4VsW Cod: Background to the 1979 Assessement

by

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Introduction

In 1978 major changes took place in the fishery for cod in
subdivision 4Vs and division 4W. Catch rates showed a marked
improvement in both commerical and research catches and the stock
seemed to concentrate more on Middle Bank and Banquereau than usual.
After a number of years in which the assessments have indicated a
declining or depressed stock size, these changes were noted with
interest by both industry and the government scientists. It was
decided that a detailed analysis of this stock was needed to determine
their meaning and implications. The CAFSAC Groundfish Subcommittee
held a special meeting to consider this stock on April 19-20, 1979 and
gave it further consideration at the annual assessment meeting
May 28-June 9, 1979. This document presents the data considered at
those meetings with an explanation of sources and methods of analysis.

Nominal Catches

From 1958 to 1972, the nominal catch fluctuated between 50 and 70
thousand metric tonnes and the average catch was 61 thousand mt.
TAC's were first set on this stock in 1973 and for the first three
years they were set at about this average catch level: 60,500 mt in
1973, 60,000 mt in 1974 and 1975. However the TAC was not reached in
any of these years with little over 50% of it being taken in 1975.
Based on a detailed reappraisal of the stock, the TAC was cut to 30,000
mt for 1976. As a result of analyses on the stock that showed it to be
in a severe decline and a catch in 1976 that was again below allowed
levels, the TAC was reduced to 7,000 mt for 1977 and 1978. In both of
these years there was a problem with the accuracy of reported catch
areas for the Canadian mobile fleet but it is estimated that for both
years the catch was above allocation, in fact in 1978 it was probably
at least three and a half times the TAC. These nominal catches and

TAC's are shown in Tables 1 and 1a and Figure 1. All values up until 1977 are ICNAF Statistical Bulletin figures. For 1978 the figures are best estimates developed from flash reports, International Obersver data and provisional data submitted to ICNAF.

Prior to 1977, there does not appear to be a problem with the reported area of catch for the Canadian fleet and therefore the Canadian nominal catches are probably fairly accurate. In spite of low allocations and a shortage of fish in most areas, Canada never took its allocations in the years 1973-1976 with utilization falling to only 41% in 1975. In 1974 and 1975 the catches of most other countries were also well under their allocation with the notable exception of the USSR whose reported catch approximately equals its quota in all years. Catches against allocations are shown in Table 2.

The composition of the Canadian fleet has varied considerably over the years. Gears other than otter trawlers, mainly longliner and gillnets with an increasing number of seiners in recent years, have consistently taken about 6,000 mt per year mainly from 4W. The otter trawl catch has varied much more in amount and area reacting more to available catch rates in different parts of 4VsW as well as catch rates and allocations in other areas. Both gear groups had catches in 1978 that were nearly historical highs. Canadian catch by gear grouping and area is shown in Table 3 and Figure 2.

Research Survey Results

Since 1970, there has been a summer research survey using the A.T. Cameron every year. In 1978 there was also a fall survey run using the Lady Hammond and this will become part of the regular research program. The two trips in 1978 agreed quite well as to age composition and population estimates, but since this was the first fall cruise it is impossible to say whether any differences are due to the vessel, the time of year or random fluctuation. Therefore only the A.T. Cameron cruises were used in this analysis.

Due to the small number of tows per stratum, the survey results show large apparently random fluctuations. The 1977 increase over 1976 appeared to be due to this variation or a change in availability since all age groups showed an increase. However the increase continued in the 1978 data which showed definite improvement in the numbers of younger fish. This trend had not been as apparent from a look at preliminary data from this cruise in the fall of 1978. These revised figures along with those for previous years are found in Table 4a.

In 1973, two sets hit dense concentrations of young fish, one in stratum 58 and one in stratum 59 (the area on and north of Middle Bank). Though young fish are known to concentrate in these areas, patches with densities such as found on these two sets are rarely

encountered on the research cruises and distort the entire set of estimates. To determine an estimate for 1973 that was more comparable with the average situation, these two sets were removed and the figures reworked. The adjusted data is presented in Table 4b.

The data still shows a highly variable pattern so to try to produce a better picture of long-term stock trends, a three year running average of the 4+ and 5+ population estimates was tried. This does not give an estimate for 1978. To get such a figure, various averagings can be used and a straight 1977-78 average was accepted. This is more conservative than putting more weight on the 1978 number but it does produce a fairly smooth trend from 1975 to 1978. Averaged figures for the adjusted and unadjusted series are presented in Table 5 and Figure 3. All series show a marked decline to 1974 or 1975 followed by a slightly slower recovery.

Commerical Catch Per Unit Effort

In 1978, about 97% of the catch went to the Canadian fleet. Much of this catch, particularly most of the portion caught by otter trawls was misreported as to catch location. Reported effort levels were also unreliable, and therefore there is no usable effort data for 1978. Hence most of the catch per unit effort series presented have appeared before (Gray, 1978).

Table 6 and Figure 4 review Spanish catch per unit effort for all Subareas. There is a consistency in apportionment of catches between Subareas but it is in keeping with normal trends and variations in the relative success of fishing in the various Subareas as reflected by the statistical record of other countries. Catch rate trends of Spanish pair trawlers fishing cod, although similar in different Subareas and Divisions, agreed well with catch rate trends of other countries and reflect the general downward trend in catch rates for northwestern Atlantic cod stocks in the late 1960's until the mid 1970's. There is no reason to disbelieve that the catch rate trends of Spanish pair trawlers in Division 4VsW are an accurate reflection of their fishing success.

Table 7 presents five commercial catch per unit effort series. The first is derived from the total catch and effort by Spanish pair trawls tonnage class 4 in February and March. The second and third are from trips that caught greater than 50% cod in February and March by Canada Maritimes and Quebec otter trawlers tonnage class 4 and 5 respectively. In 1974-75 the Canadian tonnage class 5 vessels changed from a Western trawl to an Engel trawl with an estimated change in efficiency of 30-40%. Figures are also given that account for this adjustment. The last series comes from the USSR mixed fishery by tonnage class 7 and used the Chikuni (1976) method for analysing catch and effort. Figures given are for cod levels of 10% of the catch.

The first four CPUE series are also presented in Figure 5 while
Figure 6 compares the Spanish PTB4 series, the Canadian OTB5 series and
the survey 4+ population estimates rescaled to show relative changes
over the past 12 years. Figure 6 shows a marked decline in all series
until 1974 or 1975 with improvements in more recent years. The largest
declines are in the Spanish and research series. The former is for a
directed cod fishery and the latter is for a fishery with randomly
allocated effort. The Canadian fishery is an opportunistic fishery in
which effort depends on available allocations, open areas, catch rates,
prices and costs. Figure 2 demonstrated the volatility of this
fishery. Without a detailed analysis of cost and price pressures and
available catch rates in other areas, it is impossible to determine to
what extent values derived from this fishery depend on biological
interactions or economic trends.

Catch at Age

For 1978 there were length and age samples of the catch of most
segments of the Canadian fleet and length samples from the
International Observer Program for the catches of most other countries.
The length samples for foreign fisheries were "aged" with research
survey age-length keys. Catch at age was estimated by weighting the
appropriate samples with catch by country and gear in the usual
fashion.

The catch at age for past years differs from Gray (1978) for two
reasons. The 1977 catch figures are adjusted to reflect final reported
catch while the earlier figures used preliminary data. International
Observer data indicates that the USSR reported cod by-catch is below
the actual cod by-catch. Estimates were made of the cod by-catch by
bumping up the amount of cod caught on trips with observers by using
the ratio of cod to silver hake or squid caught. This produced
estimated cod catches of 367 mt in 1977 and 479 mt in 1978, the latter
being used in Table 1. In 1977, the USSR reported (preliminary ICNAF
Statistical Bulletin) 97mt and in 1978 they reported 310 mt to Flash.
The average ratio of estimated catch to reported catch for the two
years is 2.66. The figures for 1977 were adjusted to include a catch
of 367 mt by USSR and their catch for 1966-1976 was multiplied by 2.66.
Table 9 gives the new adjusted estimates of removals at age. Table 10
shows the adjustment made for years 1966-1977; this is a substantial
increase in the estimated catch of small fish.

Table 9 shows marked change in the age distribution of the catch
for the last two years. With the removal the Spanish directed cod
fishery and the restrictions placed on the small mesh fisheries, the
catch of young fish has been substantially reduced.

Mean Age and Lengths

Table 8 presents data on the size and age of the otter trawl catch in 4Vs in February. Traditionally, February has been the peak month for the fishery and the sampling is most consistent for that month. Though the figures are highly variable, this years catch is younger and larger at age than most previous years. The large size may indicate a small population while the lower mean age may indicate improved recruitment.

Cohort Analysis

To run a cohort analysis on the developed catch matrix, it was necessary to decide on a partial recruitment and a final fishing mortality. It was not possible to develop partial recruitments by the usual method of averaging values in earlier years after making a trial run because of the recent extreme change in the fishery.

Various data were analysed to determine if the partial recruitment vector used in last year's assessment (Gray, MS 1978) was reasonable. The 1978 commercial catch curve supports the conclusion that full recruitment takes place at age 5 and implies a curve of the same general shape as used in 1978. It appears that the lack of 1 year olds in the catch in 1977 was only partially due to the small 1976 year-class and the partial recruitment on age 1 had to be raised to obtain estimates of the 1977 year-class within reasonable bounds; 0.015 was accepted for initial runs. Comparing commercial and research catch curves implied full recruitment did not occur until age 8. However it appears that the fishery concentrated on Middle Ground and Banquereau where, assuming cod stratify somewhat with depth as shown on a research cruise using the Cape Bauld in 1978, younger fish concentrate. When partial recruitments of this sort were tried in cohort analyses no agreement between population size estimates could be obtained. However the commerical fishery does not peak at the time of the research cruise, so this difference in age distributions may just show seasonal changes in availability. Thus the partial recruitment vector used in 1978 was accepted for initial runs with the value for age 1 raised to 0.015.

With this partial recruitment vector, trials were made to find the final F that gave the best agreement between estimates of 4+ population size from the smoothed research data and from the cohort analysis. The process was started with an F set at the $F_{0.1}$ level because results from a tagging program on a concentration of fish in the heavily fished area indicated it could possibly be this high. However such an F gave a poor fit and the fit only improved if F was lowered. Good agreement was achieved between the two sets of numbers when F was lowered to 0.15 but the 1978 point was not well predicted by earlier points. At an F of 0.18, the correlation between the two sets of numbers gave an R^2 of .74 and the differences between the 1978 point from the cohort and that predicted by earlier points was about 5%.

This method adjusting the cohort analysis only considered ages 4+ and thus is not affected by the size of the 1975-77 year-classes. The size of these year-classes versus the average size of earlier year-classes in this cohort run did not agree with the ratio between the estimates of these and earlier year-classes from research data. For population estimates-at-age for the 1975-77 year-classes each estimate was divided by the average estimate for the same age group from 1970-74. This provided one or more ratios for each year-class and the average was taken for each year-class. This was compared with the similiar average for the year-class from the research cruise estimates (Table 16a). The partial recruitments were adjusted until the averages from cohort agreed with the averages from research data (Table 16b). This led to the partial recruitments in Table 11 and the final estimates of population numbers and fishing mortalities are given in Tables 12 and 13.

The survey 4+ numbers were used to decide on the cohort parameters and the agreement is shown in Figure 7. The results were also compared with some other series and the results are presented in Table 14 and Figures 8 and 9. The cohort biomasses agree well with the Canadian OTB5 and Spanish PTB4 CPUE series. The Canadian OTB4 series does not agree with either other series or the cohort biomasses.

Yield Per Recruit

Using the mean weights at age and partial recruitments of Table 11 and an M of 0.2, a Thompson-Bell yield per recruit analysis was run. This gave a maximum yield per recruit of 0.81 kg at a fishing mortality of 0.34 and an $F_{0.1}$ of 0.20 with a yield per recruit of 0.76 kg.

Catch Projection

The cohort numbers in 1978 adjusted by the research cruise data estimates of the sizes of the 1975-77 year-classes were projected to 1980 assuming a catch of 30,000 mt in 1979 and fishing at $F_{0.1}$ in 1980. The 1978 and 1979 year-classes were set at 100 million fish, the geometric mean of the 1965-1973 year-classes. The results are presented in Table 15. This analysis implies that fishing at $F_{0.1}$ in 1980 would result in a yield of 45 thousand mt.

Summary

A re-evaluation of the research survey data, the verification that the catch of small cod in the small mesh fisheries was a larger problem than first reported, and the evidence that the cutback in these fisheries has released a much improved recruitment to the Canadian cod fishery has led to a more optimistic view of the short-term future of this stock. The long run predictions still indicate that catch levels could return to pre-1970 values. However since these predictions are

based on catches being concentrated on older fish than was the case in the 1960's, to support such a fishery stock numbers and biomass will have to be greater than they have been for some time. Therefore some conservatism is needed in the immediate future if these stock levels are to be reached in a reasonable amount of time.

References

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    multispecies and multi-gear groundfish fisheries in the Bering
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Table 1   Div. 4Vs-W Cod - Nominal Catches (m.t.)

Year	Canada	France	Portugal	Spain	USSR	Others	Total	Div. 4Vs	Div. 4W	Catch Quota
1958	17,938	4,577	1,095	14,857	-	124	38,591	23,790	14,801	-
1959	20,069	16,378	8,384	19,999	-	1,196	66,026	47,063	18,963	-
1960	18,390	1,018	1,720	29,391	-	126	50,645	27,689	22,956	-
1961	19,697	3,252	2,321	40,884	113	42	66,309	34,237	32,072	-
1962	17,579	2,645	341	42,146	2,383	60	65,154	26,350	38,804	-
1963	13,144	72	617	44,528	9,505	307	68,173	27,566	40,607	-
1964	14,330	1,010	-	39,690	7,133	1,094	63,257	25,496	37,761	-
1965	23,104	536	88	39,280	7,856	124	70,988	36,713	34,275	-
1966	17,690	1,494	-	43,157	5,473	356	68,170	27,163	41,007	-
1967	18,464	77	102	33,934	1,068	512	54,157	26,607	27,550	-
1968	24,888	225	-	50,418	4,865	29	80,425	48,781	31,644	-
1969	14,188	217	-	32,305	2,783	664	50,157	22,309	27,848	-
1970	11,818	420	296	41,926	2,521	446	57,427	28,632	28,795	-
1971	17,064	4	18	30,864	4,506	107	52,563	24,128	28,435	-
1972	19,987	495	856	28,542	4,646	7,119	61,645	36,533	25,112	-
1973	15,929	922	849	30,883	2,918	2,569	54,070	23,401	30,669	60,500
1974	10,700	34	1,464	27,384	3,097	1,060	43,740	19,610	24,130	60,000
1975	9,939	1,867	546	15,611	3,042	1,512	32,517	11,694	20,823	60,000
1976	9,567	697	-	11,090	1,018	2,035	24,407	11,553	12,854	30,000
1977	9,890	68	-	-	97	31	10,086	2,873	7,213	7,000
1978 [1]	24,631	250	22	31	479	41	25,454	-	-	7,000 [2]

[1] Preliminary

[2] By-catch

9.

Table 1a   Nominal Catches   (mt) - Breakdown of 'Other' Category

Year	Bulgaria	Cuba	Denmark	FRG	Ireland	Italy	Japan	Norway	Poland	USA	TOTAL
1975	4	481	622	5	4	-	-	381	-	15	1,512
1976	-	587	1417	-	-	-	-	26	-	5	2,035
1977	-	19	-	8	-	-	+	-	2	2	31
1978[1]	3	21	-	-	-	14	3	-	-	-	41

[1] Preliminary

Table 2   4VsW Cod - Reported Catch vs Quota Allocation (mt)

Country	1973 Quota	Catch	1974 Quota	Catch	1975 Quota	Catch	1976 Quota	Catch	1977 Quota	Catch
CANADA	18400	15929	24250	10700	24250	9939	17500	9567	6550	9890
FRANCE	500	922	1500	34	1500	1867	700	697	250	68
PORTUGAL	1150	849	-	1464	500	546	150	-	-	-
SPAIN	31550	30883	28500	27384	28500	15611	9600	11090	-	-
USSR	2900	2918	2900	3097	2900	3042	900	1018	-	97
OTHERS	6000	2569	2850	1060	2350	1512	1150	2035	200	31
TOTAL	60500	54070	60000	43740	60000	32517	30000	24407	7000	10086

Table 3 . Div. 4 VsW Cod: Canadian nominal catches by otter trawls[1] and other gear

| Year | Div. 4VS | | Div. 4W | | Totals | | |
	Trawls	Other Gear	Trawls	Other gear	Trawls	Other Gear	Total[4]
1958[2]	4258	2092	4892	5731	9150	7823	16973
1959	4181	1286	7294	7308	11475	8594	20069
1960	1924	750	10228	5488	12152	6238	18390
1961	1135	136	12895	5531	14030	5667	19697
1962	1495	93	11762	4229	13257	4322	17579
1963	1258	34	7779	4063	9037	4097	13144
1964	2059	41	7324	4906	9383	4947	14330
1965	7366	106	10293	5338	17659	5444	23103
1966	6375	156	6614	4545	12989	4701	17690
1967	6729	132	6463	5140	13192	5272	18464
1968	9501	66	8367	6954	17868	7020	24888
1969	3539	51	4424	6174	7963	6225	14188
1970	3054	22	3596	5146	6650	5168	11818
1971	5826	41	4745	6452	10571	6493	17064
1972	9856	119	4732	5280	14588	5399	19987
1973	6397	77	4723	4731	11120	4808	15928
1974	4640	60	1343	4658	5983	4718	10701
1975	1815	72	3556	4496	5371	4568	9939
1976	3496	301	934	4836	4430	5137	9567
1977	2751	54	1873	5212	4624	5266	9890
1978[3]	9110	310	7888	6768	16998	7078	24076

[1] Total of OTB1, OTB2, OTM, OTB

[2] Does not include catch reported only as 4V which is included in Table 1.

[3] Preliminary, Maritimes only; Newfoundland is included in Table 1.

[4] Totals may differ from Table 1 due to rounding.

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Table 4a. 4VsW cod: Summer research cruise population estimates (thousands of fish).

	1970	1971	1972	1973	1974	1975	1976	1977	1978
0	97	23	0	0	866	69	0	0	174
1	1,273	1,539	6,210	16,128	5,174	3,372	2,242	808	3,053
2	16,123	7,680	9,674	122,780	32,961	8,412	14,066	10,145	13,065
3	5,196	35,664	11,881	104,965	19,246	13,000	16,098	26,372	31,245
4	7,682	8,027	31,536	59,948	5,623	6,171	10,187	17,059	34,205
5	3,734	15,803	5,812	22,524	2,017	2,959	6,621	11,353	9,461
6	1,227	5,775	5,989	1,870	2,244	675	1,264	4,893	3,490
7	1,532	3,459	1,621	2,907	372	867	656	1,081	889
8	466	1,475	547	901	463	235	1,308	878	185
9	104	638	495	431	224	433	-	244	90
10+	701	471	153	910	340	91	1,180	223	158
UK	274	112	0	202	44	74	36	114	53
TOTAL	38,408	80,666	73,917	333,564	69,575	36,359	53,657	73,171	96,067
Z 5+/6+		-0.42	1.14	0.73	2.09	0.90	0.18	0.41	1.36

Table 4b. 4VsW cod: Summer research cruise population estimates (thousands of fish), adjusted to remove two large anomalous sets in 1973.

	1970	1971	1972	1973	1974	1975	1976	1977	1978
0	97	23	0	0	866	69	0	0	174
1	1,273	1,539	6,210	2,295	5,174	3,372	2,242	808	3,053
2	16,123	7,680	9,674	8,778	32,961	8,412	14,066	10,145	13,065
3	5,196	35,664	11,881	13,760	19,246	13,000	16,098	26,372	31,245
4	7,682	8,027	31,536	10,788	5,623	6,171	10,187	17,059	34,205
5	3,734	15,803	5,812	6,799	2,017	2,959	6,621	11,353	9,461
6	1,227	5,775	5,989	428	2,244	675	1,264	4,893	3,490
7	1,532	3,459	1,621	951	372	867	656	1,081	889
8	466	1,475	547	676	463	235	1,308	878	185
9	104	638	495	96	224	433	–	244	90
10+	701	471	153	534	340	91	1,180	223	158
UK	274	112	0	202	44	74	36	114	53
TOTAL	38,408	80,666	73,917	45,306	69,575	36,359	53,657	73,171	96,067

Z
5+/6+   -0.42   1.14   1.69   0.96   0.90   0.18   0.41   1.36

Table 5.   4VsW Cod: Summer Research Cruises 4+ and 5+ numbers (in thousands)

	1970	1971	1972	1973	1974	1975	1976	1977	1978
4+	15446	35648	46153	89491	11283	11431	21216	35731	48478
5+	7764	27621	14617	29543	5660	5260	11029	18672	14273
4+ 1973 adjusted				20272					
5+ 1973 adjusted				9484					
3 year moving average using unadjusted numbers									
4+		32416	57097	48976	37402	14643	22793	35142	42105[1]
5+		16667	23927	16607	13488	7316	11654	14658	16473[1]
3 year moving average using adjusted numbers									
4+		32416	34024	25903	14329	14643	22793	35142	42105[1]
5+		16667	17241	9920	6801	7316	11654	14658	16473[1]

[1] two year average

Table 6.   Cod Catch & Effort - Spain PTB-4

Year		0	1	2	3	4	5	6	TOTAL
				Subarea					
1969	Catch (mt)	-	21925	4	139929	41292	13749	-	216,899
	Effort (hrs fished)	-	19546	24	100082	24280	9373	-	153,305
	CPUE	-	1.12	0.17	1.40	1.70	1.47	-	1.41
1970	Catch (mt)	-	17499	214	146447	48154	7249	-	219563
	Effort (hrs fished)	-	15802	70	111454	31918	5325	-	164569
	CPUE	-	1.11	3.06	1.31	1.51	1.36	-	1.33
1971	Catch (mt)	-	22086	367	151645	36261	7619	-	217978
	Effort (hrs fished)	-	19276	217	120321	29073	5892	-	174779
	CPUE	-	1.15	1.69	1.26	1.25	1.29	-	1.25
1972	Catch (mt)	-	1776	-	90346	16934	3842	-	112898
	Effort (hrs fished)	-	3191	-	93665	16444	4998	-	118298
	CPUE	-	0.56	-	0.96	1.03	0.77	-	0.95
1969	Catch (%)	-	10	+	65	19	6	-	100
	Effort (%)	-	13	+	65	16	6	-	100
	CPUE / average CPUE	-	0.79	0.12	0.99	1.21	1.04	-	1.00
1970	Catch (%)	-	8	+	67	22	3	-	100
	Effort (%)	-	10	+	68	19	3	-	100
	CPUE / average CPUE	-	0.83	2.30	0.98	1.14	1.02	-	1.00
1971	Catch (%)	-	10	+	70	17	3	-	100
	Effort (%)	-	11	+	69	17	3	-	100
	CPUE / average CPUE	-	0.92	1.35	1.01	1.00	1.03	-	1.00
1972	Catch (%)	-	2	-	80	15	3	-	100
	Effort (%)	-	3	-	79	14	4	-	100
	CPUE / average CPUE	-	0.59	-	1.01	1.37	0.81	-	1.00

Table 6 cont'd

17.

Year	0	1	2	3	4	5	6	TOTAL
1973 Catch (mt)	-	1874	20	62432	16593	2676	-	83595
Effort (hrs fished)	-	3847	36	82009	19966	3466	-	109324
CPUE	-	0.49	0.56	0.76	0.83	0.77	-	0.76
1974 Catch (mt)	-	532	860	46184	10763	478	-	58817
Effort (hrs fished)	-	1007	991	70345	17173	655	-	90171
CPUE	-	0.53	0.87	0.66	0.63	0.73	-	0.65
1975 Catch (mt)	-	720	111	26161	6165	2272	-	35429
Effort (hrs fished)	-	3812	166	38689	15720	17226	-	75613
CPUE	-	0.19	0.67	0.68	0.39	0.13	-	0.47
1976 Catch (mt)	-	-	-	10954	5048	970	-	16972
Effort (hrs fished)	-	-	-	12190	7906	2392	-	22488
CPUE	-	-	-	0.90	0.64	0.41	-	0.75
1973 Catch (%)	-	2	+	75	20	3	-	100
Effort (%)	-	4	+	75	18	3	-	100
$\frac{CPUE}{average\ CPUE}$	-	0.64	0.74	1.00	1.09	1.01	-	1.00
1974 Catch (%)	-	1	1	79	18	1	-	100
Effort (%)	-	1	1	78	19	1	-	100
$\frac{CPUE}{average\ CPUE}$	-	0.82	1.34	1.02	0.97	1.12	-	1.00
1975 Catch (%)	-	2	+	74	17	6	-	100
Effort (%)	-	5	+	51	21	23	-	100
$\frac{CPUE}{average\ CPUE}$	-	0.40	1.43	1.45	0.83	0.28	-	1.00
1976 Catch (%)	-	-	-	65	30	6	-	100
Effort (%)	-	-	-	54	35	11	-	100
$\frac{CPUE}{average\ CPUE}$	-	-	-	1.20	0.85	0.55	-	1.00

Table 7.   4VsW Cod: Catch per unit effort series (mt/hour).

Year	Spanish Pair Trawls TC4 February - March	Canadian (M.Q.) Otter Trawls Trips ≥ 50% Cod February-March TC4	TC5	TC5	Russian Otter Trawls TC7 Chikuni method at 10% Cod
1967	1.875	.549	.753		.197
1968	2.472	.528	.746		.359
1969	1.783	.483	.562		.265
1970	1.477	.413	.610		.052
1971	1.207	.437	.665		.232
1972	1.142	.573	.575	35% increase in	.237
1973	0.820	.442	.548	efficiency about 1975	.240
1974	0.603	.362	.384		.269
1975	0.234	.554	.488	.361	.216
1976	0.509	.445	.502	.372	.272
1977	-	.553	.664	.492	.205

Table 8.   Mean age and mean lengths at age (cm).   Canada (M.Q.) otter trawl samples - 4Vs - February: (   ) indicates   5% of sample.

Year	No of Samples	Mean Age	Mean Age for Can (M.Q.) OTB Complete Year, 4Vs & 4W	Mean Length at Age (cm)					
				4	5	6	7	8	9
1978	1	6.14·	5.00	46.40	56.99	64.63	72.63	(81.37)	68.10·
1977	2	7.42	5.93	(44.87)	52.57	57.59	60.89	69.85	70.28
1976	-	-	5.76	-	-	-	-	-	-
1975	1	7.33	6.16	(41.71)	46.43	53.60	60.96	63.53	(69.77)
1974	-	-	4.54	- ·	-	-	-	-	-
1973	1	5.83	5.85	43.89	46.24	51.99	56.28	56.62	(59.73)
1972	1	6.75	4.94	44.00	49.90	54.72	63.32	64.89	(77.51)
1971	4	6.40	5.87	47.29	53.48	55.71	61.42	69.28	(78.35)
1970	1	5.86	5.63	44.56	54.04	63.39	67.99	70.84	(82.00)
1969	-	-	5.34	-	-	-	-	-	-
1968	·1	6.78	5.45	(47.93)	48.86	53.83	57.61	59.05	58.47
1967	1	5.28	5.45	47.16	54.05	·59.29	59.77	(65.59)	(66.16)
1966	-	-	5.08	-	-	-	-	-	-
1965	-	-	5.44	-	-	-	-	-	-
1964	-	-	5.38	-	-	-	-	-	-
1963	-	-	5.41	-	-	-	-	-	-
1962	-	-	5.61	-	-	-	-	-	-
1961	-	-	5.89	-	-	-	-	-	-
1960	-	-	5.97	-	-	-	-	-	-

Table 9.   4VsW Cod: Removals at age, adjusted for underreporting in small mesh fishery (thousands of fish).

Age	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978
1	2806	548	2495	1426	1293	2311	2383	1418	1482	1792	728	2	177
2	17891	4235	16045	9097	8631	15218	17738	12142	8451	9979	4061	24	153
3	17493	6267	17413	7684	8886	12582	14227	14881	12885	9485	3587	386	1004
4	13973	7989	17783	13724	14802	9146	13361	7507	9947	4341	3713	1073	3650
5	10577	9456	15633	10248	13673	8809	9661	9755	7130	4549	4818	1559	4621
6	4461	4338	8297	6073	4539	10262	8780	3823	2766	2594	2412	871	2441
7	3256	1467	3482	2144	1942	5160	3432	2996	944	2627	1426	501	768
8	1590	1239	895	510	759	1849	1919	3724	1323	612	611	220	213
9	856	664	816	237	236	496	358	1166	413	497	184	128	112
10	496	647	361	50	72	114	393	273	369	660	49	35	80
11	666	325	152	95	137	131	79	299	15	153	22	44	26
12	24	65	211	58	56	72	2	3	5	126	107	55	28
13	14	16	33	12	9	98	37	7	0	36	1	11	26
14	0	5	17	2	12	12	0	5	0	9	4	3	9
15	2	7	1	2	4	51	1	5	0	9	1	2	4
16	1	2	10	2	3	17	1	20	0	18	1	7	2

Table 10:   4VsW Cod: Estimated removals at age added to previous figures to adjust for underreporting in small mesh fishery (thousands of fish).

AGE	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977
1	1751	342	1557	890	807	1442	1487	885	925	1118	373	1
2	11165	2178	9925	5677	5143	9193	9477	7379	5153	6229	2083	17
3	7224	1409	6423	3674	3328 .	5948	6132	3770	4271	5164	1727	161
4	1313	256	1167	669	606	1081	1116	715	730	882	295	88
5	438	86	388	222	201	360 .	372	314	106	128	43	19
6	0	0	0	0	0	0	0	5	48	58	20	4
7	0	0	0	0	0	0	0	17	0	0	0	1
8	0	0	0	0	0	0	0	7	3	5	2	0
9	0	0	0	0	0	0	0	2	0	0	0	0

Table 11: 4VsW Cod: Mean weights at age and partial recruitments used in the analysis.

Age	1	2	3	4	5	6
Weight (kg)	0.20	0.62	0.95	1.25	1.68	2.47
Partial recruitment	0.013	0.023	0.10	0.4	1.0	1.0

Age	7	8	9	10	11	12
Weight (kg)	3.61	5.23	5.59	6.54	7.92	9.21
Partial recruitment	0.9	0.9	0.9	0.9	0.9	0.9

Age	13	14	15	16
Weight (kg)	10.40	9.75	8.68	12.21
Partial Recruitment	0.9	0.9	0.9	0.9

Table 12   4VsW Cod: Population estimates (thousands of fish) from a cohort analysis run on the catch matrix of Table 9 using M=0.2, fully recruited F in 1978 of 0.18 and the partial recruitments of Table 11.

Age	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978
1	170086	134973	92214	109819	96174	97691	82236	84234	91859	113601	93447	49905	83552
2	121727	136715	110011	73241	88621	77571	77892	65173	67682	73867	91387	75849	40857
3	82468	83473	108101	75551	51733	64747	49740	47722	42373	47766	51448	71147	62078
4	52381	51691	62672	72750	54903	34315	41626	27850	25607	23033	30525	38876	57901
5	25546	30243	35092	35220	47144	31557	19819	21991	16009	11965	14930	21632	30858
6	9446	11345	16205	14585	19563	26227	17866	7485	9178	6656	5680	7864	16301
7	7453	3697	5363	5760	6447	11910	12187	6683	2669	5012	3102	2468	5650
8	3709	3156	1700	1240	2776	3521	5082	6873	2761	1331	1726	1250	1567
9	2353	1598	1463	582	554	1586	1210	2425	2257	1063	536	860	824
10	1735	1152	707	459	262	240	850	666	930	1474	421	272	589
11	949	972	358	252	331	149	93	340	299	428	610	300	191
12	64	174	502	155	121	147	4	5	8	231	212	479	206
TOTAL	477917	459188	434386	389615	368629	349662	308605	271448	261631	286427	294024	270902	300574
BIOMASS	284	319	297	261	277	201	209	164	173	146	171	237	312
4+ BIOMASS (thousands of mt)	150	163	161	161	184	130	137	102	96	72	80	120	206

Table 13. 4VsW cod: fishing mortalities estimated by cohort analysis run on the catch matrix of Table 9, using M = 0.2, a fully recruited F in 1978 of 0.18 and the partial recruitments of Table 11.

AGE	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978
1	0.018	0.004	0.030	0.014	0.015	0.026	0.033	0.019	0.018	0.018	0.009	0.000	0.002
2	0.177	0.035	0.176	0.148	0.114	0.244	0.290	0.231	0.148	0.162	0.050	0.000	0.004
3	0.267	0.087	0.196	0.119	0.211	0.242	0.380	0.423	0.410	0.248	0.080	0.006	0.018
4	0.349	0.187	0.376	0.234	0.354	0.349	0.438	0.354	0.561	0.234	0.144	0.031	0.072
5	0.612	0.424	0.678	0.388	0.386	0.369	0.774	0.674	0.678	0.545	0.441	0.083	0.180
6	0.738	0.549	0.834	0.616	0.296	0.566	0.783	0.831	0.405	0.563	0.634	0.131	0.180
7	0.659	0.577	1.264	0.530	0.405	0.652	0.373	0.684	0.496	0.866	0.709	0.254	0.162
8	0.642	0.569	0.872	0.606	0.360	0.868	0.540	0.913	0.754	0.710	0.496	0.216	0.162
9	0.514	0.615	0.959	0.598	0.636	0.424	0.396	0.758	0.226	0.727	0.477	0.180	0.162
10	0.380	0.970	0.830	0.128	0.362	0.744	0.716	0.603	0.577	0.683	0.138	0.153	0.162
11	1.496	0.461	0.634	0.538	0.612	3.506	2.734	3.575	0.057	0.503	0.041	0.177	0.162
12	0.525	0.525	0.615	0.525	0.705	0.765	0.900	1.065	1.185	0.900	0.800	0.135	0.162
5+ F weighted by population	.648	.490	.784	.465	.367	.515	.665	.761	.558	.631	.505	.115	.177

Table 14. 4VsW Cod: Correlations between CPUE series and biomass estimates from cohort analysis.

	Canadian OTB (Directed Catch) TC 5	Spanish PTB4	Cohort Biomass estimates	
			4+	1+
Canadian OTB TC 4	0.25	0.28	0.11	0.28
(Directed catch) TC 5		0.89	0.82	0.81
Spanish PTB4			0.88	0.92
Cohort Biomass 4+ Estimates				0.91

Table 15: 4VsW Cod - Catch projection
Partial Recruitment and Weights as in Table 11. Recruitment 100 million at age 1 after 1978. Catch for 1979 set at 30,000 mt. F fully recruited 1980 set at $F_{0.1}$ = 0.20.

Year	Pop (Millions)	Biomass (thousands of t)	4+ Biomass (thousands of t)	Catch (thousands of t)
1978	301	309	208	25
1979	334	361	267	30
1980	361	423	299	45

Table 16a.4VsW Cod - Year-class size comparisons for adjusted research estimates and initial cohort runs.

Adjusted Research Data

Age	Mean Population estimate (x10^{-3}) 1970-74	Population estimates			Ratios		
		1976	1977	1978	$\frac{1976}{mean}$	$\frac{1977}{mean}$	$\frac{1978}{mean}$
1	3298.2	2242	808	3053	0.680	0.245	0.926
2	15043.2		10145	13065		0.674	0.868
3	17149.4			31245			1.822

Cohort Numbers

Age	Mean population estimates (x10^{-3}) 1970-74	Population estimates			Ratios		
		1976	1977	1978	$\frac{1976}{mean}$	$\frac{1977}{mean}$	$\frac{1978}{mean}$
1	90438.8	62845	28739	72424	0.695	0.318	0.801
2	75387.8		50794	23527		0.674	0.312
3	51263.0			41565			0.680

Year-class	Average Ratio Research	Average Ratio Cohort	$\frac{Research}{Cohort}$
1975	1.059	0.683	1.551
1976	0.557	0.315	1.768
1977	0.926	0.801	1.156

Old partial recruitment (ages 1-3)	.015	.04	.15
New partial recruitment	.013	.023	.10

Table 16b.

4VsW Cod - Year-class size comparisons for the new cohort estimates

Age	Mean population estimates $(\times 10^{-3})$ 1970-74	Population estimates			Ratios		
		1976	1977	1978	$\dfrac{1976}{\text{mean}}$	$\dfrac{1977}{\text{mean}}$	$\dfrac{1978}{\text{mean}}$
1	90438.8	93447	49905	83552	1.033	0.552	0.924
2	75387.8		75849	40857		1.006	0.542
3	51263.0			62078			1.211

Year-class	Average ratio Research	Average ratio cohort	$\dfrac{\text{Research}}{\text{cohort}}$
1975	1.059	1.083	0.978
1976	0.557	0.547	1.018
1977	0.926	0.924	1.002

Figure 1. Div. 4VsW Cod: Catch and Total Allowable Catch
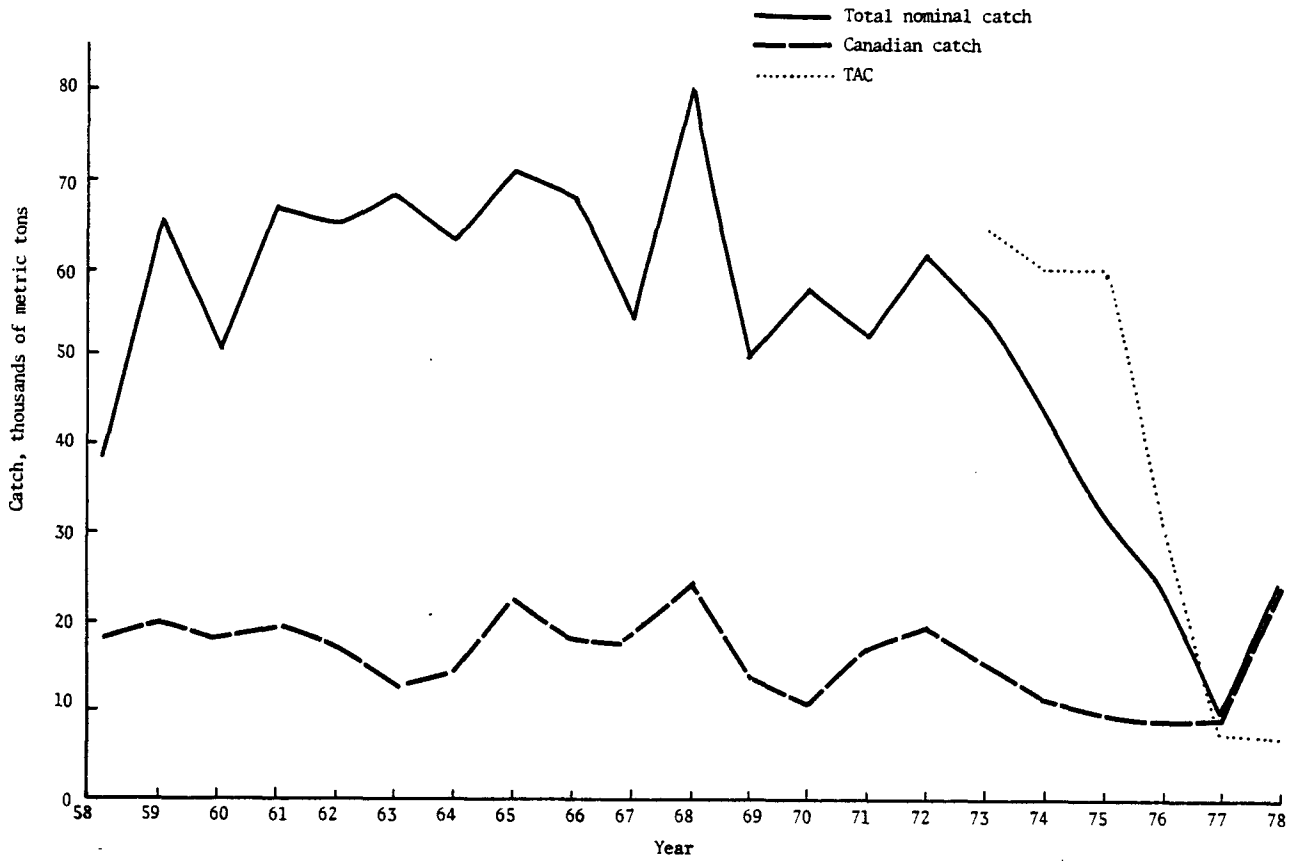
Figure 2. Div. 4VsW Cod: Canadian Nominal Catch by Otter Trawls and other Gears
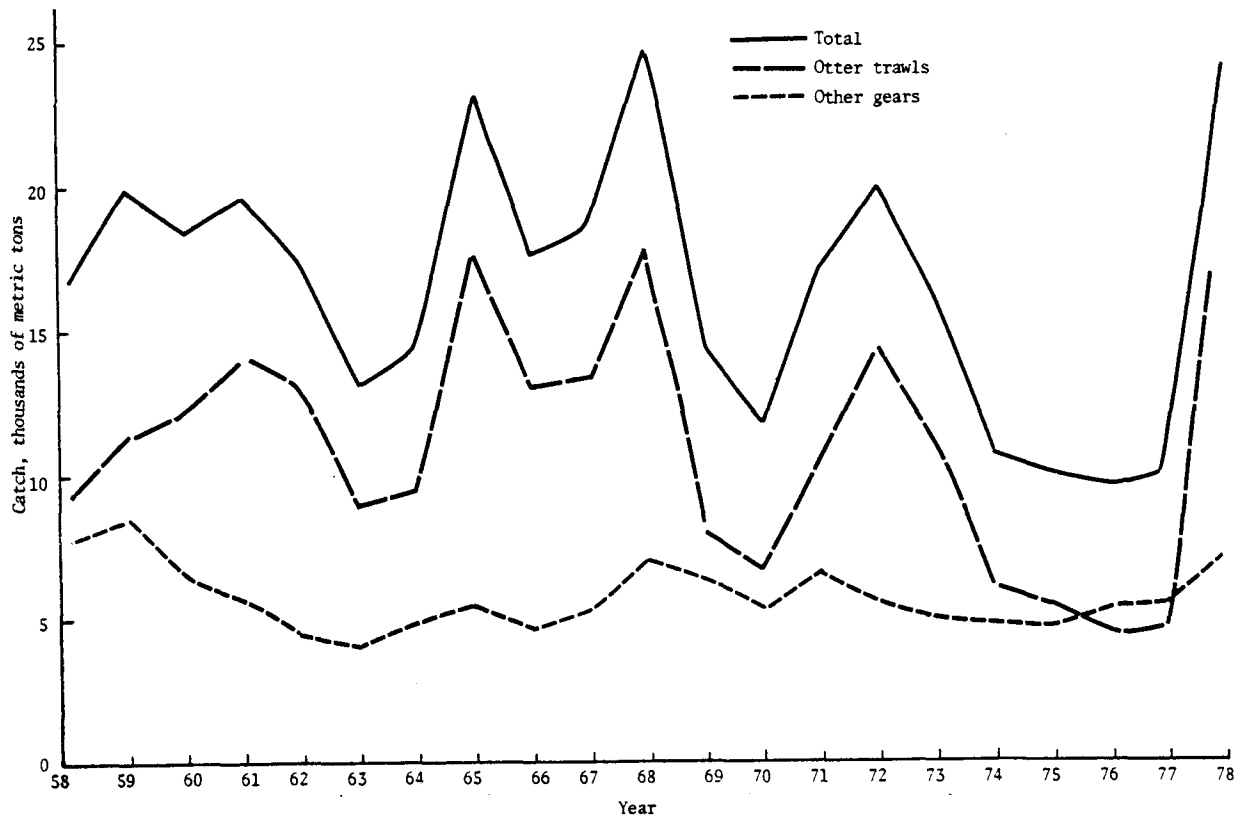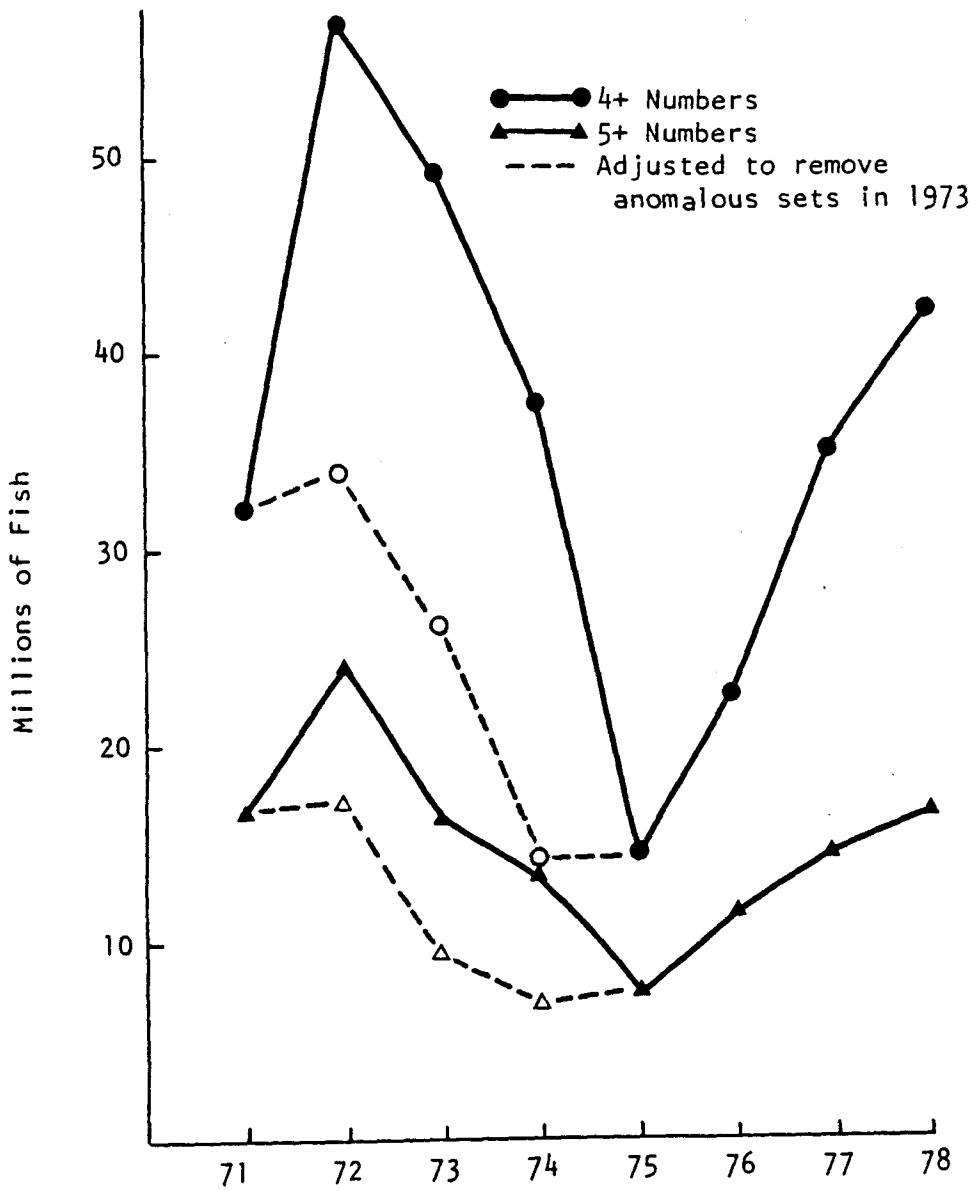
Fig. 3. 4VsW Cod: 3-Year Moving Average of Survey
4+ and 5+ Population Estimates

Figure 4.   Cod catch per Unit Effort By Subarea -
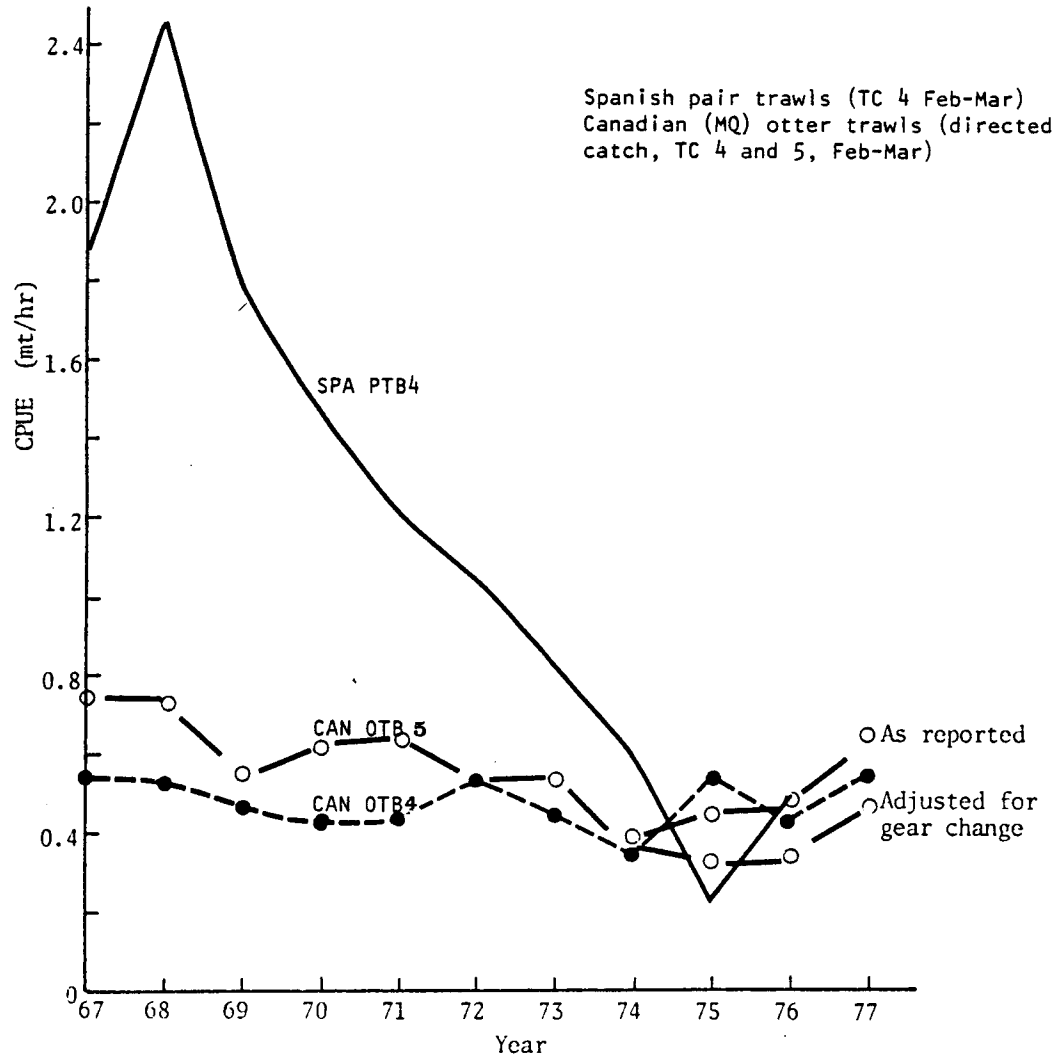   Spain PTB-4

Figure 5: 4VsW Cod: CPUE.

Spanish pair trawls (TC 4 Feb-Mar)
Canadian (MQ) otter trawls (directed
catch, TC 4 and 5, Feb-Mar)
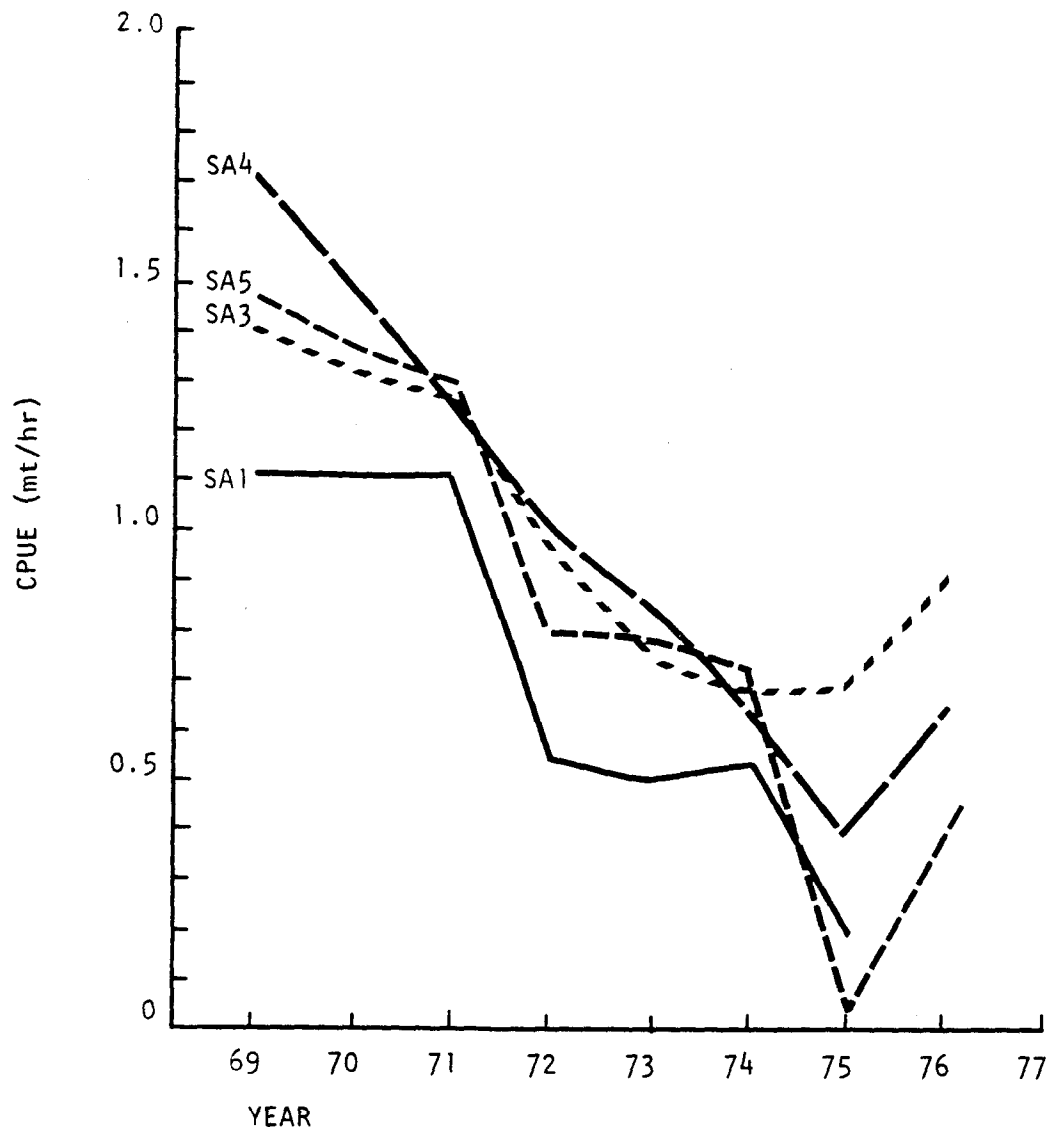
Fig. 6. 4VsW Cod: Comparison of some catch rates scaled to indicate relative changes; catch rates of Spanish 151-500 gt pair trawlers (mt/hr fished) in 1967-76, catch rates of Canadian 501-900 gt otter trawlers (mt/hr fished) in 1967-77 and in the period 1975-77 showing catch rates unadjusted and also adjusted for changed gear efficiency due to adoption of the Engel trawl, and research vessel survey estimates of age 4+ population numbers shown as three year running averages except the 1978 point which is the average of 1977 and 1978.
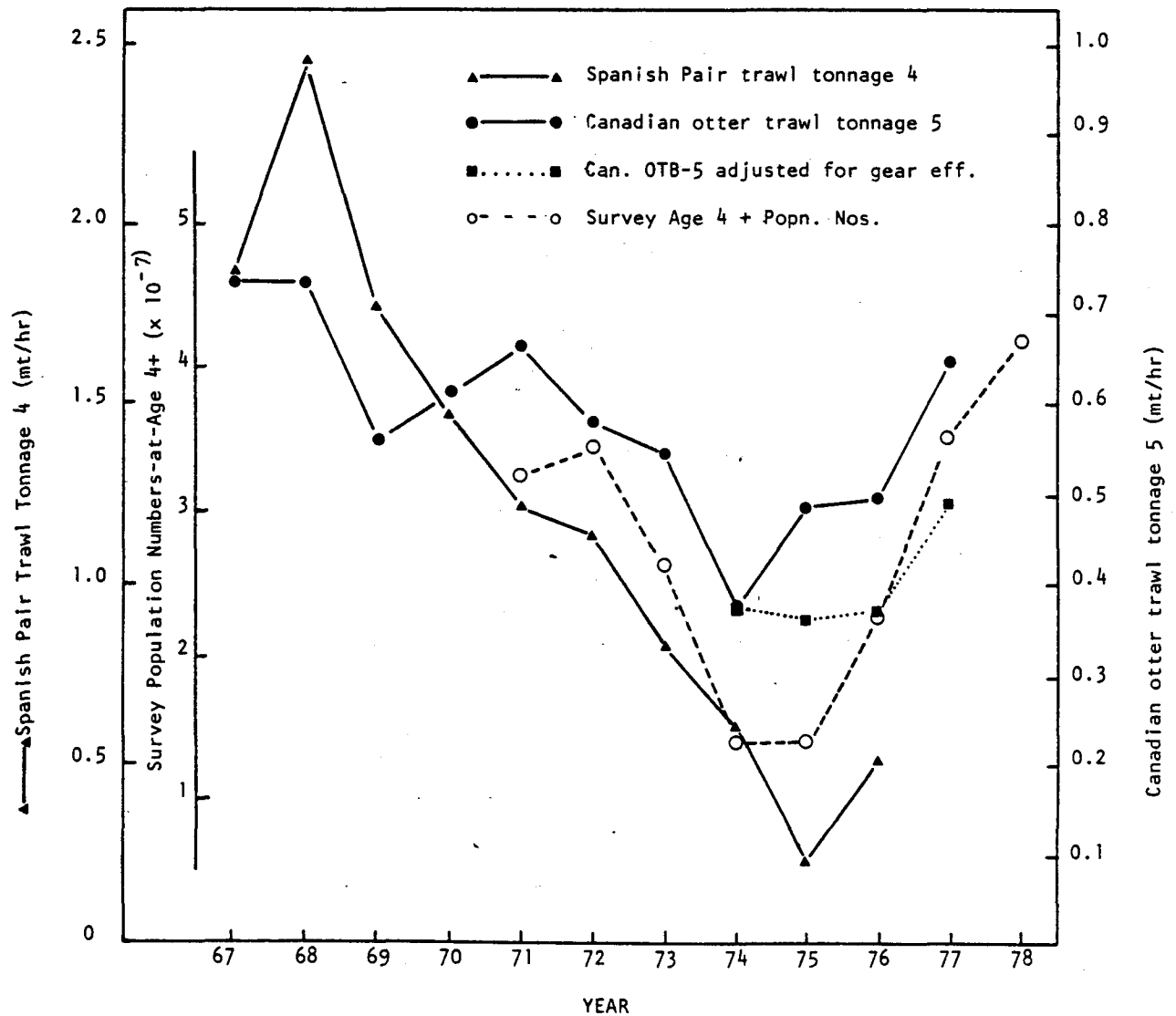
Fig. 7. 4VsW Cod: Comparison of 4+ population size from research surveys and cohort analysis

Fig. 8. 4VsW Cod: CPUE Spanish pair trawls vs 1+ biomass estimates, line fitted by eye.
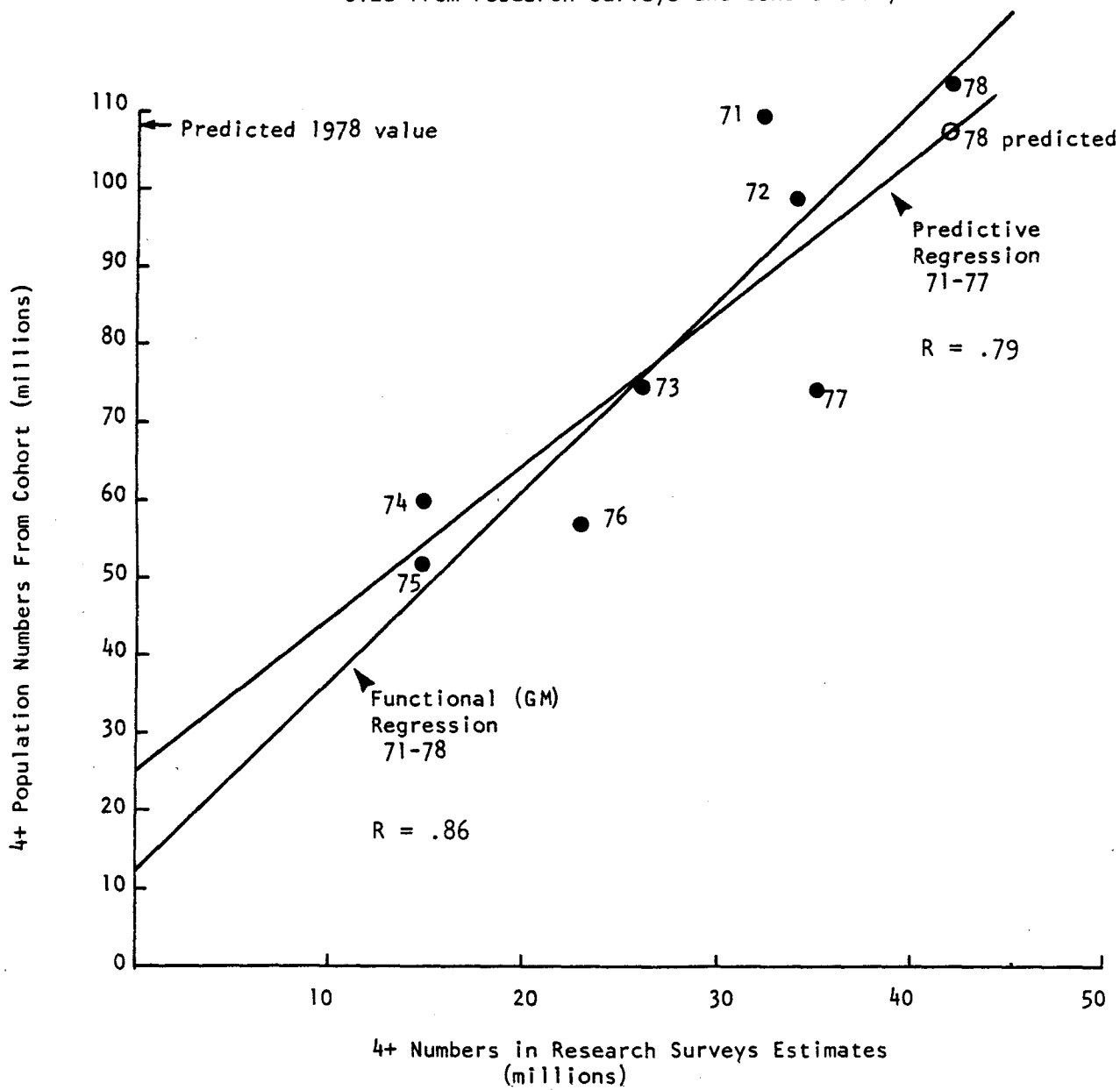

Fig. 8. 4VsW Cod: CPUE Spanish pair trawls vs 1+ biomass estimates, line fitted by eye.
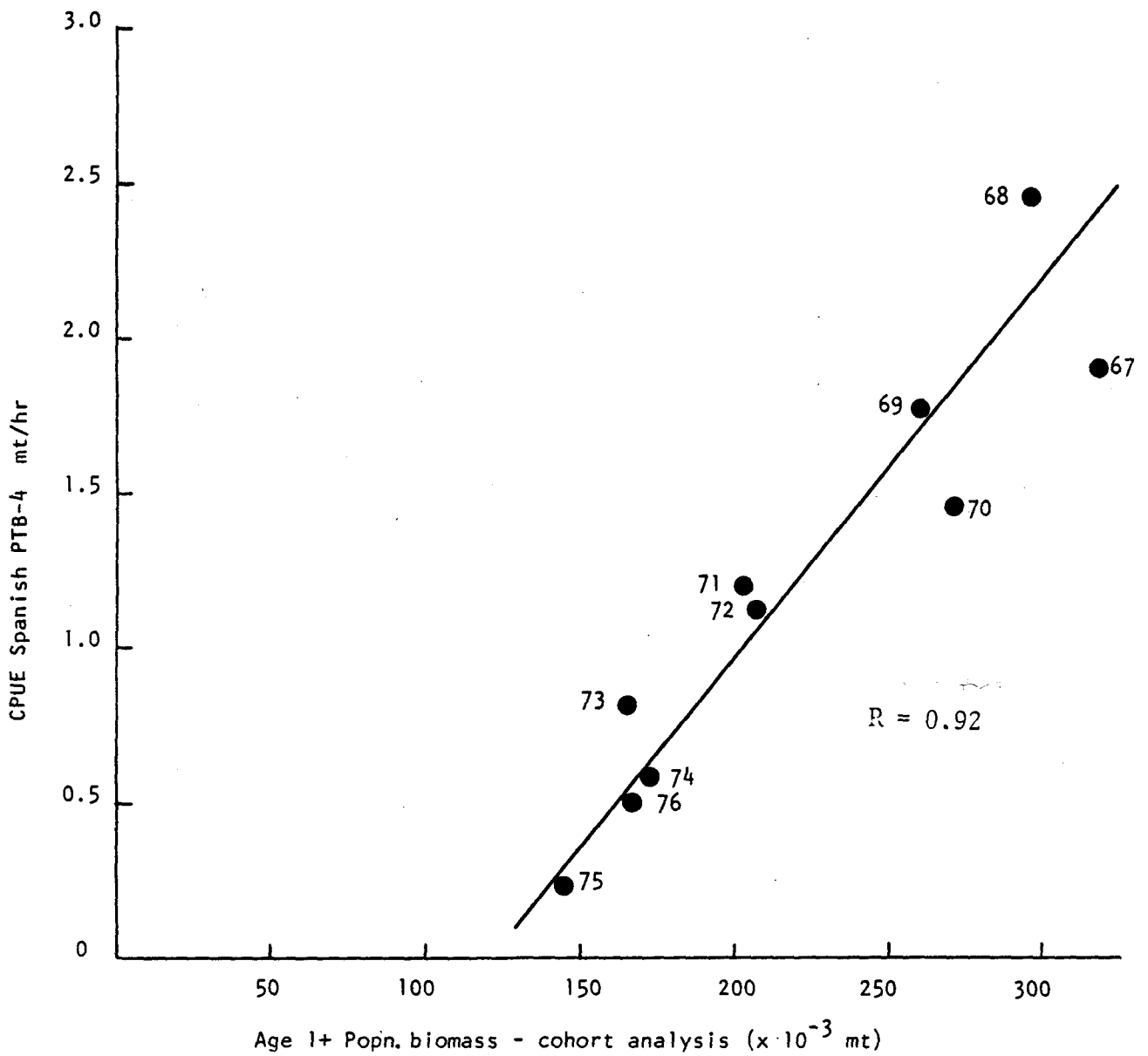
Fig. 9   4VsW Cod: CPUE Spanish pair trawls vs 4+ biomass
         estimates, line fitted by eye.