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An analysis of the silver hake fishery on the Scotian Shelf.

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1. INTRODUCTION

The USSR is the only major exploiter of silver hake on the Scotian Shelf (ICNAF Div. 4VWX). Nominal catches increased from 2 metric tons (mt) in 1961 to 123,000 mt in 1963, but declined to 2,500 mt by 1967 (Table 1). A second major increase in catches began in 1969 with a peak catch of 169,000 mt in 1970. Catches remained above 100,000 in 1971 and 1972 and increased to 299,000 mt in 1973. Catches in 1974 of 90,000 mt were limited by catch quota. A catch quota of 120,000 mt is in effect for 1975. Most of the catches have been taken in ICNAF Div. 4W.

Several assessments of the status of silver hake on the Scotian Shelf have been presented to the Assessments Subcommittee of ICNAF (Halliday, MS 1973, unpublished 1974; Doubleday, unpublished 1975). The 1973 and 1974 assessments were based on Soviet data on the age composition of the commercial catch. It was noted in 1974 that events in the fishery, particularly the large 1973 catches, could not be adequately explained using available data. Anderson and Nichy (MS, 1975), using a new ageing technique for SA5 silver hake, demonstrated that there are substantial differences in interpretation of age from otoliths between USSR and USA scientists, USA scientists obtaining age readings one to two years younger. It was concluded by the authors that similar ageing problems for SA4 silver hake caused the difficulties in explaining fishery events on the Scotian Shelf. Thus, Doubleday (unpublished, 1975) reassessed the SA4 stock using Div. 5Y silver hake age length keys obtained using the new USA technique (provided by Dr. E. Anderson, unpublished data). This analysis suggested that the

fishery was largely dependent on age 1 and age 2 fish and that the 1976 fishery will be heavily dependent on the strength of the 1974 year class on which no reliable information is available.

This document describes growth of SA4 silver hake from length-frequency data (i.e. independently from previous ageing techniques), the age composition of commercial and research vessel survey catches, and size and age at sexual maturity. From these analyses, the validity of Doubleday's previous analysis of the fishery is assessed, and inferences are made on which future management policy can be based.

2. DISTRIBUTION AND STOCK STRUCTURE

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 fath 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. It is likely that silver hake caught in Div. 4V are taken from the eastern fringe of the Sable Island Bank stock. As the Div. 4W-4X dividing line 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 landings 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.

3. AGEING

Due to controversy over the ageing of silver hake by otoliths (Anderson and Nichy, 1975), methods of estimating mean length at age and numbers at age using only length frequency samples were examined. The fitting of parabolas by least squares to the logarithms of numbers of fish at length, a method proposed by Buchanon-Wollaston and Hogeson (1929) was found to yield good estimates of mean length at age and fair estimates of numbers at age for ages one and two and, in some cases for age three. A nominal date of spawning of June 30 was adopted, and the age of fish increased one year on January 1st.

Length frequency samples from USSR catches of silver hake in 4W were aged using a Hewlett-Packard 9821A programmable calculator and plotter. The first step consisted of entering numbers at length and plotting the natural logarithms of numbers at length vs. length (Fig. 2). A parabola was then fitted to the lengths corresponding to the youngest age group. Whenever possible, one length group or more to the right of the first mode was included in the fitting procedure. When the first parabola was fitted, the remaining length frequencies were corrected to remove the estimated numbers of fish in the first age class. The fitting procedure was repeated for the second age group, and when possible, for the third. In some cases, adequate separation of the modes for successive age classes was not observed and the sample was recorded as unresolved.

In order to compare this method of ageing with ageing by otoliths, the method was applied to Oct., Nov., and Dec. length frequencies from Table 1 of Anderson and Nichy. Fig. 3 shows the fitted parabolas for October and November. The December sample was unresolved. Table 2 compares the estimated mean length at age for ages one, two, and three with that of Anderson and Nichy. The methods are in agreement for ages one and two but not for age three.

The analysis of Canadian research vessel length frequencies for 4W silver hake indicated that recording of silver hake lengths by 1 cm groups instead of two cm groups is preferable. The finer measurement doubles the number of points used in the curve fitting process.

For further discussion of the use of fitted parabolas in the ageing of fish, see Doubleday (MS 1975).

4. GROWTH

Table 3 contains estimated mean lengths at age for USSR silver hake catches from ICNAF division 4W from 1969 to 1974. Earlier years were not included due to fluctuations in the number of samples taken from year to year. Samples whose age components were not resolved are indicated by asterisks.

Fig. 4 illustrates the monthly growth of 4W silver hake. It appears that growth is most rapid from March to June and September to December with a slower rate from July to September and January to March. The wavy curve was drawn free-hand to follow the seasonal trends. Attempts to fit a Von Bertalanaffy growth curve to these data were unsuccessful so that the following empirical procedure was adopted. From 19 months onward, the growth rate appeared to be roughly constant and the line

$$L = 17.85 + 0.428A \qquad R^2 = 0.78$$

was fitted by least squares, where A is the age in months and L is the length in cm. Fish in a length group were assigned the mid-length of the interval (i. e. 16.00 - 17.99 became 17). Growth from 9 to 21 months was estimated by fitting a quadratic curve.

$$L = - 8.8703 + 3.2768A - 0.07.4773A^2 \qquad R^2 = 0.92$$

One year old fish are approximately 13 cm long in March and reach 26 cm by December. By the following December, they are 31 cm long.

5. 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 each year from 1970 (Halliday and Kohler, MS 1971). Silver hake has a low availability to the gear used and uncorrected estimates of population biomass are substantially below recent catch levels (Table 4). Surveys suggest that abundance declined in 1971 from the 1970 level, increased in 1972 and again in 1973 to above the 1970 level, then decreased slightly in 1974.

Survey estimates of population length-frequencies contain a wider range of sizes than those of commercial catches and are distinctly bimodal with modes at approximately 20 cm and 28 cm (Table 5). The above growth analysis from commercial catch length-frequencies confirm that these modes represent one year old and two year old fish respectively. Analysis of survey length-frequencies shows that most of the catch is of age 2 fish (Table 6).

Sex ratios in survey catches in Div. 4W are fairly consistent for age 2 fish, approximately half as many males as females being caught (Table 7). At age 1, however, the ratio of males to females has declined from 1.6 in 1971 to 0.5 in 1974.

6. 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 1974 are given in Table 8A and B. On average over the four 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 8 were then applied to the length-frequencies of these age groups to obtain the proportion mature at age (Table 9). 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 both age 1 and 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 1971-74, a very small proportion of age 1 males were recorded as mature and almost all age 2 males were mature (Table 7A). 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 9B). 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 25% for the four 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 average, 75% of females mature at age 2 but that this may vary from 50% to almost 100%.

7. WEIGHT-LENGTH KEYS

Table 10 contains parameter estimates for length-weight keys for silver hake caught in 4W on Canadian research vessel cruises in July, 1969 to 1974. The relation:

$$\log Wt = \log A + B \log L$$

where Wt is measured in grams and length L in cm. For the purpose of yield calculations, parameter estimates for all six years were averaged to give the combined key

$$\log Wt = -2.403534 + 3.177198 \log L.$$

8. AGE COMPOSITION OF COMMERCIAL CATCHES

Ageing analysis of USSR Div. 4W commercial length-frequencies provides estimates of the proportion at age in the catch in the months samples. As noted in Section 1, most of the commercial catch is taken by the USSR in Div. 4W. Thus, USSR Div. 4W age compositions are taken as representative of the entire fishery. For months for which sampling data were available, the mean weights provided with USSR samples were divided into total Div. 4W catches for that month giving estimates of numbers removed which were then prorated over ages.

Catches for which there were no sampling data were prorated on an annual basis on the annual proportions at age obtained by summing over months for which sampling data were available. Silver hake catches prior to 1965 were not broken down by month in ICNAF Statistical Bulletins. Thus, estimates of numbers removed at age could be calculated only from 1965 to 1974.

Age 1 and age 2 fish could be separated out in most catches, but it was necessary to lump fish age 3 and older together as these age groups could not be separated sufficiently often to provide adequate estimates of their contribution to catches.

Age 2 fish predominate in the catches of all years (except 1966) and from 1970 onwards, age 1 fish made a significant contribution in terms of numbers (Table 11). Comparison of age composition using length-frequency analysis with that obtained using Anderson's Div. 5Y age-length keys (Table 12) and also with that obtained using USSR ageing (Table 13 - reproduced from Rikhter, unpublished 1975) indicate a broad agreement on age composition using length-frequency analysis and USA age-length keys, but these are very substantially different from USSR age compositions. This confirms the hypothesis that USSR ageing is erroneous for the Scotian Shelf silver hake stock and is supporting evidence for the general accuracy of USA ageing in SA5.

9. YIELD PER RECRUIT

The growth equations of section 4 and the weight-length key of section 7 were used to derive a yield per recruit isopleth diagram (Fig. 5). 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 nine month old fish. 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.

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

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.

10. VIRTUAL POPULATION ANALYSIS AND CATCH PROJECTIONS

The numbers removed from the stock at age are probably most accurately estimated for ages 1 and 2 by length-frequency analysis, but inability to separate ages 3 and older preclude the use of virtual population analysis on these data. Although there are undesirably large differences in numbers at age between these and estimates obtained using Div. 5Y age-length keys, there are broad similarities between the two data sets. The latter are used for virtual population analysis as they appear to be sufficiently accurate to allow meaningful examination of the relative importance of recruitment assumptions to projected catch levels for 1976.

Using M = 0.40, the data in Table 12 were analysed assuming an F in 1974 of 0.50 for ages 2-6 and of 0.12 for age 1. F at age 6 in earlier years was chosen to correspond to F levels for younger age groups in the same year. Results of the calculations are displayed in Tables 14 and 15.

Means of the F's 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 >1800 gross ton otter trawlers. The data series are as follows:

	1968	1969	1970	1971	1972	1973
$\bar{F}_{2-5}$	0.07	0.48	1.05	0.96	0.74	1.51
Effort	1677	2871	5405	6823	4813	9333

These data have a correlation coefficient of R = 0.96 (R^2 = 0.92), and an intercept on the Y-axis of approximately -0.10 (Fig. 6). This suggests that the VPA results adequately explain recent fishery events and that an M = 0.40 is likely an overestimate of the actual natural mortality rate.

Estimates of numbers at age 1 indicate that recruitment improved in 1969 with entry of the 1968 year class to the fishery and it appears that the 1967 y.c. was a modest improvement over that of 1966 (Table 14). The 1969 y.c. and 1970 y.c. were of comparable size to that of 1968, but the 1971 y.c. was almost twice as large and the 1972 y.c. also good. The estimated size of the 1973 y.c. is a direct function of the F chosen in 1974 of 0.12. The ratio of F's at age 1: age 2 in the previous six years varies from 0.15 to 0.28, averaging 0.23. Using the average ratio of 0.23, i.e that $F_{age\ 1} = 0.115$ gives an estimate for the 1973 y.c. of 975 x 10^6 fish. Thus, it is likely that the 1973 y.c. is poorer than the preceeding five.

The 1974 population estimates in Table 14 are taken as the starting point for projection of potential yield in 1976 (Table 16). The calculated 1974 catch weight is 7.8% above the actual reported catch indicating that the mean weights used are slightly high. Thus, calculated catches for 1975 and 1976 have been corrected downwards. The 1974 year class is assumed to contain 1.0 x 10^9 fish at age 1. Assumptions on the strength of the 1975 year class are insignificant.

An F = 0.70 on age 2+ fish is required in 1975 to approximately attain the quota of 120,000 mt. At the present age at recruitment of about 15 months, this value of F maximises yield per recruit. $F_{max} = 0.70$ is applied in 1976 giving a calculated yield of approximately 100,000 mt.

This calculation is critically dependent on the F values assumed for 1974 and the assumed size of the 1974 year class. The assumed F = 0.50 for 1974 is only one third the level of F calculated for 1973 and implies a reduction in effort to around the 1969 level of approximately 3000 days fished. No information on 1974 effort is available at this time. It seems likely, however, that the authors have erred on the conservative side. The size of the 1973 year class is particularly sensitive to assumptions on F.

The assumed size of the 1974 year class appears modest in comparison with the good year classes of 1968 to 1972. However, if the comparison is extended to include 1962 to 1972, this estimate is certainly above the overall average. It must be pointed out that the 1971 and 1972 year classes which formed the basis of the record 1973 catch were exceptionally strong and not an indication of what is to be expected in general. If the 1974 year class is 50% larger than has been assumed, the projected 1976 catch is increased by 20,000 tons.

11. 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 of Sable Island Bank less than 50 fathoms deep were obtained by averaging bottom temperature measurements for that area taken on Canadian research vessel cruises. The number of observations averaged varied from ten to fifty nine with about fifteen for most years. Catch per hour fished of one and two year old silver hake in 4W by USSR greater than 1800 gross ton otter trawlers was calculated using estimated numbers at age from section eight. Table 17 contains the computed values. Unfortunately, the effort for 1974 is not yet known. Catch per effort of two year old fish appeared to be a more reliable measure of year

class size than the corresponding quantity for one year olds. Fig. 7 shows the relation between temperature at spawning and catch per hour fished of two year olds. Evidently, temperatures near six degrees are favorable while temperatures near four degrees are unfavorable. A two variable equation with catch per unit effort of parents and temperature in July would predict the catch per unit effort of the two 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.

On the basis of observed temperatures for 1972-1974, the 1972 year class is expected to be moderate, the 1973 year class weak, and the 1974 year class strong.

12. DISCUSSION

Estimation of the age composition of USSR silver hake catches in 4W by analysis of length frequency samples revealed a consistent pattern of monthly growth in agreement with the results of Anderson and Nichy (MS, 1975) and at variance with USSR estimates of catch at age.

Biological samples from Canadian research vessel catches indicate that a negligible proportion of one year old silver hake are sexually mature. While almost all two year old males are mature, the proportion of immature two year old females averages 25% and can be considerabley higher.

Yield per recruit calculations show that, for a range of natural mortality rates, yield is increased by not catching one year old fish. When $M = 0.4$ and the mean age of selection is at the current level of fifteen months, the optimal value for F is 0.7. Very little yield is lost by increasing the mean age of selection beyond the optimal level.

Estimated age compositions of the USSR commercial catch of silver hake in 4W derived by analysis of length frequency samples are in agreement with age compositions derived using U.S. age-length keys for SA5. The largest proportion of the catch, in numbers, is made up of two year old fish. A further large fraction consists of one year old fish. Thus, a high fishing mortality is exerted on a year class before it reaches maturity.

The current mean age of selection of fifteen months has two serious implications on the future of the fishery. In terms of weight contributed to the total catch, two and three year old fish overshadow all other ages. Thus, a sequence of two mediocre year classes can cripple the fishery. Secondly, the breeding stock consists mainly of two and three year old fish so that the spawning stock biomass is extremely vulnerable to fluctuations in recruitment. There is some evidence that the 1973 year class is poor. Increasing the mean age of selection would help to stabilize the catch and the spawning stock size by allowing greater survival to age four.

There is some indication that year class success and temperature are related. Available evidence suggests that the 1973 year class is poor to moderate while the 1974 year class is moderate to good. The availability of one year old fish is variable from year to year so that the catch per hour fished of one year olds shows no clear relationship with temperature (Fig. 8).

Catch projections based on the assumption that 1974 effort was at the 1969 level and that the 1974 year class was moderate (10^9 fish) indicate that a 1976 quota of 100,000 m.t. is appropriate. The assumed year class size for 1974, while lower than those of 1971 and 1972, is high in comparison with year class sizes over the history of the fishery from 1963 to 1974. Only strong evidence that the 1974 year class considerably exceeds 10^9 fish could justify a higher quota since underestimation of year class strength is equivalent to increasing the mean age of selection which, in this case, results in increased yield.

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

Year	ICNAF DIVISION					COUNTRY				
	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	-	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[7]	...	...	...	...	90,342	10	67	89,984	-	281[6]

[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

Table 2. Comparison of mean length at age.

AGE	OCT. MEAN L.	NOV. MEAN L.	ANDERSON & NICHY MEAN L.
1	25.0	27.2	25.2
2	30.6	32.2	30.3
3	38.4	38.2	34.5

Table 3. Mean length (cm) at age by month for USSR silver hake sampling 1969 - 1974.

Age \ Yr. Class	66	67	68	69	70	71	72	73
6						12.7		
9			12.8				14.6	*
10				13.9		16.5	*	17.3
11				16.3		18.6	18.5	18.7
12			20.3	*			18.3	19.1
13				19.3		20.7	20.7	21.5
14				21.4		21.3	22.6	22.6
15				22.5	21.6	21.3	23.1	25.2
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	
23		29.2	27.1		27.7	28.1	26.2	
24		29.1	*		*	28.5	29.1	
25		29.8	28.7		27.5	28.4	30.0	
26			28.2		*	29.2	29.8	
27			28.7	29.8	26.7	29.3	30.7	
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		*	*	*		
35		*		33.0	*			
36		*		*	*	*		
37		*			*	*		
38		*			*	*		
39					*	*		
40					*			
41								
42		39.5						

Table 4 . Div. 4VWX Silver hake — Canadian research vessel survey estimates of biomass (metric tons), population numbers ($x10^{-6}$), and catch per tow, 1970-74.

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

Table 5. Div. 4VWX Silver hake - estimated population length-frequency from Canadian research vessel surveys (x 10^{-3}).

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

Table 6. Div. 4VWX silver hake - estimated numbers at age ($x10^{-6}$) from Canadian research vessel population estimates.

Year	Age 1	Age 2	Age 3+	Total
1970	38.3	100.8	3.6	142.7
1971	21.3	26.1	5.9	53.3
1972	31.9	46.9	9.0	87.8
1973	70.8	148.5	10.6	229.9
1974	36.4	120.0	27.1	183.5

Table 7. Div. 4W silver hake - sex ratios (males:females) at ages 1 and 2 in Canadian research vessel surveys.

Year	Age 1	Age 2
1971	1.62	0.48
1972	1.52	0.43
1973	0.93	0.29
1974	0.50	0.68

Table 8a. 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		Combined		%
	Imm	Mat	Imm	Mat	Imm	Mat	Imm	Mat	Imm	Mat	Mature
15	12		8		7		2		29		-
16	11		11		5		5		32		-
17	22		18	1	12		14		66	1	1
18	48		26	-	17		22		113	-	-
19	35		26	-	18		28	1	107	1	1
20	24		31	-	21	1	30	3	106	4	4
21	14		18	3	8	-	21	-	61	3	5
22	5		8	5	14	-	15	4	42	9	18
23	2	2	10	2	9	-	6	3	27	7	21
24	-	4	6	2	4	3	6	12	16	21	57
25	-	9	4	11	2	19	2	24	8	63	89
26	-	14	1	22	-	52	1	43	2	131	98
27	2	26	1	28	-	49	4	97	7	200	97
28	-	34		24	-	71	-	89	-	218	100
29	1	25		11	1	39	-	86	2	161	99
30		14		16	1	24	-	82	1	136	99
31		6		13	1	19	1	57	2	95	98
32		4		8		14		25		51	100
33		3		6		16		13		38	100
34		-		2		8		3		13	100
35		-		-		3		2		5	100
36		-		2		1		2		5	100
37		1		1				1		3	100
38				1				-		1	100
39				1				-		1	100
40								1		1	100

Table 8b. 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	1971		1972		1973		1974		Combined		%
(cm)	Imm	Mat	Imm	Mat	Imm	Mat	Imm	Mat	Imm	Mat	Mature
15	8		5		5		5		23		-
16	12		6		4		8		30		-
17	16		15		19		14		64		-
18	32	2	18		25		33		108	2	2
19	28	1	26	1	21	1	42		117	3	3
20	19	-	38	-	16	-	48	1	121	1	1
21	16	-	15	-	12	-	33	1	76	1	1
22	9	-	20	2	9	1	26	1	64	4	6
23	5	-	17	-	8	-	21	-	51	-	-
24	1	-	11	-	6	-	20	1	38	1	3
25	3	1	5	2	8	-	18	3	34	6	15
26	4	4	14	3	5	16	27	6	50	29	37
27	6	21	19	11	16	49	33	26	74	107	59
28	9	42	16	27	17	72	29	37	71	178	71
29	-	52	10	20	11	90	21	45	42	207	83
30	2	54	9	21	2	81	5	69	18	225	93
31	1	43	1	16	1	43	4	109	7	211	97
32	1	38	4	24	2	36	1	81	8	179	96
33		30	2	27		25	3	92	5	174	97
34		24	1	26		11		67	1	128	99
35		9	-	19		24		43	-	95	100
36		7	1	10		26		41	1	84	99
37		7		6		21		33		67	100
38		2		6		18		20		46	100
39		3		6		17		8		34	100
40		1		3		11		12		27	100

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

Table 9b. 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	
(cm)	Age 1	Age 2	Age 1	Age 2	Age 1	Age 2	Age 1	Age 2
10								
11			1					
12			4					
13	1		18					
14	4		58				7	
15	17		156		71		7	
16	57		352		246		53	
17	141		658		661		261	
18	263		1022		1383		885	
19	372		1318		2255		2070	
20	400		1411		2864		3333	
21	325		1254		2834		3697	
22	201		925	6	2184		2826	
23	94		567	58	1311		1488	16
24	33	1	288	348	613	2	534	113
25	9	9	122	1391	224	37	135	557
26	2	81	43	3654	63	403	23	1921
27		422	12	6323	14	2193	3	4703
28		1281	3	7204	2	5950		8164
29		2258	1	5405		8046		10060
30		2313		2670		5423		8791
31		1376		869		1822		5448
32		476		186		305		2395
33		96		26		25		747
34		12		2		1		166
35		1						26
36								3
% mature	1.7	94.0	1.6	51.5	2.2	88.5	1.9	71.1

Table 10. Length-Weight Keys from Canadian Research Vessel Cruises for Silver Hake in 4W in July.

Year	Log A	B
1969	-2.296819	3.093991
70	-2.70482	3.38285
71	-2.264429	3.099391
72	-2.411192	3.180211
73	-2.343713	3.135717
74	-2.400230	3.171025
Average	-2.403534	3.177198

$$Wt(gr) = A\ L(cm)^{B}$$

Table 11. Silver hake commercial catch - nos. at age x 10^{-3} Div. 4W from length-frequency analysis.

Year	Age 1	2	3+	Total
1965	1,671	170,422	43,888	215,981
66	10,220	9,795	462	20,477
67	-	7,576	915	8,491
68	84	18,218	2,173	20,475
69	21,456	242,169	22,436	286,061
1970	208,319	702,322	77,926	988,567
71	65,461	553,957	223,647	843,064
72	149,692	414,279	120,802	684,773
73	102,212	1,449,980	136,718	1,688,911
1974	80,432	405,044	57,153	542,629

Table 12. Silver hake commercial catch - nos. at age x 10^{-3} Div. 4W from application of USA Div. 5Y age-length keys.

Year	Age 1	2	3	4	5	6	Total
1968	11,288	8,737	2,432	203	55	77	22,792
69	104,245	134,717	44,714	4,939	1,680	184	290,479
1970	320,628	522,578	156,226	14,123	4,563	2,369	1,020,487
71	181,418	510,203	168,553	12,234	3,183	2,537	878,128
72	300,142	306,441	131,866	17,004	6,589	-	762,042
73	432,907	1,078,980	316,463	33,806	12,208	2,817	1,878,120
1974	87,830	331,433	115,173	11,876	4,971	1,105	552,388

Table 13. Silver hake commercial catches - nos. at age x 10^{-3}
Div. 4W - from Rikhter (unpublished 1975)

Years	AGE 1	2	3	4	5	6	7	8	9	Total
1963		26,316	143,111	134,308	33,314	3,743	750	802	1,032	343,376
1964	831	6,745	92,038	131,754	26,460	6,378	486			264,692
1965		523	44,712	103,797	29,846	4,387	364			183,629
1966	22	3,786	4,599	6,805	3,950	565	18	-	-	19,745
1967		68	1,511	5,077	1,570	239	24	-	-	8,489
1968	467	6,298	11,336	1,752	583	145	276	84		20,941
1969	19,314	16,022	78,858	97,177	32,147	10,875	2,420	1,196	-	258,009
1970	86,630	131,550	343,014	183,496	58,867	4,236	2,672	1,151	128	811,744
1971	18,969	80,260	422,419	379,144	92,960	13,196	5,429	5,853	2,339	1020,569
1972	40,953	130,957	249,592	145,966	96,815	13,929	2,651	801	1,612	683,276
1973	52,221	85,912	675,502	599,698	203,829	47,167	13,476	3,369	1,684	1,684,542
1974	30,145	98,317	246,892	149,370	32,782	7,490	3,233	1,912	737	571,378

Table 14. Div. 4W silver hake - stock in numbers at age $x10^{-6}$

	A G E					
Year	1	2	3	4	5	6
1968	768.2	144.0	38.3	10.6	0.7	0.4
1969	1,630.6	506.2	89.5	23.7	7.0	0.4
1970	1,832.4	1,008.6	231.2	24.7	11.9	3.3
1971	1,687.7	969.6	263.9	33.8	5.5	4.3
1972	3,017.8	984.4	247.7	45.6	12.9	-
1973	2,019.8	1,779.7	414.5	62.2	17.0	3.5
1974	975.0	1,005.3	349.3	36.0	15.1	2.0

Table 15. Div. 4W silver hake - F

	A G E						Mean
Year	1	2	3	4	5	6	Ages 2
1968	0.02	0.08	0.08	0.02	0.10	0.10	0.07
1969	0.08	0.38	0.89	0.29	0.34	0.30	0.48
1970	0.24	0.94	1.52	1.11	0.61	1.00	1.05
1971	0.14	0.96	1.36	0.56	0.56	0.56	0.96
1972	0.13	0.47	0.98	0.59	0.92	-	0.74
1973	0.30	1.23	2.04	1.02	1.75	1.75	1.51
1974	0.12	0.50	0.50	0.50	0.50	0.50	-

1/ Excludes age 5 F which is a starting value.

Table 16. Silver hake - catch projection. (Population numbers x 10^{-6}, and catch wt. (m.t.) x 10^{-3}.)

Age	Popn. no. 1974	F	Catch Wt. 1974	Popn. no 1975	F	Catch Wt. 1975	Popn no. 1976	F	Catch wt. 1976	Mean Wts(kg)
1	975	0.115	4	1,000	0.14	5	1,000	0.14	5	0.051
2	1005	0.500	53	582	0.70	39	583	0.70	39	0.159
3	349	0.500	31	409	0.70	47	194	0.70	22	0.270
4	36	0.500	5	142	0.70	26	136	0.70	25	0.426
5	15	0.500	3	15	0.70	4	47	0.70	13	0.635
6	2	0.500	1	6	0.70	2	5	0.70	2	0.905
Calculated catch			(97)			(123)			(106)	
Corrected catch			90			114			98	

Table 17.

Temperature and Catch per Unit Effort for 40 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		

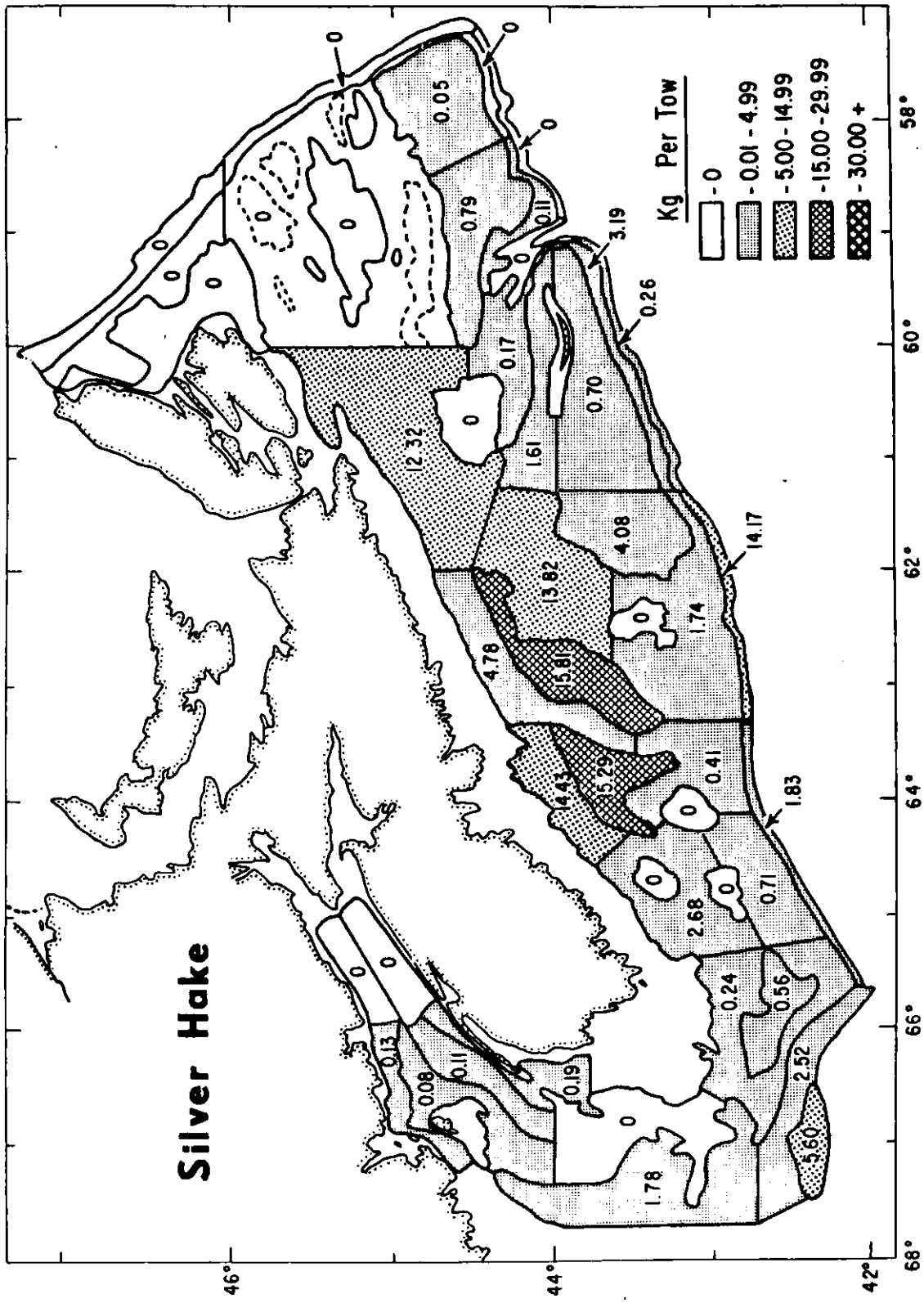

Fig. 1. Silver hake : distribution and abundance from Canadian research vessel surveys in 1970-72.

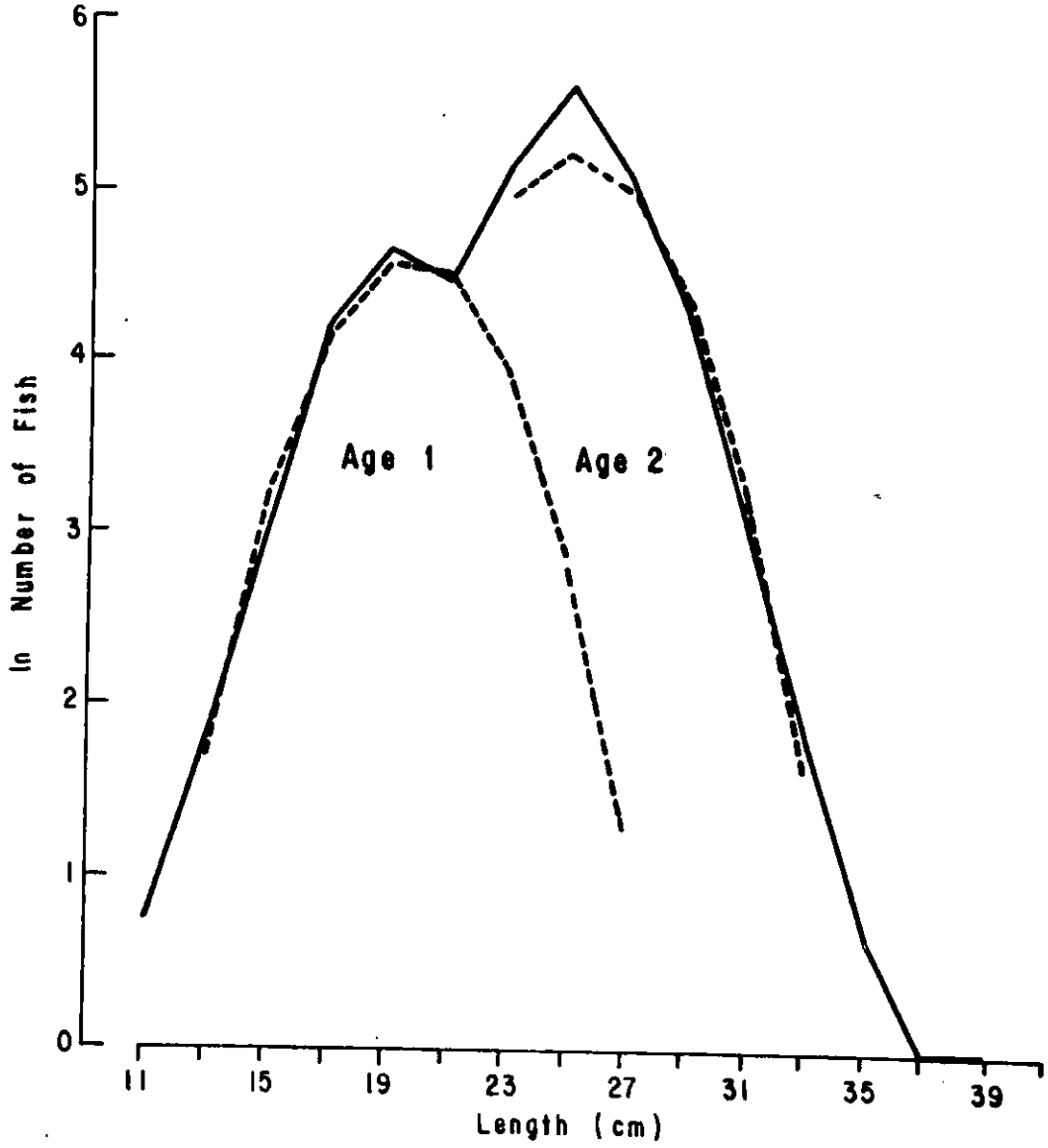

Fig. 2. Parabolas fitted to USSR length frequency sample for August, 1972.

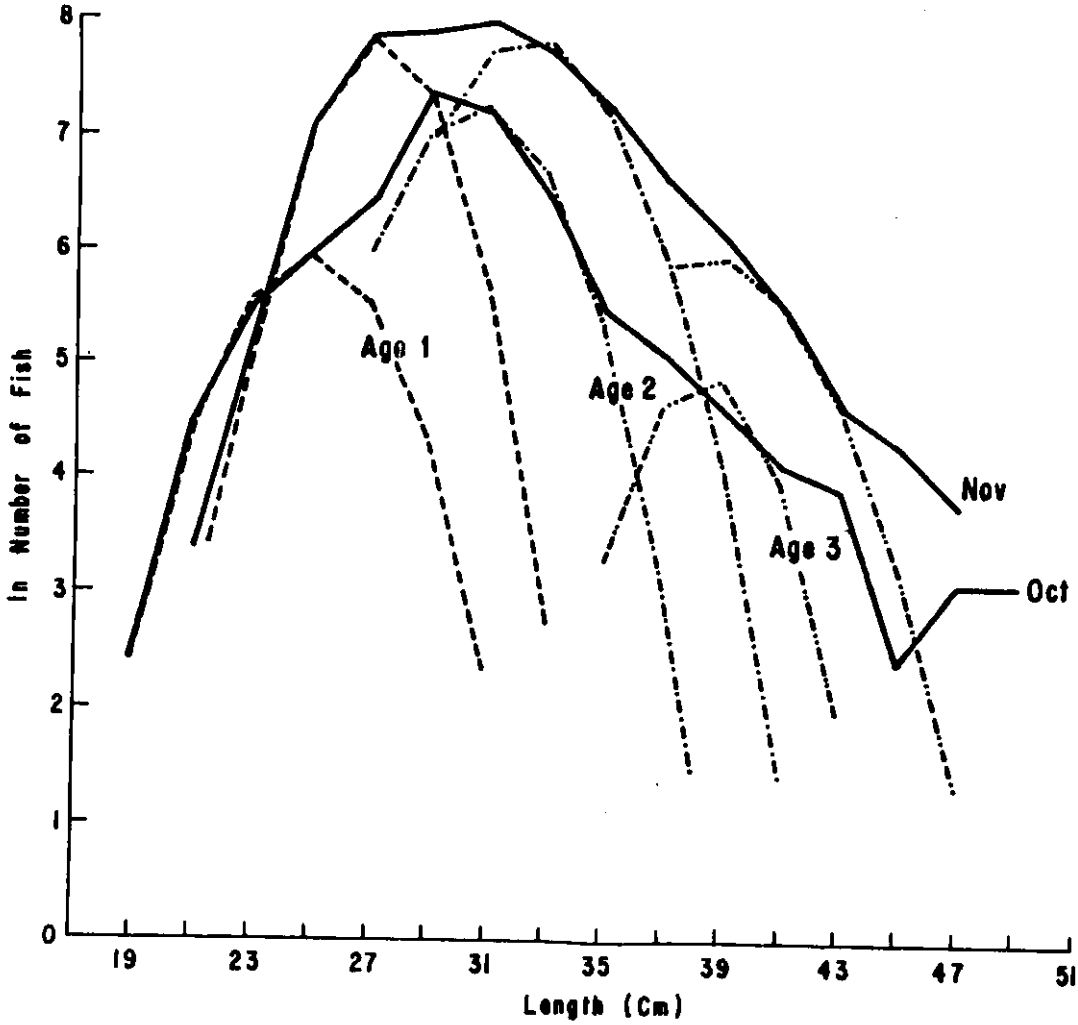

Fig. 3. Parabolas fitted to data from table 1 of Anderson and Nichy (1975).

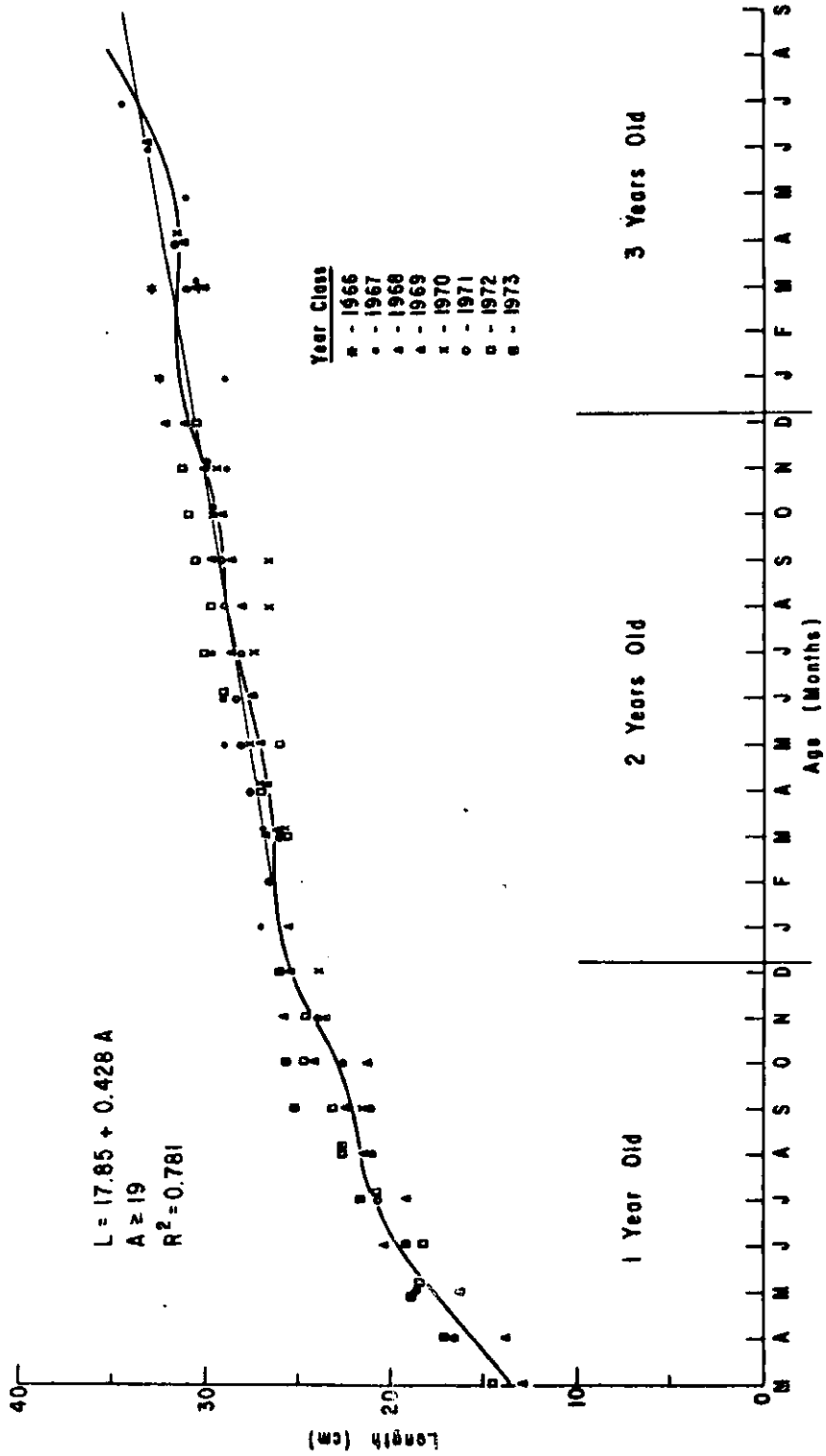

Fig. 4. Estimated length at age for silver hake in ICNAF division 4W based on USSR length frequency samples.

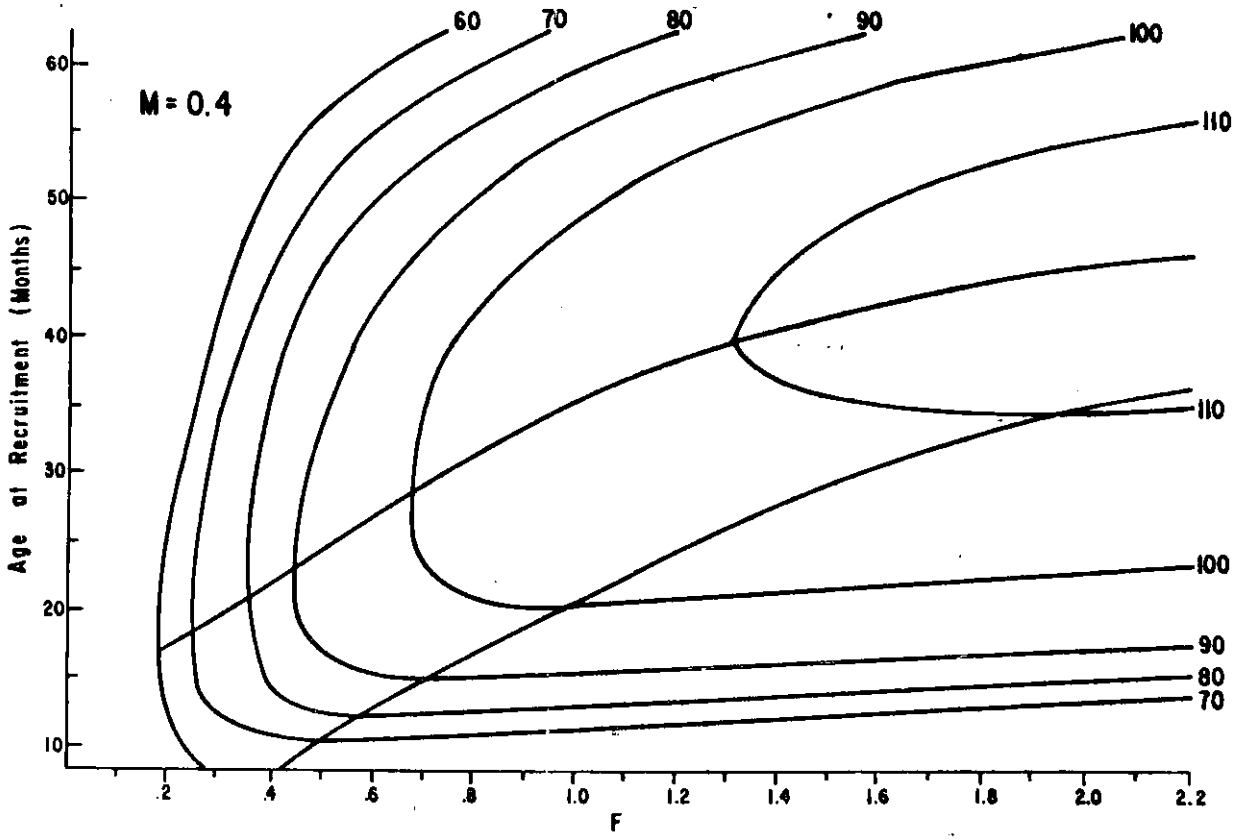

Fig. 5. Yield per recruit isopleth diagram. The lower solid line gives the F with greatest yield for a given age at recruitment and the upper line the age at recruitment with greatest yield for a given F.

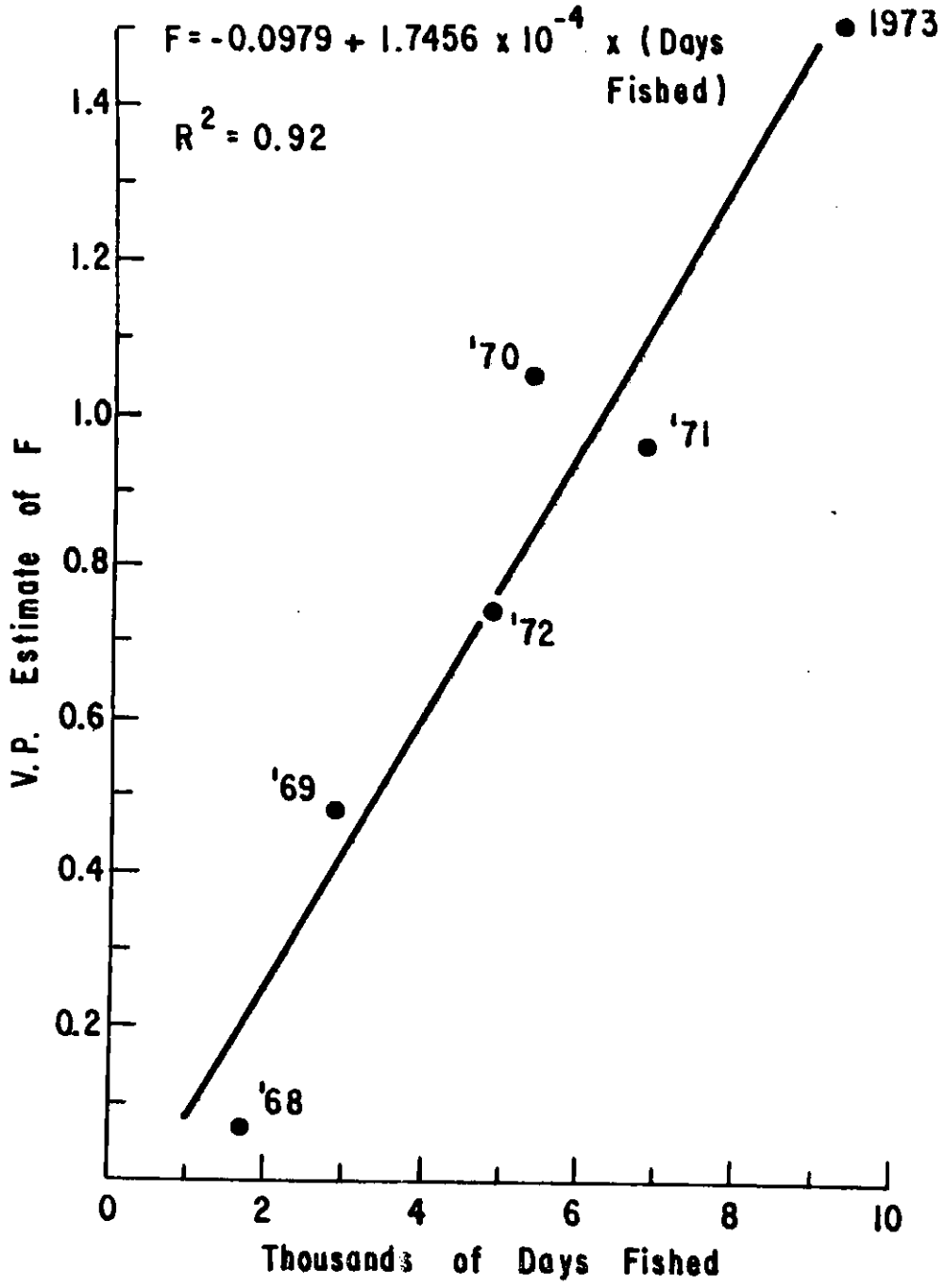

Fig. 6. Regression of V.P estimates of F on days fished by USSR >1800 gross ton otter trawlers.

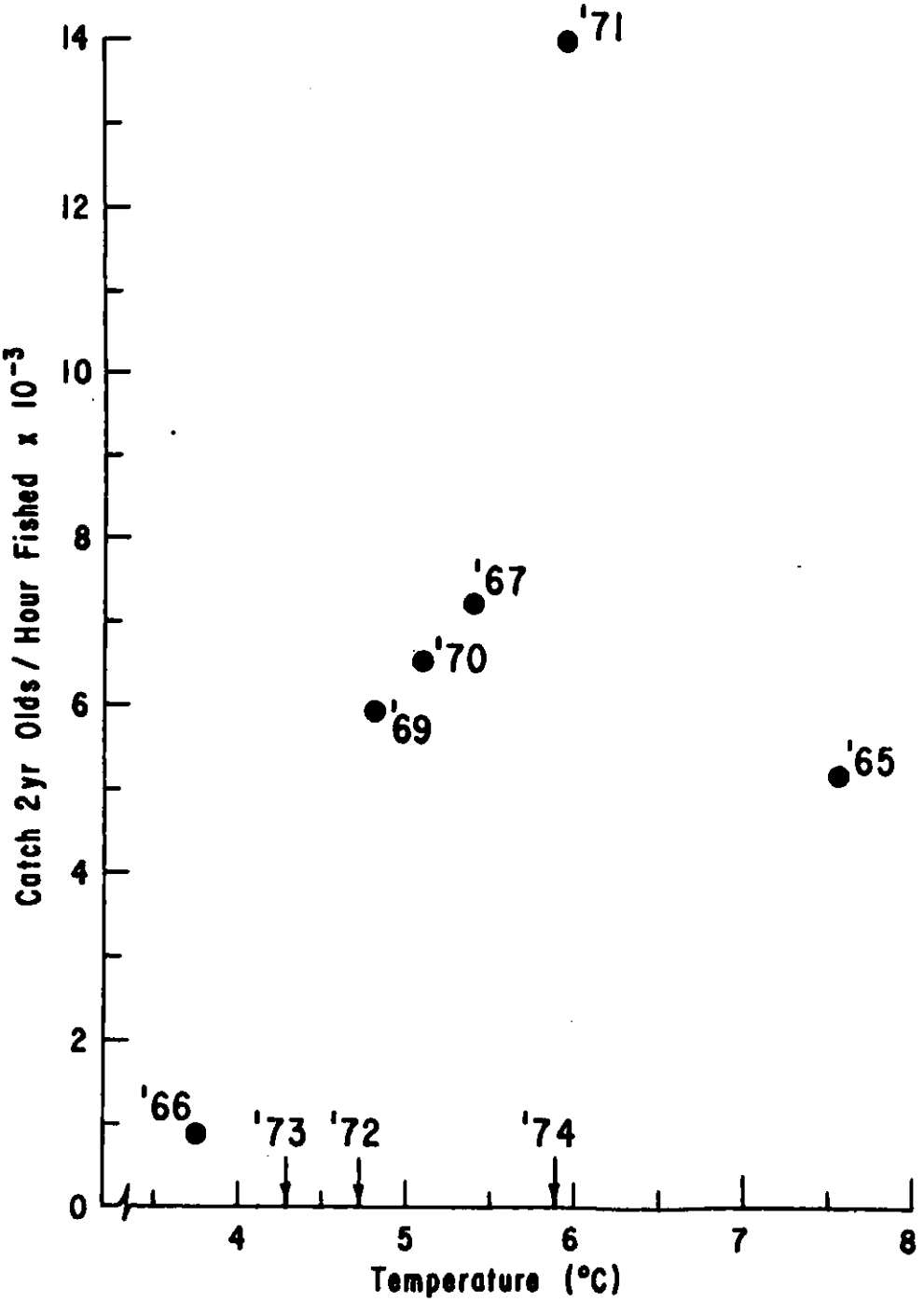

Fig. 7. Catch per unit effort of two year old silver hake in relation to July bottom temperature on Sable Island Bank in the year of spawning.

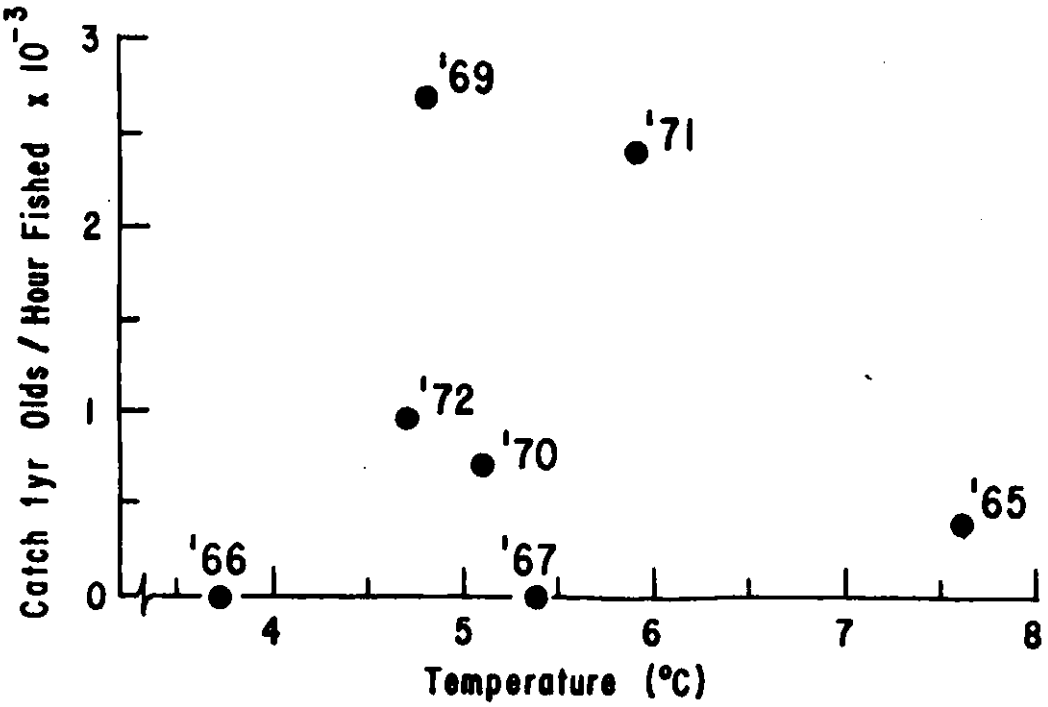

Fig. 8. Catch per unit effort of one year old silver hake in relation to July bottom temperature on Sable Island Bank in the year of spawning.