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Updated Assessment of the Eastern Scotian Shelf (4VW) Haddock Stock with Projections to 1981

by

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Abstract

Research vessel surveys of the eastern Scotian Shelf indicate that the resident haddock stock has been increasing in recent years. This increase in biomass estimates has been complimented with only slight increases in landings. The stock assessment for this haddock stock indicates that the 1979 fishing mortality is less than that calculated in previous years. Projection to 1981 indicates increases from 2,000 t TAC in 1979 to a 23,000 t TAC in 1981.

Résumé

Les relevées des navires de recherche sur le plateau néo-écossais oriental indiquent que l'abondance du stock d'aiglefin a augmenté au cours des dernières années. Les débarquements ont toutefois augmenté dans une proportion monidre que les estimations de biomasse. L'évaluation de ce stock suggére que la mortalité par pêche en 1979 est inférieure à celle calculée pour les années antérieures. Les projections indiquent que le TPA va passer de 2,000 t en 1979 à 23,000 t en 1981.

INTRODUCTION

The Scotian Shelf haddock stocks are divided into two groups: the ICNAF Divison 4VW and 4X stocks (McCracken 1963). Between 1960 and 1975, the eastern Scotian Shelf haddock stock (4VW), was exploited primarily by the Canadian, Spanish, and Soviet fleets. Prior to 1965, this stock was fished at levels from 13,000 tons to 34,000 tons averaging 27,000 tons. In 1965 the total fleet reported a large haddock catch of 55,000 tons which was twice that of the pre 1965 average of 27,000 tons (Fig. 1). Canadian catches accounted for 8,700 t of this total, while the USSR caught 43,000 t. After this, the fishery decreased to yearly levels from one-half to one-eighth of those prior to 1965. This decrease continued until 1977 when the catches began an upswing under stringently low TACs.

The Canadian domestic fishery for 4VW haddock was exploited by large trawlers (TC 4 and 5), long-lines, traps, and hand-lines. Those fisheries conducted by the USA, USSR, and Spain, used trawlers ranging in size from TC 4 to 7. Spain used primarily pair trawlers while the USA and USSR employed both side and stern trawlers.

Peak catches by Canada occurred in 4W during late winter and early spring (Figure 2). Both the USSR and Spanish fleets fished during the summer and early fall in 4W and 4VW respectively.

Most foreign catches of haddock were a by-catch to some other species. The USSR haddock catch was almost exclusively a by-catch of the small mesh silver hake fishery with the possible exception of the 1964 to 1966 fisheries. Spanish vessels caught haddock as a by-catch in their cod fishery. The Spanish cod fishery persisted until 1975, while the USSR continues to fish for silver hake today, although within a rather restricted area.

For the years 1963 - 1966, the USSR concentrated its fishery on Middle Ground and the southern tips of Banquereau and Sable Island Banks (Clay 1979). Both Scott (1979) and Hare (1977) indicate that the latter area is one which has a high concentration of haddock.

POSSIBLE IMPACT OF SMALL MESH FISHERIES ON 4VW HADDOCK

Halliday (1971) suggests that the selectivity of the 40 mm nets used in the Soviet silver hake fishery would be similar to that used on Canadian research vessels (32 mm). Data reported to ICNAF suggest that 67% of the 1965 USSR haddock catch was obtained in a directed silver hake fishery. Also, the catch of haddock for the directed silver hake fishery was reported to be 41% of the silver hake catch by weight. Such data suggests that these two fisheries were being conducted simultaneously.

The USSR fishing patterns reported by Clay (1979) indicate that the USSR fished the same areas from 1963 - 1965, yet the by-catch in 1963 and 1964 was well below the 1965 level (3 - 7% compared to 41%). Therefore, it is highly unlikely that the USSR would have equipped its vessels with 114 mm nets in order to direct a fishery toward haddock for only one year. The most plausible scenario would be that the USSR small meshed fishery was capitalizing on the large 1962 and 1963 year-classes of haddock (Table 1).

Further adjustment to reported catches for the USSR were calculated from data collected during the 1977 and 1979 Observer Programs. Comparison of reported by-catch of haddock in the 1977 USSR silver hake fishery (0.1%) to that actually observed (1.0%) demonstrates that the USSR could have under reported its catch by 111 tons (Waldron 1978). Similar results were observed in 1978 and 1979 where it was estimated that the USSR may have under reported its haddock catch by at least 246 and 405 tons (Table 2) (Waldron 1979). These quantities, although small in relation to the total 4VW haddock catch, are nonetheless important since they represent predominantly 1 and 2 year-old haddock (Table 3).

These adjustments are likely to be underestimates of the actual events since the current silver hake fishery has been restricted to an area south of Sable Island. Experiments to evaluate the placement of this line were conducted in both 1977 and 1978. Both the USSR and Cuba suggested the studies would benefit directly by not only removing restriction on where the vessels could fish but also elminating the 1% by-catch regulation for cod and haddock. The results may have been biased with fleet commanders attempting to minimize the amount of by-catch, yet they do demonstrate that by-catches of haddock in a directed silver hake fishery on the Shelf, ranging from between 1.1 and 3.7%, were higher than those observed in areas near the slopes which ranged from .5 to 2% (Waldron 1979). These observations would increase again the total haddock catch in small-meshed fisheries from those estimated.

RESEARCH VESSEL SURVEYS

Random stratified surveys of the Scotian Shelf have been conducted since 1970 during July and August. The estimated 4VW haddock biomass has varied from a low of 9,000 tons to a high of 69,500 tons. Generally there has been an increasing trend since 1974, with 1978 and 1979 estimates being 69,500 tons and 69,400 tons respectively (Fig. 3). The decrease in numbers reported for 1979 is primarily due to the conspicuous absence of the 1978 year-class (Table 4).

The 1979 survey also suggests that the 1979 year-class is the largest in the history of these surveys. Although there are subsequent cruises in 1979, the data are not yet available to corroborate these observations.

EFFORT STANDARDIZATION

The most consistent effort series was that of Maritime-based TC 4 vessels. Directed CPUE and total catch of OTB 1 and 2 from February to June were obtained from ICNAF statistics. Catch per unit of effort for tonnage classes 3 to 5 were standardized to 1966 (Table 5). These indices were weighted to the total OTB catches for that year. The final effort index was obtained by dividing the total catch of all fisheries by the weighted CPUE index.

In some years the Maritimes-based vessels caught less than 30% of the reported catch, both Spain and the USSR reported most catches of haddock as by-catches of either a directed cod or silver hake fishery. In recent years, the offshore catch of haddock has decreased by all gears. The percentage removed by OTB and long-lines has remained fairly consistent, except during the period 1974-1977 when long-lines increased their take. The effort series is affected both by the low percentage of total removals and the fact that the CPUE index is based on only part of the population supporting the fishery i.e. older age groups (see below). Thus it is not likely that this effort series will reflect total effective effort in the fishery.

REMOVALS AT AGE

Historically, there have been three major fishing fleets operating in the 4VW haddock fishery. The Spanish and Canadian fisheries were required by regulations to utilize 114 mm gear until 1974 and 130 mm through to present, while it is speculated that the USSR utilized 40 mm gear (Halliday, 1971). Removals at age for all countries except the USSR were calculated from Canadian commercial age length keys (Table 6).

The high catches of haddock by the USSR in 1965 were unsampled. The only USSR samples reported to ICNAF were from 1966 and consisted of three age, and 14 length frequency, samples. USSR removals for 1960, 1965, 1967, 1969, and 1970-76 were calculated from Canadian research

vessel cruises which used mesh sizes of approximately 35 mm. The years 1961-64 were extrapolated from the 1960 Canadian research vessel cruise, while 1968 used the average of the 1967 and 1969 research cruises. Removals at age for 1977 and 1978 were obtained from Canadian sampling onboard USSR vessels.

Comparison of 1977 Canadian research and observed estimates of Soviet removals at age showed similar results, estimates of both indicating full recruitment at age 2 (Table 7). Age 0 fish caught by the Canadian research vessel were not observed in USSR vessel catches. This should not necessarily be interpreted as implying that the USSR did not catch 0 group fish but, rather, it could represent sampling variation. In order to avoid bias in population estimates, age 0 fish are not included in the cohort analysis. The removals at age matrix used in the cohort analysis (Table 10) is the summation of USSR removals (Table 3), Canadian (Table 6) and for 1979 other countries estimated removals-at-age (Table 8) based on observed and reported data (Table 9) adjusted to USSR removals-at-age.

STOCK ASSESSMENT (Option 1, reported catch).

Partial recruitment - An initial partial recruitment vector was derived from a relationship between commercial fishery removals-at-age and research vessel estimates of population numbers-at-age in 1979. Research vessel numbers at ages 1, 2 and 3 for 1979 were adjusted to compensate for partial recruitment to the survey gear relative to age 4 (Tables 11a to 11b). The resultant numbers-at-age were divided into the commercial numbers-at-age and plotted against age in order to obtain the initial partial recruitment (Table 12). Full recruitment occurred at age 6 and partial recruitments for earlier ages were read from the curve. These were used during the initial runs of the cohorts. A partial recruitment of 0.040 .050 .178 .550 .673 1.0 1.0 1.0 1.0 1.0 1.0 for ages 1-11 was finally utilized as this gives a high correlation ($r = 0.97$) between numbers at age 1 from the cohort and numbers at age 1+2 in research vessel surveys.

Fishing Mortalities - Starting F's were calculated for each year from average Z values after full recruitment. The cohort began with a terminal F of 0.2 derived from an earlier assessment and M of 0.2. Effort calculated from the weighting of commercial CPUE did not give any statistically signifcant relationships with F. With the above partial recruitment and terminal F's, cohort runs were made to find the final F which gave the greatest GM correlation between estimates of age 3+ numbers from the cohort and research vessel surveys (Fig. 4). The best ($r = 0.96$) was obtained with an F of 0.1 (Table 13).

Recruitment - The geometric relationship between age 1, as calculated from the cohort analysis, and age 1 + 2 from research surveys gave an $r = 0.97$ (Fig. 5). The 1962-64 year-classes were the largest in the time period studied (Table 13). However, the assumptions involved in determining removals at age will have resulted in some smoothing over adjacent year-classes. From analogy with haddock stocks to the southwest of 4VW, it is likely that it was the 1963 year-class which was extraordinarily large. The 1962 year-class

was probably also above average strength, but neither it nor the 1964 year-class are likely to have been quite as strong in relation to the 1963 year-class as shown here. The 1965 to 1973 year-classes were extremely poor. However, the 1974-77 year-classes, which are responsible for the recent increase in population abundance are comparable in size to those of 1959-61.

For projection purposes the 1979 year-class size at age 1 was assumed to be equal in size to the geometric mean of age 1 numbers over the years 1970-78 i.e. 14.0 million fish.

YIELD PER RECRUIT

Using mean weights at length obtained from research vessel cruises, with length at age in commercial catch sampling data, and using partial recruitments as derived for 1979, a Thompson-Bell yield analysis was run. This gave a maximum yield per recruit at age 1 of 0.630 kg at a fishing mortality of 0.60. $F_{0.1}$ was 0.31 and gave a yield per recruit of 0.585 kg. (Table 14).

PROJECTION

The projected catch in 1980 at $F_{0.1}$ is 18,500 tons.

Year	Population Age 1+		Catch	
	Numbers ($x10^{-6}$)	Biomass (tons)	Numbers ($x10^{-6}$)	Weight (tons)
1979	121.3	114,000	3.0	4,000
1980	110.5	126,000	12.3	18,500
1981	93.4	123,000	12.7	22,400

Stock Assessment - Option 2 (Increased catch)

Terminal F for option 1 resulted in a vector of F's lower than those calculated for previous years. Although the standard correlations described in Option 1 were maximized the resultant 1979 fishing mortalities were well below those calculated for previous years (table 13). The reason for this apparent dichotomy of high correlations and low terminal F were unexplainable with the data available.

It may be postulated that the low terminal F was the result of correlating the cohort to research vessel surveys which could conceivably be biased upward in most recent years. The low catch in 1979, compared to 1977 and 1978, did not correspond to the increasing biomass estimates from research vessel surveys. However, indications, from both Federal Government fisheries management personnel and contracted observer reports, are that more haddock were caught by Canadian vessels in 4VW than what was reported. As the raising of the reported Canadian catch would increase the terminal F calculated in Option 1, this option is investigated.

Ratios of numbers-at-age from cohort analysis and research vessel surveys, in Option 1, suggested that cohort analysis progressively underestimates older aged haddock.

Ratio Cohort/Research numbers-at-age

Period/Age	1	2	3	4	5	6	7	8	9	10	11
1970-73	1.7	.9	1.0	1.2	1.7	1.2	1.7	1.1	2.7	-	-
1976-79	2.1	1.1	1.0	.6	1.0	.6	.5	.7	-	.3	.3

This underestimating could be caused by a terminal F which is too high or removals in the last year being too low. The latter explanation is favoured for, as has already been pointed out, the Option 1 terminal F is substantially below those calculated for 1977 and 1978.

Removals-at-age

Removals-at-age for 1960-1978 remained the same as those used in Option 1. Removals-at-age for ages 3 and greater, in 1979, were adjusted upwards to reflect a total catch of 10,000 t while ages 1 and 2 removals remained unaltered as follows:

Removals-at-age

Age	1	2	3	4	5	6	7	8	9	10	11
1979 Option 1	1	202	570	1324	651	124	98	7	4	1	1
1979 Option 2	1	202	1425	3310	1628	310	245	18	10	3	3

Partial recruitment

The initial partial recruitment vector calculated in Option 1 was used for Option 2. Fishing mortalities for 1979 were iterated over the years 1975-1978. The highest correlation ($r = 0.98$) between cohort 1 and research survey 1 + 2 (same yearclass) numbers-at-age resulted in the following partial recruitment for ages 1 - 11: 0.005, 0.010, 0.080, 0.290, 0.418, 0.675, 1.000, 0.808, 0.640, 0.510, 1.000. Full recruitment occurs at age 7 as opposed to age 6 in Option 1.

Terminal Fishing Mortality

Several cohort runs were made using the above partial recruitment and various F's ($M = 0.2$). The best AM correlation ($r = 0.95$) between cohort analysis 3+ numbers and research vessel surveys 3+ numbers were obtained with an F of 0.4 (Figure 6, table 17). However, this correlation analysis appears to be insensitive for a range of F's from 0.1 to 0.6. Comparison of the above cohort to research values for terminal F's equal 0.4 and 0.6 suggest that a terminal F of 0.6 results in a closer agreement than does the similar values for a terminal of 0.4. However, the terminal F of 0.4 is favoured because of the overall correlation since 1970.

Recruitment

The geometric relationship between cohort age 1 and research vessel surveys age 1 + 2, with a terminal F of 0.4, gave an r = 0.98 (figure 7). For projection the 1979 year-class size at age 1 was assumed to be equal to the geometric mean of age 1 numbers over the years 1970 - 78 i.e. 15.0 million fish.

Cohort/Research Survey Ratios

Ratios of numbers-at-age from cohort analysis and research vessel surveys were calculated for Option 2. Although there are high correlations between commercial and research vessel data for recruitment and population numbers-at-age the relationship of these ratios for the periods 1970-73 and 1976-79 have not improved in Option 2. The cohort is still overestimating the younger ages. There is no definite explanation for the cohorts response except the Partial Recruitment used could be too low for ages 1 to 4.

Ratio Cohort/Research Vessel numbers-at-age

Period/Age	1	2	3	4	5	6	7	8	9	10	11
1970-73	1.3	.8	1.0	1.1	1.5	1.2	1.4	1.1	2.4	.9	.7
1976-79	4.2	1.5	.7	.4	.4	.5	.3	.4	2.5	.2	.3

Continued analysis of this option is not warranted and until the results of new research vessel surveys become available the results of Option 1 are favoured.

Discussion

Neither of the calculations of stock status given are particularly satisfactory. Option 1 produces an estimate of 1979 terminal F which is unreasonably low. Option 2 corrects this but requires assumption of the 1979 catch at a level substantially higher than that reported. It also produces estimates of recent yearclass sizes which rival the very large yearclasses of 1962-63 in size. While this is not impossible, there are no supportive data.

All these analyses depend heavily on the reliability of research vessel data and weight has been put on the assumption of catchability being independent of stock size. Irrespective of this, however, high survey estimates occur only in the last three years of the data series and any set of input parameters to cohort analysis which result in higher stock sizes in more recent years will produce high correlations between survey and cohort population estimates.

Under the circumstances, the calculations should be taken only as guidelines to management decisions. In the 1950's and early 1960's average catches were about 27,000 t under heavy fishing pressure. The present stock recovery is supported by 4 yearclasses, those of 1974-77, which appear to be at least as strong as the average in the 1950's. However, it is already clear from research vessel surveys that the 1978 yearclass is poor, and possibly extremely poor. Although the 1979 yearclass, from first indications, is good, this requires confirmation from future surveys. It would not be overcautious at this juncture to take the lower estimate of potential yield in 1981 i.e. the 22,000 t given by Option 1, thus allowing a steady expansion of the fishery while data for a refined assessment accumulates.

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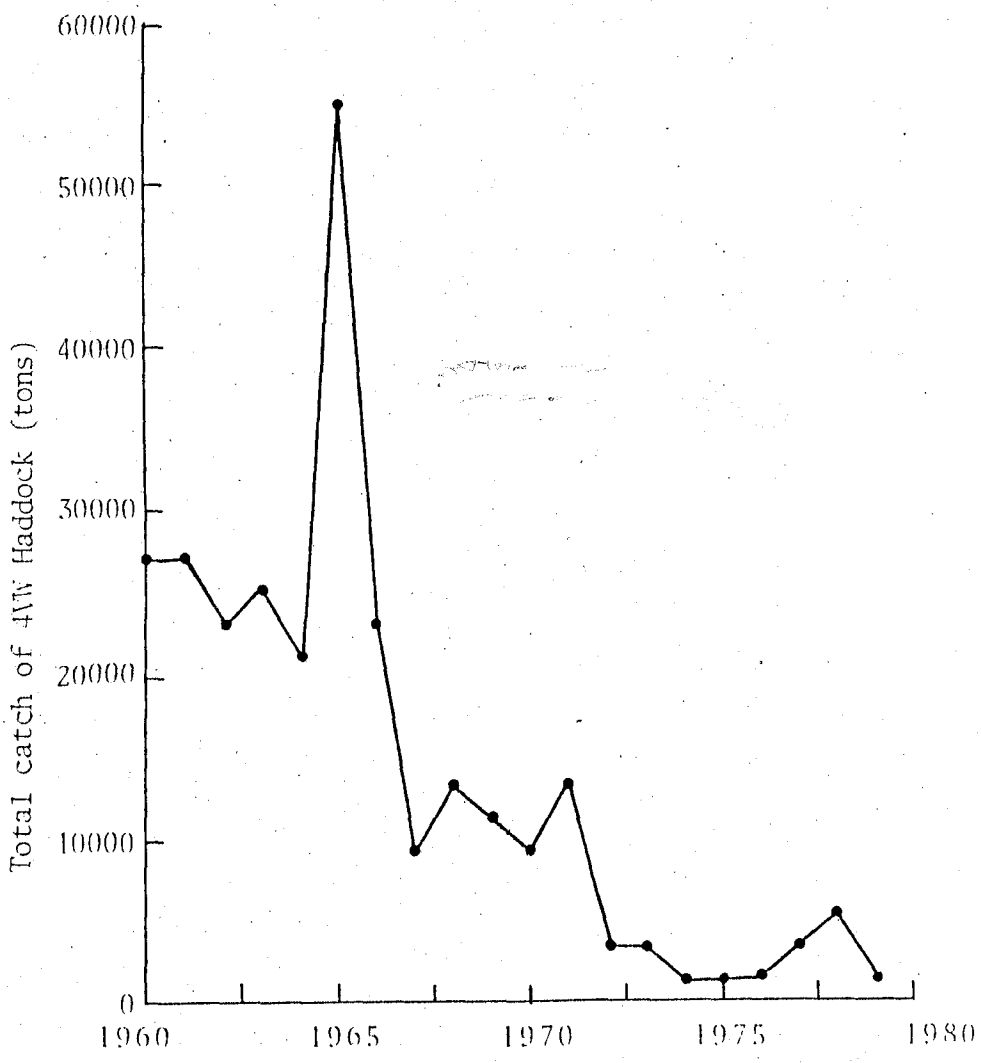

Figure 1. Plot of nominal catches of Div 4VW Haddock (tons). Nominal catches for 1978 and 1979 are preliminary.

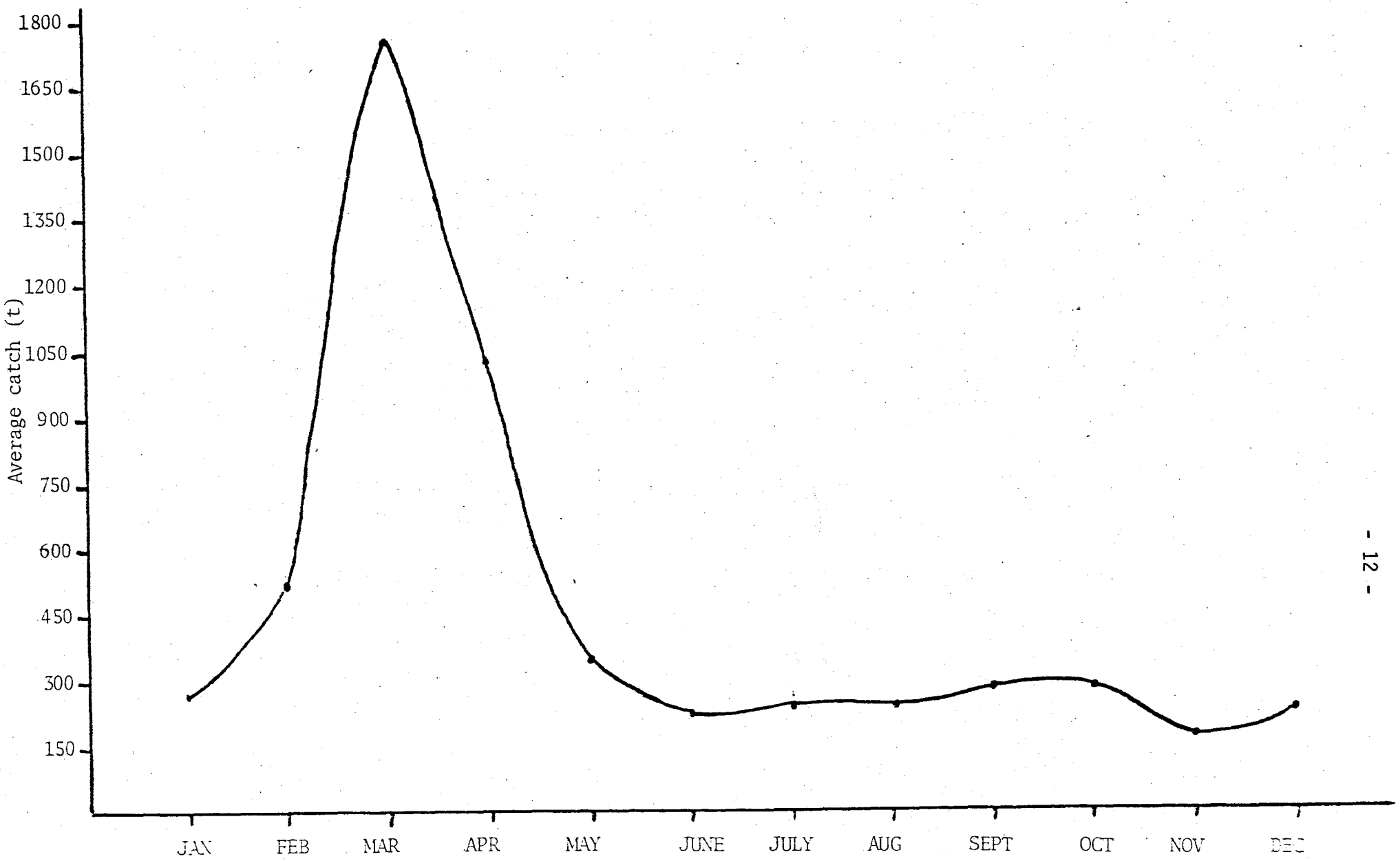

Fig:2 Average Monthly Catch of 4VW Haddock (1969-78) by Canada.

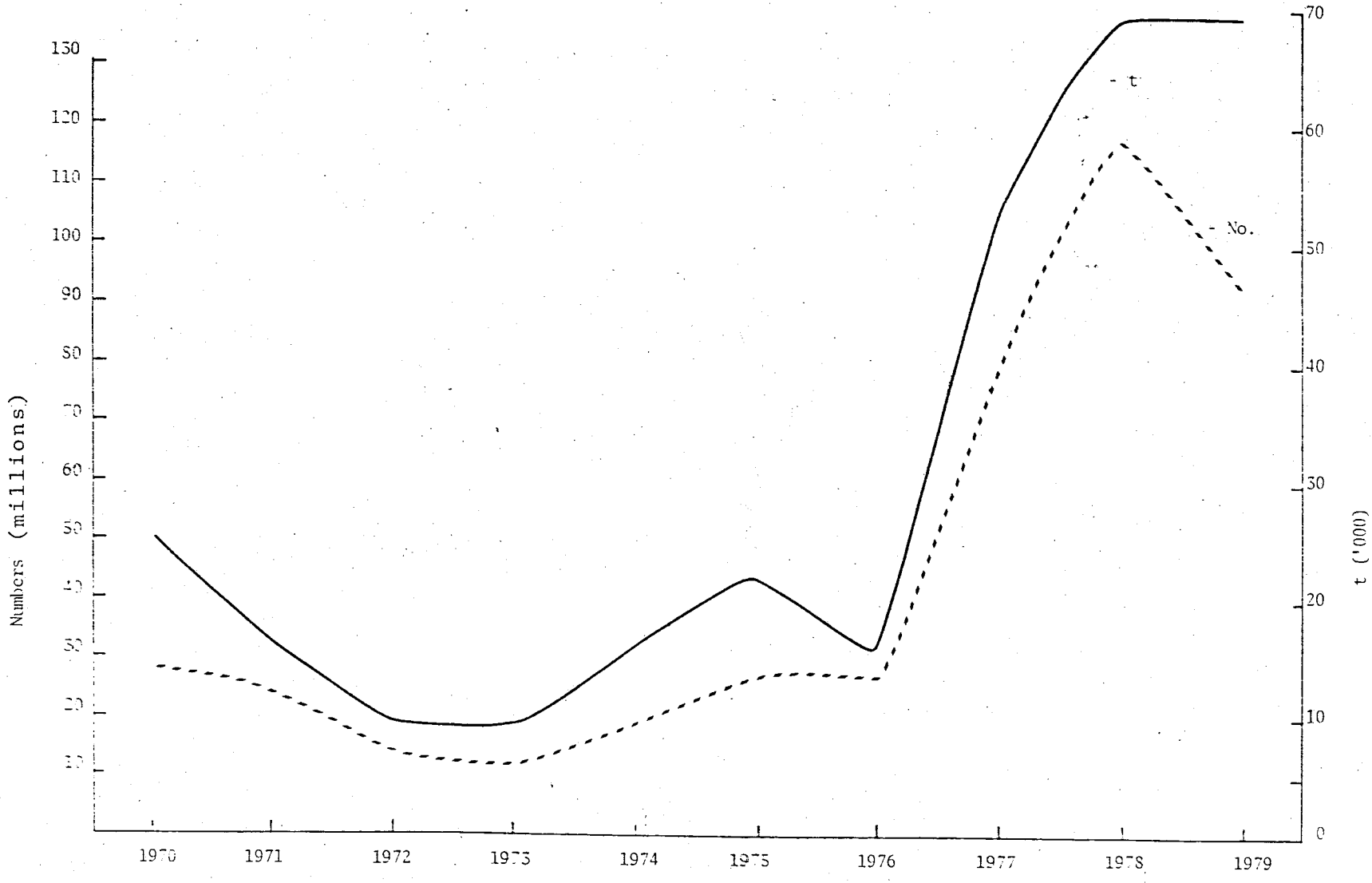

Figure 3. Research vessel estimate numbers and biomass (t) for 4VW Haddock.

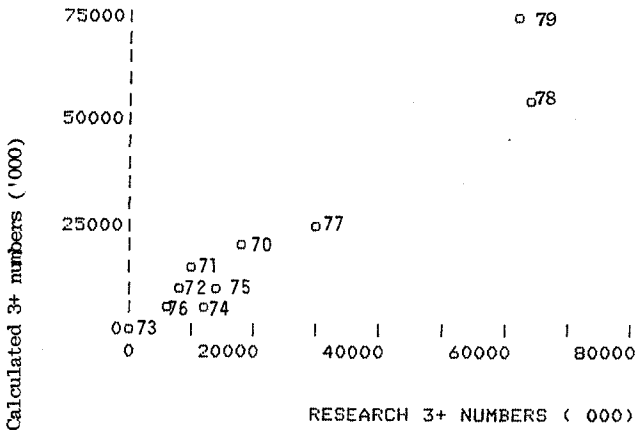

FIG. 4: CALCULATED 3+ NUMBERS ('000) AGAINST RESEARCH 3+ NUMBERS ('000) FOR THE 4VW HADDOCK STOCK. (R = 0.96)

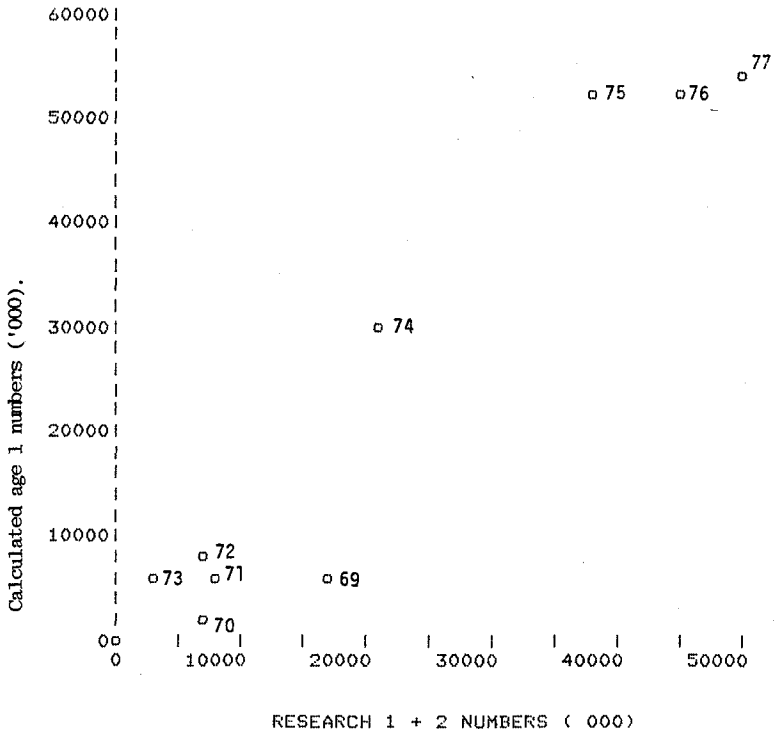

FIG. 5 CALCULATED AGE 1 NUMBERS ('000) AGAINST RESEARCH 1 + 2 NUMBERS ('000) FOR THE 4VW HADDOCK STOCK. (R = 0.97)

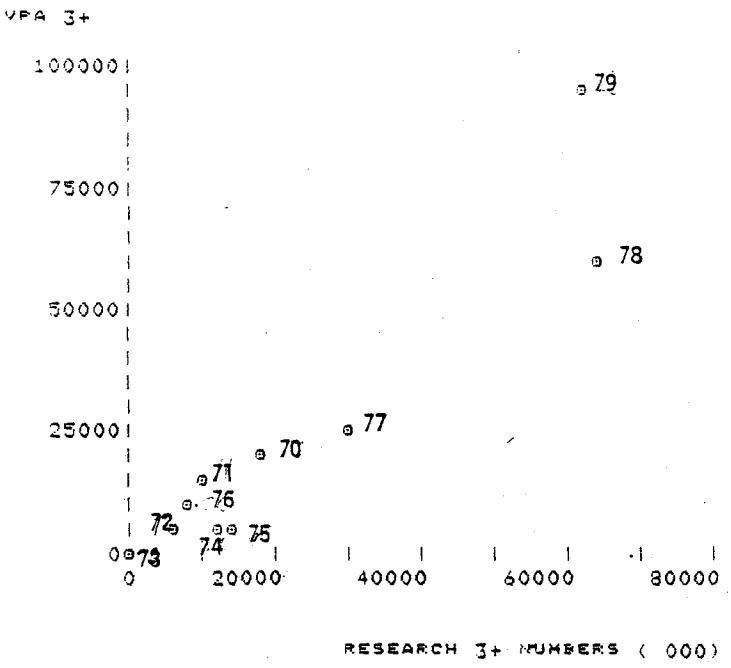

FIG. 6 ; CALCULATED 3+ NUMBERS (000) AGAINST RESEARCH 3+ NUMBERS (000) FOR THE 4VW HADDOCK STOCK, (R = 0.95)

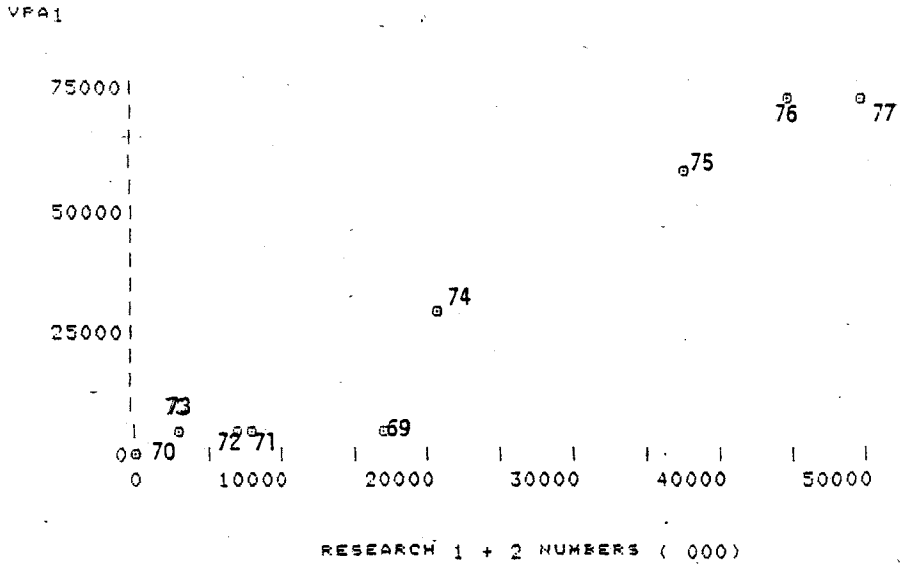

FIG. 7 ; CALCULATED AGE 1 NUMBERS (000) AGAINST RESEARCH 1 + 2 NUMBERS (000) FOR THE 4VW HADDOCK STOCK, (R = 0.98

TABLE 1 USSR DIRECTED S. HAKE FISHERY (4VW) AND ASSOCIATED BYCATCHES (mt)

YEAR / MONTH	1960			1961			1962			1963			1964			1965		
	S.Hake	Haddock	Cod	S.Hake	Haddock	Cod	S.Hake	Haddock	Cod	S.Hake	Haddock	Cod	S.Hake	Haddock	Cod	S.Hake	Haddock	Cod
January										7884	9	683	160	16	103			
February										4101		4	180	7	255			
March										5860		1630	1207	177	706	18		
April							837	102	256	6763		1182	3	-	3			
May										38839	294	1256	29009	99	479	15577	148	507
June							1		1	23946	434	1292	678	10	293	511	74	80
July										2			13235	424	1317	14227	10997	593
August										13040	246	619	19531	3018	3009	2048	2558	1030
September										12564	493	891						
October										1750	1655	1021	1			27		
November							4595	306	-	2403	602	858	67		3			
December							4678	232	-	2764	-	165	23			650	165	
Total Rpt Dir (other)							9273	640	257	119935	3733	9601	64094	4256	6968	33658	13942	2107
Total Reported				151		113	8825	2567	2383	116388	3301	9505	62905	4391	7133	49644	42876	7896
Yearly Ratio							1.000	0.073	0.029	1.000	.032	.082	1.000	0.068	0.111	1.000	0.412	0.062

[2] Clay, 1979

YEAR / MONTH	1966			1967			1968			1969			1970			1971		
	S.Hake	Haddock	Cod	S.Hake	Haddock	Cod	S.Hake	Haddock	Cod	S.Hake	Haddock	Cod	S.Hake	Haddock	Cod	S.Hake	Haddock	Cod
January										459	26	33				3		
February										860	5	43	41			3246	26	51
March										1363	76	44	4326	38	155	30817		
April										9079	7	108	16546		605	19363	66	299
May				58	12		626	67	222	5035	5	55	17820	52	446	6746	68	423
June				1746	13	917							17473	122	165	9186	64	1096
July				20						5235	51	399	34601	177	673	22118	18	435
August				10						12299	15	221	43165	99	58	21101	8	261
September										6992	45	1254	18787	137	115	8174	21	174
October							972		389	1631	-	401	6129	45	142	1057	6	52
November										1747	5	61	4115		43	581	2	88
December													1010		110			
Total Rpt Dir.				1834	25	917	1598	67	611	44709	235	2619	164013	679	2513	122413	279	2909
USSR Total Reported	3660	10501	6016	1834	554	1077	3305	254	4065	44769	235	2783	164013	679	2521	122445	475	4506
Ratio				1.00	.014	.500	1.000	.042	0.382	1.000	.005	.059	1.000	.001	.015	1.000	.002	.024

TABLE 1. USSR DIRECTED SILVER HAKE FISHERY (4VW) AND ASSOCIATED BYCATCHES (mt)

YEAR / MONTH	1972			1973			1974			1975			1976			1977		
	S.Hake	Haddock	Cod	S.Hake	Haddock	Cod	S.Hake	Haddock	Cod	S.Hake	Haddock	Cod	S.Hake	Haddock	Cod	S.Hake	Haddock	Cod
January							1039	-	-	2381	-	108	982	11	75			
February				104	-	-				83	-	-	1146	-	88			
March	7166	28	247	11264	37	42	6963	-	40	2565	1	63	14644	1	177	37		
April	11445	-	39	69254	-	52	8562	3	249	12501	4	245	9579	-	137	4840	6	10
May	19675	-	494	71540	20	290	11967	22	1128	12120	9	517	4952	-	360	3721	2	12
June	16336	-	796	40103	17	1079	12617	15	470	5978	3	445				1820	2	
July	24043	35	971	38789	-	464	10114	6	311	23789	27	166	12719	-	62	8723		17
August	14610	38	339	13116	2	321	9883	29	347	18260	8	146	6088	6	-	14		
September	11481	1	136	8314	-	126	2072	-	-	17621	-	113	5058	-	19	695		
October	3213	-	156	5394	-	171	3628	1	47				6533	-	4	112		
November				1060	-	4	4699	-	140				3480	-	12	183	1	
December				7945	-	15	9637	15	97				4873	-	38			
Total	107969	102	3178	266883	76	2564	81181	91	2829	95298	52	1803	70054	18	972	20145	10	39
USSR Total Reported	108657	106	4646	268511	76	2918	87497	132	3099	96853	52	3642	74823	24	1018	27351	14	97
Ratio	1.000	.001	.029	1.000	.0003	.010	1.000	.002	.035	1.000	.001	.031	1.000	.0003	.014	1.000	.0005	.0020

Table 2. Adjusted USSR haddock catches (t) in ICNAF division 4VW based upon observed data in 1977 and 1978.

	1	2	3	4	5	6
Year	Directed Catch of S.Hake by USSR (4VW)	Reported Catch of Haddock in Directed S.Hake Fishery by USSR	Reported Total Catch of Haddock by USSR	Estimated USSR Haddock Catch in Directed S.Hake Fishery	Difference Between Reported and Estimated	Adjusted Haddock Cat for USSR
					(4-2)	(3+5)
1971	122413	279	475	918	639	1114
1972	107969	102	106	810	708	814
1973	268511	76	76	2014	1938	2014
1974	81181	91	132	609	518	650
1975	95298	52	52	715	663	715
1976	70054	18	24	525	507	531
1977	20145	10	14	121	111	125
1978	41915 [2]	-	131	377	-	377
1979	44444.3[3]	-	148	400	-	400
1979[4]	44940	-	72[5]	405	-	405

[1] Adjusted Haddock Catch = [Total Reported Haddock - Haddock Catch in S.Hake] + Estimated Haddock Catch.

[2] Report of directed fisheries not available from ICNAF to date. Estimated from Observer Programme.

[3] Reported to Canada and entered into the FLASH system.

[4] Reported in NAFO Circular Letter 80/9 - February 12, 1980

[5] Excludes 4W + 4X.

Table 3. Removals ('000) at age for USSR commercial catches of 4VW Haddock.

AGE	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
1	0	67	1133	1456	1937	45318	1869	123	42	47	231	179	453	290	26	318	348	36	105	1
2	0	16	271	348	463	40548	2089	80	41	63	84	409	95	1016	216	36	238	60	178	156
3	0	190	3229	4151	5522	31075	9735	172	72	95	155	133	271	272	293	132	40	51	150	169
4	0	136	2308	2967	3947	8527	4102	234	69	63	119	177	169	252	51	118	98	24	69	176
5	0	34	580	745	991	2076	1597	227	55	35	54	68	158	105	54	29	103	7	21	50
6	0	10	175	225	299	2562	548	68	35	54	39	36	86	209	27	52	22	11	34	6
7	0	3	49	63	83	854	120	20	18	34	51	16	46	35	19	14	25	2	6	5
8	0	5	80	103	137	105	0	45	11	7	14	26	26	53	6	6	5	1	2	2
9	0	1	12	15	20	210	0	12	6	10	7	1	15	17	5	3	2	1	3	10
10	0	1	10	13	17	39	0	15	4	2	0	0	7	19	2	3	2	0	0	0
11	0	5	93	119	159	53	0	10	2	1	2	0	0	0	3	0	2	1	3	0

Table 4. Haddock numbers-at-age ('000) from research vessel surveys in 4VW.

Age	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
0	273	161	40	0	594	192	780	645	0	3874
1	7100	4489	3435	1508	944	12025	8547	15666	25779	229
2	2640	9451	2321	4978	5587	1700	9400	29656	28842	23780
3	4788	3117	3378	1490	7556	4991	1322	23396	38613	25874
4	5325	4104	1524	1401	1369	4463	2569	3176	21592	26879
5	2548	1633	1271	514	1409	1170	2465	950	1372	7538
6	1632	925	955	1023	702	2135	542	1879	1234	969
7	1817	426	392	214	523	557	592	531	323	752
8	924	663	186	251	208	226	151	306	39	256
9	388	30	111	81	118	117	41	0	0	0
10	86	0	49	119	86	134	40	179	29	98
11	98	0	0	0	101	0	41	23	36	47

Table 5. Adjusted CPUE index for OTB TC 3→5 for the 4VW haddock stock (CPUE directed) adjusted to 1966.

YEAR	TC3		TC4		TC5		TOTAL OTB CATCH	WTD CPUE INDEX	GRAND TOTAL CATCH	EFFORT INDEX (HRS)
	CPUE	MT	CPUE	MT	CPUE	MT				
1960	0.6051	767	1.2213	10259			11301	1.1497	27795	24175
1961	2.220	1704	1.4773	14017			16108	1.5204	27196	17887
1962	1.2864	737	0.9398	10003			10792	0.9589	24822	25885
1963	1.4687	598	1.1358	6245			7070	1.1275	25507	22622
1964	0.6300	246	0.9925	5826			6094	0.9743	22778	23378
1965	1.000	299	1.5821	3710		251	4274	1.3733	55070	40100
1966	1.000	357	1.000	7283	1.000	358	8000	0.9997	23421	23428
1967	1.2330	42	1.3174	4649	1.2607	779	5475	1.3075	10747	8219
1968		8	0.8685	4584	0.6365	1666	6261	0.8052	13377	16613
1969			0.7633	3431	0.6289	3367	6798	0.6967	11169	16031
1970	1.2424	120	0.4823	2083	0.4820	1398	3601	0.5075	9820	19350
1971	0.4372	97	0.6541	3592	0.5696	690	4379	0.6360	13672	21497
1972	0.3957	25	0.4688	678	0.3301	978	1681	0.3870	4821	12457
1973			0.4264	1253	0.3502	981	2235	0.3928	6373	16225
1974	1.8456	60	0.1841	153	0.2531	68	281	0.5583	2913	5218
1975	0.3293	19	0.4225	176	0.3987	161	354	0.4091	2583	6314
1976	0.2214	4	0.6135	139	0.1793	92	235	0.4368	2034	4657
1977	0.5202	3	0.4245	166	0.3586	297	438	0.4076	3380	8292
1978	1.9037	28	1.5705	827	0.8090	1343	2198	1.1095	6222	5608

TABLE 6: REMOVALS AT AGE ('000) FOR CANADIAN CATCHES OF 4VW HADDOCK.

AGE	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	16	2	168	102	0	0	1	21	5	32	0	0	246	67	4	11
3	125	43	213	30	185	343	899	578	253	289	288	453	176	167	331	187	84	781	415	363
4	2848	2939	977	1483	485	1227	4097	1532	1255	1020	950	1313	336	798	107	454	97	339	1363	1108
5	5106	6289	5004	1327	2894	1100	2342	1943	1965	1525	832	1822	461	533	215	189	150	423	278	590
6	2556	3492	4159	3443	1091	1753	678	853	1730	1434	849	799	343	351	173	88	118	190	465	117
7	1986	1103	1257	1712	1718	539	1168	335	549	699	717	631	179	205	52	35	97	64	137	92
8	1754	868	572	448	939	633	306	463	267	208	224	792	98	74	21	17	22	37	40	5
9	411	701	227	111	237	287	212	162	294	97	46	193	86	31	2	3	4	11	16	3
10	172	179	146	30	50	55	68	131	86	86	22	26	4	56	6	0	6	7	6	1
11	178	57	35	11	31	37	9	42	53	28	8	14	11	1	5	1	5	5	2	1

Table 7. Removals at age ('000) for USSR catches in 1977 estimated by using observed samples and Canadian research.

	Canadian Research		USSR Sampled	
Age	No.	%	No.	%
0	1	0.51	0	-
1	36	18.46	34	19.54
2	60	30.77	68	39.08
3	51	26.15	54	31.03
4	24	12.31	6	3.45
5	7	3.59	8	4.60
6	11	5.64	3	1.72
7	2	1.03	1	0.57
8	1	0.51		
9	1	0.51		
10	0	-		
11	1	0.51		
11+	-	-		
TOTALS	195	100.00	174	100.00

Table 8. Removals-at-age ('000) - 1979 Revised

	CANADA OTB		CANADA L. L.		CANADA TOTAL		USSR		Other[2] Countries	Total All Countries	
AGE	Jan 80	Apr 80	Jan 80	Apr 80	Jan 80	Apr 80	Jan 80	Apr 80	Apr 80	Jan 80	Apr 80
0	-	-	-	-	-	-	25	25	6	27	31
1	-	-	-	-	-	-	1	1	0	1	1
2	5	7	3	3	8	11	154	156	35	172	202
3	162	237	105	112	267	363	167	169	38	462	570
4	446	653	369	395	815	1108	174	176	40	1053	1324
5	192	281	242	259	434	590	49	50	11	14	651
6	37	54	49	52	86	117	6	6	1	98	124
7	24	35	44	47	68	92	5	5	1	78	98
8	1	1	3	3	4	5	2	2	0	6	7
9	1	1	1	1	2	3	1	1	0	3	4
10	1	1	-	-	1	1	-	-	-	1	1
11	1	1	-	-	1	1	-	-	-	1	1
11+	1	1	-	-	1	1	-	-	-	1	1
TOTAL	871	1276	816	872	1687	2292	584	591	132	2418	3015
Catch (t)	1184	1733[1]	1152	1232	2336	3176	400	405	91	2913	3672

[1] Includes 91 t from Nfld. + 1642 t from Maritimes.

[2] Includes countries fishing in 4VW. REmovals based upon USSR removals.

Table 9. Estimated 4VW Haddock catches during the 1979 Scotian Shelf foreign fisheries

Country	Species	1979 RPT[1] catch (t) in 4VWX	Estimated catch in 4VW from Observer Prog. (%)	(t)	Ratio Haddock to directed fishery 4VW		Estimated catch (t) of Haddock in 4VW
Bulgaria	S. Hake Squid	7629	99	7553	.006		45.000
Cuba	Argentine S. hake Squid	5667[2]	100	5667	.004		22.000
FRG	Squid	1240	100	1240	.000[3]		.002
France	Squid	1926	100	1926	.000[3]		.267
Ireland	Squid	655	100	655	-		-
Italy	Squid	1326	100	1326	.000[3]		.002
Japan	Argentine Squid	6443	>99	6439	.004		23.000
Poland	Squid	9827	100	9827	.000[3]		.129
Portugal	Squid	1841	100	1841	-		-
Romania	Squid	830	100	830	-		-
Spain	Squid	4436	100	4436	.000[3]		.073
						TOTAL	90.473

[1] Reported to FLASH

[2] No reported catch for Argentine - observed Argentine was 0.2 t

[3] Less than .000

TABLE 10 REMOVALS AT AGE ('000) FOR THE 4VW HADDOCK STOCK.

AGE	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
1	0	67	1133	1456	1937	45318	1869	123	42	47	231	179	453	290	26	318	348	36	105	1
2	0	16	271	348	479	40550	2257	182	41	63	85	430	100	1048	216	36	484	127	182	202
3	125	233	3442	4181	5707	31418	10634	750	325	384	443	586	447	439	624	319	124	832	565	570
4	2848	3075	3285	4450	4432	9754	8199	1766	1324	1083	1069	1490	505	1050	158	572	195	363	1432	1324
5	5106	6323	5584	2072	3885	3176	3939	2170	2020	1560	886	1890	619	638	269	218	253	430	299	651
6	2556	3502	4334	3668	1390	4315	1226	921	1765	1488	888	835	429	560	200	140	140	201	499	124
7	1986	1106	1306	1775	1801	1393	1288	355	567	733	768	647	225	240	71	49	122	66	143	98
8	1754	873	652	551	1076	738	306	508	278	215	238	818	124	127	27	23	27	38	42	7
9	411	702	239	126	257	497	212	174	300	107	53	194	101	48	7	6	6	12	19	4
10	172	180	156	43	67	94	68	146	90	88	22	26	11	75	8	3	8	7	6	1
11	178	62	128	130	190	90	9	52	55	29	10	14	11	1	8	1	7	6	5	1

Table 11a. Adjustment of survey estimates numbers at age ('000) at M = 0.2 for ages 1 to 3 to compensate for partial recruitment relative to age 4.

Survey Year	YEAR CLASS			
	1978	1977	1976	1975
1979	407	33364	23912	26879
1978		45834	40466	
1977			27854	
Average	407	39599	30744	26879
Ratio to Age 4	0.015	1.473	1.144	1.000

Table 11b. 1979 research survey numbers at age ('000) prior and after adjustment to compensate for partial recruitment at age 4.

AGE	1	2	3	4
Original #'s	229	23780	25874	26879
Adjusted #'s	407	39599	30744	26879

Table 12. Initial and Final Partial recruitments and mean weights at age.

AGE	1	2	3	4	5	6	7	8	9	10	11
Initial Par. Rec.	.040	.069	.178	.386	.673	1	1	1	1	1	1
Final Par. Rec.	.040	.050	.178	.550	.673	1	1	1	1	1	1
Mean wt. at age (kg)	.103	.590	.820	1.220	1.690	2.150	2.660	3.020	3.630	3.900	3.61

Table 13. Population numbers ('000) and fishing mortalities at M = 0.2

POPULATION NUMBERS

	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
1	46602	31190	46904	86108	95065	66807	11285	10104	7582	4812	5561	2991	6175	7854	5650	29900	51181	52863	54691	276
2	20329	38155	25476	37376	69182	76080	13692	7548	8161	6170	3897	4344	2287	4646	6168	4602	24192	41589	43248	44682
3	29501	16644	31224	20612	30286	56208	25598	9167	6015	6645	4994	3114	3168	1782	2856	4854	3735	19369	33935	35244
4	27313	24040	13416	22450	13093	19632	17591	11336	6827	4631	5093	3688	2019	2189	1062	1773	3686	2946	15105	27272
5	14615	19785	16900	8012	14354	6709	7248	6983	7683	4391	2811	3202	1671	1196	842	726	934	2841	2084	11071
6	6265	7346	10477	8784	4684	8237	2619	2370	3754	4463	2184	1500	912	808	402	446	397	536	1937	1435
7	4876	2817	2845	4656	3873	2578	2839	1035	1107	1477	2307	985	473	358	155	148	239	199	257	1134
8	3733	2195	1306	1148	2206	1541	850	1159	526	393	546	1194	221	183	76	63	77	85	103	81
9	1151	1469	1007	479	441	833	594	419	489	179	127	231	238	68	35	38	31	39	35	46
10	358	570	568	608	278	129	232	294	186	129	50	56	14	103	13	22	26	20	21	12
11	418	138	304	323	459	167	20	128	109	71	26	21	23	1	17	3	16	14	10	12
	155161	144348	150426	190557	233922	238921	82568	50545	42440	33360	27597	21327	17200	19190	17274	42576	84513	120499	151425	121266

FISHING MORTALITY

	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
1	0.000	0.002	0.027	0.019	0.023	1.385	0.202	0.014	0.006	0.011	0.047	0.068	0.085	0.042	0.005	0.012	0.008	0.001	0.002	0.004
2	0.000	0.000	0.012	0.010	0.008	0.889	0.201	0.027	0.006	0.011	0.024	0.116	0.050	0.287	0.039	0.009	0.022	0.003	0.005	0.005
3	0.005	0.016	0.130	0.254	0.234	0.962	0.615	0.095	0.062	0.066	0.103	0.233	0.170	0.318	0.276	0.075	0.037	0.049	0.019	0.018
4	0.122	0.152	0.316	0.247	0.469	0.796	0.724	0.189	0.241	0.299	0.264	0.591	0.324	0.755	0.180	0.441	0.060	0.146	0.111	0.055
5	0.488	0.436	0.454	0.337	0.355	0.741	0.918	0.421	0.343	0.499	0.428	1.056	0.526	0.890	0.435	0.403	0.356	0.183	0.173	0.067
6	0.599	0.748	0.611	0.619	0.397	0.865	0.728	0.561	0.733	0.460	0.597	0.955	0.734	1.451	0.798	0.426	0.493	0.535	0.335	0.100
7	0.598	0.569	0.708	0.547	0.721	0.909	0.696	0.476	0.835	0.795	0.459	1.296	0.747	1.348	0.705	0.455	0.833	0.457	0.954	0.100
8	0.733	0.579	0.803	0.756	0.774	0.753	0.507	0.662	0.876	0.927	0.658	1.415	0.970	1.451	0.497	0.519	0.490	0.682	0.599	0.100
9	0.502	0.751	0.304	0.344	1.032	1.078	0.502	0.614	1.132	1.076	0.615	2.611	0.635	1.492	0.249	0.192	0.245	0.421	0.910	0.100
10	0.756	0.429	0.362	0.081	0.310	1.645	0.391	0.794	0.768	1.399	0.665	0.712	2.070	1.630	1.208	0.160	0.423	0.502	0.385	0.100
11	0.626	0.675	0.616	0.578	0.601	0.882	0.659	0.584	0.797	0.597	0.543	1.266	0.754	1.388	0.749	0.439	0.669	0.647	0.823	0.100
	0.136	0.156	0.184	0.130	0.120	1.033	0.543	0.187	0.228	0.244	0.227	0.566	0.241	0.372	0.123	0.050	0.025	0.021	0.026	0.028

Table 14. Yield per recruit for the 4VW Haddock (M = 0.20, partial recruitment and wt. at age as in Table 10.

	FISHING MORTALITY	CATCH (NUMBER)	YIELD (KG)	AVG. WEIGHT (KG)	YIELD PER UNIT EFFORT
	0.050	0.08834	0.198	2.246	1.000
	0.100	0.15651	0.337	2.153	0.849
	0.150	0.20992	0.434	2.065	0.728
	0.200	0.25244	0.501	1.983	0.631
	0.250	0.28684	0.547	1.906	0.551
	0.300	0.31513	0.578	1.835	0.486
F0.1---	0.313	0.32175	0.585	1.817	0.471
	0.350	0.33877	0.599	1.769	0.432
	0.400	0.35883	0.613	1.709	0.386
	0.450	0.37611	0.622	1.653	0.348
	0.500	0.39119	0.627	1.602	0.316
	0.550	0.40451	0.629	1.555	0.288
FMAX---	0.595	0.41531	0.630	1.516	0.267
	0.600	0.41640	0.630	1.512	0.264
	0.650	0.42713	0.629	1.472	0.244
	0.700	0.43688	0.627	1.435	0.226
	0.750	0.44582	0.625	1.402	0.210
	0.800	0.45406	0.622	1.370	0.196
	0.850	0.46171	0.619	1.341	0.184
	0.900	0.46884	0.616	1.314	0.172
	0.950	0.47552	0.613	1.288	0.163
	1.000	0.48180	0.609	1.265	0.154

Table 15. 4VW Haddock population numbers ('000) using terminal F = 0.4 and M = 0.3. Option 2.

POPULATION NUMBERS

	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
1	46602	31190	46904	86108	95065	66807	11285	10104	7582	4788	5581	3003	6129	6792	5663	31195	62355	73612	73245	474
2	20329	38155	25476	37376	69182	76080	13692	7548	8161	6170	3877	4361	2297	4608	5298	4613	25253	50737	60236	59873
3	29501	16644	31224	20612	30286	56208	25598	9167	6015	6645	4994	3098	3181	1790	2824	4142	3744	20237	41425	49152
4	27313	24040	13416	22450	13093	19632	17591	11336	6827	4631	5093	3688	2006	2200	1068	1748	3103	2954	15816	33405
5	14615	19785	16900	8012	14354	6709	7248	6983	7683	4391	2811	3202	1671	1185	851	732	913	2364	2090	11653
6	6265	7346	10477	8784	4684	8237	2619	2370	3754	4463	2184	1500	912	808	393	453	402	519	1546	1440
7	4876	2817	2845	4656	3873	2578	2839	1035	1107	1477.	2307	985	473	358	155	141	245	202	243	815
8	3733	2195	1306	1148.	2206	1541	850	1159	526	393	546	1194	221	183	76	63	71	90	106	70
9	1151	1469	1007	479	441	833	594	419	489	179	127	231	238	68	35	38	31	34	39	49
10	358	570	568	608	278	129	232	294	186	129	50	56	14	103	13	22	26	20	17	15
11	418	138	304	323	459	167	20	128	109	71	26	21	23	1	17	3	16	14	10	8
	155161	144348	150426	190557	233922	238921	82568	50545	42440	33336	27598	21340	17163	18098	16394	43151	96158	150782	194772	156953

Table 16. 4VW Haddock fishing mortalities at terminal F = 0.4 and M = 0.2. Option 2.

FISHING MORTALITY

	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
1	0.000	0.002	0.027	0.019	0.023	1.385	0.202	0.014	0.006	0.011	0.047	0.068	0.085	0.048	0.005	0.011	0.006	0.001	0.002	0.002
2	0.000	0.000	0.012	0.010	0.008	0.889	0.201	0.027	0.006	0.011	0.025	0.115	0.049	0.289	0.046	0.009	0.021	0.003	0.003	0.004
3	0.005	0.016	0.130	0.254	0.234	0.962	0.615	0.095	0.062	0.066	0.103	0.235	0.169	0.316	0.280	0.089	0.037	0.047	0.015	0.032
4	0.122	0.152	0.316	0.247	0.469	0.796	0.724	0.189	0.241	0.299	0.264	0.591	0.326	0.750	0.178	0.449	0.072	0.146	0.105	0.116
5	0.488	0.436	0.454	0.337	0.355	0.741	0.918	0.421	0.343	0.499	0.428	1.056	0.526	0.903	0.430	0.399	0.365	0.224	0.172	0.167
6	0.599	0.748	0.611	0.619	0.397	0.865	0.728	0.561	0.733	0.460	0.597	0.955	0.734	1.451	0.826	0.417	0.486	0.559	0.441	0.270
7	0.598	0.569	0.708	0.547	0.721	0.909	0.696	0.476	0.835	0.795	0.459	1.296	0.747	1.348	0.705	0.485	0.801	0.447	1.051	0.400
8	0.733	0.579	0.803	0.756	0.774	0.753	0.507	0.662	0.876	0.927	0.658	1.415	0.970	1.451	0.497	0.519	0.544	0.630	0.577	0.323
9	0.502	0.751	0.304	0.344	1.032	1.078	0.502	0.614	1.132	1.076	0.615	2.611	0.635	1.492	0.249	0.192	0.245	0.499	0.767	0.256
10	0.756	0.429	0.362	0.081	0.310	1.645	0.391	0.794	0.768	1.399	0.665	0.712	2.070	1.630	1.208	0.160	0.423	0.502	0.503	0.204
11	0.626	0.675	0.616	0.578	0.601	0.882	0.659	0.584	0.797	0.597	0.543	1.266	0.754	1.388	0.749	0.439	0.669	0.647	0.823	0.400
	0.136	0.156	0.184	0.130	0.120	1.033	0.543	0.187	0.228	0.244	0.227	0.565	0.241	0.395	0.130	0.050	0.022	0.017	0.021	0.053

Table 17. Comparison of age 3 F numbers from cohort analyses using various terminal F's compared to age 3+ research vessel survey numbers of the 4VW Haddock stock (nos. x 10^{-3}).

1979 3+ numbers	0.1	0.2	0.4	0.6	0.8	1.0
Research	62413	62413	62413	62413	62413	62413
Cohort	375032	189396	96607	65701	50267	41020
Predicted from Regression	284233	145179	84704	52541	40991	34076
Cohort - Reg.	90799	44218	11903	13160	9276	6944
r =	0.941	0.943	0.945	0.942	0.934	0.920