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The 4VWX silver hake fishery

by

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Introduction

The Scotian Shelf silver hake *(Merluccilus bilinearis)* fishery is carried out almost exclusively by the USSR. Nominal catches rose from 2 tons in 1961 to 123,000 tons in 1963 and subsequently declined to 2,500 tons in 1967 (Table 1). A second period of rising catches began in 1969 with 46,500 tons and reached a limit of 300,000 mt in 1973. A quota of 90,000 tons and a catch of 95,600 tons were imposed in 1974. The preliminary nominal catch for 1975 is 110,000 tons while the catch quota was 120,000 tons. The total allowable catch for 1976 is 100,000 tons.

The present assessment is an extension of the methodology of ICNAF Res. Doc. 75/104 "An Analysis of the Silver Hake Fishery on the Scotian Shelf" by Doubleday and Halliday. The above document may be referred to concerning the method of ageing USSR commercial length frequency samples by modal analysis adopted here.

Canadian research vessel survey catches in July 1970-72 indicate that silver hake are widely distributed on the Scotian Shelf, except in the cold water area to the north of Banquereau and in the head of the Bay of Fundy (Fig. 1). Highest catch rates were in the deep holes and along the continental slope in depths greater than 100 fm in the central shelf area (the Scotian Gulf) and to the north of Sable Island Bank. A small concentration was also located in the Fundian Channel between Browns and Georges' Banks. These areas of the shelf are frequently inundated with incursions of warm "slope water".

Major spawning concentrations occur on the west bar of Sable Island Bank, with spawning taking place between June and August (Sarnits and Sauskan, 1967; Halliday, personal observation). It is likely that silver hake caught in Div. 4V are taken from the eastern fringe of the Sable Island Bank stock. As the dividing line between Div. 4W and 4X runs through the centre of the Scotian Gulf which is a major area of concentration of the Sable Island stock, it is likely that much of the catches recorded from Div. 4X are also from the Sable Island stock. Concentrations of silver hake do occur and are fished in the Browns Bank area. This may be a small separate stock or part of the Georges Bank or Gulf of Maine stocks.

Canadian Research Vessel Catches

Canada has conducted groundfish inventory cruises by research vessel, covering the entire Scotian Shelf, in the late June to early August period of each year from 1970 (Halliday and Kohler, MS 1971). Silver hake has a low availability to the gear used (probably due to the low headrope height of approximately 9 ft (2.7 m) and uncorrected estimates of population biomass are substantially below recent catch levels (Table 2). Surveys suggest that abundance declined in 1971 from the 1970 level, increased in 1972 and again in 1973 to above the 1970 level, and then decreased slightly in 1974 and sharply in 1975.

Survey estimates of population length-frequencies contain a wider range of sizes than those of commercial catches and are distinctly biomodal with modes at approximately 20 cm and 28 cm (Table 3). Growth analysis from commercial catch length frequencies confirm that these modes represent 1-year-old and 2-year-old fish respectively. Analysis of survey length frequencies shows that most of the catch consists of age-2 fish (Table 4).

Sex ratios in survey catches in Div. 4WX have varied considerably from year to year (Table 5).

Size and Age at Sexual Maturity

Observations on sexual maturity of silver hake were made on research vessel cruises and the basic data for 1971 to 1975 are given in Table 6. On the average, over the five years, almost all males greater than 25 cm in length were mature, the 50% maturity point lying between 23 cm and 24 cm. Almost all females greater than 30 cm were mature, the 50% maturity point lying between 26 cm and 27 cm. There was some variation among years.

Research vessel estimated population length frequencies from Div. 4W were taken as representative of the size composition of the actual population. Age-groups 1 and 2 were separated out for males and females separately. The maturity keys in Table 6 were then applied to the length frequencies of these age-groups to obtain the proportion mature at age (Table 7). The actual ages of individual fish on which maturity observations were made are not known. Thus, the convention was used that, at length groups where age-1 and age-2 fish occur, immature fish were assigned to age 1 with the residual, if any, being assigned to age 2. This makes the reasonable assumption that younger fish of the same size are less likely to be mature.

In the years 1971-75, a very small proportion of age-1 males were recorded as mature and almost all age-2 males were mature (Table 7). Given that there will have been a small proportion of errors in assigning maturity stages and a small error in age designation, it is concluded that essentially all age-1 males are immature and all age-2 males mature.

For females, in those years, a small proportion of age-1 fish are also recorded as mature (Table 7). For the reasons cited above, it is concluded that essentially all age-1 females are immature. Substantially higher proportions of age-2 females are recorded as immature in contrast to the observations for males. As few as 6% are recorded as immature in 1971, and as many as 48% in 1972, averaging 20% for the five years. An explanation of this variation is not obvious at this time. The 1972 data, in particular, have been examined in detail for potential sources of error, but this did not provide a plausible explanation of the high proportion of immatures in that year. Thus, it is tentatively concluded that, on the average, 80% of females mature at age 2, but that this may vary from 50% to almost 100%.

Commercial Catches

Table 8 relates the catch rates of USSR otter trawlers > 1800 gt to the nominal catches from 1963-1974. Catch rates have paralleled trends in total catch, declining from above 1.5 mt/hr in 1963 to 0.15 mt/hr in 1966.

Catch rates subsequently increased with the expansion of the fishery in the late sixties and showed peaks of 1.58 mt/hr in 1970 and 2.62 mt/hr in 1973. In 1974, catch rates declined to 1.16 mt/hr.

Age compositions of Soviet commercial catches from 1966-74 were derived from tables 11 and 12 of Doubleday and Halliday 1975 by apportioning the estimated numbers of 3+ fish from modal analysis on the proportions of ages 3-6 from table 12.

The composition of the USSR catch for Subareas 4WX in 1975 was estimated by applying modal analysis to the available length frequency samples and apportioning the estimated numbers at age 3+ by the age length keys used in Doubleday and Halliday 1975. Catches for the first and second and for the third and fourth quarters respectively were assessed to have equivalent age compositions since samples were only available for catches in May - Sept. The estimates of mean length at age derived from modal analysis shown in table 9 are in agreement with those of earlier years.

The estimated catch compositions are shown in table 10. The large estimate of 1-yr.-old silver hake in 1975 is mainly due to the September length frequency sample of which 65% were of age 1.

Yield Per Recruit

Yield per recruit calculations of Doubleday and Halliday 1975 are reproduced here for ease of reference.

Monthly growth and mortality were calculated and yield was accumulated to 72 months of age. Yield-per-recruit calculations were based on knife-edge selection at a given age and are calculated per 9-month-old fish, i.e., t_0 = 9 months. Nine months of age was chosen as a reference point due to the large effect of natural mortality (M) on year-class size, as the age of recruitment varies. A value of M = 0.4, similar to Anderson (MS 1975), was assumed. Identical calculations with M = 0.5 and M = 0.6 were carried out with lower yields per recruit but with qualitatively similar results with respect to the effect of fishing mortality.

Yield per recruit increases rapidly over a wide range of fishing mortalities as the age of selection increases from 12 to 18 months. Recalling that silver hake nominally reach 12 months of age in June, this observation implies that age-1 fish should not be caught at all. The current mean age of selection is approximately 15 months in the USSR silver hake fishery in Div. 4W.

Yield per recruit rises steeply as the rate of fishing mortality (F) rises to 0.5 and more slowly as F increases to 0.7. For F greater than 0.7, little increase in yield is observed. With knife-edge selection at 15 months, 0.7 is the value of F which maximizes yield per recruit (Fig. 2).

Virtual Population Analysis

Using M = Q.40, the data in table 10 were analysed by vitual population analysis. For 1975, it was assumed that F = 0.5 for ages 4-6 while F for ages 2 & 3 were 1.5 and 1.2 respectively. These rates were chosen to be conservative in relation to those estimated for 1974. For earlier years F for age 6 was roughly equated with the previously obtained F estimate for age 5. The results are displayed in tables 11 & 12.

In view of the dominance of age 1 silver hake in the September commercial catch, recruitment appeared to be essentially complete for these fish. Thus the average fishing mortality on 1 year olds in 1975 may well be 0.4 or greater. No value was assumed.

Means of F-values calculated for ages 2-5 in each year fluctuate in close relationship to fluctuations in annual effort (days fished) on the Scotian Shelf by USSR otter trawlers greater than 1800 gross registered tons. The data series are as follows:

	1967	1968	1969	1970	1971	1972	1973	1974
Mean F (ages 2-5)	0.125	0.136	0.505	0.779	1.288	1.267	1.983	1.219
Fishing effort	318	1677	2871	5405	6813	4813	9333	5223

These data have a correlation of 0.94 ($R^2 = 0.89$). The line $F = -0.1239 + 2.201 \times 10^{-4}$ Days Fished was fitted to the points (fig. 3).

Length at Age 1 and Year Class Size

Figs. 4 and 5 show the relationship between the length of one-year-old silver hake (l_1) in September with estimates of abundance. The data are as follows:

Year class	1967	1968	1969	1970	1971	1972	1973	1974
l_1 cm	24.22[1]	21.85[2]	22.46	21.62[3]	21.34	23.14	25.53	24.14
Biomass Age 2	4.70	12.21	8.64	7.18	17.40	5.69	5.49	
Catch rate Age 2			5.97	6.55	13.92	6.85		

1. Adjusted from July by the age length curve of Doubleday & Halliday.
2. Adjusted from November by the age length curve of Doubleday & Halliday.
3. Based on a sample of 200 fish.

In spite of the point for the 1970 year class which is derived from a sample of only 200 fish, a clear inverse relationship between length in September at age 1 and year class size is evident for both measures of abundance. The mean length for September was chosen because this is the age of nearly full recruitment into the fishery. The size of the 1974 year class is expected to be 450×10^6 fish at age 2 or less than 750×10^6 fish at age 1. The location of the 1973 point is extremely sensitive to the choice of starting F for the virtual population analysis.

Catch Projections

The 1975 population estimates in table 12 are taken as the starting point for projections of potential yield in 1976 (Table 13). The calculated 1975 catch weight is an underestimate by 35% due to the increased growth rates of the 1972 and 1973 year classes over former years. Calculated catches for 1976 and 77 have been adjusted upwards by a factor of 1.35. The 1974 year class is assumed to be composed of 750×10^6 fish at age one on the basis of the l_1, length. Recruitment at age 1 in 1976 and 1977 is assumed to be 1×10^9 fish.

In view of the reduced catch rates in 1974 and the likelihood based on l_1 length that the 1973 year class is weak, the stock composition for 1974 used here is likely to be an overestimate of stock size. Assuming the strength of the 1974 year class to be 1×10^9 fish would result in a catch of 83×10^3 mt in 1977.

The use of fishing mortality of 0.7 on mature fish in 1977 is in accord with the yield per recruit calculations quoted earlier.

Temperature and Abundance

The relationship between bottom temperature on Sable Island Bank in July and year-class success was examined. Bottom temperatures for the area (less than 50 fm) were obtained by averaging bottom temperature measurements taken on Canadian research vessel cruises. The number of observations used

varied from 10 to 59 with about 15 for most years. Catch per hour fished of age-1 and age-2 silver hake in Div. 4W by USSR otter trawlers (>1800 GRT) was calculated using estimated numbers at age from Table 10 (Table 14). The effort data for 1975 are not yet known. Catch per unit effort of 2-year-old fish appears to be a more reliable measure of year-class size than the corresponding data for 1-year-olds. Fig. 6 shows the relation between temperature at spawning and catch per hour fished of 2-year-olds. Evidently, temperatures near 6°C are favourable while temperatures near 4°C are unfavourable. A two-variable equation with catch per unit effort of parents and temperature in July would predict the catch per unit effort of the 2-year-old filial populations well for all year-classes except 1971. However, in view of the small number of data points, the fitting of a response surface does not appear justified.

Discussion

Comparison of tables 8 and 12 shows that USSR catch rates have reliably reflected abundance over the history of the fishery. The decline in catch rates by one third from 1973 to 1974 indicates a reduction in abundance of silver hake. This observation is supported by the drastic decline of Canadian research vessel catch rates in 1975.

The length of age one silver hake in September, the usual month of recruitment to the fishery, shows a clear inverse relation with year class size. On this basis the 1974 year class is likely to be moderate to weak and is estimated to be less than 750×10^6 fish.

The relationship between bottom temperature on Sable Island Bank to catch rates of two year olds two years later suggests the 1974 year class to be moderate to strong while the 1972, 1973, and 1975 year classes are expected to be moderate to weak on this basis.

In 1973-1975 the Soviet commercial catch in numbers has consisted of approximately 90% fish aged one and two while the ratio in the catch of age one fish to age two fish has increased from 0.07 to 0.20 to 0.28. Analysis of Canadian research vessel survey data clearly indicates fish of the size and age of these one year olds are nearly 100% immature. Two year old males are virtually 100% mature while about 20% of two-year-old females are immature on the average. Thus, in 1974 and increasingly in 1975 the USSR fishery has concentrated on immature fish and fish spawning for the first time.

Consideration of the monthly changes in the proportion of two-year-old fish in the commercial catch from September to December shows no sudden drop which could be associated with a high spawning mortality. One-year-old fish are sometimes caught in considerable numbers in August, and sometimes not until October so that there is no one month when the fishery regularly shifts to the new recruits. Thus, in the absence of evidence of massive predation, there seems to be no justification for assuming a natural mortality rate greater than 0.4.

Virtual population analysis indicates that silver hake of ages two and three have suffered very high mortality rates of up to 2.7 (1973) which bear a close relationship with reported fishing effort. These high rates of fishing mortality adequately explain the scarcity of fish aged 4 and older. Yield per recruit calculations indicate that, with the current recruitment pattern, little yield is gained by employing levels of F higher than 0.7.

Reduction of the level of fishing mortality to 0.7 would increase stock stability by increasing the number of year classes in the fishery. Dependence on estimates of year class sizes of 0 group and age 1 fish for the management of the fishery would be reduced.

In view of the decrease in commercial and research vessel catch rates, the increased length of the 1972-1974 year classes at recruitment, the shift of the commercial catch age composition to younger fish, and the evidence of current high rates of fishing mortality, it is recommended that the 1977 quota be reduced to the region $60 - 70 \times 10^3$ mt.

Acknowledgement

The examination of the relation of l_1 length to year class size was prompted by the work of P. F. Lett (1976).

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Table 1. Silver hake landings from ICNAF Div. 4VWX by Division and Country (metric tons round).

	ICNAF DIVISION					COUNTRY				
Year	4Vn	4Vs	4W	4X	Total	Canada	Japan	USSR	USA	Others
1960	-	-	-	187	187	-	-	-	187	-
1961	-	-	-	2	2	-	-	-	2	-
1962	-	-	8,825	29	8,854	-	-	8,825	29	
1963	168	-	116,388	6,472	123,028	-	-	123,023	5	-
1964	32	-	62,905	18,210	81,147	-	-	81,147	-	-
1965	180	2	49,461	379	50,022	5	-	49,987	27	3[2]
1966	40	0	3,860	6,423	10,323	-	-	10,323	-	-
1967	-	-	1,834	643	2,483	-	6[1]	2,476	1	-
1968	2	237	3,150	58	3,523	5	76[1]	3,441	1	-
1969	-	1,230	43,563	1,558	46,564	-	213[1]	46,323	-	28[3]
1970	-	5,116	158,938	4,991	169,045	-	129	168,916	-	-
1971	11	3,000	119,452	6,190	128,653	-	8	128,633	1	11[4]
1972	-	75	108,769	5,204	114,048	-	63	113,774	-	211[5]
1973	-	3,431	265,105	30,085	298,621	-	88	298,533	-	-
1974	-	659	86,927	845	95,601	1[1]	67	95,371	-	152[6]
1975[7]	...	...	...	...	110,250	100	54	108,398	7	1,698[8]

1 Not recorded by Division
2 France (SP)
3 GDR
4 Spain
5 FRG 10 m.t., Cuba 201 m.t.
6 FRG
7 Preliminary statistics
8 Bulgaria

Table 2. Div. 4VWX Silver hake - Canadian research vessel survey estimates of biomass (metric tons), population numbers ($x10^{-6}$), and catch per tow, 1970-75.

Year	Biomass	Kg/tow	Popn. No.	No/tow
1970	23,520	4.90	142.7	29.32
1971	7,880	1.59	53.3	10.78
1972	15,260	3.09	87.9	17.72
1973	38,190	7.69	229.9	46.29
1974	36,140	7.28	183.5	36.95
1975	7,500	1.50	43.8	8.82

Table 3. Div. 4VWX Silver hake - estimated population length-frequency from Canadian research vessel surveys ($x10^{-3}$).

Length cm.	1970	1971	1972	1973	1974	1975
≤ 10	37	90	-	-	-	-
11	-	-	46	47	71	-
12	68	46	-	48	-	-
13	34	123	139	313	17	-
14	239	534	371	672	187	73
15	645	1,139	1,128	1,346	384	172
16	1,297	1,649	1,467	2,149	552	365
17	2,111	2,620	2,689	4,274	1,680	760
18	3,790	5,797	3,066	8,355	3,864	1,047
19	4,554	4,318	3,921	12,767	6,146	1,356
20	6,490	2,520	3,986	13,554	8,854	3,380
21	7,991	1,917	3,099	12,740	6,622	4,013
22	5,352	698	4,650	9,886	5,174	3,350
23	2,938	512	3,462	4,432	2,478	2,825
24	1,342	241	1,527	2,377	1,824	1,601
25	3,317	728	3,762	3,015	3,203	829
26	9,987	1,237	7,423	9,940	10,048	559
27	18,389	3,946	11,402	22,291	20,435	998
28	24,417	6,255	11,135	36,325	25,129	1,807
29	19,768	5,635	6,245	30,186	20,849	3,760
30	10,210	3,883	4,474	19,849	18,736	3,018
31	6,765	2,603	2,118	10,221	11,930	3,529
32	3,375	1,999	2,705	4,486	7,307	2,242
33	2,197	1,489	1,768	3,506	7,197	2,120
34	1,711	805	1,524	2,283	4,320	959
35	885	337	1,391	2,615	2,735	524
36	838	306	1,153	2,271	2,442	568
37	953	349	557	1,986	2,200	139
38	203	77	360	1,201	1,265	180
39	550	114	218	975	600	170
40	376	99	170	529	561	94
41	252	87	280	801	624	122
42	100	71	188	547	781	158
43	394	203	114	730	440	153
44	174	248	65	209	670	53
45	120	145	87	426	366	62
46	138	-	-	322	413	117
47	240	157	142	479	877	8
48	140	104	50	270	355	169
49	136	55	101	34	410	103
≥ 50	158	158	848	1,419	1,797	355
	142,681	53,294	87,831	229,876	183,543	41,738[1] (43,819)

[1] Fish from one set not measured. Thus total of L-F is less than total numbers.

TABLE 4. Silver hake in Div. 4VWX: estimated age composition of the population from Canadian research vessel surveys, 1970-75

Population numbers ($x10^{-6}$)

Age	1970	1971	1972	1973	1974	1975
1	38.3	21.3	31.9	70.8	36.4	20.4
2	100.8	26.1	46.9	148.5	120.0	20.0
3+	3.6	5.9	9.0	10.6	27.1	3.5
TOTAL	142.7	53.3	87.8	229.9	183.5	43.9

Table 5 . Silver hake in Div. 4VWX: sex ratios for ages 1 and 2 from Canadian research vessel surveys, 1971-75.

Age	Sex ratios (male : females)				
	1971	1972	1973	1974	1975
1	1.62	1.52	0.93	0.50	1.52
2	0.48	0.43	0.29	0.68	0.76

Table 6a . Div. 4VWX silver hake - size at sexual maturity observed on Canadian research vessel cruises. (Number of observations at length and percentage mature at length).

A. MALES

Length (cm)	1971		1972		1973		1974		1975		1971 - 75		% mature
	Imm	Mat	Imm	Mat	Imm	Mat	Imm	Mat	Imm	Mat	Imm	Mat	
15	12		8		7		2		2		31		-
16	11		11		5		5		5		37		-
17	22		18	1	12		14		6		72	1	1
18	48		26	-	17		22		13		126		-
19	35		26	-	18		28	1	13		120	1	1
20	24		31	-	21	1	30	3	28		152	4	3
21	14		18	3	8	-	21	-	30		91	3	3
22	5		8	5	14	-	15	4	29		71	9	11
23	2	2	10	2	9	-	6	3	19		46	7	13
24	-	4	6	2	4	3	6	12	10		26	21	45
25	-	9	4	11	2	19	2	24	8		16	63	80
26	-	14	1	22	-	52	1	43	2	2	4	133	97
27	2	26	1	28	-	49	4	97	1	9	8	209	96
28	-	34		24	-	71	-	89	1	13	1	231	99
29	1	25		11	1	39	-	86	1	40	3	201	99
30		14		16	1	24	-	82		26	1	162	99
31		6		13	1	19	1	57		18	2	113	98
32		4		8		14		25		7		58	100
33		3		6		16		13		3		41	100
34		-		2		8		3		1		14	100
35		-		-		3		2				5	100
36		-		2		1		2		1		6	100
37		1		1				1				3	100
38				1				-				1	100
39				1				-				1	100
40								1				1	100

Table 6b. Div. 4VWX silver hake - size at sexual maturity observed on Canadian research vessel cruises. (Number of observations at length and percentage mature at length).

B. FEMALES

Length (cm)	1971		1972		1973		1974		1975		1971 - 75		% mature
	Imm	Mat	Imm	Mat	Imm	Mat	Imm	Mat	Imm	Mat	Imm	Mat	
15	8		5		5		5		1		24		-
16	12		6		4		8		3		33		-
17	16		15		19		14		11		75		-
18	32	2	18		25		33		8		116	2	2
19	28	1	26	1	21	1	42		15		132	3	2
20	19	-	38	-	16	-	48	1	36		157	1	1
21	16	-	15	-	12	-	33	1	40		116	1	1
22	9	-	20	2	9	1	26	1	34		98	4	
23	5	-	17	-	8	-	21	-	31		82	-	-
24	1	-	11	-	6	-	20	1	13		51	1	2
25	3	1	5	2	8	-	18	3	5		39	6	13
26	4	4	14	3	5	16	27	6	5	1	55	30	35
27	6	21	19	11	16	49	33	26	2	4	76	111	59
28	9	42	16	27	17	72	29	37	1	18	72	196	73
29	-	52	10	20	11	90	21	45	1	35	43	242	85
30	2	54	9	21	2	81	5	69		32	18	257	93
31	1	43	1	16	1	43	4	109		48	7	259	97
32	1	38	4	24	2	36	1	81		41	8	220	96
33		30	2	27		25	3	92		44	5	218	98
34		24	1	26		11		67		24	1	132	
35		9	-	19		24		43		15	-	110	100
36		7	1	10		26		41		11	1	85	99
37		7		6		21		33		6		67	100
38		2		6		18		20		6		46	100
39		3		6		17		8		3		34	100
40		1		3		11		12		4		27	100

Table 7a. Div. 4W silver hake - length-frequencies of ages 1 and 2 fish by sex (nos. x 10^{-3}) from Canadian research vessel surveys and percentage mature at age.

A. MALES

Length (cm)	1971		1972		1973		1974		1975	
	Age 1	Age 2	Age 1	Age 2	Age 1	Age 2	Age 1	Age 2	Age 1	Age 2
10			4							
11			10							
12	1		29						1	
13	5		70						5	
14	20		155				3		21	
15	60		303		9		17		70	
16	145		532		59		86		191	
17	283		835		274		307		437	
18	444		1170		884		769		835	
19	561		1466		1974		1374		1332	
20	570		1643		3042		1750		1775	
21	466		1645		3239		1588		1975	
22	307		1472		2382		1026		1836	
23	163		1178	7	1211	2	473	4	1426	1
24	69	5	842	133	425	40	155	78	925	9
25	24	68	538	1043	103	316	36	653	501	54
26	7	387	308	3385	17	1232	6	3186	227	227
27	1	1049	157	4531	2	2314	1	7816	86	646
28		1352	72	2502		2096		9632	27	1237
29		829	29	570		915		5965	7	1598
30		242	11	54		193		1856	2	1392
31		33	3	2		20		290		818
32		2	1			1		23		324
33								1		86
% mature	5.8	97.3	12.3	100.0	2.9	99.5	8.5	98.7	9.0	91.0

Table 7b. Div. 4W silver hake - length-frequencies of ages 1 and 2 fish by sex (nos. $x10^{-3}$) from Canadian research vessel surveys and percentage mature at age.

B. FEMALES

Length	1971		1972		1973		1974		1975	
(cm)	Age 1	Age 2	Age 1	Age 2	Age 1	Age 2	Age 1	Age 2	Age 1	Age 2
10										
11			1							
12			4							
13	1		18						1	
14	4		58				7		4	
15	17		156		71		7		16	
16	57		352		246		53		58	
17	141		658		661		261		169	
18	263		1022		1383		885		399	
19	372		1318		2255		2070		768	
20	400		1411		2864		3333		1204	
21	325		1254		2834		3697		1535	
22	201		925	6	2184		2826		1593	
23	94		567	58	1311		1488	16	1345	
24	33	1	288	348	613	2	534	113	925	2
25	9	9	122	1391	224	37	135	557	517	8
26	2	81	43	3654	63	403	23	1921	235	32
27		422	12	6323	14	2193	3	4703	87	104
28		1281	3	7204	2	5950		8164	26	277
29		2258	1	5405		8046		10060	7	601
30		2313		2670		5423		8791	1	1059
31		1376		869		1822		5448		1515
32		476		186		305		2395		1760
33		96		26		25		747		1661
34		12		2		1		166		1273
35		1						26		792
36								3		401
% mature	1.7	94.0	1.6	51.5	2.2	88.5	1.9	71.1	6.3	93.7

Table 8. Div. 4VWX Silver hake - total international catch in Div. 4VWX, and catch rates by USSR otter trawlers >1800 gt in Div. 4W (12 month mean of monthly catch rates).

Year	International catch (mt)	USSR OT >1800 gt mt/hr
1963	123,028	(1.82)¥
1964	81,147	(1.37)¥
1965	50,022	0.68
1966	10,323	0.15
1967	2,483	0.29
1968	3,547	0.15
1969	46,564	0.98
1970	169,045	1.58
1971	128,657	1.13
1972	114,048	1.26
1973	298,621	2.62
1974	95,745	1.16

¥ Catch rate of "other groundfish", mainly silver hake.

Table 9. Mean length (cm) at age by month for USSR silver hake sampling 1969 - 1975.

Age \ Yr. Class	66	67	68	69	70	71	72	73	74
6						12.7			
9			12.8				14.6	*	
10				13.9		16.5	*	17.3	20.4
11				16.3		18.6	18.5	18.7	18.8
12			20.3	*			18.3	19.1	23.8
13				19.3		20.7	20.7	21.5	20.3
14				21.4		21.3	22.6	22.6	22.9
15				22.5	21.6	21.3	23.1	25.2	24.1
16			21.1	24.0		22.7	24.7	25.5	
17			23.6	25.8		24.0	24.6	*	
18				25.5	26.5			26.0	
19		27.0	*						
20						26.7			
21		26.9	26.2	26.8	25.7	26.0	25.6		
22			26.9		27.2	*	27.1	27.9	
23		29.2	27.1		27.7	28.1	26.2	28.5	
24		29.1	*		*	28.5	29.1	30.4	
25		29.8	28.7		27.5	28.4	30.0	30.3	
26			28.2		*	29.2	29.8	30.8	
27			28.7	29.8	26.7	29.3	30.7	31.6	
28		*	29.3		29.7	29.8	31.0		
29		29.0	30.2		*	30.0	31.4		
30			31.1	32.1			*		
31	32.6				*				
32	33.1	*	*	30.1		31.2			
33		*	*	31.3	*	31.6			
34		31.1		*	*	*	34.4		
35		*		33.0	*		36.8		
36		*		*	*	*	37.4		
37		*			*	*	36.2		
38		*			*	*	36.1		
39					*	*	35.7		
40					*				
41									
42		39.5							

Table 10. Age composition of commercial catches of silver hake in Div. 4W, 1965-74 and 4WX 1975.

	Numbers at age ($x10^{-3}$)					
Year	1	2	3	4	5	6
1966	10220	9795	406	34	9	13
1967	-	7576	804	67	18	26
1968	84	18218	1910	159	43	61
1969	21456	242169	19474	2154	740	90
1970	208319	702322	68653	6234	2026	1013
1971	65461	553957	202177	14761	3802	3131
1972	149692	414279	102440	13167	5074	-
1973	102212	1449980	118398	12715	4512	1094
1974	80432	405044	49437	5087	2115	457
1975	140181	368615	41387	4258	1770	383

Table 11. Fishing Mortality Estimates for Scotian Shelf Silver hake 1966-75.

Year	AGE 1	2	3	4	5	6
1966	0.156	0.534	.419	.075	.055	.1
1967	-	0.207	0.092	.138	.063	.1
1968	-	0.275	0.091	0.029	.153	.15
1969	0.014	0.932	0.689	0.174	0.225	.3
1970	0.178	1.118	1.045	0.644	0.308	.3
1971	0.071	1.365	1.986	0.902	0.9	0.9
1972	0.067	1.126	1.602	0.991	1.349	-
1973	0.136	2.722	2.006	1.344	1.859	1.5
1974	0.112	1.708	1.381	0.563	1.224	1.0
1975		1.5	1.20	0.5	0.5	0.5

Table 12. Estimated population numbers at age for 4WX Silver hake 1966-75.

Year	Population numbers at age ($\times 10^{-6}$) 1	2	3	4	5	6
1966	85.17	28.23	1.42	0.57	0.20	0.65
1967	135.86	48.83	11.09	0.63	0.36	0.13
1968	701.68	91.07	26.61	6.78	0.37	0.22
1969	1845.65	470.35	46.37	16.29	4.42	0.21
1970	1540.40	1221.02	124.20	15.60	9.18	2.36
1971	1149.68	864.35	267.50	29.27	5.49	4.52
1972	2776.52	717.57	148.02	24.60	7.96	-
1973	972.41	1739.73	156.07	20.00	6.12	1.39
1974	916.46	569.05	76.67	14.07	3.50	0.64
1975		549.03	69.14	12.92	5.37	0.69

Table 13. Population numbers and catch projections for Scotian Shelf Silver hake 1975-77.

	1975			1976			1977			
Age	Stock Size (10^{-6})	F	Catch Wt. (10^{-3}) tons	Stock Size (10^{-6})	F	Catch Wt. (10^{-3})tons	Stock Size (10^{-6})	F	Catch Wt. (10^{-3})tons	Mean Wt. Kg.
1	750	.26	7	1000	0.31	11	1000	.1	4	0.051
2	549	1.5	59	388	1.80	45	492	.7	33	0.159
3	69	1.2	11	82	1.44	15	43	.7	5	0.270
4	13	.5	2	14	0.60	2	13	.7	2	0.426
5	5.4	.5	1	5.4	0.60	1	5	.7	1	0.635
6	0.7	.5	0	2.2	0.60	1	2	.7	1	0.905
Calculated catch			80.078			74.9			46.7	
Corrected catch			108.398			100			63.	

Table 14 .

Temperature and Catch per Unit Effort for 4W silver hake.

Year	Temp.	Catch per hour fished 1 yr olds $x10^{-3}$	Catch per hour fished 2 yr olds $x10^{-3}$
1965	7.56	0.04	4.40
66	3.76	0.38	0.37
67	5.39	0.00	5.17
68		0.00	0.89
69	4.82	0.64	7.23
70	5.10	2.69	9.06
71	5.92	0.71	5.97
72	4.72	2.37	6.55
73	4.33	0.98	13.92
74	5.88	1.36	6.85
75	4.30		

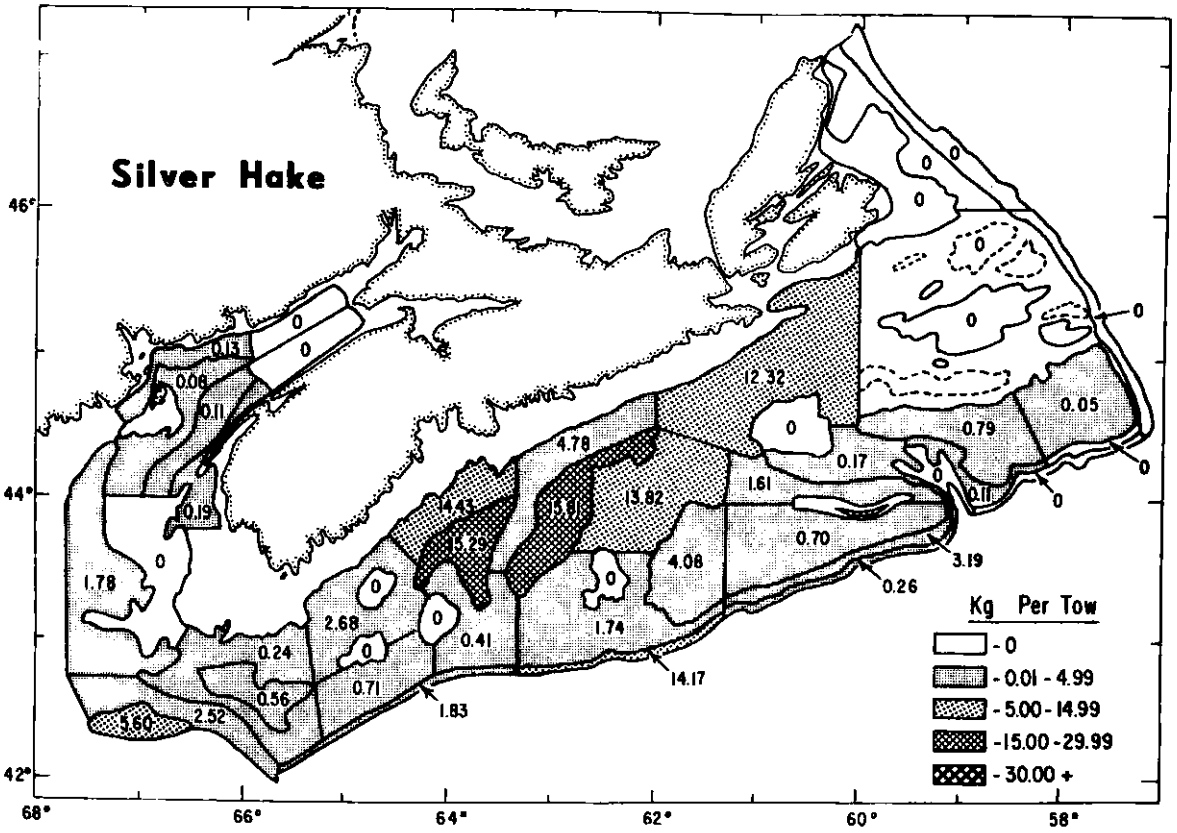


Fig. 1. Distribution and abundance of silver hake in Canadian research vessel surveys, 1970-72.

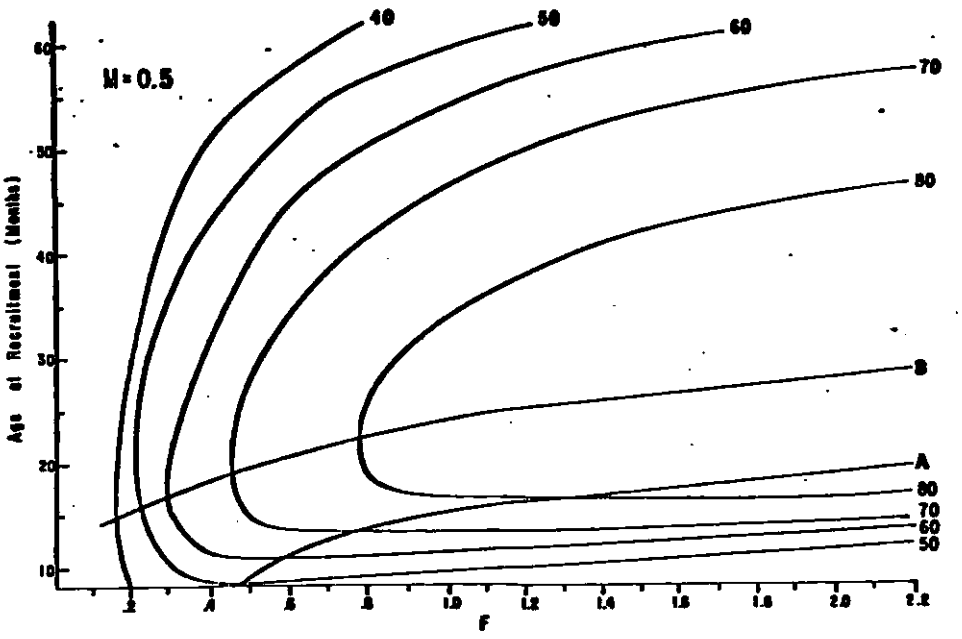
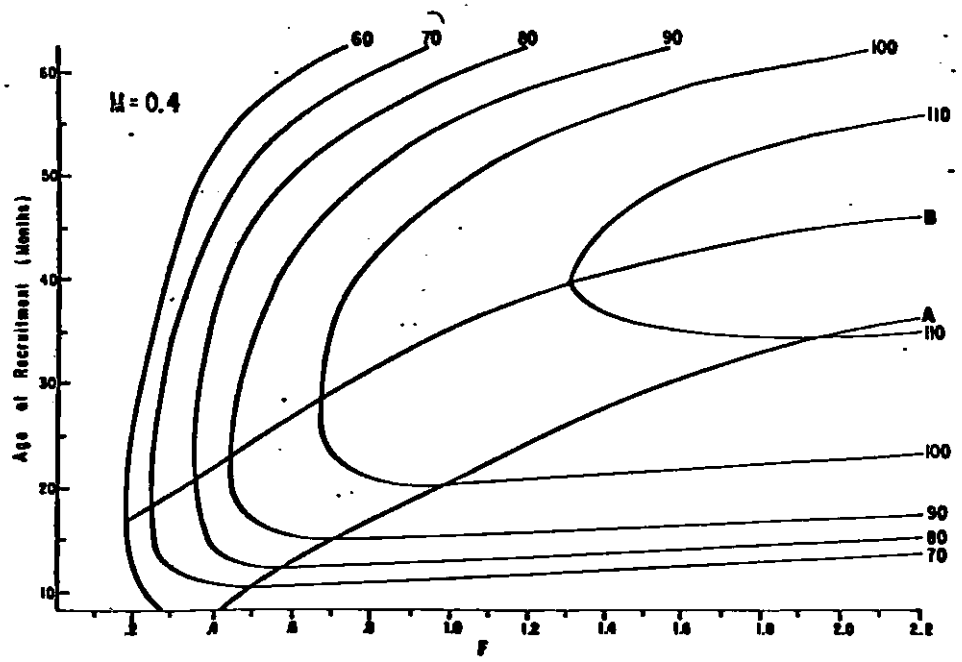


Fig. 2 Yield per recruit isopleth diagram. The lower line (A) imposed on the isopleth gives the F with greatest yield for given ages at recruitment and the upper line (B) gives the age at recruitment with greatest yield for given levels of F.



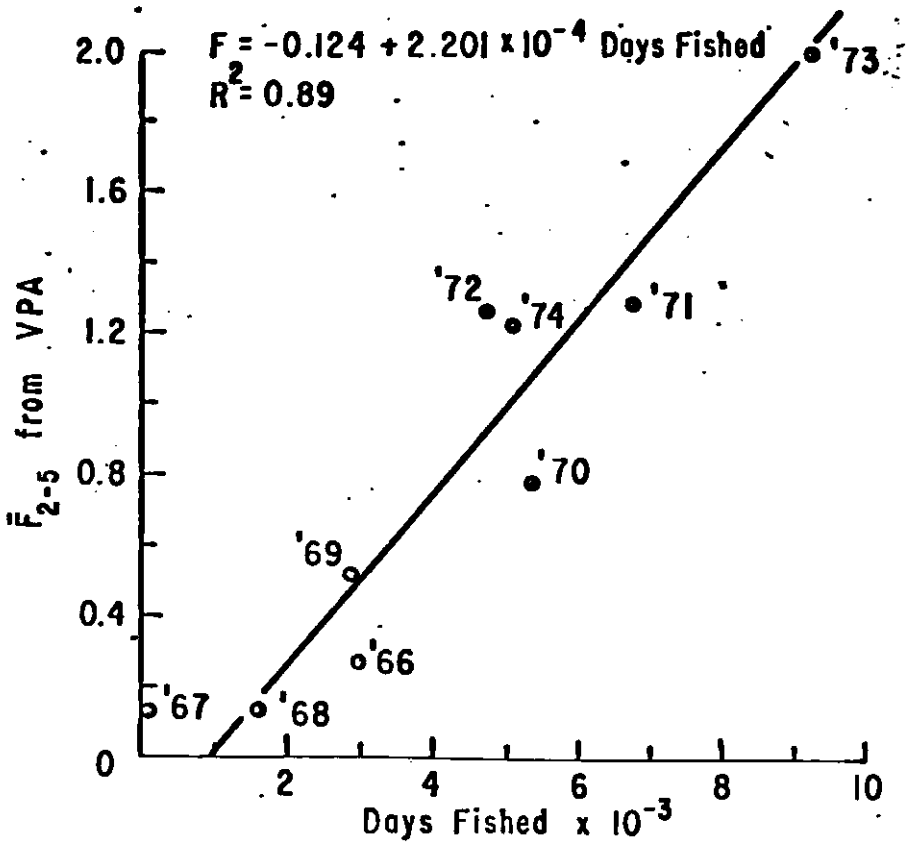


Figure. 3. Regression of V.P. estimates of F on days fished by USSR >1800 gross ton otter trawlers.

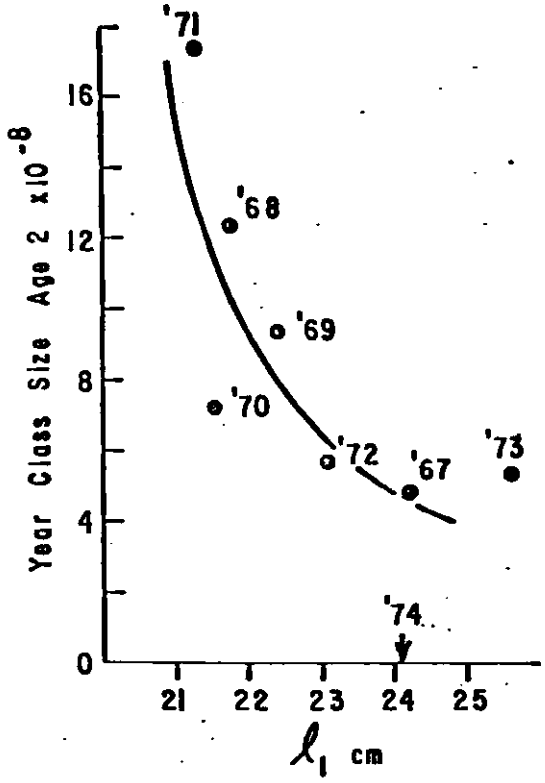


Figure 4. Regression of L_1 in September and year class size at age 2 from V.P. estimates.

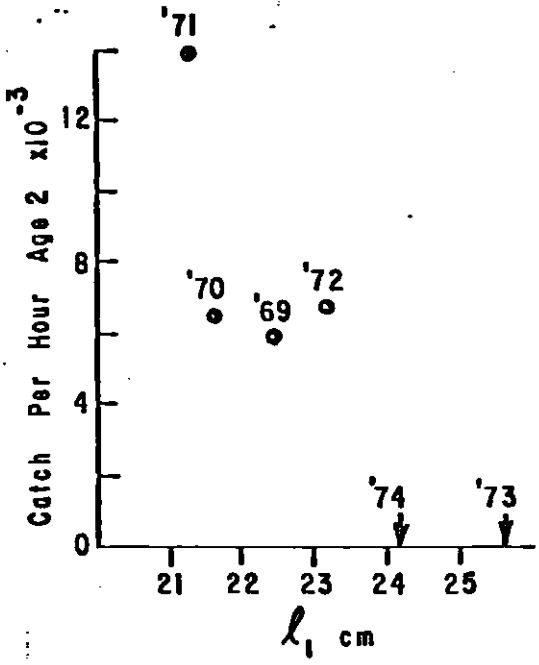


Figure 5. Regression of L_1 in September and catch rates at age 2.

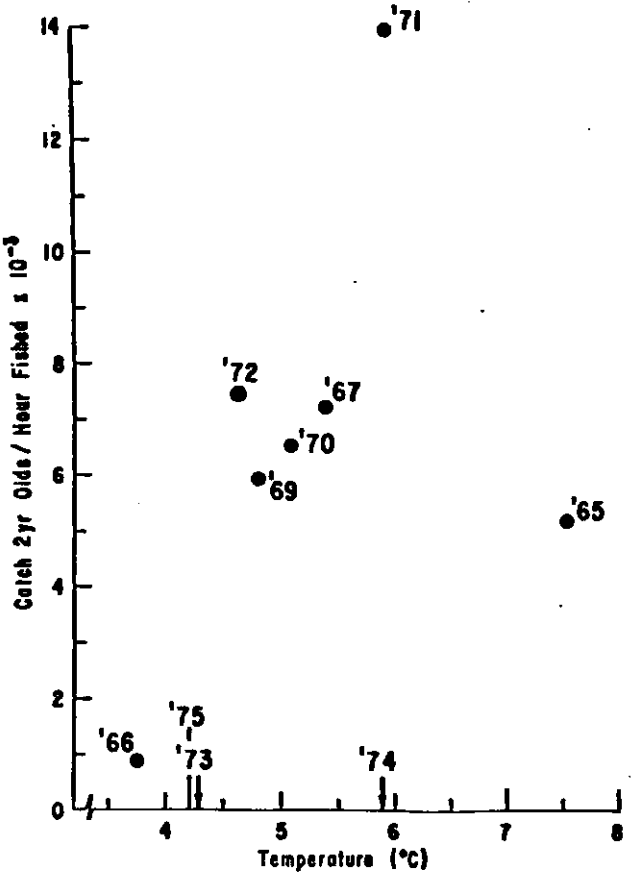


Fig. 6 Catch per unit effort of 2-year-old silver hake in relation to bottom temperature on Sable Island Bank in July of the year of spawning.