International Commission for the Northwest Atlantic Fisheries

Serial No. 4056
(D.c.3)

ICNAF Res.Doc. 76/XII/160

NINTH SPECIAL COMMISSION MEETING - DECEMBER 1976

A Revised Assessment of the 4VWX Silver Hake Fishery Incorporating Preliminary 1976 Data[1]

by

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Introduction

The Scotian Shelf silver hake *(Merluccilus bilinearis)* fishery has been 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 was imposed in 1974 with a subsequent catch of 95,600 tons. Of the 1975 quota of 120,000 tons, 112,600 were taken and in 1976 preliminary statistics indicate that 75,900 tons of a TAC of 100,000 tons were taken. Of the preliminary 1976 total, 1/8 was taken by Cuba (Table 1).

The closure of the Subarea 4 USSR silver hake fishery in 1976 prior to reaching the TAC was due to limitation of fishing effort. In earlier years of quota regulation, virtually the whole TAC was taken.

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, and ICNAF Res. Doc. 76/VI/59 by Doubleday, Hunt, and Halliday. The former document may be referred to concerning the method of ageing USSR commercial length frequency samples by modal analysis adopted here.

The predictive and monitoring abilities of ongoing research vessel surveys are examined and compared to data from commercial catches.

Conclusions on stock distribution and definition of ICNAF Res. Documents 75/104 and 76/VI/59 have not altered with new information and will not be discussed here. Silver hake in ICNAF divisions 4VWX are assessed as a single unit as before.

Research Vessel Surveys

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 with recovery in 1976 to about the 1972 level.

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

[1] See Appendix I for revisions at the Ninth Special Commission Meeting, December 1976 (page 23 of this document).

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).

Observations on sexual maturity of silver hake were made on research vessel cruises and the basic data for 1971 to 1976 are given in Table 6. On the average, over the six 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 1971-76, 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%.

Canadian survey estimates of overall abundance and relative year class size are available for 1970-1976, and similar estimates from USSR fall surveys are available for 1972-1975 (unpublished data). It is possible to compare research survey estimates with subsequent events in the commercial fishery to determine the ability of these surveys to monitor abundance and to predict year class size. Table 8 contains commercial catch rates in numbers at age 2 by USSR >1800 GRT otter trawlers in ICNAF Subdiv. 4W, virtual population analysis estimates at age 1, and average catch rates in mt/hour of USSR >1800 GRT otter trawlers in ICNAF Subdiv. 4W derived below, together with survey estimates of relative year class strength and abundance from Canadian and USSR surveys. Fig. 1 shows the relationship between commercial fishery events and survey estimates. In no case, is a predictive relationship evident.

It is concluded that, at present, research surveys are poor measures of silver hake abundance and year class size and consequently are not employed in this assessment.

Feeding Habits

The possibility of silver hake eating small cod in Div. 4W was raised in the 1976 April meeting of the ICNAF assessments subcommittee. Dr. J. S. Scott (personal communication) examined 103 silver hake stomachs taken on a bottom trawling research cruise in groundfish survey stratum 62 northwest of Sable Island Bank in July, 1976. The contents were:

Squid in 2 stomachs
Silver hake in 3 stomachs
Unidentified fish in 2 stomachs
Euphausiids in 17 stomachs
Empty in 49 stomachs
Everted in 32 stomachs

While no cod were identified, the number of stomachs examined was too small for conclusions to be drawn.

Yield per Recruit

Von Bertalanffy growth curves for male and female silver hake from ICNAF Subarea 4 have been derived by one of the authors (J. J. Hunt, "Age, Growth and Distribution of Silver Hake *(Merluccius bilinearis)* on the Scotian Shelf from Modal Analysis of Length Frequencies", ICNAF Res. Doc. (this meeting). The parameters are:

	Males	Females
L_{inf}	36.01	37.88
K	0.720	0.838
t_o	-0.070	-0.148

Using the averages of these parameters and the length weight relationship

$$\log_{10} W \text{ (gr)} = -2.403534 + 3.177198 \log_{10} L \text{ (cm)}$$

of Doubleday and Halliday (1975), Beverton and Holt yield per recruit calculations were carried out on the basis of silver hake entering the fishing grounds at nine months of age (March) and recruiting from twelve months (July) to twenty-four months. The natural mortality rate was assumed to be 0.4.

Fig. 2 is the yield isopleth diagram derived from these calculations. Table 9 records yields and stock biomasses in the exploited phase for various fishing mortality rates and ages of recruitment.

The overall relationship between age of recruitment, yield, and fishing mortality is very similar to that of Doubleday and Halliday (1975).

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 yeild is observed. With the current pattern of recruitment $F_{0.1}$ is 0.5 and F_{max} is 1.25 giving a slightly higher yield (4%) than the $F_{max} = 0.7$ calculated by Doubleday and Halliday (1975). For assessment purposes, $F_{0.1}$ is taken to be 0.5.

Commercial Catches

Table 10 relates the catch rates of USSR otter trawlers >1800 GRT in ICNAF Subdiv. 4W to the nominal catches from 1963-1975. Due to incomplete data from 1975, the international catch of silver hake was divided by hours fished by the >1800 GRT USSR otter trawlers, slightly overestimating the catch rate. 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 but rose slightly to 1.27 mt/hr in 1975.

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 and 1976 were 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. For 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 age and mean weight composition

for all catches were assumed equal to that of USSR Otter trawl catches for 1975 and 1976. For 1976, catches for Jan. - Feb. and Aug. - Sept. were combined due to a lack of samples.

The estimated catch compositions are shown in Table 11. The large estimate of 1-yr.-old silver hake in 1975 is mainly due to the September length frequency samples of which 65% were of age 1.

Growth

Samples from 1976 USSR commercial catches enabled the length at age table derived by Doubleday et al.(1976) to be extended. The new data were consistent with the established pattern of growth (Table 12).

Midwater and Otter Trawls

In 1976, 11 samples of length composition of silver hake catches by USSR >1800 GRT midwater trawlers were available for comparison with samples from the same months from otter trawl catches. The comparison is shown in Fig. 3.

From the size composition of the samples, it is evident from modal analysis results that the midwater trawl samples contained virtually no age 1 fish.

Virtual Population Analysis

Using M = 0.40, the data of Table 12 were analysed by virtual population analysis. A regression relating days fished by USSR >1800 GRT otter trawlers in ICNAF Subdivisions 4VWX versus the average fishing mortality for ages 2 to 5 from the V.P.A. of Doubleday et al. (1976) for 1967 to 1972 was fitted to give the line

$$F = -0.026 + 1.94 \times 10^{-4} \text{ Days Fished.} \quad R^2 = 0.83$$

Exclusion of 1973 to 1975 removes possible biases due to the starting F assumed in the previous assessment. From this regression, an estimated average fishing mortality for ages 2-5 for the USSR in 1976 of 0.6 was obtained. Since the 1976 provisional catch was significantly larger than the USSR catch for the first time in recent years, the starting F was increased to 0.7 in proportion to the international catch. F's for ages 1-6 were obtained by applying the average F in the same proportions as for 1975 in Doubleday et al. (1976). F for age 6 in 1975 was set at 1.0 from derived estimates of F at ages 4 and 5. Starting F's for age 6 for earlier years were taken from the previously mentioned V.P.A.

Results of the V.P.A. are displayed in Tables 13 and 14. The size of the 1975 year class is not well estimated, being determined entirely by the starting F so that this estimate was not used for projections.

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.

	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
Mean F (ages 2-5)	0.125	0.132	0.485	0.746	1.293	1.279	2.080	1.370	1.343	
Fishing effort	318	1677	2871	5405	6813	4813	9333	5223	6290	3160

A line

$$F = -0.0818 + 2.25 \times 10^{-4} \text{ Days Fished} \quad R^2 = 0.89$$

was fitted to these data and the relationship is shown in Figure 4.

There is also a close relationship between the catch ratio of USSR >1800 GRT otter trawlers in ICNAF division 4W and calculated stock biomasses (Tables 10, 13) for ages 1 and older in ICNAF Divisions 4VWX (Figure 5). A line

$$B = 2.40 \times 10^{4} + 1.58 \times 10^{8} \text{ catch/hour} \quad R^2 = 0.81$$

was fitted to these data.

Length at Age 1 and Year Class Size

Doubleday et al. (1976) hypothesized an inverse relationship between the length of silver hake at age 1 referred to September and year class size. Unfortunately, sampling of commercial catches was not extensive in 1969 and 1971 so that modal estimates for the 1968 and 1970 year classes were not well established.

Examination of modes from separate tows by a Canadian research vessel of 177 and 542 fish taken within two miles of each other in July, 1976, indicated a difference in the mode for age 1 of 1.1 cm. Thus, it was decided to smooth such sampling variations in the estimate of ℓ_1, especially for years with few samples.

The smoothing was carried out by adjusting estimated modal lengths for August and October to a September length by the length increment of the growth curve of Doubleday and Halliday (1975) and to average these adjusted values. In years with heavy sampling, unweighted averages were used, but in 1969 and 1971, samples from November and December were included and weights proportional to the number of fish sampled in each month were used. The estimate of ℓ_1 in September together with year class size at age 2 from V.P.A. and catch rates of age 2 per hour in ICNAF Div. 4W by USSR >1800 GRT otter trawlers are found below.

Year class	1968	1969	1970	1971	1972	1973	1974	1975
Months	O, N	A, S, O	S, O	A, S, O	A, S, O	A, S, O	A, S	A
ℓ_1 (cm)	21.5	22.7	23.6	21.8	23.5	24.5	24.1	24.1
Year class $\times 10^{-6}$ age 2	1221	863	705	1738	570	532	680	
Catch rate age 2 ($\times 10^{-4}$/hr)		5.97	6.55	13.92	6.85	4.94		

The relationships are shown in Figures 6 and 7.

The curve

$$\ell n \text{ (Year class size x } 10^{-3}) = 15.359 - .3755\ \ell_1 \qquad R^2 = 0.84$$

was fitted to the data excluding the 1974 values.

A clear inverse relationship between year class size and length at age 1 is visible. The 1974 year class estimate from V.P.A. is in agreement with this relationship supporting the choice of starting F. It is suggested that the 1974 and 1975 year classes consist of about 10^9 fish at age 1.

Catch Projections

The 1976 population estimates of Table 14 are projected forward to 1977 and 1978 using $F_{0.1}$ of 0.5 and the previously recommended maximum F of 0.7. New recruitment was assumed to be 10^9 fish. The results are shown in Table 15.

The increase in projected catch to 66200 tons for F = 0.5 and 83200 tons for F = 0.7 is due to the reduction of fishing in 1976 from the assumed level in Doubleday et al. (1976) and to increased optimism regarding recruitment of the 1974 and later year classes.

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 16). The effort data for 1976 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. 8 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.

While the addition of the 1973 year class to the plot supports the above hypothesis formed in 1975 by Doubleday and Halliday, an observation of the 1976 catch rate per hour for the 1974 year class is needed before curve fitting would be justified.

Discussion

USSR catch rates and virtual population analysis of age compositions determined by modal analysis combine with inferences on growth of young silver hake to reveal a clear and consistent picture of the recent history and current status of the 4VWX silver hake fishery.

Research survey results, while useful in indicating the relation of age and length to maturity are unable to monitor or predict the performance of the commercial fishery or year class success.

The length of age one silver hake adjusted to 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

560×10^6 fish at age 2, 24% less than the value obtained in virtual population analysis.

The 1975 year class is expected to be of similar size with about 10^9 or less fish at age 1.

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, 1973,1975 and 1976 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.

In 1976, with reduced fishing effort, this ratio decreased to 0.12 while the overall proportion of ages 1 and 2 in the commercial catch has remained the same. 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. In 1976, the reduction of fishing effort reduced the pressure on immature fish. Comparison of length frequency samples from midwater and otter trawls suggests that use of midwater trawls can greatly reduce the fishing mortality on immature silver hake.

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, and that $F_{0.1}$ is 0.5. In view of the slight gains in yield with higher levels of F and the drastic resulting reduction in the spawning biomass per recruit, it is recommended to manage the level of fishing activity to cause a fishing mortality rate of 0.5 on ages 2 and older.

Reduction of the level of fishing mortality to 0.5 would increase stock stability by increasing the number of year classes in the fishery. Dependence on estimates of year class size of 0 group and age 1 fish for the management of the fishery would be reduced. Catch rates would also increase.

Projections indicate that fishing at $F_{0.1}$, the 1977 TAC would be 66,200 metric tons.

References

Doubleday, W. G., and R. G. Halliday. MS 1975. An analysis of the Silver Hake Fishery on the Scotian Shelf[1]. *Int. Comm. Northw. Atlant. Fish.* Res. Doc. 75/104.

Doubleday, W. G., J. J. Hunt, and R. G. Halliday. MS 1976. The 4VWX Silver Hake Fishery. *Int. Comm. Northw. Atlant. Fish.* Res. Doc. 76/VI/59.

Halliday, R. G., and A. C. Kohler. MS 1971. Groundfish survey programmes of the St. Andrews Biological Station, Fisheries Research Board of Canada - objectives and characteristics. *Int. Comm. Northw. Atlant. Fish.* Res. Doc. 71/35, serial no. 2520 (mimeographed).

Hunt, J. J. MS 1976. Age, growth, and distribution of silver hake *(Merluccius bilinearis)* on the Scotian Shelf from modal analysis of length frequencies. *Int. Comm. Northw. Atlant. Fish.* Res. Doc. 77 (this meeting).

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	-	712	86,927	8,106	95,745	11[1]	67	95,371	-	296[6]
1975[8]	-	1,468	95,385	15,713	112,566	100	54	108,398	7	1,698[7]
1976[8]	...	...	...	...	75,900	22	-	66,330	1	9,547[9]

[1] Not recorded by Division
[2] France (SP)
[3] GDR
[4] Spain
[5] FRG 10 mt, Cuba 201 mt
[6] FRG
[7] Bulgaria
[8] Preliminary Statistics
[9] Cuba 9,464, FRG 83

Table 2. Div. 4VWX silver hake - Canadian research vessel survey estimates of biomass (metric tons), population numbers ($x10^{-6}$), and catch per tow, 1970-76.

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
1976	18,573	3.74	95.15	19.16

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	1976
≤ 10	37	90	-	-	-	-	-
11	-	-	46	47	71	-	-
12	68	46	-	48	-	-	-
13	34	123	139	313	17	-	-
14	239	534	371	672	187	73	21
15	645	1,139	1,128	1,346	384	172	43
16	1,297	1,649	1,467	2,149	552	365	95
17	2,111	2,620	2,689	4,274	1,680	760	377
18	3,790	5,797	3,066	8,355	3,864	1,047	1044
19	4,554	4,318	3,921	12,767	6,146	1,356	1190
20	6,490	2,520	3,986	13,554	8,854	3,380	4390
21	7,991	1,917	3,099	12,740	6,622	4,013	5284
22	5,352	698	4,650	9,886	5,174	3,350	5963
23	2,938	512	3,462	4,432	2,478	2,825	2558
24	1,342	241	1,527	2,377	1,824	1,601	1560
25	3,317	728	3,762	3,015	3,203	829	1161
26	9,987	1,237	7,423	9,940	10,048	559	5787
27	18,389	3,946	11,402	22,291	20,435	998	9299
28	24,417	6,255	11,135	36,325	25,129	1,807	12256
29	19,768	5,635	6,245	30,186	20,849	3,760	11485
30	10,210	3,883	4,474	19,849	18,736	3,018	8898
31	6,765	2,603	2,118	10,221	11,930	3,529	6732
32	3,375	1,999	2,705	4,486	7,307	2,242	4761
33	2,197	1,489	1,768	3,506	7,197	2,120	3720
34	1,711	805	1,524	2,283	4,320	959	2006
35	885	337	1,391	2,615	2,735	524	1401
36	838	306	1,153	2,271	2,442	568	1660
37	953	349	557	1,986	2,200	139	1427
38	203	77	360	1,201	1,265	180	808
39	550	114	218	975	600	170	616
40	376	99	170	529	561	94	594
41	252	87	280	801	624	122	400
42	100	71	188	547	781	158	216
43	394	203	114	730	440	153	88
44	174	248	65	209	670	53	356
45	120	145	87	426	366	62	36
46	138	-	-	322	413	117	48
47	240	157	142	479	877	8	77
48	140	104	50	270	355	169	115
49	136	55	101	34	410	103	36
≥ 50	158	158	848	1,419	1,797	355	704
	142,681	53,294	87,831	229,876	183,543	41,738[1] (43,819)	97212

[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, 1970-76.

	Population numbers ($x10^{-6}$)						
Age	1970	1971	1972	1973	1974	1975	1976
1	38.3	21.3	31.9	70.8	36.4	20.4	21.4
2	100.8	26.1	46.9	148.5	120.0	20.0	61.2
3+	3.6	5.9	9.0	10.6	27.1	3.5	14.6
TOTAL	142.7	53.3	87.8	229.9	183.5	43.9	97.2

Table 5. Silver hake in Div. 4VWX: sex ratios for ages 1 and 2 from Canadian research vessel surveys, 1971-76.

Age	Sex ratios (males : females)					
	1971	1972	1973	1974	1975	1976
1	1.62	1.52	0.93	0.50	1.52	0.84
2	0.48	0.43	0.29	0.68	0.76	1.02

Table 6(a). 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		1976		1971-76		% Mature
	Imm	Mat	Imm	Mat	Imm	Mat	Imm	Mat	Imm	Mat	Imm	Mat	Imm	Mat	
15	12		8		7		2		2		2		33		-
16	11		11		5		5		5		1		38		-
17	22		18	1	12		14		6		9		81	1	1
18	48		26	-	17		22		13		9		135	-	-
19	35		26	-	18		28	1	13		15		135	1	1
20	24		31	-	21	1	30	3	28		41		193	4	2
21	14		18	3	8	-	21	-	30		37	2	128	5	4
22	5		8	5	14	-	15	4	29		40	4	111	13	10
23	2	2	10	2	9	-	6	3	19		21	2	67	9	12
24	-	4	6	2	4	3	6	12	10		7	9	33	30	48
25	-	9	4	11	2	19	2	24	8		2	12	18	75	81
26	-	14	1	22	-	52	1	43	2	2	-	16	4	149	97
27	2	26	1	28	-	49	4	97	1	9	1	35	9	244	96
28	-	34		24	-	71	-	89	1	13	2	33	3	264	99
29	1	25		11	1	39	-	86	1	40	-	32	3	233	99
30		14		16	1	24	-	82		26	-	21	1	183	99
31		6		13	1	19	1	57		18	-	17	2	130	98
32		4		8		14		25		7	1	9	1	67	99
33		3		6		16		13		3	-	11	1	52	98
34		-		2		8		3		1		6		20	100
35		-		-		3		2				3		8	100
36		-		2		1		2		1		4		10	100
37		1		1				1				-		3	100
38				1				-				2		3	100
39				1				-				-		1	100
40								1						1	100

Table 6(b). 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		1976		1971-76		% Mature
	Imm	Mat	Imm	Mat	Imm	Mat	Imm	Mat	Imm	Mat	Imm	Mat	Imm	Mat	
15	8		5		5		5		1		1		25		-
16	12		6		4		8		3		1		34		-
17	16		15		19		14		11		6		81		-
18	32	2	18		25		33		8		11		127	2	2
19	28	1	26	1	21	1	42		15		18		150	3	2
20	19	-	38	-	16	-	48	1	36		44		201	1	1
21	16	-	15	-	12	-	33	1	40		55	1	171	2	1
22	9	-	20	2	9	1	26	1	34		46	2	144	6	4
23	5	-	17	-	8	-	21	-	31		23	1	105	1	-
24	1	-	11	-	6	-	20	1	13		16	1	67	2	3
25	3	1	5	2	8	-	18	3	5		3	4	42	10	19
26	4	4	14	3	5	16	27	6	5	1	3	10	58	40	41
27	6	21	19	11	16	49	33	26	2	4	7	35	83	146	64
28	9	42	16	27	17	72	29	37	1	18	5	33	77	229	75
29	-	52	10	20	11	90	21	45	1	35	8	62	51	304	86
30	2	54	9	21	2	81	5	69		32	1	65	19	322	94
31	1	43	1	16	1	43	4	109		48	3	50	10	309	97
32	1	38	4	24	2	36	1	81		41	-	46	8	266	97
33		30	2	27		25	3	92		44	-	38	5	256	98
34		24	1	26		11		67		24	-	20	1	152	99
35		9	-	19		24		43		15	-	23	-	133	100
36		7	1	10		26		41		11	1	21	2	106	98
37		7		6		21		33		6		20		87	100
38		2		6		18		20		6		11		57	100
39		3		6		17		8		3		17		51	100
40		1		3		11		12		4		15		42	100

Table 7(a). 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		1976	
	Age 1	Age 2	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		3	
17	283		835		274		307		437		29	
18	444		1170		884		769		835		176	
19	561		1466		1974		1374		1332		675	
20	570		1643		3042		1750		1775		1636	
21	466		1645		3239		1588		1975		2513	
22	307		1472		2382		1026		1836		2444	1
23	163		1178	7	1211	2	473	4	1426	1	1505	18
24	69	5	842	133	425	40	155	78	925	9	587	181
25	24	68	538	1043	103	316	36	653	501	54	145	1050
26	7	387	308	3385	17	1232	6	3186	227	227	22	3600
27	1	1049	157	4531	2	2314	1	7816	86	646	2	7287
28		1352	72	2502		2096		9632	27	1237		8711
29		829	29	570		915		5965	7	1598		6149
30		242	11	54		193		1856	2	1392		2563
31		33	3	2		20		290		818		631
32		2	1			1		23		324		91
33								1		86		7
% mature	5.8	97.3	12.3	100.0	2.9	99.5	8.5	98.7	9.0	91.0	4.3	96.3

Table 7(b) 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.

B. FEMALES

Length	1971		1972		1973		1974		1975		1976	
(cm)	Age 1	Age 2	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		4	
17	141		658		661		261		169		37	
18	263		1022		1383		885		399		203	
19	372		1318		2255		2070		768		734	
20	400		1411		2864		3333		1204		1749	
21	325		1254		2834		3697		1535		2760	
22	201		925	6	2184		2826		1593		2883	5
23	94		567	58	1311		1488	16	1345		1993	28
24	33	1	288	348	613	2	534	113	925	2	912	114
25	9	9	122	1391	224	37	135	557	517	8	276	370
26	2	81	43	3654	63	403	23	1921	235	32	55	970
27		422	12	6323	14	2193	3	4703	87	104	7	2063
28		1281	3	7204	2	5950		8164	26	277		3558
29		2258	1	5405		8046		10060	7	601		4975
30		2313		2670		5423		8791	1	1059		5640
31		1376		869		1822		5448		1515		5185
32		476		186		305		2395		1760		3866
33		96		26		25		747		1661		2337
34		12		2		1		166		1273		1145
35		1						26		792		455
36								3		401		146
% mature	1.7	94.0	1.6	51.5	2.2	88.5	1.9	71.1	6.3	93.7	4.4	95.6

Table 8. Comparison of abundance estimates of silver hake from research vessel surveys with catch rates at age 2, UPA population estimates, and average catch rate of USSR otter trawlers (>1800 gt).

Year-class	Catch rate (N) at age 2	UPA estimate age 1	Av. catch (mt/hr) of USSR otter trawlers 1969-75	Survey Results: USSR			Survey Results: CANADA		
				N age 1/tow	kg/tow	N/tow	N age 1	kg/tow	N/tow
1968	9.06	1,847	0.98	-	-		-	-	-
1969	5.97	1,539	1.58	-	-		36,150	4.90	29.32
1970	6.55	1,131	1.13	-	-		20,462	1.59	10.78
1971	13.92	2,773	1.26	635	101.0	962.8	30,386	3.09	17.72
1972	6.85	970	2.62	438	120.5	873.0	71,763	7.69	46.29
1973	4.94	871	1.16	725	170.9	1,342.0	36,653	7.28	36.95
1974	-	1,132	1.27	2,024	335.2	2,629.2	17,309	1.50	8.82
1975	-	-	-	-	-		21,384	3.74	19.16

Table 9. Yield Per Recruit

Age of Recruitment (months)	F_{max} $F_{0.1}$ F=0.7	Yield/Recruit (grams)	Biomass/Recruit (grams)
12	0.95	101	106
	0.45	92	193
	0.70	99	142
15	1.25	108	87
	0.50	94	193
	0.70	104	148
18	1.80	114	64
	0.51	100	191
	0.70	105	151
21	2.0	118	59
	0.55	98	179
	0.70	105	150
24	2.0	120	60
	0.65	101	155
	0.70	103	147

Table 10. 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)[1]
1964	81,147	(1.37)[1]
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
1975	112,566	1.27

[1]Catch rate of "other groundfish" mainly silver hake.

Table 11. Age composition of commercial catches of silver hake in Div. 4W, 1965-74 and 4WX 1975-76.

	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	143125	376358	422256	4347	1807	391
1976	48637	397254	33817	3568	1279	117

Table 12. Mean length (cm) at age by month for USSR silver hake sampling 1969-76.

Note: For comparison with 1 cm interval research samples, 1 cm should be added to the estimated lengths.

Age \ Yr. Class	66	67	68	69	70	71	72	73	74	75
6						12.7				
9			12.8				14.6	*		
10				13.9		16.5	*	17.3	20.4	16.0
11				16.3		18.6	18.5	18.7	18.8	17.3
12			20.3	*			18.3	19.1	23.8	19.5
13				19.3		20.7	20.7	21.5	20.3	22.2
14				21.4		21.3	22.6	22.6	22.9	23.0
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	*						26.9	
20						26.7			26.7	
21		26.9	26.2	26.8	25.7	26.0	25.6		27.2	
22			26.9		27.2	*	27.1	27.9	27.2	
23		29.2	27.1		27.7	28.1	26.2	28.5	28.1	
24		29.1	*		*	28.5	29.1	30.4	29.8	
25		29.8	28.7		27.5	28.4	30.0	30.3	30.0	
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 13. Estimated population numbers at age for 4VXW Silver hake 1966-76.

	Population numbers at age ($x15^{-6}$)						
Year	1	2	3	4	5	6	Biomass 1+ (mt)
1966	85.18	28.22	1.42	0.57	0.21	0.07	9,647
1967	145.26	48.83	11.09	0.63	0.36	0.13	18,776
1968	693.60	97.80	26.61	6.78	0.37	0.22	61,433
1969	1847.32	470.35	50.87	16.29	4.42	0.21	192,667
1970	1539.04	1221.02	124.20	18.57	9.18	2.36	322,042
1971	1131.57	863.43	267.50	29.27	7.46	4.52	288,490
1972	2774.11	705.41	147.44	24.61	7.97	2.00	310,690
1973	973.17	1738.18	148.26	19.64	6.12	1.39	379,208
1974	890.96	569.56	75.87	9.60	3.27	0.64	163,230
1975	1186.74	531.98	69.45	12.41	2.43	0.55	171,183
1976	1,011.30	679.69	66.21	13.52	4.85	0.24	186,579

Table 14. Fishing Mortality Estimates for Scotian Shelf Silver Hake 1966-76.

	Age					
Year	1	2	3	4	5	6
1966	0.156	0.534	0.419	0.075	0.055	0.100
1967		0.207	0.092	0.138	0.063	0.100
1968		0.254	0.091	0.029	0.153	0.150
1969	0.014	0.932	0.608	0.174	0.225	0.300
1970	0.178	1.118	1.045	0.512	0.308	0.300
1971	0.073	1.367	1.986	0.902	0.916	0.900
1972	0.068	1.160	1.616	0.991	1.349	-
1973	0.136	2.732	2.337	1.392	1.859	1.500
1974	0.116	1.704	1.410	0.976	1.388	1.000
1975	0.157	1.684	1.236	0.540	1.912	1.000
1976	0.060	1.150	0.920	0.380	0.380	0.380

Table 15. Population numbers and catch projections for Scotian Shelf silver hake 1976-78.

	1976			1977			1978			
Age	Stock size (10^{-6})	F	Catch (10^{-3} tons)	Stock size (10^{-6})	F	Catch (10^{-3} tons)	Stock size (10^{-6})	F	Catch (10^{-3} tons	Mean Weight kg
1	1000	0.06	2453	1000	0.04	1746	1000	0.04	1746	0.051
2	679	1.15	63163	631	0.81	47240	643	0.81	48070	0.159
3	66	0.92	9130	144	0.65	15670	188	0.65	20399	0.270
4	13	0.38	1520	18	0.27	1475	50	0.27	4209	0.426
5	5	0.38	812	6	0.27	770	9	0.27	1126	0.635
6	0.2	0.38	57	2	0.27	394	3	0.27	562	0.905
$\bar{F}$ 2-5		0.71			0.50			0.50		
Calculated catch			77136			67295			76113	
Corrected catch			75900			66217			74893	
1	1000	0.06	2453	1000	0.06	2453	1000	0.06	2453	0.051
2	679	1.15	63163	631	1.15	58665	631	1.15	58665	0.159
3	66	0.92	9130	144	0.92	19896	134	0.92	18479	0.270
4	13	0.38	1520	18	0.38	1988	39	0.38	4332	0.426
5	5	0.38	812	6	0.38	1039	8	0.38	1358	0.635
6	0.2	0.38	57	2	0.38	531	3	0.38	679	0.905
$\bar{F}$ 2-5		0.71			0.71			0.71		
Calculated catch			77136			84570			85965	
Corrected catch			75900			83215			84588	

Table 16. Temperature and catch per unit effort for 4VWX silver hake.

Year	Temp. °C	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
1966	3.76	0.38	0.37
1967	5.39	0.00	5.17
1968	--	0.00	0.89
1969	4.82	0.64	7.23
1970	5.10	2.69	9.06
1971	5.92	0.71	5.97
1972	4.72	2.37	6.55
1973	4.33	0.98	13.92
1974	5.88	1.36	6.85
1975	4.30	1.88	4.94
1976	5.03		

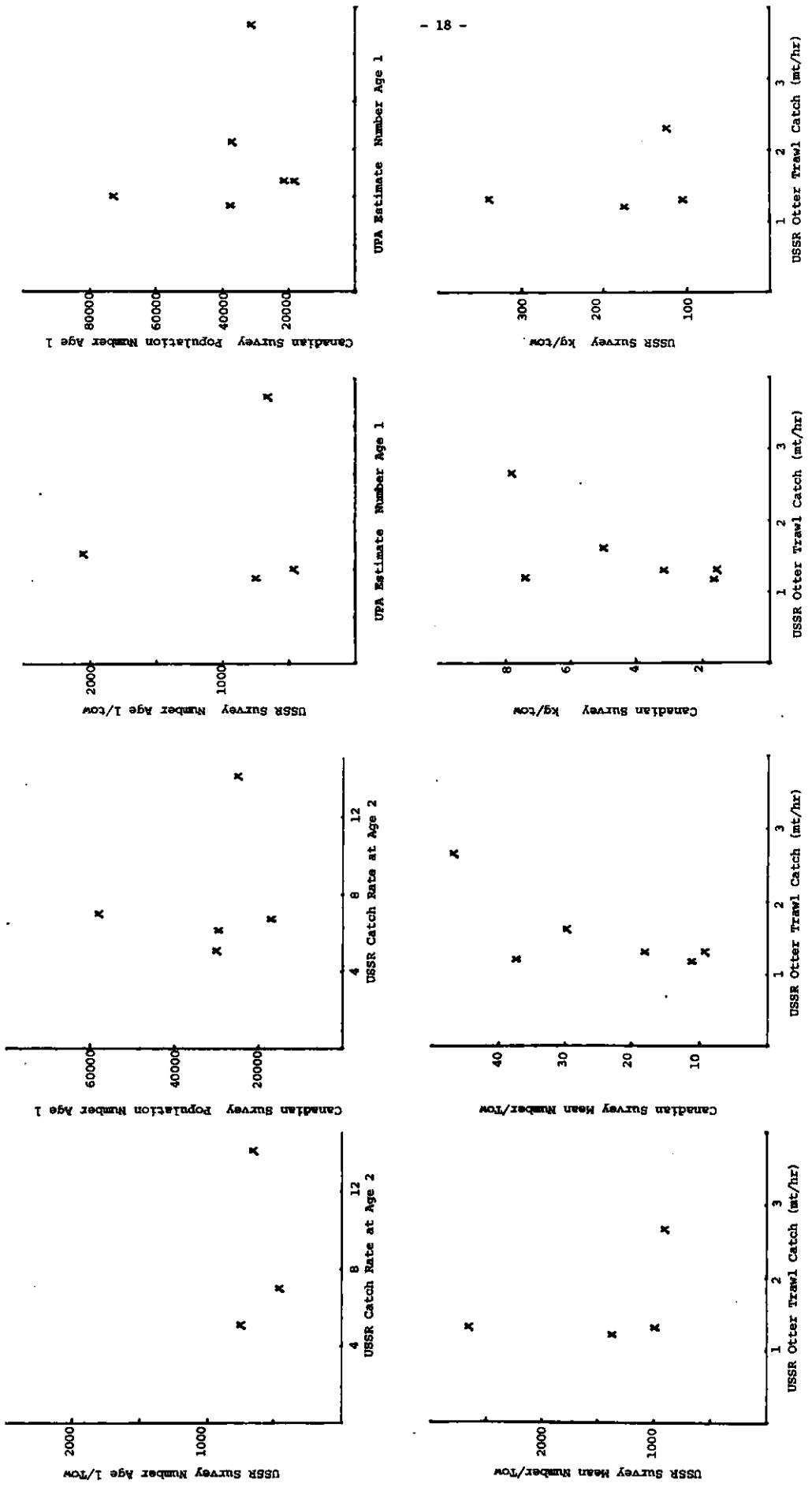

Figure 1.Comparison of abundance estimates of silver hake from research and commercial sources.

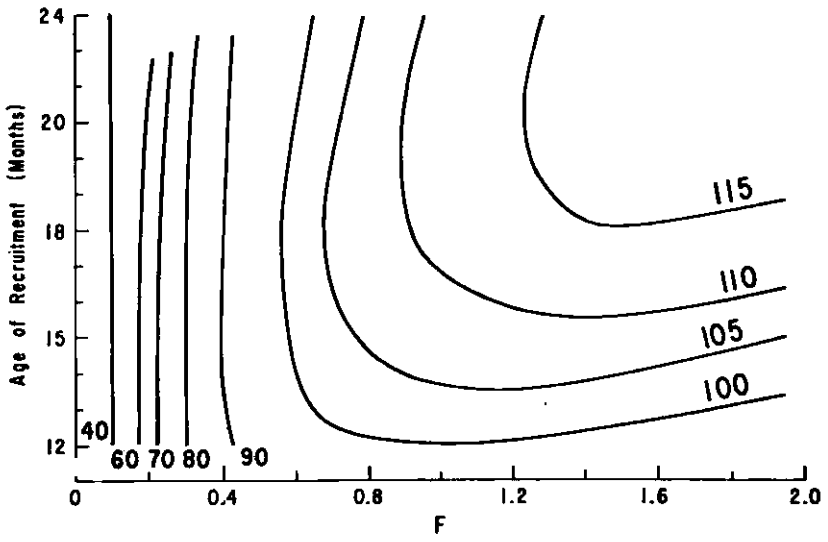

Figure 2. Yield per recruit isopleth diagram.

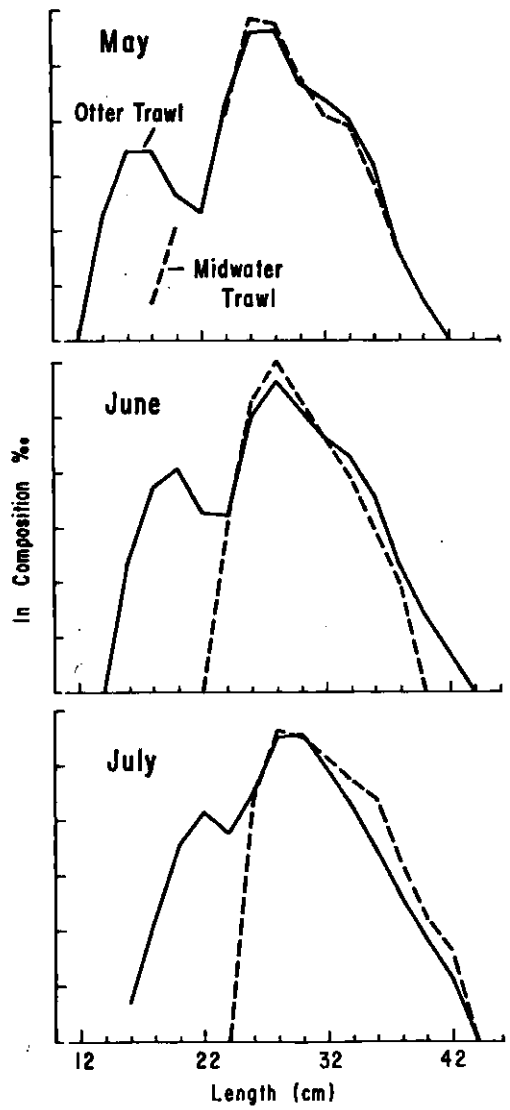

Figure 3. Comparison of length frequencies from commercial otter trawl and midwater trawl catches.

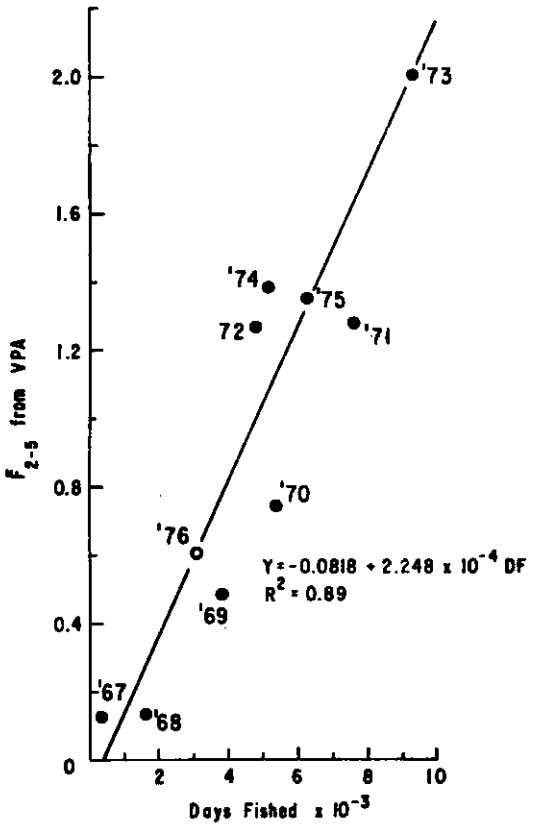

Figure 4. Regression of day fished by >1800 GRT USSR otter trawlers in Division 4W and mean F on ages 2-5 from VPA.

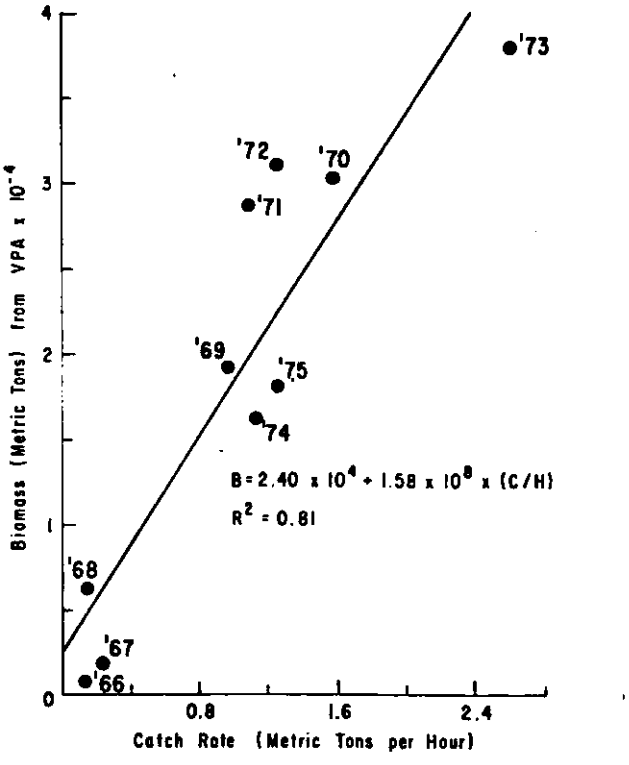

Figure 5. Regression of catch rate by >1800 GRT USSR otter trawlers and biomass estimates from VPA.

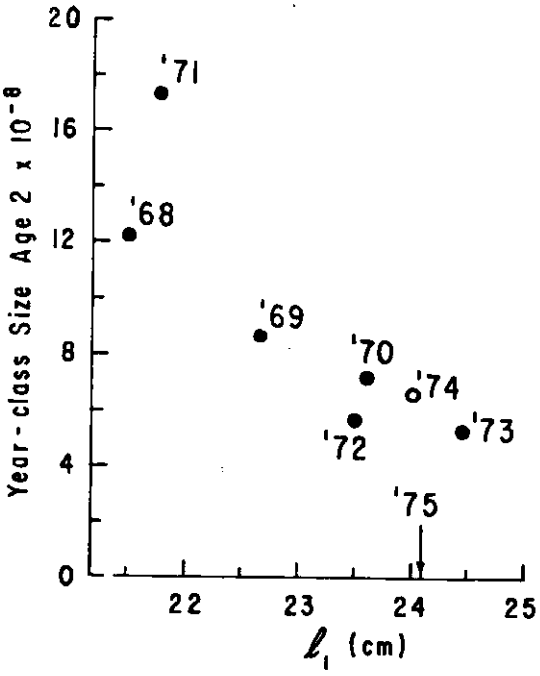

Figure 6. Regression of length at age 1 in September and year-class size at age 2.

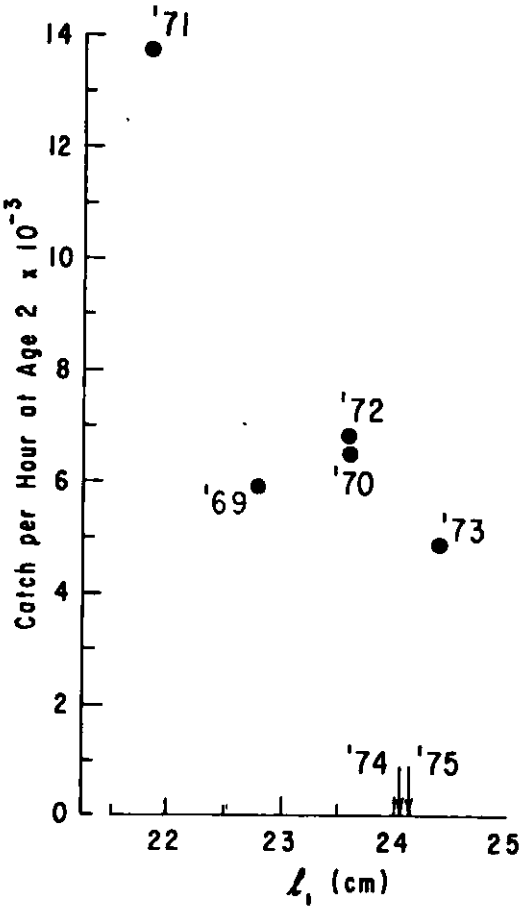

Figure 7. Regression of length at age 1 in September and catch per hour at age 2 by USSR otter trawlers.

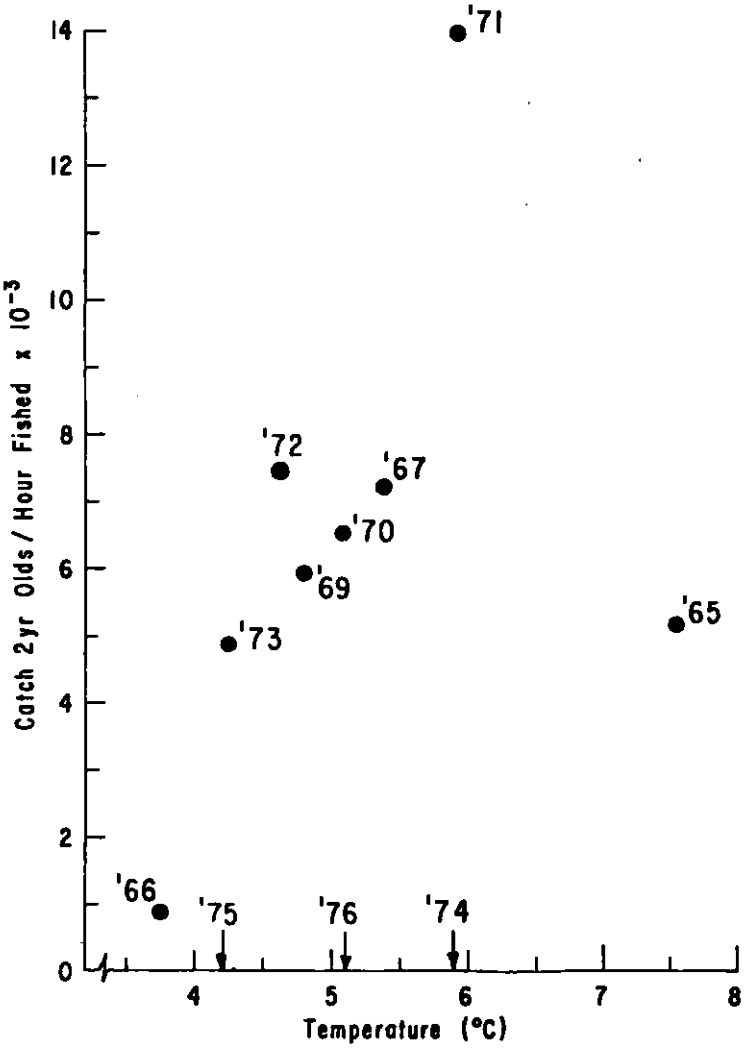

Figure 8. Average bottom temperature on Sable Island Bank in July and catch per hour of age 2 fish.

Appendix I

Silver hake assessment - Div. 4VWX

The VPA analysis and catch projections for 1977 were revised at the Ninth Special Commission Meeting, Tenerife, Canary Islands, Spain, December 1976, to allow for projected catches for the fourth quarter of 1976.

Table 13 (Revised). Estimated population numbers at age for Div. 4VWX silver hake, 1966-77.

Population Size (10^{-6})

	Age					
Year	1	2	3	4	5	6
1966						
1967						
1968			UNCHANGED			
1969						
1970						
1971	1,134					
1972	3,179	707				
1973	975	1,813	149.0			
1974	901	571	82.8	10		
1975	1,266	539	70.1	14	2.8	
1976	1,011	732	70.6	14	5.0	0.458
1977						
Population	1,000	631	127	16	6.0	2.0
Catch	32.36	296	51	3.1	1.2	0.4
F	.04	.81	.65	.27	.27	.27

Catch (metric tons) = 64,929 (uncorrected)

Corrected catch = 63,888

Table 14 (Revised). Fishing mortality estimates for Scotian Shelf silver hake, 1966-1976.

	Age					
Year	1	2	3	4	5	6
1966						
1967						
1968						
1969			UNCHANGED			
1970						
1971	0.072					
1972	0.062	1.155				
1973	0.135	2.586	2.289			
1974	0.114	1.697	1.277	0.894		
1975	0.147	1.634	1.216	0.489	1.404	
1976	0.071	1.354	1.083	0.447	0.447	0.447