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Silver Hake (*Merluccius bilinearis*) in Divisions 4VWX: A Stock Assessment and an Estimate of the Total Allowable Catch for 1980

by

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Introduction

Silver hake (Merluccius bilinearis) have been fished off the coast of Nova Scotia since 1958. There has been a variable history of catches with the USSR being the major harvesting nation, taking over 98% of the catch from 1961 until 1975. The highest individual annual catch was nearly 300,000 tonnes in 1973. From 1974 until 1976 quotas were imposed and the catch averaged about 100,000 tonnes. During 1977 and 1978 area and gear restrictions were also placed on the fishery. These factors coupled with by-catch limitations and a large biomass of squid interacting in a mixed fishery have reduced the catch for the last two years to 37,650 and 48,200 tonnes respectively.

Catches

The provisional catch statistics are taken from ICNAF Circular Letters (monthly) and provisional data of Statistics Branch, Fisheries and Marine Service, Canada (Table 1).

Catch-at-age

Length frequency samples were collected and tabulated on a weekly basis by the International Observer Program. These data were weighted by month, by country, and by division (where possible) to give the catch at length table. This was then broken down to the catch at age table by an age length key prepared by the Ageing Unit, Marine Fish Division, St. Andrews Biological Station, N. B., Canada, according to the criteria laid down at the ICNAF Ageing Workshop (1978) (ICNAF 1978). The otoliths read to prepare this key were collected by the International Observer Program during 1978.

The catch at age table (Table 2) is considerably different from those of earlier years (Halliday et al., 1978). This is due to a re-analysis of all the earlier data 1958-1977 according to age length keys that have only become available this year (Clay, 1979a). This is an attempt to fulfill the ICNAF recommendations (ICNAF 1976) for a complete recalculation of the Silver hake age compositions.

Weight-at-age

The weights at age for ages 1 - 5 and 6+ are different from those used by Halliday et al (1978).

Weight/Age	1	2	3	4	5	6+
Weight (kg) 1978 (assess)	0.044	0.122	0.204	0.298	0.425	0.732
Weight (kg) 1979 (assess)	0.043	0.100	0.168	0.218	0.340	0.560

This great difference in the 5 and 6+ age groups is due to the increased number of older males in the 1978 catch. The asymtotic length of males (from the Von Bertlanaffy growth equation) is 36.5 cm whereas the females have a maximum length of 61.6 cm. This has had the effect in 1978 population of spreading the 6+ age groups over the range 31-65 cm with the mode at 35-36 cm and a mean weight-at-age of 0.560 kg.

Natural Mortality

The natural mortality used in previous assessments (M = 0.4) was based on work done by Terre and Mari (1977) on the earlier catch at age table of Doubleday et al (1976). As no better estimates were obtained in preliminary tests of this data the same M was used this year as last (M = 0.4).

Virtual Population Analysis (VPA)

Arbitrary partial recruitments (PR) were applied to the oldest age group and the last year of fishing. From these, improved estimates of the partial recruitments were obtained and the starting fishing mortalities (F) re-calculated. This was carried out until the relationship between F and effort (f) became nearly linear. The final partial recruitment (normalized to 1 at the highest fishing mortality) was then calculated for 1970-1976 inclusive (Figure 1).

Separate analysis were run for pre-quota (1970-1973) and post-quota (1974-1977) periods with no real difference being discernable. Mesh selection analysis by Clay (1979b) indicates there should be little effect on the PR's in changing from 40 mm to 60 mm mesh codends. Moreover, length of fish by depth analysis by Clay (1979a) further indicates there should be little effect on the PR's caused by the small mesh gear line. The F table (Table 3) however, shows a change in PR's in 1977, and this cannot be completely attributed to gear or area changes. The population numbers (Table 3) do, however, show a great reduction in recruitment beginning in 1976 and continuing in 1977. As such a change in recruitment can affect the PR's, they were altered by averaging the historical pattern and those of 1977. The results from this analysis (Table 4) still indicate a drop in recruitment to 30-50% of the mean of 1970-1975. To get the recruitment of age 1 in 1977 up to 0.7 x 10^9 fish, the F in 1978 has to be dropped by over 50% of that in Table 4 - even at this low mean F (0.086) the 1976 year class is still small. Therefore if the recruitment in 1976 was low (age 1 in 1977) and this affected the PR's then it will also affect the PR's in 1978. Therefore we have chosen the mean between the PR of 1977 and the historical pattern and applied them for the VPA (Table 4).

Validation of the VPA

The mean fishing mortality for ages 2 to 5 was plotted against effort (f) (Figure 2). The GM regression was:

$$f = -8651 + 141380\ \overline{F}_{(2-5)},\ (r^2 = .93,\ n = 9)$$

The intercept is very close to the origin and the fit (r^2 = .93) is very good.

The catch per unit effort (CPUE), as estimated from that portion of the USSR fleet with Canadian observers on board, was 2.05 tonnes per hour landward of the small mesh gear line and 1.37 tonnes seaward of the line. Weighting these CPUE's by catch (i.e. 10,000 and 38,000 tonnes respectively) an average CPUE of approximately 1.5 tonnes per hour is achieved. This gives an effort of approximately 32,000 hours. This value puts the 1978 point for mean F of 2-5 year olds at 0.30 and the fully recruited F for the PR's used at 0.35.

Figure 3 plots the fishable biomass of age 2+ (population numbers of Table 4 multiplied by the normalized partial recruitments) against the CPUE in tonnes gives a GM regression of:

$$\text{CPUE} = 0.47 + 4.876 \times 10^{-6}\ \text{BIOMASS}\ (2+),\ (r^2 = .56,\ n = 9)$$

Yield Per Recruit

The yield per recruit (YPR) is 0.049 kg at a fully recruited $F_{0.1}$ of 0.558. The F_{max} is 1.2 with a YPR of 0.054 kg.

Recruitment

A good recruitment relationship is very difficult to achieve. With silver hake, recruitment is the single most important factor in the catch projection. This is because two year-classes (2 and 3) generally make up over 75% of the catch composition and before 1976 the age 2's made up approximately 70% of the catch numbers. The relationship used by Halliday et. al. (1978) which related length of age 1 in September to year-class size of 2 year olds has not been holding together in the last few years. Therefore a new attempt to draw up a stock recruitment estimate has been made. As the drastic drop in recruitment of the 1976 year-class appears to coincide with rising squid biomass (Dufour, 1979), a multiple regression of squid biomass ($\times 10^3$) and mean bottom temperature (°C) in July on the Scotian Shelf was tried against population numbers of 1-year olds ($\times 10^9$) in the following year. Figure 4 indicates the data points used to obtain the equation: -

$$\text{POP}_1 = 1.206 + 0.141\ (\text{B. Temp. °C}) - 0.006\ (\text{Squid}), (r^2 = 0.37,\ F = 1.79,\ T2 = 1.87,\ T1 = 0.34)$$

The squid biomass handles the majority of the variation in recruitment in this (admittedly) poor relationship. The recruitment for the 1978 year-class - if this relation holds - is 1.82×10^9 fish into age 1 in 1979 (mean bottom temperature = 4.81°C and squid biomass = 11,000 mt).

Fitting a curve by eye to the recruitment vs squid biomass (Figure 4) gives an estimate of 1.9×10^9 fish in age 1 in 1979.

As this data appears to have a logarithmic form and as bottom temperature appears to have no relation a further regression of population size at age 1 vs the natural logarithm of the squid biomass was run. A much better fit results in the equation: -

$$\text{POP}_1 = 214.60 - 30.84\ (\ell n\ \text{squid}),\ (r^2 = 0.85,\ n = 7)$$

This gives a recruitment estimate for the 1978 year-class of 1.4×10^9 fish at age 1 in 1979. There is rapid growth of squid on the Scotian Shelf (Clay, 1979b) and the weighted mean length of squid occurring in the Canadian R/V surveys (Dufour, 1979) has ranged from 15 to 20 cm between 1970 and 1978. This change in length amounts to a range of 100 to 200 g which will affect the biomass estimates and may bias the results. Therefore a final regression of squid numbers and population size was run (Fig. 5) to give the equation: -

$$\text{POP}_1 = 321.48 - 40.34\ (\ell n\ \text{squid nos.}),\ (r^2 = 0.87,\ n = 7)$$

A feeding study on squid (Amaratunga _et. al._, 1979) indicates that during October-November fish make up over 30% of the diet. Although the majority of this is listed as either "unidentified fish" or "gadidae" some _Merluccius_ sp. was identified and at a level of even 1% (by weight) of the squid biomass the effect on age 1 hake would be substantial. The extreme case (1976) would result in a mortality of some 1.3×10^9 fish of less than age 1.

Catch Projection

As recruitment appears to be dropping, a below average recruitment of 0.75×10^9 fish was assumed for 1979-1982. The summarized results with fishing at an $F_{0.1}$ level of .558 for all years are:

Year	Pop Numbers	Pop Biomass	Catch Numbers	Catch Biomass	Corrected Catch biomass
1978	1686196	228432	254378	47506.24	48,200
1979	1660127	207287	338769	52915.99	53,689
1980	1539183	171202	315885	43984.40	44,627 TAC*
1981	1494768	153675	306258	39411.59	39,987
1982	1477233	141563	303014	36729.59	37,265

In order to correct for the difference in the weights at age and the true weights, the 1978 catch must be divided through by 47,506 tonnes to obtain the correction factor of 0.99. All the catch biomass levels are then multiplied by 0.99 to obtain the true 1980 TAC of 44,627 tonnes. This is fishing at the $F_{0.1}$ level for 1979, the TAC for 1979 is 70,000 tonnes. Fishing at the full quota for 1979 gives a TAC = 39,763 tonnes.

As this is a pessimistic recruitment projection another was carried out using the geometric mean of the historic recruitment (1965-1976) 1.0×10^9 fish. These results (Table 5) indicate a quota of 46,232 tonnes would be appropriate based on an $F_{0.1}$ of 0.558 for 1980 and a full quota of 70,000 tonnes for 1979. Halliday _et al_ (1978) predicated the TAC of 1978 would not be reached and suggested a drop from 81,000 to 33,000 tonnes (actual catch = 48,000 tonnes). The currect projection indicates the TAC for 1979 of 70,000 tonnes will also be on the high side. If fishing occurs at $F_{0.1}$ and the 1979 TAC is not reached the results would be:

Year	Pop Numbers	Pop Biomass	Catch Numbers	Catch Biomass	Corrected Catch Biomass
1978	1686196	228432	254378	47506.24	48200
1979	1910127	218037	356033	53658.36	54442
1980	1963239	197309	388284	50240.21	50974 TAC*
1981	1984168	189682	396642	48688.80	49399
1982	1993283	183039	400297	47510.99	48204

Using the very high recruitments of Figure 5 (i.e. 1.4×10^9 fish) the TAC for 1980 jumps considerably. Fishing the full TAC for 1979 and the $F_{0.1}$ level for 1980 to 1982 the results are: -

Year	Pop Numbers	Pop Biomass	Catch Numbers	Catch Biomass	Corrected Catch Biomass
1978	1686196	228432	254378	47506.24	48,200
1979	2310127	235237	484754	68992.61	70,000
1980	2532565	223644	480469	55797.32	56,612 TAC*
1981	2694413	239183	533010	61376.24	62,273
1982	2762441	245801	553024	63818.60	64,751

Acknowledgements

Fred Rahey assisted in the tedious calculations required for the new catch at age table.

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Table. 1 ICNAF provisional catch statistics for 1978 (taken from ICNAF monthly circular letters). All catches for Canada include preliminary statistics from Statistics Branch, Fisheries and Oceans, Canada.

Mesh Size (mm)[2]	60	60	60	40-60	30-40			
MONTH	USSR	CUBA	BULGARIA	JAPAN	ITALY	CANADA[1]	FDR GERMANY	TOTAL
January	-	-	-	-	-	-	-	0
February	-	-	-	-	-	-	-	0
March	-	-	-	-	-	-	-	0
April	2,171	-	-	-	-	-	-	2171
May	8,129	522	-	-	-	0.5	-	8,651.5
June	11,346	1,427	75	26	-	0.5	-	12,874.3
July	13,574	639	527	12	-	0.2	-	14,752.2
August	8,452	894	-	3	-	5.5	-	9,354.5
September	111	-	-	1	34	39.8	-	185.8
October	-	1	-	3	71	51.7	3	129.7
November	-	-	-	16	-	9.0	-	25
December	-	-	-	-	-	56.0	-	56
TOTAL	43,783	3,483	602	61	105	163.0	3	48,200

[1] Canada includes 16 tonnes by inshore gear reported by Statistics Branch, 8 tonnes reported by ICNAF and developmental charters with the USSR (46.9 tonnes) and Japan (92.1 tonnes).
2. Mesh sizes approximated from International Observer reports.

Table 2. Catch at age table for 4VWX Silver hake.

	Catch numbers ('000 s of fish) at age for 4VWX Silver hake.								
Age/Year	1970	1971	1972	1973	1974	1975	1976	1977	1978
1	125484	146043	253744	256893	135582	148215	159687	11078	21468
2	580982	369582	534271	1487089	411973	415730	359111	83376	69398
3	369703	227813	265045	155463	103574	73476	73909	88087	85485
4	125785	101239	84805	86185	4854	42593	41191	16229	37652
5	22281	28011	24164	44699	10167	18010	8331	2749	25165
6+	12574	15415	15132	34527	3746	37843	7288	1360	15210

Table 3. **Population numbers and fishing mortality using partial recruitments from Figure 1 with an M = 0.4.**

POPULATION NUMBERS 24/ 3/79

	1970	1971	1972	1973	1974	1975	1976	1977	1978
1	2383433	1743291	3394667	1636366	1596225	1461376	928384	276661	212748
2	1587293	1495830	1050207	2069792	889406	960109	859569	493436	176456
3	862948	600292	705577	282175	242038	269696	313340	290600	263460
4	277291	284673	220727	261557	66889	79936	121799	150586	124209
5	72622	86113	109964	80355	106377	40901	20030	48709	87803
6	25148	30830	35308	54257	18730	63072	13118	6800	30420
	5208736	4241029	5516450	4384503	2919665	2875091	2256240	1266792	895096

FISHING MORTALITY 24/ 3/79

	1970	1971	1972	1973	1974	1975	1976	1977	1978
1	.066	.107	.095	.210	.108	.131	.232	.050	.130
2	.572	.351	.914	1.746	.793	.720	.684	.227	.630
3	.709	.600	.592	1.039	.708	.395	.333	.450	.490
4	.769	.551	.610	.500	.092	.984	.517	.139	.450
5	.457	.492	.306	1.056	.123	.737	.680	.071	.420
6	.400	.400	.300	.700	.100	.600	.500	.100	.400

Table 4. **Population numbers and fishing mortality using mean of partial recruitments from Figure 1 and the PR of 1977 from Table 4 with an M = 0.4.**

POPULATION NUMBERS 24/ 3/79

	1970	1971	1972	1973	1974	1975	1976	1977	1978
1	2368736	1739041	3394667	1717164	1795557	1667563	1204851	433888	663405
2	1587293	1485980	1047359	2069792	943492	1093679	997712	678511	281843
3	859450	600292	699001	280317	242038	305276	401621	382052	387370
4	277291	281706	220727	257200	65687	79936	145544	209601	185220
5	70049	86113	107995	80355	103481	40096	20030	64515	127344
6	25148	29117	35308	52941	18730	61131	12588	6800	41014
	5186967	4222249	5505058	4457770	3168984	3247681	2782347	1775367	1686196

FISHING MORTALITY 24/ 3/79

	1970	1971	1972	1973	1974	1975	1976	1977	1978
1	.066	.107	.095	.199	.096	.114	.174	.031	.040
2	.572	.354	.918	1.746	.728	.602	.560	.161	.350
3	.714	.600	.600	1.051	.708	.341	.250	.324	.308
4	.769	.559	.610	.510	.094	.984	.414	.098	.280
5	.478	.492	.313	1.056	.126	.759	.680	.053	.271
6	.400	.450	.300	.750	.100	.650	.550	.100	.236

Table 5. Stock size, catch and fishing mortality by age for silver hake, 1978-82.

Population Numbers

	1978	1979	1980	1981	1982
1	663405	1000000	1000000	1000000	1000000
2	281843	427257	594580	614319	614319
3	387370	133133	133020	228116	235689
4	185220	190842	47827	56636	97125
5	127344	93817	73879	21501	25462
6	41014	65078	36725	33484	9745
	1686196	1910127	1886031	1954056	1982339

Population Biomass

	1978	1979	1980	1981	1982
1	28526.41	43000.00	43000.00	43000.00	43000.00
2	28184.30	42725.00	59457.99	61431.85	61431.85
3	65078.16	22366.37	22347.39	38323.52	39595.77
4	40377.96	41603.55	10426.31	12346.63	21173.22
5	43296.96	31896.83	25118.88	7310.47	8656.92
6	22967.84	36443.48	20566.10	18750.78	5457.13
	228431.63	218036.93	180916.66	181163.25	179314.89

Catch Numbers

	1978	1979	1980	1981	1982
1	21468	93499	69057	69057	69057
2	69398	193374	213452	220538	220538
3	85485	51975	40610	69627	71938
4	37652	67664	13154	15577	26713
5	25165	32743	19978	5814	6885
6	15210	19678	8521	7769	2261
	254378	458933	364763	388382	397392

Catch Biomass

	1978	1979	1980	1981	1982
1	923	4020	2969	2969	2969
2	6940	19337	21345	22054	22054
3	14361	8732	6821	11697	12086
4	8208	14751	2868	3396	5823
5	8556	11133	6792	1977	2341
6	8518	11020	4772	4351	1266
Catch	47506	68993	45567	46444	46539
Correct Tac	48200	70000	46232	47122	47218

Fishing Mortality

	1978	1979	1980	1981	1982
1	.040	.120	.087	.087	.087
2	.350	.767	.558	.558	.558
3	.308	.624	.454	.454	.454
4	.280	.549	.399	.399	.399
5	.271	.538	.391	.391	.391
6	.236	.449	.326	.326	.326

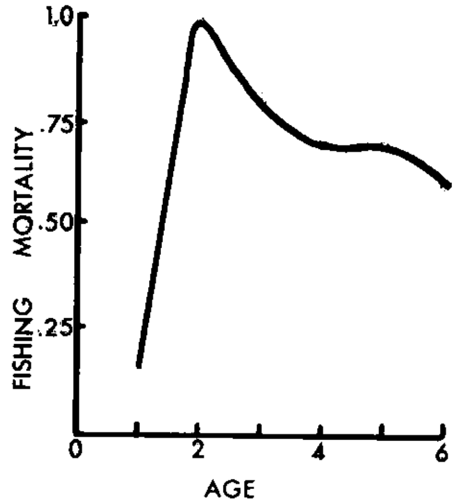

Fig. 1. Partial recruitments (normalized to 1 for fully recruited age classes) used for the 1980 stock assessment of silver hake in ICNAF Divisions 4VWX.

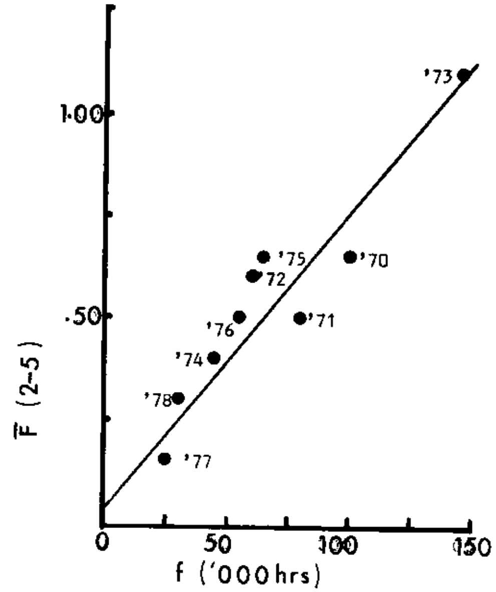

Fig. 2. Fishing mortality (F) for ages 2 to 5 vs effort (f) at an M = 0.4. A GM regression is: $f = -8651 + 141380\ \bar{F}_{(2-5)}$,

$(r^2 = .93,\ n = 9)$.

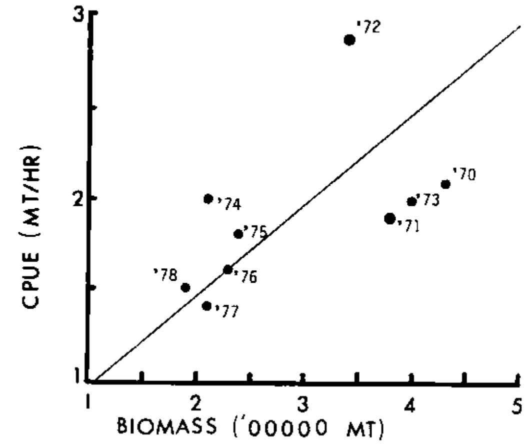

Fig. 3. Catch per unit effort (CPUE) in tons against the fishable biomass of the 2+ age groups.

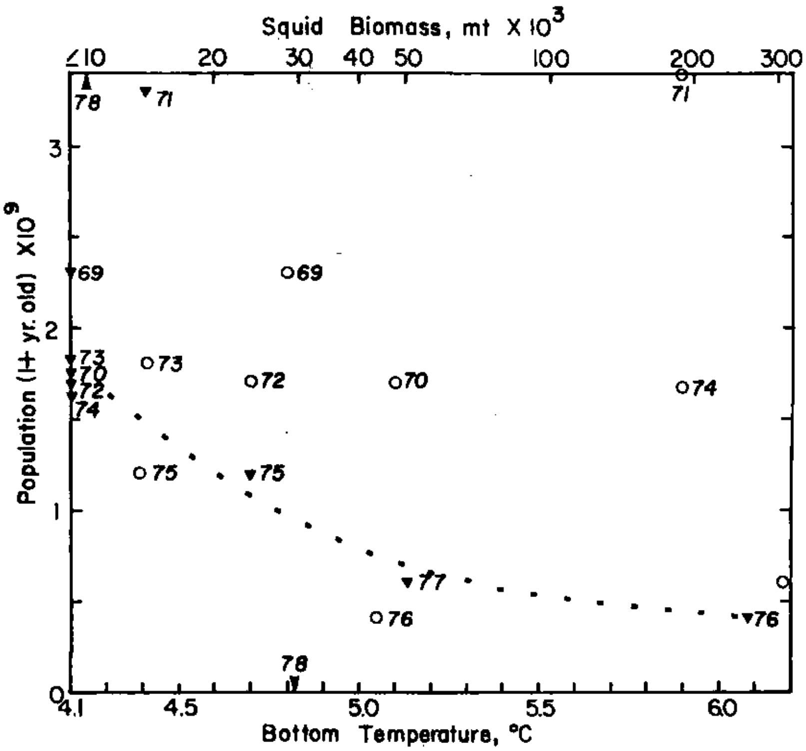

Figure 4. The Scotian Shelf squid biomass (triangles) and Sable Island Bank bottom temperature (circles) plotted against the population numbers at age 1. The dotted line is a curve for squid biomass fitted by eye. The numbers on the graph indicates year class.

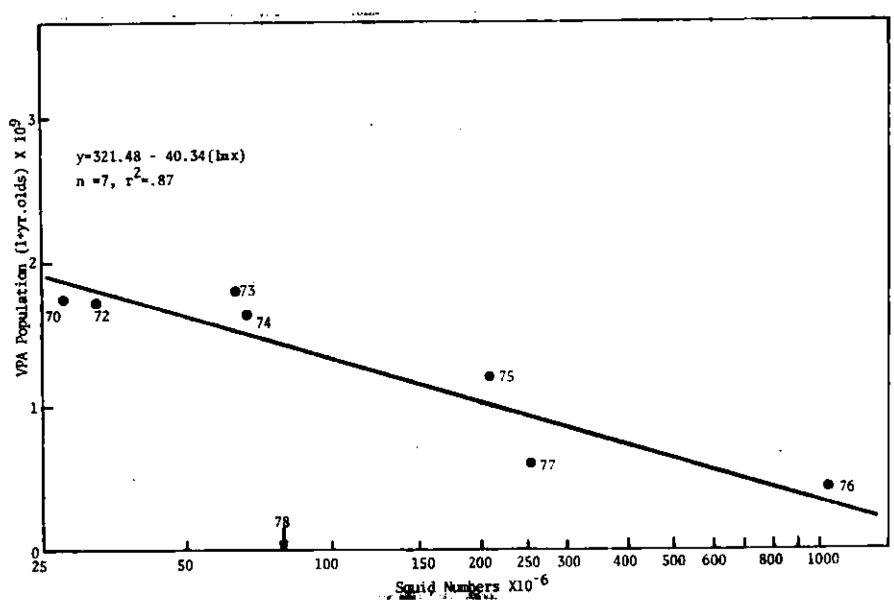

Fig. 5. The Scotian Shelf squid numbers (taken from Canadian R/V summer cruises) plotted against population of silver hake numbers at age 1.