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A REVIEW OF THE CANADIAN SWORDFISH FISHERY

by

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Abstract

The history of the Canadian swordfish fishery, together with pertinent details of the life history, are reviewed. Changes in the fishery, re-opened in 1979 after eight years, are described. Temporal and areal contraction of the fishery has occurred, largely as a result of extended jurisdiction, and fleet size and effort have decreased substantially. Catch rate and mean fish size have shown only partial recovery after the period of reduced effort.

Résumé

Les auteurs passent en revue l'historique de la pêche canadienne à l'espadon, ainsi que les détails pertinents de son cycle biologique. Ils décrivent les changements qui se sont produits dans cette pêche, reprise en 1979 après une interdiction de huit ans. Il s'est produit une contraction, tant dans le temps que dans l'espace, de la pêche, en grande partie par suite de l'extension de la juridiction, et les effectifs de la flottille ainsi que l'effort de pêche ont diminué de façon substantielle. Après cette période d'effort réduit, le taux de capture et la taille moyenne des poissons ne montrent qu'un rétablissement partiel.

Life History

Swordfish, like the associated species of billfishes and tunas, is referred to as a highly migratory species and occurs world-wide from about latitude 45°N to 45°S in all tropical, subtropical and temperate seas. Wise and Davis (1973) summarized the distribution of swordfish catches in the Atlantic Ocean from 1956 to 1968 using data from the Japanese longline fishery (Fig. 1). They concluded that there was little difference in distribution with reference to longitude, latitude, land masses, open ocean areas or even with season. However, in the northwest Atlantic, definite patterns of seasonal distribution are present. Beckett (1974) provided a detailed description of these seasonal variations. In winter, swordfish are confined to waters associated with the Gulf Stream where surface temperatures exceed 18°C. However, in summer, the edge of the Gulf Stream moves north, the temperature of surface waters over the continental shelf increases and swordfish are found over a much wider area. The summer range extends along the edge of the continental shelf from Cape Cod to the Grand Banks, with fish moving over the shelf in the western part and near the mouth of the Gulf of St. Lawrence, along the Cape Breton shore. The summer distribution is generally limited by the 13°C isotherm. Distribution by size shows there is a size difference in that larger fish are found in cooler water. Sex ratio also differs with temperature as few males are found in water under 18°C. Males comprise 25 to 30% of the catch in warmer waters and predominate in catches in the Caribbean and adjacent regions.

The occurrence of larvae indicates migration of swordfish between the northern feeding and southern spawning areas (Markle 1974). The only known spawning areas in the west Atlantic are in the Caribbean. Spawning in this area, apparently occurs throughout the year with the peak of spawning from April to September (Arata 1954). The vast majority of gonads from fish captured north of latitude 35°N have been in the quiescent stage and reports of fish with ripening ova are rare (Beckett 1974).

The stock structure of swordfish in the Atlantic is poorly understood. The separate nature of the actual areas where larvae have been found suggests the possibility of stock separation between these areas (Beckett 1974). From Canadian tag results, 22 of 23 returns are from fish recaptured on the same summer feeding ground as those from which they were released. Morphometric data suggest some heterogeneity between fish on Georges Bank and those on the Grand Banks during the summer (Beckett 1974). An analysis of catch rate and fish size by unit area, that shows higher values of both parameters when fishing is initiated in a different unit area, suggests a lack of mobility between the different areas (Beckett 1971).

Growth information on swordfish is limited and contradictory. Swordfish hatch at a length of 4.0 to 4.2 mm and larvae 5.5 mm are about 5 days old (Sanzo 1922). Tibbo and Lauzier (1969) reported a larval growth rate of approximately 2 mm/day while Arata (1954) stated larval swordfish have a growth rate of only 0.6 mm/day. There are no scales in adult swordfish, otoliths are minute and ring counts of vertebrae, operculae and fin rays do not present consistent results (Beckett 1974). Based upon modal analysis of size frequencies in the commercial catch and upon tagging data, Beckett (1974) suggested a rapid growth for female swordfish with weights of 4, 15, 50, 70 and 110 kg for ages one to five years old. Guitart-Manday

(1964) stated that a swordfish 160 cm and 59 kg was two years old. Using eye orbit-fork length data from tropical Atlantic swordfish and combining the Petersen's curves method and probability paper method, Ovchinnikov et. al. (1980) calculated mean lengths of 65, 90, 110, 140, 150, 170, 200 and 210 cm for swordfish aged one to 8 years old. However, a Canadian tagged swordfish recovered in 1979 afters 11 years at large was reported to weigh 120 kg (dressed weight - approximately 160 kg round weight) and measure 325 cm (total length). There is evidence of differential growth rates between male and female swordfish with females attaining larger sizes (Cavaliere 1963; Guitart-Manday 1964). Beckett (1974) suggested few males exceed 200 cm fork length and reported the largest swordfish of verified size weighed approximately 550 kg round weight. There is little information on size and age at first maturity.

Length-weight relationships have been reported from the Canadian longline fishery (Caddy 1976), the American recreational fishery (Beardsley et al. 1979), the Brazilian longline fishery (Amorim et al. 1979) and the Spanish fisheries (Amorim et al. 1979; Rey and Garces 1979). Weight frequencies have been reported for the Canadian longline fishery (Beckett and Tibbo 1968; Beckett 1974) while length frequencies have been reported for the American recreational fishery (Beardsley et al. 1979), the Brazilian longline fishery (Amorim 1977; Amorim et al. 1979) and the Spanish fisheries (Amorim et al. 1979). Sexes have not been distinguished in length-weight relationships or size frequencies.

Palko et al. (1979) presented a synopsis of the biology of swordfish.

Historical Review

Tibbo et al. (1961) presented a summary of the development of the North American swordfish fishery to 1960. The fishery came into existence between the years 1840 and 1855 on the south coast of New England. Effort did not extend north of Cape Cod until 1867 and the Canadian fishery began in 1903. The collection of Canadian swordfish fishery statistics began in 1909 and Tibbo et al. (1961) documented both Canadian and American landings and landed values from 1909 to 1959. Landings appear in Table 1. Beckett (1971) and Caddy (1976) presented descriptions of the Canadian swordfish fishery until its closure in 1971 and Caddy (1976) commented on the continuing fishery until 1975. Figure 2 summarizes Canadian and American landings from 1960 to 1978.

Before the introducton of longlining for swordfish in 1962, the Canadian swordfish fishery was exclusively a harpoon fishery. Fish were harpooned on sunny, calm days while swimming at, or near the surface, over the continental shelf where surface waters ranged from 14° to 17°C (Beckett 1971). The season started in late June on Georges Bank and the Scotian Shelf and spread north and east to the western Grand Banks by mid-September. In some years, landings continued beyond September until early November. All fish were females averaging 120 kg round weight with few under 60 kg. Tibbo et al. (1961) reported that the swordfish fleet consisted of two types of vessels; inshore vessels which confined their operation to only short distances from shore and offshore vessels capable of searching for fish over very wide areas. The inshore vessels were based almost entirely in Cape Breton Island, were 9 to 12 m in length, and carried a crew of two or three.

Few vessels took more than one or two fish during an entire season. The offshore fleet accounted for more than 90% of the landings. In 1957, the offshore fleet consisted of 85 vessels less than 18 m in length, 14 vessels 18 to 21 m in length, 24 vessels 24 to 30 m in length and 43 vessels of unspecified type. The larger vessels carried a crew of 9 or 10. Catch and effort statistics for 1950 to 1970 appear in Table 2.

Night fishing for swordfish using floating longlines was first introduced into the Canadian swordfish fishery in August 1962 as a result of reports of incidental swordfish catches by foreign longliners fishing for tuna and lamnid sharks and of occassional catches on bottom longlines (Beckett 1971). The offshore fleet rapidly converted to longline gear, which proved to be far more efficient. Unlike harpooning, which is basically a hunting technique, longlining does not rely on visual detection of fish and is not selective for sex or size of fish. Longline gear can be used under conditions, such as poor weather or fog, which were not suitable for harpooning and catches can be made away from the main areas of harpooning, particularly in warmer water and over greater depths. As a result, the fishing area expanded rapidly (Figs. 4, 5). The season was extended to the end of the year since boats moved further offshore as the water cooled over the continental shelf. The larger vessels continued fishing throughout the winter and spring, with operations centered off Cape Hatteras during January to April resulting in considerable extension of fishing area and an almost continuous season (Beckett 1971). Longline fleet size was over 100 vessels in 1964 (Beckett 1971), 110 vessels in 1968, 100 in 1969 and 97 in 1970 (Caddy 1976).

The effect of longlining on annual landings was spectacular. Canadian swordfish landings rose to 7546 mt round weight in 1963 from 2096 mt in the previous year. This level was maintained in 1964 (7127 mt) but thereafter landings fell to 4000 to 5000 mt round weight (Fig. 3). This rapid decline in catch and catch rate occurred despite increased effort (Fig. 6) and the maintenance of high landings in 1964 was primarily due to the great increase in effort (2.5 times the 1963 level). Fishing area continued to expand and considerable expansion occurrred in 1966 and 1970 (Figs. 4, 5) with only temporary increase in catch rate.

Unlike harpoon fishing, longline gear takes male swordfish as well as females, and does not select for larger fish. As a result, mean size of fish landed, which had remained relatively steady at almost 100 kg dressed weight prior to the advent of longlining, fell to 82 kg in 1963 and to 40 kg by 1970. Expansion of the fishery into more southern and warmer waters was initially believed to be responsible for the continuing decline in annual mean landed size (Beckett and Tibbo 1968); but a detailed analysis examining discrete geographic areas (Beckett 1971) showed a real trend of declining size and catch rate over time (Table 3). Local abundance and mean size of swordfish is strongly affected by local environmental conditions, especially water temperature, and this leads to a high degree of variability in catch rate and mean size seen in Table 3 values; however, the decline in each area is clear.

Both the Canadian and American swordfish fisheries ceased in early 1971 as a result of information on mercury content of swordfish tissues becoming available and restrictions being placed on mercury levels in food for human consumption. The sale of swordfish with more than 0.5 ppm total

mercury was prohibited in both countries. This, in effect, resulted in a complete cessation of the Canadian fishery since too small a proportion of the catch would fall below the prescribed limit and no practical method was available to rapidly screen the catch for mercury content. Levels ranging up to 4.90 ppm total mercury of dorsal muscle tissue have been found in swordfish (Beckett and Freeman 1974). Mercury content of dorsal muscle tissues of swordfish showed a linear relationship with size and some evidence was found indicating mercury levels decreased with time during the season in the northern range; however no viable regulation options for the fishery were found based upon the prescribed limit of 0.5 ppm total mercury content.

Since the United States Food and Drug Administration ruling could only effectively be applied to shipments across state lines and into the United States from abroad, a limited fishery soon revived in New England based on fish reported to have been caught within three miles of the coast (within state jurisdiction). By 1974, the American fleet consisted of approximately 50 vessels landing 1075 mt (dressed weight) in New England (Caddy 1976). At least some of this catch consisted of swordfish transshipped at sea from Canadian vessels which had continued fishing or re-entered the fishery but were prohibited from landing their catch in either country.

Beginning in 1975, swordfish fishing began to intensify off the Atlantic coast of Florida. During 1976 and 1977, fishing by an increasing fleet of small inshore vessels expanded along this coast. Swordfish fishing has since been reported in the Gulf of Mexico. This fishery has developed uncontrolled and virtually unmonitored because swordfish is not covered by a management plan in the United States; however it appears this fishery is making substantial catches throughout the year and there are rumours of declining catch rates and decreasing average size.

With the estblishment of 200 mile fishing zones by Canada and the United States in 1977 and the lack of a reciprocal fishing agreement, the situation in New England waters became even more difficult. The reported swordfish landings in 1978 of 2314 mt (round weight) by Canada and 3039 mt by the United States are estimates, and likely underestimate total removals.

In 1978, the United States Food and Drug Administration mercury rulings on swordfish were raised to 1.0 ppm total mercury content; however, this level is still too low to result in a substantial increase in the quantity of Canadian caught swordfish permitted to enter the United States legally.

Population Estimates

Caddy (1977) presented preliminary estimates of population parameters. Estimates of total mortality (Z) for the western Atlantic were made for the harpoon fishery (0.12 to 0.65) and for the longline fishery (0.16 to 0.59). Estimates of natural mortality (M) indicated a range from 0.21 to 0.43. A rough estimate of size at first capture using a comparison of commercial size frequencies by longline and harpoon in the mid-1960's suggested that the knife-edge size at first capture by harpoon is in the vicinity of 36 kg (155 cm fork length) and in the vicinity of 4.5 kg (80 cm fork length) by longline. Caddy (1977) concluded that little progress can

be made in applying standard assessment techniques until better parameter estimates are available and made specific recommendations for further research.

Caddy (1976) examined the relationship between harpoon and longline effort from 1950 to 1970. It was concluded that no combined effort measure for the two gear types could be obtained with the data available. The marked difference in size, sex and presumably age composition between the two gear types makes it impossible to pool catch data. The short duration of the longline fishery prior to the 1971 closure was insufficient to calculate a relationship between effort and yield using standard methods. Neither accurate catch data nor effort data are available since the 1971 closure. Using available data, Caddy (1976) concluded that a sustained effort of no more than 3 million hooks would produce a maximum sustainable yield in the vicinity of 3500 to 5000 mt for the northwest Atlantic.

1979 Fishery

Canadian mercury restrictions were removed from swordfish in June 1979 and the fishery re-opened in July 1979 with a TAC of 3000 mt. Efforts were made to monitor the fishery but coverage was poor. Observers were deployed on 4 vessels and approximately 100 hours of interviews were conducted by an observer over the course of the season. Whereas logbook coverage of this fleet prior to the 1971 closure ranged from 40 to 60% (Beckett 1971), it is estimated to be only 22% in 1979, based upon catch figures. Through logbook coverage, sales slips, and interviews with fishermen and statistical and fisheries officers in the ports involved, total catch was estimated to be 2970 mt (round weight). The 22% coverage rate was estimated by adjusting the total dressed weight reported in logbooks by a correction factor (1.053) calcualted by comparing hail figures with actual weigh-out totals, then converting that corrected dressed weight total to round weight using the factor (1.32) estimated for this fishery by Beckett and Tibbo (1968), and comparing this value to the estimated total catch. This estimate of coverage rate is therefore only an approximation, to be used in the absence of more accurate data.

The most lucrative market for swordfish in recent years has been the New England wet fish market where ex-vessel prices have reached $2.50 U. S. The New England market is for fresh fish and the frozen product brings only a fraction of the price. Similarly, other foreign markets will not pay a price competitive with those in the United States. As a result, Canadian swordfish fishermen will continue to transship their catches when possible, until that market is entirely closed to them or market enhancement produces a new competitive market.

A total of 27 longline vessels participated in the fishery (Table 4) and an unknown number of small inshore vessels made incidental harpoon catches. The majority of these harpoon catches were landed in Canada and are covered by sales slips (but not log books) and these catches account for less than 1% of the total catch in 1979. At least 5 longliners made preliminary swordfish trips in late June and early July. Thereafter logbook coverage is fairly representative of the entire fleet, with logs submitted by 20 of the 27 longliners which were involved in the fishery. Fishing occurred from mid-June to late October, with a concentration during August and September, and did not extend south of Georges Bank (Table 5).

Using dressed weight estimates from the available logs, an annual mean dressed weight of 61 kg for the longline fishery (compare to Fig. 7) and a catch rate of 0.89 mt dressed weight per 1000 hooks fished (compare to Fig. 6) were estimated. Using effort figures from the available logs and the estimated coverage rate, total longline fleet effort was estimated at 2500×10^3 hooks (compare to Fig. 6). Estimates of the extent of the fishing grounds of 276×10^3 NM^2 and catch per unit area of 10.8 kg (dressed weight) per NM^2 were made from available logs (compare to Fig. 5), based upon the estimates of Caddy (1976). For comparison to the analysis of Beckett (1971), catch rate (as number of fish per 100 hooks) and mean fish size (as dressed weight in kg) were estimated by 5° x 5° squares from available logs (Table 3).

Interpretation of this data is complicated by factors such as accuracy of the data, change in the temporal and areal distribution of the fishery, experience of the participants in the fishery and the complex relationship between hydrographic conditions and abundance, size and distribution of swordfish. The reduction in total effort is a reflection of the reduction in number of participants and temporal and areal contraction of the fishery. The increase in annual mean weight is not simply a reflection of contraction of the fishery and elimination of catches of smaller fish from warmer waters, since the analysis by 5° x 5° squares shows an increase in each unit area. Similarly, the increase in catch rate as weight is not simply a reflection of the increase in annual mean weight since the catch rate in numbers also increased. These increases are significant and may reflect a partial recovery of the stocks due to the last decade of reduced effort. However, further analysis may be necessary relating environmental conditions and swordfish abundance, size and distribution when more accurate data becomes available.

Longline effort of the Canadian fleet alone in the northwest Atlantic in 1979 is estimated to be as high as 2.5 million hooks. The Canadian swordfish catch in 1979 is estimated to have reached almost 3000 mt. Taking into account the American swordfish catch, total removals from the northwest Atlantic were likely in the vicinity of 4000 to 6000 mt.

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Table 1. Canadian and United States swordfish landings (MT dressed weight), 1909-59 (from Tibbo et al. 1961).

Year	Canadian	United States	Totals
1909	66	743	809
1910	124	471	595
1911	360	682	1042
1912	298	821	1119
1913	604	1080	1684
1914	226	680	906
1915	840	1018	1858
1916	421	804	1225
1917	197	895	1092
1918	165	469	634
1919	336	481	817
1920	152	1148	1300
1921	311	741	1052
1922	506	1489	1995
1923	651	1114	1765
1924	253	1046	1299
1925	206	693	899
1926	587	1130	1717
1927	331	1057	1388
1928	367	1584	1951
1929	287	2320	2607
1930	541	1948	2489
1931	573	1204	1777
1932	470	1676	2146
1933	777	1264	2041
1934	639	664	1303
1935	1013	1099	2112
1936	810	564	1374
1937	681	717	1398
1938	496	776	1272
1939	811	747	1558
1940	1039	519	1558
1941	611	215	826
1942	877	254	1131
1943	1370	211	1581
1944	902	442	1344
1945	1232	1024	2256

Table 1 (cont'd.)

Year	Canadian	United States	Totals
1946	1259	713	1972
1947	813	588	1401
1948	1069	358	1427
1949	1013	351	1364
1950	977	330	1307
1951	1154	73	1227
1952	1432	110	1542
1953	1508	88	1596
1954	1950	125	2075
1955	2062	129	2191
1956	2092	178	2270
1957	2350	294	2644
1958	2439	568	3007
1959	3040	246	3286

Table 2. Catch and effort statistics for the Canadian harpoon and longline fisheries, 1950-70 (from Caddy 1976).

	Landings			Effort			Catch per unit effort		
	Landings dressed weight (mt)			Days fished		Estimated effort in '000 hooks	Catch per days fished (mt)	Catch per days fished (mt)	Catch per '000 hooks (mt)
Year	Harp	LL	Total	Harp	LL	LL	Harp	LL	LL
1950	978	-	978	3,195	-	-	0.31	-	-
1951	1,154	-	1,154	3,773	-	-	0.31	-	-
1952	1,432	-	1,432	4,614	-	-	0.31	-	-
1953	1,508	-	1,508	5,186	-	-	0.29	-	-
1954	1,952	-	1,952	6,122	-	-	0.32	-	-
1955	2,062	-	2,062	4,841	-	-	0.43	-	-
1956	2,092	-	2,092	4,760	-	-	0.44	-	-
1957	2,350	-	2,350	5,345	-	-	0.44	-	-
1958	2,439	-	2,439	7,112	-	-	0.34	-	-
1959	3,040	-	3,040	6,204	-	-	0.49	-	-
1960	1,764	-	1,764	5,260	-	-	0.34	-	-
1961	1,450	-	1,450	4,756	-	-	0.30	-	-
1962	1,349	236	1,585	4,424	325	114	0.30	0.73	2.07
1963	606	5,062	5,668	1,260	3,807	2,323	0.48	1.33	2.18
1964	160	5,218	5,378	572	6,653	5,786	0.28	0.78	0.90
1965	393	3,148	3,541	945	4,707	5,335	0.42	0.67	0.59
1966	532	2,826	3,358	1,249	4,325	4,740	0.43	0.65	0.60
1967	197	3,435	3,632	700	4,102	4,930	0.28	0.84	0.70
1968	39	3,289	3,328	186	5,261	6,735	0.21	0.63	0.49
1969	82	3,143	3,225	225	4,971	6,769	0.36	0.63	0.46
1970	83	3,553	3,636	218	4,263	6,216	0.38		

Table 3. Trends in Canadian swordfish longline fishey -- 5° x 5° squares

Lat.	40		45		40		40		40		40	
Long.	45		50		50		55		60		65	
	A	B	A	B	A	B	A	B	A	B	A	B
1963	4.24	96	0.96	95	3.45	91	2.66	96	1.40	80	3.59	62
1964	--	--	1.13	71	1.21	92	0.88	85	2.14	63	1.49	62
1965	0.99	73	--	--	0.76	82	0.60	106	0.68	67	1.07	65
1966	1.69	62	1.16	44	0.83	78	0.70	70	0.84	66	1.07	64
1967	1.09	60	0.62	18	1.50	54	1.11	64	1.01	52	1.56	51
1968	1.23	48	--	--	0.76	60	0.77	55	0.92	51	1.30	44
1969	1.76	50	--	--	0.71	69	0.59	53	0.80	50	0.97	49
1979	0.94	57	1.07	67	0.91	74	1.11	72	1.33	57	1.94	51

A - Catch rate (number of fish) per 100 hooks

B - Mean fish size (estimated dressed weight in kg)

Table 4. Construction particulars of longline vessels in the 1979 swordfish fishery. (No information is available for the remaining 2 of the 27 vessels involved.)

Year	Registered length (ft)	Gross tonnage	Registered tonnage	Home port
1957	56	56	43	Lockeport
1972	46	38	36	Upper Port LaTour
1964	86	143	66	Sambro
1958	56	66	58	Terrance Bay
1965	90	156	70	Shelburne
1971	36	14	13	Barrington Passage
1962	65	92	53	Lockeport
1946	78	109	74	Lockeport
1965	90	148	60	Lockeport
1967	51	40	27	Wood Harbour
1973	36	24	21	Shelburne
1961	90	136	86	Lockeport
1957	60	68	54	Lockeport
1967	74	91	45	Port Mouton
1966	91	108	41	Sambro
1958	57	59	47	Lockeport
1972	46	43	25	Wood Harbour
1957	58	57	50	Sambro
1966	85	173	83	Port Mouton
1961	64	66	45	Port aux Basques,Nfld.
1965	63	72	38	Port Mouton
1965	91	107	39	Newellton
1966	63	81	46	Terrance Bay
1965	62	73	41	Newellton
1959	57	58	41	Port Mouton
1963	66	83	48	Mean

Table 5. 1979 swordfish longline catch and effort data by month (as reported in log books).

Month	# of vessels fishing	# of days fishing	1000's on hooks fished	# of fish caught	Estimated dressed wt of fish caught (mt)
July	10	88	95.2	975	53.92
August	15	175	206.9	2626	173.88
September	17	179	196.2	3528	201.54
October	8	43	42.2	520	28.57
Total	20	485	540.5	7649	457.91

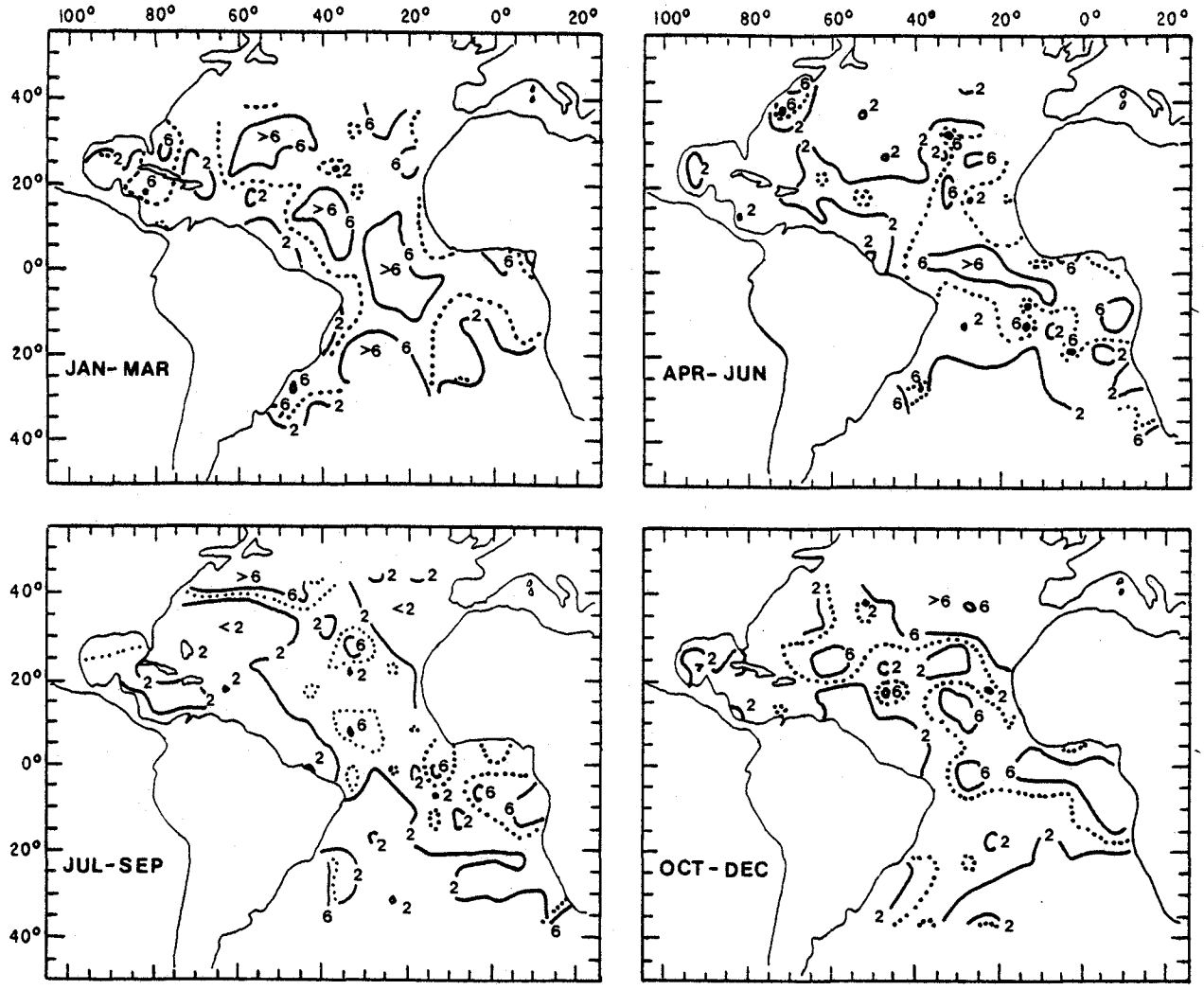

Fig. 1. Distribution of catches of swordfish (per 10,000 hooks in the four quarters of the year, 1956-68 (from Wise and Davis 1973).

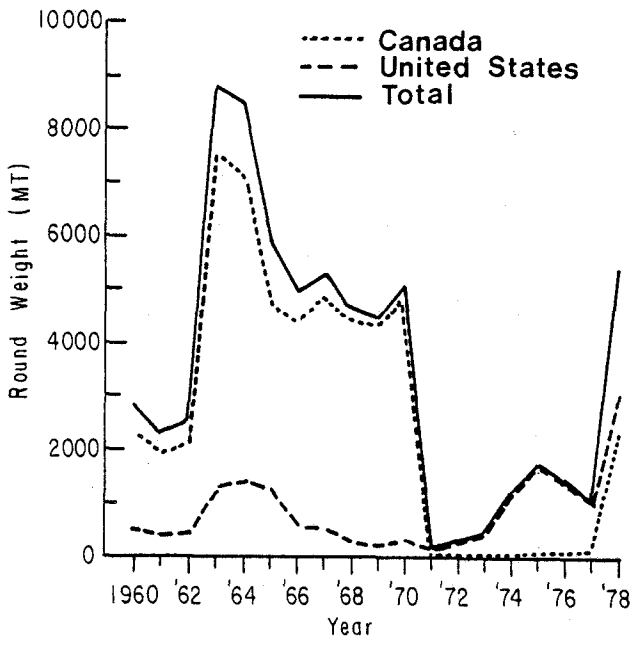

Fig. 2. Canadian and American swordfish landings (MT round weight) 1960-78.

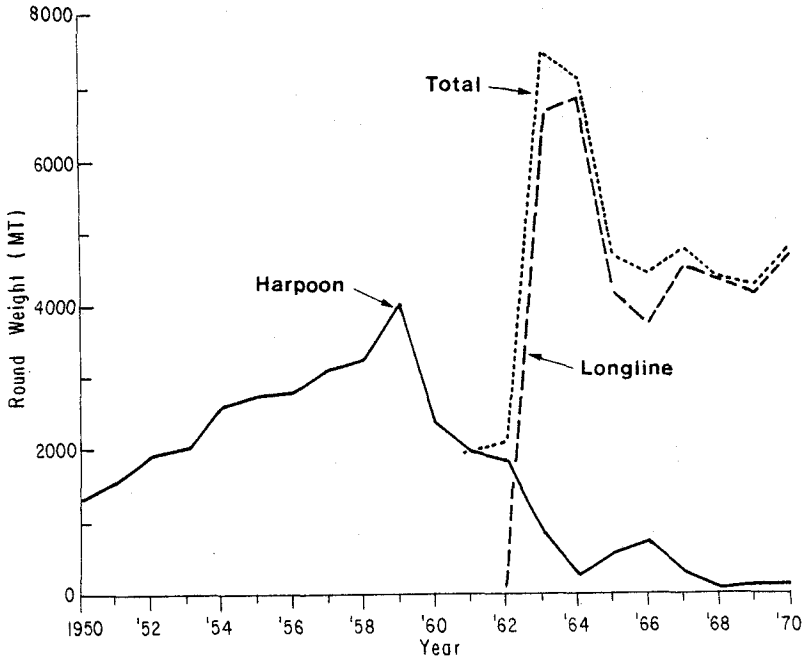

Fig. 3. Canadian swordfish landings (MT round weight) 1950-70.

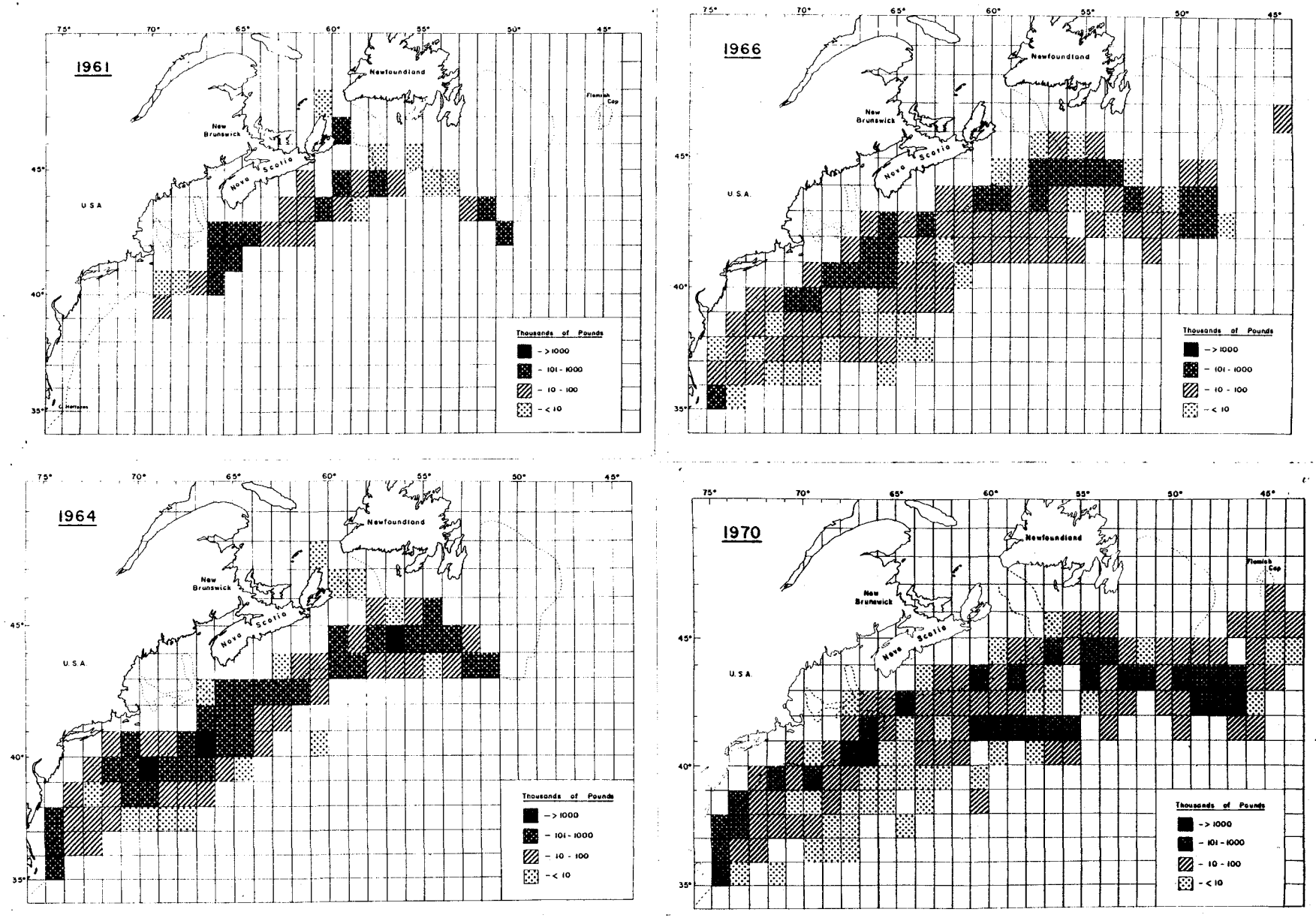

Fig. 4. Canadian swordfish catches by 1° squares (from Beckett 1971).

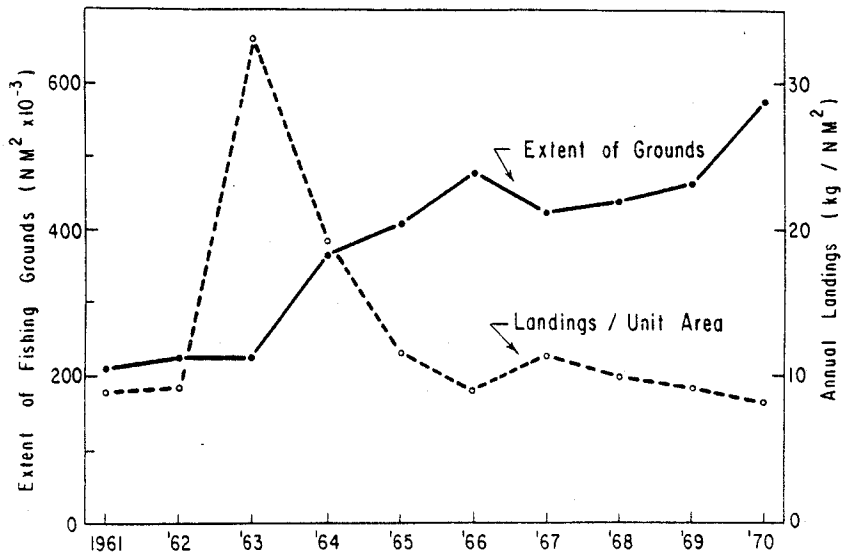

Fig. 5. Trends in the Canadian longline fishery between 1961 and 1970 in areas fished (equivalents of 5° x 1° rectangles of Lat. x Long.), and catch expressed as a fraction of the area of sea surface that received at least some fishing effort in each year (from Caddy 1976).

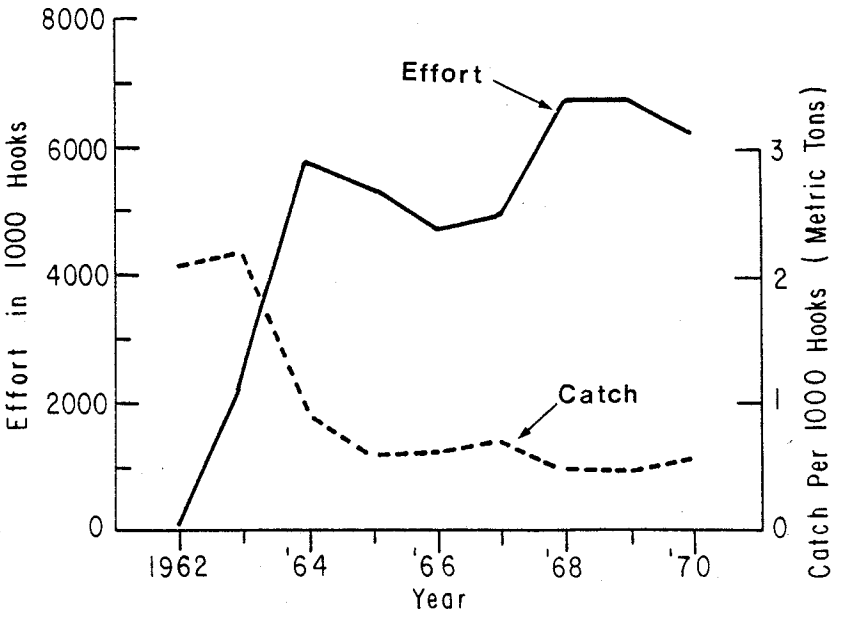

Fig. 6. Effort and catch per unit effort data from the Canadian longline swordfish fishery (1962-70).

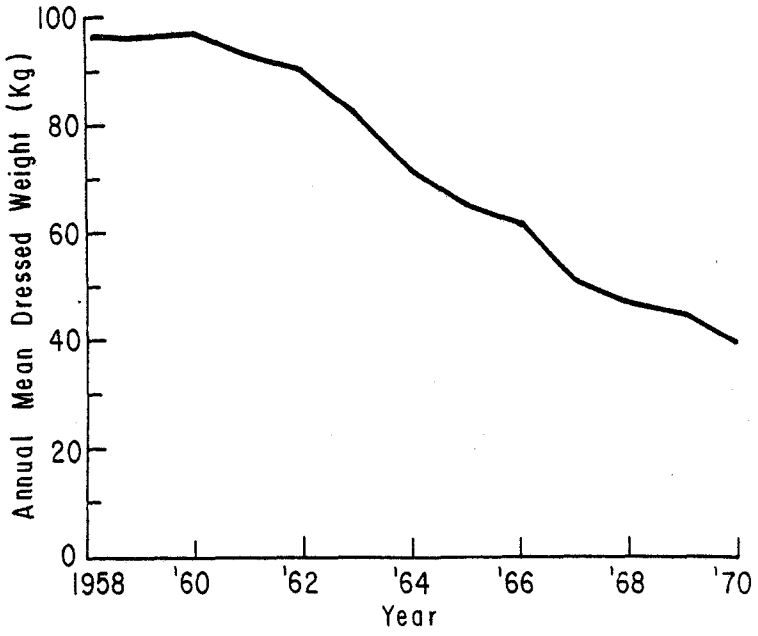

Fig. 7. Annual mean dressed weight of swordfish landed in Canada (1958-70).