulletin 191. 382 pp

Sasaki, T. 1971. Information on the blackcod in the North Pacific. Fish. Agency Japan, Inter. N. Pac. Fish. Comm. doc. ser. No. 1422. 36 pp

Taylor, C.C. 1958. Cod growth and temperature. J. Cons. Int. Explor. Mer 23: 366-370.

Williams, T. and B.C. Bedford. 1974. The use of otoliths for age determination. pp. 114-123 IN T.B. Bagenal, ed., the aging of fish. Unwin, Old Woking. 234 pp.

Use of oxytetracycline and other methods to validate a method of age determination for sablefish

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Abstract

Length frequency analysis, tagging studies and daily growth ring counts were used to identify annuli for juveniles. The identification of annuli for adults was validated by marking otoliths with oxytetracycline. A dosage of 100 mg/kg of oxytetracycline caused increased mortality in the natural environment but not in the laboratory. The most suitable dosage appeared to be 50 mg/kg. Most fish that had been at liberty for 3 to 5 years were found to have added the number of annuli equivalent to, or very close to, the years at liberty. There was no indication that the method over-estimated true ages. The position of the oxytetracycline mark confirmed that otoliths continue to grow in thickness and that otolith surface growth was irregular or absent. The irregularity of growth at the periphery of the external surfaces indicates that older fish cannot be aged reliably by viewing the surface of the otolith.

The method of age determination is valid for most fish although interpretation of annuli can be difficult and some older fish may not form annual growth zones.

Introduction

The method of ageing sablefish (*Anoplopoma fimbria*) was developed and partially validated by Beamish and Chilton (1982). The range of ages produced by this method was considerably greater than ages produced in other studies (see Beamish and Chilton, 1982) that relied on interpretations of annuli using the otolith surface. Beamish and Chilton acknowledged that the interpretation of the otolith section was difficult, however, their preliminary attempts at validating their interpretations confirmed that the zones identified as annuli did form once a year. In contrast, estimates from other studies were not validated, thus, they concluded that their interpretations should not be rejected in favor of a technique that produced younger ages. Successful validation of any age determination technique requires that ages assigned to all age groups are proven to be accurate (Beamish and McFarlane, 1983). Ages assigned beyond the oldest validated age should not be assumed to be correct as there is a risk that changes in the pattern of growth of the structure used for age determination will obscure annuli, resulting in an under-estimate of the true age.

In this study, the position of the first annulus was identified using daily growth zone counts as well as length frequency analysis. Length frequency analysis and tagging studies were used to validate ages of juveniles. Adult ages were validated by tagging and injecting fish with oxytetracycline. The appropriate dosage of oxytetracycline was important and had to be determined in field trials. The oxytetracycline studies were also used to study the pattern of otolith growth.

The purpose of this report is to provide additional information about the validity of the method developed by Beamish and Chilton (1982).

Methods

Fish were collected from commercial catches and research cruises. They were measured for fork length, sex was determined and both otoliths (sagittae) were cleaned and stored in a 50% glycerin solution. Tagging and injection procedures have been described previously (Beamish et al., 1979; 1980). Otoliths were processed and examined according to the procedures described by Chilton and Beamish (1983).

Otoliths of 9 juvenile sablefish were prepared for the examination of daily growth increments by grinding and acid-etching using 6% hydrochloric acid (HCl). The otolith was mounted on a glass slide with epoxy and ground using lapping film paper (Neilson and Geen, 1982). The slide was held by hand during grinding. The grinding was alternated with immersion in 6% HCl for approximately 3 seconds, followed by immersion in water for a few seconds (A. Wild, pers. comm.). The whole otolith was mounted on the slide with the interior (concave) side up. Photographs of daily increments were taken, starting with the exterior edge and proceeding towards the center. It was not possible to expose all daily increments at one time.

Oxytetracycline was used to produce a "time" mark in the otolith. A dosage of 100 mg/kg was initially determined from previous studies (Kobayashi et al., 1964; Weber and Ridgway, 1962, 1967; Lanzing and Hynd, 1966). When recoveries indicated that the dosage of 100 mg/kg was causing increased mortality, field studies were initiated to determine the most appropriate dosage. The 100 mg/kg dosage and a 25 mg/kg dosage were also tested in the laboratory.

During March and June 1981, sablefish captured off the west coast of the Queen Charlotte Islands were tagged and injected with oxytetracycline. Approximately one quarter were tagged in the routine manner and received an intraperitoneal injection of 100 mg/kg (Beamish et al., 1978). One quarter were tagged and given the same volume of oxytetracycline diluted with 1% saline to produce one quarter of the concentration (25 mg/kg), one quarter were tagged and injected with the same volume of 1% saline solution and one quarter were tagged and not injected.

In November 1981 off the west coast of the Queen Charlotte Islands, one quarter of the sablefish were tagged and given an intraperitoneal injection of 25 mg/kg body weight, one quarter were tagged and given an intraperitoneal injection of 50 mg/kg, one quarter were tagged and given an intraperitoneal injection of 75 mg/kg, one eighth were tagged and received no injection, and one eighth of the fish were tagged and given an intermuscular injection of 25 mg/kg.

Otolith pairs from all injected and recaptured fish were recovered and stored in 50% glycerin in a darkened container. Prior to storage the otoliths were wiped clean of all tissues.

Some otoliths were stored for up to 2 years before being examined. One otolith of each pair was examined in a darkened room using a Leitz Laborlux 12 microscope equipped with an ultraviolet light. The otolith was broken dorso-ventrally through the nucleus and the broken surface examined. The position of the mark was noted and the distance from the distal edge of the mark to the edge of the otolith section was measured. The section was then burnt (Beamish and Chilton, 1982) and the age was determined. The postion of the mark was identified using the previous measurements since burning destroyed the mark. The number of annuli that formed after the mark were then counted. For some sections it was not necessary to burn the otolith as the annuli were distinguishable using the reflected ultraviolet light.

Only the otoliths from fish that had been at liberty for 3 or more years after tagging and injection were examined. Otoliths from fish that had been at liberty for 1 or 2 years frequently had grown very little, making it difficult to identify annuli. When the reader examined the area distal to the oxytetracycline mark, in most cases the reader was aware that there could be 3 to 5 annuli. Because the annual growth zones are very narrow and sometimes difficult to identify, we wanted to be certain that these zones formed annually, thus, many otoliths were examined with a prior knowledge of the years between release and recapture.

A smaller sample was examined so that the accuracy of the determination could be estimated. The age from one broken and burnt section was determined and the age from the nucleus to the mark was determined from the remaining half. The difference in these two determinations was then compared to the time at liberty between marking and recapture.

Results and Discussion

Position of first annulus

The sample of 9 fish used for daily growth increment counts was collected in February 1982 and fish ranged in size from 23 to 27 cm. Since most sablefish in the Canadian zone spawn in February (Mason et al., this symposium), these fish could be one or more years old. The lengths of the smallest sablefish captured in the Canadian zone in 1977 and 1978 (McFarlane and Beamish a, this symposium) suggest that sablefish grow very rapidly during their first year and that the fish in this sample would be age 1. Exact counts of daily growth increments were difficult to make, however the total increment count for the 9 specimens ranged from 270 to 350 suggesting that these fish were age 1 (or approximately 360 days old). The range from 270 to 350 resulted in part from the inability to count all increments and probably represents minimum counts.

The daily formation of these rings must be validated, just as the yearly formation of annuli must be validated and as yet it has not been possible to prove the daily formation of these increments. It was possible to show that the widths of the daily zones became compressed at the edge of the otolith suggesting that the first annulus was forming on the edge (Fig. 1).

Fig. 1. Daily growth increments from the center, middle and edge of an otolith from a 26 cm sablefish.

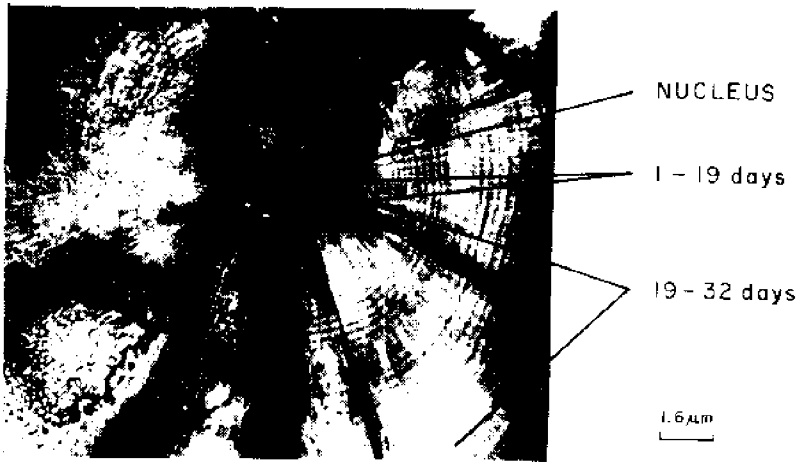


Fig. 1A. Nucleus area showing the zones thought to form immediately after hatching (1-19), and after absorption of yolk (19-32).

Fig. 1B. Center of otolith showing evenly spaced wide zones.

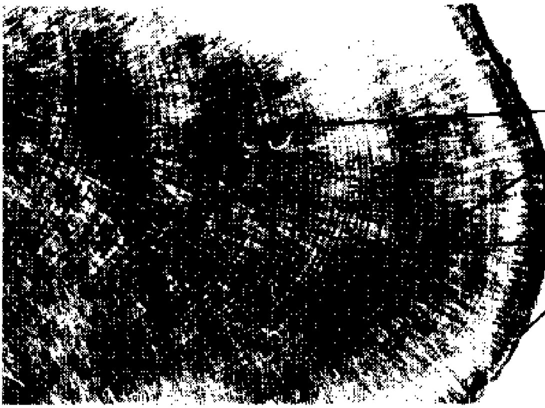


Fig. 1C. Edge of otolith showing the compression of zones in the area thought to be the annulus.

Increment growth from the nucleus to the area of compression was quite regular except for some zones that formed 2 to 4 months after hatching. It is probable that these zones do form daily and that the average estimate of 313 zones for the 9 fish is an approximation of the actual number of days since hatching or that these fish were age 1.

Juveniles

Beamish and Chilton (1982) used length frequency distributions to estimate the age of juveniles. An updated length frequency appears in McFarlane and Beamish a, (this symposium) and shows that while there is variation among samples, it is possible to use length to estimate age up to 2 and possibly 3 years. Length should only be used for 3 year olds when the length frequency of the sample is known. For example, fish B7707425 (see Fig. 6D) was 50 cm when tagged and 51 cm when recovered 5 years later. This fish was age 10 when tagged and 15 when recovered. If the length frequency of a sample has a broad distribution of lengths that extends beyond 55 cm, then fish in that sample should not be assumed to be 3 years old. The use of daily growth zones to identify the position of the first annulus corroborates the interpretation of age 1 fish from length frequency distributions. Because growth in length is rapid up to approximately 45 cm or age 2+, it appears that the use of length to estimate age for the first 2 years will be accurate.

Juveniles that were tagged in 1979 had an average length of approximately 44 cm (Beamish et al., 1980). The abundance of these fish and their length frequency distribution clearly indicated they were from the successful 1977 year-class and were age 2+ when tagged in 1979. In 1982, 57 of these tagged fish were recovered, 20 of which were sampled for otoliths.

These fish were aged without any prior knowledge of their history and 50% were aged correctly as 5 year olds (Table 1). When it was known that the fish should be age 5, it was possible to age 85% correctly but 3 fish still were estimated to be age 6.

Table 1. Estimate of age from sablefish tagged in 1979 as age 2+ and recovered in 1982 as age 5.

	Age years (n)		
	5	6	7
Unbiased reading[1]	10	9	1
Biased reading[2]	17	3	

[1]Reader had no previous knowledge of fish.

[2]Reader knew they should be age 5.

Interpretation of growth zones is not unequivocal and can be quite difficult (Fig. 2). Younger growth is more difficult to age than older growth and there is a possibility that some fish were not age 2+ as thought. The estimates of these known age fish were either accurate or close to the true age, illustrating that the method is valid for younger fish but subject to error. At present the error appears to be interpretative. While accuracy will improve through the validation procedure it is unlikely that this age determination method for sablefish will result in error free determinations.

Adults

Dosage of oxytetracycline. The dosage of oxytetracycline of 100 mg/kg of fish weight caused increased mortalities in the natural environment. There was an obvious difference in the recovery percentages of injected and uninjected fish from the three releases in which the 100 mg/kg dosage was used (Table 2). There also was an obvious difference in recovery percentages between these releases that received the 100 mg/kg dosage (5.4%) and all other adult releases that received no injection (15.0%).

Table 2. Summary of recoveries until December 31, 1981, of fish released with oxytetracycline injections, 1977-1978 and all other releases.

Cruise	Number injected	Number recovered	% recovered	Number uninjected	Number recovered	% recovered
September 1977	5,279	160	3.0	226	1	0.4
May 1978	4,418	240	5.4	866	292	33.7
June 1978	5,463	418	7.7	2	0	-
All other releases of uninjected fish	-	-	-	36,147	5,422	15.0

The results of the laboratory experiment to examine the effect of a dosage of 100 mg/kg and 25 mg/kg on mortality and growth of juveniles (Beamish et al., 1980) were completed in 1981 (Table 3). There was no immediate mortality associated with either treatment and while some mortalities have occurred there is no difference among treatments.

Fig. 2. Sections of broken and burnt otoliths from juveniles tagged in 1979 at age 2+, photographed using reflected light.

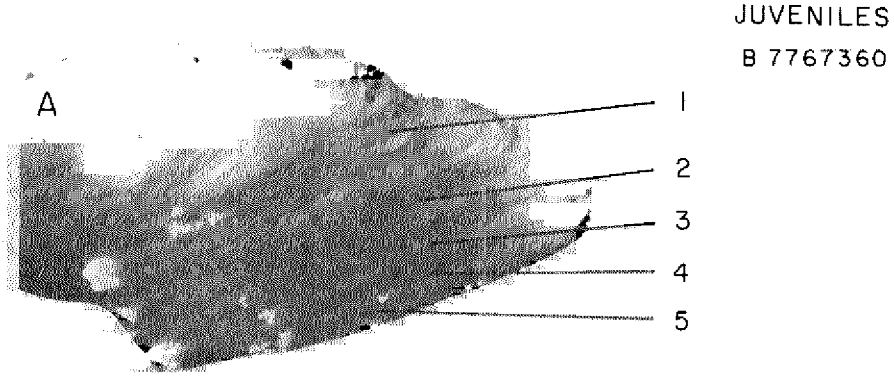


Fig 2A. A female, 43 cm when tagged in November and 47 cm when recovered in May 1982. The position of the first two annuli are difficult to identify without having examined otoliths from fish "known" to be age 1 and 2.

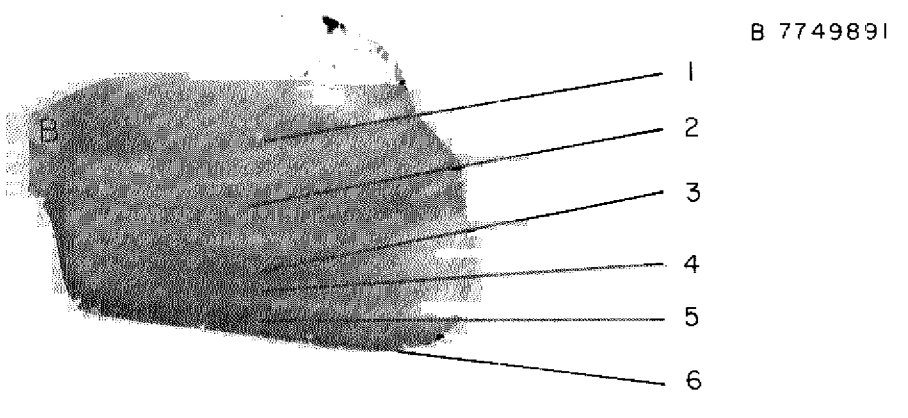


Fig. 2B. A male, 37 cm when tagged in October and 48 cm when recovered in October 1982. The otolith is difficult to age and it is aged incorrectly probably because the 5th and 6th years are only one annual growth zone.

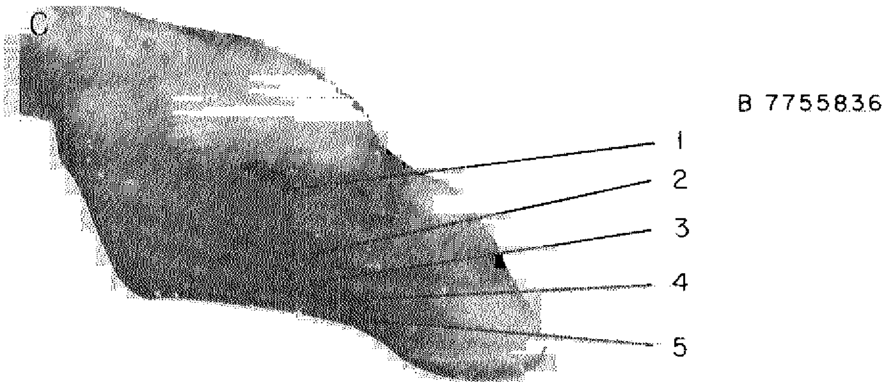


Fig 2C. A male, 45 cm when tagged in October and 59 cm when recovered in late August 1982.

Differences in growth were examined by testing the coincidence of regression lines, and no significant differences were found ($p>0.05$). Thus, in the laboratory the range of dosages does not affect growth or mortality. Since there is a definite increase in mortality in the natural environment, it was concluded that the experiment in the laboratory did not simulate natural conditions and definitely was not a "control" experiment for this species.

For technical reasons, the dosage studies conducted in the natural environment had to be separated into two cruises. This resulted in the first release receiving more fishing pressure than the second release. There also was some change in the fishing pattern in 1982 making it difficult to compare the two releases, however, it is possible to compare the results within each release. Of the 1,477 fish tagged and receiving no injection during March and June, 62 or 4.2% were recovered during the remainder of 1981 (Table 4). Of 1,481 fish tagged and injected with a full dose (100 mg/kg) only 11 or 0.7% were recovered. Of the 1,472 fish tagged and injected with 25 mg/kg diluted with 1% saline to provide the same volume of oxytetracycline, 68 or 4.6% were recovered. Eighty or 5.4% of the 1,484 fish receiving the same volume of 1% saline but no oxytetracycline were recovered. As all fish were released in the same area and were subjected to the same fishing pressure the difference in recovery percentages between the 100 mg/kg is real and significant (t-test, $p<0.05$). These results also indicate that the concentration of oxytetracycline and not the volume of fluid injected is contributing to the increased mortality in the injected fish.

In the second experiment, the recovery percentage from the 75 mg/kg dosage was significantly lower (t-test, $p<0.05$) than the percentage of uninjected fish recovered (Table 4). The dosage of 50 mg/kg produced a lower percent recovery than uninjected fish although it was not significant (t-test, $p>0.05$). More recoveries should be made to determine if a 50 mg/kg dosage has any effect on survival. There was no difference in the recovery percentages between fish that received intraperitoneal and intermuscular injections.

Table 3. Summary of growth of sablefish held in captivity.

Date in tank	Dosage of OTC	Remeasurement														
		Dec/79			April/80			July/80[a]			Oct/80			Jan/81[a]		
		Mean length (cm)	S.D.	n	Mean length (cm)	S.D.	n	Mean length (cm)	S.D.	n	Mean length (cm)	S.D.	n	Mean length (cm)	S.D.	n
Dec 13/79	none	52.80	2.15	20	57.97	2.25	19	61.65	2.27	19	64.92	2.88	17	66.68	3.72	17
	none	48.83	2.43	20	57.78	2.48	19	61.77	2.97	18	64.90	3.52	17	66.92	3.78	17
	25 mg/kg	49.49	1.92	20	57.92	2.45	19	61.03	3.05	19	63.84	3.34	19	65.59	3.41	19
	100 mg/kg	48.23	2.88	20	55.71	3.64	20	58.45	3.73	19	61.24	4.63	19	62.62	5.22	19

Date in tank	Dosage of OTC	Remeasurement											
		May/81[a]			Sept/81			Jan/82[a]			May/82[a]		
		Mean length (cm)	S.D.	n	Mean length (cm)	S.D.	n	Mean length (cm)	S.D.	n	Mean length (cm)	S.D.	n
Dec 13/79	none	69.05	4.00	15	70.56	4.76	15	72.13	5.42	13	72.14	4.50	8
	none	68.58	4.06	17	70.06	4.34	16	71.20	4.49	16	72.36	4.96	14
	25 mg/kg	67.11	3.64	20	68.16	3.99	20	69.21	4.45	19	69.46	4.71	17
	100 mg/kg	64.19	5.80	16	64.50	5.98	16	65.08	6.58	14	65.48	6.86	13

[a]Used to calculate mean growth.

Table 3 (cont'd)

	.5 years			1.0 years			1.5 years			2.0 years			2.5 years		
Dosage	$\bar{x}$ growth	S.D.	n	$\bar{x}$ growth	S.D.	n	$\bar{x}$ growth	S.D.	n	$\bar{x}$ growth	S.D.	n	$\bar{x}$ growth	S.D.	n
none	12.33	1.36	19	17.02	2.89	17	19.13	3.34	15	22.44	4.77	13	22.80	4.39	8
none	13.29	1.81	18	18.44	2.80	17	20.09	2.96	17	22.76	3.33	16	23.65	3.61	14
25 mg/kg	11.51	2.38	19	16.22	2.91	19	17.62	3.45	20	19.51	3.98	19	20.02	4.85	17
100 mg/kg	11.01	2.64	19	14.54	3.98	19	16.10	4.07	16	17.00	4.65	14	17.86	5.20	13

Table 4. Results of oxytetracyline injections experiments as of December 1982.

Experiment 1 (March-June 1981)

Dosage	No. injected	No. recovered	% recovered
No injection	1477	155	10.5
1% saline[1]	1484	173	11.7
25 mg/kg[2]	1472	141	9.6
100 mg/kg	1481	37	2.5

[1]Volume equal to 100 mg/kg dosage.

[2]Volume equal to 100 mg/kg dosage by diluting with 1% saline.

Experiment 2 (November 1981)

Dosage	No. Injected	No. recovered	% recovered
No injection	535	19	3.6
Intermuscular 25 mg/kg	607	23	3.8
Intraperitoneal 25 mg/kg	1187	37	3.1
50 mg/kg	1010	27	2.7
75 mg/kg	1072	10	0.9

As reported previously (Beamish et al. 1980), the measurements of recovered blackcod indicate there has been no net increment in length no matter how long the fish have been at liberty (Table 5). In fact, if all measurements are used there has been a net decrease in some length groups. The absence of an average net increase is related to shrinkage during freezing (Beamish et al., 1980). If fish were measured immediately upon recovery, without freezing then there was a definite trend to a net increase in length with time (Table 5). Freshly measured fish that had been at liberty for 1 year or more grew at an average annual increment of 0.79 cm/yr (Table 5). Combining samples of both sexes and by time at liberty rather than by sex and age can bias the results if unequal numbers of younger, faster growing fish are recovered. To compare growth of injected and uninjected fish, juveniles were excluded and sexes were considered separately, however, because of the small sample sizes, ages had to be combined. It does appear that the dosage of 100 mg/kg has resulted in significant reduced growth in the year of tagging (t-test, $p<0.05$) that was followed by a rapid increase in growth in the second year (Table 6). Beyond the second year sample sizes are probably too small to allow any conclusions about growth.

Table 5. Average growth of recovered sablefish.

Years after tagging	All recovered sablefish: Average growth (cm)	S.D.	N.	Only sablefish in fresh condition measured by fisheries staff: Average growth (cm)	S.D.	N.
0	-0.63	2.14	820	0.99	2.91	51
0.5	-0.25	1.95	1324	0.52	1.81	138
1.0	-0.51	2.30	1490	0.43	2.63	38
1.5	-0.53	2.33	425	0.99	2.81	19
2.0	-0.62	2.40	328	0.61	1.54	36
2.5	-0.62	2.97	83	-0.18	0.87	11
3.0	-0.99	2.77	128	6.1	5.88	5
3.5	-1.5	0.71	2	-	-	-

Table 6. Average growth (cm) of recovered sablefish with release length greater or equal to 60 cm, and measured in fresh condition by fisheries staff. (Includes recoveries up to December 31,1981.)

Number of growing seasons[a] at large	Uninjected fish: x̄ annual increment	n	Injected fish: x̄ annual increment	n
Males				
1	0.47	28	-0.67	6
2	0.16	21	0.40	6
3	0.76	3	-0.17	2
x̄ annual increment	0.47		-0.15	
Females				
1	0.54	58	-0.05	21
2	0.44	45	0.85	10
3	0.95	5	0.12	6
4	1.39	5	0.93	1
5	0.80	2	-	-
x̄ annual increment	0.80		0.46	

[a]Growing season taken as June to September.

In the laboratory experiment, the 25 mg/kg dosage produced an acceptable mark in the otolith. A similar dosage has produced a suitable mark in dogfish sharks (Squalus acanthias) (Beamish and McFarlane, 1983) and lingcod (Ophiodon elongatus) (unpublished data). However, fish that had the 25 mg/kg dosage in the natural environment did not develop as prominent a mark in the otolith as the 50 mg/kg dosage (Table 7). Hence, the 25 mg/kg dosage does appear to be too weak for this species.

Table 7. Prominence of oxytetracycline mark.

Dosage	N	Years at liberty	Number of fish		
			Prominent	Faint	No mark
100 mg/kg	11	5	6	3	2
75 mg/kg	10	1	7	2	1
50 mg/kg	21	1	11	7	3
25 mg/kg	29	1	7	12	8

The 50 mg/kg dosage appears to be the more appropriate since a mark was present on most otoliths and the dosage did not cause significant mortalities. The mark that was present from stronger dosages was more prominent, however the dosage did affect survival.

A total of 154 pairs of otoliths were recovered in 1980 and 1981 from fish injected with oxytetracycline in 1977 and 1978. One hundred and twenty-nine (Table 8) of these were examined to determine if an annulus formed each year and 36 (Table 9) were used to test the reader's interpretation of annuli. Fish used in the total sample had been at liberty for 2 to 4 years. Most had completed three growing seasons and a few had completed four growing seasons. Thus, there should be between two and four annuli distal of the oxytetracycline mark.

Table 8. Estimated years at liberty for tagged and injected sablefish. Reader was aware of expected number of annuli.

Expected number of annuli during liberty	Estimated number of annuli (numbers in parenthesis)			Number with mark on or close to edge	Number with no mark
	1	2	3		
2	-	(7)	-	8	4
	2	3	4		
3	(4)	(67)	(5)	20	9
	3	4	5		
4	-	(4)	-	-	1

The oxytetracycline mark was visible on the broken sections of most otoliths. In some there was no mark and all otoliths that had fungal growth resulting from improper cleaning prior to storage did not have a mark.

In this study 65% of the recovered fish were either the same size or shorter than the size at tagging. While measurement error and shrinkage during storage occur (Beamish et al., 1980), there can be little doubt

Table 9. Calculated years at liberty from age estimates for tagged and injected fish that had been at liberty for 3 growing seasons. Reader was unaware of expected number of annuli.

	Years at liberty					
	0	1	2	3	4	unreadable
No.	2	6	9	13	5	1
%	6	17	25	36	14	3

that growth in length of the fish has been very small during the release period and that the narrow annual growth increments on the otolith are an accurate indication of slow growth.

The annual growth zones in the vicinity of the oxytetracycline mark were quite narrow for older fish (Figs. 3, 4, 5). Annuli, distal of the oxytetracycline mark, could be counted on 74% of the subsample of 129 fish (Table 8). In almost all cases (90%) it was possible to identify the expected number of annuli (Table 8).

Fig. 3. Section of otolith from sablefish B7720670.

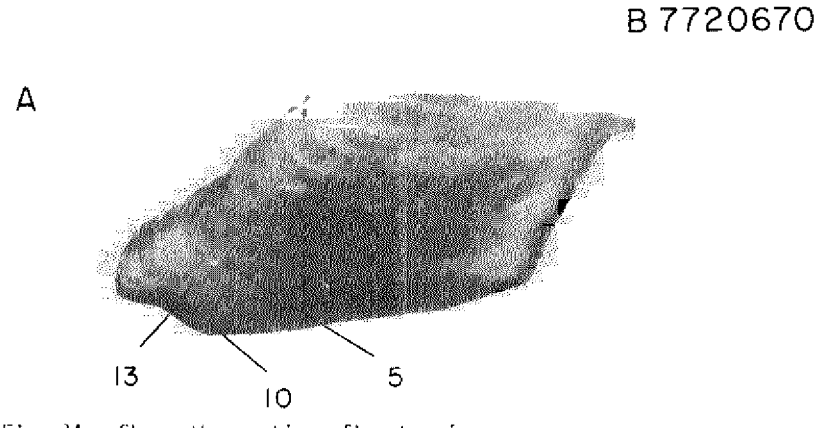


Fig. 3A. Shows the section after burning.

The expected number of annuli were accurately determined in 36% of the subsample (Table 9) when the reader was not influenced by knowing that the fish had been at liberty for 3 years. The expected number of annuli, + 1 year were determined correctly in 75% of the sample. In no case was the estimate of the number of annuli that formed while at liberty sufficiently large to produce a serious over-estimate of age.

Errors that occurred clearly resulted from a difficulty in interpreting growth zones. While it was necessary to consider how to group some growth zones, it usually was possible to distinguish checks from the wider more prominent annuli.

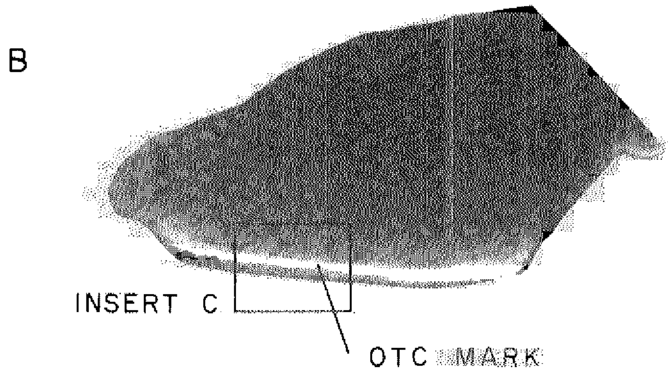


Fig. 3B. Shows the oxytetracycline (OTC) mark that is yellow under ultra-violet light.

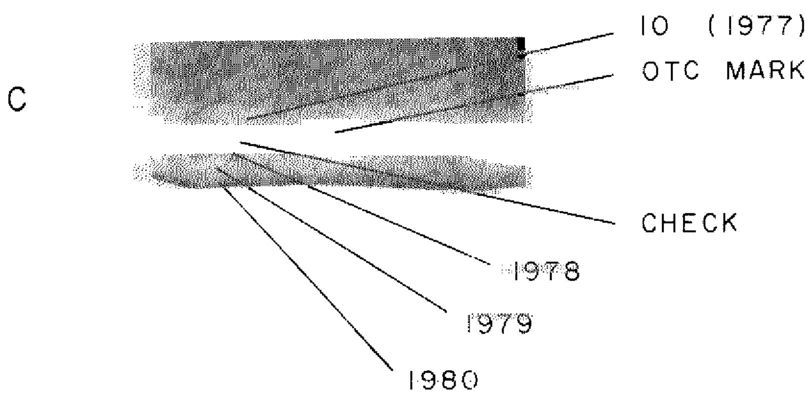


Fig. 3C. An enlargement of the growth zones that formed before and after the mark.

Fig. 4. Section of otolith from sablefish B7725711.

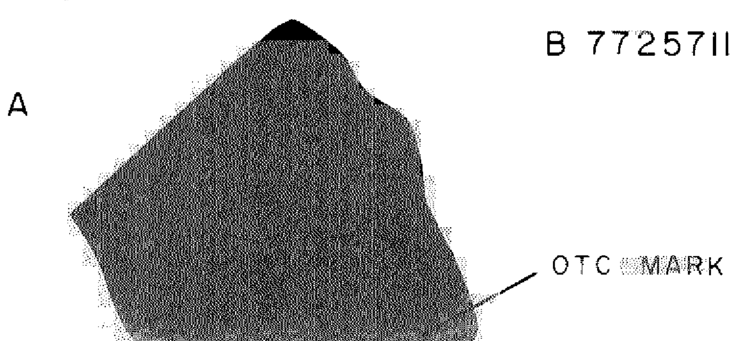


Fig. 4A. Shows the oxytetracycline (OTC) mark that is yellow under ultraviolet light.

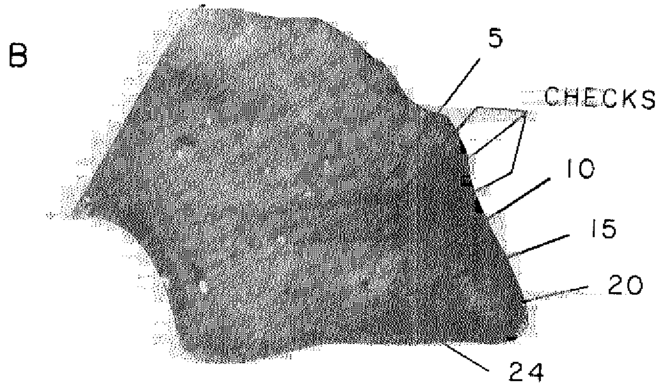


Fig. 4B. Shows the section after burning.

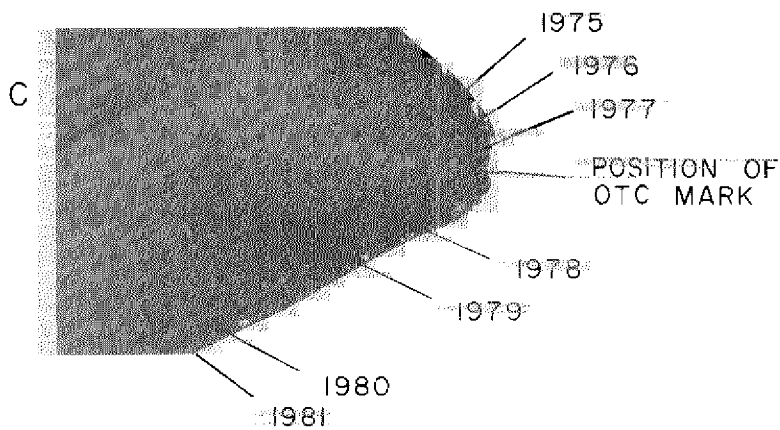


Fig. 4C. An enlargement of the growth zones that formed before and after the OTC mark.

Fig. 5. Section of otolith from sablefish B7705298.

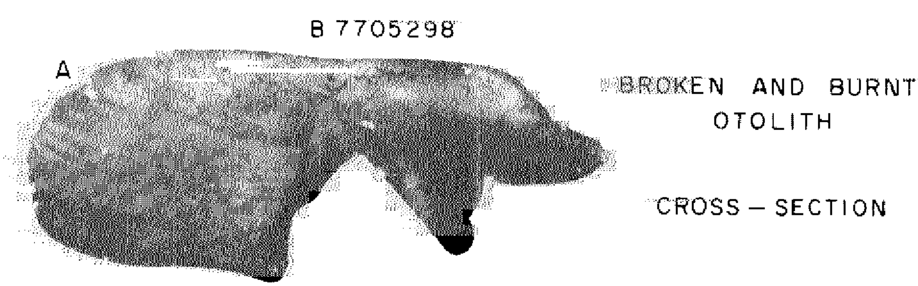


Fig. 5A. Shows the section after burning.

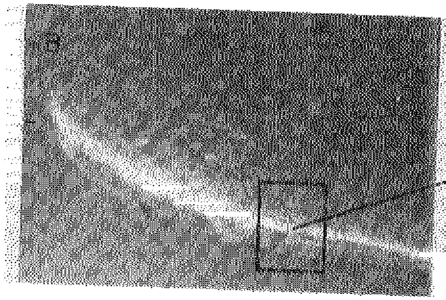


Fig. 5B. The enlarged section showing the oxytetracycline mark.

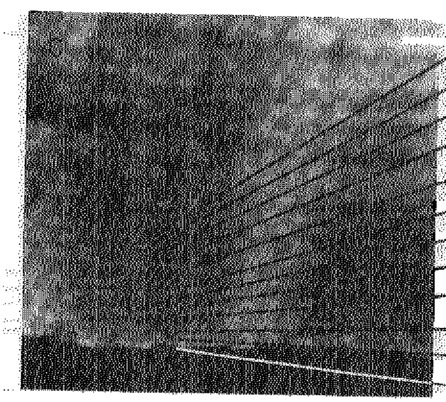


Fig. 5C. An enlargement of the burnt section showing the position of the oxytetracycline mark and the annual growth zones before and after the mark.

For example, fish B7720670 (Fig. 3) was a female tagged in June 1978 and recovered in June 1981. Since most growth occurs in the summer, this fish was at liberty for three growing seasons. Length at tagging was 79 cm but no length at recovery was obtained. The oxytetracycline mark is clearly visible on the interior surface and the annuli before and after the mark are visible. (The annuli are more difficult to identify from photographs than from freshly broken and burnt sections.) Note that the oxytetracycline mark has formed only on the interior surface, indicating that most otolith growth was confined to the interior surface. That is, otolith growth was primarily in thickness and not in length or width or both.

Fish B7725711 was a female tagged in June 1978 and recovered in July 1981. It had been at liberty for three growing seasons and increased in length from 81 to 82.5 cm. The oxytetracycline mark was close to the edge on the interior surface and on the edge on the dorsal, ventral and exterior surface. The interpretation of annuli proximal and distal to the mark is difficult but typical. The broken and burnt section (Fig. 4) indicates that checks can cause some difficulty in identifying the annuli that form when the fish is younger but checks become less of a problem with age. Checks are not prominent in all areas of the otolith while annuli remain identifiable wherever growth zones can be distinguished.

The mean width of the three annuli proximal to the oxytetracycline mark was 0.57 mm compared to 0.46 mm distal to the mark and was significantly wider than the distal zones (t-test, $P<0.01$). When a sample of 50 untagged fish was examined, the mean width of the last three annuli was 0.46 mm while the group of three annuli immediately preceeding the last three annuli was 0.62 mm. Again the widths of the last (older) group of three annuli was significantly smaller (t-test, $P<0.01$). The smaller widths of annuli or groups of annuli that form as the fish ages is consistent with asymptotic growth of fishes. The similarity of response of otolith growth of tagged and untagged fish is indicative that tagging and injecting probably has not had a major effect on growth of the otolith and that the observations from tagged and injected fish are representative of untagged fish. The effect of the dosage of oxytetracycline on otolith growth has not been examined at the time of preparing this report because the fish that have received the various dosages have not been at liberty long enough for otolith growth to be compared.

In 1982, otoliths were recovered from 11 fish that were given oxytetracycline injections in 1977. When recovered these fish were estimated to range from 15 to 28 years. Otoliths from 6 fish had very little growth beyond the oxytetracycline mark and it was not possible to identify 5 annual growth zones between the release and recapture period. If this pattern of growth is normal and not influenced by tagging and injection of oxytetracycline then these fish would definitely be underaged. The remaining otoliths did form five distinct growth zones between release and recapture.

The clearest example was fish B7705298 which was a male that was 62 cm when tagged September 6, 1977, and 69 cm when recaptured July 14, 1982. The oxytetracycline mark is close to the edge indicating relatively little otolith growth, however, the annual growth zone widths before and after the oxytetracycline mark are similar (Fig. 5). The pattern of growth on the other otoliths was similar although the growth zones beyond the oxytetracycline mark were not as distinct. There was no tendency to over-estimate age, rather the difficulty was identifying growth zones. As mentioned, the separation of "checks" and annuli for older growth is not a major problem. Because growth zones are very narrow in the older part of the otolith, it is probable that the method of age determination will under-estimate age rather than over-estimate.

Of all otoliths examined only a very small percentage had an oxytetracycline mark on the exterior surface. When a mark was visible it was usually confined to the anterior and posterior tips of the otoliths. The various sections of otoliths in this report (Figs. 3A, 5, 6) illustrate very clearly that growth on older otoliths is concentrated on the interior surface. While it cannot be proven that growth did not occur on the exterior surface, it is apparent that if growth occurred it would be minimal.

Fig. 6. Sections of otoliths showing the tendency for the oxytetracycline (OTC) mark to form on the interior surface.

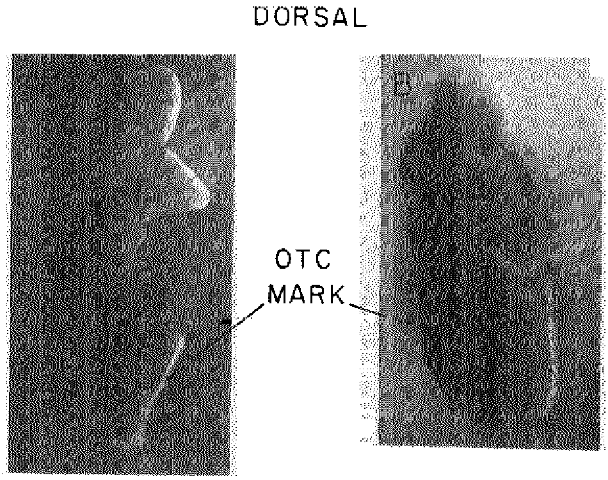


Fig. 6A. A 24 year old male that was 54 cm when marked but no length was available when recovered, OTC mark is barely visible on exterior surface.

Fig. 6B. A 26 year old male that was 62 cm when marked and 64 cm when recovered, the OTC mark is only visible on the interior surface.

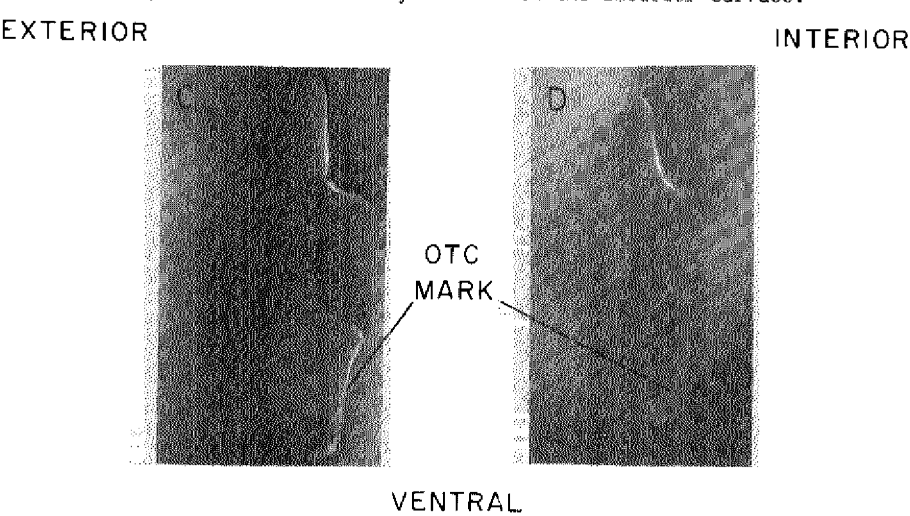


Fig. 6C. A 19 year old female that was 74 cm when marked and 72 cm (loss of length) when recovered, the OTC mark is only on the interior surface.

Fig. 6D. A 15 year old female that was 50 cm when marked and 51 cm when recovered, the OTC mark is close to the edge except for the interior ventral tip.

Beamish and Chilton (1982) reported on the recapture of fish tagged in 1972 as juveniles. These fish were age 1+ when tagged and have been recovered each year since 1979. Otoliths were not collected until 1980 when the fish were age 9 and 9+. The ages estimated without any knowledge of the history of the fish were close to the known age and ages estimated when the history was known were almost identical (Table 10). Examination of these known age fish, again indicates that growth zones can be difficult to identify but the interpretation is accurate or very close to being accurate (Fig. 7). There is no indication that many checks are being misidentified as annuli resulting in a serious over-estimate of age. The pattern of growth zone formation in Fig. 7 is similar to the early growth period in otoliths from older fish (Figs. 3, 4, 5). As the fish ages it appears that growth zones become narrower. These narrow zones can be difficult to identify but they do appear to be present in most fish even when there is very little fish growth. In some fish annual growth zones could not be identified.

Table 10. Estimated ages of fish tagged in 1972 when 1+ years.

Recapture year	N	Known age	Lengths (cm)	Age[1] unbiased	Age[2] biased
1979[3]	2	8 or 8+	62,68	-	-
1980	4	9 or 9+	60, 63, 64, 68	8+, 9+, 8+, 10	9, 9, 9+, 10
1981	2	10 or 10+	72, 77	11,11	11, 10
1982	1	1 or 11+	-	10+	10+

[1]Ages estimated without any prior knowledge of the fish.

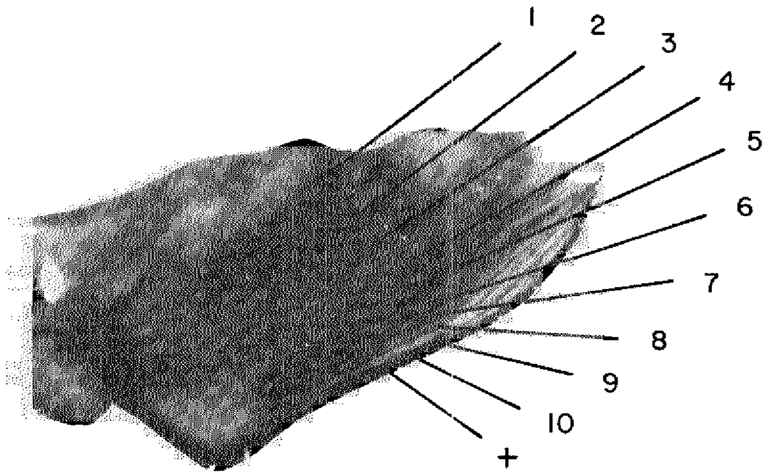
[2]Age estimated knowing the expected age.

[3]No otoliths collected.

Sablefish populations are composed of strong year-classes that occur at approximately 10 year intervals (McFarlane and Beamish b, this symposium). The 1977 year-class was particularly strong and shows as a prominent mode in age frequency distributions for samples collected in 1980, 1981 and 1982 (McFarlane and Beamish a, this symposium). The timing of other strong year-classes, identified in age frequency distributions corrected for mortality, agreed with independent observations of increased juvenile sablefish abundance (McFarlane and Beamish b, this symposium). Thus, the age determination method is capable of identifying dominant age groups in successive years and this is an indication that the method produces valid ages.

The evidence to date does suggest that the method is valid for most fish but difficult to apply. There is evidence that ages of older fish may be underestimated because of interpretative problems or because annual growth zones do not form. There is no evidence of serious over-estimation of age and fish that ranged from 4 to 43 years old when tagged have in many cases added the approximate number of annuli equivalent to the time at liberty. When errors occur they appear to be related to interpretation problems, however, some older fish may not form annual growth zones that are identifiable or they may not form annual growth zones at all.

Fig. 7. A male that was 37 cm (age 1+) when tagged on August 13, 1972 and 76 cm when recaptured in August 1982. The fish should be age 11+.



Acknowledgments

Many people have contributed to this study and we appreciate their assistance. Mr. M. Wellby provided the counts of daily growth rings. Shayne MacLellan assisted with the preparation of the manuscript and the estimates of ages. Mr. Ray Scarsbrook was in charge of most of the tagging studies. Kathy Best and Ivana Barber have maintained the data base for the tagging study. Mr. Bruce Leaman kindly reviewed the manuscript.

References

Beamish, R. J., C. Wood, and C. Houle. 1978. A summary of sablefish tagging studies conducted during 1977. Fish. Mar. Serv. Data Rep. 77: 103 p.

Beamish, R. J., C. Houle, C. Wood, and R. Scarsbrook. 1979. A summary of sablefish tagging and exploratory trapping studies conducted during 1978 by the Pacific Biological Station. Can. Data Rep. Fish. Aquat. Sci. 162: 113 p.

Beamish, R. J., C. Houle, and R. Scarsbrook. 1980. A summary of sablefish tagging and biological studies conducted during 1979 by the Pacific Biological Station. Can. MS Rep. Fish. Aquat. Sci. 1588: 194 p.

Beamish, R. J. and D. E. Chilton. 1982. Preliminary evaluation of a method to determine the age of sablefish (Anoplopoma fimbria). Can. J. Fish. Aquat. Sci. 39: 277-287.

Beamish R. J. and G. A. McFarlane. 1983. The forgotten requirement for age validation in fisheries biology. Submitted for publication.

Chilton, D. E. and R. J. Beamish. 1983. Age determination methods for fishes studied by the Groundfish Program at the Pacific Biological Station. Can. Spec. Publ. Fish. Aquat. Sci. 60: 102 p.

Kobayashi, S., R. Yuki, T. Furui, and T. Kosugiyama. 1964. Calcification in fish and shellfish - I. Tetracycline labelling patterns on scale, centrum and otolith in young goldfish. Bull. Jpn. Soc. Sci. Fish. 30: 6-13.

Lanzing, W. J. R., and J. S. Hynd. 1966. Tetracycline distribution in body tissues of marine fishes. Aust. J. Sci. 29(6): 177-178.

Mason, J. C., R. J. Beamish, and G. A. McFarlane. 1983. Sexual maturity, fecundity, spawning and early life history of sablefish (Anoplopoma fimbria) off the Pacific Coast of Canada. This symposium.

McFarlane, G. A. and R. J. Beamish. 1983a. Preliminary observations on the juvenile biology of sablefish (Anoplopoma fimbria) in waters off the west coast of Canada. This symposium.

1983b. Biology of adult sablefish (Anoplopoma fimbria) in waters off western Canada. This symposium.

Neilson, J. D. and G. H. Geen. 1982. Chinook salmon otolith daily growth increments and factors influencing their production. Can. J. Fish. Aquat. Sci. 39: 1340-1347.

Weber, D. D. and G. J. Ridgway. 1962. The deposition of tetracycline drugs in bones and scales of fish and its possible use for marking. Prog. Fish-Cult. October: 150-155.

1967. Marking Pacific salmon with tetracycline antibiotics. J. Fish. Res. Board Can. 24: 849-865.

Session III

Reproduction

Preliminary observations on the juvenile biology of sablefish *(Anoplopoma fimbria)* in waters off the west coast of Canada

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Abstract

Young-of-the year sablefish were found inshore in July at an average length of 5 cm and increased to 28 cm by November. In 1977, large numbers of juveniles were found in Hecate Strait, Queen Charlotte Sound, Strait of Georgia, and mainland inlets. These fish remained in these areas until age 3+ (4) when they began to move offshore. Larger juveniles were the first to move offshore. Approximately 30,000 to 60,000 t of juvenile sablefish were present in these waters during 1979-1980.

Mean length of fish that had completed their 1st, 2nd, 3rd, and 4th years of growth was 28, 40, 45, and 50 cm, respectively. The length-weight relationship was $Wt(gm) = 7 \times 10^{-6}(L)^{3.0619}$. Sex ratio of juveniles was equal.

Juveniles fed actively on other fishes and were a major source of mortality for other commercially important fishes. It was estimated that juveniles from the 1977 year-class over the age range from 0 to 4 consumed 1,189,086 t of food.

Introduction

This report describes the biology of sablefish up to the age of 50% maturity. As with many species, juvenile biology is difficult to study and therefore has been poorly documented. In 1977, the appearance of large numbers of juveniles in Hecate Strait, Queen Charlotte Sound, and mainland inlets (inside waters), afforded the opportunity to examine the biology of juvenile sablefish, particularly distribution, migration, growth and age, size and location of recruitment.

This is the first description of the biology of juvenile sablefish from hatching to recruitment. Most of the observations in this report are based on the 1977 year-class. Study of the biology of juveniles from other year-classes are necessary to confirm that the observations made on this year-class are not atypical.

Methods

Data for the report were collected from commercial catches at sea by vessel observers and port samplers, and from surveys conducted by the Canadian Department of Fisheries and Oceans.

All sablefish were measured for fork length to the nearest centimetre and examined for sex and maturity. Otoliths were collected for age determination. Juvenile sablefish were aged from "broken and burnt" otoliths (Beamish and Chilton, 1982), length frequency analysis and analysis of daily growth increments (Beamish et al., this symposium). Validation of the age determination method is described elsewhere in this symposium (Beamish et al., this symposium). Stomach contents and weights of juveniles were determined from a few samples considered to be representative of the catch.

Juveniles were anaesthetized prior to tagging using MS222 (tricaine methane sulfonate). Tags and tagging methods are outlined in Beamish et al. (1980).

Results and discussion

Onshore movement

Sablefish spawn from January to March along the entire Pacific coast of Canada at depths exceeding 300 m (Mason et al., this symposium). After hatching, the young move into the surface waters. There have been few collections of larval sablefish. Mason et al. (this symposium) found larvae along the entire west coast of British Columbia in April 1981. Beamish and Chilton (1982) reported juveniles ranging from 5-15 cm from the stomach contents of seabirds in mid-August, 1977. In early July, 1981, 9 juveniles averaging 5 cm were captured in surface waters of Queen Charlotte Sound (Mason et al., this symposium). It is apparent from these observations that juveniles are found in inshore waters by mid-summer.

Previous studies have also reported the capture of juvenile sablefish. Kobayashi (1957) captured sablefish ranging in length from 1-3 cm off the Aleutian Islands. He made particular reference to the large paddle-like pectoral fin. Brock (1940) reported 4 juveniles (21-35 mm) taken at the surface in May, 200 miles seaward of Cascade Head, Oregon. Sameoto and Jaroszynski (1969) captured 4 larvae (9-10 mm) in March in surface waters along tow line "P", 45 and 110 miles offshore. Juveniles, 12-16 cm have been taken at depths of 320-410 m off Oregon during July (Heyamoto, 1962) and larger fish 20-30 cm were frequently observed in shallow bays and inlets from California to Alaska (Bell and Gharrett, 1945; Edson, 1954). Juveniles estimated to be age 1 and 2 were observed during 1978 at depths of 100-200 m in an area from Unimak Island to 59 degrees north (Wakabayashi and Yake, 1981; Wakabayashi and Fujita, 1981).

Juveniles are commonly observed inshore. Fishermen have routinely reported juvenile sablefish in major inlets. They are habitually present in many areas indicating that onshore movement is a feature of juvenile biology. For example, juveniles are commonly found in Johnstone Strait off northern Vancouver Island and in 1972, Kennedy and Smith (1972) tagged approximately 1,000 juveniles in this area. The continued occurance of juveniles in some areas has caused "some fishermen to believe that some juvenile sablefish never become adults".

Distribution

During late 1977 and 1978, juvenile sablefish were found to be abundant in the inshore waters along the entire coast of British Columbia (Fig. 1). A substantial number of discards of age 1+ fish were reported in 1978 from the major trawling grounds, particularly in Hecate Strait, Queen Charlotte Sound, and off the southwest coast of Vancouver Island. Although these reports reflect the fishing activities of the domestic fleet and are not necessarily representative of coastwide concentrations, they do indicate the relative abundance and distribution of this year-class. The reported abundance continued to be high during 1979 and early 1980 (Fig. 2, 3). Discards declined sharply in late 1980 and 1981 (Fig. 4) despite high trawl effort. Coincidentally with this was an increase in reported discards from the commercial trap fisheries off the west coast of the Queen Charlotte Islands and the northwest coast of Vancouver Island, indicating that the 1977 year-class was beginning to move offshore during their fourth year.

Recaptures of juveniles (1977 year-class) tagged in the inside waters in 1979, 1980, and 1981, indicated that there has been movement to offshore areas (Fig. 5). While most recoveries have been made in the area of release (Fig. 5; Table 1), increasing numbers of recoveries with time have been made off the west coast of the Queen Charlotte Islands, west coast of Vancouver Island and in United States waters (Beamish and McFarlane, this symposium).

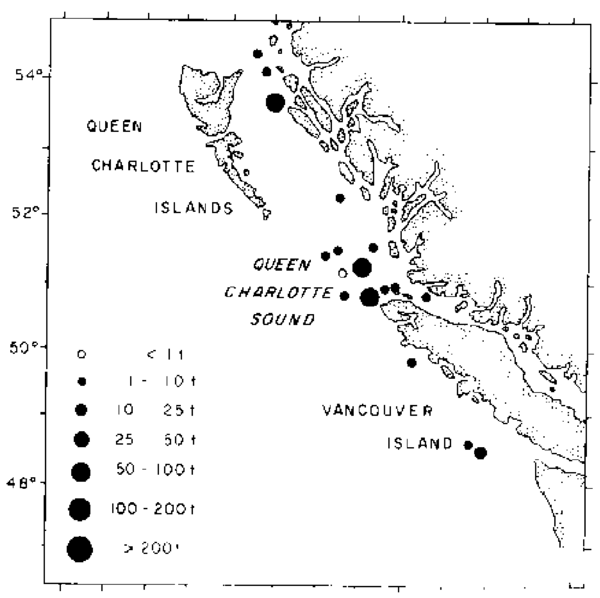

Fig. 1. Distribution of juvenile sablefish during 1978 as reported from the Canadian trawl and trap fisheries.

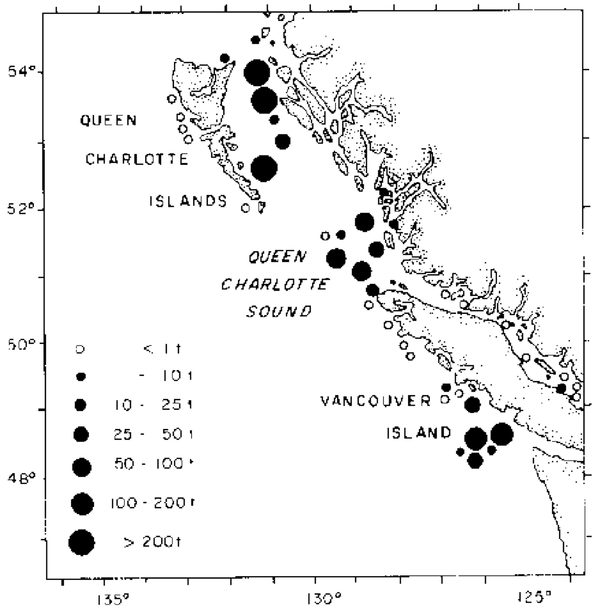

Fig. 2. Distribution of juvenile sablefish during 1979 as reported from the Canadian trawl and trap fisheries.

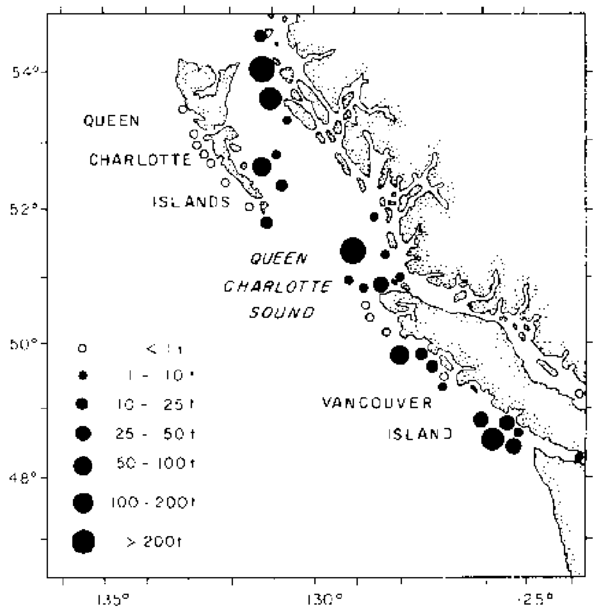

Fig. 3. Distribution of juvenile sablefish during 1980 as reported from the Canadian trawl and trap fisheries.

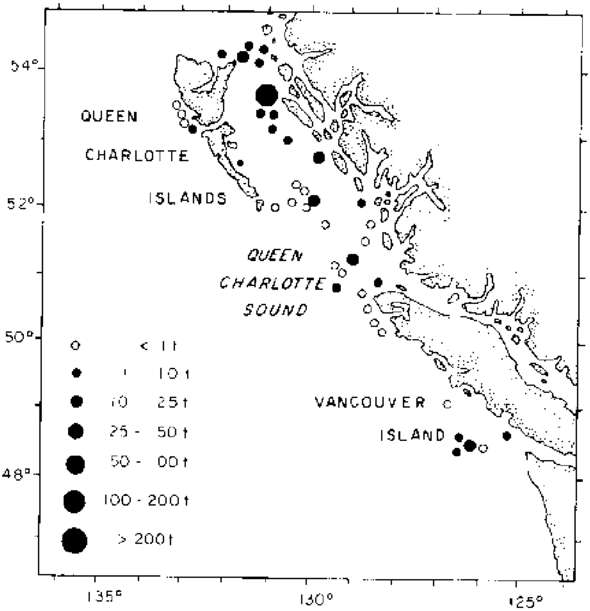

Fig. 4. Distribution of juvenile sablefish during 1981 as reported from the Canadian trawl and trap fisheries.

Movement within the inside waters is complex (Fig. 5) and within each area and year of release the percentage of movement from the release area increases with time (Table 1). The large number of recoveries in the area of release in the 1980 inlet tagging study (Table 2) is a reflection of a directed fishery in this area, although it does indicate that a large percentage of these fish remain in the inlets at least until age 5+. There was no apparent migration pattern for juveniles recovered in the inside waters. There was a definite northward migration of fish that moved out of the inside waters (Beamish and McFarlane, this symposium).

Offshore movement and recruitment to the adult population

By 1981, approximately 50% of the juvenile recoveries (age 4+ fish) were made in offshore waters (Table 1) (Beamish and McFarlane, this symposium). Of fish moving out of the inside waters during 1981 approximately 68% were recovered in the Gulf of Alaska (Beamish and McFarlane, this symposium). Juveniles tagged in 1981 were excluded from this analysis as a large percentage (40%) were from succeeding year-classes (Beamish and McFarlane, this symposium). Correcting this movement for 70% non-reporting in the United States zone (Bracken, 1982) the percentage of offshore recoveries in the Gulf of Alaska becomes approximately 88% for 1981. In 1982, the percentage of juveniles recaptured in the Gulf of Alaska increased (Beamish and McFarlane, this symposium), however, for this report only 1981 figures are used, as calculations are based on 1981 age composition data. Very few fish have been recovered south of the Canadian zone. It is apparent that rearing

Table 1. Recoveries of tagged juveniles from tagging studies in Queen Charlotte Sound and Hecate Strait 1979-1981. % recoveries are in parentheses.

Release Date	Release area	Recovery date	Total	Recoveries: Queen Charlotte Sound	Hecate Strait	Offshore
1979	Queen Charlotte Sound	1980	92	72 (78)	7 (8)	13 (14)
		1981	45	12 (27)	1 (2)	32 (71)
		1982	39	8 (21)	3 (8)	28 (71)
		Total	176	92 (52)	11 (6)	73 (42)
	Hecate Strait	1980	65	3 (5)	55 (85)	7 (10)
		1981	36	4 (11)	7 (19)	25 (71)
		1982	18	3 (17)	2 (11)	13 (73)
		Total	119	10 (8)	64 (54)	55 (38)
1980	Queen Charlotte Sound	1981	5	2 (40)	-	3 (60)
		1982	1	-	-	1 (100)
		Total	6	2 (33)	-	4 (67)
	Hecate Strait	1981	74	10 (14)	37 (50)	27 (36)
		1982	49	5 (10)	7 (14)	37 (76)
		Total	123	15 (12)	44 (36)	64 (52)
1981	Queen Charlotte Sound	1982	143	58 (41)	1 (1)	84 (58)
	Hecate Strait		59	14 (24)	26 (44)	19 (32)

Table 2. Recoveries of tagged juveniles from tagging studies in inlets during 1980. % recoveries are in parentheses.

Release date and area	Recovery date	Total	Recoveries: Inlets	Queen Charlotte Sound	Hecate Strait	Offshore
1980 Inlets	1980	480	472 (98)	3 (1)		5 (1)
	1981	274	189 (69)	28 (10)	9 (3)	48 (18)
	1982	229	161 (70)	30 (13)	3 (1)	35 (16)
	Total	983	822 (84)	61 (6)	12 (1)	88 (9)

Table 3. Contribution of the 1977 year-class to commercial catches in 1979-1981.

Area	% in numbers: 1979	1980	1981
Queen Charlotte Islands	0	10.2	6.2
Queen Charlotte Sound	-	11.3	20.6
Vancouver Island	6.9	18.9	32.4
Total	6.9	14.2	19.3

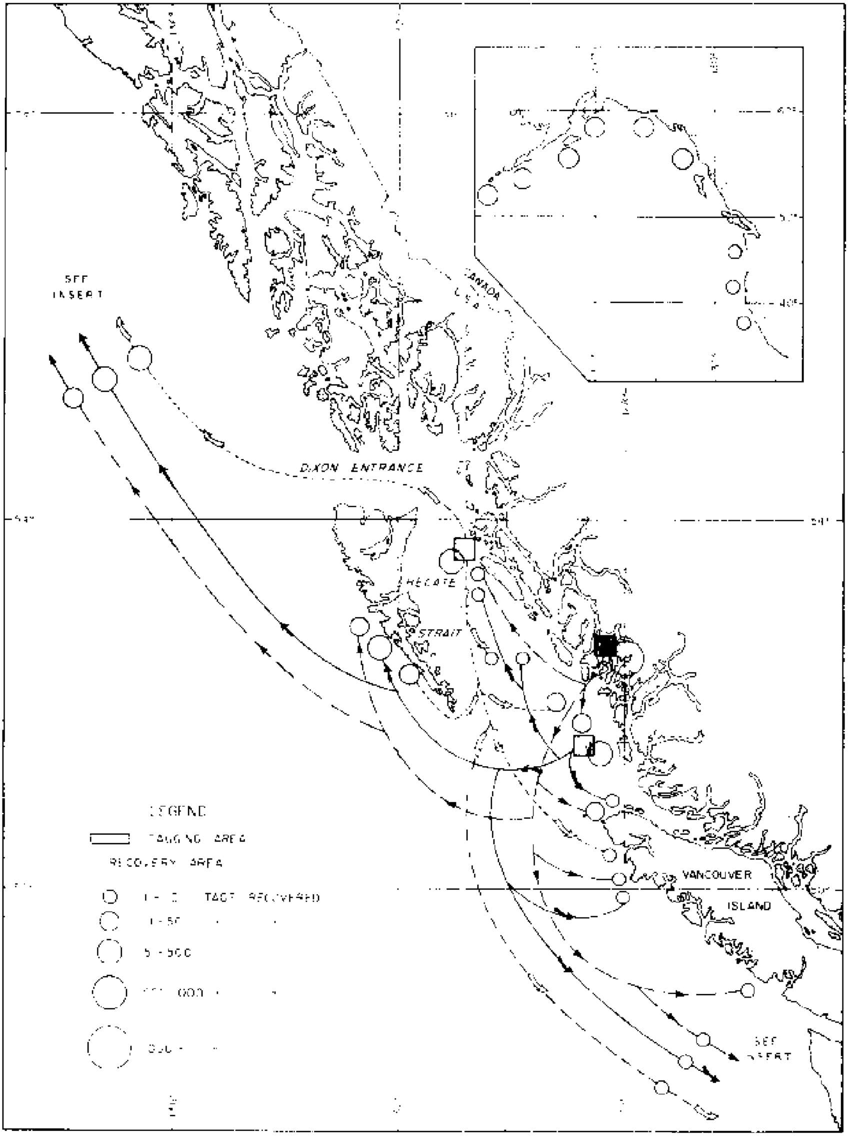

Fig. 5. Recoveries as of December 31, 1982 of juvenile sablefish released in Queen Charlotte Sound, Hecate Strait and the coastal inlets in 1979-1981. Insert shows fish recovered in U.S. waters.

grounds in Hecate Strait and Queen Charlotte Sound make a significant contribution to the United States fishery in the Gulf of Alaska.

The movement of the 1977 year-class offshore occurs at the age previously determined to be the age at 50% maturity (Mason et al., this symposium). Catches from the coast-wide fishery (Table 3) showed an increase in the contribution (in numbers) of the 1977 year-class from 6.9 percent in 1979 to 14.2 and 19.3 percent in 1980 and 1981 respectively (fish completing their 3rd and 4th years of growth). Thus the juveniles which moved offshore matured for the first time in 1981 and spawned in 1982.

Because the percent recoveries offshore increased in 1982 it is probable that recruitment will continue in 1983. It was not determined if the juveniles remaining inshore during 1981 matured.

Recoveries of juveniles tagged in the inside waters were distributed equally in the offshore areas (Fig. 5; Beamish and McFarlane, this symposium). Commercial catches of untagged juveniles indicated a much greater concentration off the west coast of Vancouver Island and off Queen Charlotte Sound (Table 3). These increased concentrations probably resulted from movement from coastal inlets on the northwest coast of Vancouver Island.

The recoveries of the juveniles tagged by Kennedy and Smith (1972) off the northwest coast of Vancouver Island indicate that while some moved out of the Canadian zone, most recoveries have been and are being made in the offshore zone adjacent to the release area (Fig. 6).

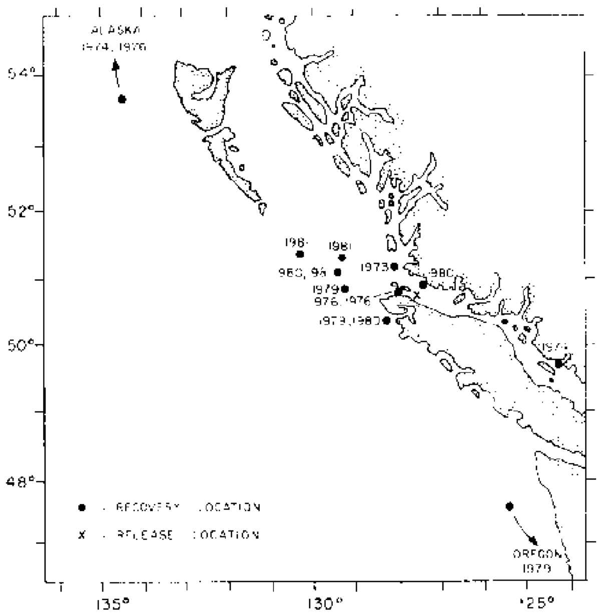

Fig. 6. Location and year of recovery of sablefish tagged off the northeast coast of Vancouver Island during 1972.

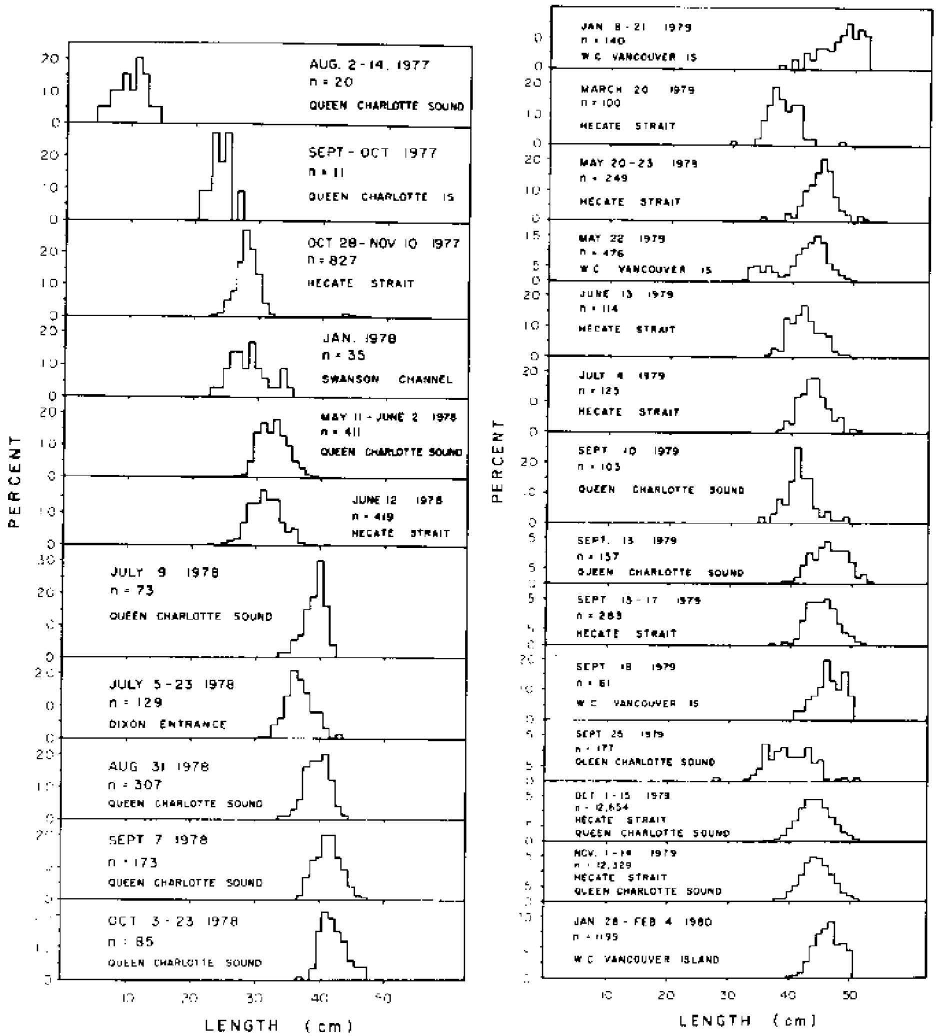

Fig. 7. Length frequencies of the 1977 year-class between August 1977 and October 1980.

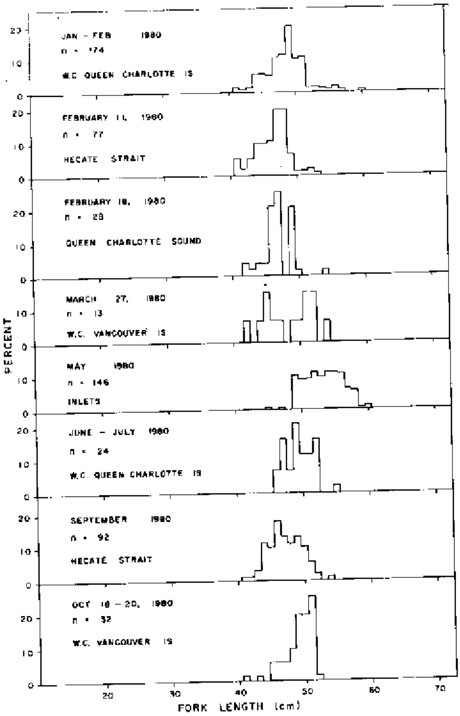

Fig. 7 (cont'd). Length frequencies of the 1977 year-class between August 1977 and October 1980.

Table 4. Mean lengths of tagged juveniles recovered off shore and in inside waters during 1980-1982 (number of fish in brackets).

Year	Sex	Inside waters $\bar{X}$ (cm)	Offshore $\bar{X}$ (cm)
1980	Male	45.0 (34)	48.8 (8)
	Female	46.0 (60)	49.2 (7)
1981	Male	49.0 (36)	52.7 (23)
	Female	51.6 (17)	56.0 (45)
1982	Male	51.8 (20)	54.1 (55)
	Female	52.5 (36)	56.9 (91)

The mean lengths of tagged juvenile sablefish from the 1977 year-class recovered offshore during 1980, 1981, and 1982 were 48.8, 52.7, and 54.1 for males and 49.2, 56.0, and 56.9 for females. The mean lengths of these offshore recoveries were significantly greater (t-test, $p<0.05$) than those recovered from inside waters for the same years, 45.0, 49.0, and 52 for males and 46.0, 51.6, and 52.5 for females (Table 4). The majority of fish began to move offshore in 1981 (Beamish and McFarlane, this symposium) at mean lengths of 52.7 and 56.0 for males and females, respectively. These mean lengths are similar to size at 50% maturity, (Mason et al., this symposium; McFarlane and Beamish, this symposium) indicating that recruitment to offshore waters is in preparation for spawning and is size related. These fish were tagged in 1979 and 1980 and samples taken at this time indicated they were almost exclusively the 1977 year-class. Thus, the larger fish of a year-class were the first to move offshore. Of the 1977 juveniles recovered offshore in the fall of 1981, for which maturity data is available, 50% were mature.

Growth

Examination of modes in the length frequencies (Fig. 7) indicates that growth in length is quite rapid initially with fish averaging 28 cm in November at the end of their first year of growth (0+). Samples of this year-class in the spring averaged 31-33 cm (Fig. 7), indicating that growth is greatly reduced during winter months. Juveniles reach 40 cm by the end of their second year of growth (age 1+) and at age 2+ and 3+ (third and fourth years of growth) mean lengths were 45 and 50 cm, respectively.

Table 5. Mean length (cm) of each age-class of juvenile sablefish caught in Hecate Strait and Queen Charlotte Sound in 1979. (Sample size is in parentheses.)

Age	Male	Female	Male and female
<u>September</u>			
1			37.0 (4)
2			41.5 (86)
3			42.7 (10)
<u>November</u>			
0	29.4 (5)	30.7 (7)	30.2 (12)
1	40.26 (6)	39.3 (8)	39.7 (14)
2	43.4 (79)	44.8 (65)	43.7 (145)
3	45.6 (7)	49.0 (10)	47.6 (17)

Growth curves constructed from the mean lengths (Fig. 8) for each frequency distribution were similar to growth determined from otoliths (Beamish et al., 1980; 1983). The von Bertalanffy growth equation (Fig. 8) for juveniles is

$$L_t = 52.2\ (1-e^{-0.07(t-0.24)})$$

with length in cm and time in months.

Samples collected in Hecate Strait and Queen Charlotte Sound during November 1979 and August 1981 indicated that the average length of females after age 2+ was significantly greater (t-test, $p<0.05$) than that for males (Table 5). While sample sizes are small it does appear that differences in the rate of growth of males and females begin before maturity.

Juveniles in the samples ranged in weight from 165 g to 1,755 g. The mean weight of fish estimated to be age 0+, 1+, 2+, and 3+ in November was 240 g, 550 g, 740 g, and 960 g. The length-weight relationship (Fig. 9) can be expressed by the equation $W = 7 \times 10^{-6}(L)^{3.0619}$: where weight is in g and fork length in cm.

At age 1 there is an inflection in the growth curve indicating a slowing down of rapid growth in length and a corresponding increase in the growth in weight.

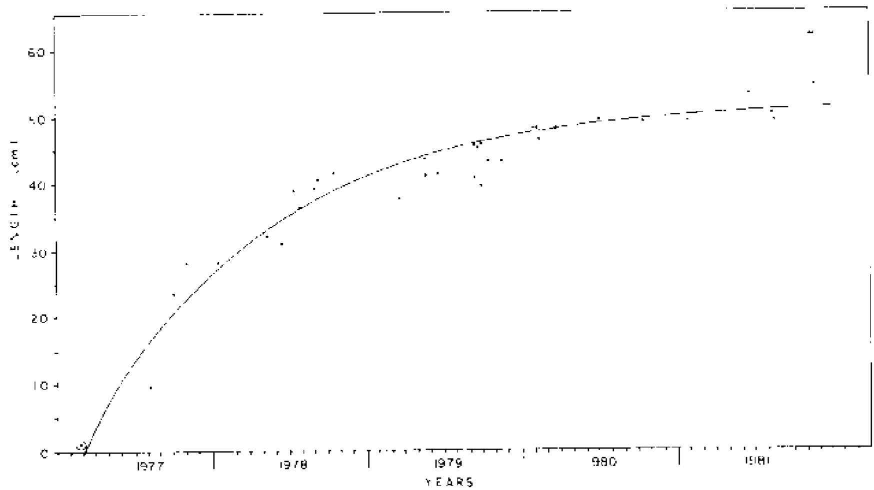

Fig. 8. Growth curve of juvenile sablefish as determined by the mean lengths of the 1977 year-class at various times of the year. The curve was derived from the von Bertalanffy growth equation

$$L_t = 53.2(1 - e^{-0.07(t-0.24)})$$

with length in cm and time in months.

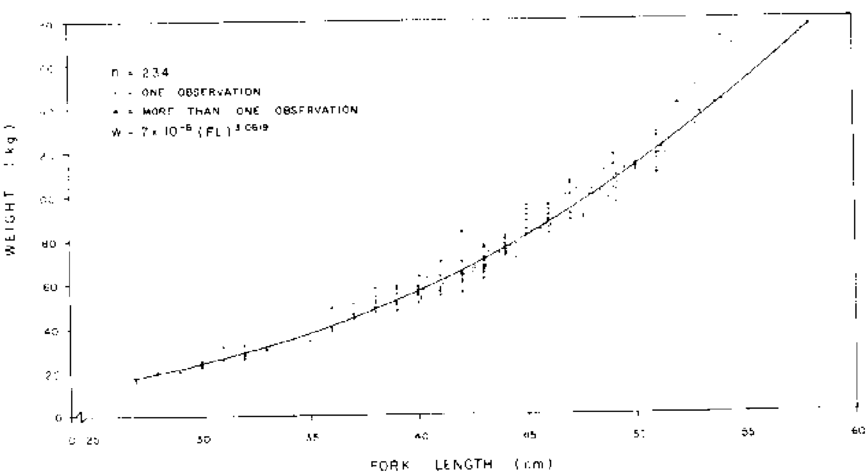

Fig. 9. Relationship between fork length and round weight for juvenile sablefish captured in Queen Charlotte Sound and Hecate Strait.

Sex ratio

Samples of trawl-caught juveniles captured in November 1979, October 1980, and August 1981 indicated that the male/female ratio was 1:1; 296:269; 224:244; and 101:99, respectively. Unless there is differential mortality acting on adult fish after maturity, it is probable that the male/female ratio found in the commercial fishery during spawning (1:3), and at other times (1:1.5) (Beamish et al., 1983; Mason et al., this symposium), is a reflection of a sampling bias due to the fishery.

Feeding and predation

Examination of the stomach contents of 864 juvenile sablefish captured in bottom trawls in Queen Charlotte Sound and Hecate Strait during 1979 and 1980 indicated that fish comprised the major component of the diet. Pacific herring (Clupea harengus) were 41% by volume and unidentified fish remains 20%. Euphausiids, were the major invertebrate prey (25%), unidentified crabs and shrimp, jellyfish, squid and unidentified invertebrates were also consumed.

Although adult sablefish probably have few natural enemies, juveniles undoubtedly experience high mortality due to predation. Juvenile sablefish are frequently found in the stomachs of halibut (Hippoglossus stenolepis) (Bell and St. Pierre, 1970) and large sablefish (Kodolov, 1976). In Canadian waters, large numbers have been identified in the stomachs of Pacific cod (Gadus macrocephalus) (Westrheim and Harling, 1983), lingcod (Ophiodon elongatus) and spiny dogfish (Squalus acanthias) (unpublished data).

Relative abundance of the 1977 year-class and impact on other commercially important species

An estimate was made of the abundance of the 1977 year-class based on reported trawl discards (Table 6). The reported discards totalled 2,090 and 1,503 t in 1979 and 1980, respectively. Many fishermen interviewed simply reported "large numbers" or "large amounts" of discards. We estimated that total discards could be 50-100% higher than reported and could approach 3,000 t.

Since fishermen did not direct their effort on juveniles, we estimated the exploitation rate to be 5%. This exploitation rate is approximately 1/2 to 1/4 of exploitation rates for most commercial species and may be high. Biomass estimates calculated assuming this exploitation rate and the reported and estimated discards ranged from 41,000 to 60,000 t for 1979 and 30,000 to 60,000 t for 1980.

Estimated biomass of the 1977 year-class was also determined using cohort analysis based on 1981 age composition data from research cruises and the commercial catch. The 1977 year-class contributed 19.3% (numbers) to the 1981 fishery (Table 3). Contribution to the stock was determined using population abundance estimates from tag release-recovery studies (McFarlane and Beamish, this symposium) and 50% recruitment at age 4. The abundance of this year-class in the fishery in 1981 was estimated to be 4,079 t. However, as discussed previously approximately 88% (corrected for 70% non-reporting) of the juveniles moving out of the inside waters moved northward into the Gulf of Alaska during 1981 and are not present in the Canadian fishery. Correcting for this migration rate

Table 6. Reported Canadian blackcod discards (t), 1977-81.

Year	Area								Total
	4B	3C	3D	5A	5B	5C	5D	5E	
1977	-	-	2.7	-	-	-	9.1	-	11.8
1978	6.8	63.8	-	86.1	101.9	8.6	89.9	.4	357.5
1979	4.2	383.0	24.6	160.6	298.1	271.9	942.1	5.1	2089.6
1980	3.3	281.3	83.7	34.7	307.2	107.0	663.3	22.0	1502.6
1981	0.2	48.2	0.6	5.2	63.5	44.3	180.5	4.27	346.8

Table 7. Estimated production of the 1977 year-class. Estimated biomass at age is based on age composition data from research and commercial catches and tag release-recovery population estimates.

Date	Mean wt (gm) $\bar{W}$	Inst. growth rate G	Inst. growth rate Z	Year -class[a] biomass (tonnes) B	Mean biomass (tonnes) $\bar{B}$	Production (tonnes) P
Mar 77	$2X10^{-3}$			2,400		
		11.700	1.609		18,014	210,764
Nov 77	241			33,628		
		0.808	0.511		39,155	31,637
Nov 78	541			45,294		
		0.313	0.357		44,312	13,870
Nov 79	740			43,368		
		0.260	0.357		41,331	10,746
Nov 80	960			39,383		
		0.189	0.223		38,721	7,318
Nov 81	1,160			38,070		

[a]Corrected for migration of 1977 juveniles into Gulf of Alaska and 70% non-reporting.

Table 8. Estimated food consumption of the 1977 year-class.

Age	Conversion rate K	Production (tonnes) P	Ration (tonnes)
0+	0.25	210,764	843,055
0+ - 1+	0.20	31,637	158,185
1+ - 2+	0.17	13,870	81,588
2+ - 3+	0.17	10,746	63,211
3+ - 4+	0.17	7,318	43,047

gives biomass estimates of 43,368 t for 1979 and 39,383 t for 1980 (Table 7), similar to the estimates obtained from discard analysis.

It is probable that fisheries for many species will be affected by sablefish predation and competition. It is the purpose of this preliminary analysis to estimate the potential impact of the 1977 year-class on the trophic system.

Preliminary estimates of the production were determined using the procedure outlined by Chapman (1968) and estimated food consumption (ration) was calculated by:

$$K = \frac{\text{Production}}{\text{Ration}}$$

where K = production efficiency.

Estimated production and ration requirements for this year-class are presented in Table 7 and 8. Although data is lacking to permit quantitative estimates of consumption for individual prey species it is apparent that the impact of strong year-classes on the entire trophic system may be substantial. For instance, up to age 1+ (2nd year of growth) the estimated food consumption of this year-class is approximately 1 million t, predominately plankton. Competition between species which share the midwater plankton resource must be examined and the response of both prey and other predators determined.

The impact of sablefish predation on other fish species is an important component of the system. For example, during their third, fourth and fifth year of life the estimated consumption of this year-class was 187,896 t (Table 8). Samples collected in the fall of 1979 and 1980 indicated that fish composed 61% of the diet by volume, accounting for 114,586 t over the 3 year period or 35,000 t annually. As reported previously herring was the major food item, accounting for 41% of the total diet or 68% of the fish species eaten. This can be converted to a total biomass of 77,017 t over the 3 year period or an annual consumption of herring of approximately 25,000 t. It is unlikely that the estimate is truly reflective of herring consumption as samples were obtained only during the fall, however it does indicate the importance of sablefish predation on other fish species. Predator-prey relationships are an important feature of sablefish dynamics and must be examined.

The interaction of a strong year-class with succeeding year-classes may be a key parameter in determining the age structure of the stock. Direct competition and cannibalism are probably equally important in determining year-class strength.

Acknowledgments

Many people have participated in various parts of this study and we appreciate their support and cooperation. The assistance of K. Best, A. Cass, M. Smith, and R. Scarsbrook is gratefully acknowledged. Dr. D. Ware made helpful suggestions for calculating production and feeding rations. We also appreciate the cooperation of the fishermen in returning tagged fish and allowing us to accompany them on commercial trips and sample the catch. Mr. S. J. Westrheim and Mr. A. Cass kindly reviewed the manuscript.

References

Beamish, R. J., and D. E. Chilton. 1982. Preliminary evaluation of a method to determine the age of sablefish (Anoplopoma fimbria). Can. J. Fish. Aquat. Sci. 39: 277-287.

Beamish, R. J., C. Houle, and R. Scarsbrook. 1980. A summary of sablefish tagging and biological studies conducted during 1979 by the Pacific Biological Station. Can. MS Rep. Fish. Aquat. Sci. 1588: 194 p.

Beamish, R. J., G. A. McFarlane, R. J. Scarsbrook. A. Cass, D. Chilton, W. Shaw, K. Best, and I. Barber. 1983. A summary of sablefish tagging and biological studies conducted during 1980 and 1981 by the Pacific Biological Station. Can. MS Rep. Fish. Aquat. Sci. (In press).

Beamish, R. J., G. A. McFarlane, and D. E. Chilton. 1983. Use of oxytetracycline and other methods to validate a method of age determination for sablefish. This symposium.

Beamish, R. J. and G. A. McFarlane. 1983. Summary of results of the Canadian sablefish tagging program. This symposium.

Bell, F. H. and J. T. Gharrett. 1945. The Pacific coast blackcod (Anoplopoma fimbria). Copeia. 1945(2): 94-103.

Bell, F. H. and G. St. Pierre. 1970. The Pacific halibut. Int. Pac. Halibut Comm. Tech. Rep. 6: 24 p.

Bracken, B. E. 1982. Sablefish (Anoplopoma fimbria) migration in the Gulf of Alaska based on Gulf-wide recoveries, 1973-1981. Alaska Dept. of Fish & Game Info. Leaflet 199.

Brock, V. E. 1940. Note on the young of the sablefish Anoplopoma fimbria. Copeia 2: 94-103.

Chapman, D. W. 1968. Production. In Methods for assessment of fish production in fresh waters. Ed. W. E. Ricker. Blackwell Sci. Pub. Oxford. P. 182-196.

Edson, Q. A. 1954. A preliminary report on the Alaska sablefish fishery. Pac. Mar. Fish. Comm. Bull. 3: 73-86.

Heyamoto, N. 1962. Age of young sablefish, Anoplopoma fimbria (Pallas) 1811. J. Fish. Res. Board Can. 19: 1175-1177.

Kennedy, W. A. and M. S. Smith. 1972. Juvenile sablefish tagging Northwestern Vancouver Island 1972. Fish. Res. Board. Can. MS 1222: 22 p.

Kobayashi, K. 1957. Larvae and young of the sablefish Anoplopoma fimbria (Pallas), from the sea near the Aleutian Islands. Bull. Jap. Soc. Sci. Fish. 23: 376-382.

Kodolov, L. S. 1968. Reproduction of the sablefish (Anoplopoma fimbria Pall.). Problems in Ichthyology 8(4): 531-535.

——— 1976. Details of biology and distribution of blackcod (Anoplopoma fimbria Pall.). Izv. Tikhookean. Nauchno-Issled. Inst. Rybv-Khoy. Okeanogr. 100: 19-42.

Mason, J. C., R. J. Beamish, and G. A. McFarlane. 1983. Sexual maturity, fecundity, spawning and early life history of sablefish (Anoplopoma fimbria) off the Pacific coast of Canada. This symposium--Abstract only.

McFarlane, G. A. and R. J. Beamish. 1983. Biology of adult sablefish (Anoplopoma fimbria) in waters off western Canada. This symposium.

Sameoto, D. D. and L. O. Jaroszynski. 1969. Otter surface sampler: a new neuston net. J. Fish. Res. Board Can. 25: 2240-2244.

Wakabayashi, K. and M. Yake. 1981. Report on the biological research of groundfish in the eastern Bering Sea by SHINYO MARU in 1978. In Report of the biological research of groundfish in the Bering Sea in 1978. Far Seas Fisheries Research Laboratory, Fisheries Agency of Japan, Shimizu 424: 1-186.

Wakabayashi, K. and H. Fugita. 1981. Report on the groundfish survey in the eastern Bering Sea by the crab research vessel WAHATABE MARU in 1978. In Report on the biological research of groundfish in the Bering Sea in 1978. Far Seas Fisheries Research Laboratory, Fisheries Agency of Japan, Shimizu 424: 187-243.
Westrheim, S. J. and W. R. Harling. 1983. Principal prey species and periodicity of their incidence in stomachs of trawl-caught Pacific cod (_Gadus macrocephalus_), rock sole (_Lepidopsetta bilineata_) and petrale sole (_Eopsetta jordania_) landed in British Columbia, 1950-80. Can. MS Rep. Fish. Aquat. Sci. 1681: iv + 38 p.

Sexual maturity, fecundity, spawning, and early life history of sablefish *(Anoplopoma fimbria)* in waters off the Pacific coast of Canada

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Observations of maturity state from over 12,000 sablefish collected from locations all along the west coast of Canada (Fig. 1) indicated that the period of peak spawning was mid-February. Using daily observations we show that 50% of the females spawned by February 12 (Fig. 2). This date proved equally appropriate for fish sampled off Vancouver Island, Queen Charlotte Sound and the Queen Charlotte Islands, indicating no significant latitudinal effect. Little spawning was evident in January or April based upon our maturity data.

Ichthyoplankton hauls indicated that highest individual catches of eggs were taken in January and February (Fig. 3). The geometric mean catches by cruise indicated peak spawning activity in February. The number of positive stations for larvae was greatest in April, suggesting a period of embryological development exceeding several weeks. The ichthyoplankton survey and the maturity survey both showed that spawning occurs almost simultaneously all along the coast. From the greater abundance of eggs in mid-February, the ichthyoplankton surveys indicate a greater spawning activity in late January than was indicated from the maturity observations. Since maturity observations were made on trapped fish, one might argue that such observations are biased toward feeding fish. However, the present data preclude effective testing of this assumption and we conclude that most spawning occurred during January and February, with peak spawning occurring in February.

The samples of spawning fish were obtained at depths ranging from 175 m to 1450 m but most fish were caught at approximately 700 m as this is an average fishing depth for commercial fishermen. The largest catches of both eggs and larvae were taken at stations where tow depth exceeded 400 m. Of 27 catches exceeding 25 eggs/10 m^2, 23 catches (85%) were taken at sampling depths exceeding 400 m. Similarly, the six highest

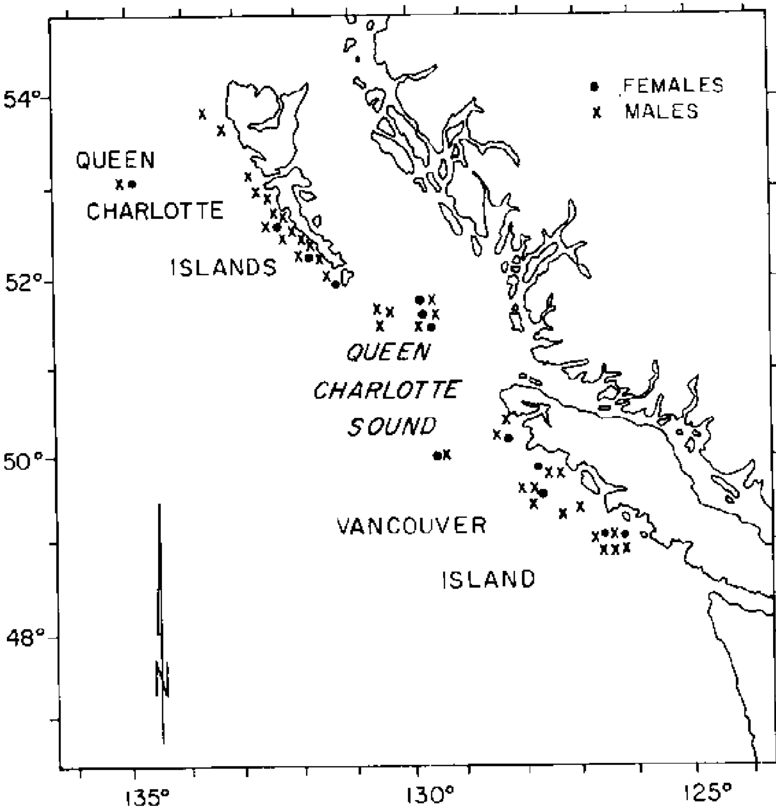

Fig. 1. Capture locations for spawning blackcod.

catches of larvae were taken in tows deeper than 400 m, and 11 of 15 catches (73%) were made at tow depths exceeding 400 m.

Almost all eggs were found at stations over or adjacent to the continental slope. There was no indication of major spawning areas in Johnstone Strait, Hecate Strait or Queen Charlotte Sound. While fishermen have reported that small stocks of sablefish spawn in some mainland inlets, there remains little doubt that the major spawning area is along the continental slope.

The coastwide distribution of spawning activity suggests an absence of spawning migration, and this interpretation is supported by the results of our tagging study. A total of 128 tagged sablefish were recovered during the maturity study. These fish were tagged from February to September, 1977 to 1980, as part of a program to identify sablefish stocks in the Canadian zone. Of 128 tags recovered, 90% were taken within 200 km and 81% within 100 km of the tagging location indicating that there is no extensive annual spawning migration, although localized movements may occur.

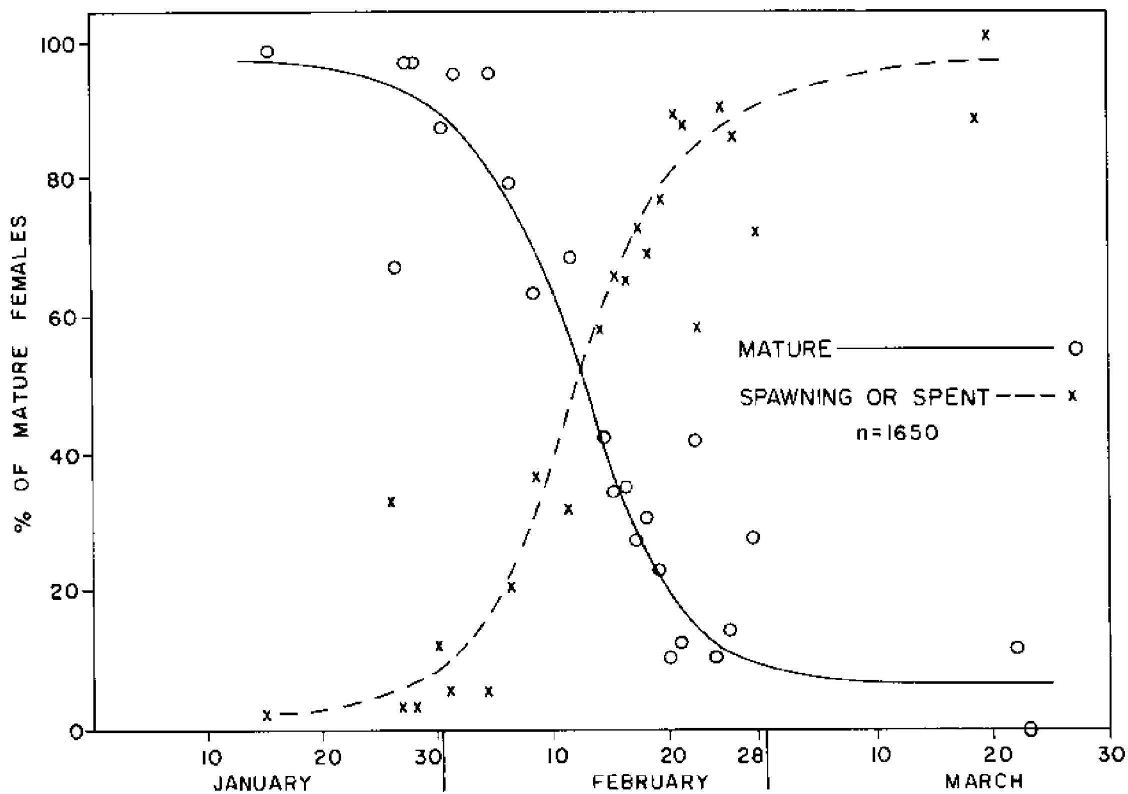

Fig. 2. Percent maturities for all female fish sampled between January and March on the British Columbia coast that were recorded on specific days.

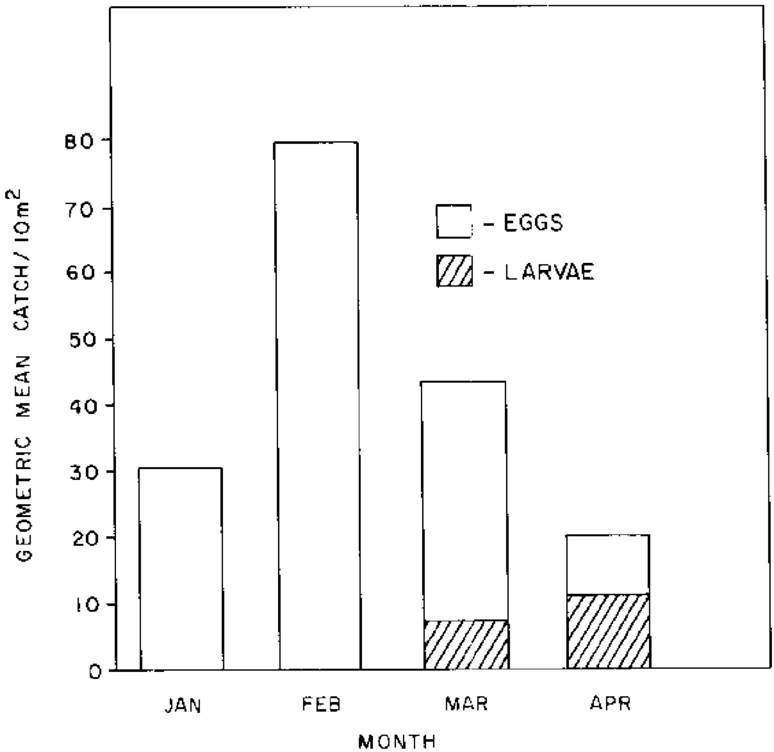

Fig. 3. Geometric mean catches of blackcod eggs and larvae along the Pacific coast of Canada, 1980.

Fifty percent of females and males spawned for the first time at an age of approximately 5 yr. Length at 50% maturity was approximately 58 cm for females and 52 cm for males. The adult male-female ratio during the spawning season was approximately 1:3 for both years. During all other sampling periods the ratio was 1:1.5. The sex ratio of juveniles was equal. Fecundity estimates are described by the equation

$F = 1.11987FL^{2.8244}$.

After hatching in March and April, postlarvae moved into the surface waters and were found >100 miles off shore in late March. Juveniles were found on the surface in inside waters in July and August, attaining a length of 9 cm by early August. Juveniles may remain in inside waters until maturity when they return to the spawning areas.

Daily growth increments were examined from 9 juvenile sablefish (see Beamish, McFarlane, and Chilton, this symposium, "The use of oxytetracycline and other methods to validate a method of age determination for sablefish"). The pattern of daily growth suggested that the first month of growth occurs at spawning depths, then there is a period of approximately 4 months during which growth is irregular as the larval sablefish moves inshore in the surface waters.

Session IV

Migration and Stock Structure

Progress in the study of the biochemical genetics of sablefish

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This is a progress report in our study of the biochemical genetics of sablefish (*Anoplopoma fimbria*). Our results will be considered more completely elsewhere.

Biochemical genetic data has served as a means for identifying discrete stocks and separating mixtures into component stocks (eg. Ryman *et al.*, 1979; Grant *et al.*, 1980). Over time, the genetic compositions of reproductively isolated populations may diverge. This divergence may provide a means for identifying discrete stocks, or at least infer the presence of discrete stocks in a mixture. Because little is known about the population structure of sablefish, we undertook to examine this problem from a genetical point of view. Starch gel electrophoresis is a tool commonly employed for obtaining genetic data on a population. The nature of the data is binomial or multinomial and is somewhat similar to that of ABO blood grouping in humans.

Tissue samples of more than 1900 sablefish were collected for biochemical genetic analysis between 1978 and 1981. The samples were procured primarily through the Northwest and Alaska Fisheries Center (NWAFC) (US National Marine Fisheries Service). The geographical locations sampling extend from Patton Escarpment off southern California along the continental shelf of Oregon, Washington, and southeast Alaska and along the Alaskan Peninsula and the Aleutian Islands to Kiska Island. Included also were a sample from the Bering Sea, samples from seamounts in the Gulf of Alaska, and samples from the inside waters of southeast Alaska. Thirty seven separate collections were made. For purposes of analysis, collections made in the same season of the same year, within 1° latitude and 1° longitude of each other and which displayed no heterogeneity were pooled. Pooled collection of less than 40 specimens were eliminated from the analysis. Twenty-one groups resulted from

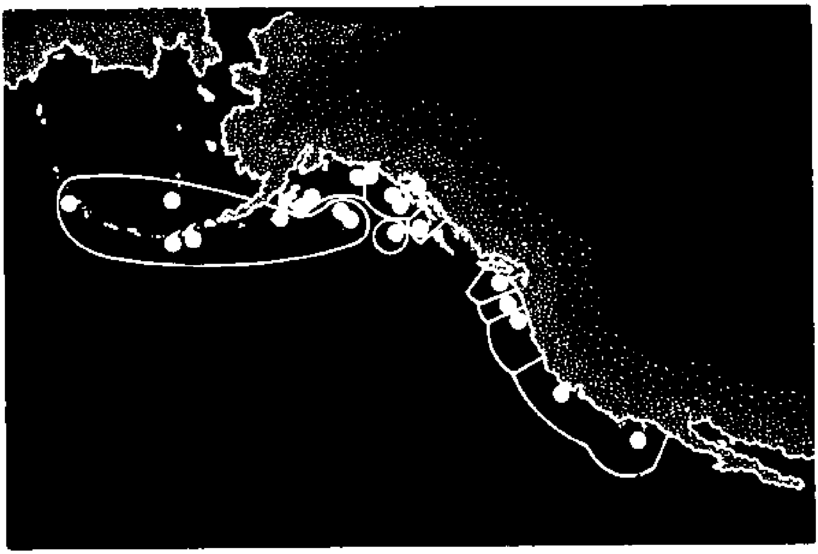

Figure 1. Geographical locations of collections of sablefish and tentative groupings of maximum insignificance as determined from a stepwise test procedure using G-statistics.

this treatment (Figure 1).

These collections were not made on spawning populations and, therefore, do not necessarily represent discrete stocks.

Two laboratories were involved in this project, those of Wishard and of Gharrett. We exmained 37 electrophoretically detectable loci, and disdiscovered considerable polymorphism. Thirty of the thirty seven loci were polymorphic and five of the loci each had between five and eight alleles. The large number of possible banding patterns, the poor quality of some of the samples, and slight procedural differences employed by the two laboratories, introduced the possibility of interpretational error. To eliminate this possibility, and because many of the allelic frequencies were so small they would have to be pooled to be useful statistically, the frequencies of less common alleles were pooled with frequencies of alleles having similar electrophoretic mobilities. Nine loci had sufficient variability to be useful in examining the existence of stock structure (Table 1).

Inter lababoratory comparisons were made with data pooled as described above for these nine loci. While there was considerable overlap in the geographical range of samples examined by each lab there was no a priori reason that the total samples for the two labs should be homogeneous. However, log-liklihood ratio comparison (Sokal and Rohlf, 1969) indicated that with the exception of phosphomannose-isomerase (PMI), they were homogeneous (See Table 2). These results suggest that interpretation of banding patterns was consistent between

Table 1. Electrophoretic loci used in Analyses

Adenosine deaminase (ADA)
Alcohol dehydrogenase (ADH)
Creative Kinase (CK)
Phosphoglucose Isomerase (PGI2)
Phosphoglucomutase (AGM1)
Phosphomaunose Isomerase (PMI2)
6 Phosphogluconate dehydrogenase (6PG2)
Sorbitol dehydrogenase (SDH)
Superoxide dismutase (SODL)

The data were then stratified by depth of capture into four groups differing by approximately 140 meters. Log-liklihood ratio analysis was performed on the four groups for all eight loci. No significant differences were observed that related to depth of capture (Table 3).

Analyses were made of the geographical variation among collections. These data will be more completely reported elsewhere. It was found that after performing stepwise test procedures (STP) using log-liklihood analysis (Sokal and Rohlf, 1969), some genetic substructure does exist. In several geographical regions, collections were relatively homogeneous whereas other regions appeared to be comprised of more discrete groups of sablefish. The distribution of maximally insignificant collections is depicted in Figure 1. It appears that collections from California are homogeneous as are the southeastern Alaskan samples, the northern Gulf of Alaska samples, and the Aleutians Island and Bering Sea samples. Samples from the Pacific Northwest and northern British Columbia appear to exhibit considerable heterogeneity suggesting the existance of localized populations. It is possible that some of this structure may be attributed to oceanographic conditions.

A comparison was made between the heterogeneity observed within groupings to that observed between groupings. This was done by creating an F-statistic from the ratio of the two G-statisics describing those heterogeneities. Although the groupings were originally derived by using a maximum nonsignificance procedure, the F-statistic indicates there is only a $3.1 X 10^{-7}$ chance that these two levels of heirarchy reflect comparable heterogeneties.

Table 2. Interlab comparison of data taken at 9 loci from 1900 specimens. Log likelihood ratios (G statistics) and degrees of specimens presented.

ADA	ADH	CK	PGI2	PGM1	PMI2	6PG2	SDH	SODL
2.99	0.37	2.07	0.00	0.99	14.16	0.13	2.95	6.34
1df	2df	1df	1df	1df	1df	1df	2df	3df

Total 33.53 30df

w/o PMI2 19.19 19df

Table 3. Genetic comparison of sablefish captured at different depths. The limits for each of the four depth ranges compared and the sample size for the locus at which the fewest observations were made for each depth range are shown. The G-statistic for the comparisons involving eight loci and the degrees of freedom are also shown.

Depth Range	Minimum Sample Size
305–430 m	60
480–560 m	218
675–692 m	71
794–1292 m	89

G = 45.163 36df

the two labs. To obtain the most conservative interpretation, subsequent analyses were performed without PMI data.

NOTE in the presentation at the symposium, it was stated that the two California collections were distinct. Review of the data, however, shows no differences between them. The other data presented were correct.

Acknowlegements

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References

Grant, W.S., G.B. Milner, P. Krasnowski, and F.M. Utter, 1980. Use of biochemical genetic variants for identification of sockeye salmon (Oncorhynchus nerka) stocks in Cook Inlet, Alaska. Can. J. Fish. Aquat. Sci. 37 1236-1247.

Ryman, N., F.W. Allendorf, and G. Stahl, 1979. Reproductive isolation with little genetic divergence in sympatric populations of brown trout (Salmo trutta). Genetics 92:247-262.

Sokal, R.R., and F.J. Rohlf 1969. Biometrics. W.H. Freeman and Co. San Francisco.

Summary of results of the Canadian sablefish tagging program

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Abstract

After five consecutive years of marking and recapturing sablefish, a total of 115,604 fish were tagged and 7,576 recaptured as of December 31, 1981. Most fish (88.7%) were recaptured within 200 km of the release area, indicating that once adults are recruited into the fishery they were fished as localized stocks. In general, within the Canadian zone the pattern of movement off Vancouver Island and the Queen Charlotte Islands is different. There is a slow movement of adults out of the release area and there are small numbers of fish that undergo extensive movements. A total of 5.5% (or 9% when adjusted for non-reporting of tags) of the recoveries of adults were made in the United States zone. Preliminary results from the United States tagging program show that more adults move into the Canadian zone from the Gulf of Alaska than move into the Gulf of Alaska from the Canadian zone. There was no indication that large numbers of adult sablefish undergo short-term or long-term directional movements. These movements indicate sablefish are one population but the pattern of movement, the number that moved more than 200 km and the nature of the Canadian fishery indicated that sablefish should be managed as several stocks. In contrast to adults, juveniles tagged in Hecate Strait and Queen Charlotte Sound have moved offshore in increasing numbers and in 1982, 70% of all offshore recoveries were made in waters off Alaska. Estimates of the abundance of the juveniles reared in Hecate Strait and Queen Charlotte Sound and the very high percentage of these fish that are recruited into the fishery off Alaska, indicate that the Canadian zone provides an important rearing area for juvenile sablefish that are recruited into the United States zone.

Introduction

The Canadian sablefish (Anoplopoma fimbria) tagging program was initiated in 1977 to identify stocks in the Canadian zone. Adults were tagged off the west coasts of Vancouver Island, the Queen Charlotte Islands and outside of Queen Charlotte Sound (Figs. 1, 2, 3). A few adults were tagged in mainland inlets and in Queen Charlotte Sound. Juveniles, primarily from the 1977 year-class were tagged in Hecate Strait and Queen Charlotte Sound. The program was well advertised and is strongly supported by Canadian fishermen.

In addition to studying the movements of adults and juveniles, the program was used to validate the method of age determination developed for sablefish by Beamish and Chilton (1982). The tagging study was also used to make an approximate estimate of biomass, however the study was not designed to produce population estimates.

The results of the age validation studies, population estimates and biological information collected during the program are summarized in other papers in the symposium (Beamish et al., McFarlane and Beamish a, b).

Materials and Methods

Fishing methods

The various gear that was used to catch sablefish has been described in Beamish et al. (1978, 1979, 1980, 1983). Rectangular and Korean style traps baited with frozen herring were used in most cruises. Bottom trawls were used to collect most juveniles and a small percentage of fish were captured with long-line gear. Fishing times were adjusted to ensure best survival of adults and juveniles. Very little mortality was observed in trawl- or trap-caught fish. For example, 3,909 juveniles in lots of 300-400 were held in recovery tanks for 1/2 to 3 hours and only 30 or 0.8% died.

Tagging methods

The primary tag used was the Floy FD-68 anchor tag. Approximately 10% of the fish received a second "suture" tag (White and Beamish, 1972; Beamish et al., 1979). Trap-caught fish were transferred directly into holding tanks that had a continuous supply of sea water. Each fish was dipped out, measured for fork length, tagged and then released immediately over the side of the vessel. The majority of fish sounded and were out of sight within seconds. Condition of the fish, and any problems with the tags were recorded. The long-line caught fish were "dipnetted" as they came to the surface and were brought on board in the net. The hook was then carefully removed and the fish put into a holding tank. Approximately 30% of long-line caught fish were not tagged due to hook wounds. Anaesthetic was not needed with either the trap- or long-line-caught fish.

Trawl-caught juvenile sablefish were anaesthesized prior to tagging using MS 222 (Tricaine Methane Sulfonate). The response to anaesthetic was monitored and fresh sea water was added to the anaesthetic tank if the opercular movements were thought to be excessively reduced. Fish were tagged with either anchor tags or suture tags. No juvenile fish received two tags and none had injections of oxytetracycline.

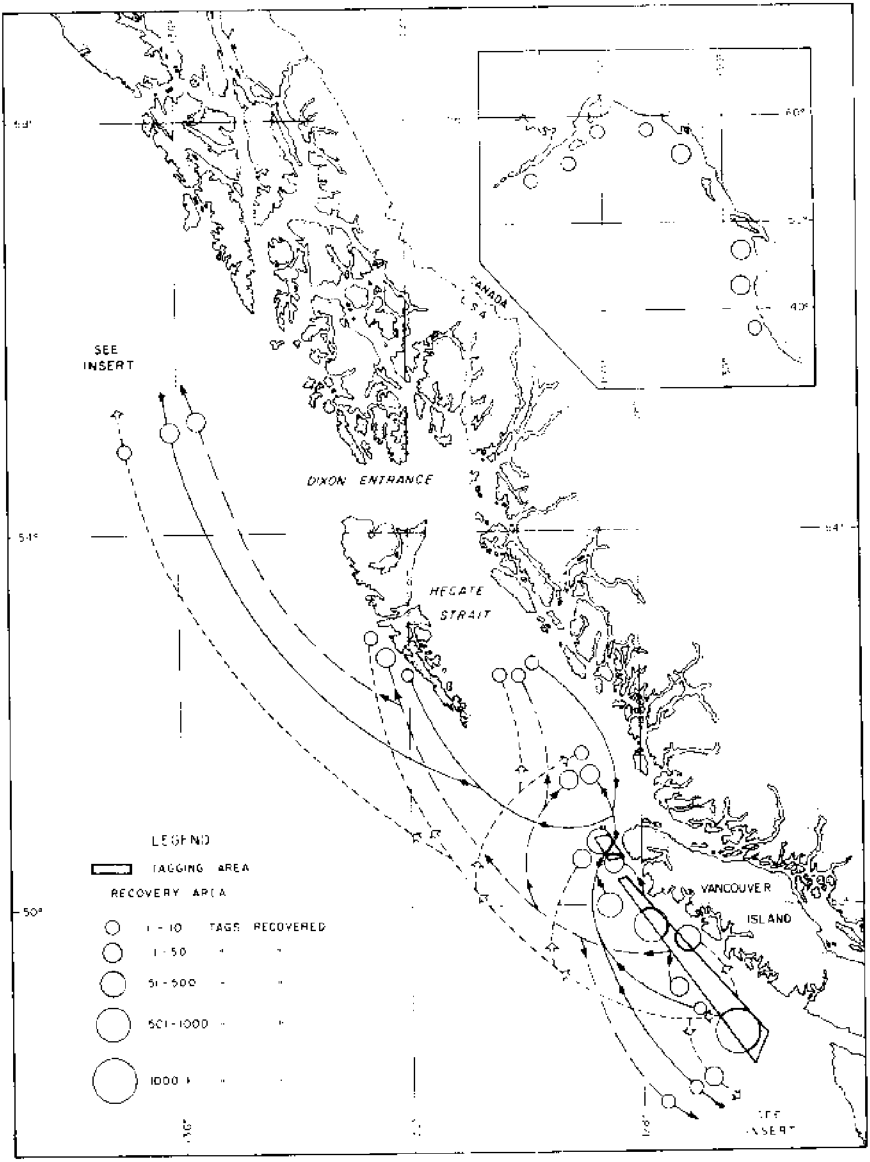

Fig. 1. Recoveries as of December 1981 of sablefish released off the west coast of Vancouver Island from 1977-1980. Insert shows tags recovered in USA waters.

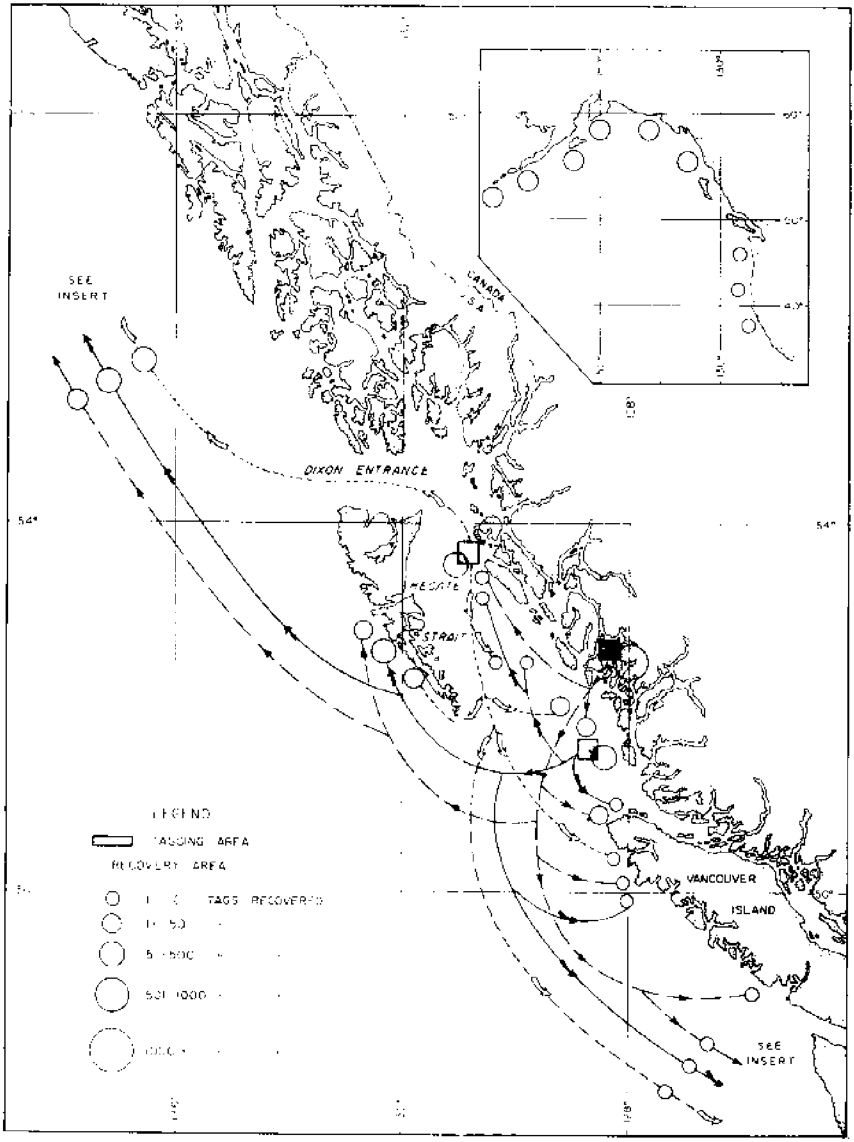

Fig. 2. Recoveries as of December 1982 of juvenile sablefish released in Queen Charlotte Sound, Hecate Strait and the coastal inlets in 1979-1981. Insert shows fish recovered in USA waters.

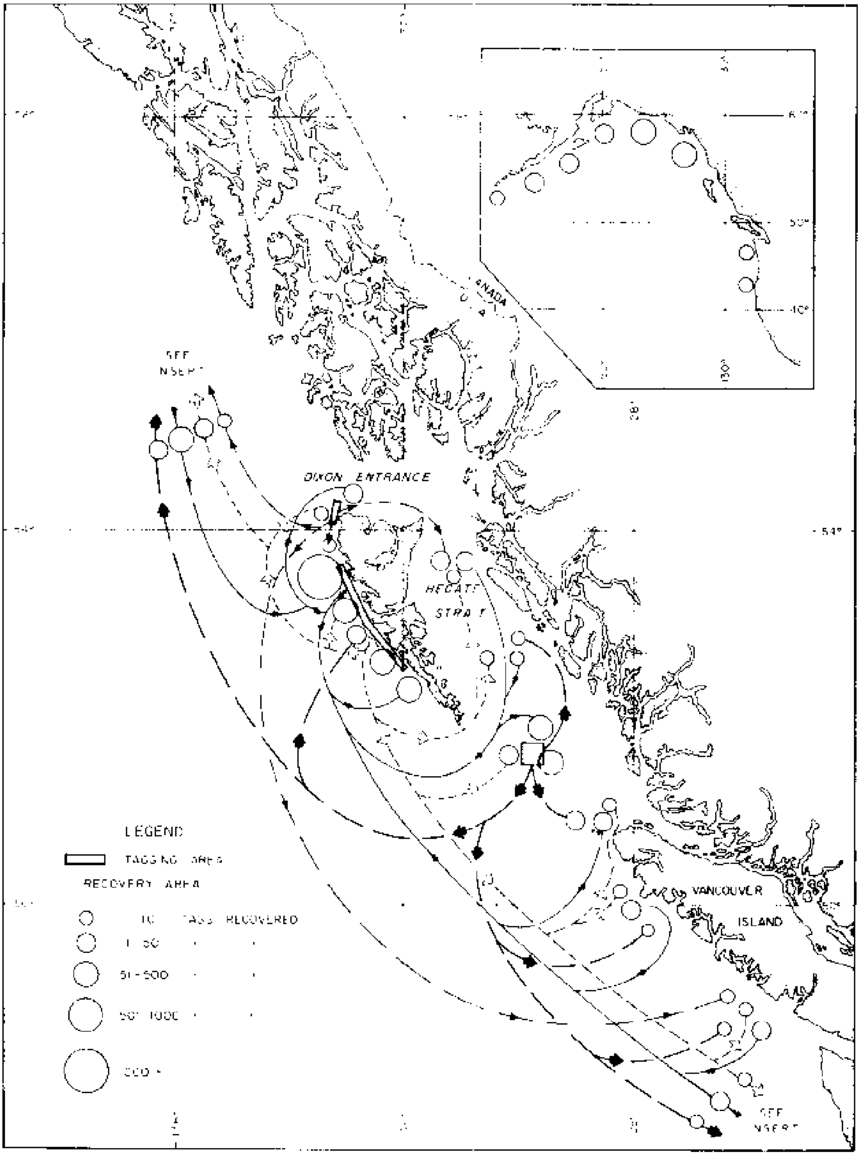

Fig. 3. Recoveries as of December 1981 of sablefish released off the west coast of the Queen Charlotte Islands and Queen Charlotte Sound from 1977-1981. Insert shows fish recovered in USA waters.

Sampling methods

Starting in 1980, sablefish were measured for fork length to the nearest millimetre rather than to the nearest centimetre as in previous years. Lengths to the nearest mm were recorded to ensure that careful measurements were taken and to attempt to document the slow growth of sablefish beyond the juvenile stage. Sample lots of fish were measured for length and weight, sex and maturity were determined, and otoliths collected for age determination. Sample lots were selected that were thought to be representative of the size composition of the catch.

Recovered tagged sablefish were measured for fork length to the nearest millimetre, examined for sex, maturity, stomach contents, abnormal tag wounds or other injuries, and sampled for otoliths. Most recovered fish were frozen before measurements of length were taken.

Age was determined from broken and burnt otoliths as described by Beamish and Chilton (1982).

Oxytetracycline dosage studies

The validation of an age determination method is essential for the understanding of the biology of any fish. One of the few methods for validating age determination is to inject oxytetracycline into a fish so that a mark is deposited in the ageing structure. The most suitable dosage necessary to produce this mark in sablefish was determined initially from previously published studies (Kobayoshi et al., 1964; Weber and Ridgway, 1962, 1967). It was soon realized that this dosage (100 mg/kg) caused increased mortality (Beamish et al., this symposium). The most appropriate dosage from field studies was then determined.

Recoveries from 1982 were being tabulated at the time of writing this report. Where possible the results up to December 31, 1982 have been used.

Results and Discussion

Tag loss

In the experiments where double tagging was conducted, 9.1% of the fish received a second tag. The recovery percentage of double-tagged fish (8.1%, Table 1) is very similar to the release percentage indicating that no increased mortality resulted from applying two tags. There was an overall loss of one tag from 12.6% of the double-tagged fish (Table 1) with the suture tag being lost from 5.3% and the anchor tag from 7.3%. There is no obvious trend to the loss so it is not possible to conclude that one type of tag is more suitable. Recoveries of fish with lost tags have occurred each year with no increased trend (Table 1), indicating that most losses occurred shortly after tagging.

It is apparent from the double-tag studies that tag loss is important. While it is possible that the loss of one of the two tags is not indicative of the loss when a fish receives only one tag, it is more probable that the results are representative of actual tag loss.

Based on a previous study (White and Beamish, 1972) it was expected that the suture tag would not be lost if properly applied. However there were losses, possibly because of the technical difficulty of applying the tag.

Table 1. Double-tagged fish, cumulative tag recoveries for 1977-81. Percentages indicate tag loss from fish that received both tags.

Release year		Recovery year after tagging 0	1	2	3	4	Total (%)
1977	suture lost	-	-	-	1	2	3 (2.1)
(n=1026)	anchor lost	2	3	-	1	-	6 (4.3)
	both tags	11	64	30	18	9	132 (93.6)
	total	13	67	30	20	11	141
1978	suture lost	-	2	4	-		6 (8.3)
(n=1054)	anchor lost	-	1	-	1		2 (2.8)
	both tags	8	24	23	9		64 (88.9)
	total	8	27	27	10		72
1979	suture lost	3	4	7			14 (5.3)
(n=1386)	anchor lost	7	9	9			25 (9.4)
	both tags	92	93	41			226 (85.3)
	total	102	106	57			265
1980	suture lost	6	4				10 (7.1)
(n=1610)	anchor lost	4	8				12 (8.6)
	both tags	60	58				118 (84.3)
	total	70	70				140
Total		193	270	114	30	11	618 (8.1)

Recovery rates

A total of 115,604 sablefish have been tagged in this study as of December 31, 1981, 55,984 of which were juveniles from mainland inlets, Hecate Strait or Queen Charlotte Sound (Table 2). These areas will be referred to as inside waters. Oxytetracycline injections, with dosages derived from the literature, were suspended in 1978 when it was determined that the dosage was causing mortality (Table 3). In 1981, 10,431 fish were tagged and injected with varying concentrations of oxytetracycline as part of the study to determine an effective and safe dosage for sablefish. Results of these studies are reported elsewherein this symposium (Beamish et al., this symposium).

As of December 31, 1981, 7,576 tagged sablefish have been recovered (Table 2). The total percent recovery is 6.6% or 10.7% if juveniles tagged in the inside waters are excluded. Recovery rates that exclude these juveniles probably are more representative since they are only beginning to be recruited into the "offshore" fishery. Also, if the fish injected with a dosage of 100 mg/kg of oxytetracycline are excluded because of the increased mortality, then the percent recovery becomes 15.0%.

Table 2. Releases and recaptures of tagged sablefish as of December 31, 1981 for all tagged sablefish.

Release area and date		No. of fish tagged	No. (%) of tagged fish recovered
Queen Charlotte Islands	July 77	5,158	1,204 (23.3)
Vancouver Island	Sept 77	5,505	161 (3.0)
Queen Charlotte Islands	May 78	5,284	532 (10.1)
Vancouver Island-Queen Charlotte Sound	June 78	5,465	418 (7.6)
Queen Charlotte Island	Oct 78	121	21 (17.4)
Vancouver Island	May 79	9,111	1,204 (13.2)
Queen Charlotte Island	June 79	6,339	1,390 (21.9)
Queen Charlotte Island	Aug 79	282	21 (7.4)
Queen Charlotte Sound-Hecate Strait	Oct 79	12,983	146 (1.1)
Queen Charlotte Sound-Hecate Strait	Nov 79	12,528	80 (0.6)
Departure Bay	Dec 79	26	1 (3.8)
Queen Charlotte Islands	Feb 80	1,538	151 (9.8)
Vancouver Island	Mar 80	4,703	560 (11.9)
Queen Charlotte Sound	Mar 80	3,110	399 (12.8)
Inlets	May 80	7,019	754 (10.7)
Queen Charlotte Islands	July 80	2,547	116 (4.6)
Queen Charlotte Sound-Hecate Strait	Oct 80	11,148	75 (0.7)
Queen Charlotte Islands	Mar 81	3,112	118 (3.9)
Queen Charlotte Islands	June 81	2,908	104 (3.6)
Queen Charlotte Sound-Hecate Strait	Aug 81	12,306	40 (0.3)
Queen Charlotte Islands	Nov 81	4,411	0
Unknown release area			81
Total		115,604	7,576 (6.6)

The recovery percentage of 6.6% is higher than that observed for any other major sablefish tagging study (Wespestad et al., 1978, 2.9%; Sasaki, 1979, 1.6%; Phillips, 1969, 0.22-4.63%) and the percentage in this study obviously will increase with time. The percentage is high because the relatively small number of fishermen in the Canadian fishery are extremely supportive of the study and make every effort to return fish. We suspect that care during the tagging operation and the tendency for fish to remain in the release area also are important reasons for the high rate of returns.

Recovery percentages vary among release areas, treatments and time at liberty (Table 2). The highest percentage recovery of 23.3% is for the July 1977 cruise off the west coast of the Queen Charlotte Islands. The lowest percentages for fish that have been at liberty for more than 2 years is 3.0% for fish injected with oxytetracycline and released off the west coast of Vancouver Island in September 1977 (Table 3). The projected asymtotic recovery percentage using the equation for the curve in Fig. 4 is 25% for the high recovery study. No asymtotic recovery percentage is projected for the low recovery rate as cumulative recoveries are continuing to increase (Fig. 4).

Table 3. Releases and recaptures of tagged and injected sablefish released offshore as of December 1981.

Release area and date		Number released		Number recovered %			
				Non-injected		Injected	
		Non-injected	Injected	Total		Total	
Queen Charlotte Islands	July 77	5,158	-	1,204	(23.3)	-	
	May 78	866	4,418	292	(33.7)	240	(5.4)
	Oct 78	121	-	21	(17.4)	-	
	June 79	6,339	-	1,390	(21.9)	-	
	Aug 79	282	-	21	(7.4)	-	
	Feb 80	1,538	-	151	(9.8)	-	
	July 80	2,547	-	116	(4.1)	-	
	Mar 81	855	2,257	35	(4.2)	83	(3.7)
	June 81	728	2,180	27	(3.7)	77	(3.5)
	Nov 81	535	3,876	-		-	
Strait of Georgia	Dec 79	26	-	1		-	
Vancouver Island	Sept 77	226	5,279	1	(0.4)	160	(3.0)
	May 79	9,111	-	1,204	(13.2)	-	
	Mar 80	4,703	-	560	(11.9)	-	
Queen Charlotte Sound-Vancouver Island	June 78	2	5,463	0		418	(7.7)
Queen Charlotte Sound	Mar 80	3,110	-	399	(12.8)	-	
Total		36,147	23,473	5,422	(15.0)	978	(4.2)

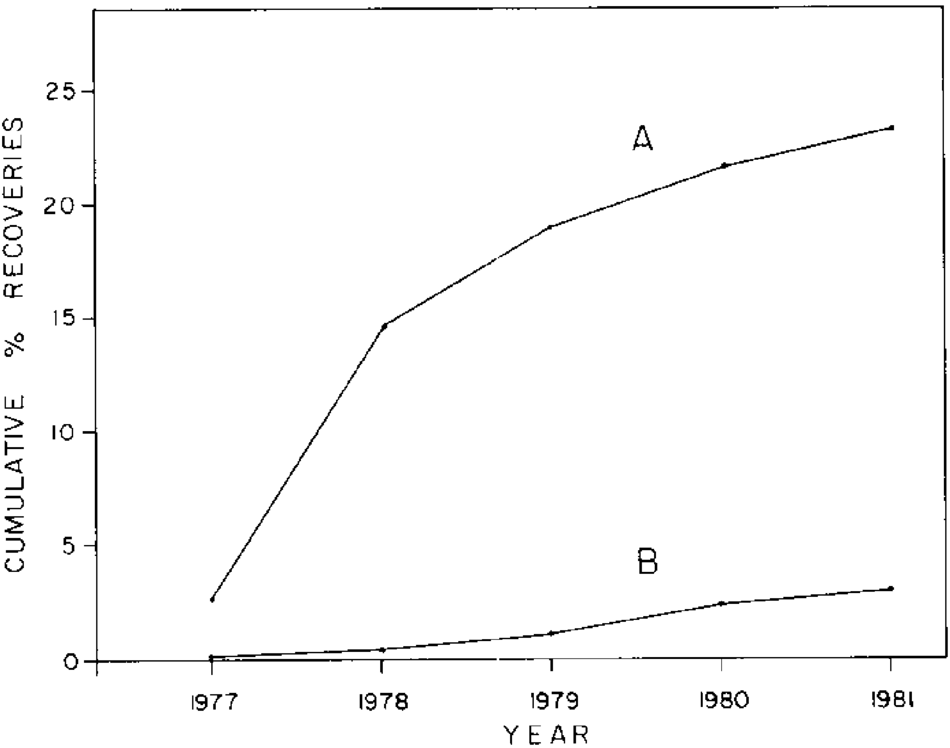

Fig. 4. Cumulative percent recovery of tagged sablefish.
A. Non-injected fish released in July 1977 (Queen Charlotte Islands).
B. Injected fish released in September 1977 (Vancouver Island).

In a few cases the recovery percentage was very low as a result of either a small number of releases or releases in an area that is not fished extensively.

Fish that were tagged in mainland inlets in May 1980 were a mixture of juveniles and adults. There was a greater number of adults in the inlet sample compared to samples from Hecate Strait or Queen Charlotte Sound (Fig. 5). The recovery percentage is high (Table 4) because of a small, but active local fishery.

The recovery percentage of most juveniles was low (Table 4). Juveniles that were tagged in Queen Charlotte Sound and Hecate Strait were almost entirely from the 1977 year-class. Since these fish were small and tended to remain in the inside waters, they were not fished commercially except as incidental discards by bottom trawlers. It is anticipated that most of these fish will be recruited into the offshore fishery during 1983.

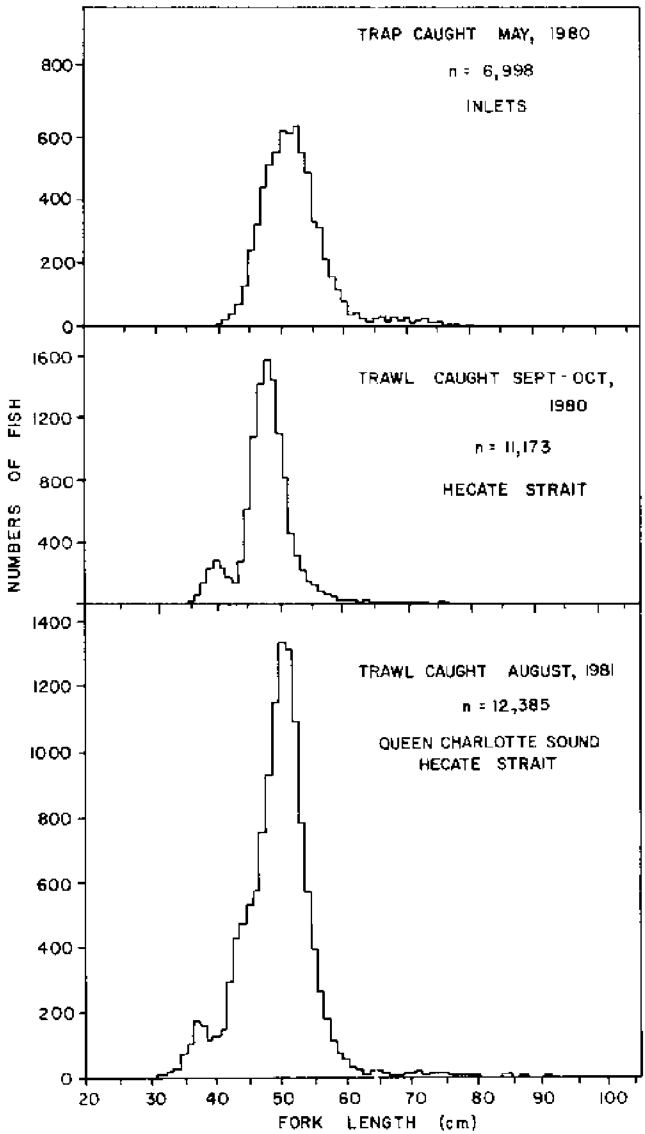

Fig. 5. Comparison of length frequencies of sablefish tagged in inside waters and in mainland inlets.

Table 4. Releases and recaptures of tagged sablefish in inshore waters as of December 31, 1982.

Release area and date		No. released	No. recaptured (%)			
			1980	1981	1982	Total
Queen Charlotte Sound - Hecate Strait	Oct 79	12,983	84	49	40	185 (1.4)
Queen Charlotte Sound - Hecate Strait	Nov 79	12,528	56	20	29	109 (0.9)
Queen Charlotte Sound - Hecate Strait	Oct 80	11,148	8	71	50	129 (1.2)
Queen Charlotte Sound - Hecate Strait	Aug 81	12,306	-	42	160	202 (1.6)
Inlets	May 80	7,019	480	274	229	983 (14.0)

As stated previously there was a lower recovery rate of fish injected with oxytetracycline. For example, in the May 1978 release, only 5.4% of the injected fish have been recovered compared to a recovery of 33.7% of the fish not injected on this cruise (Table 3). Thus, there is little doubt that a dosage of 100 mg/kg caused increased mortality. The total percent recovery of non-injected fish is significantly higher than fish injected with a dosage of 100 mg/kg (t-test $P<.05$).

The number and percentage of recoveries will be affected by catch and effort. Since there are no area restrictions within the Canadian zone, we assumed that fishermen will concentrate their effort in areas of fish concentrations. We are assuming that effort is proportional to biomass and catch can be used as an index of relative abundance among areas. Using this assumption and assuming that tags were distributed proportionally by area, we feel that tags are recovered in proportion to abundance and movement of tagged fish is indicative of movement within the population when the recoveries from different areas are weighted according to catch.

In the Canadian zone, the International North Pacific Fisheries Commission (INPFC) area, Charlotte, is approximately equivalent to the area off the west coast of the Queen Charlotte Islands, and the area off the west coast of Vancouver Island is approximately equivalent to the Vancouver area. Using catch data compiled by INPFC area for all nations fishing sablefish off North America (Table 5), it is apparent that, except, in 1981, there have not been major changes in the proportion of catch taken in the Charlotte and Vancouver areas. In 1981 there was a major increase in the catch in the Charlotte area and a corresponding decrease in the Vancouver area.

The catches in United States waters to the north and south of the Canadian zone have fluctuated substantially (Table 5). In addition, non-reporting of recoveries off Alaska is considered to be a serious problem where it is estimated that 70% of the recoveries of tagged fish are not reported (Bracken, 1982). Thus, recaptures in the United States zone should be compared to recaptures in the Canadian zone by standardizing for catch and population size as well as correcting for non-reporting. These adjustments can best be made by comparing exploitation rates. Unpublished estimates of exploitation rates in

Canada and off Alaska indicate that rates may both be approximately 0.1 (McFarlane, G. A., unpublished; Balsiger, J., unpublished). If this is correct then adjustments need to be made only for non-reporting when comparing recoveries in the United States and Canadian zones since most foreign recoveries are made off Alaska. The total percent recovery of adults in United States waters as of December 31, 1981 was 5.5%. Adjusted for a 70% non-reporting rate the percentage recovery becomes 9.0%. Because the 70% non-reporting rate is only an estimate and appears high, and we are assuming no spatial differences, and a 100% reporting rate in Canada, it is probable that the percentage recovery rate of 9.0% is closer to a maximum value. This rate is relatively small compared to recoveries in Canadian waters and indicates that relatively few recoveries have been made in the United States zone from 1977 to 1981.

Table 5. All-nation catch of sablefish in the northeast Pacific. Japanese catch included in total and listed in brackets.

INPFC Area	1977	1978	1979	1980	1981[a]
Shumagin	1241	1371	809		
	(1240)	(1371)	(809)	(684)	(469)
Chirikof	1360	968	990		
	(1360)	(968)	(990)	(1204)	(391)
Kodiak	3002	1925	2138		
	(3000)	(1925)	(2084)		(345)
				(2605)	
Yakutat	5149	2710	2455		
	(5002)	(2623)	(1938)		(118)
Southeastern	4400	1180	2115	2346	1710
	(3724)	(32)	(79)	(12.9)	(2.4)
Charlotte	2155	1814	1640	1895	2790
	(1818)	(1339)	(264)		
Vancouver	2463	2066	2027	1898	1097
	(1143)	(764)	(125)		
Columbia	893	1953	8357	3693	3645
Eureka	1140	1334	2088	1418	2488
				(1305)[b]	
Monterey	3390	3556	3089	1569	3770

[a]Jan-July only.
[b]California. Exact INPFC area unknown.

Movement of juveniles

Juveniles were tagged in 1979, 1980 and 1981. Inlet-tagged fish have been treated separately from those tagged in Queen Charlotte Sound and Hecate Strait because of the highly localized fishery on the specific inlet stock that was used in the tagging study (Table 6, 7).

In 1980, most recoveries (91.3%) were made in Queen Charlotte Sound and Hecate Strait (Fig. 2). During 1981 and 1982 there was an increasing percentage of recoveries offshore. In 1982, there were 179 recoveries made in offshore waters (Table 6) and 61% of these were in the United States zone. Almost all of the recoveries in the United States zone (91.7%) were from waters off Alaska. In the Canadian zone recoveries were made in all offshore areas with a higher percentage off the west coast of the Queen Charlotte Islands (Table 6).

Ages of a sample from the 1981 tagging had both 1977 and 1979 year-classes while the 1979 and 1980 samples were exclusively from the 1977 year-class. Since recruitment of these 2 year-classes offshore probably does not occur simultaneously, movements of juveniles were examined using only the 1979 and 1980 releases. Most recoveries in 1980 of tagged fish from the 1977 year-class were made in Queen Charlotte Sound and Hecate Strait (Table 6). From 1980 to 1982 there was a linear decline in catches from these waters and a corresponding increase in outside waters (Fig. 6). In 1982, 73.1% of all recoveries were made offshore and 76% of these were in the United States zone. Most of these fish (93.8%) were recovered off Alaska.

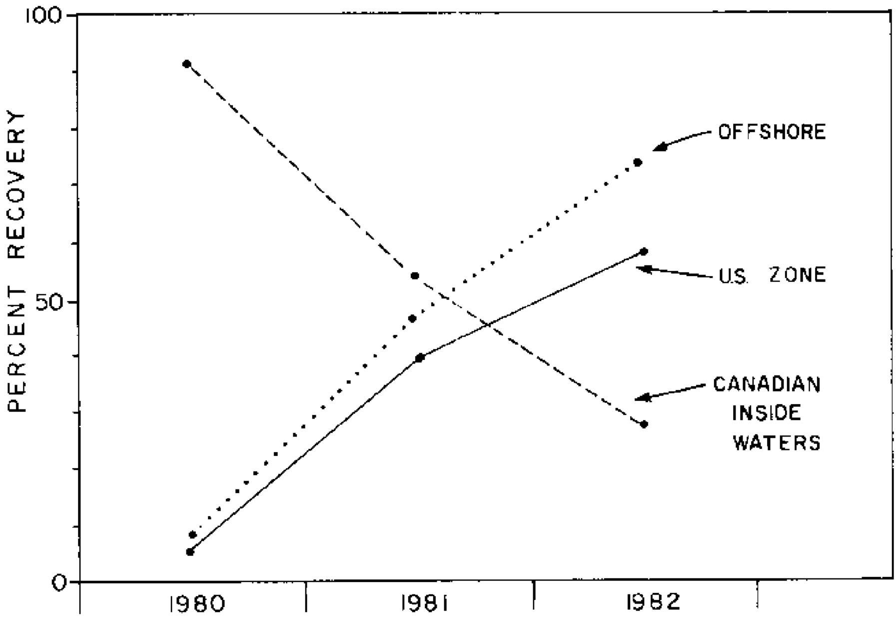

Fig. 6. Percent recovery of fish from the 1977 year class released in 1979 and 1980 (inlet tagged fish not included and not corrected for non-reporting of recaptures). Offshore recoveries include all fish from Canadian and United States wat

Interpretation of these recovery percentages requires an appreciation of the fishing practices in the various areas off the west coast of North America. Off Washington, Oregon and California, sablefish in the 50-60 cm range are retained. Thus, most juveniles of the 1977 year-clas captured in this area probably will be retained, however, we have no estimate of the non-reporting percentage from this area. In Canada in 1981 the mean size of the 1977 year-class in the offshore area was 56.7 cm and samples from commercial catches indicated that this year-class accounted for approximately 19.3% of the catch by numbers. In 1982, the 1977 year-class averaged 62.3 cm and while its contribution to the commercial catch remains to be estimated, preliminary indications are that it will be higher than in 1981. These sizes are above the minimum legal size limit of 55 cm and many would be retained by fishermen. Also, it is believed that any Canadian fishermen finding a tagged fish would retain and report that fish even though it may not be a desired size. Thus, it is probable that in Canada most tagged juveniles would be returned. Off Alaska the Japanese fishery retains fish in the 50-60 cm range and hence would retain tagged fish of the 1977 year-class. The United States fishery off Alaska does not retain fish smaller than 1.4 kg or approximately 57 cm. Thus, it is probable that the number of recoveries of tagged 1977 year-class fish has been under-reported by United States commercial fisheries off Alaska.

Despite this probability of significant under-reporting, the very high percentage of recoveries in waters off Alaska clearly indicates that most of the fish that moved offshore were recruited into the United States waters. If Bracken's figure of 70% non-reporting is used to correct the recoveries in the United States zone, then in 1982 approximately 63% of all of the members of the 1977 year-class tagged in Canadian waters were recaptured in the United States zone. Estimates of the biomass of that segment of the 1977 year-class reared in Hecate Strait and Queen Charlotte Sound, and recruited into the commercial fishery in 1982, range from 30,000 to 60,000 t with a best estimate of approximately 38,000 t (McFarlane and Beamish a, this symposium). The 1982 recovery percentage of 63% (corrected for non-reporting in the United States zone) would indicate approximately 20,000 t would be recruited into the fishery off Alaska.

If the pattern of recovery continues as in 1982, there will be little doubt that sablefish reared in Hecate Strait and Queen Charlotte Sound are an important source of recruitment to the sablefish fishery in waters off Alaska and a major loss to the Canadian fishery. If most of the fish move offshore as expected, the percentage of the tagged 1977 year-class recovered off-shore in 1983 will be higher than the 73.1% that moved offshore in 1982 (Table 6). As recruitment of the 1977 year-class is probably still incomplete, the ultimate amount of recruitment into waters off Alaska will be greater than the estimated 20,000 t.

Fish tagged in mainland inlets were recaptured at a higher rate than juveniles tagged in other areas (Tables 6 and 7). The pattern of migration was similar to other releases except that a higher percentage of fish was recaptured at the tagging site. The higher recovery percentage resulted from increased fishing effort in the inlets that was directed at adults, some of which were tagged and released along with juveniles. The recovery of adults is included in the total percentages as it was not possible to separate adults from juveniles using only lengths.

Table 6. Numbers of juveniles recovered as of Dec. 31, 1982.

Release date/ area	Recovery date	Recovery area: Queen Charlotte Sound	Hecate Strait	West coast Queen Charlotte Islands	West Coast Vancouver Island	Northern U.S.A. zone	Southern U.S.A. zone	Unknown	Total
October-November 1979									
Queen Charlotte Sound	1980	72	7	1	2	7	-	3	92
	1981	12	1	7	3	18	2	2	45
	1982	8	3	7	1	18	1	1	39
Hecate Strait	1980	3	55	1	-	2	-	4	65
	1981	4	7	2	6	16	-	1	36
	1982	3	2	1	1	8	2	1	18
October 1980									
Queen Charlotte Sound	1981	2	-	1	-	2	-	-	5
	1982	-	-	-	-	1	-	-	1
Hecate Strait	1981	10	37	1	1	23	-	2	74
	1982	5	7	5	1	27	3	1	49
August 1981									
Queen Charlotte Sound	1982	58	1	39	4	37	4	-	143
Hecate Strait	1982	14	26	11	-	8	-	-	59
Total		191	146	76	19	167	12	15	626

Table 7. Number of fish recovered from tagging in a mainland inlet.

Release date/ area	n	Recovery date	Recovery area: Inlets	Queen Charlotte Sound	Hecate Strait	West coast Queen Charlotte Islands	West coast Vancouver Island	Alaska	Southern U.S.A.	Unknown	Total
May 1980											
Inlets	7019	1980	472	3	–	2	–	–	–	3	480
		1981	189	28	9	23	3	20	–	2	274
		1982	161	30	3	16	1	16	2	–	229
		Total	822	61	12	41	4	36	2	5	983

Movement of sablefish tagged as adults

Distance travelled by tagged fish was summarized as those fish that moved less than 50 km, 50–200 km, and greater than 200 km. The selection of these groups had no particular significance other than that 50 km would obviously indicate very limited movement. Since commercial vessels often work an area approximately 100 to 200 km long during one trip, we have used the category >200 km to indicate major movements out of a fishing area.

As of December 31, 1981, 6,337 (88.7%) recaptures had been made within 200 km of the release area (Table 8). The average net movement for all of these recaptures was 141.7 km. Thus, most sablefish have been recaptured close to the release area. There were some movements of 2000 to 3000 km (Table 8) but they remain in the minority.

Movement as indicated by the percent of fish recaptured among major areas must be carefully assessed. If exploitation rates are similar among areas and reporting rates are similar, then movement has a direct relationship to recovery percentages. However, it is difficult to determine exploitation rates, and local and annual variation of these rates will occur. Within the Canadian zone we do not believe non-reporting of tags to be a serious problem but it appears that it is in the United States zone. This inability to determine exact recovery percentages restricts the amount of analysis, however, it is possible to draw some reasonably reliable general conclusions about sablefish movement.

Tagged fish released off Vancouver Island were recovered from California to the Aleutians (Fig. 1). Of all recaptures from the releases off Vancouver Island from 1977–1981, 81.3% were made off Vancouver Island, 2.1% in the United States zone south of Vancouver Island, 1.7% in the United States zone north of Dixon Entrance, and the remaining 14.9% in other areas within the Canadian zone (Queen Charlotte Sound and off the Queen Charlotte Islands). More fish (7.7%) have been recovered in Queen Charlotte Sound than off the west coast of the Queen Charlotte Islands (1.3%) even though catches have been larger off of the Queen Charlotte Islands.

Most fish (81.7%) tagged and released off the west coast of the Queen Charlotte Islands were recovered there. Recoveries can be quite close to the exact site of release. The net movement from exact release site has been examined for one cruise (Fig. 7, Table 10). Over a period of 5 years, 50% were recovered within 20 km of the release site. Migrants did not move as far south but did move further westward (as far as the Aleutian Islands) than did fish released off Vancouver Island. The percentages recovered in the United States zone north of Dixon Entrance were higher (6.6%) than recoveries from Vancouver Island releases but lower (0.3%) in the United States zone south of Vancouver Island. In contrast to recoveries of Vancouver Island releases, fish tagged off the Queen Charlotte Islands were recovered in Dixon Entrance and northern Hecate Strait.

Recaptures off Vancouver Island from releases in the immediate area were proportionately larger than were recaptures off the Queen Charlotte Islands from releases off those islands (Table 9a, b).

Table 8. Number and percent of sablefish recovered at various distances from the release areas.

Release area and date		Minimum distance travelled[a] (%) <50 km	50–200 km	>200 km	Maximum distance travelled (km)	Mean distance travelled (km)
Queen Charlotte Islands	July 77	808 (68.0)	244 (20.5)	137 (11.5)	3280	128
Vancouver Island	Sep 77	99 (65.6)	32 (21.2)	20 (13.2)	2001	117
Queen Charlotte Islands	May 78	381 (73.0)	87 (16.7)	54 (10.3)	2474	109
Vancouver Island–Queen Charlotte Sound	June 78	307 (76.6)	47 (11.7)	47 (11.7)	2113	107
Queen Charlotte Islands	Oct 78	13 (61.9)	5 (23.8)	3 (14.3)	611	89
Vancouver Island	May 79	925 (81.7)	118 (10.4)	89 (7.9)	2947	67
Queen Charlotte Islands	June 79	926 (72.2)	198 (15.4)	158 (12.3)	2446	102
Queen Charlotte Islands	Aug 79	13 (68.4)	3 (15.8)	3 (15.8)	1112	178
Queen Charlotte Sound–Hecate Strait	Oct 79	75 (52.8)	33 (23.2)	34 (23.9)	2622	269
Queen Charlotte Sound–Hecate Strait	Nov 79	22 (29.7)	30 (40.5)	22 (29.7)	1964	382
Departure Bay	Dec 79	1(100.0)	–	–	7	7
Queen Charlotte Islands	Feb 80	54 (38.3)	57 (40.4)	30 (21.3)	1844	204
Vancouver Island	Mar 80	394 (76.2)	77 (14.9)	46 (8.9)	1918	70
Queen Charlotte Sound	Mar 80	302 (85.3)	34 (9.6)	18 (5.1)	1742	61
Inlets	May 80	650 (87.4)	27 (3.6)	67 (9.0)	2974	76
Queen Charlotte Islands	July 80	81 (71.7)	16 (14.1)	16 (14.2)	1223	113
Queen Charlotte Sound–Hecate Strait	Oct 80	24 (32.9)	22 (30.1)	27 (37.0)	2428	499
Queen Charlotte Islands	Mar 81	65 (53.2)	28 (23.0)	29 (23.8)	1909	178
Queen Charlotte Islands	June 81	86 (81.9)	15 (14.3)	4 (3.8)	1195	50
Queen Charlotte Sound–Hecate Strait	Aug 81	36 (87.8)	2 (4.9)	3 (7.3)	269	28
Queen Charlotte Islands	Nov 81	–	–	–	–	–
Total		5,262 (73.7)	1,075 (15.0)	807 (11.3)		

[a] Does not include fish of unknown recapture area.

Table 9a. Recoveries of sablefish at various distances from release areas off the west coast of the Queen Charlotte Islands for each year after release.

Tagging year	Recovery year	Total numbers recovered	% (no.) recoveries from release area <50 km (no.)	50–200 km (no.)	>200 km (no.)
1977	1977	132	87.9 (116)	9.1 (12)	3.0 (4)
	1978	624	77.9 (486)	18.1 (113)	4.0 (25)
	1979	221	49.8 (110)	25.8 (57)	24.4 (54)
	1980	133	48.1 (64)	27.8 (37)	24.1 (32)
	1981	82	42.7 (35)	30.9 (24)	24.4 (20)
	1982	40	55.0 (22)	22.5 (9)	22.5 (9)
1978	1978	209	92.3 (193)	7.2 (15)	0.5 (1)
	1979	176	68.2 (120)	20.4 (36)	11.4 (20)
	1980	101	54.4 (55)	21.8 (22)	23.8 (24)
	1981	59	47.5 (28)	32.2 (19)	20.3 (12)
	1982	17	41.2 (7)	29.4 (5)	29.4 (5)
1979	1979	472	81.1 (383)	13.1 (62)	5.7 (27)
	1980	512	64.0 (327)	19.9 (102)	16.2 (83)
	1981	323	72.4 (234)	11.5 (37)	16.1 (52)
	1982	82	48.8 (40)	23.5 (19)	28.0 (23)
1980	1980	92	55.4 (51)	28.3 (26)	16.3 (15)
	1981	164	52.5 (85)	28.4 (46)	20.1 (33)
	1982	65	43.1 (28)	38.5 (25)	18.4 (12)
1981	1981	232	66.4 (152)	17.9 (41)	15.1 (35)
	1982	365	60.8 (222)	20.3 (74)	18.9 (69)

Table 9b. Recoveries of sablefish at various distances from release areas off the west coast of Vancouver Island for each year after release.

Tagging year	Recovery year	Total numbers recovered	% (no.) recoveries from release area <50 km (no.)	50–200 km (no.)	>200 km (no.)
1977	1977	6	66.7 (4)	33.3 (2)	– (0)
	1978	13	30.8 (4)	61.5 (8)	7.8 (1)
	1979	38	57.9 (22)	18.4 (7)	23.7 (9)
	1980	62	79.0 (49)	12.9 (8)	8.1 (5)
	1981	37	67.6 (25)	21.2 (7)	15.2 (5)
	1982	18	94.4 (17)	5.6 (1)	– (0)
1978[a]	1978	22	81.8 (18)	9.1 (2)	9.1 (2)
	1979	143	70.6 (101)	14.0 (20)	15.4 (22)
	1980	169	82.8 (140)	7.7 (13)	9.5 (16)
	1981	67	71.6 (48)	17.9 (12)	10.4 (7)
	1982	31	80.7 (25)	16.1 (5)	3.2 (1)

Table 9b (cont'd)

Tagging year	Recovery year	Total numbers recovered	% (no.) recoveries from release area					
			<50 km (no.)		50–200 km (no.)		>200 km (no.)	
1979	1979	333	82.0	(273)	10.2	(34)	7.8	(26)
	1980	634	88.6	(562)	7.3	(46)	4.1	(26)
	1981	173	55.9	(95)	23.7	(41)	21.8	(37)
	1982	220	87.3	(192)	4.5	(10)	8.2	(18)
1980	1980	305	81.6	(249)	10.2	(31)	8.2	(25)
	1981	214	68.5	(146)	21.5	(46)	10.3	(22)
1981[b]			-	-	-	-	-	-

[a]1978 release cruise—west coast of Vancouver Island and southern part of Queen Charlotte Sound.

[b]No release in 1981 off the west coast of Vancouver Island.

Table 9c. Recoveries of sablefish at various distances from release areas in Queen Charlotte Sound for each year after release.

Tagging year	Recovery year	Total numbers recovered	% (no.) recoveries from release area					
			<50 km (no.)		50–200 km (no.)		>200 km (no.)	
1980	1980	122	87.7	(107)	7.4	(9)	4.9	(6)
	1981	233	84.1	(196)	10.7	(25)	5.2	(12)
	1982	111	82.9	(92)	12.6	(14)	4.5	(5)

Table 9d. Recoveries of sablefish at various distances from release areas in the inshore waters—inlets for each year after release.

Tagging year	Recovery year	Total numbers recovered	% (no.) recoveries from release area					
			<50 km (no.)		50–200 km (no.)		>200 km (no.)	
1980	1980	472	98.5	(465)	1.1	(5)	0.4	(2)
	1981	272	68.0	(185)	8.1	(22)	23.9	(65)
	1982	227	68.3	(155)	8.8	(20)	22.9	(52)

Recovery percentages within 50 km of the release area off Vancouver Island, did not show the continuous decline found off the Queen Charlotte Islands. Off Vancouver Island, movement beyond 200 km appeared anomalous in 2 years. In 1981 the catches off Vancouver Island were approximately 50% lower than in the previous year (Table 5) and increased recoveries beyond 200 km are related to the change in the fishery, not to a change in the pattern of movement. In 1979 there also was an apparent rapid increase in movement out of the release area but there was a four-fold increase in catch to the south of the Canadian zone and a doubling to the north (Table 5). Of the 57 fish recovered in 1979 beyond 200 km of their release area off Vancouver Island (Table 9b), approximately one-half (data not included in tables) were from waters off the United States. There was definitely a relationship between the increased catch in the United States zones and apparent movement out of the release area but there also was an increased movement beyond 200 km within the Canadian zone.

Off the Queen Charlotte Islands there was a very definite movement out of the release area. In all releases (Table 9a) there was a continuous annual decline in recovery percentages close to the release area indicating continued emigration. Movement beyond 200 km increased sharply in 1979 and has remained more or less constant since that time. The increased recoveries in 1979 were predominantly in waters off Alaska and between 1978 and 1979 there was a doubling of the catch in the waters immediately north of Canada. However, there were ten recoveries made in this area in 1978 and again in 1979 (data not included in tables), thus the increased catch does not explain the increased movement in 1979 to waters north of the Canadian zone. The increased movement out of Canadian waters in 1979 and the apparent reduction of subsequent movement may be real or it may relate in part to changes in reporting of recaptures. It is apparent that releases off Vancouver Island and off the Queen Charlotte Islands behaved differently and it is possible that the movements in 1979 were more than artifacts of changing fishing patterns. It is known that the strong 1977 year class started moving offshore in 1979 but it is unknown whether this "invasion" had an effect on the behaviour of resident adults.

Fish tagged and released in Queen Charlotte Sound (Fig. 3) were recovered in most areas where recoveries were reported and behaved like Vancouver Island releases.

Adults that were tagged in the inside waters moved at a greater rate than those released from the offshore areas. This probably is a consequence of the recovery effort being almost entirely offshore.

Because the number of recoveries may be highest in the period immediately after release, a comparison using all recoveries will bias the significance of longer term recoveries. If the number of fish recovered at distances greater than 200 km are compared with total recoveries in the third, fourth, and fifth year of liberty, for releases in 1977 and 1978 off the west coast of the Queen Charlotte Islands (Table 11) there is an almost constant percentage (20-27%) of fish recovered at distances greater than 200 km each year, possibly indicating that movement beyond 200 km occurred soon after release. The percentage of these fish found in the United States zone is lower and more variable and does decrease.

Table 10. Recoveries of sablefish in relation to individual release location within the general tagging area off the west coast of the Queen Charlotte Islands in July 1977.

Release location (Fig. 7)	Total no. released	No. recovered 1977–1979	No. recovered 1980	No. recovered 1981	No. (%) recovered within 20 km of release location 1977–1979	No. (%) recovered within 20 km of release location 1980	No. (%) recovered within 20 km of release location 1981	Total no. and % recovered 1977–1981 no.	Total %	% ≤ 20 km
A	191	32	8	1	20 (63)	2 (25)	-	41	21.5	54.0
B	176	41	5	3	25 (61)	1 (20)	-	49	27.8	53.0
C	367	52	4	6	29 (56)	-	1 (17)	62	16.9	48.0
D	195	45	3	5	23 (51)	-	2 (40)	53	27.2	47.0
E	241	38	5	5	19 (50)	2 (40)	1 (20)	48	19.9	46.0
F	287	40	8	9	22 (55)	4 (50)	2 (22)	57	19.9	49.0
G	251	38	8	3	19 (50)	2 (25)	1 (33)	49	19.5	45.0
H	227	48	6	3	10 (21)	3 (50)	2 (67)	57	25.1	26.0
I	332	51	10	3	18 (35)	5 (50)	1 (33)	64	19.3	38.0
J	232	37	8	6	14 (38)	4 (50)	3 (50)	51	22.0	41.0
K	406	77	14	7	34 (44)	7 (50)	4 (57)	98	24.1	46.0
L	503	85	11	3	42 (49)	4 (46)	1 (33)	99	19.7	47.0
M	298	67	10	7	48 (72)	1 (10)	4 (57)	84	28.2	63.0
N	383	54	12	3	38 (70)	2 (17)	-	69	18.0	58.0
O	252	52	8	6	29 (56)	7 (88)	3 (50)	66	26.2	44.0
P	304	80	9	3	46 (56)	2 (22)	1 (33)	92	30.3	53.0
Q	294	65	7	8	39 (60)	5 (71)	3 (38)	80	27.2	59.0
R	230	79	2	4	41 (52)	2 (100)	1 (25)	85	40.0	52.0
Total	5,159	981	138	85	516 (53)	53 (38)	30 (35)	1,204	23.3	50.0

Table 11. Recoveries of all tagged adult sablefish >200 km from release area and those in the U.S. zone for the 3rd, 4th, and 5th years of liberty. Brackets indicate % of total recaptures.

Area	Release	Recovery					
		1979		1980		1981	
		>200 km	U.S. zone	>200 km	U.S. zone	>200 km	U.S. zone
Queen Charlotte Islands	1977	54 (24%)	44 (20%)	32 (24%)	20 (15%)	22 (27%)	8 (10%)
	1978	-	-	24 (24%)	11 (11%)	12 (21%)	8 (14%)
Vancouver Island	1977	9 (24%)	6 (16%)	4 (6%)	0 (0%)	5 (15%)	1 (3%)
	1978	-	-	12 (9%)	8 (5%)	5 (14%)	0 (0%)

For releases in 1977 and 1978 off the west coast of Vancouver Island (Table 11) the percent recoveries of fish that moved more than 200 km varies from 6 to 24% with approximately one third of the recoveries made in the U.S. zone. If only recoveries in the third, fourth, and fifth years are considered, the percentage of fish recovered annually off the United States (Table 11) is higher than the 5.5% when all recoveries are considered.

Directional movement was studied by comparing the number of fish that moved north and south across boundaries of Canadian statistical areas. In Canada, a major statistical area ranges from approximately 100 to 200 km in latitude. Since longer term movements were being examined, only the movements of adult fish that were tagged in 1977 and 1978 were examined. Juveniles tagged in 1979 were examined since large numbers of juvenile sablefish were not tagged until 1979. The number of recoveries with exact recovery locations was small.

In the Charlotte area, 6% of recovered fish moved north and 3% south (Table 12, 13). In the Vancouver area also, fish moved more to the north than to the south (Table 14, 15). As mentioned earlier, juveniles also tended to move north rather than south (Table 16). It appears that the tendency for more fish to move north rather than south is real, however, only a small number of fish migrate further than 200 km and about two-thirds of these move north while one-third move south. The total number of adults that moved more than 200 km north represents only 6.7% of all recoveries.

In contrast to the direction of movements of fish that migrated more than 200 km, fish that moved less than 200 km and crossed a minor area boundary, exhibited a strong tendency to move southward in one case and northward in the other. Of the fish tagged in 1977 and 1978 off the west coast of the Queen Charlotte Islands, 232 fish moved south and 10 north. Of fish tagged in 1977 and 1978 off Vancouver Island, 105 moved north and 58 moved south. The apparent migration south from the Queen Charlotte Islands and north from Vancouver Island may result in part from increasing catches in Queen Charlotte Sound. In 1977 only 17 t were landed from Queen Charlotte Sound compared to 1,360 t in 1981.

Recoveries of sablefish by month (Table 17; Beamish et al., 1983) show no trends that can't be explained by changes in fishing effort and commercial regulations. We have been unable to detect trends in movement of fish specifically related to sex or size (Table 12, 13, 14, 15, 16).

Fishermen report that there are migratory and non-migratory sablefish. They identify sablefish with a "silver" belly as a migratory fish because they note that while bottom trawling these forms will appear on the fishing grounds only at certain times of the year. We attempted to confirm this claim but were unable to make a clear distinction between a so-called silver belly and a non-silver belly. Nevertheless it is possible that the migratory habit is restricted to a particular component of the population.

Numbers of fish moving between waters off Alaska and British Columbia

The number of tagged adult sablefish moving into waters north of the Canadian zone is 4.7% of the number recaptured in the Canadian

Table 12. Summary of distance and direction travelled by length interval for male and female sablefish tagged off the west coast of the Queen Charlotte Islands during 1977 and recaptured 1977–1981.

Release length (cm)	Sex		Distance from release area (km) and predominant direction														
			1977			1978			1979			1980			1981		
			<50	50–200	>200	<50	50–200	>200	<50	50–200	>200	<50	50–200	>200	<50	50–200	>200
≤50	M&F	No. of fish (direction)	2	–	–	4 1(S)	–	–	2	–	–	–	–	–	–	–	–
>50	M&F	No. of fish (direction)	94 20(S)	5 7(S)	4(N)	445 36(S)	83 2(N) 28(S)	14(N) 11(S)	92 15(S)	25 1(N) 31(S)	45(N) 9(S)	54 9(S)	19 2(N) 16(S)	16(N) 14(S)	32 2(S)	16 9(S)	8(N) 14(S)
50–55	M	No. of fish (direction)	–	–	–	2	–	–	1 1(S)	–	–	–	–	–	1	–	–
56–60	M	No. of fish (direction)	6	–	–	11	1	–	4 1(S)	1	1(N) 1(S)	1	4	–	2	–	–
>60	M	No. of fish (direction)	20 3(S)	1(S)	1(N)	89 9(S)	3 2(N) 2(S)	1(N)	25 3(S)	3 4(S)	13(N)	26 3(S)	9 5(S)	7(N) 3(S)	9	1 3(S)	4(N) 2(S)
50–60	F	No. of fish (direction)	1	–	–	2	–	–	1	–	2(N)	1	–	1(N) 1(S)	–	–	–
61–70	F	No. of fish (direction)	24 4(S)	2(S)	1(N)	51 6(S)	3 3(S)	1(N) 1(S)	15 1(S)	3 4(S)	6(N) 1(S)	4	2 5(S)	4(N) 3(S)	7	1 1(S)	1(S)
>70	F	No. of fish (direction)	33 13(S)	3 4(S)	–	119 17(S)	10 18(S)	3(S)	41 7(S)	12 12(S)	2(N) 2(S)	19 5(S)	3 2(N) 3(S)	1(N) 3(S)	11 1(S)	13 5(S)	2(N) 5(S)

Table 13. Summary of distance and direction travelled by length interval for male and female sablefish tagged off the west coast of the Queen Charlotte Islands during 1978 and recaptured 1978-1981.

Release length (cm)	Sex		Distance from release area (km) and predominant direction											
			1978			1979			1980			1981		
			<50	50-200	>200	<50	50-200	>200	<50	50-200	>200	<50	50-200	>200
≤50	M&F	No. of Fish	-	-	-	-	-	-	1	-	-	-	-	-
>50	M&F	No. of fish	193	3 11(S) 1(N)	1(S)	106 12(S)	17 15(S) 4(N)	5(S) 14(N)	53 1(S)	12 10(S)	13(S) 9(N) 2(W)	27 1(S)	11 8(S)	4(S) 8(N)
50-55	M	No. of fish	-	-	-	-	-	-	-	-	2(S)	1	-	-
56-60	M	No. of fish	11	-	-	10	2 1(N)	-	8	2(S)	1(S) 1(N)	3	-	-
>60	M	No. of fish	37	1(S) 1(N)	1(S)	26 4(S)	3 3(S)	3(N)	15	4	2(S) 1(N)	8 1(S)	4 2(S)	1(S) 2(N)
50-60	F	No. of fish	-	-	-	-	-	1(N)	1	-	-	-	-	-
61-70	F	No. of fish	42	5(S)	-	18 1(S)	3 4(S) 1(N)	1(S)	9	1	1(S) 2(N)	2	1 1(S)	1(S)
>70	F	No. of fish	43	3 3(S)	-	35 7(S)	5 5(S) 2(N)	2(S)	14 1(S)	7 7(S)	1(W) 4(S)	11	6 3(S)	1(S) 3(N)

Table 14. Summary of distance and direction travelled by length interval for male and female sablefish tagged off the west coast of Vancouver Island during 1977 and recaptured 1977–1981.

Release length (cm)	Sex		Distance from release area (km) and predominant direction														
			1977			1978			1979			1980			1981		
			<50	50–200	>200	<50	50–200	>200	<50	50–200	>200	<50	50–200	>200	<50	50–200	>200
≤50	M&F	No. of fish	-	-	-	2	-	-	-	-	-	2	-	1(N)	2	-	-
>50	M&F	No. of fish	4(N)	2(N)	-	2	2(S) 6(N)	1(N)	14 6(S) 2(N)	3(S) 4(N)	1(S) 8(N)	40 1(N) 4(S)	4(S) 4(N)	4(N)	14 4(N)	1(S) 6(N)	5(N)
50–55	M	No. of fish	1(N)	-	-	1	1	-	-	-	2(N)	1	1(N)	1(N)	4	-	-
56–60	M	No. of fish	-	-	-	-	1(N)	-	3	-	-	5	-	-	2	1(N)	-
>60	M	No. of fish	1	-	-	-	-	-	1	-	1(N)	1	-	-	2 1(N)	-	-
50–60	F	No. of fish	-	1(N)	-	1	-	-	4	1(S)	3(N)	11	3(S)	-	-	1(N)	1(N)
61–70	F	No. of fish	2	1(N)	-	-	-	1(N)	5	1(N) 1(S)	1(S)	8 2(S) 1(N)	1(N) 2(S)	-	2 1(N)	2(N)	-
>70	F	No. of fish	-	-	-	1	-	-	3	1(N)	-	7	-	-	2	1(N)	-

Table 15. Summary of distance and direction travelled by length interval of male and female sablefish tagged off the west coast of Vancouver Island during 1978 and recaptured 1978-1981.

Release length (cm)	Sex		Distance from release area (km) and predominant direction: 1978			1979			1980			1981		
			<50	50-200	>200	<50	50-200	>200	<50	50-200	>200	<50	50-200	>200
≤50	M&F	No. of fish	-	-	-	1	-	-	-	-	-	-	-	-
>50	M&F	No. of fish	8 2(N)	1 1(N)	1(S) 1(N)	61 2(S) 36(N)	3 7(S) 6(N)	3(S) 11(N)	95 17(S) 12(N)	1 5(S) 6(N)	3(S) 9(N)	14 5(N)	2 7(S) 3(N)	1(S) 4(N)
50-55	M	No. of fish	1 1(N)	-	-	-	-	-	3 2(N)	-	-	-	-	-
56-60	M	No. of fish	1	-	-	2 1(N)	-	-	2 1(S)	-	1(S)	2 1(N)	-	-
>60	M	No. of fish	-	-	1(S)	13 7(N)	1 1(N)	1(N)	15 4(S)	2(S)	-	1 2(N)	2(S) 2(N)	-
50-60	F	No. of fish	1	-	1(N)	-	-	2(N)	2 1(N)	1(S)	-	-	-	-
61-70	F	No. of fish	2	-	-	14 2(N)	1 2(S) 2(N)	-	27 3(S) 1(N)	1 1(N)	1(S) 1(N)	1	3(S)	2(N)
>70	F	No. of fish	2	1 1(N)	-	28 1(S) 3(N)	1 1(S) 2(N)	3(N)	40 9(S) 6(N)	3(N)	1(N)	8 2(N)	1 2(S) 1(N)	1(N)

Table 16. Summary of distance and direction travelled for male and female juvenile sablefish tagged inshore during 1979 and recaptured 1979–1982.

Release length (cm)	Sex		Distance from release area (km) and predominant direction											
			1979			1980			1981			1982		
			<50	50–200	>200	<50	50–200	>200	<50	50–200	>200	<50	50–200	>200
≤50	M&F	No. of fish	15	–	–	61 6(S)	13 8(S) 26(N)	2 12(N)	6 1(S)	6 4(S) 3(N)	6(S) 30(N)	3	2 6(S) 4(N)	4(S) 36(N)
>50	M&F	No. of fish	1	–	–	3	1(S)	2(N)	–	1	2(S) 6(N)	–	2 1(S)	2(S) 2(N)
≤50	M	No. of fish	3	–	–	14 2(S)	5 10(N) 3(S)	1 5(N)	3	2 2(S) 2(N)	10(N)	3	1 1(S) 2(N)	2(S) 18(N)
>50	M	No. of fish	–	–	–	–	–	1(N)	–	–	1(N)	–	–	–
≤50	F	No. of fish	3	–	–	29 2(S)	6 4(S) 15(N)	1 2(N)	1 1(S)	4 1(S) 1(N)	15(N)	–	1 4(S) 2(N)	1(S) 15(N)
>50	F	No. of fish	1	–	–	3	1(S)	1(N)	–	1	2(S) 4(N)	–	2 1(S)	1(N)

Table 17. Examples of monthly recoveries of sablefish at various distances from release areas for each tagging cruise, 1977-1981.

Distance from release area	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
					1977 Queen Charlotte Islands - July 1977 release							
<50	-	-	-	-	-	-	-	65	35	16	0	-
50-200 km	-	-	-	-	-	-	-	2	3	7	0	-
>200 km	-	-	-	-	-	-	-	0	2	1	1	-
Total	-	-	-	-	-	-	-	67	40	24	1	-
					1978 Queen Charlotte Island - July 1977 release							
<50 km	-	-	0	5	83	105	0	97	60	66	66	4
50-200 km	-	-	1	0	47	14	2	14	7	6	22	0
>200 km	-	-	0	7	6	4	0	3	2	2	0	1
Total	-	-	1	12	136	123	2	114	69	74	88	5
					1979 Queen Charlotte Islands - July 1977 release							
<50 km	22	8	15	17	7	25	9	0	1	5	1	0
50-200 km	1	2	2	4	3	7	7	7	8	4	10	2
>200 km	2	0	2	3	5	14	8	6	7	6	1	0
Total	25	10	19	24	15	46	24	13	16	15	12	2
					1980 Queen Charlotte Islands - July 1977 release							
<50 km	0	5	1	10	3	12	8	11	8	6	0	-
50-200 km	1	4	0	4	3	3	3	15	3	1	0	-
>200 km	1	0	0	4	11	6	0	5	4	3	1	-
Total	2	9	1	18	17	21	11	31	15	10	1	-
					1981 Queen Charlotte Islands - July 1977 release							
<50 km	-	0	1	5	5	5	7	3	3	2	3	-
50-200 km	-	4	11	4	0	1	2	2	1	0	0	-
>200 km	-	0	4	5	4	3	0	2	5	0	0	-
Total	-	4	16	14	9	9	9	7	9	2	3	-

Table 18. Number (percent) of tagged adult sablefish recaptured in the Canadian and United States zones from all releases.

Recovery area	1977	1978	1979	1980	1981	1982	Total
U.S. zone south of Canada	--	2(0.2)	20(1.4)	14(0.6)	23(1.4)	21(1.8))	80(1.1)
Canada	134(97.1)	851(97.9)	1268(90.2)	2045(87.4)	1474(88.2)	1084(91.0)	6856(90.0)
U.S. zone north of Canada	4(2.9)	14(1.6)	90(6.4)	105(4.5)	86(5.1)	60(5.0)	359(4.7)
Unknown	--	2(0.2)	27(1.9)	175(7.5)	89(5.3)	26(2.2)	319(4.2)
Total	138	869	1405	2339	1672	1191	7614

zone (Table 18). Recaptures up to December 31, 1982 have been considered, however, the annual percentages have fluctuated little since 1979. If recapture percentages are considered by release year (Table 19), there has been a rather constant percentage of recoveries in each area from each of the releases.

Table 19. Percent of tagged adult sablefish recaptured in waters off Canada and off Alaska (in parenthesis).

Year of recovery	Year of release 1977	1978	1979	1980	1981
1977	97.1(2.9)	—	—	—	—
1978	97.2(2.2)	100.0(0)	—	—	—
1979	78.0(17.0)	90.1(6.8)	94.2(2.8)	—	—
1980	87.1(9.0)	88.2(6.9)	87.8(3.5)	86.4(3.9)	—
1981	84.5(5.4)	90.6(7.8)	82.3(4.6)	92.8(3.3)	90.0(10.0)
1982	80.9(4.4)	92.3(7.7)	93.6(2.4)	90.9(3.8)	90.5(8.0)

By December 31, 1982 there were 359 fish recaptured off Alaska. If 70% of the recaptures were not reported (Bracken, 1982) then 610 fish or 7.8% of all recaptures were made off Alaska.

The exploitation rate for sablefish has been estimated as 0.1 for the Canadian zone (McFarlane, unpublished) and about 0.1 for the United States zone off Alaska (Balsiger, unpublished). In both cases it was clear that the estimated exploitation rate was only approximate, however, it does indicate that the ratio of removals to total biomass from the two areas is similar and that once non-reporting is considered, the recovery percentages in the two zones are directly comparable.

Using the results of the tagging study, it was estimated that the adult biomass in the Canadian zone was approximately 38,000 t (McFarlane and Beamish, b). Assuming this estimate was constant from 1977 to 1982 and assuming an emigration percentage of 7.8% for this same period, then approximately 2,855 t of sablefish moved into the waters off Alaska over this period (and a much smaller amount into waters south of the Canadian zone). Since the recovery percentages have not steadily increased in the United States zone to the north (Table 19), either the bulk of the tagged fish moved there shortly after release or subsequently moved back into the Canadian zone. As mentioned there may also be unknown problems with the reporting of the recaptures. Since this study showed that most sablefish do not undergo extensive monthly or annual movements, it is probable that there is not an annual movement of 7.8% of the biomass between the Canadian and United States zones. Fortunately, to compare the amount of movement between the United States zone to the north, and Canada, it is not necessary to resolve how movement occurred if the pattern was similar.

Over the period 1978 to 1982, 19,304 sablefish were tagged in waters north of the Canadian zone (Bracken, & Shaw, personal communication). A total of 301 were recovered in the Canadian zone and 745 in the United States zone. After correcting the recoveries in the United States zone for a 70% non-reporting rate and assuming full reporting in the Canadian zone, the proportion taken in the Canadian zone was 19.2% of all recoveries. No biomass estimate is available for sablefish in the United States zone, but it has been estimated that the equilibrium yield in the Gulf of Alaska for 1981 was between 11,000 and 12,000 t (Balsiger, 1982). Assuming the Canadian quota of 3,500 t is an equilibrium yield for the Canadian zone and that these estimates are proportional to biomass then it can be assumed that there is approximately three times the biomass of sablefish in the Gulf of Alaska as off Canada. If the 19.2% recovery rate in the Canadian zone of tagged sablefish from the United States zone is representative of movement into the Canadian zone and biomass in the Gulf of Alaska is three times the biomass of Canada then approximately 21,080 t of adults have moved, during 1978-82 into the Canadian zone or about 7.4 times the number that have moved into the United States zone.

The 21,080 t estimate probably is high because the tagging studies indicate that there has not been an extensive amount of long range movement, i.e. fewer fish released off Vancouver Island were found in the waters off Alaska than fish released off Queen Charlotte Islands (Fig. 1). Most exchange has been between boundary areas (Fig. 3). Because the United States tagging program released fish just north of the Canadian zone, it would be expected that a relatively large number of recoveries would be made in the Canadian zone without migrating more than 200 km. Thus, it is probably more accurate to compare movement between the Canadian zone and the Southeastern-Yakutat INPFC areas. The equilibrium yield in the combined INPFC areas of Southeastern and Yakutat, immediately north of the Canadian zone was about the same as that estimated for the latter zone, suggesting that the biomass was similar to that found off Canada. Assuming equal biomass, then 7,027 t or approximately 2.5 times as many adults moved into the Canadian zone as into the United States zone.

At this time it has not been possible to obtain detailed release and recovery information on the United States tagging program off Alaska. Ideally only recoveries at a distance of more than 200 km that also traverse the boundary between each country should be compared. When this is done it is possible that there may be more equal exchange of fish. It is clear, however, that there is an exchange and that it is probable more adults move into Canadian waters than move into waters off Alaska.

The very definite migration of juveniles into the waters off Alaska and the apparent disproportionate number of adults that move into the Canadian zone from the Gulf of Alaska suggest a migratory pattern in which juveniles leaving the Canadian zone eventually return to "home ground". An alternative possibility is that juveniles undergo extensive dispersion northward and adults undergo shorter movements southward. In the boundary area between the Gulf of Alaska and the Canadian zone these relatively short movements result in a net movement into the Canadian zone. Since the majority of recaptures have been in the release area, a movement of more than 200 km appears confined to a relatively small segment of the population. Also if the rather constant percentage of fish recovered beyond 200 km is real, then fish may have moved out of the release area over a short period with very little subsequent movement or with a relatively small number of fish constantly moving in and out of the release area.

From the observed movement into the United States zone including the extensive movements of a few sablefish, we infer that there is interbreeding throughout the range and that sablefish off the west coast of North America belong to one population. However, the difference in migratory behaviour between releases off the Queen Charlotte Islands and Vancouver Island and the relatively large number of fish that remained in the immediate release area after 5 years indicate the population is composed of sub-populations or stocks.

Implications for management

The tagging study has shown that separate management problems occur for juveniles and adults. The estimate of 20,000 t of juveniles from the Canadian zone that would be recruited from the 1977 year-class to the fishery off Alaska is approximately 60 to 75% of the 1977 year-class that was reared in Queen Charlotte Sound and Hecate Strait. The 1979 year-class appears to be behaving similarly. If this pattern applies to all incoming year-classes then Queen Charlotte Sound and Hecate Strait must be regarded as important nursery areas for sablefish recruited into the United States fishery — just how important depends on the contribution of nursery areas off Alaska itself. The loss to the Canadian fishery is important and a fishery for juveniles in the Candian zone would appear to affect subsequent recruitment to the fishery off Alaska.

The study has also shown that a small but rather constant percentage of adults moves into the waters off the United States. Most of this movement is into the waters in the Gulf of Alaska. Movement into the Canadian zone of possibly 2 to 3 times the amount that moved out, occurs from the Gulf of Alaska. Whether or not this movement is sufficient to require joint management involving larger regulatory areas than now exist, involves a consideration of the economic conditions in the Canadian sablefish fishery. If one area was overexploited (e.g., the Queen Charlotte Islands area), would natural recruitment, immigration and emigration be sufficient to maintain the stability of the fishery in that particular area? In other words, would sablefish behave in such a way that the area would be restocked sufficiently quickly to maintain the industry? At present there are a number of vessels that are entitled to participate in the fishery but do not, indicating that at current prices it is not economical for many of these boats to fish. Thus, the reduction of fishing privileges, even for a few years, probably will result in severe economic hardships for those currently fishing. The amount of movement observed from this tagging study and the irregularity of recruitment (McFarlane and Beamish, b) indicate that depleted local stocks would not be rebuilt quickly. Vessels that depended on fishing these stocks probably could not survive financially during the time required to rebuild stocks. These considerations, the observations that most recoveries over the past 5 years have been close to the release area, and the differences in movement patterns within the Canadian zone, indicate that adult sablefish in the Canadian zone should be managed separately and not as part of one large stock found off the west coast of North America.

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References

Balsiger, J. W. 1982. Sablefish. In J. Balsiger (ed). Condition of groundfish resources of the Gulf of Alaska in 1982. Unpubl. Rep. 198 p. Northwest and Alaska Fisheries Center, Mar. Fish. Ser. Seattle, Wash.

Beamish, R. J., C. Wood, and C. Houle. 1978. A summary of sablefish tagging studies conducted during 1977. Fish. Mar. Serv. Data Rep. 77: 103 p.

Beamish, R. J., C. Houle, C. Wood, and R. Scarsbrook. 1979. A summary of sablefish tagging and exploratory trapping studies conducted during 1978 by the Pacific Biological Station. Can. Data Rep. Fish. Aquat. Sci. 162: 113 p.

Beamish, R. J., C. Houle, and R. Scarsbrook. 1980. A summary of sablefish tagging and biological studies conducted during 1979 by the Pacific Biological Station. Can. MS Rep. Fish. Aquat. Sci. 1588: 194 p.

Beamish, R. J. and D. E. Chilton. 1982. Preliminary evaluation of a method to determine the age of sablefish (Anoplopoma fimbria). Can. J. Fish. Aquat. Sci. 39: 277-287.

Beamish, R. J., G. A. McFarlane, R. J. Scarsbrook, A. Cass, D. Chilton, W. Shaw, K. Best, and I. Barber. 1983. A summary of sablefish tagging and biological studies conducted during 1979 by the Pacific Biological Station. Can. MS Rep. Fish. Aquat. Sci. (In press).

Beamish, R. J., G. A. McFarlane, and D. E. Chilton. 1983. Use of oxytetracycline and other methods to validate a method of age determination for sablefish. This symposium.

Bracken, B. E. 1982. Sablefish (Anoplopoma fimbria) migration in the Gulf of Alaska based on gulf-wide tag recoveries, 1973-1981. Alaska Dept. of Fish & Game Informational Leaflet No. 199: 24 p.

Kobayashi, S., R. Yûki, F. Tsuneniro, and T. Kosugiyama. 1964. Calcification in fish and shellfish - I. Tetracycline labelling patterns on scale, centrum and otolith in young goldfish. Bull. Jap. Soc. Sci. Fish. 30: 6-13.

McFarlane, G. A. and R. J. Beamish. 1983a. Preliminary observations on the juvenile biology of sablefish (Anoplopoma fimbria) in Canadian waters. This symposium.

1983b. Biology of adult sablefish (Anoplopoma fimbria) in waters off western Canada. This symposium.

Phillips, J. B. 1969. A review of sablefish tagging experiments in California. Pac. Mar. Fish. Comm. Bull. 7: 82-88.

Sasaki, T. 1979. Results of blackcod tagging experiments by Japan in the Bering Sea and Northeastern Pacific. Unpub. MS Far Seas Fish. Res. Lab. Fish Agency, Japan.

Weber, D. D., and G. J. Ridgway. 1962 The deposition of tetracycline drugs in bones and scales of fish and its possible use for marking. Prog. Fish-Cult. October: 150-155.

1967. Marking Pacific salmon with tetracycline antibiotics. J. Fish. Res. Board Can. 24: 849-865.

Wespestad, V. G., K. Thorson, and Z. Mizroch. 1978. Movement of sablefish (Anoplopoma fimbria) in the northeastern Pacific Ocean as determined by tagging experiments (1971-1977). NMFS, Northwest and AK. Fish. Center Proc. Rept. 54 p.

White, W. J. and R. J. Beamish. 1972. A simple fish tag suitable for long-term marking experiments. J. Fish. Res. Board Can. 29: 339-341.

Sablefish migration in the Gulf of Alaska based on tag recoveries

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Introduction

In 1978 the Department of Fish and Game received numerous reports of juvenile sablefish in the Ketchikan area of Southeastern Alaska. They were so abundant in some areas that they became a nuisance in the troll and gillnet fisheries for salmon. Since adult sablefish populations were extremely depressed in Clarence Strait at the time, there was no logical explanation for the unusual abundance of juveniles.

Special funding was requested from the Governor's Bottomfish Office and a limited grant was received to conduct studies during 1979.

Tagging Studies

The juvenile sablefish were schooled in shallow water and tagging studies offered an excellent opportunity to determine recruitment rate into deep water and to find out if the fish would contribute to the offshore fishery as adults.

A 26-foot combination vessel was chartered in June 1979 to serve as a working platform. Both pot and hook and line gear were used to capture the fish.

Fish were held in a live tank prior to tagging. A Dennison Mark II SS tag gun and either FD-67 or FD-68 BC tags were used. During this first cruise we tagged 1,859 fish; 713 from pots and 1,156 from hook and line.

Tagging was also conducted in shallow water in August of 1979 using hook and line gear. An additional 722 fish were tagged.

In the fall of 1979 young fish had entered deep water in Behm Canal adjacent to the summer tagging area and tagging studies were again conducted during late November and December using pot gear. Catches were good and an additional 3,761 fish were tagged in ten days. Fish were tagged in Behm Canal, again in June 1980 witn a total of 1,235 fish and in June 1981 with an additional 2,920 fish bringing the project total to 10,507.

Besides tagging, every 25th fish was sampled. Fisn were examined for paracites, disected to determine sex and maturity, and stomach contents were recorded. Otoliths were taken for age determination and stored by sex and length in 30% ethenol for future reading.

Results

As of March 1983 553 recoveries have been made. Returns are distributed throughout the North Pacific from Cape Flattery, Wasnington, to the Aleutian Island and into the Bering Sea. Areas of concentration appear in Dixon Entrance, off Queen Charlotte Islands, B.C.; and near Cape Cross, Southeastern Alaska; where the fisneries are centered. The average distance traveled prior to recovery is 171 km with a range of 0 to nearly 3700 km.

The direction of travel appears to be dependent on size of release with smaller sablefish showing a greater tendency to move north and the larger fish to move south, after leaving Dixon Entrance, with the trend changing at 60 cm. A chi-square test indicates the probability of independence is less than .005.

Sablefish are currently managed by discrete geographical areas so the extent of movement and geographical intermixing was examined. Over 24% of all fish were recovered over 100 NM from the release site with over 50% of the 65 to 74 cm size groups showing extensive movement. Over 24% of the fish were recovered at least one INPFC area away from the release site with the large fish recovered in the Canadian fisheries again showing the most movement.

ADF&G tagging results were compared to results from National Marine Fisheries Service (NMFS) and Japan's Far Seas Fisheries Research Laboratory tagging experiments in the Gulf of Alaska through 1981. Both of the other groups showed actually more movement than fish tagged by ADF&G prior to recovery. Japanese tagged fish traveled an average of 689 km and NMFS tagged fish traveled an average of 180 km per year prior to recapture.

The same trend for direction of travel by size group was displayed by the three groups with statistical analysis showing identical results. Probability of direction of travel being independent of size at tagging is less than .005 for all three experiments. (Figure 1)

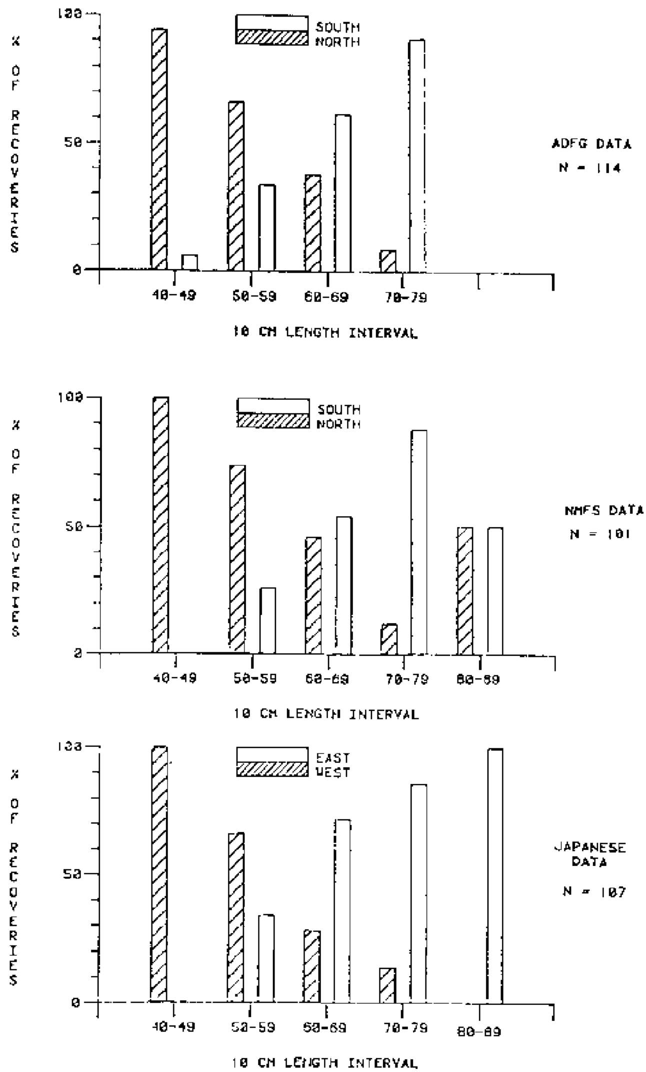

Figure 1. Direction of travel by size group of sablefish tagged in the Gulf of Alaska by ADF&G, NMFS and Japan, 1973-1982.

Botn otner tagging experiment results showed higher percentages of recaptures over 100 mm than our experiments, with the smallest length group showing the most movement in the NMFS experiments. Over 46% of the Japanese tags were recovered at least one INPFC area away from the area of tagging while only 20% of the NMFS tagged fish were recovered over one boundary away.

An attempt was made to determine a pattern of movement based upon the differential direction of travel by size group. The recoveries were divided into those less than and those greater than 60 cm. The ADF&G tag returns showed no real pattern with the majority of tags recovered within 100 km of the release site. Nearly 77% of the small fish and 61% of the large fish were recovered within 100 km.

This trend was not true for the Japanese experiments. The Japanese tags were released throughout the Gulf and fish over 60 cm released in the Eastern Gulf had a much greater probability of being recovered within 100 km than did those released in the Western Gulf (Bracken, 1982). This trend was reversed for fish released at less than 60 cm, but the results are not as conclusive. It does appear, however, that the predicted area of recapture is related to size of tagging and area of release. That could explain why a bimodal distribution of distance traveled evident in the Japanese data does not appear in the ADF&G experiments that were conducted in one location.

These comparisons are based on raw data and are not adjusted for underreporting or harvest level.

Distance traveled over time was examined for the ADF&G returns. Again, these were divided into two size groups. There appears to be no correlation between time at large and distance traveled for recoveries over 100 km from the release site which suggests random travel even though direction of movement by size indicated directed migration. We are doing further analysis by dividing returns by cruise to hopefully better understand tnis discrepency.

Distance traveled over time was used to determine an appropriate cutoff time for returns in the study area to compare results with migrating fish. Very few fish recaptured within 200 days showed movement and that cutoff was used to adjust the returns to attempt to determine the distribution of fish tagged in Behm Canal into the other management areas of the North Pacific. Results were also adjusted for underreporting. Canadian scientists estimate that 90% of all tags recaptured in their waters are returned. Return rates were calculated by management area in the U.S. fishery by determining the percent of total landings made by U.S. vessels who returned tags. In the U.S. fishery, rates ranged from 16% in the Yakutat area to over 80% in the Southeastern inside fishery. The estimated return rate for the U.S. fishery may be too high, since vessels returning any tags were assumed to have returned all tags. This was probably not the case, since some vessels did not return tags until late in the season and at least one vessel quit returning tags due to his displeasure with a management decision. Sasaki's calculation (Saskai, 1980) were used to estimate the return rate in the Japanese fishery.

Returns were then adjusted by distribution of harvest which indicated that only approximately 25% of the tagged fish had moved out of inside waters.

However, when the returns are adjusted for harvest and estimates of fish distribution by area, only slightly over 40% of the tagged population were expected to have remained in the area of tagging by the end of 1982 and the remainder were distributed according to Table 1.

Table 1. Distribution of recoveries from ADF&G sablefish tagging experiments in the Ketchikan area of Southeastern Alaska, 1978-1982.

INPFC Area Recovered	Raw Recovery No.	%	Adjusted for Return Rate[1/] No.	%	Adjusted for Return and Harvest[2/] %	Adjusted for return harvest, and estimated relative population[3/] %
Vancouver	6	1.8	7	1.2	1.1	1.3
Charlotte	90	27.0	100	18.6	6.5	18.9
S.E. Inside	168	50.5	197	36.8	68.5	37.4
S.E. Outside	22	6.6	36	6.7	4.8	5.9
Yakutat	22	6.6	110	20.5	8.3	17.4
Kodiak	13	3.9	45	8.4	4.9	11.1
Chirikof	2	0.6	7	1.3	0.9	2.0
Shumagin	5	1.5	17	3.2	2.1	1.6
Aleutian	2	0.6	7	1.3	2.2	2.4
Bering Sea	3	0.9	10	1.9	0.8	2.0

1/ Estimated percent of recaptured tags returned to the tagging agency.

2/ Average of the 1981 and 1982 harvest by INPFC area.

3/ Relative population was based on relative population numbers (RPN) calculated by Sasaki (1981) for the Gulf of Alaska and Aleutian Region and by using fisheries performance as an indicator of relative abundance in the Canadian and Bering Sea areas.

Biomass distribution by area was calculated by using relative population number (RPN) (Sasaki, 1981) for the Gulf of Alaska and assuming that harvest is directly related to biomass of the other areas where RPN values were not available.

Discussion

Evidence of the movement of tagged fish out of the area of tagging is further supported by the results of the last tagging cruise which ended March 17, 1983.

In November 1979, 3,972 fish were captured for an average of 38.6 fish per pot and 8 tags were recovered (.2%). Small fish were still recruiting to deep water in 1980. By June 1981 the average was 33 fish per pot and 16 tags were recovered out of 3,072 fish caught (.5%). This March, catch was down to 9.5 fish/pot and only 3 tags were recovered from 2,866 fish caught (.1%).

During the 1981 and 1982 season the vessel used in tagging captured an estimated 20,000 fish from Behm Canal in the commercial fishery and returned 291 tags. That is a return rate of only 1.4%. Decline of CPUE and tag return rate between June 1981 and March 1983 were 71% and 80% respectively. These results provide further evidence of extensive movement of fish out of the area of tagging.

There are still questions to be answered concerning sablefish recruitment and migration. The results of this study indicate that there is a net outward movement of young fish from coastal fjords to offshore areas even after the fish enter deep water. Movement of fish between management areas appears to be significant and should be considered when management decisions are made.

Tags will be returned from these experiments for several years. As more data is accumulated a better understanding of fish distribution and the resulting management implications should be gained. All scientists working with tagging experiments should consider adjustment by return rate, harvest, and distribution of biomass when analyzing return data.

Bibliography

Bracken, B.E. 1982. Sablefish (Anoplopoma fimbria) migration in the Gulf of Alaska based on Gulf-wide tag recoveries, 1973-1981. AK Dept. of Fish and Game Info. leaflet no. 199. 24 p. P.O. Box 667, Petersburg, AK 99833.

Sasaki, T. 1980. An interim report on U.S.-Japan blackcod tagging experiments conducted in the Aleutian Region and Gulf of Alaska in 1978 and 1979. (Document submitted to the International North Pacific Fisheries Commission) 13 p. Fisheries Agency of Japan, Tokyo, Japan 100.

________ 1981. Changes in relative population numbers and size composition of sablefish in the Aleutian Regiona and Gulf of Alaska from 1979 to 1981. (Document submitted to the International North Pacific Fisheries Commission) 16 p. Fisheries Agency of Japan, Tokyo, Japan 100.

Movement of tagged sablefish released at abundance index sites off Southeastern Alaska, Washington, Oregon, and California during 1978-81

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INTRODUCTION

The status of sablefish (Anoplopoma fimbria) stocks in the Gulf of Alaska was determined largely on the basis of fishery data obtained from foreign fleets which fished intensively throughout the Gulf for a number of years (Low et al. 1976). In the past 4 years foreign effort has been reduced in some areas and eliminated in others as a conservation measure and because domestic fisheries were taking the optimum yield. This action greatly reduced the availability of fishery statistics to be used as a means of tracking population fluctuations. In 1978, the National Marine Fisheries Service (NMFS) began a program to monitor trends in stock size by establishing abundance index sites off southeastern Alaska (Zenger and Hughes 1981). In subsequent years, the work was expanded and additional sites were selected in the Washington-California region to supplement fishing data obtained from the domestic fleet (Parks and Hughes 1981). Catch per unit effort (CPUE) and biological data were taken routinely, and any surplus sablefish in good condition were tagged and released. Abundance indexing continued in 1982, but complete recovery data only through 1981 are available.

Tagging was conducted as part of a continuing program to determine migrational behavior and to identify stocks which could be managed as units. The purpose of this report is to present preliminary results of the NMFS tagging program as an addition to a growing body of information on sablefish migration which will enhance the development of future management strategies. Specific objectives of this report are to analyze the direction and extent of sablefish migration and to examine the variables: fish length, area of release, and days at liberty. A more detailed analysis will be initiated in the near future.

Methods

Sampling sites were established off Alaska at Capes Cross, Addington, and Ommaney in 1978, Cape Muzon in 1979, and in Chatham Straits in 1981. In 1979, sampling was begun off Washington near Cape Johnson and Grays Harbor and off Oregon near Capes Lookout and Arago. Sites off California over Bodega Canyon near San Francisco and Patton Escarpment off San Diego were added in 1980. Figure 1 presents the locations of all abundance indexing and tag release sites. Traps were fished 10 to a string at 150, 225, 300, 375, and 450 fathoms at all locations except those off California where sampling occurred at 225, 300, 375, 450, and 550 and 700 fathoms (1 yr only). The gear was set five times at each depth each year, resulting in 250 trap lifts per site. Traps were fished for standard 24 hr periods through the use of corrodible timed-release devices which triggered a noose arrangement and closed trap tunnels at the end of the period. As catches were brought aboard, first priority was given to the collection of catch and biological data, so tagging was conducted only as excess specimens became available. Sablefish to be tagged were quickly removed from traps and placed in holding tanks with fresh circulating seawater.

Tagging occurred as soon as time permitted but rarely longer than 1/2 to 1 hour after placement in the holding tanks. Fish judged to be in fair to good condition were measured, tagged, and released. Anchor tags were applied with a Dennison gun just behind and under the insertion of the first dorsal fin on the right side. Tags were inscribed with the agency name, address, and tag number.

Recovery efforts were initiated with program publicity through international scientific bodies, fishery commissions, domestic fishery agencies, fishermen's associations, fish processors, and trade media. A reward of $2 was offered for each tag returned, and all who returned tags were sent a letter of appreciation containing general program information and specific release data.

Results

Although tagged sablefish were released at 11 discrete sites, the data have been summarized by state regions. This was done because regional differences were of primary interest and summarization increased the size of basic data sets while simplifying presentation of results. Loss of resolution through summarization is not considered important in the depiction of general migratory behavior, but site by site details will be included in future studies aimed at defining micromovements (i.e., transboundary exchanges), relationships of offshore and inshore populations, migrational responses to environmental factors, etc.

The total number of tagged sablefish released in all areas and years was 20,883 with the majority released in waters off Alaska and California. Those regions were of particular interest because there was a need to obtain information regarding the discreteness of stocks in the Gulf of Alaska, the relation of offshore sablefish to those inhabiting the inshore waters of southeastern Alaska, and the relation of sablefish of southern California to those off Mexico and northern California. Table 1 presents the numbers of tagged sablefish released

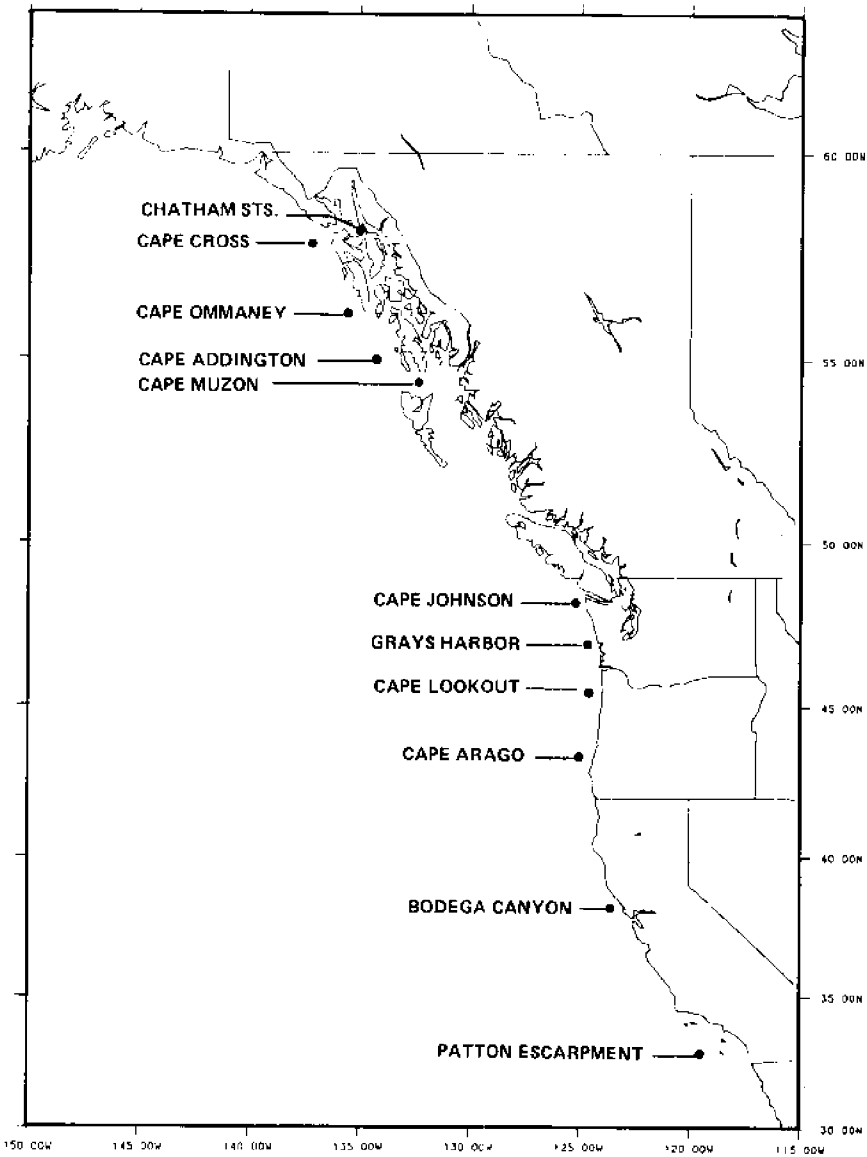

Figure 1.--Locations where tagged sablefish were released during 1978-81.

Table 1.--Numbers of tagged sablefish released during 1978-81 and mean lengths by depth of capture and state area.

	Depth range (fathoms)							
	100-199	200-299	300-399	400-499	500-599	600-699	700-799	TOTAL
				ALASKA				
Numbers	241	2117	3028	856	0	0	0	6242
Mean length (cm)	59.5	66.5	60.3	65.8	--	--	--	
				WASHINGTON				
Numbers	416	890	1013	1013	0	0	0	3852
Mean length (cm)	56.4	54.9	55.3	55.6	--	--	--	
				OREGON				
Numbers	983	735	874	280	17	6	0	2905
Mean length (cm)	55.0	58.4	54.7	55.2	60.9	59.0	--	
				CALIFORNIA				
Numbers	0	5241	1846	355	252	45	90	7869
Mean length (cm)	--	51.4	52.2	52.5	55.6	67.7	59.9	

by depth of capture and area. It should be noted that generally, fish less than 40 cm long were not captured and are not included in the analysis. In all areas except Washington, the mean length tended to increase with depth of capture.

Through 1981, 552 (2.6%) tags were returned but only 350 were returned with recapture location. Three of those returned were released without length measurements so the analysis is based on a total of 347 tagged fish. Recovery numbers (those with complete data) by release area and year are presented in Table 2. The overall recovery rate of 2.6% compares favorably with the 2.9% rate reported by Wespestad et al. (1978), but is considerably lower than the 8.2% returned by Canadian fishermen as reported by Beamish et al. (unpublished manuscript). The Canadian tagging program apparently is the benefactor of a relatively small, well-defined fishery which is unusually supportive of the study. Canadian scientists may also have achieved a lower rate of tagging mortality. Recovery rate varies among release areas with the Alaska releases yielding the highest rate of return (Table 2). Return rates often reflect the distribution of recovery (fishing) effort and differences in reporting patterns. The relatively high percentage of returns from Alaska releases is undoubtedly the result of the presence of an extensive and intensive fishery, the foreign component of which was monitored by a U.S. observer program. The recovery of sablefish released off Alaska was also enhanced by the high return rate by Canadian fishermen fishing in Canadian waters south of the release sites. Relatively small domestic fisheries operating in the Washington-California region produced the lowest rates of tag return, especially off California. The effects of variable recovery effort are discussed briefly in the Summary.

Table 2.--The number of tagged sablefish released by year and area and the number of returns with complete data, by year (recovery rates in parentheses).

Year	Releases	Recoveries 1978	1979	1980	1981	TOTALS	
Alaska							
1978	707	10	22	5	4	41	
1979	1829	--	40	19	46	105	
1980	1397	--	--	11	21	32	
1981	2316	--	--	--	11	11	
	6249					189	(3.0%)
Washington							
1979	1279	--	1	20	8	29	
1980	1458	--	--	3	24	27	
1981	1116	--	--	--	0	0	
	3853					56	(1.5%)
Oregon							
1979	433	--	6	1	3	10	
1980	1642	--	--	10	35	45	
1981	831	--	--	--	0	0	
	2906					55	(1.9%)
California							
1980	7075	--	--	11	36	47	
1981	800	--	--	--	0	0	
	7875					47	(0.6%)
TOTALS	20,883					347	

Distances traveled ranged from 0 to 1725 nautical miles (nmi) measured as straight line distances between release and recovery locations and are, therefore, considered minimal estimates of migration. The question which arises immediately is whether there is a relation between migration distances and the period between release and recapture. The miles traveled were regressed on the number of days free by state regions and for areas combined. Resulting correlation coefficients are 0.10 for fish released off Alaska, 0.01 for those released off Washington, 0.04 for those off Oregon, and 0.44 for those off California. The correlation values were positive in all regions, but only in the California region was there even a suggestion of a relationship, albeit a weak one. Figure 2 presents the distribution of migrational distances by days at liberty and by state region. Obviously, very short intervals of freedom will prevent long migrations, but relatively long intervals will not necessarily result in migration over long distances. This comparison suggests that there is no persistent movement away from the release site by a majority of the tagged fish. For the purposes of this report, the variable, days at liberty, was considered to have no effect on distances traveled.

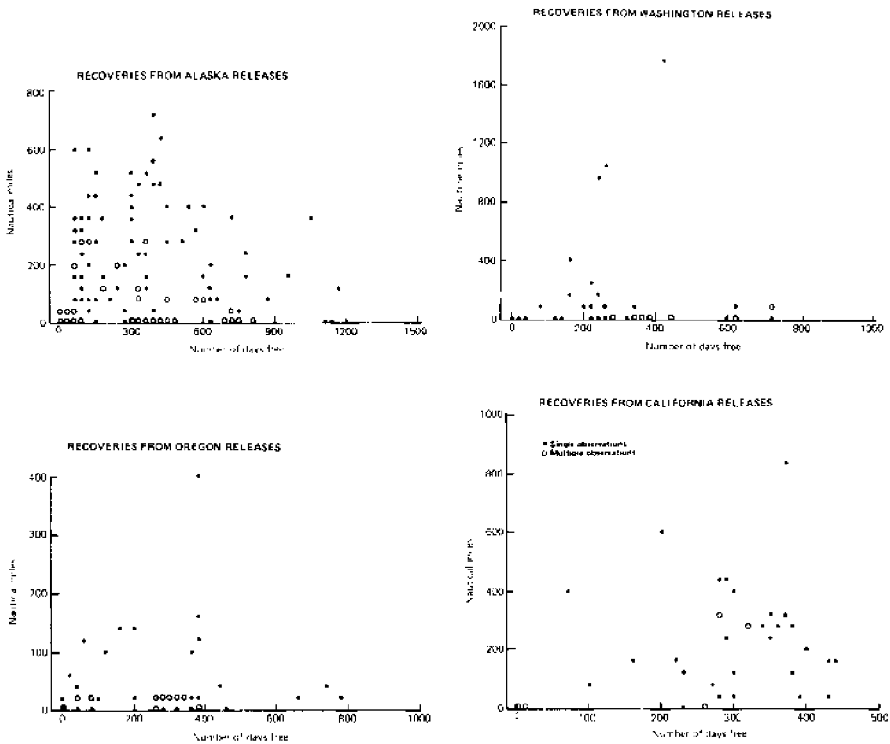

Figure 2.--Distances traveled by tagged sablefish plotted against the number of days they were free by state area of release.

The majority, 59% overall, of the sablefish returns were recovered within 50 nmi of the release site (Table 3). Eighty percent were recovered within 200 nmi of the point of release, but 12% were recovered at distances greater than 300 nmi from the release area. It appears that the most active migrants were released off southeast Alaska and off California where 22% and 35%, respectively, migrated 250 nmi or more. Sablefish tagged and released in the Washington and Oregon regions demonstrated very little movement as 88% and 85%, respectively, were recovered within 100 nmi of the release site and onlv 6% and 2% migrated 250 nmi or more. Beamish et al. (unpublished manuscript) reported that releases in British Columbian waters also demonstrated little movement as about 89% were recaptured within 200 km of the release area.

Table 3.--Minimum distances traveled (50 nautical mile increments) by tagged sablefish by states area.

Area	Nautical miles						
	0-50	51-100	101-150	151-200	201-250	251-300	300+
	No. (%)	No. (%)	No. (%)	No. (%)	No. (%)	No. (%)	No. (%)
Alaska	99 (53)	21 (11)	11 (6)	7 (4)	8 (4)	15 (8)	28 (14)
Washington	42 (75)	7 (13)	2 (4)	0 (0)	1 (2)	0 (0)	4 (6)
Oregon	46 (83)	1 (2)	6 (11)	1 (2)	0 (0)	0 (0)	1 (2)
California	18 (38)	4 (9)	4 (9)	4 (9)	0 (0)	7 (15)	10 (20)

Figures 3 and 4 present the geographical distributions of tag returns by state and region of release.

Travel distances and rates by size at tagging have ben examined by other investigators. Wespestad et al. (1978) found, while studying tagging results from Alaska to California, that analysis of variance of distance traveled by three size-at-tagging groups and time free showed no significant differences. On the other hand, Bracken (1982), examining sablefish tagged in waters off Alaska, reported a tendency for a larger proportion of fish longer than 60 cm in length to travel distances in excess of 500 nmi than those of smaller sizes.

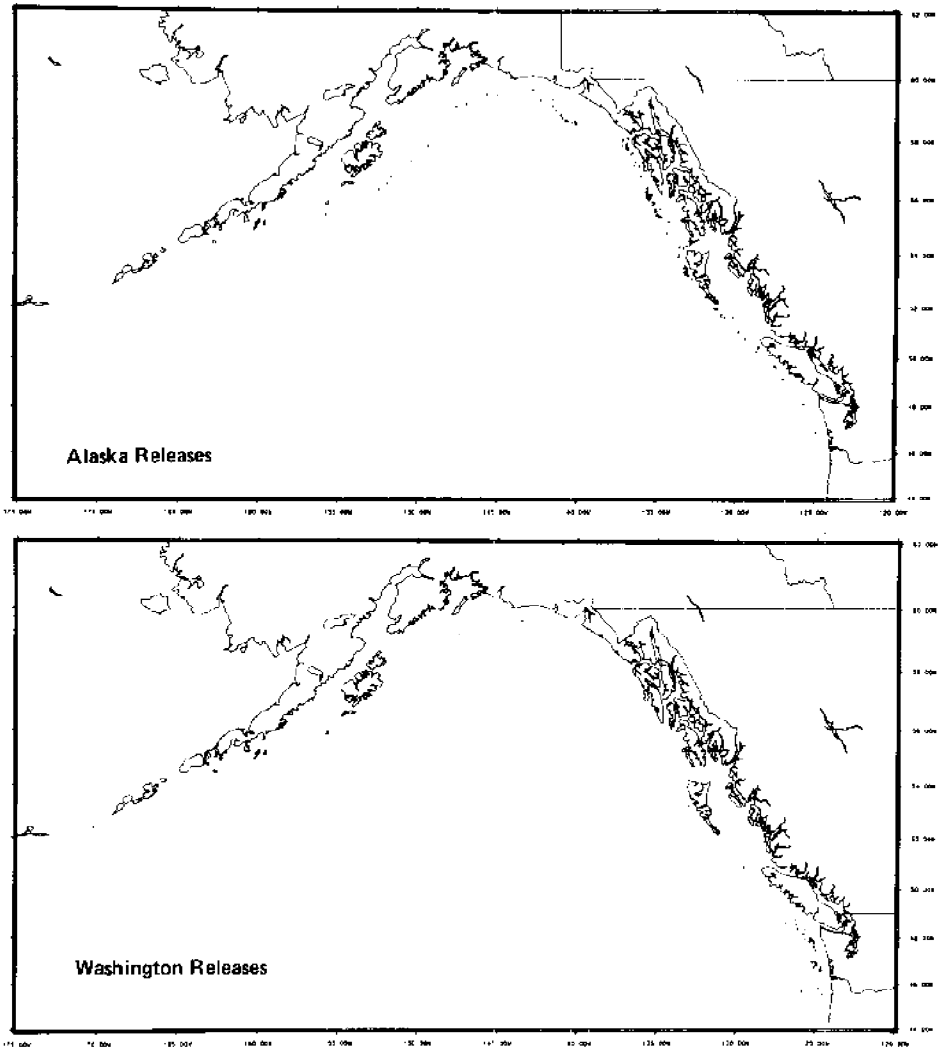

Figure 3.--Distribution of tag recoveries (1978-81) by state area of release.

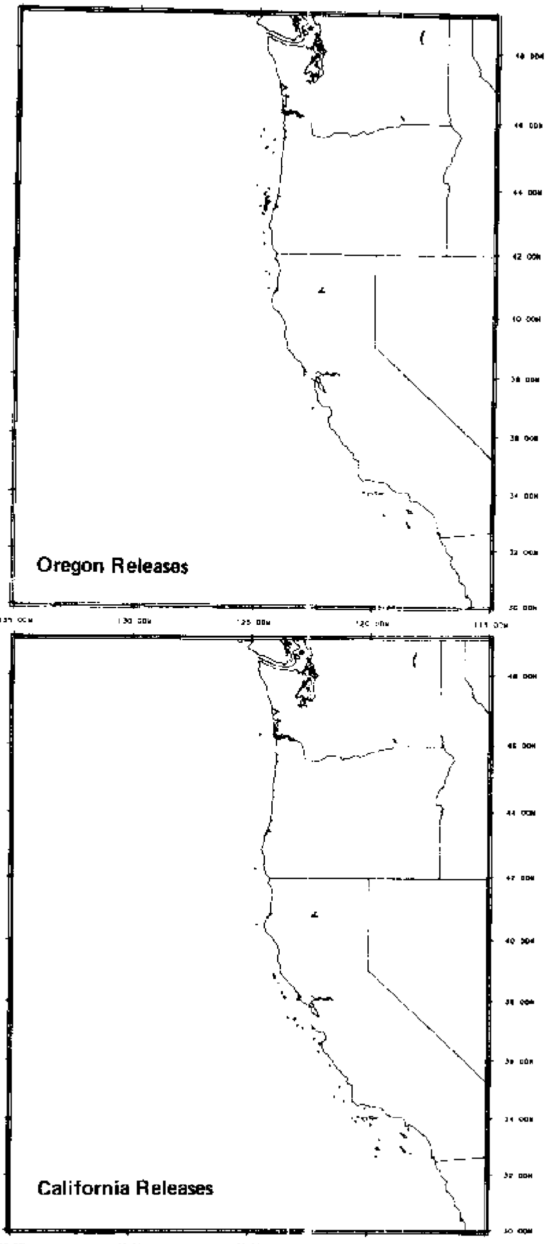

Figure 4.--Distribution of tag recoveries (1978-81) by state area of release.

For the present study, lengths-at-tagging were grouped by 10 cm intervals for comparison of distance traveled by size. Mean distances traveled by length group for each state area of release are presented in Table 4 and Figure 5. Off Alaska, the smallest length group (45-54 cm) on the average showed the greatest tendency to migrate long distances. This tendency weakened with increasing fish length. Fish tagged off Washington behaved similarly in that the greatest average miles traveled was by the smallest length group. Fish released off Oregon showed little movement at all and there is no obvious relationship between size and distance traveled. Results from Oregon releases are somewhat inconsistent with those in more northern areas in that the largest group released tended to migrate the farthest. Data from the California region also demonstrated no obvious body length-distance traveled tendency. When all data were combined, there was a slight tendency on the average for the distance traveled to decrease as the fish length at release increase, but there is no strong evidence that a relationship between migration distance and size exists. It is obvious from the wide range of migration distances associated with most size groups in all regions that a great deal of variability occurs within sizes.

Table 4.--Mean minimal distances traveled by 10 cm length groups and area of release.

Area	Release length (cm)	Tags returned	Avg. miles traveled	Range of miles traveled	Area	Release length (cm)	Tags returned	Avg. miles traveled	Range of miles traveled
Alaska	45-54	13	238	2-449	Washington	45-54	27	166	1-1725
	55-64	66	100	0-601		55-64	22	35	1-246
	65-74	87	137	0-645		65-74	6	30	2-131
	75-84	20	106	6-570		75-84	1	16	
	85-94	3	9	5-12			56		
TOTALS		189							
Area average miles traveled			125					99	
Oregon	45-54	31	40	2-402	California	45-54	26	143	0-421
	55-64	14	23	2-108		55-64	17	209	1-837
	65-74	8	10	1-15		65-74	4	145	1-429
	75-84	2	136	128-143			47		
TOTALS		55							
Area average miles traveled			38					167	

Area	Release length (cm)	Tags returned	Avg. miles traveled	Range of miles traveled
Areas combined	45-54	97	130	0-1725
	55-64	119	94	0-837
	65-74	105	122	0-635
	75-84	23	104	6-570
	85-94	3	9	5-12
TOTAL		347		
Areas combined average miles traveled			132	

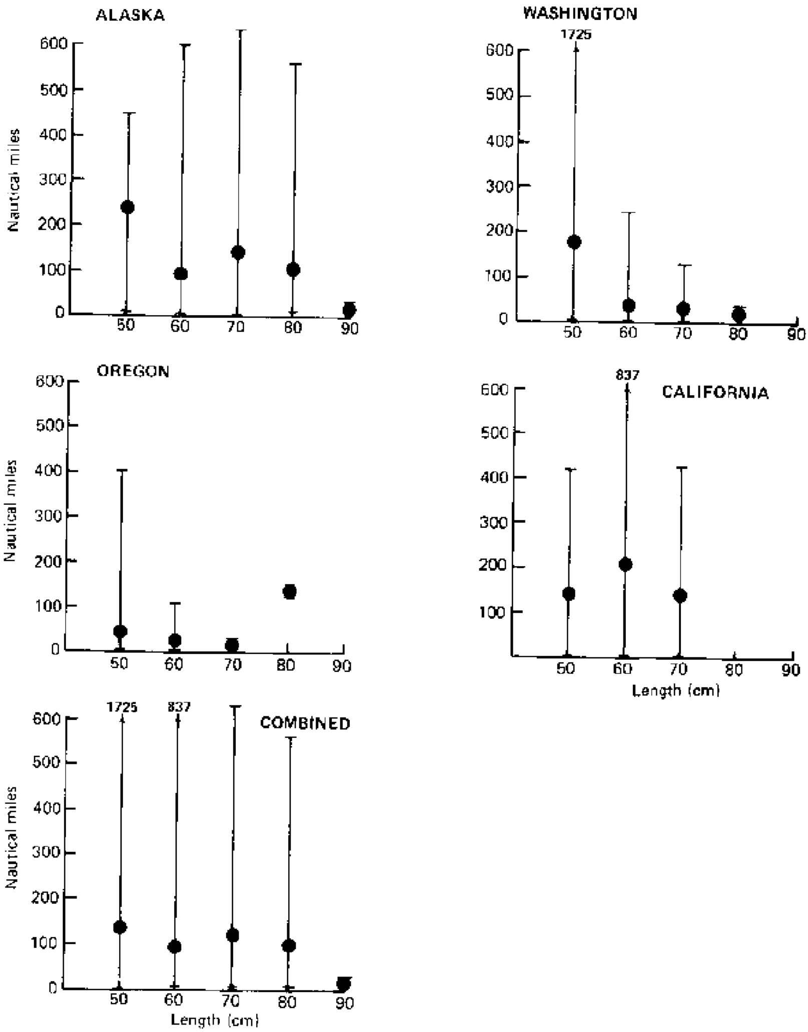

Figure 5.--The averages and ranges of distances travled by 10 cm length-at-tagging intervals and state area of release.

Direction of movement by size and area has also been a matter of interest to other investigators. Wespestad et al. (1978) found that sablefish off southeastern Alaska migrated mainly in a southerly direction, while fish tagged in areas south of Alaska tended to move northward. Bracken (1982) argues that his analysis supports a general westward migration in the Gulf of Alaska by small (<60 cm) sablefish and an eastward migration by large (>60 cm) sablefish.

Direction of migration was analyzed in this study by combining the recoveries from all years and plotting directional movement by body length at release and by area (Figure 6). Migrations of 25 nmi or less were considered insignificant (i.e., "no movement"). Results for the Alaska region (International North Pacific Fisheries Commission (INPFC) Southeastern Area) suggest that when the smaller (<65 cm) sablefish migrate, greater proportions migrate in a northerly direction while those larger (>64 cm) fish which migrate tend to move to the south. The proportion which did not migrate increased with size. Although tagged sablefish released in the Washington region migrated to a lesser extent, the fish in the 50 and 60 cm size groups demonstrated slightly more movement to the north than to the south. Again, there was an increasing tendency for "no movement" as size increased. In the Oregon region, there was little movement by any size group, and when migration occurred, there was no clear directional preference. Sablefish released in the California region demonstrated more movement, with a greater proportion of fish of all size groups migrating northward. This may be an artifact, however, because most releases were made near the U.S.-Mexico border and little or no recovery effort occurred south of the border or, recently, in the southern California region. Combined data from all sites and years (Figure 5) show that the highest proportion of migrating sablefish less than 65 cm migrated in a northerly direction, while those greater than 64 cm in length tended to migrate southward.

Summary and Discussion

During 1978-81, 20,883 sablefish were tagged and released by the NMFS at abundance indexing sites off Alaska, Washington, Oregon, and California. Through 1981, 552 tags or 2.6% of all those released were returned. Minimum distances traveled ranged from 0 to 1,725 nmi. Correlation analysis indicated no significant relation between the distance traveled and the length of time tagged fish were free. Therefore, little or no variation in the distance traveled can be explained by differences in the time at liberty. These results are consistent with those of Wespestad et al. (1978) who observed, "There was no particular trend of increase in miles with increasing time at liberty ..."

Overall, 59% of the tagged sablefish returned were recovered within 50 nmi of the release site, but 12% were recovered over 300 nmi from the point of release. Sablefish released in waters off Alaska and California seemed to be the most active migrants and migrated the greatest average distances, while relatively weak migrations occurred among sablefish released in the Washington-Oregon region. This pattern seems to be corroborated by results of previous studies. Wespestad et al. (1983) also reported that most movement occurred in areas of the Gulf of Alaska and California and almost none in the INPFC Columbia area (much of the area off Washington and Oregon). They did report a lack of movement

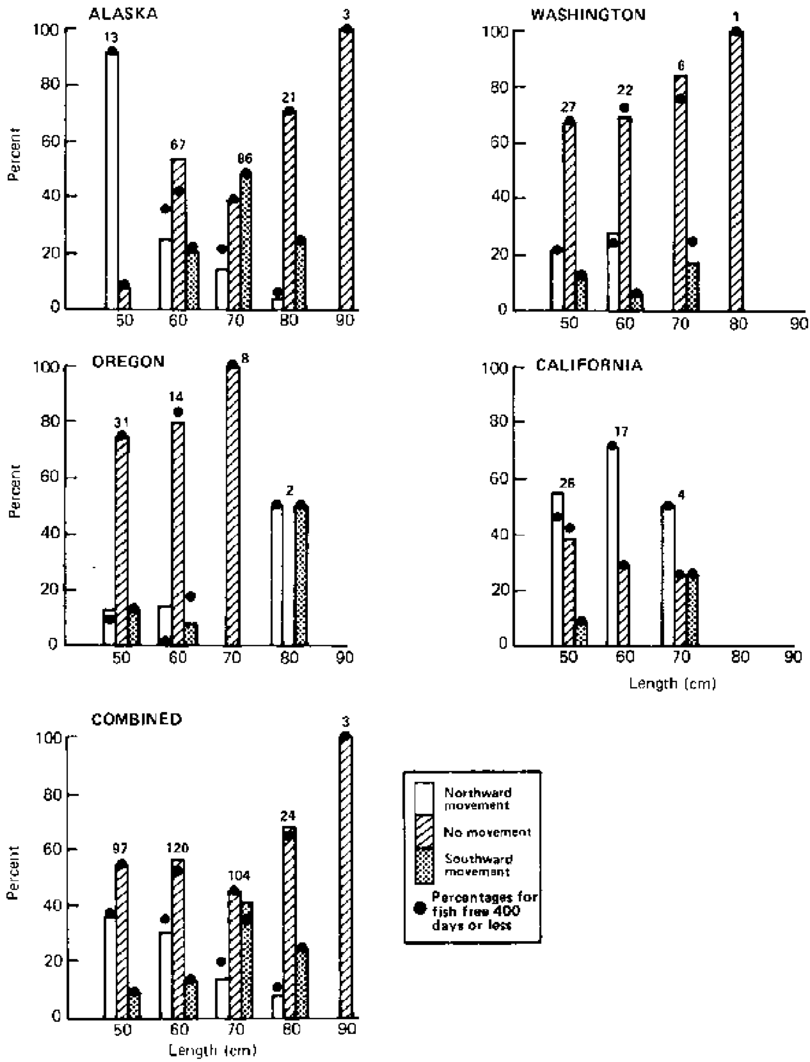

Figure 6.--Direction of travel by 10 cm length-at-tagging intervals and state area of release.

from the southeastern Alaska area, but this was probably due in part to the intensive foreign fishery in that region during the recovery period. Bracken (1982) and Sasaki (1980) found considerable movement of tagged sablefish throughout the Gulf of Alaska.

There was a slight tendency for the smaller sablefish released in Alaska and Washington regions to migrate greater distances than fish in the larger length categories, but in the other regions there was no suggestion of such a relationship. Bracken (1982) also noted that large sablefish (>60 cm) released in waters off southeastern Alaska had a considerably higher probability of being captured within the area of release than did smaller fish released in the same area. On the other hand, Wespestad et al. (1978) reported no statistically significant differences among size-at-tagging groups relative to distances traveled. Clearly, tagging data have provided varying results and have revealed only weak trends which leave uncertainty about size-related migration distances.

There does appear to be a tendency for tagged sablefish in the smaller size groups (40-65 cm) released off Alaska and Washington to migrate northward in greater proportions than do fish in larger size groups (>65 cm). This pattern was weak in the region off Washington and nonexistent off Oregon. The results from California releases should be considered with caution, because the greatest proportion of sablefish tagged and released was at the southern California abundance index site and almost all the recovery effort occurred north of that area.

Another potential source of bias in the above comparison is that many fish were free for long intervals and their size during the actual migration period may have been quite different from the size at release. In order to minimize the confounding effects of growth on the direction of migration by size analysis, a similar comparison was made using only data from tagged fish which were free 400 days or less. Very minor changes in the proportions migrating north, south, or not at all resulted in all area/size group categories (see Figure 6) which would not affect conclusions drawn using all the data. This might suggest that most movement occurred relatively soon after release before tagged fish had sufficient time to grow into size categories larger than that at release.

The results for the southeast Alaska region compare favorably with those of Bracken (1982) who observed a larger proportion of small tagged fish migrating westward (northward in this report) than large fish (>60 cm). Beamish et al. (unpublished manuscript) also reported northward movement. While only about 7% of the juvenile sablefish recovered were recovered in U.S. waters, about 97% of those were recovered in waters off Alaska.

I would caution, however, that all migration direction and distance by size data should be reevaluated in light of what is known of the geographical distribution of capture gear and the effects of associated size selectivity. It is well known, for instance, that trawls and shallow water fisheries will usually be selective for the smaller sizes of a population, while deep water longline and trap fisheries will select for larger population components. Directional movements by size data could have been seriously biased by such effects of gear selection.

Predominant movements by direction and fish size for releases in several areas are presented herein for comparison with the results of previous studies but with the full acknowledgment that these observations may be confounded by the aforementioned factors.

A basic underlying difficulty in interpreting the results of tagging studies is determining how well recoveries portray real migrational behavior and to what extent results are artifacts of distribution and intensity of recovery (fishing) effort, variable vulnerability to recovery effort, size selectivity of different regional fishing gear types, and differences in reporting rates among industry components. These variables are very difficult to adequately evaluate, as indicated by the rare occasions on which investigators have attempted to quantify all of them. The present study is no exception, but the relative distribution of recovery effort has been briefly considered. Exploitation rates by relatively small geographical units would be most useful for evaluating and quantifying sablefish movement. In the absence of estimates of exploitation rates or even adequate effort data, the relative magnitude of sablefish catches for 1978-80 was compiled and presented in Figure 7 by INPFC areas, assuming catches are a reflection of the effort expended. California catches are not included because they were incomplete. Catches occurred in all areas in all years so there always existed opportunities for recapture of tagged fish. The magnitude of these opportunities probably varied among areas and years.

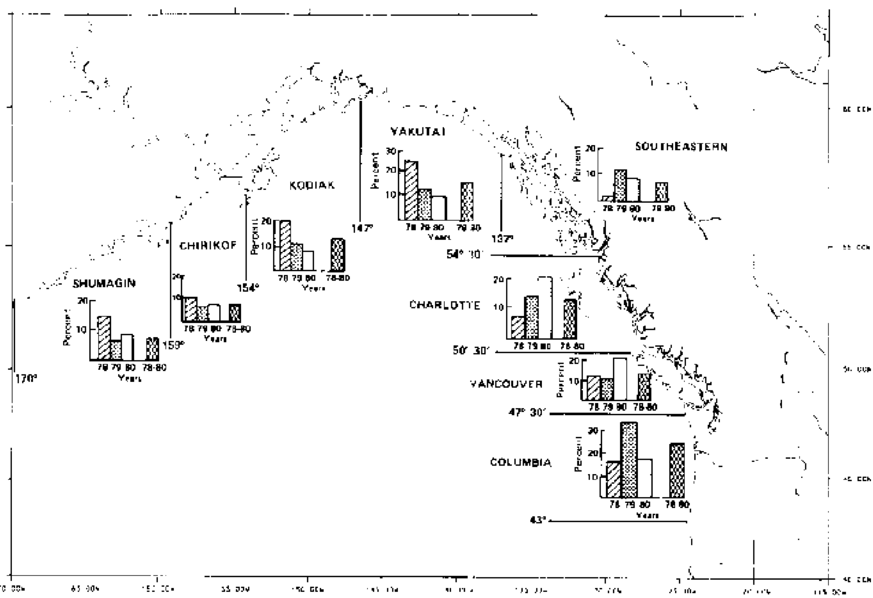

Figure 7.--Distribution of all-nation sablefish catches by INPFC areas during 1978-80.

For instance, the catch in the INPFC Southeastern Area in 1978 was very small because the foreign fishery had been excluded and the domestic fishery in the region was in its infancy. This could imply that the recovery rate in the region in 1978 was considerably lower than in 1979 when there was an 11-fold increase in the catch. It was also probably lower than recovery rates in the Kodiak and Yakutat areas in 1978 where catches were at least 20 times greater than the catch in the INPFC Southeastern Area. In 1979 the catch off Washington and Oregon in the INPFC Columbia Area was at least three times greater than it was in any other region due to a very favorable foreign market supplied by the U.S. domestic fishery. Similarly in 1980 about 60% of the total sablefish catch was taken in three INPFC areas off Canada, Washington, and Oregon with the remainder of the catch distributed almost uniformly among five INPFC areas off Alaska. While the effects of such disproportionate distribution of catches on tag recoveries cannot be assessed with any certainty, one has to be concerned about the potential for variable recovery rates and how that would affect analyses of tag returns. Tag returns can be weighted by area catches under the assumption that area population sizes are similar and differences in catches reflect differences in fishing effort; an assumption which is usually difficult to validate.

Tagging studies have provided useful information on the extent of sablefish movement in terms of minimal migration distances and directions. The presence of unmeasured variables affecting the number of returns by time and area requires careful evaluation of specifics, such as directional migration by size, and the relative importance of different areas to migrating population components. While we have begun to detect some general patterns, until more information is available, perhaps from specially designed tagging studies and additional life history investigations, we can only speculate about the exact nature of sablefish migrations, their periodicity, associated variability, and how they relate to the species' life cycle.

References

Beamish, R. J., G. A. McFarlane, R. Scarsbrook, A. Cass, W. Shaw, D. Chilton, J. Barber, and K. Best. A summary of sablefish tagging and biological studies conducted during 1980 and 1981 by the Pacific Biological Station, Fisheries and Oceans, Nanaimo, B.C. Unpublished manuscript, Pacific Biological Station, Canadian Department of Fisheries and Oceans, Nanaimo, B.C., V9R 5K6, Canada.

Bracken, B. E. 1982. Sablefish (Anoplopoma fimbria) migration in the Gulf of Alaska based on Gulf-wide tag recoveries, 1973-81. Alaska Dep. of Fish Game, Info. Leafl. No. 199. 24 p.

Parks, N. B. and S. Hughes. 1981. Changes in relative abundance and size composition of sablefish in coastal waters of Washington and Oregon 1979-80. U.S. Dep. Commer., NOAA Tech. Memo. NMFS F/NWC-8, 25 p.

Sasaki, T. 1980. An interim report on U.S.-Japan blackcod tagging experiments conducted in the Aleutian region and Gulf of Alaska in 1978 and 1979. 6 p. Far Seas Fisheries Research Laboratory, Japan Fisheries Agency, 1000 Orido, Shimizu 424, Japan.

Wespestad, V. G., K. Thorson, and S. A. Mizroch. 1978. Movement of sablefish (Anoplopoma fimbria) in the northeastern Pacific Ocean as determined by tagging experiments (1971-1977). Processed Rep., 54 p. plus append. Northwest and Alaska Fisheries Center, National Marine Fisheries Service, NOAA, 2725 Montlake Boulevard, E., Seattle, WA 98112.

Wespestad, V. G., K. Thorson, and S. A. Mizroch. 1983. Movement of sablefish, Anoplopoma fimbria, in the northeastern Pacific Ocean as determined by tagging experiments (1971-80). Fish. Bull. U.S. 81:415-420.

Zenger, H., and S. E. Hughes. 1981. Changes in relative abundance and size composition of sablefish in the coastal waters of southeast Alaska, 1978-80. U.S. Dep. Commer., NOAA Tech. Memo. NMFS F/NWC-7, 27 p.

Migration of sablefish in the Asian continental shelf area of the Bering Sea

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Abstract

Until recently it was believed that sablefish migrate only over small distances and that from within an area some local populations mix but little interaction occurs between separate populations.

Results of tagging studies made in the 1970s revealed the availability of long-distant (up to some thousand miles) migrations (Sasaki, Low and Thornson, 1975). Spawning of sablefish occurs mainly off the Pacific coast of North America and in the Gulf of Alaska (Kodolov, 1976). Seasonal migrations in the reproductive eastern part of the area have short range. Over the Asian slope of the Bering Sea the seasonal pattern is more obvious and the range of such migrations increases sharply.

Thus in the winters of 1962-64, a period of high abundance, sablefish composed significant masses in the southeastern Bering Sea where fish and invertebrates sablefish feed on were concentrated. The masses of sablefish dispersed in the spring and migrated to the northwest along the continental slope. From July to September sablefish concentrated in the area of capes Olyutorshy and Navarin; they were less abundant off the eastern Kamchatka Peninsula and only singular specimens were observed off the Kuril Islands and in the Okhotsk Sea.

Sablefish concentrations reaching the Asian continental slope do not particularly differ from those of the other areas of the sea by size-age structure. However, the domination of males and the nearly complete absence of females with maturating gonads has been observed.

While in 1962-64 total biomass of the summer concentrations of sablefish over the western Bering Sea continental slope was at a high level, in

1974-81 the fish were practically absent in catches due to overfishing. Measures for conservation of sablefish stocks were adopted in due time and enhanced their restoration. The first, but still small, assemblages of sablefish occurred here in 1982.

It has long been supposed that sablefish do not migrate for long distances, therefore there are some local populations on the Asian continental slope.

According to tagging data (Sasaki, et al. 1975) sablefish form one superpopulation and part of the stock is likely to migrate up to 1,000 miles from their original habitat. The reproductive part of the sablefish stock is located in the Gulf of Alaska and off the Pacific coast of North America where the sablefish begin their migration to the Bering Sea (Kodolov 1976). These migrations, most probably, have no characteristics of the mass; as a rule, fish over three years of age with their gonads at the resting stage participate in these migrations. According to Kodolov (1970, 1976) sablefish seem to spawn in the Bering Sea as some spawning females were caught by Fyodorov in November 1962. But this spawning area cannot provide for the entire reproduction of the Bering Sea sablefish population.

In winter sablefish concentrate over the continental slope in the Southeastern Bering Sea in the mixing zone of the transverse flow carrying the ocean waters. In this period a number of fish and invertebrates concentrate in the upper continental slope, specifically walleye pollock, the favorite prey of sablefish. During the peak of abundance, the density of the pollock assemblages reached 270-300 tons per sq. mile. In the region to the north from 58°N the pollock as a rule, formed no dense assemblages in this period though the catches were 0.5-1.0 ton per hour haul in some areas. In spring following the migration of walleye pollock and other shelf fishes from their hibernation area to the shelf area, the sablefish concentrations were less stable and dispersed. According to the true surveys in 1962-1964 in spring the sablefish begin to migrate to the northwest and in June-July the fish reach the Asian continental slope forming the maximum concentrations there in July-September (Figs. 1-3). The narrow shelf belt, having a broad range of prey, makes its inhabitants easily available for predation by sablefish.

Sablefish concentrations were rather dense and occupied the large area in the Olyutorka-Navarin region in summer 1962-1964. The total biomass of this species there was about 60,000 tons. The sablefish assemblages were less in the area off the East Kamchatka peninsula and off the Kuril Islands; and in the Okhotsk Sea only a few fish of this species (Novikov 1968) were found. While seasonal migrations of sablefish along the Eastern Bering Sea continental slope is evidently for feeding purposes (Kodolov 1976), the purpose of the further western migration has not been determined. These migrations cover great distances, one individual was recorded to come back from Paramushir Island to the Navarin cape.

Age-size structure of the sablefish concentrations in the North Bering Sea does not greatly differ from that in the other habitat areas (Table 1). The length of the individuals in the catches varying from 44 to 84 cm exceeded 75% of these catches. A decrease in percentage of fish up

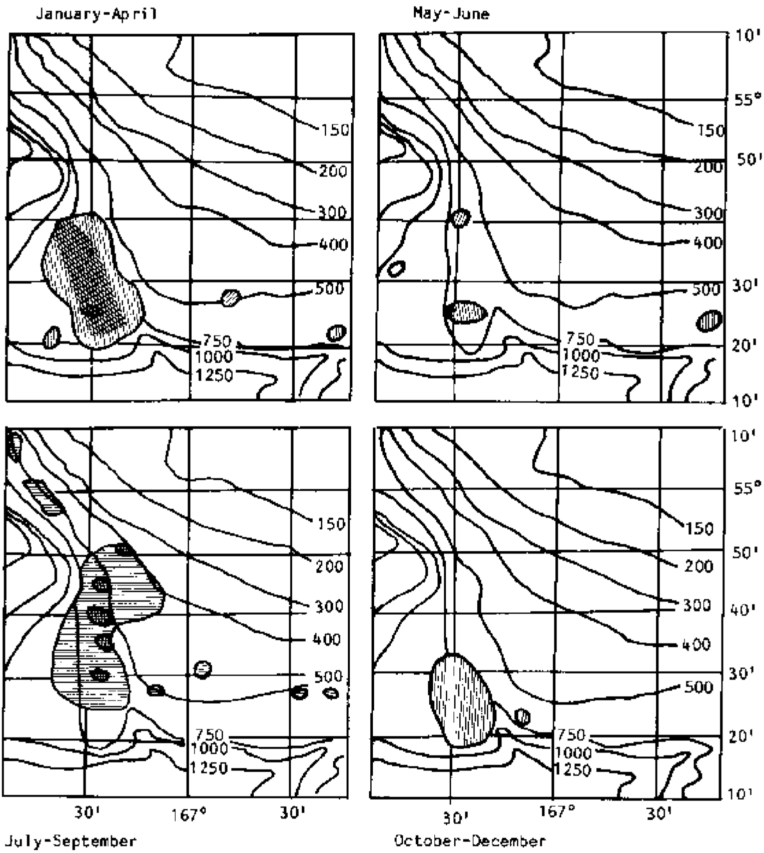

Fig. 1. Seasonal distribution of the sablefish assemblages in the southeastern area of the Bering Sea, 1962-1964.

:o 52 cm in this area in comparison with the south and east areas Aleutian Islands) has been observed.

t is worth noting that females with maturing gonads were also absent in .he continental slope. Male sablefish prevail in numbers over females n the Olyutorka-Navarin region in all seasons except spring. In spring 'emales seem to migrate to the continental slope after spawning (Table :).

ıge composition of sablefish is rather stable in the Bering Sea (Fig. ·). Three to 11 year old sablefish are found in catches over the Asian .ontinental slope, four to eight year fish prevail but younger fish, up .o three years old were not observed in this part of the sea.

ishing statistics by areas in the Bering Sea are not complete. According to Sasaki, et al. (1975) from 1963 to 1973 the Japanese catches of ablefish over the Asian continental slope were about 25% of the total

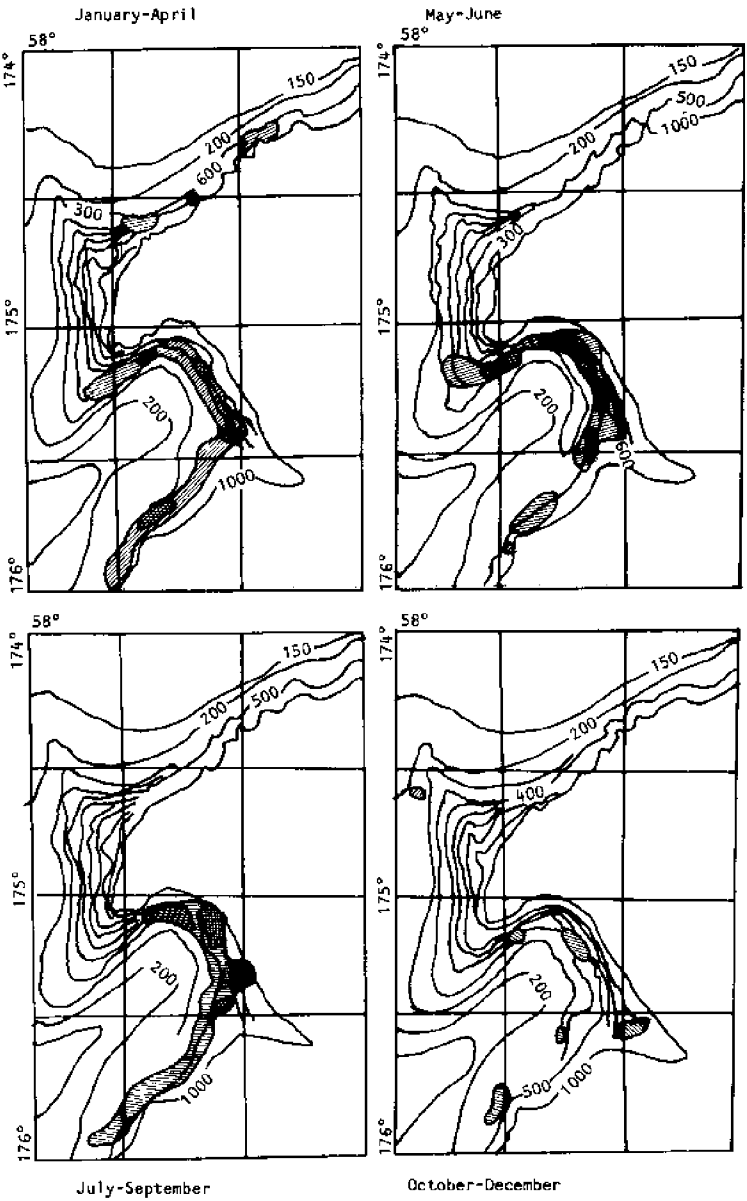

Fig. 7. Seasonal distribution of the sablefish assemblages in the central part of the Bering Sea, 1962-1964.

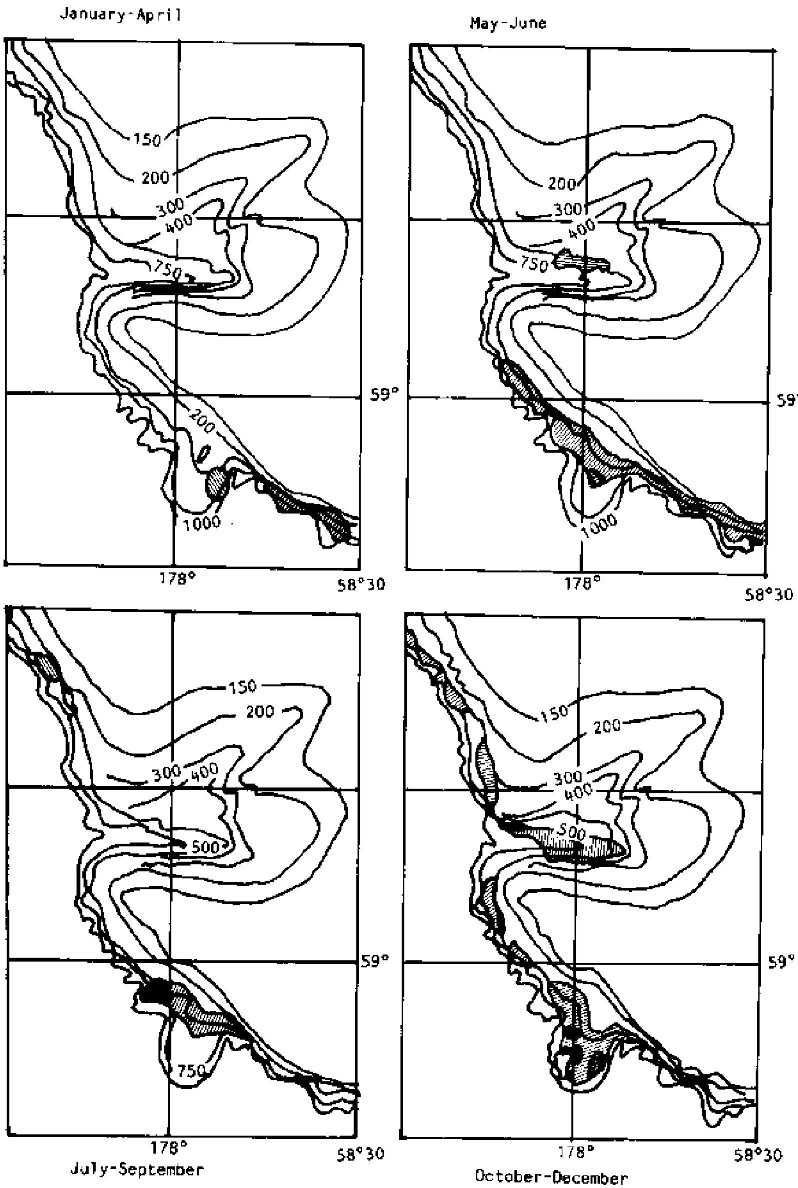

Fig. 3. Seasonal distribution of the sablefish assemblages in the north area of the Bering Sea, 1962-1964.

Table 1. Size composition of sablefish in the Bering Sea by areas, 1962-1964.

Area	20	24	28	32	36	40	44	48	52	56	60	64	68	72	76	80	84	88	92	96	n	M
North					0.2	0.1	2.5	16.7	23.3	19.9	13.8	9.7	6.8	3.1	2.6	1.2					1860	58.6
West							1.5	14.1	28.8	28.9	15.7	6.9	3.1	0.5	0.4	0.1					798	57.3
Central					0.1	0.1	1.8	15.0	28.2	20.5	13.6	8.8	5.9	3.4	1.6	0.7	0.1	0.1	0.1		15480	58.5
South-Eastern					0.1	0.6	4.2	15.4	20.6	19.2	15.8	9.3	6.0	4.0	3.2	0.3	0.1				4934	58.9
Aleutian Isl.					0.2	2.6	9.6	16.4	15.9	19.1	11.5	9.6	7.7	4.1	1.9	0.2	0.2				584	57.8
Gulf of Alaska	0.2	0.7	2.6	2.1	2.7	13.3	14.8	8.7	8.7	8.8	8.1	4.2	2.4	1.6	0.6	0.2	0.3				1285	52.4
Vancouver-Oregon area	0.1	0.2	0.2	9.3	14.1	13.5	18.8	11.2	9.7	8.3	6.4	4.6	3.7	2.1	1.5	1.1	0.6	0.3	0.1	0.1	3270	50.2

Table 2. Sablefish females maturity stages of gonads by seasons in the Bering Sea (1962-1964).

Maturity stages of gonads		1-11	11	11-111	111	111-1V	1V	V1-11	n
Seasons									
Winter	1		75.3	13.9	3.5	0.3	5.4	1.6	316
	2		100						9
Spring	1	0.3	89.5	0.3	0.6		9.5		329
	2	2.8	97.2	97.2					35
Summer	1	0.7	73.5	18.1	5.9	0.4		0.4	557
	2	2.1	92.5	1.2	1.9	0.5	0.7	1.1	188
Autumn	1		43.5	20.4	18.1	4.6	0.2	13.2	858
	2		97.6	1.2	1.2				86

Note: 1-Bering Sea; 2-Olyutorka-Navarin area.

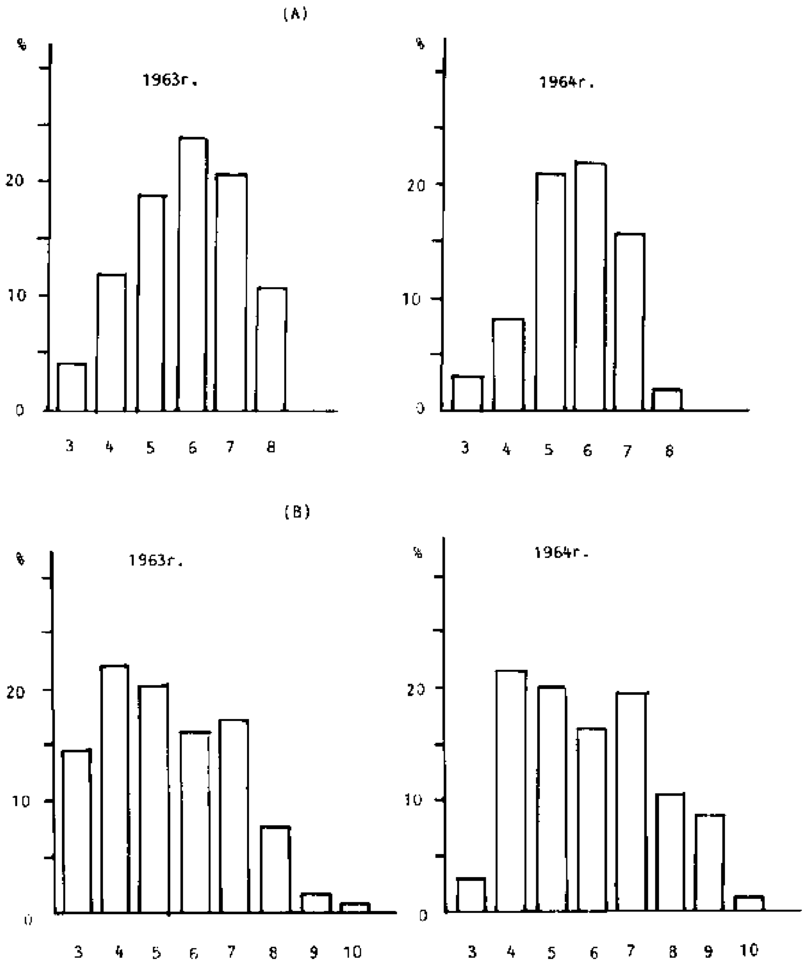

Fig. 4. Age composition of the sablefish. A - Bering Sea, B - the south area of the Bering Sea, 1962-1964.

catch in the Bering Sea. In the peak periods of fishing (1963-1964, 1967-1972) the Japanese catches of sablefish on the Asian continental slope exceeded 2,500 tons, with 16-37% in the long line fishery and 10-74% in the trawl fishery (Table 3). These catches could be attributed to the summer concentration of sablefish in the northern area when the small-tonnage, long line fishing boats are usually used.

Calculation of the biomass of sablefish over the continental slope made by the area methods showed that in summer at high abundance periods their biomass was 42,000 to 65,000 tons (Table 3).

As a result of unrestricted fishing from 1967 to 1978, the catch per unit effort in the trawl fishery decreased five to six times and over 30

Table 3. Catches of sablefish over the Asian continental slope in the Bering Sea (percent to the total catch).

Year	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	
Trawl fishery	21.2	47.9	73.8	29.0	10.2	20.8	4.6	2.6	-	-	-	22.6
Long line fishery		-	-	-	37.3	36.2	26.8	29.3	16.0	22.2	27.9	27.2

Table 4. Biomass of sablefish in the north area (thousand tons).

Year	1962	1964	1970	1981	1982
Biomass	42.1	64.9	2.1	4.2	4.5

times in the long line fishery (Sasaki, et al. 1975). The sablefish biomass has fallen too in the area of the Asian continental slope. Therefore, in the late 70s few sablefish were found in the trawl catches.

Decrease of fishing pressure on the sablefish stock in the late 70s has enhanced the restoration of sablefish abundance in the eastern Bering Sea area (Ermakov 1982) and the likely increase of their migration to the Bering Sea. During the Darvin cruise in 1982 some small assemblages of sablefish were again observed. According to the preliminary calculations the total biomass of sablefish were not less than 4,500 tons in 1982 (in the northwestern part of the Bering Sea).

REFERENCES

Ermakov, Yu.K. Izmeneniya v donnoi faune Vankuverskogo i Vashingtonsko-Oregonskogo raionov v usloviyakh tralovogo lova morshkikh okunei i Tikhookenskogo kheka. Vsesoyuznaya konferenciya po teriformirovaniya chislennosti i ratsionalnogo ispolzovaniya stad promyslovykh ryb. M. 1982. str. 128-129.

Kodolov, L.S. 1970. Biologiya i raspredelenije ugolnoi ryby Gering morija. Dis. na soisk. uchyon. step. k.b.n. Vladivostok, 1970.

Kodolov, L.S. Osobennosti biologii i raspredelenije ugolnoi ryby (Anoplopoma fimbria Pale). Izvestija TINRO, V. 100, vyp. 5.

Novikov, N.P. Mechenije ugolnoi ryby. Voprosy ikhtiologiji, t. 8, v. 5.

Sasaki, Low and Thorson. 1975. Sablefish (Anoplopoma fimbria) Resources of the Bering Sea and Northeastern Pacific ocean. Northwest Fisheries Center, Washington. p. 58.

Session V

Stock Assessment

Relative abundance and size composition of sablefish in coastal waters of Southeast Alaska, 1978-82

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ABSTRACT

In May 1978, the NMFS Northwest and Alaska Fisheries Center implemented a research program to monitor sablefish abundance and stock composition in the coastal waters of southeast Alaska. Annual surveys were performed in 1978-82 at sites between Cross Sound and Dixon Entrance.

Four fishing sites on the coastal southeast Alaska fishing grounds near Cape Cross, Cape Ommaney, Cape Addington, and Cape Muzon were surveyed. At the first three sites, longlines holding 10 traps were fished near depths of 150, 225, 300, 375, and 450 fathoms. Each set of gear was hauled and set five times at each depth. At Cape Muzon depths were restricted to 205-231 fathoms. Fishing time was standardized with timed release devices that caused the trap tunnels to close after approximately 24 hours.

Annual differences in the numbers of sablefish captured at each site and for the grouped sites were tabulated as percentage change. Sablefish abundance index catches increased 45% from 1978 to 1980 due to the influx of premarketable-size fish from the 1977 year-class and a 34% increase in the number of marketable-size fish, the bulk of which appeared in 1979. In 1981 survey catches of marketable sablefish decreased 53% from 1980 levels. Survey catch levels of sablefish declined again in 1982.

Introduction

Sablefish (Anoplopoma fimbria) is one of the most widely distributed and highly valued groundfish species in the northeastern Pacific Ocean. In North American waters, they are captured from Baja California northward through the Gulf of Alaska, along the Aleutian Islands, and in the Bering Sea. Prior to 1978, foreign fleets (primarily Japanese) dominated the fishery in the eastern Gulf of Alaska.

During the 1960's and 1970's prior to enactment of the Magnuson Fishery Conservation and Management Act (MFCMA) of 1976, U.S. scientists monitored sablefish catch and effort records and, with evidence of declining stock condition, negotiated for reduced foreign catch quotas. Declines in the catch per unit effort (CPUE) among Japanese longliners from 1967 to 1977 (Low, 1977) necessitated a reduction of fishing effort exerted on the sablefish stocks. Annual sablefish catches off southeast Alaska and associated Japanese longline CPUE data which were used to monitor changes in that area's sablefish resources during 1966-77, are summarized in Table 1.

Table 1.--Summary of sablefish catch data for southeast Alaska including total (all gear) catch, U.S. (all gear) catches for 1967-82, and Japanese longline catch and effort data (1967-77) previously used by U.S. scientists to monitor annual changes in sablefish abundance (Low, 1977).

Year	Total catch (t)	U.S. catch (t) 1/	Japanese longline catch (t)	Japanese longline effort (10 hachi units)	Japanese CPUE (t/10 hachi units) 2/
1967	862	NA	217	720	0.301
1968	7,224	NA	6,364	25,958	0.245
1969	7,064	211	6,169	26,835	0.230
1970	7,888	365	6,805	29,681	0.229
1971	8,695	261	7,737	37,980	0.204
1972	11,012	749	9,311	44,844	0.208
1973	6,527	852	5,949	29,327	0.203
1974	7,377	779	6,574	33,653	0.195
1975	6,358	1,088	5,604	30,417	0.184
1976	6,648	798	5,489	28,717	0.191
1977	3,730	818	3,586	25,749	0.139
1978	1,738	1,703			
1979	2,920	2,826			
1980	2,186	2,130			
1981	1,689	1,615			
1982	2,001	2,001			

1/ Data furnished by Alaska Department of Fish and Game, Petersburg.
2/ Hachi unit = standard unit of Japanese longline gear.

In 1977 MFCMA took effect providing the means for U.S. management of foreign fisheries conducted within the U.S. fishery conservation zone (200-mile limit). Under MFCMA, gulf-wide sablefish catch quotas were reduced to 8,000 metric tons (t) and area closures for foreign longliners were implemented during domestic fishing seasons for Pacific halibut (Hippoglossus stenolepis). In 1978 regulations were applied to exclude foreign longlining for sablefish east of 140 degrees west longitude. This measure was taken to permit stock recovery and to allow expansion of the small but viable U.S. fishery that has operated in southeast Alaska since prior to World War II (Alton, 1981). Annual domestic catch peaked in southeast Alaska in 1979 and has decreased since then (Table 1).

Before the exclusion of foreign sablefish longlining, the primary data source used to determine stock condition in southeast Alaska was catch and effort analysis of Japanese longline catches. Following exclusion of foreign longline effort, the National Marine Fisheries Service (NMFS) Northwest and Alaska Fisheries Center implemented a research program to monitor sablefish abundance and stock composition to provide an alternate index of stock condition. Surveys have been conducted annually since 1978 at sites located between Cross Sound and Dixon Entrance (Figure 1). The fishery assessment technique employed in this study is known as "abundance indexing." Using standardized fishing procedures and sablefish trap gear, changes in relative abundance and size composition of sablefish are monitored at specific sites during the same time period each year. Since traps are a passive fishing gear and their sphere of influence while on bottom is presently unknown, absolute fish abundance or biomass cannot be calculated from trap catches. It is assumed that changes in the absolute number and sizes of sablefish in the survey area are reflected proportionally by changes in the annual survey catches.

This report describes the methodology used and summarizes the results of five sablefish abundance indexing surveys. Results are evaluated and suggestions made to improve spatial coverage at the same level of effort.

Survey Methods and Gear

Indexing sites were established in offshore waters near Capes Cross, Ommaney, Addington, and Muzon (Figure 1). The first three sites were surveyed annually from 1978 to 1982, and the fourth site was surveyed annually from 1979 to 1982. The standard survey time period was 25 May to 15 July, although in 1982 the survey was undertaken about 2 weeks earlier.

Metal-framed rectangular, collapsible traps described by Hipkins (1974) were used. They measured 34" x 34" x 8' and were covered with 3-1/2" white nylon web and equipped with a single tunnel of 2-1/2" green nylon web. Each trap was baited with 2 lb of chopped Pacific herring (Clupea harengus pallasi) held in perforated plastic jars. Ten of these traps were fished on a groundline, as shown in Figure 2.

At the Cape Cross, Cape Ommaney, and Cape Addington sites sampling occurred near depths of 150, 225, 300, 375, and 450 fathoms. At each depth a string of traps was set and hauled five times resulting in 250

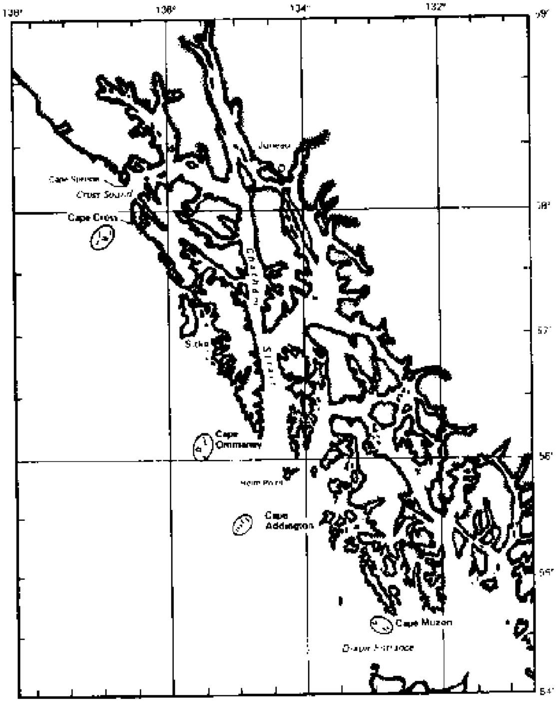
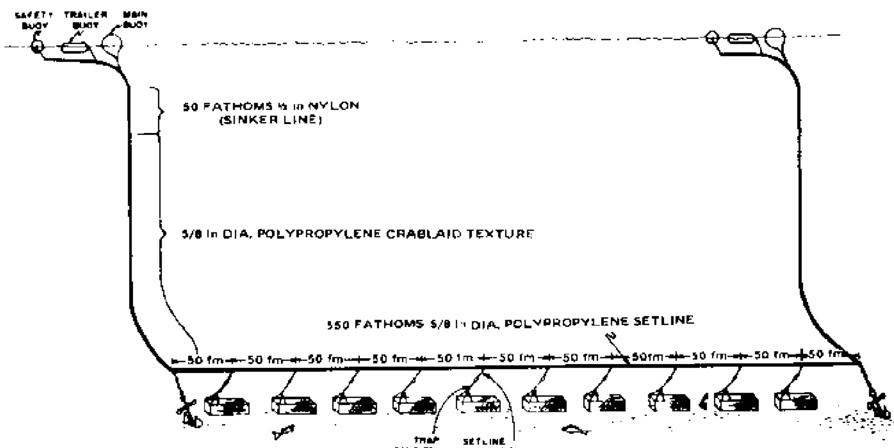


Figure 1. (left) Locations of sablefish abundance indexing sites surveyed off southeast Alaska, 1978-82.

Figure 2. (bottom) A pictoral view of a string of trap gear used in the sablefish adundance index studies (from Hipkins, 1974).



trap lifts per site. At the Cape Muzon site sampling was limited to 205-231 fathoms because of the irregular bottom terrain at the other depths (150 and 300-450 fathoms). Four strings of gear were set and hauled four times for a total effort of 160 trap lifts at that interval. At all sites the gear was set at approximately the same location each year by means of Loran-C, radar, and depth sounder. All NMFS surveys were conducted from the NOAA ship John N. Cobb.

Previous studies indicated that catch rates of sablefish traps decrease with increasing soak time (Hughes et al., 1970). Therefore fishing time was standardized by use of corrodible magensium-alloy time-release devices which were calibrated to close trap entrances via a noose arrangement after approximately 24 hours (Zenger, 1983). Thus, when gear could not be hauled on schedule due to weather or operational problems, effective trap fishing time was standardized.

The abundance index can be partitioned to examine changes in the marketable-size and prerecruit-size (premarketable-size) fish from year to year. This allows us to assess the changes in the marketable portion of stock, to anticipate the relative magnitude of prerecruit year classes, and estimate a time for their entry into the fishery. The southeast Alaska fishing industry regards marketable-size dressed sablefish as those weighing 3 lb or more, coinciding with a fork length of 57 cm or more. Fish measuring less than 57 cm are classified as prerecruits which technically have not entered the fishery, although they are captured and undoubtedly suffer "shaker mortality" when returned to the sea. Small marketable sablefish weigh 3-5 lb dressed weight and large marketable sablefish weigh more than 5 lb dressed and are 67 cm or more in fork length. Length frequency figures reflect annual changes in abundance fish length, because all captured sablefish were measured.

Most commercial fishermen in southeast Alaska prefer longline gear to harvest sablefish because of its versatility for varying seabed conditions; but for research purposes, longline effort is difficult to standardize. Bait loss and the catch of species other than sablefish must be considered in standardizing catch rates from longline gear. The effective fishing time of traps can be more readily standardized than that of longline gear, and traps are more selective in catching sablefish.

Results

Trends in sablefish abundance at southeast Alaska index sites

Abundance index data are summarized in Table 2. Numbers of fish captured at each site and the annual percentage changes in catches of total sablefish (all sizes), marketable-size, and prerecruit-size sablefish are presented.

Since the three northern sites best represent the area fished by the bulk of the domestic sablefish vessels, they are considered separately from the Cape Muzon site. As stated previously, the Cape Muzon site is unique in its depth distribution and sampling density. Its distance from ports and the strong tidal currents that sweep Dixon Entrance have not encouraged the development of an Alaska sablefish fishery there.

Table 2.--Numbers of total, marketable-size and prerecruit-size sablefish captured at southeast Alaska abundance index sites during the 1978-81 annual surveys. Annual percentage change in numbers of sablefish, and the percentage change from the baseline year are indicated by site and size category for 1979-82.

	Total sablefish			Marketable-size 1/			Prerecruit-size 2/		
Site/Year	Number	Annual change (%)	Change from baseline year (%)	Number	Annual change (%)	Change from baseline year (%)	Number	Annual change (%)	Change from baseline year (%)
Cape Cross									
1978	513			459			54		
1979	473	- 8	- 8	399	- 13	- 13	74	+ 37	+ 37
1980	506	+ 7	- 1	315	- 21	- 31	191	+158	+254
1981	339	- 33	- 34	199	- 40	- 59	150	- 21	+178
1982 3/		- 15	- 44		- 10	- 66		-13	+141
Cape Ommaney									
1978	475			417			58		
1979	857	+ 80	+ 80	796	+ 91	+ 91	61	+ 5	+ 5
1980	703	- 18	+ 48	591	- 26	+ 42	117	+ 84	+ 93
1981	505	- 28	+ 6	263	- 55	- 37	242	+116	+317
1982		- 42	- 36		+ 12	- 44		- 75	+ 6
Cape Addington									
1978	540			421			119		
1979	785	+ 45	+ 45	492	+ 17	+ 17	293	+146	+146
1980	1,011	+ 29	+ 87	838	- 70	+ 99	173	- 41	+ 45
1981	504	- 50	- 7	279	- 67	- 34	225	+ 30	+ 89
1982		+ 20	+ 12		- 6	- 30		+ 36	+160
Cape Mizon 4/									
1979	754			692			62		
1980	832	+ 10	+ 10	725	- 5	- 5	107	+ 73	+ 73
1981	555	- 33	- 26	423	- 42	- 39	132	+ 23	+113
1982		- 7	- 32		- 39	- 62		+ 94	+313
Cape Cross Cape Ommaney Cape Addington									
1978	1,528			1,297			231		
1979	2,115	+ 38	+ 38	1,687	- 30	- 30	428	+ 85	+ 85
1980	2,220	+ 5	+ 45	1,744	3	+ 34	476	+ 11	+ 106
1981	1,348	- 39	- 12	731	58	- 44	617	+ 30	+ 167
All four sites									
1979	2,869			2,379			490		
1980	3,052	+ 6	+ 6	2,469	- 4	+ 4	583	+ 19	+ 19
1981	1,903	- 38	- 34	1,154	- 53	- 51	749	+ 28	+ 53

1/ 67 cm or greater fork length.
2/ Less than 67 cm fork length.
3/ Data for 1982 supplied by Auke Bay Biological Laboratory, Juneau. Percentage change between 1981 and 1982 and change from baseline year based on catch per trap.
4/ Only one depth interval (205-231 fathom) was fished at this site.

Valid estimates of the percentage change of relative sablefish abundance cannot be made directly from data collected during the 1982 survey. Weather prohibited the completion of established effort levels at some sites and bait used during some parts of the survey was of poor quality causing reductions in catch rates. A bait comparison study was performed and adjustments were made to the raw data to standardize catches. The change in number of fish per trap served as alternate index of abundance to total catch in numbers for comparison of 1982 catch data to those of previous years.

Cape Cross site--Survey catches of sablefish at Cape Cross remained relatively stable during the 1978-80 period. However, mean lengths decreased (Figure 3) and marketable-size fish represented a diminishing part of the index catch. Through 1980, prerecruits increased as catches of larger fish decreased, thereby maintaining overall sablefish survey catch levels. The largest decrease in relative abundance (33%) occurred during the 1981 survey. Catches of marketable and prerecruit sablefish decreased 40% and 21%, respectively (Table 2). Between 1978 and 1981, the relative abundance of marketable-size sablefish decreased 59% at the Cape Cross site.

Cape Ommaney site--Annual survey catches at Cape Ommaney have shown considerable variability in numbers and size composition. In 1978, the area yielded the lowest survey catch rate of the 4-year period. The overall 1979 survey catch increased 80% from the previous year due primarily to catches of large, recently spawned fish (Table 2). During the 1980 and 1981 survey years, the survey catch of marketable sablefish decreased. In 1981, the index catch of marketable-size fish was 37% below the 1978 level. Two trends typify catches at this site. The first is the decrease in the abundance of marketable-size sablefish after 1979 and the other is the growing strength of prerecruit size classes (Figure 4).

Cape Addington site--One of the highest catch rates of marketable sablefish found during any of the surveys was recorded at this site in 1980 (Figure 5). During the previous year, a relatively strong prerecruit year class appeared there giving rise to speculation that southeast Alaska sablefish stocks were growing through an influx of small fish. By 1981, survey catches of marketable fish decreased to a level 34% below the 1978 baseline catch (Table 2). Prerecruits composed almost half of the catches and the dominant mode in the size frequency distribution was at 49 cm (Figure 5). Major frequency modes above 60 cm virtually disappeared between the 1980 and 1981 surveys.

Cape Muzon site--The 1981 sablefish index catch at Cape Muzon was 26% below the 1979 figure. Marketable-size fish were 39% less numerous and prerecruits were 113% more abundant than during the 1979 survey (Table 2). Mean length of sablefish at the site decreased from 67 cm in 1979 to 62 cm in 1981 (Figure 6), and to 58 cm in 1982.

Sablefish length-weight relationships

Sablefish length-weight data were collected at all survey sites in 1978 and at Cape Muzon in 1979. Length-weight regression equations are shown in Table 3. Females were usually heavier than comparably sized males. Dressed weight with pectoral girdle attached was 71% of the round weight of marketable-size sablefish.

Sablefish length at age

The validity of sablefish aging techniques is undergoing critical review. Research to define the most reliable technique is being pursued at various institutions. Age data presented in this report should be viewed as provisional.

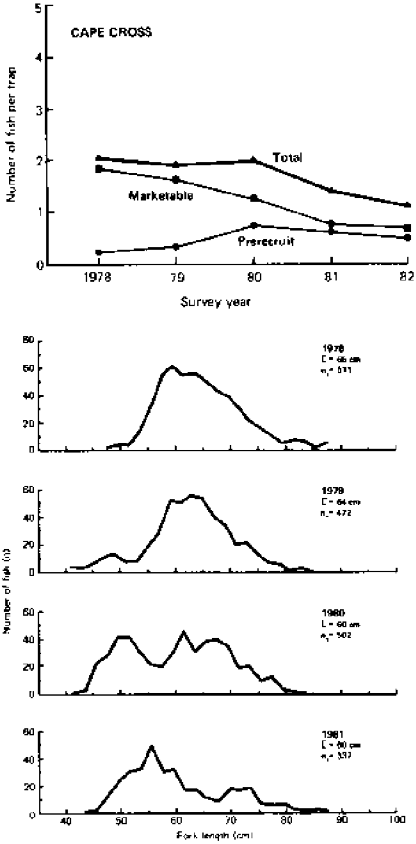


Figure 3.
Survey catches of prerecruit, marketable and total sablefish per trap, 1978-82, and size compositions of sablefish captured, 1978-81, at the Cape Cross index site.

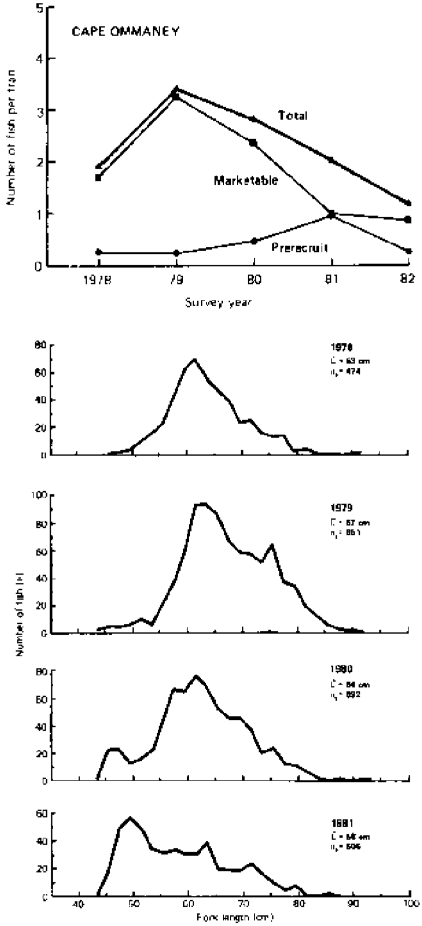


Figure 4.
Survey catches of prerecruit, marketable and total sablefish per trap, 1978-82, and size compositions of sablefish captured, 1978-81, at the Cape Ommaney index site.

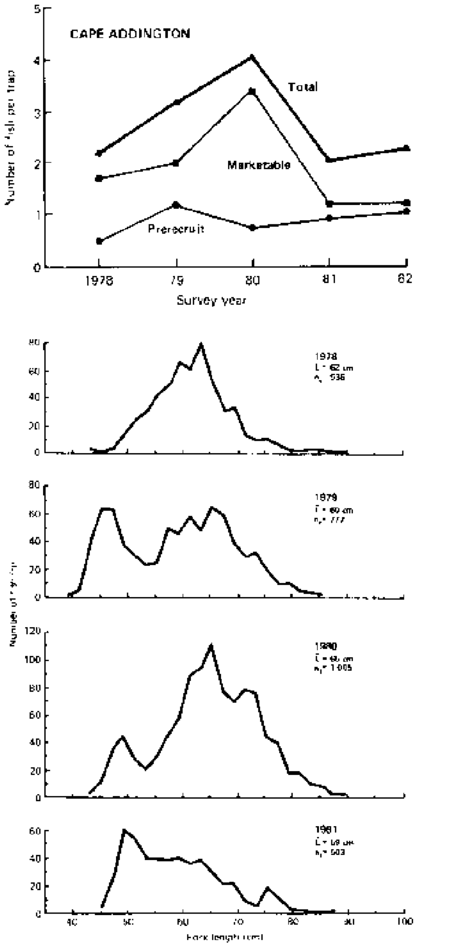


Figure 5.
Survey catches of prerecruit, marketable and total sablefish per trap, 1978-82, and size compositions of sablefish captured, 1978-81, at the Cape Addington index site.

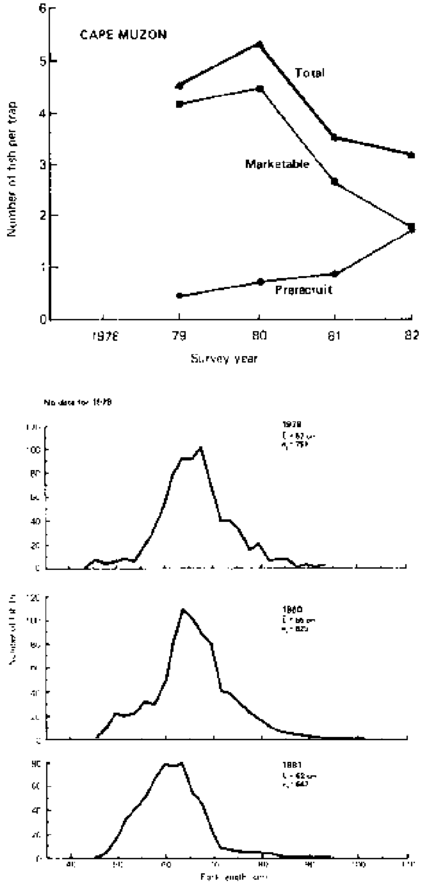


Figure 6.
Survey catches of prerecruit, marketable and total sablefish per trap, 1978-82, and size compositions, 1978-82, and size compositions of sablefish captured, 1978-81, at the Cape Muzon index site.

Table 3.--Length-weight relationships for round and dressed sablefish captured during the southeast Alaska sablefish abundance index surveys, 1978-79.

Sex	Round/ dressed	Regression equation	Sample	Correlation coefficient
Male	round	$W = 7.1*10^{-3}*L^{3.0766}$	469	0.93
Female	round	$W = 3.5*10^{-3}*L^{3.2738}$	246	0.95
Combined	round	$W = 4.2*10^{-3}*L^{3.2196}$	715	0.94
Combined	dressed	$W = 3.9*10^{-6}*L^{3.1538}$	112	0.95

Table 4.--Mean lengths at age for male and female sablefish captured during abundance index surveys off southeast Alaska, 1978-80.[1]

Age (in years)	Males 1978	Males 1979	Males 1980	Females 1978	Females 1979	Females 1980
3	50.9	49.0	50.1	48.4	47.6	50.9
4	55.1	55.4	52.2	54.6	53.0	54.6
5	59.6	58.5	56.7	58.5	60.8	59.2
6	62.1	62.3	61.1	65.[illegible]	66.1	63.8
7	65.3	65.7	63.2	71.6	72.5	67.7
8	68.6	64.7	64.6	76.[illegible]	74.2	69.8
9	-	75.7	65.3	80.[illegible]	76.7	75.1
10	-	-	65.7	-	80.6	78.5
11	-	-	64.9	-	79.4	79.2
12	-	-	66.3	.	8[illegible].5	82.2
13	-	-	67.6	-	-	84.9
14	-	-	70.0	-	-	.
15			71.6	-	-	-

1/ Age data provisional

Age data from NMFS sablefish abundance index surveys conducted off southeast Alaska are available from scales for 1978 and from otoliths for 1979 and 1980. Otoliths processed by NMFS were surface read. Table 4 summarizes the mean lengths at age for male and female fish captured in 1978-80.

Juvenile sablefish appeared in survey catches on the coastal fishing grounds at an age of 3-4 years and an average length of 47-51 cm. At approximately 5 years of age, sablefish reach marketable size. The average female reaches large marketable size at 6-7 years and males measuring 67 cm or more are at least 7 years old.

Discussion

When NMFS began sablefish abundance index surveys in 1978, sablefish resources in the Gulf of Alaska were regarded as being in a state of low and declining abundance. Population abundance indexing with fish traps was an untested technique. The program was tentatively scheduled for 5 years duration to evaluate the methodology and to determine the amount of survey effort required at each site to accurately follow trends in sablefish abundance and size composition.

Several constraints were placed on the program at the outset. The first was the amount of vessel time scheduled annually for the indexing surveys and second the limitations inherent in the vessel assigned ed to the program. About 50 vessel-days were allotted annually to the indexing program, which included round-trip running time from Seattle. The lifting capacity of the hydraulic system limited us to 10 traps per string and its deck space was sufficient to haul equipment for 5 complete strings of gear plus a replacement set. The necessity to fish five depths at each site limited areas available to establish complete sites, since bottom conditions at the deeper intervals often prohibited fishing operations.

Initially index catches were considered to be small and variability was often high. It appeared that replicate hauls at each site would be necessary to establish meaningful abundance indices. Within survey constraints, it seemed more advantageous to fish four sites with five sets in each of five depths than to expand to more sites with fewer repetitions at each, at least until a data base could be built and catch trends and indices of abundance could be established.

A possibility exists that survey data collected during 1978 may not represent a true index of sablefish abundance. In particular, we should cite the early difficulties which were encountered in setting gear in the 375 and 450 fathom intervals and a tendency for new or "unseasoned" traps to show lower catch rates than older ones.

Results of the 1978-80 sablefish abundance index surveys indicated that decreases in sablefish abundance in coastal southeast Alaska had halted and, based on survey catch indices, stock abundance (all sizes of fish) had increased 45% between 1978 and 1980 (Table 2). While this increase seemed substantial, it occurred from a low base level of abundance relative to pre-1967 conditions when the stocks were closer to virgin biomass. Thirty-eight percent of the increased survey catches (all sizes of fish) occurred during the 1979 survey. Catches during the 1980 survey (all sizes of fish) showed a 6% increase over the previous year, and the relative abundance of marketable sablefish increased by 4%. A 27% increase in the apparent abundance of marketable-size sablefish during the 1979 survey year in the Cape Cross-Cape Ommaney area was the result of catches made on what appeared to be a concentration of recently spawned adult fish off Cape Ommaney. That singlular occurrence may have caused undue optimism for the recovery potential of the stock at that time. Had more sites been included in the survey, such a fluctuation may have had less impact on general impressions of apparent stock size.

Domestic catches, especially those north of Helm Point, increased until the 1981 survey year (Table 5). However, preliminary indications are that CPUE in numbers of fish per 100 longline hooks decreased over the period 1978-81 (Bracken, pers. commun.).

Survey data from the combined Cape Cross, Cape Ommaney, Cape Addington sites indicated a 39% reduction in total number of sablefish, a 58% decrease in marketable-size sablefish, and a 30% increase in prerecruit fish between the 1980 and 1981 surveys. Sablefish were 12% less abundant in the 1981 survey catches than in the 1978 baseline year. Marketable-size sablefish were 44% less abundant in the 1981 survey catches than in the 1978 baseline survey (Table 2). Prerecruits have increased from 15% of survey catches in 1978 to 46% in 1981 (Table 6). Dividing the marketable category into small and large, we find that the small marketable portion of the annual sablefish survey catches has decreased steadily since 1978. Large marketable sablefish made up 38-39% of the total survey catches in 1979 and 1980 but dropped to 21% in 1981.

Cape Addington and Cape Muzon showed increases in prerecruit abundance since the 1981 survey. A small increase in the number of marketable-size sablefish was found at Cape Addington (Table 2).

Table 7 pools the catch data from the 1978-81 surveys at Capes Cross, Ommaney, and Addington showing the relative abundance of prerecruit-size, small and large marketable-size sablefish. As verified previously in Table 2, 1979 and 1980 yielded the largest overall catches with 29 and 31% of the total 4-year catch. Prerecruits made steady gains in abundance over the first four survey years. Small marketable fish maintained a fixed proportion of the overall catch (12%) until 1981 when their relative abundance dropped by half. In 1981, prerecruits composed the most abundant size class.

Table 5.--Sablefish landings, domestic and foreign, taken from coastal waters of southeast Alaska and Dixon Entrance from June 1977 through May 1982.

1978 Survey Year (June 1977-May 1978)	Weight (t)	Percentage
Domestic, Cape Spencer to Cape Ommaney 1/	864.6	23
Domestic and Canadian, Helm Pt.-Dixon Entrance 2/	75.5	3
Foreign (coastal waters, all gear) 3/	2,041.7	69
TOTAL	2,981.8	100

1979 Survey Year (June 1978-May 1979)	Weight (t)	Percentage
Domestic, Cape Spencer to Cape Ommaney	1,063.4	91
Domestic and Canadian, Helm Point-Dixon Entrance	83.7	7
Foreign (coastal waters, trawl)	21.4	2
TOTAL	1,171.5	100

1980 Survey Year (June 1979-May 1980)	Weight (t)	Percentage
Domestic, Cape Spencer to Helm Point	1,134.6	63
Domestic and Canadian, Helm Point-Dixon Entrance	561.8	31
Foreign (coastal waters, trawl)	97.6	6
TOTAL	1,799.0	100

1981 Survey Year (June 1980-May 1981)	Weight (t)	Percentage
Domestic, Cape Spencer to Helm Point	1,422.8	80
Domestic and Canadian, Helm Point-Dixon Entrance	295.4	17
Foreign (coastal waters, trawl)	55.6	3
TOTAL	1,773.8	100

1982 Survey Year (June 1981-May 1982)	Weight (t)	Percentage
Domestic, Cape Spencer to Helm Point	736.0	73
Domestic and Canadian, Helm Point-Dixon Entrance	266.0	27
TOTAL	1,002.0	100

1/ Data provided by the Alaska Department of Fish and Game, Juneau.
2/ Canadian data provided by Pacific Biological Station, Nanaimo, B.C.
3/ Data provided by the NMFS Foreign Observer Program, Seattle.

Table 6.--Relative abundance of sablefish of prerecruit, small marketable, and large marketable size at the Cape Cross, Cape Ommaney, and Cape Addington abundance index sites during four annual surveys, 1978-81. Relative abundance is shown as the percentage that each category of fish contributes to the total catch in numbers each year.

Year and site	Prerecruit [1] (%)	Small [2] (%)	Large [3] (%)	Total (%)
1978				
Cape Cross	4	18	12	34
Cape Ommaney	4	18	9	31
Cape Addington	7	21	7	35
Total	15	57	28	100
1979				
Cape Cross	4	11	7	22
Cape Ommaney	3	17	21	40
Cape Addington	14	13	11	38
Total	21	41	39	100
1980				
Cape Cross	9	[illegible]	7	21
Cape Ommaney	5	14	12	31
Cape Addington	8	18	20	46
Total	22	39	39	100
1981				
Cape Cross	11	8	6	25
Cape Ommaney	18	12	6	36
Cape Addington	17	13	7	37
Total	46	33	21	100

1/ Less than 57 cm fork length.
2/ 57-66 cm fork length.
3/ 67 cm or greater fork length.

Table 7.--Relative abundance of prerecruit, small marketable, and large marketable size sablefish for the combined 1978-81 survey period at Capes Cross, Ommaney, and Addington.

Year	Prerecruit [1] (%)	Small [2] (%)	Large [3] (%)	Total (%)
1978	3	12	6	21
1979	6	12	11	29
1980	7	12	12	31
1981	9	6	4	19
			Total	100

1/ Less than 57 cm fork length.
2/ 57-66 cm fork length.
3/ 67 cm or greater fork length.

Table 8.--Changes in the apparent abundance of sablefish from the baseline year of 1978, at the Capes Cross, Ommaney, and Addington sites at four levels of survey fishing effort.

Site-Year		5 Sets	4 Sets	3 Sets	2 Sets
Cross	1979	-8	+5	+6	+38
	1980	-1	+2	-4	+15
	1981	-14	-33	-25	-11
Ommaney	1979	+50	+54	+65	+98
	1980	+48	+47	+57	+93
	1981	+6	+1	-7	+20
Addington	1979	+45	+59	+129	+166
	1980	+61	+127	+180	+164
	1981	[illegible]	+12	+43	+56
All Sites	1979	+34	+45	+63	+99
	1980	+45	+53	+74	+88
	1981	-12	-7	+3	+22

The dominant 60-65 cm modes found in the 1978-80 surveys virtually disappeared from sablefish length frequency distributions during the 1981 survey year (Figure 7). Mean lengths of sablefish captured at the northern three sites remained stable at about 64 cm during those first 3 years, decreasing to 59 and 58 cm in 1981 and 1982, respectively.

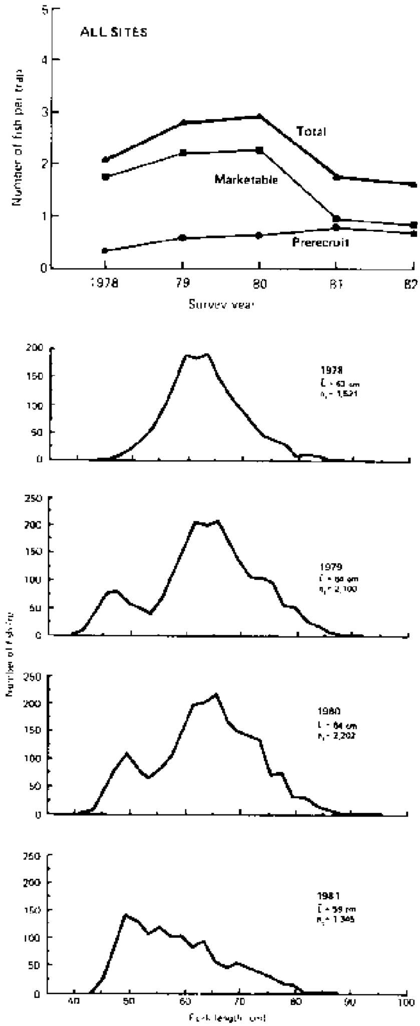


Figure 7.
Survey catches of prerecruit, marketable and total sablefish per trap, 1978-82, and size compositions of sablefish captured, 1978-81, at Cape Cross, Cape Ommaney, and Cape Addington index sites.

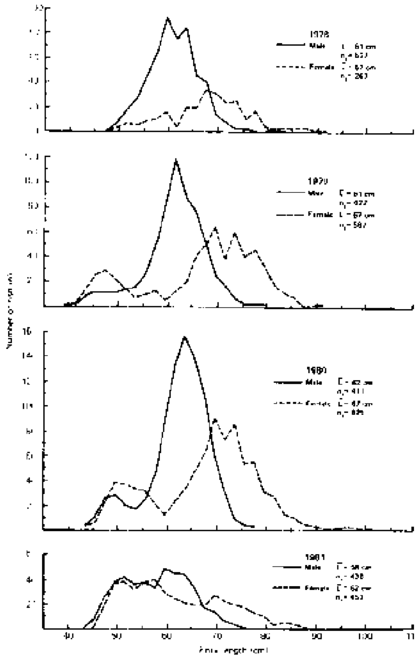


Figure 8.
Length compositions of male and female sablefish captured at the combined coastal index sites during annual surveys, 1978-81.

There was a large decrease in the catch of marketable fish in 1981, with an apparent leveling off in 1982.

Survey results indicated that decreases in marketable-size sablefish abundance were greatest on northern coastal fishing grounds where the majority of the domestic catch was taken (Table 5). An aspect of concern was the reduction in numbers of large marketable-size fish. They have the greatest reproductive capacity, most being females, and the highest value per pound. It appears that at least 3 years pass before the fish that enter the fishery as small marketables grow into the large marketable category.

Sex composition changed from male dominance in 1978-80 to a slight numerical superiority for females in 1981. Prerecruits were composed mostly of females in 1979 and 1980. Mean fork lengths of both sexes decreased between the 1980 and 1981 surveys (Figure 8).

Sablefish aging techniques employed by NMFS are undergoing review, but our data suggest that sablefish move into the coastal fishing grounds at ages 3 and 4 and that some grow to marketable size by age 5. Uncertainty of growth and mortality parameters and possible migration patterns complicate the determination of the effect that coastal recruitment levels have on overall sablefish abundance off southeast Alaska.

Since 1978, a Japan-U.S. cooperative longline survey has been conducted to determine the relative abundance of sablefish in the Gulf of Alaska. Reporting the results of those studies, Sasaki (1982) notes increases in the relative abundance of prerecruit-size sablefish since 1979 and their subsequent growth to marketable-size category. He also states that Japanese tagging studies indicate extensive sablefish movement across the Gulf of Alaska. Bracken (1982) presents a migration model for sablefish that takes into account tag returns from Alaska Department of Fish and Game, Japanese, and NMFS tagging programs. It shows prerecruit-size fish from southeast Alaska moving extensively northward and westward and larger, mature fish moving southward and eastward toward what is hypothesized to be the principal sablefish spawning and juvenile rearing area in southeast Alaska and British Colombia waters.

Evaluation of the sablefish abundance indexing technique

The survey data were examined to determine if sampling effort could be reduced at each site and yet be sufficient to reflect changes in relative abundance. Any savings in effort would then be used in future surveys for additional index sites. By hindcasting the results of the 1978-81 surveys at the Capes Cross, Ommaney, and Addington sites using 5, 4, 3, or 2 strings, I weighed the benefits and disadvantages of conducting the survey at reduced effort levels. Table 8 lists the percentage changes in numbers of sablefish captured since the baseline year at four levels of survey effort. Results at the 5-string level of effort often reflect a much different picture of changes in sablefish abundance than their indices at 2 or 3 strings of effort. Lower levels of survey fishing effort tend to indicate higher sablefish abundance. This was apparently caused by the tendency for larger catches to appear in the first three sets at any given site. To verify that possibility, a simple ranking procedure was followed (Table 9). The overall ranks support the hypothesis that the fourth and fifth sets were smaller than the first three during the 1978-81 survey period.

Table 9.--Ranks of index survey sablefish catches[1/] by year, site, and set number at the Capes Cross, Ommaney, and Addington sites for the 1978-81 annual surveys.

	Set number				
Year/site	1	2	3	4	5
1978					
Cape Cross	1	2	5	4	3
Cape Ommaney	2	4	5	3	1
Cape Addington	1	2	3	5	4
Sum of ranks	4	8	13	12	8
1979					
Cape Cross	3	4	5	2	1
Cape Ommaney	4	3	1	2	5
Cape Addington	5	4	2	3	1
Sum of ranks	12	11	8	7	7
1980					
Cape Cross	2	1	5	4	3
Cape Ommaney	5	4	3	2	1
Cape Addington	5	2	4	3	1
Sum of ranks	12	7	12	9	5
1981					
Cape Cross	4	2	5	1	3
Cape Ommaney	2	5	1	4	3
Cape Addington	4	5	2	3	1
Sum or ranks	10	12	8	8	7
Overall rank	3.5	3.5	5	2	1

1/ Ranked from lowest to highest catch.

By replacing the annual percentage change in total numbers of sablefish captured per site (the traditional index of abundance used in this research) with mean numbers of sablefish captured per trap per site, we find that at the 3 set per site level of survey effort, the trends in apparent abundance closely parallel those found at the 5 set per site level (Figure 9). This opens the possibility of expansion to include more sites with less effort per site, at the same time providing for continuity of data comparison between subsequent data collections and the established data base.

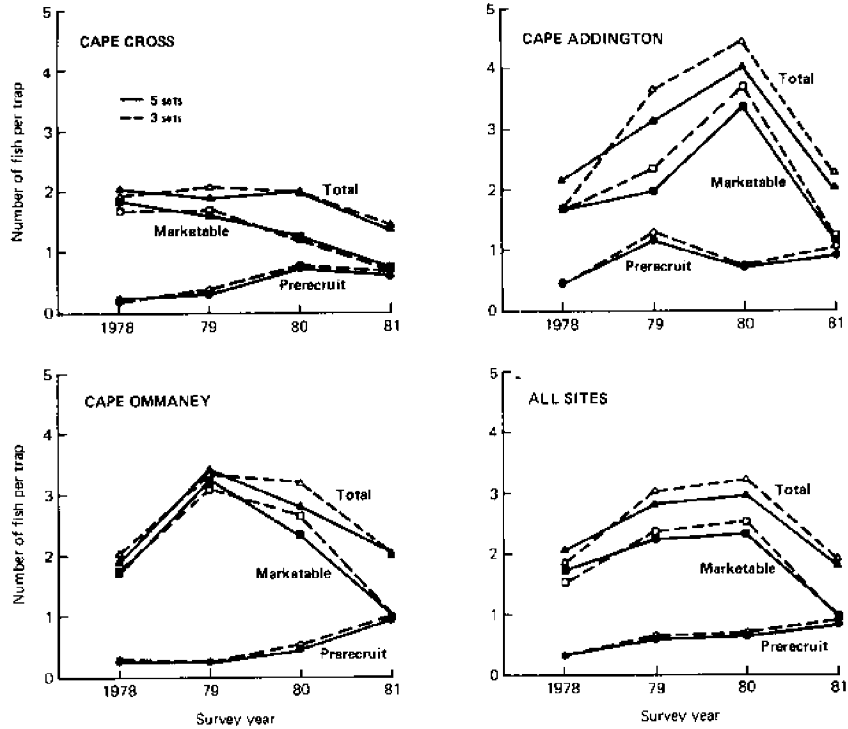


Figure 9.--Catch of sablefish per trap for 3 and 5 strings of survey effort at Capes Cross, Ommaney, and Addington, 1978-81.

Summary

In light of the above conclusions, it appears that the NMFS trap study should be expanded to more completely cover at least the Yakutat-Dixon Entrance region. Expansion appears to be necessary to effectively monitor sablefish abundance and size composition at one of the species' most important geographical focal points.

A principal criticism of the trap survey has been that the relatively small number of sites distributed over a large coastal area do not reflect the true picture of sablefish abundance. Judging from analyses of trap indexing CPUE data, the survey would effectively show abundance trends by performing 3 repetitions instead of 5, assuming that survey time period, trap fishing time, bait, and fishing techniques remain standardized as during 1978-1981. This will allow redistribution of effort and expansion from 4 to 6 sites. Additional effort is needed between the Cape Ommaney and Cape Cross sites and between Cape Cross and Yakutat. Since an increase in vessel time dedicated to this survey is not anticipated, a reduction of effort at the sites presently sampled will be necessary.

Another suggested weakness of the NMFS trap survey is the low CPUE on which the indices of abundance are based. This may not be a valid point, since the results seem to compare favorably with trends in the domestic fishery. Between 1977 and 1981, the CPUE (number of sablefish caught per 100 hooks) in the coastal domestic fishery decreased from over 10 to about 6 fish, and the average weight of fish landed decreased (Bracken, pers. commun.).

References

Alton, M. S.
1981. Gulf of Alaska bottomfish and shellfish resources. U.S. Dep. Commer., NOAA Tech. Memo. NMFS F/NWC-10, 51 p.

Bracken, B. E.
1982. Sablefish (Anoplopoma fimbria) migration in the Gulf of Alaska based on gulf-wide tag recoveries, 1973-1981. Alaska Dep. Fish Game, Inf. Leafl. 199, 24 p.

Hipkins, F. W.
1974. A trapping system for harvesting sablefish, Anoplopoma fimbria. Natl. Mar. Fish. Serv., Fishery Facts 7, 20 p.

Hughes, S. E., D. D. Worlund, and F. W. Hipkins.
1970. Adaptation of king crab pots for capturing sablefish (Anoplopoma fimbria). J. Fish. Res. Board Can. 27:1747-1755.

Low, L. L.
1977. Status of the sablefish resource in the Bering Sea and northeastern Pacific through 1977. Unpubl. manuscr., 37 p. Northwest and Alaska Fisheries Center, National Marine Fisheries Service, NOAA, 2725 Montlake Blvd. E., Seattle, WA 98112.

Sasaki, T.
1982. Condition of sablefish stocks in the North Pacific. Unpubl. manuscr., 17 p. Japan Fisheries Agency, 2-1, Kasumigaseki, Chiyoda-Ku, Tokyo, Japan.

Zenger, H. H.
1983. Use of corrodible magnesium-alloy links to standardize fishing time in sablefish traps. (Within this publication.)

Relative abundance and size structure of sablefish in the eastern Bering Sea, Aleutian region and Gulf of Alaska based on the results of Japan-U.S. joint longline surveys from 1979 to 1982

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Abstract

Japan and the United States jointly conducted a systematic groundfish survey with the use of bottom longline gear in the Gulf of Alaska for the first time in 1978. Since the 1978 survey was of a preliminary nature for the purpose of obtaining basic data necessary for making plans for future surveys, the data is used only for reference. After 1979, the longline surveys were expanded to the Aleutian region and in 1982 a survey was carried out in the eastern Bering Sea. The main objective of the bottom longline surveys was to clarify the relative abundance of the sablefish stocks living in the depth range of 101 - 1,000 m and their size structure, as well as to examine the year to year change in the stocks. The survey methods applied in the longline surveys since 1979 have basically remained unchanged. The results of the surveys reveal that the biomass of sablefish increased since 1979 in both the Aleutian region and the Gulf of Alaska, and in 1982 the biomass increased 85% in the east area of the Aleutian region and 70% in the Gulf of Alaska from the 1979 level. Such a sharp increase in the biomass is believed to have been caused by the recruitment in 1979 and 1980 of the extremely abundant 1977 year class in each of the regions. Because of the entry of this strong year class, the size structure of the sablefish stocks changed remarkably in a short period of time. On the basis of the 1982 survey, the biomass in the eastern Bering Sea and the Aleutian region was respectively estimated to be about one-tenth of that in the Gulf of Alaska.

Introduction

Up to the present, many groundfish surveys have been conducted by the research institutes of various countries in the Bering Sea and north-eastern Pacific Ocean. However, since these surveys were mainly carried out on the continental shelf, they produced limited information on the exploitable stocks of sablefish living at a depth over 200 or 300 m. Since 1978, Japan and the United States have jointly conducted systematic groundfish surveys with the use of bottom longline gear. The longline survey is the first large-scale and systematic survey for sablefish stocks in the north Pacific. Since the 1978 survey in the Gulf of Alaska was of a preliminary nature for the purpose of obtaining basic data necessary for making plans for future surveys, the data is used only for reference. Since 1979, the longline surveys have been expanded to the Aleutian region and in 1982 the survey was carried out in the eastern Bering Sea for the first time (Fig. 1). Apart from the longline surveys, large-scale and systematic trawl surveys have been conducted jointly by the United States and Japan in the eastern Bering Sea and Aleutian region since 1979. These field surveys by longline and trawl gear have produced much useful information on the sablefish stocks. Consequently, the biological information on sablefish stocks was rapidly increased.

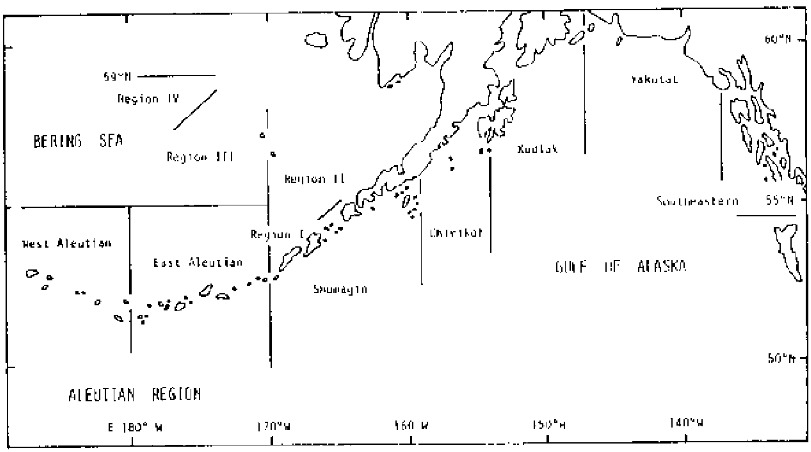

Figure 1. Definition of the region and area applied in the Japan-U.S. joint longline survey in the eastern Bering Sea, Aleutian region and Gulf of Alaska.

The important activities in the longline surveys are to collect biological data such as catch rate and size composition of major species of fish and to carry out the tagging experiment for sablefish. But, the main objective of the longline surveys is to clarify the relative stock size and the size structure of sablefish stocks living at the depth range of 101 - 1,000 m of the survey areas, as well as to trace the year-to-year change in them. This paper attempts to analyze, on the basis of the accomplishments of the longline surveys, the relative population number (RPN) and relative population weight (RPW) as an index of population size and biomass, respectively, as well as the size structure of sablefish living in the depth range of 101 - 1,000 m of the survey areas by area and by depth, and to document their year-to-year change as well.

Before proceeding with the report, the author wishes to express sincere appreciation to Mr. Duane Rodman of Northwest and Alaska Fisheries Center who cooperated with us in the longline surveys from the beginning as well as in the research activities and the data analysis, and to Mr. Michinori Kuroiwa, Dr. Tadashi Inada, Mr. Masaru Onoda, and Mr. Kenji Funato, of Japan Marine Fisheries Resources Research Center who exerted efforts as senior investigators through the surveys. The author also wishes to express thanks to Mr. Ron Tanino, Mr. John Rosapepe, Mr. Frank Shaw, and Mr. David Clausen of Northwest and Alaska Fisheries Center for their participation and cooperation in the surveys. Further, the author wishes to extend thanks to all the crew members of the Hatsue maru No. 55, Ryusho maru No. 15, Fukuyoshi maru No. 8 and Anyo maru No. 22 who extended full cooperation in the navigation of the research vessels as well as in the research activities.

Methods

Field surveys

The preliminary investigations were made in 1978 with the use of varyinc numbers of hachi, and various baits, as well as in various depths of water. But, the method used in the longline surveys since 1979 has basically remained unchanged. The utmost care was taken not to introduce any qualitative variations in the data by changing the surveying method.

The surveys have been conducted every year in the period from the middl(of May to the beginning of September with the charter of Japanese North pacific longline vessels. The longline vessels used for research activities were all 500 ton vessels with similar structure. There were 32 survey stations in 1978, 57 in 1979, 76 in 1980 and 1981, and 108 in 1982. The 1978 surveys were of a preliminary nature; and, the experimentation regarding the fishing efficiency of longline gear was separately carried out in 1979. Therefore, the numbers of survey stations in that year were less than in other years. The survey stations were distributed as evenly as possible without geographic partiality. The longline survey was conducted once a day at each survey station. Normally, the longline with 160 hachi was used in one fishing operation The longline was set in direct angle to the isobath in such a way as tc cover the depth range of 101 - 1,000 m but, the distance between the isobaths varied with the survey stations. Since the number of hachi ir one operation was kept to 160, in stations where the depth range of 101 - 1,000 m extended very widely, all of this was principally set from th direction of the shore outward, and the ship returned to the point wher the line setting began to haul the line.

In the longline survey a 100 m ground-line with 45 hooks fixed on 1.2 r gangions was used as the standard gear of one hachi. The interval between the hooks was 2 m. The size of the hook was 74 mm in length an 21 mm in width. Ring-cut short-finned squid were used as bait. The soaking time was 5 to 6 hours on the average, but it varied with the point of the longlines. Counted from the start of hauling, the soakinc time was about 3 hours, but if counted at the end of the haul it was 7 to 9 hours. The catch was recorded by fish species or species group pe hachi as to the number caught. The fishing depth was recorded with a fish finder on the basis of every 5 hachi. The water depth recorded wa right under the boat, so it may differ slightly from the actual depth.

In the 1979 surveys, no measurement of the tagged sablefish was made by water depth, so there was no information available as to the size composition by depth of all the sablefish caught. After the 1980 surveys the size composition data by depth of all the fish caught are available.

Data analysis

Since the 1978 surveys were of a preliminary nature for the purpose of obtaining the basic information necessary for further survey planning, these were excluded from the examination for the purpose of this report. Generally, the age composition is used for analyzing the change in stocks, but the age determination for the whole sample is not yet completed. Therefore, the size composition data were used for the purpose of this report. The stratification of the catch data, which is the unit of the data analysis, was made on the basis of 100 m, or a total of 9 strata for the 101 to 1,000 m depth range for each area as shown in Figure 1. As for the size composition data, the depth range of 101 - 200 was defined as one stratum, and the depth range deeper than 201 m was divided into 200 m strata.

First, on the basis of the catch data, the average catch rate was calculated for each stratum. As earlier stated, the soaking time periods varied with the point of the longline. And there is a possibility that this time difference has an effect on the catch rates. But, no correction was made on this point. The average catch rate is an indicator of the population density, but does not represent the stock size per stratum. Therefore, the average catch rate of each stratum was weighted by the area of the fishing ground of the corresponding stratum and, the value thus obtained is considered to represent the relative population size living in the stratum. Further, based on the size composition and the average body weight of the size class contained in each stratum which were weighted by the relative population number, the relative value of the biomass was obtained. The sum of the relative values of the population size or the biomass thus obtained in each stratum of each region or area will be the index representing the relative stock size of the whole region or the whole area.

The study of the size structure of the sablefish stocks was made on the basis of the size composition of the fish caught weighted by the relative population number of the corresponding stratum. The size composition obtained through the sum of the size composition of each stratum of each region or area weighted by the relative population number is considered to relatively represent the size structure of the whole stock of the region or the area.

The fishing ground area for a 50-100 fathom depth range was calculated on the basis of the charts printed in the United States, and the area for a 100 - 600 fathom depth range was likewise calculated on the basis of the United States bottom contour charts (United States Naval Oceanographic Office) with the use of a planimeter. The depth intervals in terms of fathoms were converted into those in terms of 100 m, and the depth range of 101 - 1,000 m was divided into 9 strata by a unit of 100 m. The area of each stratum was expressed in terms of km^2. The area with a 101 - 145 m depth range situated in the eastern Bering Sea, except Region I, was excluded because of inadequate survey efforts in the area as well as an extremely low density of sablefish distribution.

The area north of N59° in the Bering Sea, the Bowers Bank in the Aleutian region, and the Shelikof Strait, the Cook Inlet, Prince William Sound, and the inland waters of the Southeastern part of the Gulf of Alaska were not included in the calculation of the fishing ground area because surveys were not conducted in those areas.

Of the fishing ground area thus obtained, the Kodiak area in the Gulf is the largest, accounting for 20% of the whole area. By region, the Gulf of Alaska is the largest, accounting for 64% of the whole, followed by the Aleutian region accounting for 23%, and the eastern Bering Sea 12%. But, as for the area containing the depth range of over 401 m, which constitutes the major fishing grounds for sablefish, the Aleutian region contains the largest area, accounting for 42% of the whole area with the 401 - 1,000 depth range, followed by the Gulf of Alaska accounting for 36% and the eastern Bering Sea 22%.

Results

1) Catch rate

The geographical distribution of the catch rates per hachi, which is the index of the population density, shows that, as a general tendency, the eastern areas of the Gulf of Alaska, particularly the Southeastern area indicate high rates, and the West Aleutian area and Region IV of the eastern Bering Sea showed lower rates (Fig. ?).

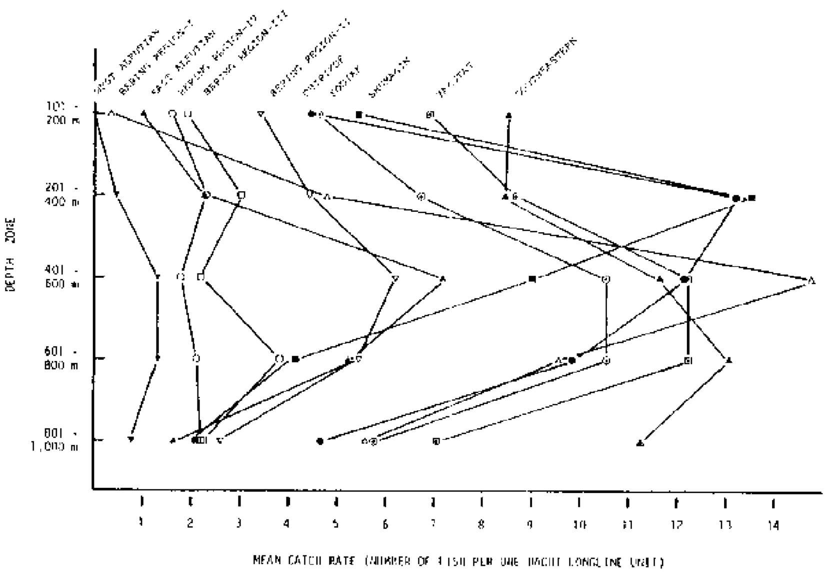

Figure 2. Mean catch rate (number of fish per one hachi longline unit) of sablefish by area and by depth in the eastern Bering Sea, Aleutian region and Gulf of Alaska in the summer of 1982.

By depth of water, the Shumagin and Chirikof areas of the Gulf of Alaska registered high rates in a relatively shallow depth zone of 201 - 400 m (Fig. 2). In other areas the catch rates were higher in the 401 - 600 m or in the 601 - 800 m depth zone. Generally speaking, the catch rates were extremely low in the 101 - 200 m depth zone in the eastern Bering Sea except the Region II and the Aleutian region.

The annual change in the catch rates after 1979 shows a general tendency of an increase in many of the areas, although there are differences in the tendency between strata.

2) Relative population number (RPN)

According to the results of the 1982 surveys, in which data were obtained from all the research areas, the sablefish population living in the 101 - 1,000 m depth range were the most abundant in the Chirikof, Kodiak, and Yakutat areas. These areas alone accounted for 62% of the whole sablefish population in all the researched areas. The population size in the southeastern area where the population density registered a high figure was not so large because the fishing ground area is small. The population size in the eastern Bering Sea and the Aleutian region was about one-tenth of that in the Gulf of Alaska, but the population distribution by depth varied with the region. According to the 1982 survey results in the eastern Bering Sea and the Aleutian region, the population size was larger in the 401 - 1,000 m depth range than in the depth shallower than 400 m. In the Gulf of Alaska, 82% of the population was observed in the 101 - 400 m depth range, and the population living in the range deeper than 401 m accounted for only 18% of the total. For this reason the difference in the population size among regions in the range deeper than 401 m, which is the major fishing ground, was not so large. If the population size in the 401 - 1,000 m depth range in the Gulf of Alaska was taken as 100, the same in the eastern Bering Sea was 35, and that in the Aleutian region was 42.

The distribution of population by area in the Gulf of Alaska shows that the Chirikof, Kodiak, and Yakutat areas contain the largest stocks based on the comparison of the population sizes in the 101 - 1,000 m depth range, but, in the range deeper than 401 m, which is the fishing ground for sablefish, the Kodiak area contains the largest population size. This area accounts for 27% of the whole population in the range deeper than 401 m in the Gulf of Alaska on the average over four years. This is followed by the southeastern area and the Yakutat area, which account for 22% and 21% respectively. The share of the Chirikof area is 18%, taking fourth place among the five areas, showing a difference from a comparison made under the whole range of 101 - 1,000 m. The Shumagin area accounts for 13%, showing a similar share as in the comparison under the 101 - 1,000 m range in the whole of the Gulf of Alaska.

Next, the year-to-year change in the population size will be described by region. As for the change in the Aleutian region from 1979 to 1980, there is no available data of the west Aleutian for 1979, so analysis can only be made of the east Aleutian. However, since most of the stocks in the region are distributed in the east Aleutian, the change in the stocks in the east Aleutian could be considered to represent the change that occurred in the whole Aleutian region. In the said area, the population size increased 149% (2.5 times) in the period from 1979 to 1980. From 1980 on, the estimated values of the relative population size in the whole region were obtained. Namely, the population size decreased 12% in 1981, but increased 13% in 1982 over the previous year. By depth, the population size in the 101 - 400 m range decreased year after year, but the same in the 401 - 1,000 m range increased, showing that the population size in 1982 registered a 141% rise over that in 1979 in the east Aleutian.

In the gulf of Alaska the population size grew 22% in the period from 1979 to 1980. This rate of growth is far lower than the rate of growth observed during the corresponding period in the eastern area of the Aleutian region registering a 149% increase. This difference came from the fact that the entry of an extremely abundant 1977 year class observed in the Aleutian region in 1980 had already occurred in the Gulf of Alaska in 1979. The population size in the Gulf of Alaska in 1981 practically remained unchanged compared with the previous year, but in 1982 the same grew 29% over the previous year. By depth, the annual change in the population size in the 101 - 400 m range is similar to the general trend of the whole population. The population size in the range deeper than 401 m decreased 14% in 1980 from the previous year, but thereafter continued to grow, until in 1982 it registered a 69% growth over 1979.

3) Relative population weight (RPW)

The distribution of and the annual change in the relative values of the biomass among areas or regions are similar to the case of the population size (Table 1). The results of the 1982 surveys reveal that the biomass in the eastern Bering Sea and the Aleutian region was about one-tenth of that in the Gulf of Alaska, which was similar to the case of the population size (Table 1 and Fig. 3). However, there was not so great a difference in the biomass in the depth below 401 m between regions, showing the Gulf of Alaska as 100, and then 28 for the eastern Bering Sea and 35 for the Aleutian region (Table 1). These ratios show a larger difference as compared with the case of the population size. This means that in the Gulf of Alaska the share of medium and large fish in the depth below 401 m is larger than that in the eastern Bering Sea or the Aleutian region.

As for the biomass in the whole depth range of 101 - 1,000 m in the Gulf of Alaska, the Chirikof, Kodiak, and Yakutat areas show large figures (Table 1 and Fig. 4). But, if the comparison were made of the biomass on the average of three years in the depth below 401 m, which is the major fishing ground for sablefish, Kodiak, Southeastern, and Yakutat areas show large figures, similar to the case of the population size. The biomass in the Chirikof area is the fourth and the Shumagin area is the smallest (Table 1 and Fig. 4).

The annual change in the biomass is similar to that in the population size. It shows a rising trend in both the Aleutian region and the Gulf of Alaska. But the degree of the change is different from the case of the population size (Table 1). In the eastern area of the Aleutian region, using the 1979 figure as the basis, the population size in 1982 increased 139%, while the biomass increased 85%. And in the Gulf of Alaska, using the 1979 figure as the basis, the population size grew 61% while the biomass grew 70% in 1982.

Table 1. Relative population weight (RPW) as an index of sablefish biomass in total, 101-400 m and 401-1,000 m depth range of the eastern Bering Sea, Aleutian region and Gulf of Alaska in the summer of 1979-1982.

AREA	YEAR	TOTAL RPW	TOTAL ANNUAL CHANGE (%)	101-400 m RPW	101-400 m ANNUAL CHANGE (%)	401-1,000 m RPW	401-1,000 m ANNUAL CHANGE (%)
EASTERN BERING SEA							
Region-I	1980[a]	1,579		37		1,542	
	1981[b]	5,779	+266	835	+2,157	4,944	+221
	1982[b]	10,628	+ 84	1,762	+ 111	6,866	+ 79
Region-II	1982[b]	16,206		8,406		7,800	
Region-III	1982	3,721		1,664		2,057	
Region-IV	1982	2,983		1,546		1,437	
T O T A L	1982	33,538		13,378		20,160	
ALEUTIAN REGION							
West Aleutian	1980	6,473		42		6,431	
	1981	6,014	- 7	337	+ 702	5,677	- 12
	1982	7,740	+ 29	587	+ 74	7,153	+ 26
East Aleutian	1979	12,545		c		c	
	1980	21,768	+ 74	6,470		15,292	
	1981	21,486	- 1	4,739	- 27	16,747	+ 10
	1982	23,244	+ 8	4,629	- 2	18,615	+ 11
T O T A L	1980	28,241		6,516		21,723	
	1981	27,500	- 3	5,076	- 22	22,424	+ 3
	1982	30,984	+ 13	5,216	+ 3	25,768	+ 15
GULF OF ALASKA							
Shumagin	1979	11,580		c		c	
	1980	17,819	+ 54	12,739		5,030	
	1981	27,851	+ 56	20,886	+ 64	6,963	+ 37
	1982	41,309	+ 48	31,353	+ 50	9,956	+ 43
Chirikof	1979	61,237		c		c	
	1980	57,951	- 5	51,319		5,632	
	1981	52,437	- 10	45,183	- 12	7,254	+ 9
	1982	87,115	+ 65	72,125	+ 60	14,990	+107
Kodiak	1979	55,413		c		c	
	1980	57,945	+ 5	48,955		8,990	
	1981	51,640	- 11	39,030	- 20	12,610	+ 40
	1982	79,715	+ 54	60,026	+ 54	19,689	+ 56
Yakutat	1979	35,148		c		c	
	1980	52,437	+ 49	44,994		7,443	
	1981	66,712	+ 27	55,991	+ 24	10,721	+ 44
	1982	67,076	+ 1	51,872	- 7	15,204	+ 42
Southeastern	1979	25,324		c		c	
	1980	27,982	+ 10	18,656		9,324	
	1981	51,123	+ 83	38,510	+ 106	12,613	+ 35
	1982	44,752	- 12	31,453	- 18	13,299	+ 5
T O T A L	1979	188,702		c		c	
	1980	214,134	+ 13	176,565		37,469	
	1981	249,763	+ 17	199,602	+ 13	56,161	+ 34
	1982	319,967	+ 28	246,829	+ 24	73,138	+ 46

a RPW is considerably underestimated, because a lot of sablefish caught by longline gear was eaten by killer whales in the course of hauling.

b RPW is a little underestimated because of interception of sablefish by killer whales.

c Not available because of incomplete size composition by depth.

4) Size structure of population

Let us discuss here the features of and the change in the size structure of the stocks weighted by the relative value of population. In the eastern Bering Sea the size structure of the stock in 1982 in the 101 - 1,000 m depth range showed a nearly normal pattern of distribution with

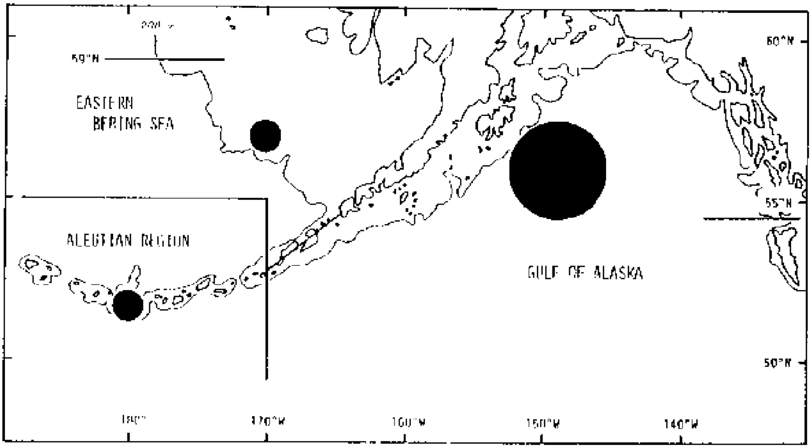

Figure 3. Comparison of regional relative biomass in 101-1,000 m depth range of the eastern Bering Sea, Aleutian region and Gulf of Alaska in the summer of 1982.

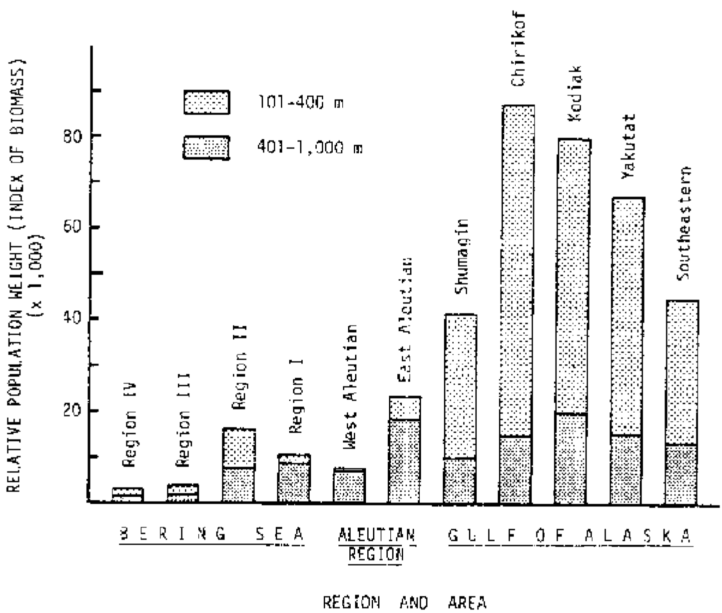

Figure 4. Relative population weight as an index of biomass by area and by depth in 101-1,000 m depth range of the eastern Bering Sea, Aleutian region and Gulf of Alaska in the summer of 1982.

the 56.1 - 58.0 cm as a mode (Fig. 5). The comparison with the case of the Aleutian region, and the Gulf of Alaska shows that the ratio of the sizes over 70.1 cm is extremely small, accounting for only 2% of the whole stock.

In the Aleutian region, an extremely abundant year class, believed to be the 1977 year class, joined the stock in the depth below 100 m in 1980. The abundance of this year class decreased in 1981, but it increased in 1982 over the previous year (Fig. 5). The 1977 year class is rapidly increasing in the size of the fish population with the sizes ranging from 50.1 to 66.0 cm as it grows. The size of the population exceeding 66.1 cm is almost unchanged and stable.

In the Gulf of Alaska, a part of the abundant 1977 year class joined the stock in the depth below 100 m in 1979 (Fig. 5). The abundance of this year class further increased in 1980, but remained unchanged in 1981, and again increased in 1982. As in the Aleutian region, the 1977 year class is rapidly increasing yearly in population with sizes ranging from 50.1 to 66.0 cm. As a result, the pattern of the size structure has changed from a near trapezoid in 1979 to the normal pattern of distribution with the 56.1 to 58.0 cm as a mode in 1982. There is no great change in the stocks of fish with 66.1 cm or larger. This size remains relatively stable.

If the size structure of the stocks is examined by depth, in the eastern Bering Sea there is no difference in the size structure observed due to the depth. In the Aleutian region, the entry of the 1977 year class was observed in 1980 in the depth zone of 101 - 200 m. But this young group of fish disappeared from this depth zone in 1981. In the 201 - 400 m and 401 - 600 m depth zone the 1977 year class of fish are growing in the size structure year after year. Even in the 601 - 800 m zone there are some effects observed of the 1977 year class. In the Gulf of Alaska, being different from the eastern Bering Sea or the Aleutian region, more of the stocks live in the depth range above 400 m. The size structure seen in the 101 - 200 m depth zone reflects the fact that part of an extremely abundant year class joined the stocks in the 101 - 200 m depth zone in 1979. This year class was hardly observed at the time of the 1978 preliminary surveys. Then, the sablefish stocks distributed in the 101 - 200 m depth zone were extremely small. Even in the depth below 200 m the effects of this year class are remarkable, showing that the said year class is helping the fish stocks grow in number as well as in the size structure.

In closing this section, let us divide the whole stock into two groups, namely, the group of small fish with a fork length of 58.0 cm (with average weight of 2.00 kg) or less having lower commercial values, and the group of middle and large size fish with a fork length of more than 58.1 cm having higher commercial values, and examine the trend of the stocks. In the period from 1979 to 1980 the small fish group increased 669% in number and 618% in weight in the east Aleutian area (Table 2). In the Gulf of Alaska the same increased 46% in number and 55% in weight in the corresponding period. The reason for a lower rate of increase in the Gulf of Alaska as compared with the Aleutian region is that the entry
of a certain year class of fish in a great number which occurred in 1980 in the Aleutian region had already occurred in the Gulf of Alaska in 1979. The small fish group decreased in both number and weight in both of the regions in 1981. But in 1982, while the same decreased 4% in

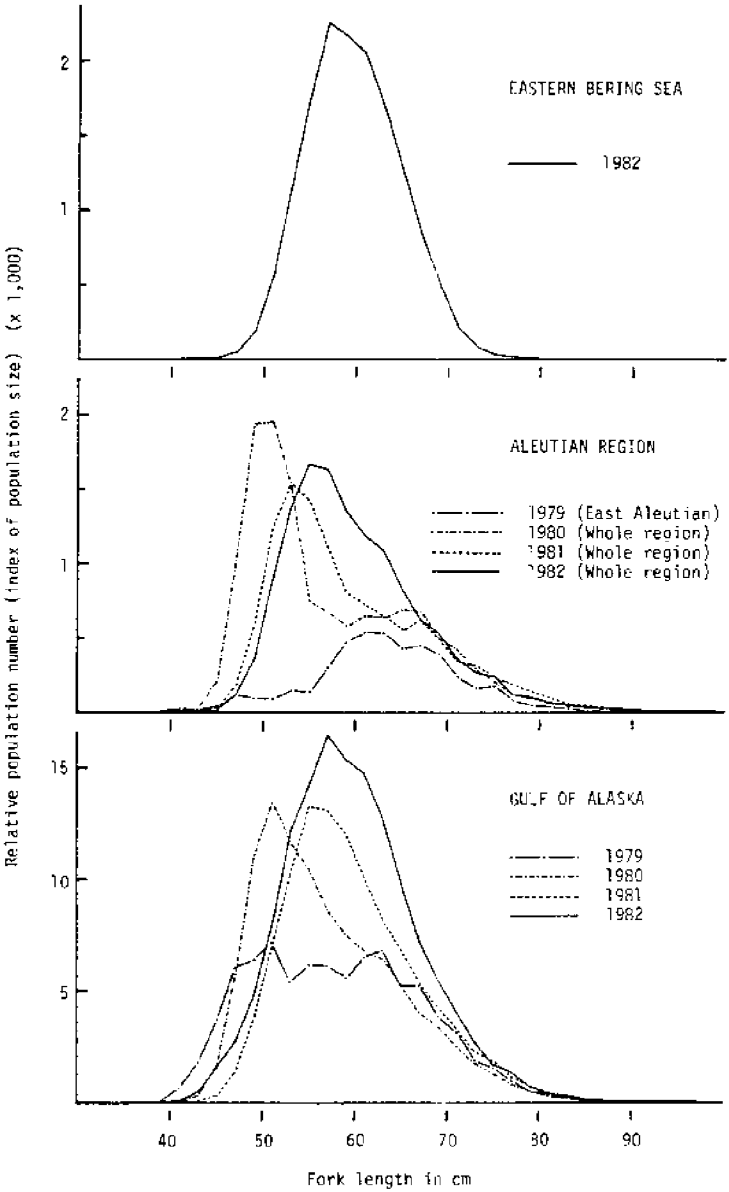

Figure 5. Size structures of sablefish population weighted by relative population numbers as an index of population size in 101-1,000 depth range of the eastern Bering Sea, Aleutian region and Gulf of Alaska in the summer of 1979-1982.

Table 2. Relative population weight (RPW) as an index of sablefish biomass in total, small-size (<58.0 cm in FL) and middle-large-size (>58.1 cm in FL) in the eastern Bering Sea, Aleutian region and Gulf of Alaska in the summer of 1979-1982.

AREA	YEAR	TOTAL RPW	TOTAL ANNUAL CHANGE (%)	SMALL-SIZE RPW	SMALL-SIZE ANNUAL CHANGE (%)	MIDDLE-LARGE-SIZE RPW	MIDDLE-LARGE-SIZE ANNUAL CHANGE (%)
EASTERN BERING SEA							
Region-I	1980[a]	1,579		688		891	
	1981[b]	5,779	+266	1,363	+ 98	4,416	+396
	1982[b]	10,628	+ 84	2,018	+ 48	8,610	+ 95
Region-II	1982[b]	15,206		6,695		9,511	
Region-III	1982	3,721		669		3,052	
Region-IV	1982	2,983		706		2,277	
T O T A L	1982	33,538		10,088		23,450	
ALEUTIAN REGION							
West Aleutian	1980	6,473		262		6,211	
	1981	6,014	- 7	254	- 3	5,760	- 7
	1982	7,740	+ 29	395	+ 56	7,345	+ 28
East Aleutian	1979	12,545		1,459		11,086	
	1980	21,768	+ 74	10,474	+618	11,294	+ 2
	1981	21,486	- 1	9,169	- 12	12,317	+ 9
	1982	23,244	+ 8	9,335	+ 2	13,909	+ 13
T O T A L	1980	28,241		10,736		17,505	
	1981	27,500	- 3	9,423	- 12	18,077	+ 3
	1982	30,984	+ 13	9,730	+ 3	21,254	+ 18
GULF OF ALASKA							
Shumagin	1979	11,580		4,087		7,493	
	1980	17,819	+ 54	6,698	+ 64	11,121	+ 48
	1981	27,851	+ 56	11,420	+ 70	16,431	+ 48
	1982	41,309	+ 48	8,667	- 24	32,642	+ 99
Chirikof	1979	61,237		23,953		37,284	
	1980	57,951	- 5	18,831	- 21	39,120	+ 5
	1981	52,437	- 10	16,775	- 11	35,662	- 9
	1982	87,115	+ 66	22,734	+ 36	64,381	+ 81
Kodiak	1979	55,413		15,360		40,053	
	1980	57,945	+ 5	26,939	+ 75	31,006	- 23
	1981	51,640	- 11	18,772	- 30	32,868	+ 6
	1982	79,715	+ 54	24,338	+ 30	55,377	+ 68
Yakutat	1979	35,148		9,924		25,224	
	1980	52,437	+ 49	26,992	+172	25,445	+ 1
	1981	66,712	+ 27	20,420	- 24	46,292	+ 82
	1982	67,076	+ [illegible]	27,445	+ 34	39,631	- 14
Southeastern	1979	25,324		5,433		19,897	
	1980	27,962	+ 10	11,389	+110	16,593	- 17
	1981	51,123	+ 83	10,916	- 4	40,207	+142
	1982	44,752	- 12	11,664	+ 7	33,088	- 18
T O T A L	1979	188,702		56,757		129,945	
	1980	214,134	+ 13	90,849	+ 55	123,285	- 5
	1981	249,763	+ 17	78,303	- 14	171,460	+ 39
	1982	315,967	+ 26	94,845	+ 21	221,119	+ 31

a RPW is considerably underestimated, because a lot of sablefish caught by longline gear was eaten by killer whales in the course of hauling.

b RPW is a little underestimated because of interception of sablefish by killer whales.

number, it increased 3% in weight in the Aleutian region. And in the gulf of Alaska the same increased 24% in number and 21% in weight.

The middle and large size fish group of 58.1 cm or larger increased in both number and weight year after year in the Aleutian region. The stock size of this group in 1982 increased 40% in number and 25% in weight from 1979 in the east Aleutian. In the Gulf of Alaska, the stock size of this group in 1980 decreased 2% in number and 5% in weight from the previous year, but in 1981 and 1982 increased in both number and weight. In 1982, the stock size of the fish group of 58.1 cm or larger in the gulf of Alaska increased 84% in number and 73% in weight from the levels of 1979.

Discussion

There is no precedent of a large-scale systematic groundfish survey conducted in the past with the use of bottom longline gear. Therefore, it was necessary to proceed with the survey plans carefully. The important point is whether the abundance of the sablefish stocks can be estimated without variability through the longline surveys. The advantages of the longline surveys are that there are less limitations in the operation due to the bottom contours or the water depth, and that the size of the research vessel or the horsepower of the engine will not affect the fishing efficiency of the fishing gear, and that the fishing gear is so simple that a gap in fishing technique will not occur due to a change of personnel, making it possible to conduct the surveys under similar conditions year after year. The disadvantages are that the stock abundance can only be estimated in terms of relative values, and that this method is only effective to limited kinds of fish species.

The longline gear has no mobility. Therefore, it is impossible with longline gear to cover many survey areas in a limited span of time as in the case of trawl surveys. For this reason, for the purpose of an abundance survey the longline is not suited for species of fish that tend to move in schools, and are distributed in patches. Yet the distribution patterns are always changeable, and under these circumstances it is difficult to obtain stable estimates of the stock abundance with small variance. It was found from the results of the 1978 surveys that although the distribution density of the sablefish greatly varies with the area or the water depth, the variance in the distribution density is small within the same stratum between the survey stations. This shows that the sablefish are relatively evenly distributed. Thus, it was determined that this species was suited for the longline surveys.

With regard to the longline surveys conducted, the survey efforts exerted in the 101 - 200 m depth zone in the Gulf of Alaska were not enough. Therefore, the accuracy of the estimated value of the relative stock size in this depth zone is questionable. It is also noted that there occurs a gap in the soaking time period of at least 5 - 6 hours between the time hauling began and the time it was completed. Also, the fishing ground area in the deep depth range is understated, and there is a gap between the fishing depth for recording and the actual fishing depth. These are the unsolved problems.

Regarding the soaking time, the experiments made with three different time periods of 6 hours, 12 hours, and 18 hours during the 1979 longline survey show there is no difference in the catch rate. It could not be determined through these experiments whether the soaking time gap of 5 - 6 hours would have an effect on catch. Setting the longline is done from the shoreside outward and the ship goes back to the starting point in order to haul the line. This method remained unchanged regardless of the year or the survey station. Therefore, if there should be any difference in fish catch due to the soaking time, there could be a difference in the stock size in the shallow depth range and in the deep depth range as compared with the results of the analysis. This point should be confirmed through experiments in the future. Regarding the fishing ground area, the difference between the area calculated on the basis of the chart and the actual area is not more than 10% at the steepest contour where the water depth most sharply changed. At most of the places, the difference is not much. Therefore, the general tendency is that there is no gap which will render serious problems, though the stock size in the deep depth range may be somewhat underestimated.

What will change by adjusting the soaking time and the fishing ground area will be the stock size in each of the depth zones. It is considered that the relative values of the stock size among the areas in the same depth zone will not basically differ from the results of the analysis in this paper. Therefore, the stock sizes and these annual changes in areas or regions can be amply grasped from the data herein submitted.

It is important to accurately record the catch depths. But, it is extremely difficult to accurately measure the depth for every hachi in the longline survey. The catch depth of record is adjusted deeper than the actual catch depth. But as far as the stratum is concerned, that gap is considered constant. There should be no problem in analyzing the trend of stocks without adjusting such a gap.

The relative size of stocks estimated on the basis of the results of the longline surveys conducted since 1979 is considered to be very stable as an estimated value of the stock abundance through field investigations. The variations in the population size and the biomass were principally caused by the entry of an extremely abundant year class, which occurred coincidentally with the survey period. It can be said from the above observations that, although there are still problems, the results of the longline surveys are reasonably credible, and provide very important materials and information in the analysis of the trends of the sablefish stocks over an extensive area of water. The remaining problems are to consider to make experiments to clarify the relationship between the average catch rate and the actual stock density as well as to exert efforts to establish not a relative value but an absolute biomass.

Summary

The results of the longline surveys conducted over a total period of four years can be summarized as follows: 1) The sablefish stocks in 1982 as compared with those in 1979 increased 139% in number and 85% in weight in the east area of the Aleutian region, and increased 61% in number and 70% in weight in the Gulf of Alaska. 2) The sablefish population in 1982 as compared with that in 1979 living in the 401 - 1,000 m depth range, which is the major fishing ground for sablefish, increased 141% in the east area of the Aleutian region, and increased 69% in the Gulf of Alaska. And the biomass of the same fish in the said depth range grew 19% in the Aleutian region and 95% in the Gulf of Alaska in 1982 over 1980. 3) The middle and large size sablefish stocks with the fork length of 58.1 cm or larger, having high commercial values, increased 40% in number and 25% in weight in 1982 as compared with 1979 in the east area of the Aleutian region. In the Gulf of Alaska they increased 84% in number and 73% in weight in 1982 over 1979.

4) The sharp increase in the stock was caused by the entry in 1979 and 1980 of an extremely abundant year class, believed to be the 1977 year class, in each of the areas. 5) The size structure of the stocks greatly changed in a short period of time under the influence of the extremely strong 1977 year class. 6) Since the remarkable year class, believed to be the 1977 year class, there has been no remarkable occurrence of abundant groups of individuals. 7) On the basis of the 1982 surveys, the biomass in the eastern Bering Sea and the Aleutian region was respectively estimated to be about one-tenth of that in the Gulf of Alaska. As for the biomass in the range deeper than 400 m, there is not much difference between regions. If the biomass in the Gulf of Alaska was taken as 100, in the eastern Bering Sea it would be 28, and in the Aleutian region it would be 35.

Condition of sablefish stocks in recent years in the eastern Bering Sea, Aleutian region and Gulf of Alaska based on the results of field surveys

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Abstract

The groundfish surveys in 1979 and 1980 have clearly proved the entry of a strong year class to the exploitable stocks in a large expanse of ocean extending from the eastern Bering Sea to Canadian waters. This strong year class has an extremely high abundance, which is believed to be the 1977 year class which brought about a drastic change to the abundance and size structure of the stocks shortly after it was recruited. This leads us to think that the sablefish recruitment is not stable from year to year, but that it is largely influenced by the entry of a strong year class which occurs suddenly. Furthermore, the latest studies reveal that the life of sablefish is much longer than previously thought, and that the stocks consist of the fish of many year classes. In view of these points, particularly of the occurrence of a strong year class, the stock assessment through a production model previously applied is not considered to give an adequate evaluation. In this paper, the recent stock condition of sablefish was examined on the basis of the results of each of the groundfish surveys, and it was determined that the ABC (Acceptable Biological Catch) after 1983 could be set at 3,000-5,000 tons in the eastern Bering Sea, 2,300 tons in the Aleutian region, and 24,000 tons in the Gulf of Alaska.

Introduction

Sablefish (Anoplopoma fimbria) is one of the important groundfish species fished in the North Pacific. The distribution of sablefish extends over a wide area. On the Asia side, distribution occurs from the Suruga Bay to Hokkaido, then through the east coast of Kamchatka to Cape Navarin off Siberia. On the American side, distribution is seen from the eastern Bering Sea to the Aleutian region, and throughout the Gulf of Alaska to Baja, California. The population density is high on the American side, particularly in the southeastern part of the Gulf of Alaska, and is very low on the Asian side.

Sablefish have been fished by the North American fishermen since the end of the 1800s. The fishery operations then were extremely limited to regional operations, but in the 1960s, Japan and the Soviet Union began to engage in large-scale groundfish fisheries in the Bering Sea as well as in the northeastern Pacific Ocean. Correspondingly, the fishery operations for sablefish were widely expanded over the major distribution areas. The sablefish catch by all nations concerned registered a peak of 66,700 tons in 1972. However, the annual catch thereafter began to fall under the catch limitations imposed by the United States and Canada, and the estimated catch in 1980 was 25,000 tons.

The trends of sablefish stocks have been analyzed on the basis of the CPUE data obtained by the Japanese longline vessels that have consistently maintained their fishery operations mainly for sablefish in most of the major distribution areas. In 1977, the United States and Canada enacted laws establishing a 200 mile fishery zone, and imposed new and various regulatory measures on foreign fleets operating fisheries within a 200 mile zone from their shores. As a result, the CPUE data of the Japanese longline vessels after 1977 not only lost the continuity with the past, but it became difficult to use such data as an index to correctly represent the trend of the overall stocks. Since 1977, field surveys of groundfish resources have actively been conducted by research institutes of the countries concerned.

These groundfish surveys have provided very useful information for the study of sablefish biology. In this paper, the recent condition of sablefish stocks is assessed on the basis of the results of the Japan-U.S. joint longline surveys as well as the results of the longline survey by the _Aomori maru_ and the U.S.-Japan joint trawl surveys in the eastern Bering Sea, Aleutian region and Gulf of Alaska. The author would like to further examine the ABC (Acceptable Biological Catch) of sablefish post-1983 in these regions, as well as some management problems.

Stock Condition in Recent Years

Commissioned by the Fisheries Agency of Japan, the _Aomori maru_, a training boat of the fishery high school of Aomori Prefecture, conducted a groundfish survey in 1969 in the Gulf of Alaska with the use of bottom longline gear. The purpose of the cruise of the _Aomori maru_ was chiefly to provide training in actual fishery operations to the students, and to obtain the resulting data. This type of cruise by the _Aomori maru_ was conducted only once. However, the information obtained through this operation by a non-commercial vessel regarding the population density is very valuable considering it was done at a time immediately after the Japanese longline fishery began to be undertaken over a large area of the northeast Pacific Ocean. The operations were mainly conducted in the depth range of 401-800 m in the Kodiak and Yakutat areas (Fig. 1). The operations in the said areas lasted 19 days, using 3,454 hachi and resulting in a total catch of 33,444 sablefish. The average catch rate in the Kodiak-Yakutat region was 9.68 fish per hachi (Table 1). Based on the size composition data, the catch weight per hachi was calculated to be 30.2 kg.

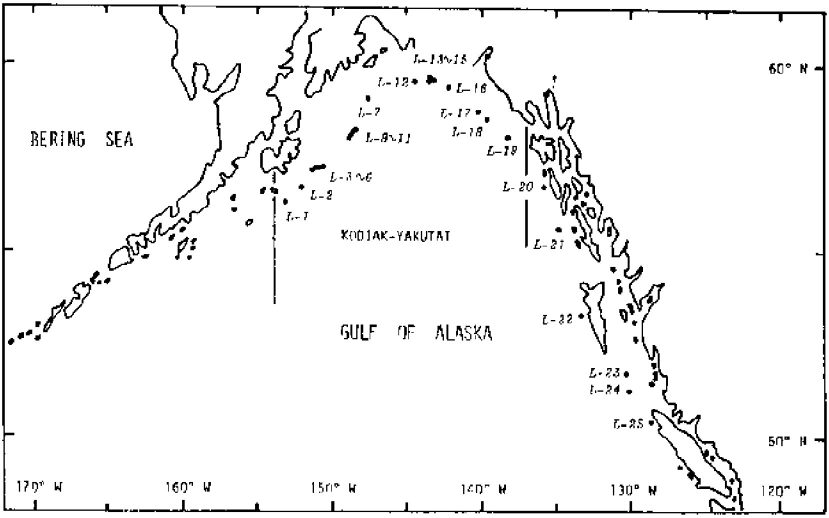

Figure 1. Longline operation area and positions by Aomori maru in the Gulf of Alaska in the summer of 1969.

Table 1. Records of longline operations by Aomori maru in the Gulf of Alaska in the summer of 1969.

Area	Operation number	Date	Depth (m)	Number of hachi used	Number of hooks used	Bait	Mean soaking times	Number of sablefish caught	Catch* rates
Kodiak	L- 1	June 11	450-730	120	6,600	Squid	8^h-40^m	1,226	10.22
	L- 2	12	450-830	160	8,800	"	9 -35	1,111	6.94
	L- 3	13	410-630	180	9,900	"	10 -07	2,053	11.41
	L- 4	14	500-550	200	11,000	"	10 -16	2,347	11.74
	L- 5	15	580-700	230	12,650	"	13 -30	2,219	9.65
	L- 6	16	510-600	240	13,200	"	16 -20	2,121	8.84
	L- 7	18	760-800	150	8,250	"	11 -34	940	6.27
	L- 8	19	480-610	215	11,825	"	15 -35	1,921	8.93
	L- 9	20	500-750	220	12,100	"	14 -00	1,249	5.68
	L-10	21	500-700	249	13,695	"	14 -14	1,977	7.94
	L-11	22	500-700	160	8,800	"	11 -13	855	5.34
				2,124	116,820			18,019	8.45
Yakutat	L-12	June 24	550-600	170	9,350	Squid	10^h-00^m	1,968	11.58
	L-13	25	600-750	180	9,900	"	11 -45	2,774	15.41
	L-14	26	550-700	180	9,900	"	12 -50	2,315	12.86
	L-15	27	550-750	170	9,350	"	11 -30	1,314	7.73
	L-16	28	500-680	180	9,900	"	11 -05	2,333	12.96
	L-17	29	500-800	190	10,450	"	10 -50	2,226	11.72
	L-18	30	550-800	190	10,450	"	15 -00	1,675	8.82
	L-19	July 1	600-650	70	3,850	"	8 -03	820	11.71
				1,330	73,150			15,425	11.60
Southeastern	L-20	July 2	500-780	80	4,400	Squid	7^h-52^m	1,097	13.71
	L-21	3	600-800	50	2,750	"	8 -10	806	16.12
				130	7,150			1,903	14.92
Charlotte	L-22	July 4	740-870	50	2,750	Squid	6^h-00^m	652	13.04
	L-23	5	500-650	60	3,300	"	7 -10	643	10.72
	L-24	6	720-880	60	3,300	"	4 -00	864	14.40
				170	9,350			2,159	12.72
Vancouver	L-25	July 7	640-1,450	45	2,475	Squid	6^h-35^m	383	8.51

* Number of fish caught per hachi.

In the *Aomori maru* survey, longline gear with 55 hooks per hachi was used. But, in the Japan-U.S. joint longline surveys conducted since 1979, longline gear with 45 hooks was used. For the purpose of comparison, if the value from the *Aomori maru* is converted in terms of 45 hooks on the basis of the relationship between the hook space and the average catch rate (Sasaki, 1979), the average catch per hachi in 1969 would be 8.22 in number and 25.4 kg in weight.

In order to make the comparison between the results of the Japan-U.S. joint longline surveys since 1979 and the results of the 1969 *Aomori maru* survey, calculation was made on the average catch in number and in weight per hachi in the 401-800 m depth range of the Kodiak-Yakutat region from the data of joint longline surveys since 1979. The results are as follows:

Average catch	1969	1979	1980	1981	1982
Number/hachi	8.22	5.58	5.60	8.71	11.48
Weight/hachi(kg)	25.4	16.7	15.6	22.3	30.2

The exploitation of the sablefish stocks in the Gulf of Alaska was intensified after 1968, when Japan began to operate longline fisheries. Even before that year, there were some Japanese vessels operating to catch sablefish with the use of longline gear. U.S. and Canadian fishermen, too, have long been engaged in this type of fishing. But, these fisheries were limited to certain sites. So, it is assumed that the stock level in the whole Gulf of Alaska was in a slightly exploited state. The stock condition in 1979 and 1980 indicated a reduction of 32% in number and 34-39% in weight from the level of 1969. In 1981 the stock condition rose 6% over the level of 1969, and in 1982 the same rose 40% in number and 19% in weight over 1969. The size composition data indicates the fact that this increase of stocks was caused by a large influx of extremely abundant young fish believed to be the 1977 year class, at a depth of 401-800 m since 1980 (Fig. 2). The size composition in 1979 and 1980 as compared with that in 1969 shows that the overall curve was lowered in proportion to a decrease in abundance. But, the range and mode of the size composition remains almost unchanged as compared with 10 years ago, showing that the sablefish stocks in the 401-800 m depth range of Kodiak and Yakutat areas still maintain an extremely stable composition even after 10 years of full-scale exploitation.

The above examinations are based on the survey data from the 401 - 800 m depth range in the Kodiak and Yakutat areas; they do not apply to the stock condition in the whole Gulf of Alaska. Since 1969 the sablefish stocks in the Gulf of Alaska have chiefly been exploited by the Japanese longline vessels in the 401 - 800 m depth range. It is also noted that the biomass in the 401 - 800 m depth range in the Kodiak-Yakutat region accounts for about a half of the total of the biomass in the 401 - 800 m depth range in the whole Gulf of Alaska. Therefore, we feel we should extend the results of our studies over the whole Gulf of Alaska region.

As earlier stated, the level of the adult stocks in 1979 in the 401 - 800 m depth range in the Gulf of Alaska as compared with that in 1969 was believed to have declined 32% in number and 34% in weight. In the

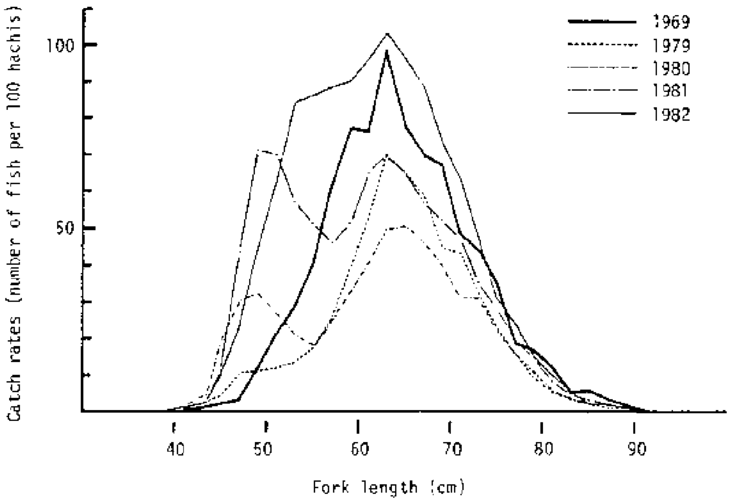

Figure 2. Size compositions of sablefish weighted by catch rates in 401-800 m depth range of the Kodiak-Yakutat region in the Gulf of Alaska from 1969 and 1979-1982 longline surveys.

period from 1969 to 1978 the cumulative catch by all the nations concerned in the Gulf of Alaska amounted to 242,300 tons, with an annual average of 24,230 tons. The major part of this catch was taken at the depth below 401 m by the Japanese longline vessels that were not allowed to catch sablefish in the depth above 400 m. The CPUE (kg/hachi) in 1969 obtained from these longline vessels was 23.5. The CPUE in 1976 was 18.6, 21% less than in 1969. The CPUE in 1979 was 10.9, 54% less than in 1969. It is noted that, as compared to 18.6 indicated in 1976, the CPUE in 1977, when the U.S. enacted a law establishing a 200-mile zone, was 13.9, showing a drastic drop. This clearly shows that there is a qualitative discontinuity between the data before 1976 and the data after 1977. Under the circumstances, considering that the CPUE in 1976 declined 21% from 1969, the estimated 34% reduction in the biomass in 1979 from the level of 1969 on the basis of the data obtained by research vessels is considered substantially reasonable even in view of the change in the CPUE as reported by commercial vessels.

To summarize the above observations, the biomass in the Gulf of Alaska was almost in the unexploited state in 1969. Thereafter an annual catch of 24,000 tons on the average has been maintained. After 10 years, in 1979 the biomass decreased 34% from the level of 1969. The stock condition in 1979 was still favorable in both abundance and size structure. This condition was maintained effectively using the irregular occurrence of a strong year class. The stock condition in 1982 sharply expanded on account of recruitment of extremely abundant young fish, which are believed to be the 1977 year class, showing a 19% rise in the biomass from the level of 1969. Further, the middle and large size stocks with fork length of 58.1 cm or larger increased 73% over 1979. After 1983 the population may decrease, but it is expected that the biomass will continue to increase for the time being.

Estimation of Biomass in 1982

Since 1979, large-scale trawl surveys have been carried out jointly by Japan and the U.S. in the eastern Bering Sea and the Aleutian region including the continental slopes. Trawl surveys as well as longline surveys were conducted in 1980 in the Aleutian region and in 1982 in the eastern Bering Sea. The reports on the 1982 trawl surveys have not been released yet. Based on the 1979 surveys the sablefish biomass in the eastern Bering Sea was estimated to be 45,400 tons (Bakkala et al., 1981). Only preliminary information is available on the results of the 1981 surveys in the eastern Bering Sea. The biomass was estimated to be 47,000 tons, 3.5% larger than in 1979 (NWAFC, computer output, July, 1982). According to the 1979 survey report, 97.2% (44,200 tons) of the sablefish stocks were concentrated in the southeastern waters off the Pribilof Islands. In the Aleutian region, a preliminary report of the 1980 trawl surveys reveals that the biomass of sablefish at the 101 - 900 m depth in the Aleutian region excluding Bowers Bank was estimated to amount to 19,464 tons (NWAFC computer output, Feb., 1983).

In 1980, aside from the trawl surveys, the longline surveys were conducted in the Aleutian region, and the relative value of the sablefish bio- mass in the 101 - 900 m depth range was estimated to be 23,602. In 1982, the longline surveys were conducted in the eastern Bering Sea, the Aleutian region, and the Gulf of Alaska, and the relative values of the biomass in respective regions were obtained. If the estimation was made of the biomass in respective regions in 1982 by relating the biomass estimates of the 1980 trawl survey conducted in the Aleutian region and the relative values of the biomass obtained by the longline survey, the biomass was estimated at 27,658 tons in the eastern Bering Sea, 25,552 tons in the Aleutian region, and 263,869 tons in the Gulf of Alaska. Likewise, the biomass in the Gulf of Alaska in 1979 was estimated at 155,618 tons. This shows the biomass in 1982 increased by 108,251 tons from the level of 1979.

The longline survey area in the eastern Bering Sea did not extend beyond N59^0 unlike the case of the trawl surveys. The ratios of the biomass in respective regions are clear from the results of the 1981 trawl surveys. If the longline survey results were extended over the whole area of the eastern Bering Sea by applying those ratios, the biomass in the whole eastern Bering Sea in 1982 could be estimated at 32,788 tons. The biomass in the eastern Bering Sea in 1981 was estimated at 47,000 tons on the basis of the trawl surveys. This figure did not include Region I. Taking that into account, the biomass in the whole eastern Bering Sea in 1981 could be estimated to amount to approximately 55,000 tons. Then, the biomass of 32,788 tons for 1982 earlier estimated through the relationship of the biomass estimate by trawl surveys to the relative values of the biomass obtained by longline surveys is considerably lower as compared with the foregoing estimate.

In an area like the Aleutian region where the variations in depth are sharp and the bottom contours are rough, a stable trawling operation is extremely difficult. The difficulty increases as the water gets deeper. In fact, the 1980 trawl surveys in the Aleutian region were conducted under many restrictions. In addition, the estimate of the biomass was tried, assuming the vulnerability of the trawl tear as 1.00. Taking these into consideration, the estimate of 19,464 tons of sablefish biomass in the Aleutian region in 1980 should be considerably underestimated.

Acceptable Biological Catch after 1983

It is necessary to maintain a certain level of adult stock in order to effectively use the opportunity of the rising of a strong year class, which is difficult to forecast. The level of adult stock which should be maintained is not clear at this time. Although the size of the adult stock in 1977 is not clear, assuming that it is not so different from the 1979 level, the level of adult stock in 1979 may be high enough to be able to breed a year class having a similar abundance to the 1977 year class, given the proper environment. This could be a yardstick in determining the biomass level that is capable of breeding an abundant year class.

As earlier mentioned, the biomass level in the Gulf of Alaska in 1982 is higher by 19% than that in 1969 when the stock condition was almost in the unexploited situation. In the 10 years since 1969, namely, in 1979 the biomass level declined about 34%. The abundance and size structure were maintained and capable of effectively using the irregular occurrence of a strong year class. There seems to be no direct relationship between the size of adult stock and the recruitment. There is no guarantee that recruitment will increase if the biomass increased over the level of 1979. Therefore, if consideration were given to maintaining the biomass at a level not lower than the 1979 level, an annual catch of 24,000 tons, (the average catch for the 10 years from 1969 to 1978), if maintained for the next 10 years, will not cause a reduction in the biomass level in the Gulf of Alaska below the level of 1979. The catch level of 24,000 tons represents 9% of 263,869 tons, which was the biomass in the Gulf of Alaska in 1982. Since the estimated biomass in 1982 was considerably understated, the exploitation rate of the stocks through the catch of 24,000 tons will actually be far lower than 9%.

Following the case of the Gulf of Alaska, if the exploitable rate of 9% should be applied to the current biomass estimated in 1982 in the eastern Bering Sea and the Aleutian region to determine the ABC in 1983 in these regions, the amounts are 3,000 tons in the eastern Bering Sea and 2,300 tons in the Aleutian region. The biomass estimated by the trawl surveys in the eastern Bering Sea in 1981 amounted to 55,000 tons. Assuming that no change occurred in the biomass in 1982 as compared with 1981, the ABC in 1983 is estimated at 5,000 tons, which is 9% of 55,000 tons. The exploitable rate of the stocks based on this catch level shall actually be considerably lower than 9%, considering that the current biomass estimate is quite understated.

Discussion

In recent years field research has actively been undertaken by the research institutes of various countries, aside from the Japan-U.S. longline surveys. All these surveys have clearly established the entry of a strong year class having a high abundance in a large expanse of waters extending from the eastern Bering Sea to the Canadian waters in 1979 or 1980 (Bakkala et al., 1981; Beamish et al., 1980; Zenger, 1981). This year class is tentatively considered as the 1977 year class. The abundance of this year class is extremely high so that it brought about a sharp change to the abundance and the size structure of all the stocks as it entered.

As the surveys up to 1982 reveal, no remarkably abundant year class since the occurrence of the strong year class believed to be 1977 has emerged. This leads us to think that the sablefish recruitment is not stable from year to year, but that it is largely influenced by the entry of a strong year class which occurs suddenly. So far, sablefish stock assessment and stock management have been conducted following the MSY theory which is based on the production model (Low and Wespestad, 1979; Sasaki, 1978; U.S. Department of Commerce, 1978). If it is true that recruitment is not stable, that the life of the sablefish is longer than previously thought (Beamish and Chilton, 1982), and that the stocks consist of many year classes, it can be said that the stock analysis results through the production model based on the catch and effort data obtained from a relatively short period of fishing will not provide a reasonable assessment. If it is true that the biomass fluctuations of the sablefish are affected by the occurrence of highly abundant strong year classes, it will be possible to estimate the maximum sustainable yield expected from the strong year classes in the future by estimating the recruitment of strong year classes through field investigations and by calculating the yield per recruit. A number of parameters are necessary to estimate the maximum sustainable yield from the recruitment. In the case of sablefish, reasonably reliable values of these parameters are not available yet. Therefore, at this time it is difficult to accurately estimate the maximum sustainable yield from the said strong year class which is believed to be the 1977 year class using a yield per recruit model.

In this paper, we have estimated the ABC after 1983 on the basis of the results of a variety of groundfish surveys made by research vessels. These estimates are based on the assumption that the natural fluctuations of the biomass in the future will not differ so much from the fluctuations observed from 1969 to 1978. It will be necessary to continue extensive surveys and to carefully keep track of the general change that may occur in the sablefish stocks. At the same time, it is important to enhance the reliability of the variety of parameters necessary for a stock model analysis so that we will be able to make stock analyses through models in the future. The current biomass level in the Gulf of Alaska is considered high. Therefore, we consider it possible to maintain the allowable catch indicated in this paper.

In the eastern Bering Sea and the Aleutian region, sablefish spawning is not effectively linked to the reproduction of the fish stocks. The stocks in these regions are considered to have been maintained by the fish that migrated chiefly from the northeastern Pacific (Kodolov, 1968). It has been proven by the tagging experiments that the sablefish stocks from the eastern Bering Sea and the Aleutian region and those from the northeastern Pacific mix with each other (Pasquale, 1964; Pattie, 1979; Sasaki, 1979). It is impossible that all the sablefish in the two regions will return to the northeastern Pacific, but it is possible that many of them will just remain in the two regions. From the point of view of the overall sablefish stocks in the North Pacific, those remaining stocks can be considered as emigrant stocks that do not contribute to reproduction. Although it may not be necessary to pay particular attention to maintaining these stocks, since there is no accurate information, it may be reasonable to keep the exploitable rate after 1983 at 9% of the biomass herein estimated. At any rate, it will be necessary to clarify the scale and pace of inter-mixture of stocks between the regions.

The sablefish stocks in the Gulf of Alaska are managed under the division of three districts. According to the results of the 1982 longline surveys, the difference in the stock size between the areas has been considerably narrowed as compared with the previous year. This leads us to think that the inter-mixture between the areas are quite active. The results of tagging experiments made in recent years also indicate an active migration of sablefish in the Gulf of Alaska (Sasaki, 1980). Therefore, we think there is no reason for managing the stocks under divisions. But, if it is considered necessary to manage the stocks under divisions for a reason other than biological reasons, the management of stocks should be done through allocating the allowable catch in proportion to the biomass. The results of the longline surveys reveal that the ratios of the biomass among districts are 13% for the western district (Shumagin area), 52% for the central district (Cherikof and Kodiak area), and 35% for the eastern district (Yakutat and Southeastern area).

In addition, Bracken (1982) concluded, on the basis of the tagging experiments, that the sablefish in the Gulf of Alaska actively migrate. At the same time, he considered that the young sablefish that occurred in southeastern Alaska migrate west where they grow, and then return to southeastern Alaska for spawning. If this is so, the size composition in the Shumagin and Chirikof areas, which are in the west, should be small as compared with the size composition in the Yakutat and Southeastern areas, which are in the east. However, no such tendency has been observed. From this fact it is thought that, though there may be such movement by some of the fish, the majority of the fish do not make such regular movement. It follows that, if the exploitable rate in the western district of the Gulf of Alaska is controlled, the stock abundance in the east cannot be expected to rise.

Conclusion

After examining all the results of various field surveys made by the longline vessels as well as by other types of research vessels, it can be established that the ABC (Acceptable Biological Catch) for sablefish after 1983 will be 3,000-5,000 tons in the eastern Bering Sea, 2,300 tons in the Aleutian region, and 24,000 tons in the Gulf of Alaska. If the 24,000 tons in the Gulf of Alaska should be divided under the three management districts in proportion to the current biomass, the figures should be 3,100 tons in the western district, 12,500 tons in the central district, and 8,400 tons in the eastern district.

References Cited

Bakkala, R., K. Wakabayashi, J. Traynor, H. Yamaguchi, K. Okada, M. Nelson, T. Sample, and M. Alton. 1981. Results of cooperative U.S.-Japan groundfish investigations in the Bering Sea during May-August 1979. Northwest and Alaska Fisheries Center, National Marine Fisheries Service, NOAA, 2725 Montlake Blvd. E., Seattle, WA 98112 (Unpubl. MS).

Beamish, R., C. Houle, and R. Scarsbrook. 1980. A summary of sablefish tagging and biological studies conducted during 1979 by the Pacific Biological Station. Canada MS Rep. Fish. Aquat. Sci. 1588 : 194 p.

Beamish R., D. Chilton. 1982. Preliminary evaluation of a method to determine the age of sablefish (Anoplopoma fimbria). Canadian Journal of Fish. and Aquat. Sci. 39(2) : 277-287.

Bracken, B. 1982. Sablefish (*Anoplopoma fimbria*) migration in the Gulf of Alaska based on Gulf-wide tag recoveries, 1973-1981. ADF&G Informational leaflet 199 : 24 p.

Kodolov, L. 1968. Reproduction of the sablefish (*Anoplopoma fimbria* (Pall.)). Prob. Ichthy., 8(3) : 531-535.

Low, L. and V. Wespestad. 1979. General production models on sablefish in the North Pacific. (Document submitted to International North Pacific Fisheries Commission, January 1979). 16 p. NWAFC, NMFS, NOAA, 2725 Montlake Blvd. E., Seattle, WA 98112.

Pasquale, N. 1964. Notable migrations of sablefish tagged in Puget Sound. Washington State Dept. of Fisheries, Fisheries Research Papers. 2(3) : 68.

Pattie, B. 1970. Two additional long-range migrations of sablefish tagged in Puget Sound. Washington State Department of Fisheries, Technical Report 5 : 22-23.

Sasaki, T. 1978. Recalculation of longline effort and stock assessment of blackcod in the North Pacific. (Document submitted to INPFC, September 1978). 23 p. Far Seas Fisheries Research Laboratory, Fisheries Agency of Japan, Shimizu 424.

——— 1979. Results of blackcod tagging experiments by Japan in the Bering Sea and northeastern Pacific. (Document submitted to INPFC, April 1979). 41 p. FSFRL, FAJ, Shimizu 424.

——— 1979. Preliminary report on blackcod and Pacific cod survey by *Ryusho Maru No. 15* in the Aleutian region and the Gulf of Alaska in the summer of 1979. (Document submitted to INPFC, September 1979). 46 p. FSFRL, FAJ, Shimizu 424.

——— 1980. An interim report on U.S.-Japan blackcod tagging experiments conducted in the Aleutian region and Gulf of Alaska in 1978 and 1979. (Document submitted to INPFC, September 1980). 13 p. FSFRL, FAJ, Shimizu 424.

U.S. Department of Commerce. 1978. Fisheries management plan for the Gulf of Alaska groundfish fishery during 1978. North Pacific Fish. Mgmt. Council. U.S. Department of Commerce. April, 1978 : 220 p.

Zenger, H. 1981. Relative abundance and size composition of sablefish in coastal waters of Southeast Alaska, 1978-1981. NOAA Tech. Men. NMFS F/NWC-20, U.S. Dep. of Commerce, NMFS: 42 p.

Certain causes of sablefish (*Anoplopoma fimbria*) population depression

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Abstract

The spawning range of sablefish is the Gulf of Alaska and the Pacific coast of North America. At maturity, part of the stock may leave the spawning area and migrate to the Bering Sea and as far to the southwest as the Kuril Islands, while some individuals may reach Japan.

The migrations are probably not regular and the mechanism which induces sablefish to leave the spawning zone and to return is still unclear to us.

A certain part of the stock may spawn in the Bering Sea but the Bering Sea spawners cannot provide replacement of the Bering Sea commercial stock.

The abundance of the latter is related to the abundance of fish migrating from the eastern areas.

Analysis of the age pattern of sablefish in particular areas and of the pattern of recruitment stock has shown that the bulk of recruitment of the Bering Sea commercial stock are individuals of 4, 5, and 6 year-classes which prior to their migration to the Bering Sea aggregate off the eastern Aleutian Islands and in the western Gulf of Alaska (Kodolov, 1978). The involvement of those areas in the Japanese fishery, even on a relatively small scale (Sasaki et al., 1975) created a considerable shortage of recruitment from 1965 to 1966. The shortage grew worse as the fishery progressed in the following years.

A similar reduction of recruitment was observed in the Gulf of Alaska.

The pattern of recruitment rate of commercial stocks of a sablefish shows that a paramount cause of abundance decrease of sablefish in all

areas of its range is fishing pressure on immature fish and recruitment but not the spawners. This is particularly obvious in the Bering Sea sablefish stock.

Proper fishery management will enhance the population of sablefish.

Limitations imposed by the U.S. government on the sablefish fishery have already brought benign changes in the Bering Sea population and abundance of fish migrating to the Bering Sea increased noticeably in 1982.

We believe that limitations extending as far as complete banning of trawl fishing in the reproductive zone would enhance the growth of population abundance with subsequent improvement of future sablefish yield.

Banning of sablefish fishing off the eastern Aleutian Islands and in the western Gulf of Alaska would contribute to the further restoration of the Bering Sea stock.

The sablefish reproductive zone located in the Eastern Gulf of Alaska and off the Pacific coast of North America is clearly distinguished within the sablefish habitat area. Although spawning is also possible in the western areas, the stable annual reproduction is doubtful there (Kodolov, 1976). Some catches of prespawning sablefish were taken by Fedorov, V.V. in the Bering Sea in 1962; and their larvae were found by the Japanese specialists (Kobayashi, 1957). The waters of the Bering Sea, Eastern Kamchatka and Kuril Islands are the areas of sablefish distribution. The results of the Soviet-American and American-Japanese tagging programs prove the free migration of sablefish from the Northeast Pacific to the Bering Sea and back (Sasaki et al, 1975, Low et al, 1976). These migrations have no regular pattern. Thus, according to the results of tagging (Holmberg and Jones, 1954) some fish may remain in the area of tagging and others may migrate far from the area of initial habitation. Judging by the age structure and gonad maturity, the immature fish over two years of age with gonads at the resting stage of maturity, make high sea migrations to the Bering Sea. The four to six year old groups are the basic migrants. The older fish also seem to take an active part in these migrations.

The age structure of the sablefish taken from the Eastern Aleutians and Western Gulf of Alaska is close to the theoretically-calculated age composition of the Bering Sea commercial stock recruitment (Fig. 1). No doubt that the recruitment of this stock or a considerable part of it begins from this area and the recruits approach the Bering Sea slope during the warm part of the year (Kodolov, 1976).

Before 1959 the sablefish fishery was not developed and the catch did not exceed between 6,000 tons. After Japan and other countries entered this fishery, it was intensified and in 1972 the total catch amounted to 65,500 tons (FAO Yearbook). This rate of harvest was too high and was reduced in the following years. Maximum annual stable catch was estimated by American specialists to be between 42,600 and 46,500 tons; including approximately 5,000 in the Bering Sea; 2,400 off the Aleutians; 22,000 in the Gulf of Alaska and northward from Vancouver Island; 5,000

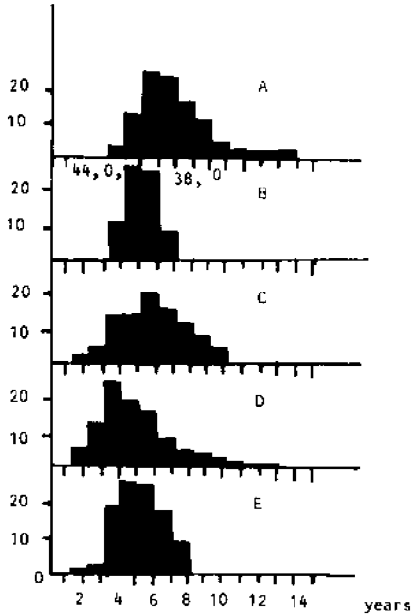

Fig. 1. Age structure of sablefish:
A - The Bering Sea, 1962-1972;
B - The eastern Aleutian Islands 1973;
C - western Alaska, 1964-1973;
D - Vancouver-Oregon area, 1966-1973;
E - recruitment of the commercial Bering Sea stock.

off British Columbia; and 7,000 off the Pacific coast of the USA (Low et al, 1976).

The Bering Sea sablefish fishery has not progressed in its harvest. From 1959 to 1962 the gross catch of sablefish reached 28,500 tons and from 1963 to 1965 the rate of exploitation was extremely reduced. In the years 1966 to 1968 the Soviet Union began exploitation of the biological resources on the continental slope, the Japanese fisheries were again intensified and the total catch of sablefish reached the peak level of 32,700 tons (Kodolov, 1976). Since that time the yield and catch per unit effort (Low et al., 1976) have been steadily decreasing. We do not know whether the Japanese fishery in the Bering Sea fluctuated due to the development of new eastern areas or the intensity fluctuations of their spawning migrations. It is only obvious that the yield exceeded the biological possibilities of the Bering Sea commercial stock.

The analysis of the 1962-1973 dynamics of sablefish age structure showed that during fishing intensification, a lack of recruitment was observed in the commercial sablefish stocks. A similar reduction in average age of sablefish stocks was observed in the early fisheries (Fig. 2). In 1965 and 1966 this lack of recruitment began to appear in the Bering Sea which we believe may have been caused by the expeditions of the fishing vessels to the western part of the Gulf of Alaska and to the Aleutians where recruits of the Bering Sea commercial stock were concentrated. From 1967 to 1973, after intensification of the fisheries in this area began, the deficiency of recruitment rapidly progressed.

Since 1969 in the Gulf of Alaska and since 1971 in the Vancouver-Oregon area this reduced recruitment has been observed, although the informa-

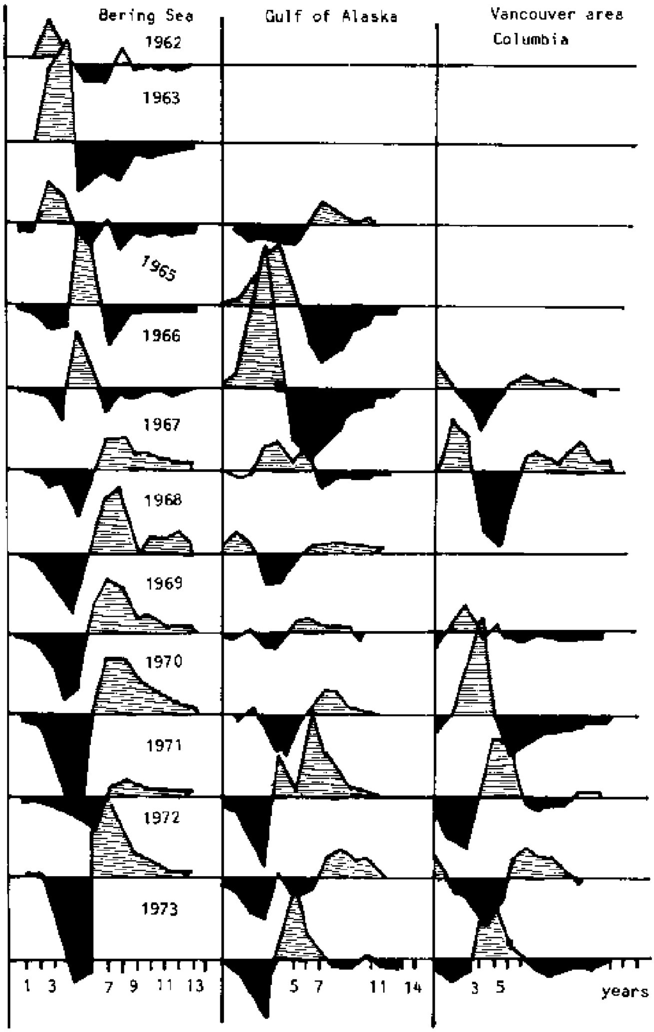

Fig. 2. The changes of sablefish age structure in 1962-1973.

tion is less comprehensive in the latter case. The reason is the high fishing pressure on the immature fish.

The decrease in recruitment was followed by the reduction of the catch per unit effort (Low et al, 1976, Sasaki et al, 1975). Thus, it is obvious that the reduction of the stock was due to the removal of the spawners and mostly due to harvesting immature recruits.

According to our estimations, about 110 million sablefish were caught in the Bering Sea from 1961 to 1972 and half of them were from the 1960 to 1964 year-classes. The year classes of 1951 to 1957 were incompletely harvested because of their late entry into the fisheries, and those of

1958 and 1959 because of the reduction of rate of exploitation in the mid 60s. The 1960 to 1963 year-classes were most completely harvested in the Bering Sea, providing 11.2 to 13.4 million sablefish each. The abundance of the consequent sablefish generations drastically decreased in the Bering Sea (Table 1), although the spawners of the 1957 to 1961 year-classes were little harvested before 1964. But they were present in sufficient numbers in the commercial stock before 1970. In other words, the reproduction decrease caused by the catch of the spawners could never result in such a drastic reduction of the commercial stock abundance. Before 1967 there were no serious obstacles to sablefish migration to the Bering Sea, although the 1956 to 1966 year-classes had already been harvested in the western Gulf of Alaska and Aleutians, where in 1964 to 1966 Japanese fishermen took 2,000 to 4,500 tons of sablefish. This caused the certain lack of recruitment, (Fig. 2) and after 1964 almost complete disappearance, of three year-old sablefish from the catch and the drastic decrease in their numbers. In 1968, after intensification of the fisheries in the eastern areas, the four year-old fish disappeared. Taking into account that it was 1968 when the Japanese fisheries in the Gulf of Alaska increased more than three-fold and four year-old sablefish were about 20% of the total catch, the relationship between the fisheries in the Gulf of Alaska and Aleutians and the numbers of sablefish migrating to the Bering Sea becomes obvious.

It is interesting that the increase of young fish migrating to the Bering Sea in 1971 (Table 2) coincides with the weakening of the fishing pressure on sablefish concentrations in the Gulf of Alaska and Aleutians in 1970 to 1971 (Sasaki et al., 1975).

In 1974 the Soviet fisheries and investigations on sablefish in the Bering Sea were stopped. Judging by the reduction of total catch and the catch per unit effort, sablefish migrations to the Bering Sea continued to decrease up to 1980. From 1974 to 1981 only single sable-fish were found on the Asian continental slope. However, the restricted measures on sablefish catches taken by the United States government were successful and in summer 1982 they began their migration to the Soviet economic zone for the first time in eight years. These migrations are not yet abundant and the question of the restoration of the specialized fisheries on sablefish have not been raised so far. Only pursuit of the proper fishing policy may restore the large-scale fisheries in the Bering Sea.

The experience of the sablefish fisheries showed that establishing the sustainable yield without consideration of the biology of the commercial object may result in unpredictable changes in the commercial stock structure. In particular, intensive fishing for sablefish during migration when a considerable number of the fish were small, and thus of lower food value, readily resulted in the complete disappearance of the Bering Sea commercial stock. Sablefish stocks also decreased in the most reproductive part of the area. We believe that the complete prohibition of the trawl fisheries for sablefish in the reproductive zone as well as the restriction on other sablefish fisheries in the western Gulf of Alaska and eastern Aleutians may have contributed to the restoration of the Bering Sea commercial stock.

Table 1. Sablefish yield in the Bering Sea by year-classes (mln items).

Year-classes	Fishing Year												Total Number
	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	
1958	0.62	2.38	1.80	0.71	0.27	0.08	0.68	0.47	0.13	0.08			7.22
1959	0.2	1.36	2.20	0.92	0.45	0.77	0.76	0.62	0.27	0.24	0.09		7.81
1960		0.14	1.08	0.78	1.57	2.19	2.74	2.50	0.68	0.39	0.18		12.25
1961		0.07	0.17	0.52	0.49	2.67	3.19	3.28	2.04	0.67	0.26		13.36
1962					0.09	0.93	3.04	3.59	3.00	1.18	0.5		12.33
1963						0.32	1.98	2.96	3.26	1.66	0.99		11.17
1964							0.46	1.25	2.86	1.74	1.44	0.1	7.85
1965									0.54	1.07	1.67	0.3	3.68
1966										0.55	2.07	2.2	4.82

Table 2. Sablefish yield in the Bering Sea by the age-groups (mln items).

Age	Fishing Year												
	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973
2	0.2	0.14	0.17										
3	0.62	1.36	1.08	0.52	0.09	0.32	0.46	-	-	-	0.27	?	?
4	?	2.38	2.20	0.78	0.49	0.93	1.98	1.25	0.54	0.55	1.39	0.33?	
5	?	3.64	1.80	1.08	1.58	2.84	3.04	2.96	2.86	1.07	2.07	2.13	
6		2.99	1.63	0.92	1.40	2.19	3.19	3.59	3.26	1.74	1.49	2.22	
7		1.97	1.06	0.71	0.45	0.97	2.74	3.28	2.99	1.66	1.44	0.9	
8		1.09	0.44	0.28	0.27	0.77	1.82	2.5	2.04	1.19	0.99	0.3	
9		-	0.17	0.16	0.14	0.08	0.76	0.47	0.68	0.6	0.54	0.12	
10		-	0.88	0.09	0.05	0.16	0.68	0.62	0.54	0.40	0.45		
11		-	-	0.05	0.05	0.08	0.3	0.47	0.27	0.32	0.18		
12							0.15	0.47	0.14	0.24	0.18		
13							0.07	-	0.27	0.08	0.09		

REFERENCES

Holmberg, K. and W.G. Jones, 1954. Results of sablefish tagging experiments in Washington, Oregon and California. Bull. 3, Pacific Marine Fisheries Commission Portland, Oregon, pp. 104-119.

Kodolov, L.S., 1976. The peculiarities of the biology and distribution of sablefish (Anoplopoma fimbria Pall.). Izv. TINRO, V. 100, pp. 19-42.

Kobayashi, K., 1957. Larvae and young sablefish, Anoplopoma fimbria (Pall), from the sea near the Aleutians. Bull. Jap. Soc. Sci. Fish., V. 23, No. 7-8, pp. 376-382.

Low, L.L., G.K. Tanonaka and H.H. Shippen, 1976. Sablefish of the north-eastern Pacific Ocean and Bering Sea. Northwest Fisheries Center processed report, 115 p.

Sasaki, T., L. Low and K. Thorson, 1975. Sablefish (Anoplopoma fimbria). Resources of the Bering Sea and North-eastern Pacific ocean. Northwest Fisheries Center, Washington, p. 58.

Changes in relative abundance and size compostion of sablefish in coastal waters of Washington and Oregon, 1979-81 and California, 1980-82

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Abstract

Since 1978, the Northwest and Alaska Fisheries Center has been conducting a long-range research program aimed at monitoring the annual changes in sablefish (Anoplopoma fimbria) abundance and size composition in the northeastern Pacific Ocean. This research was begun in southeast Alaskan waters and was expanded to include Washington and Oregon waters in 1979 and waters off California in 1980.

A total of six abundance index sites (two per state) was monitored off the coast of Washington, Oregon, and California on commercial fishing grounds. Sampling gear consisted of 50 rectangular collapsible sablefish traps, each equipped with a single tunnel, and set up to close trap entrances via a noose arrangement after approximately 24 hours of fishing. At each site, a 10-trap string was fished at five depths between 150 and 450 fathoms off Washington and Oregon and between 225 and 550 fathoms off California. Five repetitions at each depth (50 trap lifts) constituted a completed site, and all fish captured were enumerated and measured.

Sablefish abundance in index survey areas off Oregon and Washington decreased from 1979 to 1981. Catch rates decreased 67% at index sites off Oregon between 1979 and 1981, while showing a decrease of 11% at sites off Washington. Abundance index catch rates declined just over 50% between the 1980 and 1982 surveys at the site off San Diego, California. Catch rates increased 10%, however, at the Bodega Canyon site northwest of San Francisco. Reductions in catch rates were especially notable for medium and large sablefish off southern Oregon and northern Washington and for large sablefish at the Bodega Canyon site off California.

Introduction

The Pacific west coast domestic fishery on sablefish (*Anoplopoma fimbria*) has grown sporadically since 1977. The large increase in catch in 1979 resulted from the expansion of the conical trap fishery in Oregon and the longline fisheries in Oregon and Washington (Table 1). Sharply reduced sablefish prices beginning in mid-1979, led to a reduction in domestic effort and catch in 1980 and 1981. In 1982, a 3,000-pound trip limit was established in late October by the Pacific Fishery Management Council, when 95% of the optimum yield figure of 17,400 metric tons (t) had been reached, due largely to increased coastwide trawl landings of sablefish.

The economic importance of the sablefish fishery and the need for information to complement status of stock analysis based on fishery statistics stimulated the Northwest and Alaska Fisheries Center to initiate a program in 1978 to monitor the annual changes in sablefish distribution, relative abundance, size composition, biological characteristics and migratory movements in the northeastern Pacific Ocean. These surveys have been conducted in accordance with guidelines established in a coastwide research plan developed in consultation with the state fishery management agencies (Hughes, 1980).

The 1979-81 results of sablefish surveys in the Washington-California region have been reported by Parks and Hughes (1981) and Parks (1982). Results of the 1978-81 surveys of sablefish resource conditions in southeast Alaska have been reported to the fishing industry and the North Pacific Fishery Management Council by Zenger and Hughes (1981) and Zenger (1981). The purpose of this paper is to summarize and present 1979-82 data collected at index sites in the Washington to California region as a means of monitoring trends in population size.

Survey Methods and Gear

The "abundance indexing" methodology and the equipment employed in this study are described in detail by Parks and Hughes (1981). Information on changes in relative abundance from year to year was determined from the catch per unit of effort (CPUE) obtained from standardized trap fishing at four sites off the Washington-Oregon coast (monitored during the August-September period in 1979-81) and at two sites off California (monitored during November 1980-82).

Survey index sites were established on commercial fishing grounds off Cape Arago and Cape Lookout, Oregon, and off Willapa Bay and Cape Johnson, Washington (Figure 1). The California sites were on Patton Escarpment west of San Diego and near Bodega Canyon just northwest of Point Reyes (Figure 2).

At index sites off Washington and Oregon, 10-trap strings were set as near as possible to the 150, 225, 300, 375, and 450 fathom isobaths. Off California the fishing depths were at the 225, 300, 375, 450, and 550 fathom isobaths. The gear was set 5 times at each depth resulting in a total of 50 traps hauled at each depth interval and 250 traps

Table 1.--Domestic landings of sablefish by state and gear type, 1976-82.

State and gear	Sablefish landings, round weight (t) 1976	1977	1978	1979	1980	1981	1982
Washington							
Trawl	314	480	676	669	441	571	1,706
Trap	121	359	491	435	387	1,305	1,617
Longline	204	299	666	1,564	577	676	677
Troll	1	2	-	-	1	1	2
Shrimp trawl	1	6	-	-	7	11	27
Set net	-	-	-	-	45	29	141
Handline	-	-	-	-	4	4	19
Total	641	1,146	1,833	2,668	1,462	2,597	4,189
Oregon							
Trawl	443	326	958	1,494	1,024	1,318	2,945
Trap	44	40	290	4,351	1,241	303[a]	1,456
Longline	0	6	268	1,819	379	682	593
Troll	-	-	28	-	-	1	1
Shrimp trawl	20	13	70	77	63	36	45
Total	507	385	1,614	7,741	2,707	2,340	5,040
California							
Trawl	1,854	2,474	2,345	2,272	2,902	3,572	5,245
Trap and longline[b]	4,206	3,579	4,827	4,772	2,431	3,097	3,964
Total	6,060	6,053	7,172	7,044	5,333	6,669	9,209[c]
Grand Total	7,208	7,584	10,619	17,453	9,502	11,606	18,438[c]

[a]Includes 26 t taken by set net.

[b]Longline catch in California was a very small percentage of combined trap and longline catch until 1980 when longline catch rose to 28%.

[c]Preliminary data.

hauled at each site. Loran C and depth sounders were used to fix setting positions so that all replicates were made at nearly the same locations. The surveys off Oregon and Washington were conducted from the NOAA ship *John N. Cobb* beginning at Cape Arago, Oregon in early August and finishing at Cape Johnson, Washington, during late September. The 1980 California survey was conducted by the NOAA ship *Chapman* and in 1981-82 indexing was conducted by the *John N. Cobb*. The California surveys took place primarily during November.

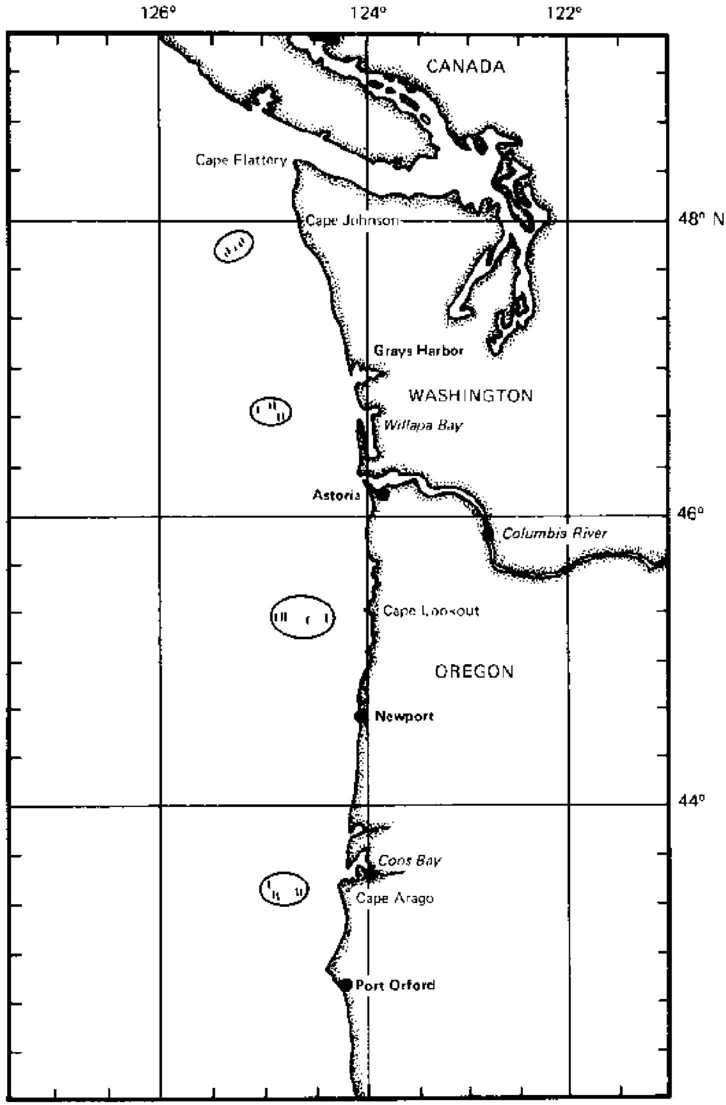

Figure 1.--Sites fished off Washington and Oregon during the 1979-81 sablefish index surveys by the NOAA ship _John N. Cobb._

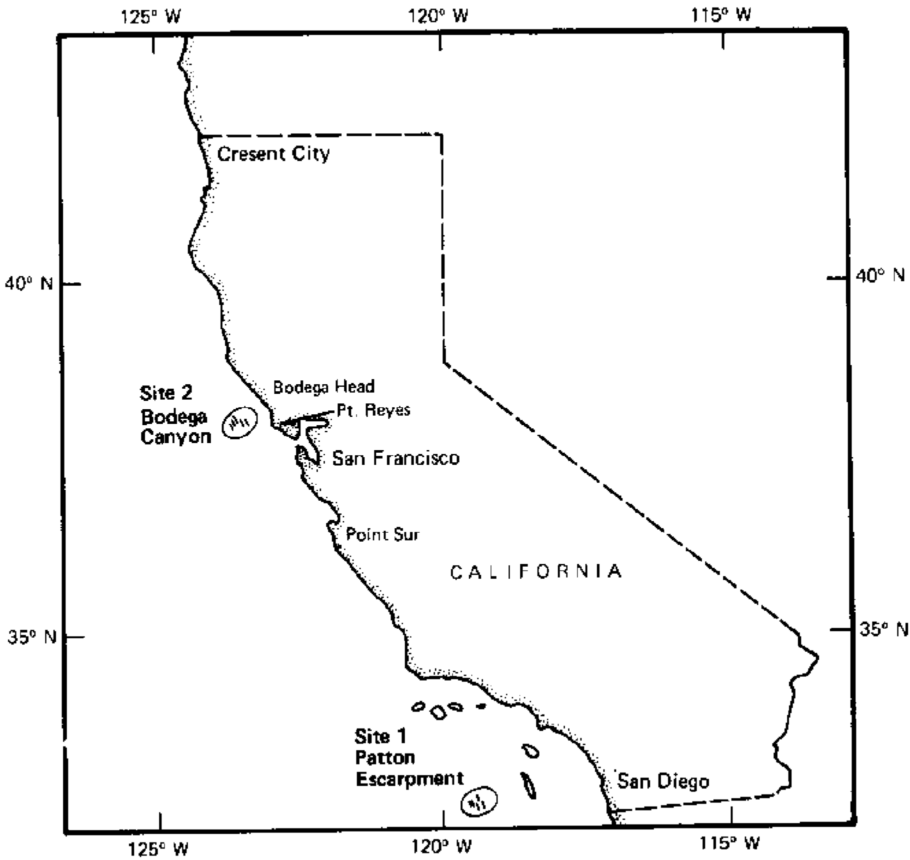

Figure 2.--Sites fished off California during the 1980-82 sablefish index surveys by the NOAA ships _Chapman_ and _John N. Cobb_.

Data collected included:

1. Number and weight of sablefish and other species captured in each trap;

2. Fork lengths of all sablefish;

3. Biological data to support life history studies which included length-weight relationships, age structures1/, sex ratio, and sexual maturity;

4. Tissue samples for stock identification studies; and

5. All sablefish not required for biological samples were tagged and released in support of ongoing coastwide migration studies.

Based upon information from the sablefish processors of Oregon and Washington, marketable-size sablefish were defined as fish measuring 52 cm or greater in fork length. Fish measuring 52 cm averaged 3.0 lb round weight. Small marketable sablefish weighed 3.0-5.0 lb round weight (head on, ungutted), medium sablefish weighed 5.0-7.0 lb, and large sablefish weighed more than 7.0 lb round weight.

Submarketable-size sablefish were defined as those fish retained by the trap gear which measured 51 cm or less and hence weighed less than 3.0 lb round weight. In California, there is no minimum size accepted by processors; those sablefish under 4.25 lb round weight were considered small, those 4.25 to 7.0 lb were medium, and those more than 7.0 lb were large. Research catches were categorized accordingly.

Results

Oregon Coast

Sablefish catches at the Cape Arago site decreased sharply between the 1980 and 1981 surveys after having increased between 1979 and 1980 (Table 2.) This large decrease in catch rates was evident in both submarketable and marketable categories. The percentage abundance of sablefish captured at Cape Arago is shown by size category in Table 3. Cape Arago produced the highest percentage of submarketable sablefish of any site in 1980 and 1981 and reductions in medium and large sablefish were noted. The length compositions in Figure 3 reflect the reduced abundance of large fish and the mean length declined from 57 cm in 1979 to 53 cm in 1981.

Sablefish catches at Cape Lookout have dropped sharply since 1979 in all size categories, with decreases ranging from 60% to 76% (Table 2). This site, however, produced the lowest percentage of submarketables and the highest percentage of medium and large sablefish of any site in 1981 as shown in Table 3. Length compositions (Figure 3) demonstrate that the fish measuring 58 cm and greater remained relatively constant between the 1980 and 1981 surveys, and the decrease in 1981 abundance occurred primarily among fish measuring 57 cm and less. As a result, average size increased from 55 cm in 1980 to 57 cm in 1981.

1/ Age determinations are being postponed until present techniques are more fully evaluated.

Table 2.--Total numbers of sablefish and numbers of marketable-size and submarketable-size sablefish captured at Oregon and Washington abundance index sites during the 1979-81 surveys. Annual percentage change in numbers of sablefish and percentage change from the baseline year 1979 are indicated by site and size category.

	Total sablefish			Marketable-size[a]			Submarketable-size[b]		
Site/year	Number	Annual change (%)	Change from 1979 (%)	Number	Annual change (%)	Change from 1979 (%)	Number	Annual change (%)	Change from 1979 (%)
OREGON									
Cape Arago									
1979	1,222			929			293		
1980	1,753	+43	+43	936[c]	+ 1	+ 1	817[c]	+179	+179
1981	587	-67	-52	313	-67	-66	274	-66	- 6
Cape Lookout									
1979	2,874			2,319			555		
1980	1,125	-61	-61	700	-70	-70	425	-23	-23
1981	774	-31	-73	551	-21	-76	223	-48	-60
Cape Arago and Cape Lookout									
1979	4,096			3,248			848		
1980	2,878	-30	-30	1,636	-50	-50	1,242	+46	+46
1981	1,361	-53	-67	864	-47	-73	497	-60	-41
WASHINGTON									
Willapa Bay									
1979	1,310			846			464		
1980	974	-26	-26	675	-20	-20	299	-36	-36
1981	1,074	+10	-18	713	+ 6	-16	361	+21	-22
Cape Johnson									
1979	952			760			192		
1980	1,370	+44	+44	944	+24	+24	426	+122	+122
1981	950	-31	0	584	-38	-23	366	-14	+91
Willapa Bay and Cape Johnson									
1979	2,262			1,606			656		
1980	2,344	+ 4	+ 4	1,619	+ 1	+ 1	725	+11	+11
1981	2,024	-14	-11	1,297	-20	-19	727	0	+11

[a] 52 cm or greater fork length.

[b] 51 cm or less fork length, which was below minimum marketable size in Washington and Oregon.

[c] A correction of the number presented in the report by Parks and Hughes (1981).

Table 3.--Percentage abundance of submarketable-size and marketable-size sablefish at the four Oregon and Washington abundance index sites during the 1979-81 annual surveys.

		Marketable			
Year and area	Submarketable [a] (%)	Small [b] (%)	Medium [c] (%)	Large [d] (%)	Total (%)
1979					
Cape Arago	24	53	13	10	100
Cape Lookout	19	57	13	11	100
Willapa Bay	35	51	7	7	100
Cape Johnson	20	55	13	12	100
Average	24	54	12	10	100
1980					
Cape Arago	47	39	8	6	100
Cape Lookout	38	44	9	9	100
Willapa Bay	31	52	8	9	100
Cape Johnson	31	54	8	7	100
Average	37	47	8	8	100
1981					
Cape Arago	47	44	6	3	100
Cape Lookout	29	46	12	13	100
Willapa Bay	34	52	7	7	100
Cape Johnson	39	52	6	3	100
Average	37	49	8	6	100

[a] Less than 52 cm fork length = less than 3.0 lb round weight.

[b] 52-61 cm fork length = 3.0-5.0 lb round weight.

[c] 62-67 cm fork length = 5.0-7.0 lb round weight.

[d] 68 cm or greater fork length = more than 7.0 lb round weight.

Combined data for the Oregon area show that catch rates declined steadily from 1979 to 1981 (Table 2). The 1981 catch rates represent a 67% decrease from 1979 catch rates. Declines occurred in catches of both marketable-size and submarketable-size sablefish. The mean lengths of males decreased from 54 cm in 1979 to 52 cm in 1981, and the mean length of females decreased from 61 cm to 59 cm. The sex composition of sablefish captured off Oregon ranged from 48% to 53% males. The length at which 50% reached maturity at the 95% level of confidence was 49.7 ± 0.3 cm for males, and 54.9 ± 0.5 cm for females for all years combined.

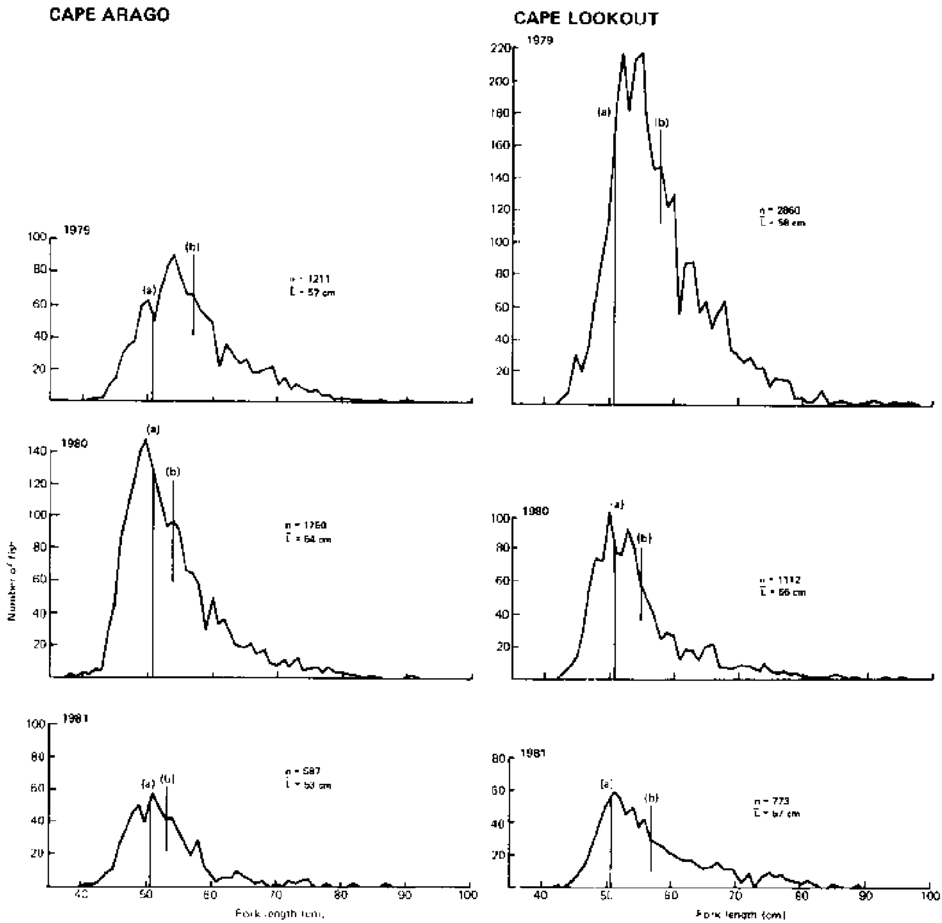

Figure 3.--Length composition of sablefish captured at the Cape Arago and Cape Lookout, Oregon, sites during the 1979-81 index surveys. Vertical line (a) is the division between sub-marketable-size and marketable-size sablefish and vertical line (b) is the mean length ($\bar{L}$).

Washington Coast

Off Washington, sablefish catch rates at the Willapa Bay site decreased overall since 1979, but slight increases in both size categories were noted between 1980 and 1981 (Table 2). The percentages of marketable and submarketable-sizes have remained relatively stable since 1979 (Table 3). Willapa Bay was the only site off Oregon and Washington which showed increased catches in 1981. The length composition and mean length of sablefish captured at the Willapa Bay site is similar in all three years (Figure 4).

Sablefish catch rates at Cape Johnson in 1981 were essentially unchanged from 1979; however, moderately lower catches occurred in both size categories between 1980 and 1981 (Table 2). A sharp increase in the percentage of submarketable-size fish and a major decrease in percentage of medium- and large-size sablefish at Cape Johnson was evident since 1979 (Table 3). There was decreased abundance in all sizes 47 cm and greater between 1980 and 1981, and the mean length decreased from 58 cm in 1979 to 54 cm in 1981 (Figure 4).

The combined data for Washington sites indicate that sablefish abundance decreased slightly between 1979 and 1981 (Table 2). Marketable-size sablefish decreased 19%, while the abundance of submarketable-size sablefish increased 11%. The mean lengths of males changed only slightly (53, 54, 52 cm), whereas female mean length declined from 61 cm in 1979 to 57 cm in 1981. As in waters off Oregon, a large decrease in the number of females greater than 57-58 cm has occurred since the 1979 survey. Males were predominant in the the sex composition of sablefish captured during all years, making up 54-57% of the catches. The length at which 50% reached maturity at the 95% level of confidence was 48.2 ± 0.5 cm for males, and 54.6 ± 0.6 cm for females for all years combined.

California Coast

Sablefish catches at the Patton Escarpment site off San Diego decreased moderately between 1980 and 1981. This decrease occurred in all sizes, especially in medium and large categories (Table 4). Sablefish catch rates declined further in 1982 with a 40% decrease since 1981. Both small and medium sizes showed lower catch rates while there was an increase in the few large-size sablefish taken in 1982. Since 1980, catch rates of sablefish at the Patton Escarpment site have decreased 51% and this decrease was evident in all size categories (Table 4). Small sablefish dominated the catch in all three survey years off San Diego making up 90-93% of the fish captured. Medium-sized sablefish made up an average of 8% while large-sized sablefish made up less than 1% of the catch in all three years (Table 5). The length data (Figure 5) illustrate the generally unimodal characteristic of sablefish length distributions of catches off San Diego. Mean length was 51-52 cm on all three surveys.

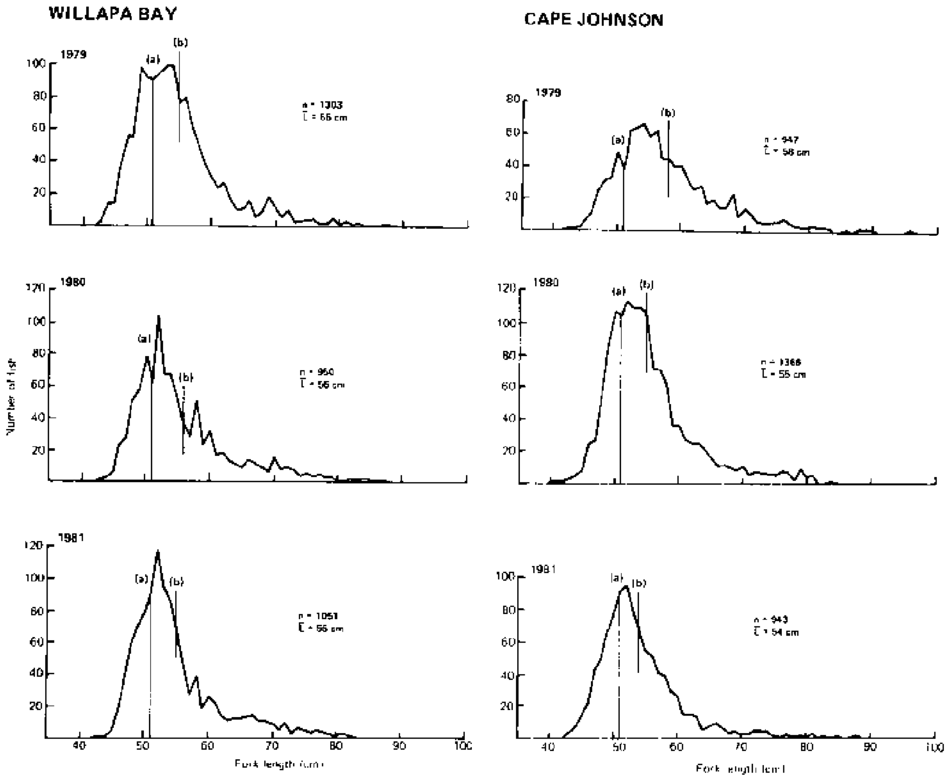

Figure 4.--Length composition of sablefish captured at the Willapa Bay and Cape Johnson, Washington, sites during the 1979-81 index surveys. Vertical line (a) is the division between submarketable-size and marketable-size sablefish and vertical line (b) is the mean length ($\bar{L}$).

Table 4.--Total numbers of sablefish and numbers of small, medium, and large sablefish captured at California index sites during the 1980-82 surveys. Annual percentage change in numbers of sablefish and percentage change from the baseline year 1980 are indicated by site and size category.

	Total sablefish			Large sablefish			Medium sablefish			Small sablefish		
Site/year	No.	Annual change (%)	Change from baseline year (%)	No.	Annual change (%)	Change from baseline year (%)	No.	Annual change (%)	Change from baseline year (%)	No.	Annual change (%)	Change from baseline year (%)
Patton Escarpment												
1980	1,524			7			139			1,378		
1981	1,247	-18	-18	3	-57	-57	96	-31	-31	1,148	-17	-17
1982	753	-40	-51	5	+67	-29	49	-49	-65	699	-39	-49
Bodega Canyon												
1980	1,255			72			206			977		
1981[a]	--	--	--	--	--	--	--	--	--	--	--	--
1982[b]	1,379	--	+10	22	--	-69	210	--	+2	1,147	--	+17

[a] The Bodega Canyon site was not fished in 1981 because of adverse weather conditions.

[b] Since two complete strings of gear were lost on the fourth repetition at the 225 and 450 fathom depth intervals, and a third string was lost on the fifth repetition at the 300 fathom depth interval at the Bodega Canyon site in 1982, all to drag vessels, means of catch values for the 2nd and 3rd repetitions at 225 and 450 fathom, and 2nd through 4th repetitions were substituted for the missing data in the 1982 survey.

There was a strong dominance of females in catches from the Patton Escarpment site during all three survey years. The length composition, mean lengths by sex, and the percent of male and female sablefish in a subsample are shown in Figure 6. The length at which 50% reached maturity at the 95% level of confidence was 54.8 ± 1.3 cm for males, and 56.3 ± 0.5 cm for females for all years combined.

Extended adverse weather precluded sampling in 1981 at the Bodega Canyon site and the loss of three strings of trap gear prevented completion of all scheduled sampling in 1982.

Gear was lost on the fourth repetition at the 225 and 450 fathom depth intervals, and on the fifth repetition at the 300 fathom depth interval. In order to render the 1982 data useful for comparison with the 1980 results, means of catch values for the second and third repetitions at 225 and 450 fathoms, and the second through fourth repetitions at 300 fathoms were substituted for the missing data. Catches from the first set were not used in calculating substitute mean values because these catches are usually considerably higher than those in subsequent sets.

Table 5.--Percentage abundance of small, medium, and large-size sablefish captured at the Patton Escarpment and Bodega Canyon index sites during the 1980-82 annual surveys.

Site and Year	Small[a] (%)	Medium[b] (%)	Large[c] (%)	Total (%)
Patton Escarpment				
1980	90	9	<1	100
1981	92	8	<1	100
1982	93	7	<1	100
Average	92	8	<1	100
Bodega Canyon				
1980	78	16	6	100
1981[d]	-	-	-	-
1982	83	15	2	100
Average	80	16	4	100

[a] Less than 4.25 lb round weight = less than 59 cm fork length.

[b] 4.25-7.0 lb round weight = 59-68 cm fork length.

[c] More than 7.0 lb round weight = 69 cm or greater fork length.

[d] Bodega Canyon was not fished in 1981 because of adverse weather conditions.

Sablefish catches at the Bodega Canyon site increased 10% between 1980 and 1982 (Table 4). The increase was almost entirely a result of an extraordinarily large catch on the first repetition at the 300 fathom depth interval. If this value is considered aberrant or an outlier, one could substitute a catch value calculated on the average rate of decline between the first and second repetitions for the other four depth intervals. This results in a total catch of 1,259 (Table 4), indicating little change in total sablefish abundance between 1980 and 1982. While catch rates of both small- and medium-sized sablefish increased, the catch rate of large sablefish was down 69% (Table 4). Small sablefish made up 78% of the catch in 1980 and 83% of the catch in 1982. The proportion of medium-sized sablefish was at 16% and 15%, with large sablefish down from 6% of the catch in 1980 to 2% in 1982 (Table 5). The length compositions shown in Figure 5 are similar but a reduction in the number of fish greater than 70 cm is evident in 1982. Mean size of all sablefish remained unchanged at 54 cm.

Although males were slightly more abundant at the Bodega Canyon site in 1980, 55% of the 1982 catch was female. The sample length compositions, mean lengths by sex, and the percent of males and females are shown in Figure 6. The length at which 50% reached maturity at the 95% level of confidence was 52.7 $\pm$ 0.6 cm for males, and 55.3 $\pm$ 0.9 cm for females for the two years combined.

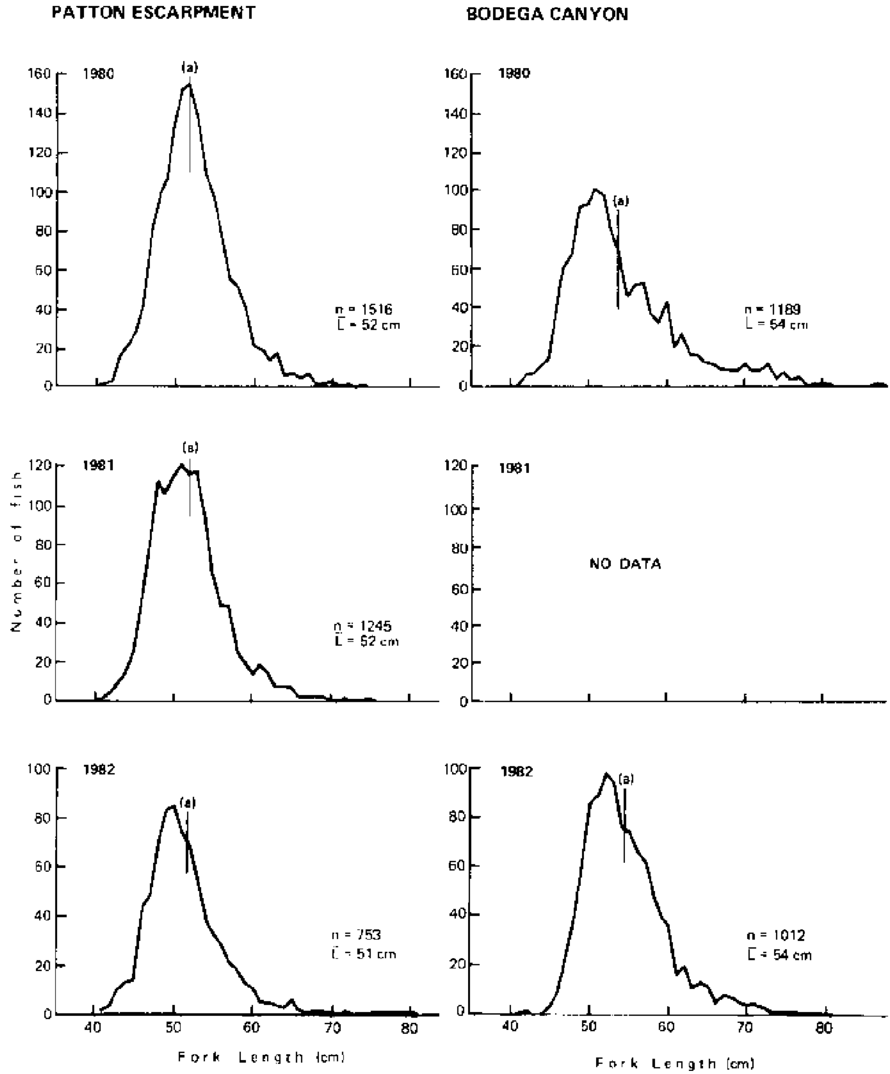

Figure 5.--Length composition of sablefish captured at the Patton Escarpment and Bodega Canyon, California, sites during the 1980-82 index surveys. Vertical line (a) is the mean length ($\bar{L}$).

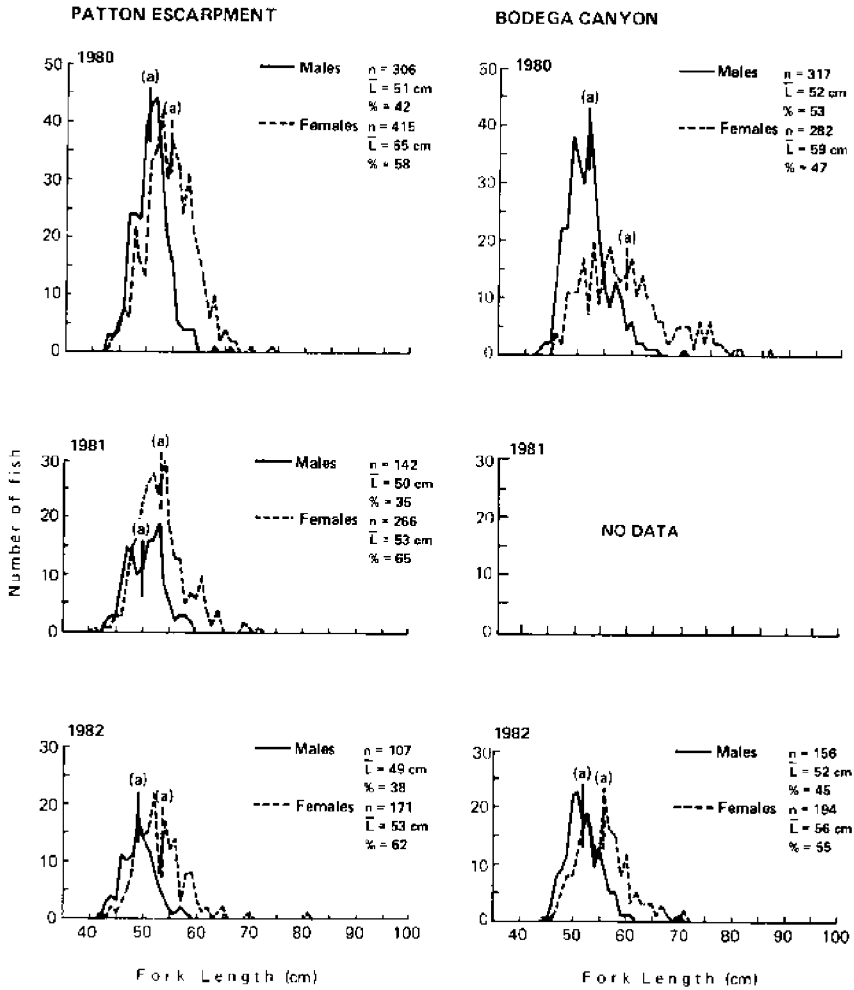

Figure 6.--Length composition of male and female sablefish captured at the California abundance index sites during the 1980-82 index surveys. Vertical lines (a) are the mean lengths ($\overline{L}$).

Summary and Conclusions

Survey catch rates suggest that sablefish abundance at Oregon index sites has been decreasing since 1979. Catches taken off Cape Arago in 1980 and 1981 contained a relatively large proportion of submarketable-size sablefish and, at the same time, there had been a notable reduction in the numbers of medium and large marketable-size sablefish.

Survey catch rates off Washington indicate that sablefish abundance at index sites declined only slightly since 1979. Size composition remained stable off Willapa Bay, but there was a large reduction in the percentage of medium and large marketable-size sablefish at the site off Cape Johnson.

These reductions in numbers of medium and large marketable-size sablefish off southern Oregon and northern Washington are of special concern, as those fish have the greatest reproductive capacity and a much higher commercial value.

Consistent declines in sablefish catch rates have occurred off southern California, with the percentage of small sablefish ranging from 90% to 93%. Large sablefish made up less than 1% of the catches in all surveys. Mean lengths of both males and females generally declined throughout the period of the surveys. The 1982 catch rates off northern California indicate a slight increase in sablefish abundance, but again, the proportion of large sablefish has declined markedly. The percentage of small sablefish increased from 78% to 83% between 1980 and 1982. Mean length of males remained constant while mean length of females decreased 3 cm.

Presently, we are at a point of evaluating past indices of abundance and identifying future needs. The need for sablefish resource assessment continues and is especially important during the time when the Pacific Fishery Management Council is developing a system for collecting comprehensive fishery statistics suitable for stock assessment studies. The trap indexing study has progressed to a stage allowing for review of results and general performance appraisal. Following this evaluation, we anticipate developing an enhanced assessment study using the information and experience gained from the initial effort.

References

Hughes, S. 1980. Pacific west coast and Alaska research plan on sablefish (Anoplopoma fimbria), 1980-84. Unpubl. manuscr., 17 p. Northwest and Alaska Fish. Cent., Natl. Mar. Fish. Serv., NOAA, 2725 Montlake Blvd. E., Seattle, WA 98112.

Parks, N. B., and S. E. Hughes. 1981. Changes in relative abundance and size composition of sablefish in coastal waters of Washington and Oregon, 1979-80. U.S. Dep. Commer., Natl. Oceanic Atmos. Admin., Natl. Mar. Fish. Serv., NOAA Tech. Memo. NMFS F/NWC-8, 25 p.

Parks, N. B. 1982. Changes in relative abundance and size composition of sablefish in coastal waters of Washington and Oregon, 1979-81, and California, 1980-81. U.S. Dep. Commer., Natl. Oceanic Atmos. Admin., Natl. Mar. Fish. Serv., NOAA Tech. Memo. NMFS F/NWC-26, 28 p.

Zenger, H., and S. E. Hughes. 1981. Changes in relative abundance and size composition of sablefish in the coastal waters of southeast Alaska, 1978-80. U.S. Dep. Commer., Natl. Oceanic Atmos. Admin., Natl. Mar. Fish. Serv., NOAA Tech. Memo. NMFS F/NWC-7, 27 p.

Zenger, H. H., Jr. 1981. Relative abundance and size composition of sablefish in the coastal waters of southeast Alaska, 1979-81. U.S. Dep. Commer., Natl. Oceanic Atmos. Admin., Natl. Mar. Fish. Serv., NOAA Tech. Memo. NMFS F/NWC-20, 42 p.

Recruitment processes of sablefish in the eastern Bering Sea

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Abstract

Adult sablefish (*Anoplopoma fimbria*) generally occupy continental slope waters (greater than 200 m) in the eastern Bering Sea. Sablefish have been infrequently encountered in the shelf region during annual Northwest and Alaska Fisheries Center (NWAFC) demersal trawl surveys conducted since 1971. In 1978, juvenile sablefish were first observed in relatively high abundance on the southeastern shelf of the Bering Sea. Length frequency and age data identified these fish as 1 year olds of the 1977 year-class. This year-class has been recognized as being unusually strong in the Aleutian Islands, the Gulf of Alaska, and along the Pacific West Coast. The recruitment of this year-class initially to shelf waters in the eastern Bering Sea and subsequently to continental slope waters occupied by the adult population is described in this paper.

Introduction

The Resource Assessment and Conservation Engineering (RACE) Division of the Northwest and Alaska Fisheries Center (NWAFC) has conducted annual demersal crab and groundfish trawl surveys in the eastern Bering Sea since 1971. Sampling effort has been largely restricted to the continental shelf region at depths less than 200 m. Sablefish, *Anoplopoma fimbria*, were infrequently encountered in these waters until 1978 when juveniles were observed in relatively large numbers in the southeastern Bering Sea. These fish were identified as one year olds from the strong 1977 year-class. The success of this year-class has also been observed in the Gulf of Alaska, off British Columbia, and as far south as California.

This paper describes the emergence of the 1977 year-class as juveniles in the eastern Bering Sea shelf region and their subsequent recruitment to the adult population located along the continental slope. The possible origin of these juveniles will also be discussed.

Overall Distribution of Sablefish in the North Pacific Ocean

Sablefish have a wide overall geographical distribution in the North Pacific Ocean extending from waters off Mexico northward through the Gulf of Alaska and the Bering Sea, and south along the Siberian coast and Kamchatka Peninsula to the central north Pacific coast of Japan. Within the fishery jurisdictions of the United States and Canada, survey data and catch statistics indicate that approximately 67% of the overall sablefish biomass is located in the Gulf of Alaska, 13% in the Vancouver-California region, an additional 13% in the Bering Sea, and about 7% in the Aleutian Islands area (Low et al., 1976). Sablefish also occupy a very broad bathymetric range during various stages of development and growth. Eggs are apparently located at depth, while larvae have been found in surface waters. Juveniles are primarily restricted to surface and nearshore waters at depths less than 150 m, while adults are found in greatest abundance at water depths ranging from 150-1200 m (Alton and Webber, 1976).

In the eastern Bering Sea, sablefish are normally found in greatest abundance between 200 and 800 m based on the observations of Kulikov (1965) and data from NWAFC surveys. Until 1978, sablefish were rarely taken in shelf waters (<200 m).

Commercial Catches in the Bering Sea

The commercial fishery for sablefish in the Bering Sea has been exclusively conducted by foreign nations. Japan initiated a fishery in the eastern Bering Sea during 1958 which expanded rapidly through the early 1960's (Table 1). In the mid-1960's, the Japanese extended their fishery to the Aleutian Islands area. Although the U.S.S.R. and the Republic of Korea have also targeted on sablefish at times, annual catches made by Japan have far exceeded those of other countries. Additionally, sablefish have been taken incidentally in fisheries conducted by other nations (Table 1).

Throughout the history of the Bering Sea-Aleutian Islands fishery, the largest commercial catches of sablefish have come from the eastern Bering Sea. Highest annual catches in the eastern Bering Sea were made in 1961 and 1962 at approximately 26,000 and 29,000 t, respectively. Following those peak years, annual catches have fluctuated at moderate levels until 1973. During the period of 1973-81, all-nation catches declined significantly to range between 2,000 and 3,000 t annually in the combined eastern Bering Sea and Aleutian Islands region. The declining catches have been primarily due to reduced stock abundance.

NWAFC Resource Assessment Surveys

The NWAFC has conducted demersal trawl surveys on the eastern Bering Sea continental shelf annually since 1971 to assess the condition of crab and groundfish resources. Although sampling intensity and areal

Table 1.--Historical catches (from Narita, 1983) of sablefish in metric tons by nation in the eastern Bering Sea and Aleutian Region, 1958-81. 1/

	Eastern Bering Sea				Aleutian Region					
Year	Japan 2/	USSR	Others 3/	Total	Japan 2/	ROK	USSR	Others 4/	Total	Areas combined
1958	32	-	-	32	5/	-	-	-	5/	32
1959	393	-	-	393	5/	-	-	-	5/	393
1960	1,861	-	-	1,861	5/	-	-	-	5/	1,861
1961	26,182	-	-	26,182	5/	-	-	-	5/	26,182
1962	28,521	-	-	28,521	5/	-	-	-	5/	28,521
1963	18,404	-	-	18,404	5/	-	-	-	5/	18,404
1964	8,262	-	-	8,262	975	-	-	-	975	9,237
1965	8,240	-	-	8,240	360	-	-	-	360	8,600
1966	11,981	-	-	11,981	1,107	-	-	-	1,107	13,088
1967	13,457	274	-	13,731	1,383	-	-	-	1,383	15,114
1968	14,597	4,256	-	18,853	1,661	-	-	-	1,661	20,514
1969	17,009	1,579	-	18,588	1,804	-	-	-	1,804	20,392
1970	9,627	2,874	-	12,501	1,277	-	-	-	1,277	13,778
1971	12,410	2,830	-	15,240	2,571	-	170	-	2,741	17,981
1972	13,231	2,137	-	15,368	3,307	-	269	-	3,576	18,944
1973	6,395	1,220	-	7,615	2,875	-	134	-	3,009	10,624
1974	5,081	77	-	5,158	2,506	-	14	-	2,520	7,678
1975	3,384	38	-	3,422	1,538	-	79	-	1,617	5,039
1976	3,267	29	-	3,296	1,573	-	61	-	1,634	4,930
1977	2,109	-	-	2,109	1,631	86	-	-	1,717	3,826
1978	1,007	-	132	1,139	798	23	-	-	821	1,960
1979	1,071	49	269	1,389	617	164	-	-	781	2,170
1980	1,649	-	522	2,171	233	26	-	8	267	2,438
1981	2,091	-	487	2,578	320	56	-	1	377	2,955

1/ Japanese catch data for 1958-77 from Sasaki (1976) and Pers. Comm., T. Sasaki, Far Seas Fishery Research Lab., Shimizu, Japan; U.S.S.R. data for 1967-77 provided through U.S.-U.S.S.R. Bilateral Agreements; 1976 data for R.O.K. and 1978-81 data for all nations from U.S. Foreign Fisheries Observer Program.
2/ For years prior to 1977, Japanese catch data are reported by fishing year (Nov.-Dec.); later Japanese catches are reported by calendar year.
3/ Includes Republic of Korea, Taiwan, Poland, and West Germany.
4/ Includes Taiwan, Poland, and West Germany.
5/ Included in the Bering Sea catches.

coverage have varied between years, a comparative fishing area in the southeastern Bering Sea has been consistently sampled every year (Figure 1). The survey area was expanded in most years since 1975 to encompass the major portion of the continental shelf. In more recent years (1979, 1981, and 1982), during cooperative studies with the Far Seas Fisheries Research Laboratory of Japan, it has covered the slope region to depths of 1,000 m (Figure 2). All surveys were conducted during the summer months aboard NOAA research vessels and chartered commercial fishing vessels. The abundance and biological

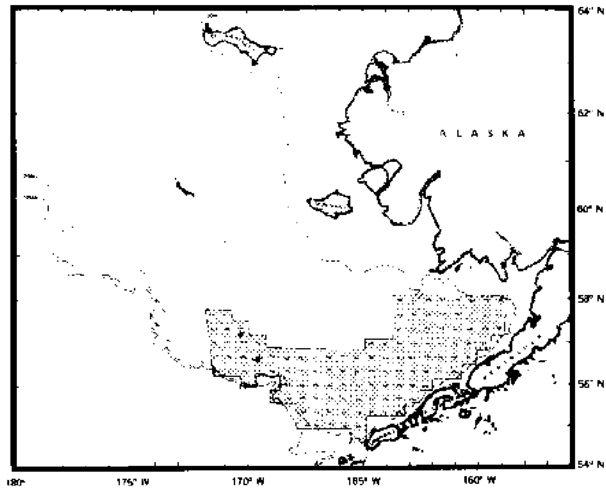

Figure 1.--Comparative fishing area sampled annually during Northwest and Alaska Fisheries Center demersal trawl surveys in 1973-82.

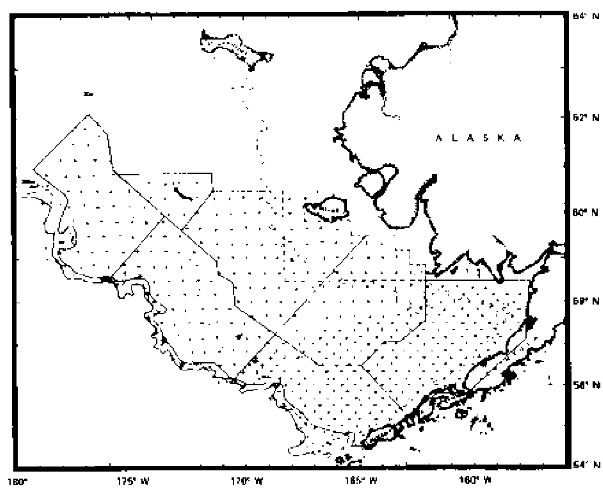

Figure 2.--Area of the eastern Bering Sea generally sampled during large-scale surveys by the northwest and Alaska fisheries Center in 1975 and 1979-82. Area within the dashed lines was not sampled during the 1981 survey.

data presented in this report are from the comparative fishing area on the southeastern Bering Sea shelf and from the slope waters mainly sampled by Japanese vessels. The juveniles of the 1977 year-class were entirely distributed in the comparative area on the shelf; catches of sablefish from other areas of the shelf during large-scale surveys were insignificant.

Emergence of the 1977 Year-Class in the Southeastern Bering Sea

Until 1978, sablefish were infrequently encountered in the comparative fishing area. Mean catch per unit effort (CPUE) values were less than 0.1 kilogram/hectare (kg/ha) each year during 1971-77 (Figure 3). Those sablefish taken were generally restricted to Outer Continental Shelf waters (>120 m) during that period. Catch rates increased significantly in 1978 (0.3 kg/ha) when juveniles were encountered for the first time in the mid-shelf area at depths of 40-120 m and in nearshore waters (<40 m) along the Alaska Peninsula from Unimak Pass to Port Moller (Figure 4). Size composition and age data identified these juveniles as 1 year olds from the strong 1977 year-class. Catch rates continued to increase in 1979 accompanied by a generalized movement of these young sablefish toward deeper shelf waters (120-200 m). CPUE peaked at approximately 1.6 kg/ha trawled during 1980. Catches decreased sharply in 1981 and were further reduced to about 0.2 kg/ha in 1982 as fish moved out of the study area.

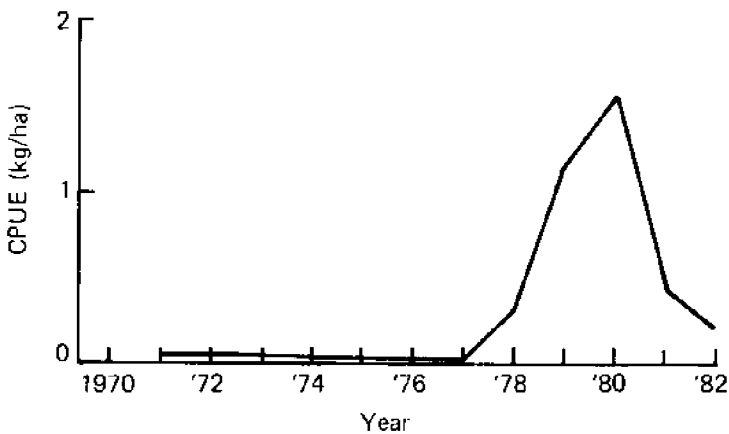

Figure 3.--Relative abundance of sablefish in the comparative fishing area as shown by Northwest and Alaska Fisheries Center research vessel data, 1971-82.

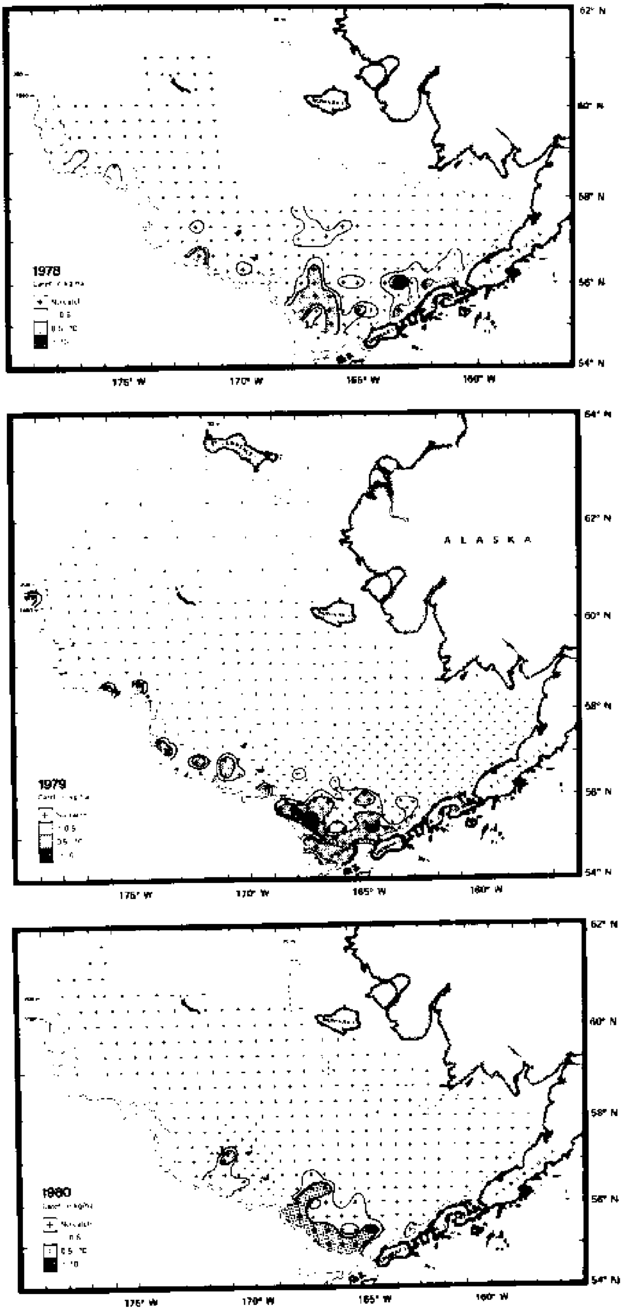

Figure 4. Distribution and relative abundance of sablefish during Northwest and Alaska Fisheries Center research vessel surveys 1978-80.

The estimated biomass of sablefish in the comparative area was 4,500 t in 1978 from a population of about 14.3 million individuals (Table 2). These and subsequent biomass and population number estimates are probably minimal values as the catchability coefficient for sablefish may be less than 1.0. The estimated biomass increased about fourfold between 1978 and 1979 to 18,500 t and increased further in 1980 to 25,300 t. Population number estimates increased to 19.4 million in 1979 and 21.4 million in 1980, indicating that additional juvenile fish may have immigrated into the southeastern Bering Sea after 1978. The apparent biomass decreased to about 6,000 t and 3,700 t during 1981 and 1982, respectively. By 1982 only 2.2 million fish remained in the shelf study area. Thus, the majority of the juvenile sablefish left shelf waters between the 1980 and 1981 summer survey periods when they were between 3 and 4 years old.

Table 2.--Apparent biomass and population numbers of sablefish in the comparative fishing area from Northwest and Alaska Fisheries Center research vessel surveys, 1971-82.

Year	Biomass (t)	Population (millions)
1971	260	0.3
1972	70	<0.1
1973	760	0.6
1974	140	0.1
1975	230	1.2
1976	3	<0.1
1977	50	0.1
1978	4,500	14.3
1979	18,500	19.4
1980	25,300	21.4
1981	6,000	3.7
1982	3,700	2.2

The destination of these juveniles is believed to be the continental slope waters of the eastern Bering Sea. The continental slope region (200-1,000 m) was sampled during cooperative trawl surveys between the NWAFC and the Far Seas Fisheries Research Laboratory of the Fisheries Agency of Japan in 1979, 1981, and 1982. Results from these studies show a major increase in sablefish abundance on the slope between 1979 and 1981. The apparent biomass in the slope area increased from 12,200 t in 1979 to approximately 40,000 t in 1981 and 1982 (Table 3). The total number of sablefish within the slope area sampled increased from 5.6 million in 1979 to 18.0 million in 1981 and to approximately 21.5 million by 1982.

Table 3.--Apparent biomass and population estimates of sablefish on the continental slope during large-scale Northwest and Alaska Fisheries Center surveys conducted in 1979, 1981, and 1982.

Year	Biomass (t)	Population (millions)
1979	12,200	5.6
1981	39,400	18.0
1982	40,100	21.5

Biological Characteristics of the 1977 Year-Class

Length and age data are not available for sablefish taken during survey years 1971-77 because of inadequate sample sizes. As sablefish abundance increased during later surveys, size and age structure samples were collected. Scales were collected for aging sablefish in 1978 but were difficult to interpret. Otoliths were collected from later surveys and were believed to produce more consistent and accurate age readings.

Sablefish sampled in the comparative area during 1978 ranged in length from 22-49 cm with an overall mean of 32.7 cm. Two size modes with peaks at approximately 30 and 45 cm were apparent from the survey data (Figure 5). The larger fish, about 40-49 cm, were primarily located near the outer shelf in the 120-200 m depth zone, whereas smaller fish, about 22-29 cm, were found in shallower waters (<120 m). These two size groups were aged as age 1 and age 2 year old fish from the 1977 and 1976 year-classes. Age data indicated that the 1976 year-class contributed approximately 60% of the sampled population, while the 1977 year-class accounted for only about 35%. However, the length-frequency data showing the major length mode at 30 cm strongly suggest that the 1977 year-class predominated in catches. This discrepancy was probably due to the unreliability of scales for aging sablefish, especially younger fish.

The length distribution was unimodal in 1979 with the fish having a mean size of 45 cm and a length range of 34-58 cm. Age data (from otoliths) show that age-2 fish (1977 year-class) comprised approximately 90% of the overall shelf population with age-3 fish contributing to the remaining 10%.

The overall mean size of the sampled population of juveniles on the shelf continued to increase to about 50.4 cm in 1980 and to 56 cm in 1981 with the 1977 year-class predominating. The decrease in population numbers between the 1980 and 1981 surveys, however, illustrates that most of the sablefish of the 1977 year-class left the shelf area following the summer of 1980.

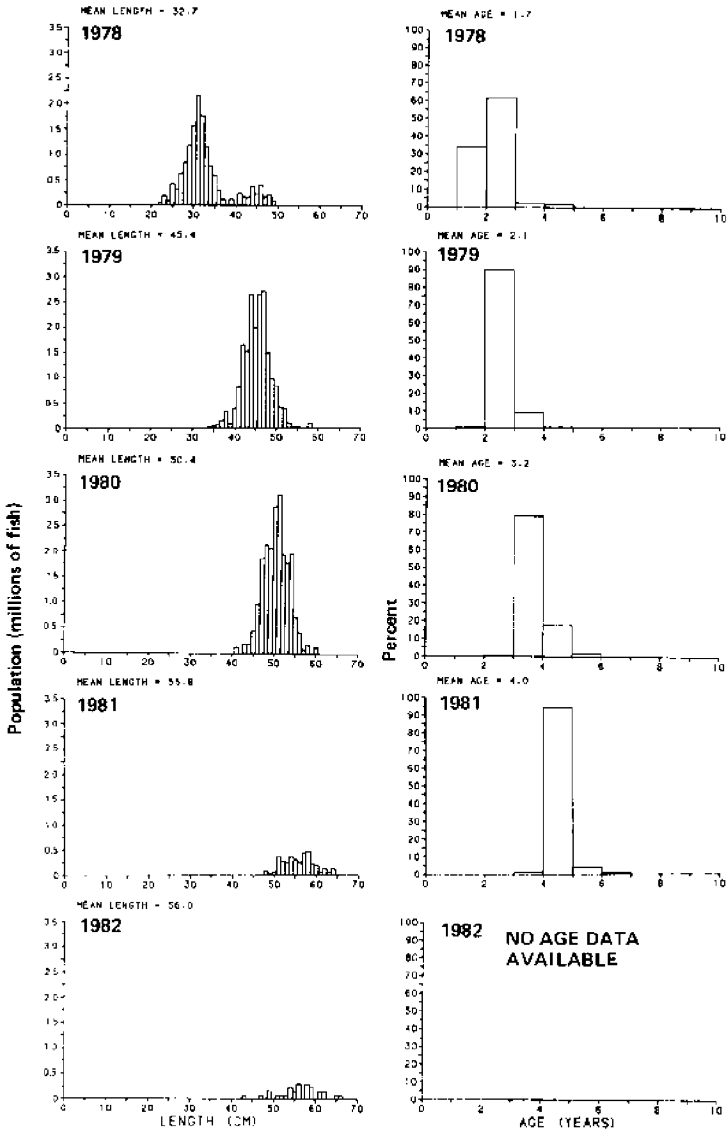

Figure 5.--Size and age composition of sablefish within the shelf comparative fishing area as shown by Northwest and Alaska Fisheries Center research vessel data, 1978-82. Age determinations for 1978 may be inaccurate due to differences in aging structures; scales were used in 1978, and otoliths were used in subsequent years.

Length and age data from continental slope waters in the eastern Bering Sea illustrate, as did abundance estimates, the apparent recruitment of the 1977 year-class to the adult population. This recruitment appears to have started as early as 1979. Some fish in the 40-50 cm length range were evident in the length distribution of sablefish on the slope in 1979 (Figure 6); this was the size range of most of the juvenile sablefish on the shelf in 1979 (Figure 5). However, most of the 1977 year-class recruited to the slope area after 1979 as shown by the major increase in population numbers in 1981. This recruitment is assumed to have occurred between the summers of 1980 and 1981 when most of the 1977 year-class migrated off the shelf. Thus, as indicated earlier, recruitment to the adult stock occurred at age-3 or -4. A high proportion of the catches in slope waters in 1981 were age-4 fish. Population numbers on the slope in 1982 were similar in magnitude to those in 1981, and although age data are not yet available, the 1982 population was probably predominated by age-5 fish of the 1977 year-class.

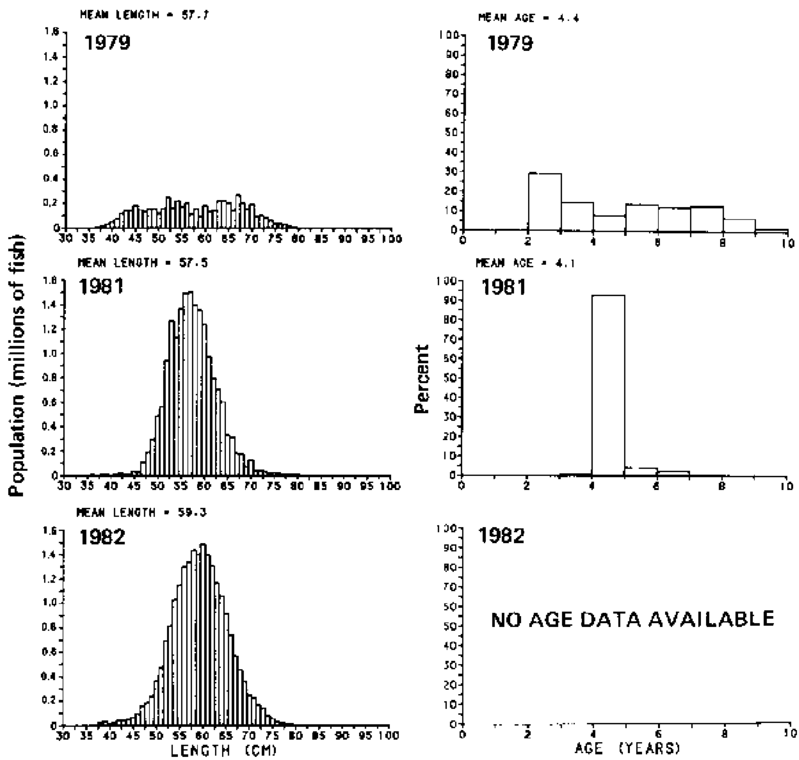

Figure 6.-- Size and age composition of sablefish along the continental slope as shown by cooperative U.S.-Japan research vessel surveys, 1979, 1981, and 1982.

Discussion

The occurrence of only a single year-class of juvenile sablefish in the eastern Bering Sea over a 12-year period raises questions about the life history of the population in this region. The sizeable adult stock in continental slope waters would logically suggest that reproduction and other life history stages occur within the eastern Bering Sea. However, spawning adults and sablefish eggs have never been observed in the eastern Bering Sea and only a few larvae had been taken in ichthyoplankton surveys through the late 1970's (Waldron, 1981).

The apparent absence of some early life history stages has led to a hypothesis that the eastern Bering Sea population originates from spawning in other areas such as the Aleutian Basin, the Aleutian Islands area, or the Gulf of Alaska (Kodolov, 1968; Wespestad et al. 1978; Sasaki, 1982). These authors suggested that the occurrence of larvae in the eastern Bering Sea resulted from passive drift with currents from these spawning areas.

The failure to observe eggs and spawning adults, however, may also simply result from the lack of sampling in time periods, areas, and depths occupied by these life history stages. As previously mentioned, sablefish spawn in deep waters; their eggs may not be available at the water depths usually sampled during ichthyoplankton surveys.

Other sources of data indicate that sablefish larvae may be more prevalent in the eastern Bering Sea than was shown by data summarized by Waldron (1981). More than 600 sablefish larvae were identified from an ichthyoplankton survey conducted during June-August, 1979; these larvae were widely distributed over the outer continental shelf of the eastern Bering Sea (Walline, 1981). Post larval sablefish were found to be one of the most abundant juvenile sablefish taken by a fine-mesh purse seine in surface waters north of the Alaska Peninsula in 1968 (Hartt et al., 1970). The appearance of the 1977 year-class in survey catches was probably the result of its relative high abundance compared to other year-classes present in the eastern Bering Seas during the years surveyed. Evidence of the presence of larvae and juveniles on a more frequent basis than previously thought would suggest that adults spawn in the eastern Bering Sea proper or in nearby waters such as the Aleutian Basin, as hypothesized by Kodolov (1968).

It is apparent that sufficient evidence is not yet available to adequately describe the life history characteristics of eastern Bering Sea sablefish. The information that is accumulating on the Bering sea sablefish from recently expanded survey activities may begin to provide a better understanding of this resource. The Far Seas Fisheries Research Laboratory of Japan has extended its annual sablefish longline assessment surveys and tagging studies to the eastern Bering Sea, and cooperative surveys between this laboratory and the NWAFC are also providing information on the adult population. As opportunities arise during special purpose surveys in the eastern Bering Sea, it is recommended that efforts be made to sample the sablefish population seasonally, collect maturity stage and other biological information, and conduct tagging studies.

References

Alton, M. S., and R. A. Webber. 1976. Sablefish (Family Anoplopomatidae). In W. T. Pereyra, J. E. Reeves, and R. G. Bakkala, Demersal fish and shellfish resources of the eastern Bering Sea in the baseline year 1975. Processed Rep., 619 p. Northwest and Alaska Fisheries Center, National Marine Fisheries Service, NOAA, 2725 Montlake Blvd. E., Seattle, Wa. 98112.

Hartt, A. C., M. B. Dell, and L. S. Smith. 1970. Tagging and sampling. Int. North Pac. Fish. Comm., Annu. Rep. 1968:68-79.

Kodolov, L. S. 1968. Reproduction of the sablefish (Anoplopoma fimbria (Pall.). Vop. Ikhtiol. 8(4):662-668. In Russian, (Transl. in Probl. Ichthyol. 8 (4):531-535).

Kulikov, M. Y. 1965. (Vertical distribution of sablefish (Anoplopoma fimbria (Pallas)) on the Bering Sea continental slope). Tr. Vses. Nauchnoissled. Inst. Morsk. Rybn. Khoz. Ikeanogr. 58 (Izv. Tikhookean. Nauchnoissled. Inst. Morsk. Rybn. Khoz. Okeanog. 53):165-170. In Russian. (Trans. by Isreal Program Sci. Transl., 1968, in Soviet fisheries investigations in the northeast Pacific, Part 4:157-161, avail. U. S. Dep. Commer., Natl. Tech. Inf. Serv., Springfield, Va., as TI 67-51206.)

Low, L-L., G. K. Tanonaka, and H. H. Shippen. 1976. Sablefish of the Northeastern Pacific Ocean and Bering Sea. Processed Rep., 115 p. Northwest and Alaska Fisheries Center, National Marine Fisheries Service, NOAA, 2725 Montlake Blvd. E., Seattle, Wa. 98112

Narita, R. E. 1983. Sablefish. In R. G. Bakkala, and L-L. Low (editors), Condition of groundfish resources of the eastern Bering Sea and Aleutian Islands region in 1982. U.S. Dep. Commer., NOAA Tech. Memo. NMFS F/NWC-42, 187 p.

Sasaki, T. 1982. Condition of sablefish stocks in the North Pacific. Unpubl. manuscr., 41 p. Far Seas Fisheries Research Laboratory, Fisheries Agency of Japan, Tokyo, Japan 100.

Sasaki, T., L-L. Low, and K. N. Thorson. 1975. Sablefish resources of the Bering Sea and northeastern Pacific ocean. Unpubl. manuscr., 56 p. Northwest and Alaska Fisheries Center, National Marine Fisheries Service, NOAA, 2725 Montlake Blvd. E., Seattle, Wa. 98112.

Waldron, K. D. 1981. Ichthyoplankton. In D.W. Hood and J.A. Calder (editors), The eastern Bering Sea shelf: oceanography and resources Volume 1, p. 471-493. U.S. Gov. Print. Off., Washington, D.C.

Walline, P. D. 1981. Distribution of ichthyoplankton in the eastern Bering Sea during June and July 1979. NWAFC Processed Rep. 81-03, 32 p. Northwest and Alaska Fisheries Center. National Marine Fisheries Service, NOAA, 2725 Montlake Boulevard E., Seattle, Wa. 98112.

Wespestad, V. G., K. Thorson, and S. Mizroch. 1978. Movement of sablefish (*Anoplopoma fimbria*) in the northeastern Pacific Ocean as determined by tagging experiments (1971-1977). Processed Rep., 54 p. plus append. Northwest and Alaska Fisheries Center, National Marine Fisheries Service, NOAA, 2725 Montlake Boulevard E., Seattle, Wa. 98112.

Use of corrodible magnesium-alloy links to standardize fishing time in sablefish traps

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ABSTRACT

A small, inexpensive magnesium-alloy cylinder is currently being used to standardize fishing time in sablefish traps. These simple devices, marketed as "timed float releases" dissolve in sea water at a rate controlled primarily by temperature and alloy metal content.

Timed-release devices (TRD) were tested in a temperature controlled sea water bath to find a specific size that would dissolve in 24 hours in the water temperatures anticipated at the survey sites. Dissolution time was directly related to temperature, and the 0.200-inch diameter best fulfilled the requirements for a 24-hour period at the target temperature of 4 degrees Celsius.

A double elastic loaded noose was developed to shut the tunnel opening. The apparatus was armed by connecting the tunnel to the stretched elastic with TRDs. When retracted, the nooses were pulled tightly shut, ensuring against sablefish entering or escaping through the tunnel.

During the 1978 survey, 800 trap sets were made off southeast Alaska. Timed-release devices were used in all traps. Two hundred traps remained soaking beyond the 24-hour standard but stopped fishing at the proper time. As a result, 25% of the CPUE data collected during a 55-day research cruise, which in this case would have been virtually useless, was rendered quantitatively reliable.

Introduction

Relatively small advances in technology sometimes cause the work of fishermen and fisheries scientists to be less difficult and more productive. A small, inexpensive magnesium-alloy cylinder with steel hooks in each end (Figure 1) has saved pot and trap fishermen the loss of untold amounts of gear and catch by holding marker buoys and buoy lines submerged, safe from passing propellers and out of poachers' sight. These simple devices, marketed as "timed float releases", dissolve in seawater at a rate controlled primarily by temperature and alloy metal content. When the dissolution time has passed, the float is released to the surface allowing the gear to be retrieved. In 1978, scientists of the National Marine Fisheries Service (NMFS) adapted the timed release devices (TRD) to make sablefish (Anoplopoma fimbria) traps more reliable as fishery research tools.

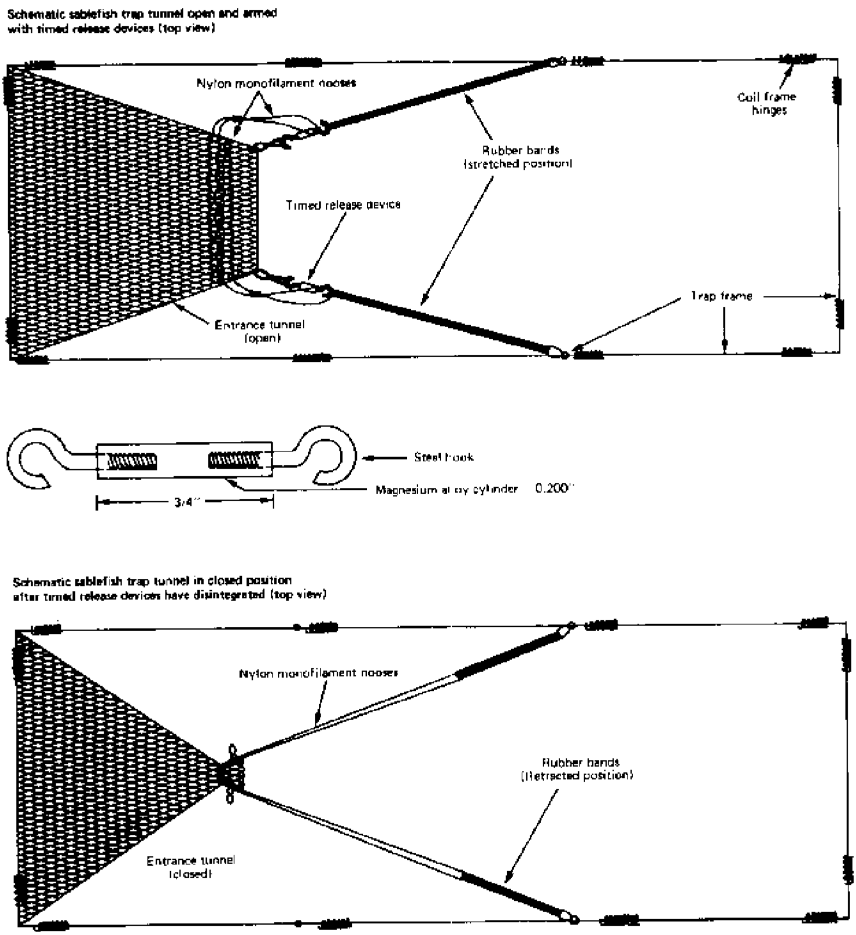

Figure 1.--Diagrams of sablefish trap tunnels, open and equipped with timed release devices (TRD's) and closed with the nooses pulled tight.

Until 1978 management of southeast Alaska sablefish stocks had been dependent on foreign catch per unit effort (CPUE) data. When foreign longliners were excluded from fishing the waters off southeast Alaska in mid-1978 under the provisions of the Magnuson Fishery Conservation and Management Act of 1976 (MFCMA), a resource assessment program to index the abundance of sablefish was implemented to replace the foreign CPUE data base. The NMFS surveys rely on standard trap fishing methods to make year-to-year comparisons of sablefish abundance. A 24-hour period was considered an optimal fishing time for capturing sablefish and for efficient use of vessel time.

When sablefish traps are fishing properly, fish are attracted to bait and enter through a narrow, webbed tunnel. Catch does not increase uniformly with lengthening soak time since the bait loses its effectiveness; in some extreme cases, the number of fish inside may reach a saturation point. Weather and vessel problems can prevent retrieval of gear on schedule and result in lack of controlled fishing time. Variable fishing times between sets has an adverse effect on the consistency of catch indices and increases the number of replicates needed to fulfill standardized sampling needs.

TRD's were examined for their use in triggering the closure of the sablefish traps after a standard fishing time.

Methods

Selection and testing of timed release devices

Timed release devices (TRD's) were tested in a temperature controlled sea water bath to find a specific size that would dissolve in 24 hours in water temperatures anticipated at the survey sites. A wood frame holding 10 TRD's at tensions of 7 lb., similar to those which would be used when attached to the closing mechanisms, was used. Initially two sizes of TRD's were tested at temperatures of 3.5°, 5.0°, and 6.5° C and salinities of 33.3-33.5 $^{0}/oo$. Each test involved five TRD's of 0.184-inch diameter and five of 0.200-inch diameter.

Application of TRD's to tunnel closing devices

A rectangular sablefish trap has a webbed tunnel entrance at one end. A double elastic-loaded noose was developed to shut the tunnel opening (Figure 1). Thick monofilament fishing line was woven through the meshes near the tunnel opening. Strong rubber bands were hung from two opposing vertical supports near the opposite end of the trap, and the nooses were attached directly to them. The apparatus was armed by connecting the tunnel to the stretched rubber bands with TRD's. When a single noose released, escapement of fish through the tunnel was virtually impossible, although a determined fish might have entered. With both nooses retracted, the tunnel closed tightly.

Results

Dissolution times of both sizes of TRD's were directly related to temperature (Figure 2) and the 0.200-inch diameter size best fulfilled the requirements for a 24-hour period at the target temperature of 4°C. Test results suggested that dissolution times would vary by plus or minus 1 hour giving an expected fishing time of 23-25 hours.

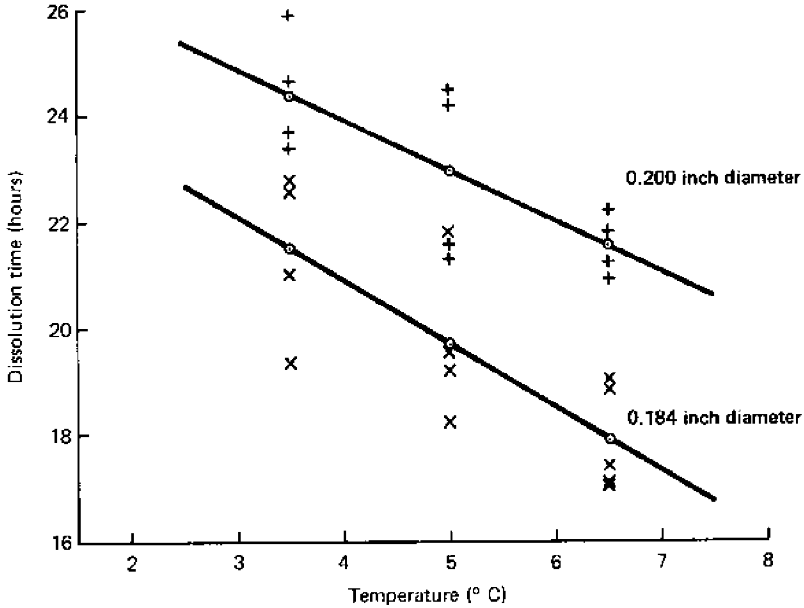

Figure 2.--Relationships between dissolution time in hours and three seawater temperatures for two sizes of magnesium alloy timed release devices (TRD's). The x's denote times for 0.184 inch diameter TRD's, +'s denote times for 0.200 inch diameter, and o's denote mean dissolution times.

Subsequently, 10 other tests have been performed since 1978 to check dissolution rates of other sizes and alloy compositions. Apparent differences in alloys caused variability in deterioration times. Cylinders of equal diameters taken from two test sets gave deterioration times that differed by approximately 3 hours in one case. The supplier reported that he had used different alloy rods to manufacture each set.

During the 1978 sablefish abundance indexing survey, 800 trap sets were made in the eastern Gulf of Alaska. Timed release devices were used in all traps. Two hundred traps were not picked up on schedule due to bad weather, but stopped fishing at the proper time. As a result, 25% of the data collected during a 55-day research cruise, which would have been virtually useless, were rendered quantitatively reliable and directly comparable to the remainder of the data set. The estimated cost to collect an equivalent amount of data was $30,000. By the end of 1982, the NMFS had set an additional 8,000 sablefish traps, all containing TRD's, at abundance indexing sites located from off southeast Alaska southward to southern California.

Conclusions

Magnesium timed release devices are an inexpensive means of standardizing fishing effort of rectangular sablefish traps. The double noose is an effective closing mechanism that ensures against sablefish entering or escaping through the tunnel. Continual use of TRD's during the 5 year sablefish abundance index program has undoubtedly contributed to the quality and quantity of resource assessment data collected.

Potential users of TRD's should plan to test each batch purchased to match the cylinder diameter to the temperature range in which they will be used. There are significant variations between batches which were attributed to differences in alloy content. This problem may be minimized by assuring that the same raw metal lot is used to manufacture the entire TRD order and the test set.

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