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Canadian Atlantic Fisheries
Scientific Advisory Committee

CAFSAC Research Document 89/57

Comité scientifique consultatif des
pêches canadiennes dans l'Atlantique

CSCPCA Document de recherche 89/57

Stock Status of 4VsW cod in 1988

by

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Abstract

The catch in 1988 was 37,489 t, a reduction of almost 7900 t from 1987. The reduced catch was a result of management measures to meet a TAC of 38,000 t. The commercial catch rate declined almost 50% compared with 1987 and the research vessel surveys indicate a continued decline in the mature (ages 4+) stock size.

Two seasonal survey series were analyzed in addition to the July survey series (1971 - 1988). The autumn (Sept-Oct) series runs from 1978 to 1984 while the spring (Feb-Mar) series covers 1979 to 1988 with the exception of 1985.

The SPA was tuned using ADAPT with the July RV population numbers at age and the standardized commercial catch rate for otter trawlers. The fully recruited fishing mortality was 0.3 and has been relatively stable over the past three years.

If the 1989 TAC of 35,000 t is taken it will generate a fishing mortality of 0.221 and the projected $F_{0.1}$=0.2 catch in 1990 would be 34,000 t. Application of the 50% rule would set the target F in 1990 of 0.21 and the resulting catch in 1990 would be 35,000 t.

Résumé

Les prises de 1988 totalisaient 37 489 t, soit une réduction de près de 7 900 t par rapport à 1987. Les prises réduites sont dues à des mesures de gestion destinées à atteindre une TPA de 38 000 t. Le taux de prise commerciale a diminué de près de 50 % par rapport à 1987 et les relevés des bateaux de recherche indiquent une diminution continuelle des stocks de poissons matures (4 ans et plus).

Deux séries de relevés saisonniers ont été analysées en plus de la série de relevés de juillet (1971-1988). La série d'automne (sept.- oct.) va de 1978 à 1984, alors que la série du printemps (févr. - mars) couvre la période de 1979 à 1988, à l'exception de 1985.

L'ASP a été raffinée à l'aide du modèle ADAPT et des valeurs de populations obtenues à l'aide des bateaux de recherche en juillet correspondant à l'âge et au taux de prise commerciale normalisé pour les chalutiers. Le taux de mortalité par pêche du groupe entièrement recruté était de 0,3 et il s'est maintenu à un niveau relativement stable depuis trois ans.

Si l'on prend pour base le TPA de 1989 de 35 000 t, on obtient un taux de mortalité par pêche de 0,221 et les prises projetées au niveau $F_{0.1}$=0,2 seraient de 34 000 t en 1990. L'application de la règle de 50 % donnerait, en 1990, un F cible de 0,21 et les prises qui en résultent seraient de 35 000 t en 1990.

Introduction

The preliminary catch reported for 1988 was 37,489 t (Table 1, Figure 1) approximately 500 t short of the TAC of 38,000 t. The foreign catch was 108 t, a slight increase over 1987, mostly from bycatch in the silver hake fishery. The decline in total catch was almost 7900 t and the relative reduction was approximately equal between 4Vs and 4W (Figure 2).

The catches by Canadian vessels are broken down by years in Table 2 and Figure 3. The miscellaneous gear catches are almost entirely handline and gillnet. The decline in total catch (83% of 1987) is reflected in the proportionate declines in trawler and longline catches. The only gears to experience increased catches were the seines and miscellaneous gears in Sub. Div. 4Vs. The offshore (vessels >100') continued under Enterprise Allocations and took 96% of their allocations. The 65-100' fleets, both fixed and mobile gears, failed to take their entire allocations, however all the gear sectors under 65' experienced varying degrees of overrun with a maximum overrun of 18% by the fixed gear <45' (Table 3). As in the previous year all vessels <65' were under a 10% bycatch limit throughout the year and a variety of trip limits at different times in the year (Table 4).

Catch at Age

The catch at age prior to 1988 was taken from Fanning et al. (1988). A total of 8 age/length keys were used to construct the 1988 catch at age (Table 5). Sampling was adequate enough to construct quarterly keys for the mobile gears (all trawlers and Scottish/Danish seines) and 3 keys for long/hand lines (1st half, 3rd and 4th quarter). There was little catch in the first quarter by the long/hand lines so lack of samples in that period is not a problem. A single key for the full year for gillnets was used for 1988. Samples for this key were minimal (2 samples/70 otoliths), however given the relatively small catch it was considered adequate. In the past, the practice has been to use the length/weight parameters estimated from the current July RV survey for all age/length keys in a year. In 1988, mean values of a and b were calculated for the 3 seasonal survey series that are available in the 4VsW area. The seasonal surveys will be described in more detail later. The resulting seasonal mean values were applied to corresponding keys by using the spring values for the 1st quarter key, July values were used for any keys covering 2nd or 3rd quarter catches and the fall values were used for 4th quarter keys.

The effect of using the seasonal mean values for the length/weight parameters was evaluated by recalculating the catch at age for the same breakdown of keys with the July 1988 RV estimates for all keys. The numbers at each age were lower when the July 1988 values were used, however for the ages where catches were large, ie. ages 4-13, the percentage reduction was less than 9% and for ages 5-10 it was less than 5%. The final formulation of ADAPT for this assessment was used to evaluate the impact of the change in catch at age. The estimate of mean fully recruited F would have been 3.3% lower (ie. 0.29 cf 0.30). The use of seasonal values of length/weight parameters averaged over a number of years removes annual variation in condition and reduces sampling variation. Further investigation of appropriate spans of years to average over is warranted, particularly with respect to the July RV series.

The resulting estimated catch at age for 1988 is given in Table 6 and is combined with other years in Table 7.. The totals at age in Table 6 were all adjusted upward by 0.36% to account for the percentage of the catch which was not represented in the sampling. The observed catch at age in 1988 is compared with the projected catch at age for last years assessment (Fanning et al., 1988) in Figure 4 where it can be seen that there was fairly close agreement except that catches of the 1981 and 1984 year classes exceeded the projected values.

The commercial weights at age (Table 8; Figure 5) continued to decline at all ages over 7 with indications of recovery or stability at ages 2, 3, 6 and 7.

Indices of Abundance

Commercial Catch Rates

A multiplicative model was used to standardize the otter trawl catch rate series from 1968 to 1988. The model and gear categories were the same as in the previous assessment (Fanning et al., 1988 and references therein). The 1988 data were obtained from the ZIFF data sets and appended to the data used in the previous assessment (Table 9). The GLIM (Generalized Linear Interaction Modelling) package (Payne, 1986) was used to estimate the model parameters because of the greater diagnostic and modelling capabilities it offers over STANDARD (Anon, 1986). Comparisons done in the previous assessment (Fanning et. al., 1988) gave identical results from both packages when estimating the same model. Factors for year, month, gear/tonnage class and division were used. The standardized C/E (Table 10, Figure 6) declined almost 50% from 1987 to 1988 and is the lowest since 1978. Unlike previous assessments using essentially the same model, the factor for division (4Vs vs 4W) was significant (Table 11). This would be consistent with a shift of the stock from 4W to 4Vs over the past several years. The factor for division would not become significant until there was sufficient years of data to outweigh the previous history of no difference in catch rate between divisions. This implies that the fixed, non-interacting factor model currently used for catch rate standardization is inadequate for this stock. A model utilizing nested factors may be more appropriate.

The International Observer Program (IOP) observed 2417 trawl sets from domestic TC5 stern trawlers in 4VsW during 1988; of these, 1233 sets were cod directed. The coverage level for 1988 was 11% of the total catch (table below). Directed TC5 catch rates were observed to be marginally higher in the first half of the year.

	Reported Catch	Total Obs Domestic Catch	Observed TC5 Catch	Observed Directed TC5 Catch	Observed Directed TC5 Effort	Observed Directed TC5 CPUE
Jan-June	16584	1732	886	780	713	1.094
July-Dec	20797	2251	1955	1865	2049	0.910
Total	37381	3983	2841	2645	2762	0.958

The IOP catch rates reported here is restricted to TC5 vessels which results in a somewhat higher number than the standardized catch rate which includes TC2-4 as well.

Research Vessel Surveys

The annual Scotian Shelf groundfish survey conducted every July since 1970 was the major RV index used for this assessment. Two other survey series were also examined, a Fall series conducted in September-October from 1978 to 1984 and a Spring series conducted in March from 1979 to 1988, excluding 1985.

The estimates of population numbers at age from each RV survey (Table 12a, b, c) were calculated for Div. 4W and Sub. Div. 4Vs using separate age-length keys and then summed to the whole stock area. The variances were also calculated for 4Vs and 4W separately and were used to generate the coefficients of variation (CV's) (Tables 13a,b,c).

Looking at the July series, the estimated total numbers in 1988 (Figure 7) remained nearly equal to 1987, however the age 4+ numbers declined to the second lowest value seen since 1980. In spite of the decline, the 1988 4+ value remains high relative to the years 1970 to 1980. The distribution of the age 4+ stock between 4W and 4Vs (Figure 8) was less skewed than in the past two years with the 4W percentage increasing to 46% compared to 12% in 1987.

The population trends from the two seasonal surveys (Figure 9) were compared to the July survey. Neither seasonal survey has the extremely high peak in abundance seen in July 1982. The July 1982 survey had very large catches of the 1979-80 year classes. The spring survey indicates the same two year classes to be large, but they are not as well detected until a year later. The same year classes are predominant in the Fall surveys in 1982 and 1983, however the total estimates for those years are relatively low. Separating the 3 seasonal survey estimates by area, ie. 4Vs and 4W (Figures 10, 11) reveals considerable differences in the inter-annual patterns. The most dramatic examples of this are seen in 1973 and 1982. Both of these years have extremely high survey estimates relative to adjacent years, however the large spike in estimated numbers in both years comes entirely from 4W. The only spike in 4Vs is in 1984 and is of much lower magnitude than either of the 4W spikes. The 1982 (4W) and 1984 (4Vs) spikes when combined give a picture of very large recruitment (1979 & 1980 year classes) in 4W which only spread into 4Vs two years later (ie. 1984).

Distribution by Age in Research Vessel Surveys

To examine changes in the distribution with age, the survey catches by age groupings (0-1, 2-3, 4-5, 6-7 and 8+) in the spring, summer and fall 1981 RV surveys are presented in a series of maps (Figures 12, 13 and 14 respectively).

The year 1981 was chosen as an example due to the fact that all 3 surveys were available and the very large year classes coming in to the population had not overly influenced the surveys. It is interesting that the patterns by age are very similar for all 3 surveys. The youngest ages seem to be more predominant in 4W and as the age increases the predominance shifts eastward until the oldest ages, although widely scattered, appear to be more abundant in 4Vs.

Length/Weight Relationships

The three seasonal surveys were also used to estimate length/weight parameters (a's and b's). The resulting estimates by year and season are used to predict the weight of a 60 cm fish (Figure 15). All three series indicate an overall trend of decreasing weight at length, ie. decreasing condition from the late 70's to the end of each series. The July and March series both indicate that condition was the lowest in 1986 and has increased in 1987 and 1988. As reported in the section on catch at age, the mean a's and b's for each season for all available years were used to construct the catch at age.

The effect of variations in the a's and b's on the construction of catch at age will be investigated in future. For the spring survey, further investigation of the effect of proximity to the spawning season is required.

Variation in Size at Age by Area

Mean length at age in the July RV survey was calculated for 4Vs and 4W separately (Table 14a and 14b) to investigate whether variation in size at age by area could potentially cause a significant change in overall observed size at age due to the shift in the fishery from 4W to 4Vs. The question was explored graphically by plotting the ratio of mean length at age in 4Vs over 4W by year (Figure 16). For the youngest ages (1 and 2) there is no apparent trend with time while ages 3-5 show some indication of sequences above or below the line. Ages 6 to 9 show a consistent pattern with the ratio above 1 for 1979 to 1985 for all 4 ages.

When all ages are averaged together (Figure 17), there is a fairly clear trend over time, although 1973 stands out as an exceptional year. The magnitude of the observed trend is quite small with the overall mean size between divisions varying by less than 10% in all years. Thus, while there is some annual pattern between divisions, the large changes in mean size at age observed in this stock are unlikely to be due in large part to shifts in the areal distribution of the fishery.

Sequential Population Analysis

The input partial recruitment was calculated as the mean partial recruitment of the penultimate 3 years assuming ages 7-10 to be fully recruited. Mean fully recruited F in each year was calculated on ages 7-10 weighted by population numbers. The values of the input PR for ages 1 and 2 were set to 0.001 as was done last year. A flat-topped PR for the oldest ages was assumed for all SPA calculations. Comparison of the input PR (based on 1985-87) with those used in the past two assessments is given below:

Year Assessed	Years Averaged	AGE 1	2	3	4	5	6	7+
1987	83-85	.005	.005	.060	.350	.800	1.000	1.000
1988	84-86	.001	.001	.021	.271	.695	1.000	1.000
1989	85-87	.001*	.001*	.013	.245	.673	1.000	1.000

* Set equal to previous year

The trend over years of decreasing PR at ages 3-5 is consistent with the decline in mean weight at age over the same years.

Calibration

Natural mortality was assumed to be 0.2 for all ages and years. The SPA was calibrated using the adaptive framework (Gavaris, 1988) implemented in the APL workspace ADAPT3 (see Appendix 1 for listings). The 1988 population size was estimated at ages 3-8. The tuning framework included residuals from the July RV survey from 1971-88 and the standardized catch rate series for the same years. Residuals from each of the indices were weighted by the reciprocal of the estimated standard errors for the index.

Table 15 summarizes the model and objective function that produced the population matrix (Table 16), F matrix (Table 17), residual matrices (Table 18) and calibration statistics (Table 19). Terminal F in 1988 was estimated at 0.30.. The two residuals for 1974 age 5 and 1975 age 6 were deleted because they generated unacceptable patterns in the residual plots at age. Removing the two points had very little effect on the estimates of population size, however the RV calibration slopes changed considerably. The resulting plots (Figure 18) show the deleted points to be extreme outliers, while the remaining points are well distributed.

The CPUE index and RV index were each used alone in ADAPT to calibrate SPA's. The CPUE calibration indicated that terminal F was approximately 0.35 while the RV series alone indicated F_t to be 0.22.

Other runs of ADAPT were made using the seasonal surveys with the July RV and CPUE. The fall survey was not used because the series ended in 1984 and therefore has no information on recent trends in the stock. The spring RV survey is not subject to the same drawbacks as the fall series, however there are two concerns which need to be dealt with before the series can be used as an input to the tuning process. A method of adjusting for unsampled strata is necessary because of the relatively high frequency of ice preventing complete coverage of the survey area. The timing of the spring survey relative to the spawning season of the cod is also important. If the survey is conducted when the fish are highly aggregated to spawn, then it is possible that the resulting population estimates will be artificially high. This relationship to the spawning season will also have a considerable impact on the length/weight parameters estimated. If the samples are collected when the fish are in late pre-spawning condition then observed weight at length will be much higher then it would be a few weeks later when the fish have mostly all spawned.

Assessment Results

The current stock status can be seen in perspective in the long term 1958-88 mean 3+ number and biomass (Figure 19). The biomass and number are still well above the low levels of the 1970's, however there has been a significant decline since the 1983-85 period. The last year class for which a reliable estimate of recruitment is available is 1984 (Figure 20). The 1984 year class seems to be small, about the size of the small 1971-77 year classes. The 1983 year class appears to be the smallest year class since 1958 by a factor of 2. The mean fully recruited fishing mortality (Figure 21) is 0.3 which is well above the $F_{0.1}$ level of 0.2, however the mortality rates for 1986-88 have been nearly stable and are well below the exploitation experienced by this stock prior to 1977.

The ongoing fishery mortality above $F_{0.1}$ is continuing the trend of declining numbers and biomass since 1985. There are still no clear indications of incoming recruitment to offset the current trend.

Prognosis

Catch projections to 1990 were made from beginning of year 1989 numbers using the average weights at age from the years 1986-88 and the average partial recruitment from the same years. Recruitment for the 1985-89 year classes to the age 1 population was set to the geometric mean at age 1 of the 1970-84 year classes (83.7 million fish). This reflects a somewhat larger estimate of the 1985 year class which had been set equal to the smallest previously observed in the last assessment. The input data for projections are:

Age	Numbers in 1989	Mean Weight	Partial Recruitment
1	83762*	0.067	.0003
2	68578*	0.262	.0003
3	56122*	0.565	.014
4	45760*	0.921	.206
5	34608	1.271	.705
6	6941	1.661	.818
7	23533	2.120	1
8	10640	2.644	1
9	8005	3.455	1
10	4297	4.406	1
11	1575	5.707	1
12	688	6.467	1
13	414	7.774	1
14	164	10.543	1
15	28	10.742	1

* set as described in text

If the 1989 TAC of 35,200 t is taken it will generate a fishing mortality of 0.221 and the projected $F_{0.1}$ catch in 1990 would be 34,000 t. Application of the 50% rule would set the target F in 1990 at 0.21 and the resulting catch in 1990 would be 35,000 t.

Retrospective

The assessment results of the last 6 years for terminal F and age 3 recruitment are summarized below:

Assessment Year	F_t	Year class at age 3 (millions) 1979	1980	1981	1982	1983	1984	1985
1984	.35	111	112	(72)*	(72)			
1985	.40	81	69	43	(72)			
1986	.30	89	71	44	43	(61)		
1987	.35	74	87	54	48	43		
1988	.28	85	101	62	57	31	(31)	
1989	.30	85	94	66	76	18	54	(56)

* numbers in parentheses were assumed

The perception of the 1979-81 year classes has not changed significantly over the previous assessment, however the 1982 year class now appears substantially larger and the 1983 year class substantially smaller than in the previous assessment.

Acknowledgements

The authors would like to thank Stephen J. Smith of the Marine Fish Division for assistance with the standardized catch rate analysis and other matters (bringing coffee, levity, etc.).

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Table 1. 4VsW cod nominal catches by country and NAFO Divisions.

YEAR	CANADA	FRANCE	PORTUGAL	SPAIN	USSR	OTHERS	TOTAL	SUBDIV. 4Vs	DIV. 4W	TAC
1958	17938	4577	1095	14857	-	124	38591	23790	14801	-
1959	20069	16378	8384	19999	-	1196	66026	47063	18963	-
1960	18389	1018	1720	29391	-	126	50645	27689	22956	-
1961	19697	3252	2321	40884	113	42	66309	34237	32072	-
1962	17579	2645	341	42146	2383	60	65154	26350	38804	-
1963	13144	72	617	44528	9505	307	68173	27566	40607	-
1964	14330	1010	-	39690	7133	1094	63257	25496	37761	-
1965	23104	536	88	39280	7856	122	70986	36713	34273	-
1966	17690	1494	-	43157	5473	711	68525	27177	41348	-
1967	18464	77	102	33934	1068	513	54158	26607	27551	-
1968	24888	225	-	50418	4865	32	80428	48781	31647	-
1969	14188	217	-	32305	2783	672	50165	22316	27849	-
1970	11818	420	296	41926	2521	453	57434	28639	28795	-
1971	17064	4	18	30864	4506	107	52563	24128	28435	-
1972	19987	495	856	28542	4646	7119	61645	36533	25112	-
1973	15929	922	849	30883	2918	2592	54093	23401	30692	60500
1974	10700	35	1464	27384	3097	1061	43741	19610	24130	60000
1975	9939	1867	546	15611	3041	1512	32517	11694	20823	60000
1976	9567	697	-	11090	1018	2035	24407	11553	12854	30000
1977	9890	68	-	-	97	335	10390	2873	7517	7000
1978	24642	437	-	57	218	51	25405	10357	15048	7000
1979	39219	18	-	2	683	108	40030	15393	24637	30000
1980	48821	17	5	5	338	66	49252	31378	17874	45000
1981	53053	-	-	-	630	35	53718	32107	21611	50000
1982	55675	-	-	-	45	34	55754	40110	15644	55600
1983	50898	-	1230	-	190	62	52380	33170	19210	64000
1984	51765	-	303	-	110	30	52546	42578	9968	55000
1985	56553	-	870	-	21	11	57062	48189	9266	55000
1986[1]	51248	-	-	-	28[2]	34[2]	51306	43819	7487	48000
1987[1]	45292	-	-	-	35[2]	45[2]	45372	39647	5725	44000
1988[1]	37381	-	-	-	89[2]	19[2]	37489	32933	4556	38000
1989										35200

[1] Preliminary Interzonal

[2] IOP

Table 2. Canadian catch of 4VsW cod by gear and (sub) Division (from NAFO).

YEAR	4Vs OTB	4Vs LL	4Vs SDN	4Vs MIS	4Vs TOTAL	4W OTB	4W LL	4W SDN	4W MIS	4W TOTAL	4VsW OTB	4VsW LL	4VsW SDN	4VsW MIS	4VsW TOTAL
1964	2056	42	2	-	2100	7324	708	88	4110	12230	9380	750	90	4110	14330
1965	7366	84	22	-	7472	10290	1339	159	3844	15632	17656	1423	181	3844	23104
1966	6374	143	14	-	6531	6614	1472	38	3035	11159	12988	1615	52	3035	17690
1967	6735	99	27	-	6861	6460	1453	71	3619	11603	13195	1552	98	3619	18464
1968	9501	48	18	-	9567	8360	1928	89	4944	15321	17861	1976	107	4944	24888
1969	3540	43	7	-	3590	4695	2647	13	3243	10598	8235	2690	20	3243	14188
1970	3054	21	1	-	3076	3602	3039	62	2039	8742	6656	3060	63	2039	11818
1971	5827	40	-	-	5867	4768	4173	26	2230	11197	10595	4213	26	2230	17064
1972	9856	115	4	-	9975	4732	3350	7	1923	10012	14588	3465	11	1923	19987
1973	6392	82	3	-	6477	4723	3173	20	1536	9452	11115	3255	23	1536	15929
1974	4644	56	-	-	4700	1335	2512	5	2148	6000	5979	2568	5	2148	10700
1975	1824	63	-	-	1887	3566	2558	11	1917	8052	5390	2621	11	1917	9939
1976	3755	42	-	-	3797	937	2289	14	2530	5770	4692	2331	14	2530	9567
1977	2751	50	4	-	2805	1873	3121	68	2023	7085	4624	3171	72	2023	9890
1978	9561	294	19	-	9874	7997	4321	839	1611	14768	17558	4615	858	1611	24642
1979	14853	438	86	-	15377	13784	5577	3245	1236	23842	28637	6015	3331	1236	39219
1980	28941	2116	321	-	31378	6298	6032	3440	1673	17443	35239	8148	3761	1673	48821
1981	27662	4274	171	-	32107	9148	7660	2433	1705	20946	36810	11934	2604	1705	53053
1982	32247	7069	794	-	40110	6352	5877	1943	1393	15565	38599	12946	2737	1393	55675
1983	26817	4475	671	-	31963	11280	4451	1936	1268	18935	38097	8926	2607	1268	50898
1984	37270	4122	879	21	42292	3475	3067	2144	1126	9812	40745	7189	3023	1147	52104
1985	38533	7449	718	609	47309	3035	2758	1229	2222	9244	41568	10207	1947	2831	56553
1986[1]	34515	8145	250	880	43791	2206	2700	626	1925	7457	36721	10845	875	2807	51248
1987[1]	32770	6218	254	385	39627	1337	2404	542	1382	5665	34107	8622	796	1767	45292
1988[1]	26165	5446	611	707	32929	1109	1698	383	1262	4452	27274	7144	994	1969	37381

[1] Preliminary Interzonal

Table 3. 4VsW cod - 1988 allocations and catches.

Gear Sector	Allocations at Specific Dates: Jan 1	June 1	Oct 1	Nov 15	Dec 31		Total Catch (Quota Report)*	
Vessels >100'	25000	25000	25064	24964	25100		24176	
FG 65-100'	560	560	520	595	559		458	
MG 65-100'	675	675	651	676	576		219	
FG 45-65'								
(Jan-Apr)	400	445	445	172	172		157	
(May-Aug)	1445	1400	1400	1121	1121		1163	
(Sept-Dec)	300	300	300	300	300	1593	304	1624
MG 45-65'								
(Jan-Apr)	1020	1020	1020	1020	1020		1085	
(May-Aug)	1020	1020	1020	1020	1020		1302	
(Sept-Dec)	1020	1020	1020	1020	1020	3060	903	3290
FG <45'								
(Jan-Mar)	200	200	200	200	200		58	
(Apr-May)	530	530	530	530	530		914	
(June-Aug)	3450	3450	3450	3450	3450		4334	
(Sept-Dec)	1065	1065	1065	1617	1617	5797	1541	6847
MG <45'								
(Jan-Apr)	330	330	330	330	330		454	
(May-Aug)	660	660	660	660	660		973	
(Sept-Dec)	325	325	325	325	325	1315	38	1465
Totals	38000				38000		38079	

* - preliminary

Table 4. 4VsW cod - 1988 management regulatory measures.

Gear SEctor	Date Effective	Trip Limit (kg)
Vessels >100'	No variation orders issued	
FG 65-100'	No variation orders issued	
MG 65-100'	No variation orders issued	
FG 45-65'	January 1	9000
	May 1	20400
	August 23	22600
	November 10	2275
MG 45-65'	January 1	9000
	February 11	1500
	March 19	9000
	April 8	4500
	May 1	9000
	May 7	1500
	June 2	9000
	August 1	0
	September 1	9000
	December 1	20000
	December 14	0
FG <45'	January 1	9000
	June 1	18000
	June 28	11300
	August 23	13600
	September 22	4500
	October 9	1500
	October 26	4500
	November 10	1500
MG <45'	January 1	9000
	February 11	1500
	March 19	0
	April 18	4500
	June 25	0

All vessels less than 65' were subject to a 10% by-catch limit throughout 1988.

Table 5. Data used to generate 1988 age length keys for 4VsW cod.

Key	Gear	Period Covered	Length-Weight Coefficient a	b	Season	Number Measured	Number Aged	Catch
1	OTB, OTM, PTB, SNU	Q_1 - Jan-Apr	0.0080	3.0744	Spring	4463	335	8613
2	OTB, OTM, PTB, SNU	Q_2 - Apr-June	0.0064	3.0398	Summer	4227	261	6367
3	OTB, OTM, PTB, SNU	Q_3 - July-Sept	0.0064	3.0398	Summer	2368	253	4081
4	OTB, OTM, PTB, SNU	Q_4 - Oct-Dec	0.0064	3.0959	Fall	6502	446	9207
5	LL, LH	Q_1+Q_2 - Jan-June	0.0064	3.0398	Summer	4221	809	2936
6	LL, LH	Q_3 - July-Sept	0.0064	3.0398	Summer	4068	640	4579
7	LL, LH	Q_4 - Oct-Dec	0.0064	3.0959	Fall	906	154	735
8	GN	Jan-Dec	0.0064	3.0398	Summer	884	70	837

Table 6. 4VsW cod catch at age ('000) by key in 1988.

Age	OTB, OTM, PTB, SNU				LL, LHP			GNS	
	Q_1	Q_2	Q_3	Q_4	Q_1 + Q_2	Q_3	Q_4	Combined	Total
1	0	0	0	0	0	0	0	0	0
2	0	0	6	3	0	0	0	0	9
3	2	23	134	55	0	0	0	0	214
4	59	176	482	784	14	28	6	0	1549
5	382	358	489	917	47	133	19	5	2350
6	885	714	963	1242	150	414	44	81	4493
7	998	1229	591	732	199	238	36	48	4071
8	947	583	236	622	208	454	56	89	3195
9	544	411	39	266	129	226	14	46	1675
10	184	71	38	76	98	128	13	6	614
11	66	62	4	8	62	56	8	2	268
12	7	43	0	35	45	23	7	1	161
13	19	9	0	2	16	17	1	0	64
14	0	0	0	0	8	3	0	0	11
15	0	3	0	0	6	2	0	0	11
16	0	1	0	0	7	4	1	0	13
Total	4093	3683	2982	4742	989	1726	205	278	18698

Table 7. 4VsW cod commercial removals at age ('000).

	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978
1	2495	1426	1293	2311	2383	1418	1482	1792	728	2	177
2	16045	9097	8631	15218	17738	12142	8451	9979	4061	24	153
3	17413	7684	8886	12582	14227	14881	12885	9485	3587	386	1004
4	17783	13724	14802	9146	13361	7507	9947	4341	3713	1073	3650
5	15633	10248	13673	8809	9661	9755	7130	4549	4818	1559	4621
6	8297	6073	4539	10262	8780	3823	2766	2594	2412	871	2441
7	3482	2144	1942	5160	3432	2996	944	2627	1426	501	768
8	895	510	759	1849	1919	3724	1323	612	611	220	213
9	816	237	236	496	358	1166	413	497	184	128	112
10	361	50	72	114	393	273	369	660	49	35	80
11	152	95	137	131	79	299	15	153	22	44	26
12	211	58	56	72	2	3	5	126	107	55	28
13	33	12	9	98	37	7	0	36	1	11	26
14	17	7	12	12	0	5	0	9	4	3	9
15	1	2	4	51	1	5	0	9	1	2	4
1+	83634	51367	55051	66311	72371	58004	45730	37469	21724	4914	13312
2+	81139	49941	53758	64000	69988	56586	44248	35677	20996	4912	13135
3+	65094	40844	45127	48782	52250	44444	35797	25698	16935	4888	12982
4+	47681	33160	36241	36200	38023	29563	22912	16213	13348	4502	11978
5+	29898	19436	21439	27054	24662	22056	12965	11872	9635	3429	8328

	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
1	12	31	3	5	0	0	0	0	0	0
2	81	152	348	149	0	2	4	2	0	9
3	1629	2034	3742	2500	3048	378	154	121	36	215
4	6164	5119	9724	7664	8251	6034	2323	4121	832	1555
5	9145	7112	7276	9953	7368	9434	8353	7506	5388	2359
6	4871	6147	4852	3449	5967	6141	7782	9026	5584	4510
7	1162	2929	2991	2408	1938	4192	3922	3527	5718	4086
8	371	1066	1455	1273	999	1318	2224	1518	2585	3207
9	76	319	393	674	576	579	978	1105	1055	1681
10	23	88	126	304	229	297	427	437	581	616
11	10	47	62	156	140	156	274	282	228	269
12	5	26	32	67	50	63	168	106	129	162
13	4	4	21	57	22	34	65	65	60	64
14	1	1	2	51	16	17	19	11	10	11
15	0	4	6	19	6	2	16	19	15	11
1+	23554	25079	31033	28728	28610	28647	26709	27846	22221	18754
2+	23541	25048	31030	28723	28610	28647	26709	27846	22221	18754
3+	23460	24896	30682	28574	28610	28645	26705	27844	22221	18745
4+	21831	22862	26940	26074	25562	28267	26551	27723	22185	18530
5+	15666	17743	17216	18409	17311	22233	24228	23602	21353	16975

Table 8. 4VsW cod mean weights at age in the commercial catch.

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
1	.02	.01	.05	.08	.13	.10	.10	.10	.20	.07	.07
2	.15	.11	.18	.22	.33	.27	.28	.28	.62	.53	.57
3	.45	.32	.44	.45	.62	.53	.57	.81	.95	.76	.80
4	.91	.64	.81	.79	1.02	.89	.96	1.09	1.25	1.06	1.15
5	1.50	1.07	1.29	1.21	1.53	1.34	1.46	1.67	1.68	1.70	1.60
6	2.19	1.56	1.85	1.72	2.13	1.87	2.03	2.36	2.47	2.39	2.21
7	2.94	2.09	2.48	2.28	2.82	2.47	2.66	3.17	3.61	3.13	3.08
8	3.73	2.65	3.14	2.90	3.58	3.12	3.35	4.58	5.23	3.71	4.31
9	4.51	3.21	3.83	3.54	4.41	3.81	4.07	4.14	5.59	4.77	5.26
10	5.28	3.75	4.52	4.22	5.28	4.53	4.80	5.33	6.54	6.84	6.92
11	6.02	4.28	5.20	4.90	6.19	5.27	5.55	4.65	7.92	7.96	7.56
12	6.71	4.77	5.87	5.59	7.13	6.01	6.29	4.91	9.21	9.41	10.19
13	7.36	5.23	6.52	6.28	8.09	6.76	7.02	7.14	10.40	10.63	7.92
14	7.95	5.65	7.14	6.96	9.05	7.51	7.74	8.59	9.75	10.03	8.13
15	8.49	6.04	7.73	7.62	10.01	8.24	8.43	10.60	8.68	11.45	14.45

	1981	1982	1983	1984	1985	1986	1987	1988
1	.07	.07	.12	.07	.07	.07	.07	.07
2	.62	.58	.39	.56	.64	.26	.21	.32
3	.83	.81	.81	.72	.70	.69	.50	.51
4	1.14	1.07	1.08	1.00	1.04	.96	.95	.85
5	1.69	1.58	1.55	1.42	1.46	1.27	1.33	1.21
6	2.13	2.39	2.10	1.91	1.98	1.68	1.61	1.69
7	2.97	2.78	3.10	2.49	2.49	2.42	1.97	1.97
8	3.94	4.07	3.53	3.44	3.17	2.77	2.76	2.40
9	5.70	5.49	4.38	3.78	3.93	3.40	4.07	2.89
10	7.16	7.08	5.76	4.96	5.11	5.02	4.32	3.88
11	7.67	8.74	6.99	6.84	6.37	5.29	6.75	5.08
12	9.26	9.10	9.04	8.10	6.12	6.84	6.64	5.92
13	11.87	11.43	10.63	8.95	9.94	10.05	7.54	5.73
14	8.65	10.59	11.71	10.23	11.17	9.42	12.59	9.62
15	9.84	12.48	12.69	11.85	11.26	11.73	13.11	7.39

Table 9. Data selection in recent years for standardization of 4VsW cod OTB 1, 2 catch rates.

1984 - CAFSAC Res. Doc. 84/78

Included: 1968-76 Spanish PTB TC 4, TC 5
1968-83 Canadian (M&Q) LLS TC 2-4
1974-77, 1980-83 Canadian (M&Q) OTB 1, TC 4
1974-77, 1980-83 Canadian (M&Q) OTB 2, TC 5

Excluded: 1968-73 Canadian (M&Q) (OTB 1, TC 4), (OTB 2, TC 5)
- these two series indicated stable or increasing biomass when other indications were that there was a substantial decline in biomass.

1978-79 Canadian (M&Q) (OTB 1, TC 4), (OTB 2, TC 5)
- removed because the possibility of substantial misreporting of catch and effort.

1985 - CAFSAC Res. Doc. 85/39

Included: 1965-76 Spanish PTB TC 4, TC 5
1965-84 Canadian (M&Q) LLS, TC 2-4
1965-84 Canadian (N) OTB 1, TC 4
1965-84 Canadian (N) OTB 2, TC 4, TC 5
1965-84 Canadian (M&Q) OTB 1, TC 4
1965-84 Canadian (M&Q) OTB 2, TC 2, TC 3, TC 4, TC 5

Excluded: All observations where catch or effort was less than 10 units.

1965-74 Canadian (M&Q) OTB 1-2 and 1978-79 Canadian (M&Q) OTB 1-2 - as 1984

7 individual points associated with abnormally large residuals were eliminated.

1986 - CAFSAC Res. Doc. 86/46

Included: As in 1985 with the addition of 1985 catch and effort for Canadian (M) and Canadian (N).

Excluded: As in 1985 with the addition of 1985 Canadian (M) OTB 2, TC 5 - due to biased catch rates caused by company imposed trip limits on cod.

Table 9. (Continued)

1987 - CAFSAC Res. Doc. 87/72

Included: 1968-76 Spanish PTB TC 4, TC 5
1968-86 Canadian (M) OTB 1, TC 4
1968-86 Canadian (M) OTB 2, TC 2, TC 3, TC 4, TC 5
1968-86 Canadian (N) OTB 1, TC 4
1968-86 Canadian (N) OTB 2, TC 4, TC 5

Excluded: All observations of catch or effort less that 10.

All longliners.

1988 - CAFSAC Res. Doc. 88/47

Included: As in 1987 with the addition of 1987 catch and effort for Canadian (M) and Canadian (N).

Excluded: As in 1987 with the addition of all OTB 2, TC 6+.

1989 - This Assessment

Included: As in 1988 with the addition of 1988 catch and effort for Canadian (M) and Canadian (N).

Excluded: As in 1988 with the addition of all OTB 2, TC 6+.

Table 10. 4VsW cod final standardized catch rate series for OTB 1-5.

Year	CPUE	Std. Error	CV	Effort
1968	1.3671	0.20107	0.1471	13065
1969	1.3370	0.18887	0.1413	6159
1970	1.1942	0.17235	0.1443	5574
1971	0.8461	0.11894	0.1406	12522
1972	0.8063	0.09816	0.1217	18093
1973	0.7749	0.08968	0.1157	14344
1974	0.5807	0.05793	0.0998	10296
1975	0.4308	0.04507	0.1046	12512
1976	0.5743	0.05722	0.0996	8170
1977	0.5743	0.06731	0.1172	8052
1978	0.6236	0.12649	0.2028	28156
1979	1.3657	0.25648	0.1878	20969
1980	1.0592	0.10566	0.0998	33269
1981	1.0236	0.09918	0.0969	35961
1982	1.2271	0.11673	0.0951	31455
1983	1.1890	0.11919	0.1002	32041
1984	1.3199	0.12983	0.0984	30870
1985	1.6477	0.16501	0.1002	25227
1986	1.9879	0.19700	0.0991	18472
1987	1.4869	0.14916	0.1003	22938
1988	0.7778	0.07781	0.1000	35066

Table 11. Estimated parameters and standard errors of 4VsW cod trawler catch rate from a multiplicative model.

d.f. = 1158 from 1200 observations

Number	Estimate	Std. Err.	Parameter
1	-0.4028	0.1003	1 - Mean over standards
	0.000	Standard	OTB1 TC4 Maritime
2	-0.6053	0.08343	OTB2 TC2 Maritime
3	-0.04930	0.06945	OTB2 TC3 Maritime
4	0.01031	0.06655	OTB2 TC4 Maritime
5	0.1607	0.06109	OTB2 TC5 Maritime
6	-0.1633	0.08628	OTB1 TC4 Newfoundland
7	0.01000	0.1046	OTB2 TC4 Newfoundland
8	0.1642	0.07625	OTB2 TC5 Newfoundland
9	0.5058	0.08056	PTB TC4 Spain
10	0.8979	0.08782	PTB TC5 Spain
11	0.000	Deleted	OTB2 TC6+ Maritime
	0.000	Standard	January
12	0.09529	0.08049	February
13	0.02711	0.07733	March
14	-0.2161	0.07855	April
15	-0.4229	0.08017	May
16	-0.4686	0.08746	June
17	-0.6015	0.09459	July
18	-0.3756	0.08861	August
19	-0.3794	0.08732	September
20	-0.4059	0.08429	October
21	-0.03909	0.08584	November
22	0.01871	0.09040	December
23	0.000	Deleted	1966
24	0.000	Deleted	1967
25	0.5699	0.1474	1968
26	0.5467	0.1423	1969
27	0.4343	0.1448	1970
28	0.08913	0.1409	1971
29	0.03845	0.1218	1972
30	-0.001967	0.1167	1973
31	-0.2923	0.1006	1974
32	-0.5904	0.1070	1975
33	-0.3034	0.1024	1976
34	-0.3013	0.1184	1977
35	-0.2050	0.2026	1978
36	0.5759	0.1836	1979
37	0.3088	0.09389	1980
38	0.2743	0.08934	1981
39	0.4555	0.08734	1982
40	0.4244	0.09448	1983
41	0.5287	0.09254	1984
42	0.7507	0.09236	1985
43	0.9383	0.09204	1986
44	0.6480	0.09297	1987
45	0.000	Standard	1988
	0.000	Standard	Subdiv. 4Vs
46	-0.09440	0.03639	Div. 4W

scale parameter taken as 0.3127

Table 12a. 4VsW cod July research vessel survey population numbers ('000).

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
0	66	16	0	0	592	47	0	0	119	695
1	1009	1051	4241	4391	3535	2262	1608	509	2085	829
2	11273	5245	6607	29985	22520	5789	8824	6561	8923	7247
3	3960	24355	8114	47138	13172	8964	10059	16605	21338	10957
4	6137	5482	21536	38294	3851	4203	6200	10785	23360	11333
5	3042	10792	3969	15352	1378	2044	3920	6721	6461	12344
6	1009	3944	4090	1274	1530	448	765	2951	2383	6182
7	1191	2362	1107	1983	254	548	367	635	607	1841
8	378	1007	373	615	316	144	616	422	126	689
9	71	436	338	294	153	279	0	99	62	280
10	167	48	105	351	110	13	424	0	54	57
11	190	93	0	113	43	0	58	66	0	31
12	69	40	0	0	40	47	0	43	0	3
13	122	141	0	0	0	0	97	0	0	13
14	0	0	0	138	0	0	0	0	0	0
15	0	0	0	18	39	0	0	0	0	0
0+	28686	55012	50480	139948	47534	24789	32938	45396	65517	52501
1+	28620	54997	50480	139948	46943	24742	32938	45396	65398	51806
2+	27611	53945	46239	135557	43408	22480	31330	44888	63313	50977
3+	16337	48700	39632	105572	20888	16691	22506	38327	54390	43730
4+	12378	24345	31519	58433	7716	7726	12448	21722	33052	32773
5+	6240	18863	9982	20140	3865	3524	6247	10937	9693	21440

	1980	1981	1982	1983	1984	1985	1986	1987	1988
0	34	56	6	48	166	0	65	105	163
1	471	3164	1747	32690	966	3066	851	1536	140
2	4795	8702	149955	31705	17327	4009	3157	3587	11204
3	12655	13177	125309	105944	30536	18777	3650	11851	17371
4	7007	20117	43770	45870	45492	22787	14686	11498	14044
5	11859	7665	9827	23549	30825	22202	9258	21105	7783
6	8263	5501	5309	10537	14307	12191	7758	8596	8129
7	3274	2825	2860	2355	9836	6102	2730	6461	4653
8	889	1042	1221	1313	970	2401	1305	3512	2326
9	231	343	273	333	792	1154	574	812	520
10	181	386	277	181	236	273	368	57	123
11	63	100	150	92	558	264	84	190	276
12	0	17	0	44	14	162	0	103	38
13	0	17	0	44	15	0	54	22	0
14	0	0	11	0	21	0	0	0	42
15	0	17	0	0	0	32	0	62	0
0+	49721	63129	340715	254704	152061	93420	44540	69498	66814
1+	49687	63073	340708	254656	151895	93420	44474	69393	66650
2+	49216	59908	338961	221966	150928	90354	43624	67856	66510
3+	44421	51206	189006	190261	133602	86345	40467	64269	55306
4+	31766	38029	63697	84317	103066	67568	36817	52418	37935
5+	24759	17912	19927	38447	57574	44781	22131	40920	23891

Table 12b. 4VsW cod spring research vessel survey population numbers ('000).

	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
0	0	0	0	0	0	0	0	0	0	0
1	496	1645	15723	5044	1623	518	0	392	722	1253
2	4047	5164	7245	42360	6040	3550	0	22668	1915	16599
3	1700	3891	10089	34130	80314	4399	0	40512	5990	19777
4	1138	3174	14843	22560	48640	22316	0	49140	9369	8883
5	2615	4800	9280	13801	9453	14799	0	24312	21127	9013
6	1944	5528	10987	3792	11142	6953	0	27359	10041	10169
7	902	2718	6108	2598	2507	6039	0	13072	6928	2988
8	546	580	2920	2062	1178	1845	0	2786	2510	3897
9	124	122	338	534	550	1200	0	1531	494	965
10	189	49	258	272	182	465	0	582	218	388
11	146	28	51	120	71	41	0	93	74	372
12	42	3	45	59	82	205	0	104	61	86
13	51	17	0	21	28	0	0	15	61	49
14	18	9	0	0	86	13	0	15	21	0
15	19	0	0	10	0	0	0	0	0	68
0+	13976	27728	77888	127362	161898	62342	0	182579	59530	74506
1+	13976	27728	77888	127362	161898	62342	0	182579	59530	74506
2+	13480	26083	62165	122318	160275	61825	0	182188	58808	73253
3+	9433	20919	54920	79959	154235	58274	0	159520	56893	56654
4+	7733	17028	44831	45828	73920	53876	0	119008	50904	36877
5+	6595	13854	29988	23269	25280	31560	0	69868	41534	27994

Table 12c. 4VsW cod fall research vessel survey population numbers ('000).

	1978	1979	1980	1981	1982	1983	1984
0	149	183	1046	48	2556	181	457
1	680	1618	314	9260	2912	8256	309
2	1675	3211	3890	9123	19562	8377	15396
3	9496	4897	16529	16553	10505	26196	36194
4	13950	8356	19627	18838	9073	11583	44493
5	11431	9706	14043	17504	7235	9869	29000
6	5204	4881	12661	6775	3346	6798	12220
7	2642	1562	9286	4296	2233	3785	6533
8	281	704	2539	986	918	1354	1222
9	174	283	1096	478	367	723	895
10	486	137	766	336	227	470	316
11	140	61	366	89	44	84	0
12	0	36	31	0	0	0	60
13	134	0	0	0	0	0	0
14	79	0	74	0	0	0	46
15	35	0	40	0	27	0	0
0+	46556	35635	82306	84284	59005	77678	147141
1+	46407	35452	81260	84236	56449	77497	146684
2+	45726	33834	80946	74977	53537	69241	146375
3+	44051	30623	77056	65854	33975	60864	130979
4+	34555	25726	60528	49301	23470	34667	94785
5+	20605	17370	40901	30463	14397	23084	50292

Table 13a. 4VsW cod CV from July research vessel survey numbers.

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
0	.610	1.000	.000	.000	.697	1.000	.000	.000	.471	.552	.644
1	.283	.363	.747	.649	.405	.341	.372	.276	.151	.226	.292
2	.258	.303	.295	.771	.525	.266	.235	.174	.441	.257	.397
3	.331	.589	.661	.622	.373	.347	.170	.197	.406	.260	.368
4	.445	.466	.844	.785	.187	.253	.257	.247	.237	.220	.243
5	.454	.582	.677	.708	.343	.187	.265	.397	.295	.191	.233
6	.345	.549	.820	.775	.394	.236	.254	.504	.174	.164	.266
7	.400	.520	.806	.679	.366	.333	.265	.514	.120	.169	.256
8	.474	.344	.624	.327	.467	.402	.616	.492	.422	.177	.339
9	.797	.695	.633	.784	.375	.464	.000	.421	.664	.187	.484
10	.541	.730	.781	.523	.580	1.000	.705	.000	.747	.522	.611
11	.844	.600	.000	.443	1.000	.000	1.000	.471	.000	.404	.688
12	1.000	1.000	.000	.000	.737	1.000	.000	.541	.000	1.000	.000
13	.476	.723	.000	.000	.000	.000	1.000	.000	.000	.885	.000
14	.000	.000	.000	.676	.000	.000	.000	.000	.000	.000	.000
15	.000	.000	.000	.713	1.000	.000	.000	.000	.000	.000	.000

	1981	1982	1983	1984	1985	1986	1987	1988
0	.760	1.000	1.000	.534	.000	.698	1.000	.588
1	.395	.307	.905	.563	.667	.368	.346	.449
2	.316	.857	.396	.285	.326	.490	.293	.458
3	.385	.826	.502	.566	.175	.286	.376	.509
4	.293	.749	.443	.478	.262	.341	.274	.319
5	.256	.414	.422	.491	.341	.347	.240	.307
6	.224	.328	.299	.481	.337	.312	.286	.483
7	.269	.350	.186	.540	.263	.290	.304	.444
8	.271	.384	.260	.357	.214	.286	.281	.393
9	.450	.301	.276	.526	.198	.300	.257	.268
10	.518	.469	.257	.311	.242	.291	.394	.347
11	.662	.495	.727	.713	.469	.542	.395	.358
12	1.000	.000	.739	1.000	.290	.000	.531	.425
13	1.000	.000	.739	.740	.000	1.000	1.000	.000
14	.000	.858	.000	.736	.000	.000	.000	.638
15	1.000	.000	.000	.000	1.000	.000	.585	.000

Table 13b. 4VsW cod CV from spring research vessel survey numbers.

	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
0	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
1	.305	.306	.932	.038	.502	.491	.000	.338	.288	.288
2	.160	.457	.542	.271	.726	.259	.000	.788	.306	.705
3	.570	.400	.274	.607	.886	.266	.000	.656	.451	.805
4	.285	.307	.278	.601	.644	.409	.000	.419	.555	.509
5	.221	.376	.301	.352	.460	.481	.000	.322	.549	.542
6	.232	.485	.274	.261	.386	.501	.000	.300	.536	.455
7	.389	.550	.228	.242	.371	.429	.000	.311	.451	.430
8	.387	.639	.240	.196	.370	.387	.000	.323	.452	.438
9	.375	.343	.245	.225	.454	.551	.000	.345	.428	.501
10	.438	.769	.345	.409	.801	.414	.000	.260	.538	.495
11	.385	.401	.630	.477	1.109	.527	.000	.464	.682	.592
12	.500	1.000	.455	.617	.614	.463	.000	.765	.468	.715
13	.702	.826	.000	.461	.960	.000	.000	.534	.468	1.000
14	.612	1.000	.000	.000	.705	1.000	.000	.534	1.000	.000
15	1.000	.000	.000	1.000	.000	.000	.000	.000	.000	.777

Table 13c. 4VsW cod CV from fall research vessel survey numbers.

	1978	1979	1980	1981	1982	1983	1984
0	.622	1.000	.767	.586	.400	.483	.345
1	.341	.666	.476	.564	.295	.419	.328
2	.283	.236	.274	.268	.248	.266	.367
3	.337	.240	.446	.256	.207	.259	.536
4	.310	.219	.267	.292	.209	.256	.541
5	.327	.199	.291	.403	.219	.334	.412
6	.341	.279	.276	.273	.251	.266	.406
7	.459	.297	.314	.274	.255	.267	.302
8	.544	.322	.347	.213	.272	.202	.303
9	.626	.412	.310	.161	.302	.247	.263
10	.752	.474	.384	.289	.389	.290	.435
11	.652	.445	.449	.539	1.000	.282	.000
12	.000	.633	.789	.000	.000	.000	.646
13	.741	.000	.000	.000	.000	.000	.000
14	.705	.000	.628	.000	.000	.000	.787
15	.529	.000	.914	.000	1.000	.000	.000

Table 14a. Mean length at age for cod in sub-division 4Vs from July RV surveys.

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
0	7.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
1	16.76	.00	24.59	20.62	22.60	22.89	19.50	26.66	20.39	18.85
2	29.19	30.15	33.72	33.63	31.70	34.22	32.12	30.39	37.81	31.13
3	40.84	35.15	41.31	40.33	39.49	41.80	38.00	41.01	42.21	38.62
4	48.77	46.54	43.99	46.35	46.53	47.80	45.78	48.73	48.84	47.56
5	52.79	52.69	54.03	50.51	52.64	54.37	52.14	54.69	57.85	53.50
6	57.66	57.10	58.12	65.64	57.57	59.21	64.33	61.80	61.00	64.61
7	60.08	57.96	57.82	65.58	61.16	64.44	71.52	70.65	75.05	74.43
8	62.52	63.68	67.38	60.33	66.22	68.73	68.31	82.80	79.00	83.96
9	97.00	70.00	90.58	82.00	66.77	75.79	.00	81.70	85.00	82.56
10	82.00	70.00	61.27	.00	83.50	88.00	79.53	.00	88.00	97.00
11	68.71	.00	.00	79.71	97.00	.00	.00	80.69	.00	91.39
12	.00	.00	.00	.00	.00	.00	.00	.00	.00	112.00
13	72.86	67.00	.00	.00	.00	.00	100.00	.00	.00	94.00
14	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
15	.00	.00	.00	82.00	115.00	.00	.00	.00	.00	.00

	1980	1981	1982	1983	1984	1985	1986	1987	1988
0	.00	.00	.00	.00	.00	.00	10.00	.00	7.00
1	16.00	20.83	20.53	15.89	22.55	18.80	13.00	14.22	.00
2	29.77	34.31	27.69	26.41	31.70	26.23	29.26	28.48	28.79
3	40.60	41.38	38.79	41.25	38.84	37.17	35.92	38.13	36.54
4	47.22	50.87	45.62	49.41	47.33	42.87	44.70	44.96	39.10
5	53.79	56.66	55.56	55.20	54.47	50.48	50.88	52.01	51.53
6	63.14	61.89	60.90	62.45	58.30	57.30	56.66	55.00	54.22
7	68.04	70.09	64.17	70.76	61.76	62.29	61.97	58.50	56.59
8	76.66	77.95	68.36	72.08	74.52	66.23	64.24	61.95	63.83
9	98.96	90.05	76.60	82.95	71.05	69.45	70.42	66.56	65.22
10	95.37	101.42	83.52	74.16	72.10	74.55	79.38	73.54	82.82
11	106.41	100.00	95.88	101.63	102.68	86.77	91.90	76.91	76.49
12	.00	112.00	.00	109.00	115.00	71.81	.00	85.26	91.00
13	.00	109.00	.00	109.00	91.00	.00	106.00	112.00	.00
14	.00	.00	103.00	.00	109.00	.00	.00	.00	105.92
15	.00	115.00	.00	.00	.00	133.00	.00	112.08	.00

Table 14b. Mean length at age for cod in division 4W from July RV surveys.

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
0	10.00	7.00	.00	.00	9.09	10.00	.00	.00	9.54	9.26
1	21.30	17.47	22.29	21.46	25.55	23.28	21.67	25.42	20.52	18.27
2	36.14	27.33	34.32	31.61	31.89	32.06	33.53	37.41	34.94	28.09
3	45.59	38.74	40.92	39.05	40.84	36.43	40.03	42.50	44.34	40.48
4	52.44	51.95	51.65	47.05	47.55	49.38	45.80	47.82	50.61	49.87
5	58.39	54.50	60.23	51.12	56.32	55.69	52.80	57.78	56.00	51.58
6	57.57	57.82	62.62	60.52	62.74	61.35	57.31	63.44	63.44	59.83
7	74.19	64.30	82.00	59.00	71.66	79.39	67.07	70.98	61.28	63.37
8	77.62	63.96	79.00	71.46	69.56	.00	.00	85.40	75.68	67.84
9	79.00	74.37	98.00	61.00	63.18	87.00	.00	.00	100.00	69.54
10	77.53	.00	.00	94.40	73.00	.00	.00	.00	118.00	.00
11	.00	67.00	.00	.00	.00	.00	88.00	.00	.00	.00
12	112.00	100.00	.00	.00	88.00	100.00	.00	76.00	.00	.00
13	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
14	.00	.00	.00	97.00	.00	.00	.00	.00	.00	.00
15	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00

	1980	1981	1982	1983	1984	1985	1986	1987	1988
0	8.80	9.07	7.00	7.00	10.70	.00	10.00	7.00	9.58
1	20.09	19.37	19.00	18.82	21.31	19.85	19.12	16.97	20.76
2	27.50	29.66	29.36	30.46	31.22	26.46	32.30	31.03	29.74
3	41.17	42.16	37.78	40.22	38.38	36.59	40.31	37.29	38.97
4	50.94	48.24	44.48	49.18	45.37	41.38	44.20	42.58	45.90
5	54.13	56.28	53.58	52.40	54.39	52.41	52.31	48.06	52.52
6	61.33	58.59	59.08	58.26	57.12	57.21	57.45	51.01	55.23
7	65.03	59.81	61.20	62.31	57.80	59.45	59.59	54.69	56.42
8	73.59	61.87	64.54	60.61	58.75	62.05	64.98	55.46	57.56
9	63.82	80.61	56.89	64.00	69.18	66.67	74.07	97.00	58.86
10	.00	79.00	.00	.00	70.00	.00	70.89	.00	.00
11	.00	94.00	.00	.00	62.96	88.00	.00	.00	.00
12	.00	.00	.00	.00	.00	100.00	.00	.00	.00
13	.00	.00	.00	.00	.00	.00	.00	.00	.00
14	.00	.00	.00	.00	.00	.00	.00	.00	.00
15	.00	.00	.00	.00	.00	.00	.00	.00	.00

Table 15. Summary of ADAPT formulations for 4VsW cod.

Parameters

Year class estimates:		$N_{i,1988}$;	$i = 3, \ldots, 8$
Calibration coefficients:	July RV	K_i ;	$i = 3, \ldots, 8$
	CPUE	K'	

Structure Imposed

- error in catch assumed neglible
- partial recruitment fixed for ages 1, 2 and 9+
- F on oldest age (15) set to weighted F on 7–10
- no intercept was fitted
- $M = 0.2$

Input

$C_{i,t}$ (catch at age);	$i = 1, \ldots, 15,$	$t = 1971, \ldots, 1988$
$MWT_{i,t}$ (mean weight at age);	$i = 1, \ldots, 15,$	$t = 1971, \ldots, 1988$
$OTB_{i,t}$ (otter trawler catch at age);	$i = 1, \ldots, 15,$	$t = 1971, \ldots, 1988$
$RV_{i,t}$ (estimated population numbers at age);	$i = 3, \ldots, 8,$	$t = 1971, \ldots, 1988$
$RVSE_{i,t}$ (RV standard errors);	$i = 3, \ldots, 8,$	$t = 1971, \ldots, 1988$
$CPUE_t$ (otter trawler catch rate);		$t = 1971, \ldots, 1988$
$CPUESE_t$ (CPUE standard errors);		$t = 1971, \ldots, 1988$

Objective Function

$$\min_{N_{i,1988},\, K_i,\, K'} \sum_{t=1971}^{1988} \left(\sum_{i=3}^{8} \left(\frac{RV_{i,t} - K_i N_{i,t}}{RVSE_{i,t}} \right)^2 \right) + \left(\frac{CPUE_t - K' \times FB_t}{CPUESE_t} \right)^2$$

where FB_t is the fishable biomass calculated as a function of $MWT_{i,t}$ and $OTB_{i,t}$.

- 2 RV residuals were given 0 weight (1974 age 5; 1975 age 6)

Summary

Number of observations:	106	RV	(108 − 2)
	18	CPUE	
Total	124		

Number of parameters: 13

Table 16.

4VsW COD TUNING MAY 1989

4VsW COD

POPULATION NUMBERS (000S)

	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88
1	95845	74442	64207	76321	82875	72878	70786	109317	101090	127488	139945	98588	113432	26514	80201	103023	40262	0
2	76290	76380	58792	51285	61146	66231	59008	57953	89341	82754	104350	114575	80713	92870	21708	65663	84348	32964
3	63904	48691	46484	37148	34342	41032	50551	48290	47310	73073	67616	85120	93671	66082	76034	17769	53758	69058
4	34251	40936	26992	24593	18756	19534	30349	41038	38628	37260	57986	51973	67428	73933	53761	62112	14439	43981
5	31002	19767	21426	15306	11135	11428	12634	23877	30297	26048	25874	39677	35617	47740	55071	41914	47124	11069
6	25030	17412	7442	8715	6080	5000	4997	8933	15367	16530	14891	14600	22660	22494	30550	37531	27525	33707
7	11737	11207	6311	2634	4633	2631	1912	3303	5105	8175	7972	7802	8833	13153	12860	17971	22560	17483
8	3404	4941	6070	2456	1302	1416	864	1112	2009	3128	4043	3820	4209	5478	6976	6980	11522	13297
9	1709	1114	2309	1600	814	513	606	508	717	1309	1597	1993	1976	2542	3292	3699	4341	7094
10	265	951	588	835	937	217	253	381	315	519	783	952	1022	1097	1557	1811	2029	2600
11	193	114	423	234	350	170	133	176	239	237	345	527	504	630	629	889	1087	1135
12	138	39	22	76	178	148	119	69	120	187	152	226	291	286	374	267	472	684
13	122	48	31	15	57	32	24	48	31	94	130	95	125	193	177	155	123	270
14	17	11	6	19	12	14	25	10	15	22	73	87	26	82	127	86	68	46
15	112	3	9	0	15	2	8	18	0	12	17	58	26	7	52	87	61	46
1+	344019	296055	241111	221239	222632	221246	232270	295032	330586	376836	425774	419094	430532	353101	343370	359955	309718	233434

Table 17.

4VsW COD TUNING MAY 1989

4VsW COD

FISHING MORTALITY

	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88
1	.027	.036	.025	.022	.024	.011	.000	.002	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
2	.249	.297	.259	.201	.199	.070	.000	.003	.001	.002	.004	.001	.000	.000	.000	.000	.000	.000
3	.245	.390	.437	.483	.364	.102	.008	.023	.039	.031	.063	.033	.037	.006	.002	.008	.001	.003
4	.350	.447	.367	.592	.295	.236	.040	.103	.194	.165	.205	.178	.145	.095	.049	.076	.066	.040
5	.377	.777	.700	.723	.601	.627	.147	.241	.406	.359	.372	.335	.260	.246	.183	.221	.135	.267
6	.604	.815	.839	.432	.638	.762	.214	.360	.431	.529	.446	.303	.344	.359	.331	.309	.254	.159
7	.665	.413	.744	.504	.985	.914	.342	.297	.290	.504	.536	.417	.278	.434	.411	.245	.329	.297
8	.917	.561	1.133	.905	.733	.648	.331	.238	.228	.473	.507	.459	.304	.309	.434	.275	.285	.308
9	.387	.439	.817	.336	1.124	.505	.266	.279	.124	.314	.317	.468	.389	.290	.398	.401	.313	.301
10	.644	.610	.720	.670	1.509	.288	.166	.264	.083	.208	.196	.436	.284	.356	.361	.310	.381	.301
11	1.387	1.451	1.522	.073	.660	.155	.455	.179	.046	.247	.221	.395	.367	.320	.656	.432	.264	.301
12	.862	.058	.164	.076	1.519	1.606	.716	.595	.046	.167	.266	.397	.211	.279	.685	.576	.359	.301
13	2.194	1.954	.292	.000	1.184	.035	.693	.925	.150	.048	.197	1.094	.217	.217	.520	.625	.774	.301
14	1.545	.000	7.555	.000	1.607	.368	.141	7.410	.073	.052	.031	1.028	1.132	.260	.180	.152	.178	.301
15	.687	.465	.909	.618	1.021	.763	.314	.281	.252	.466	.485	.436	.299	.383	.413	.274	.317	.301

Table 18.

4VsW COD TUNING MAY 1989

4VsW COD

WEIGHTED RESIDUALS FOR RV INDEX

	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88
3	.725	¯.308	1.299	1.246	.634	.186	1.202	1.079	¯.242	¯1.164	¯.639	1.007	1.556	.807	¯.105	¯.771	¯.378	.002
4	¯.970	.691	1.068	¯1.537	¯.278	.846	.878	2.227	.602	¯1.551	.925	.928	1.388	1.176	1.322	¯.448	2.390	.401
5	.280	¯.221	.937	¯4.799	¯2.103	1.003	.941	¯.564	1.551	1.515	.053	¯.424	1.252	1.045	.559	¯1.285	1.043	1.815
6	¯.938	.124	¯.278	¯1.274	¯9.219	¯1.668	.978	¯.181	2.103	1.886	1.301	.663	1.349	1.178	.885	¯1.190	.220	¯.585
7	.347	¯1.159	.735	¯2.403	¯.470	¯.089	.780	¯.936	2.550	2.141	1.848	1.373	1.205	1.384	2.273	¯1.338	.983	.522
8	1.494	¯2.147	¯.762	¯.266	¯1.104	.996	1.193	¯2.087	2.119	1.019	1.076	1.076	1.316	¯.438	2.090	¯.410	1.136	¯.436

SUM OF RV RESIDUALS : 29.75655626 MEAN RESIDUAL : 0.2807222289

RESIDUALS FROM CPUE INDEX

	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88
	¯.045	¯2.589	1.658	¯3.229	1.012	4.144	3.759	¯1.295	1.427	1.733	¯.804	¯.091	¯1.803	.748	2.624	2.977	2.099	¯2.829

SUM OF CPUE RESIDUALS : 9.495104569 MEAN RESIDUAL : 0.5275058094

Table 19.

4VsW COD TUNING MAY 1989

4VsW COD

ESTIMATED PARAMETERS AND STANDARD ERRORS
APPROXIMATE STATISTICS ASSUMING LINEARITY NEAR SOLUTION

ORTHOGONALITY OFFSET......... 0.001304
MEAN SQUARE RESIDUALS 2.204295

PAR. EST.	STD. ERR.	T-STATISTIC
6.91775E0004	5.29892E0004	1.30550E0000
4.40835E0004	1.63342E0004	2.69884E0000
1.11363E0004	3.80475E0003	2.92694E0000
3.38523E0004	7.84490E0003	4.31521E0000
1.75982E0004	3.87022E0003	4.54708E0000
1.33874E0004	3.24326E0003	4.12776E0000
2.83009E0002	3.69098E0001	7.66758E0000
3.20225E0002	3.61037E0001	8.86958E0000
4.08069E0002	4.76761E0001	8.55920E0000
3.81398E0002	4.36373E0001	8.74019E0000
2.73260E0002	2.77512E0001	9.84678E0000
2.75566E0002	3.44549E0001	7.99786E0000
5.95966E¯006	2.72436E¯007	2.18755E0001

Parameter Correlation Matrix

	1	2	3	4	5	6	7	8	9	10	11	12	13
1	1.000	.034	.053	.058	.003	¯.001	¯.170	¯.013	¯.009	¯.005	.000	.000	¯.004
2	.034	1.000	.065	.082	.012	¯.002	¯.201	¯.150	¯.014	¯.009	¯.002	¯.002	¯.009
3	.053	.065	1.000	.110	¯.064	¯.053	¯.309	¯.040	¯.040	.011	.023	.027	.001
4	.058	.082	.110	1.000	.040	.012	¯.340	¯.128	¯.122	¯.099	¯.011	¯.011	¯.024
5	.003	.012	¯.064	.040	1.000	¯.592	¯.016	¯.061	¯.140	¯.040	¯.087	¯.005	¯.257
6	¯.001	¯.002	¯.053	.012	¯.592	1.000	.005	.009	.039	¯.109	¯.077	¯.188	¯.205
7	¯.170	¯.201	¯.309	¯.340	¯.016	.005	1.000	.074	.053	.032	.002	.001	.023
8	¯.013	¯.150	¯.040	¯.128	¯.061	.009	.074	1.000	.026	.019	.011	.008	.032
9	¯.009	¯.014	¯.040	¯.122	¯.140	.039	.053	.026	1.000	.025	.021	.014	.062
10	¯.005	¯.009	.011	¯.099	¯.040	¯.109	.032	.019	.025	1.000	.030	.039	.083
11	.000	¯.002	.023	¯.011	¯.087	¯.077	.002	.011	.021	.030	1.000	.038	.093
12	.000	¯.002	.027	¯.011	¯.005	¯.188	.001	.008	.014	.039	.038	1.000	.107
13	¯.004	¯.009	.001	¯.024	¯.257	¯.205	.023	.032	.062	.083	.093	.107	1.000

Figure 1. Nominal catch and TAC for 4VsW cod.

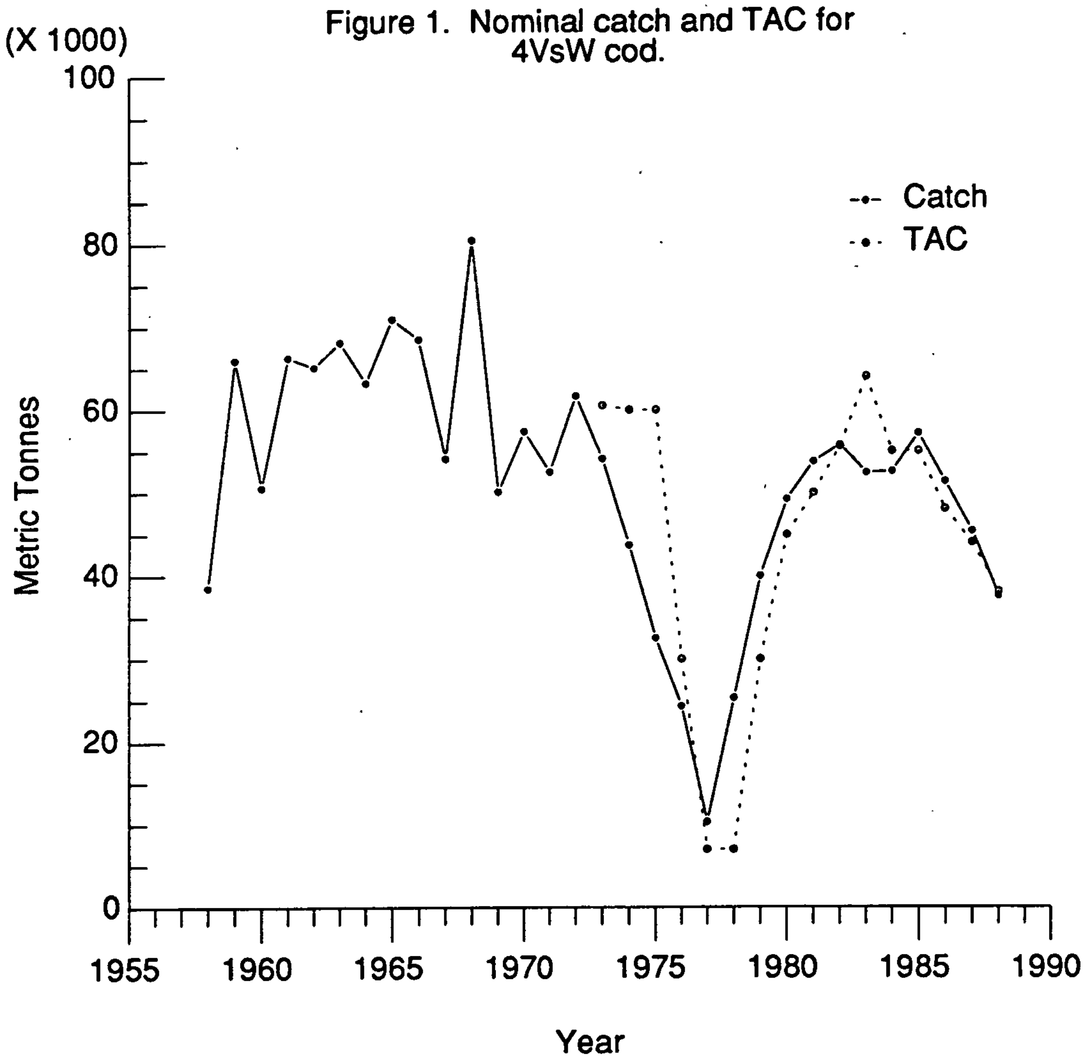


Figure 2. Comparison of cod catches in areas 4Vs and 4W.

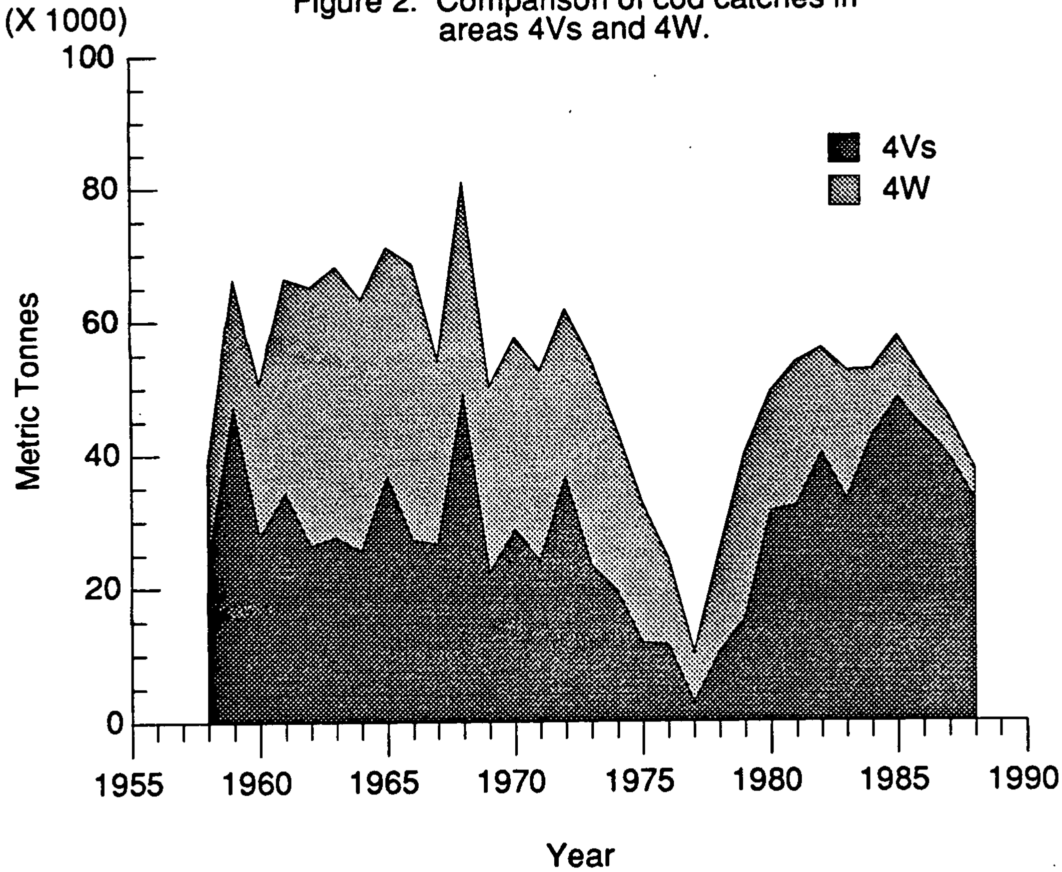


Figure 3. Comparison of Canadian catches of 4VsW cod by different gears.

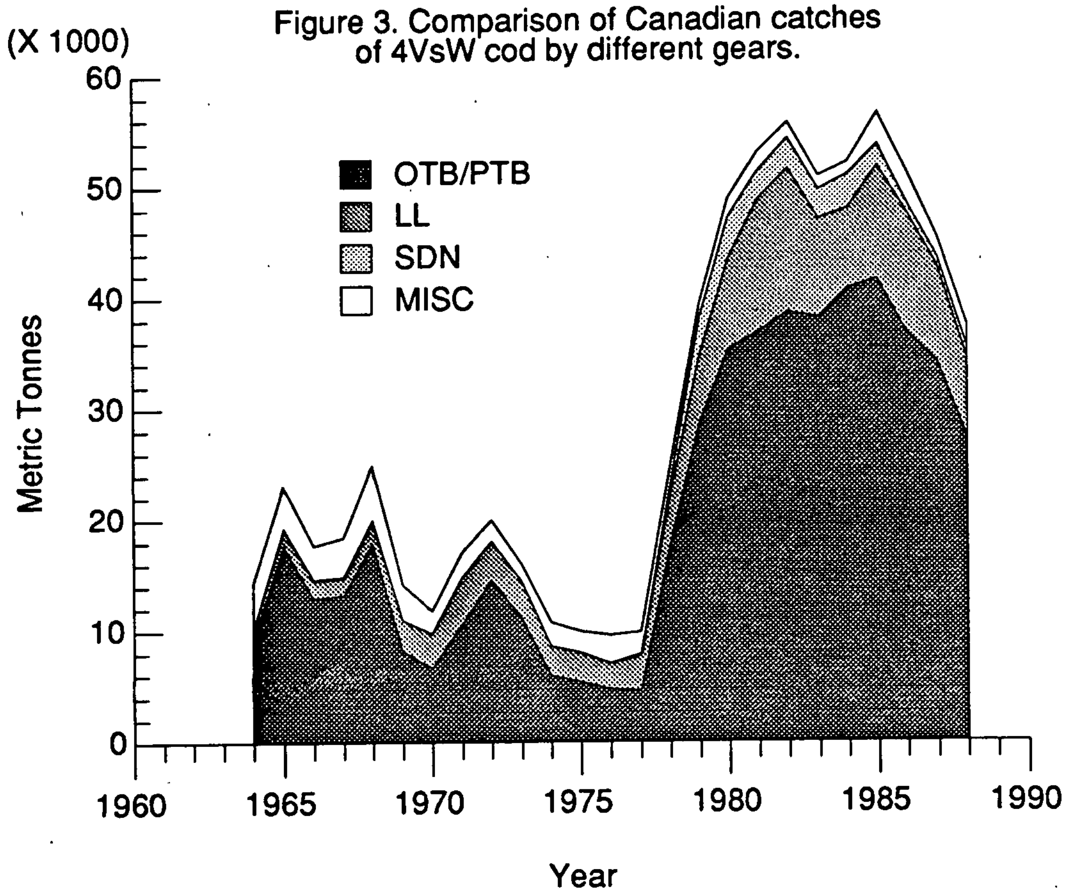


Figure 4. Projected and estimated catch at age ('000) for 4VsW cod in 1988.

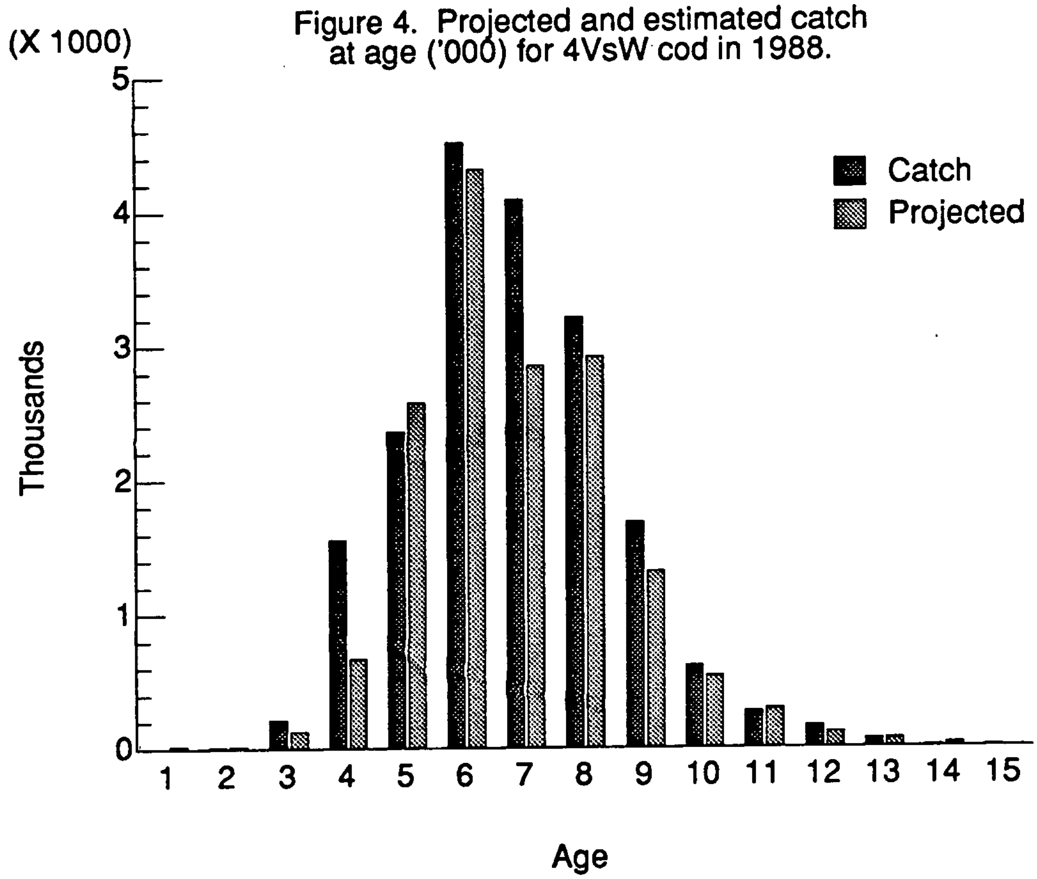


Figure 5. Commercial mean weights at age for 4VsW cod ages 3 to 8.

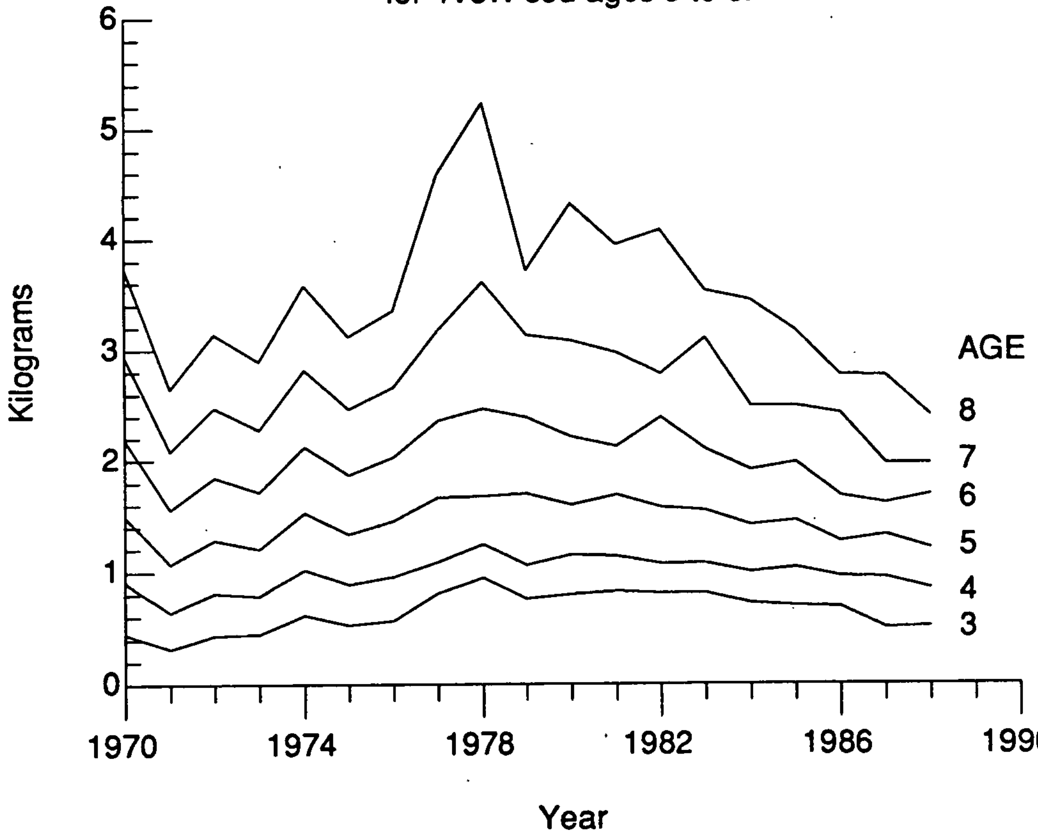


Figure 6. Standardized 4VsW cod catch rates.

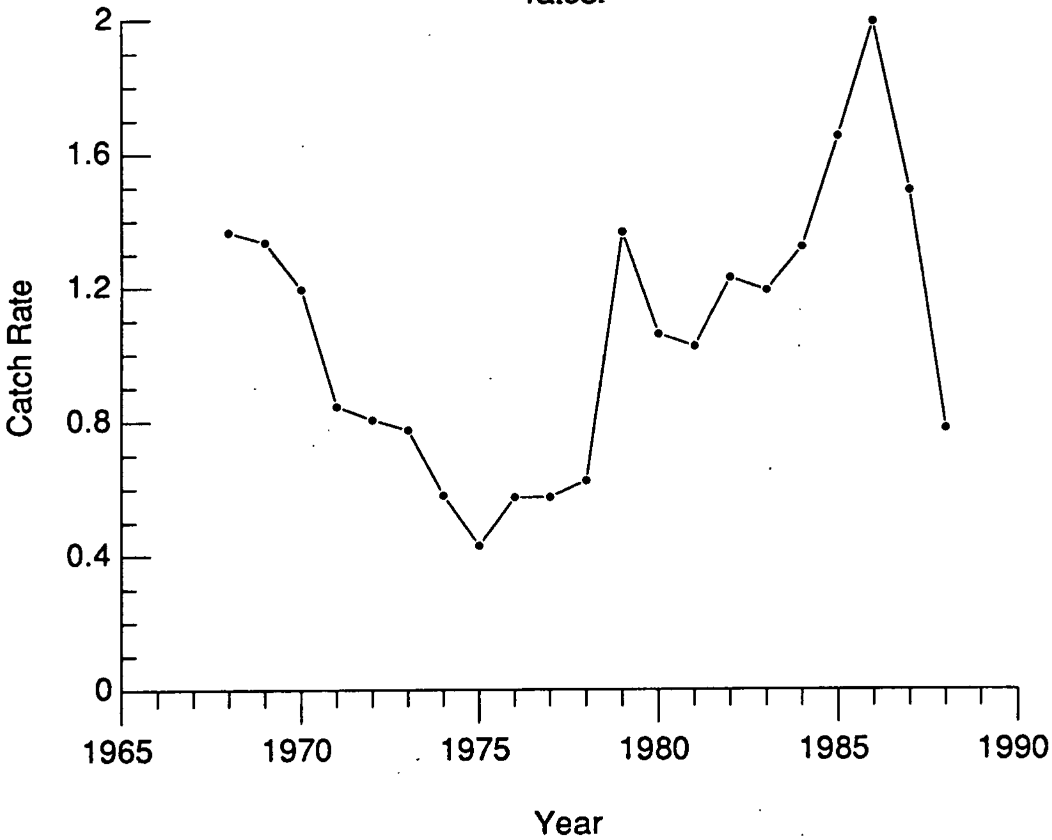


Figure 7. Total numbers ('000) and ages 4+ for 4VsW cod from July surveys.

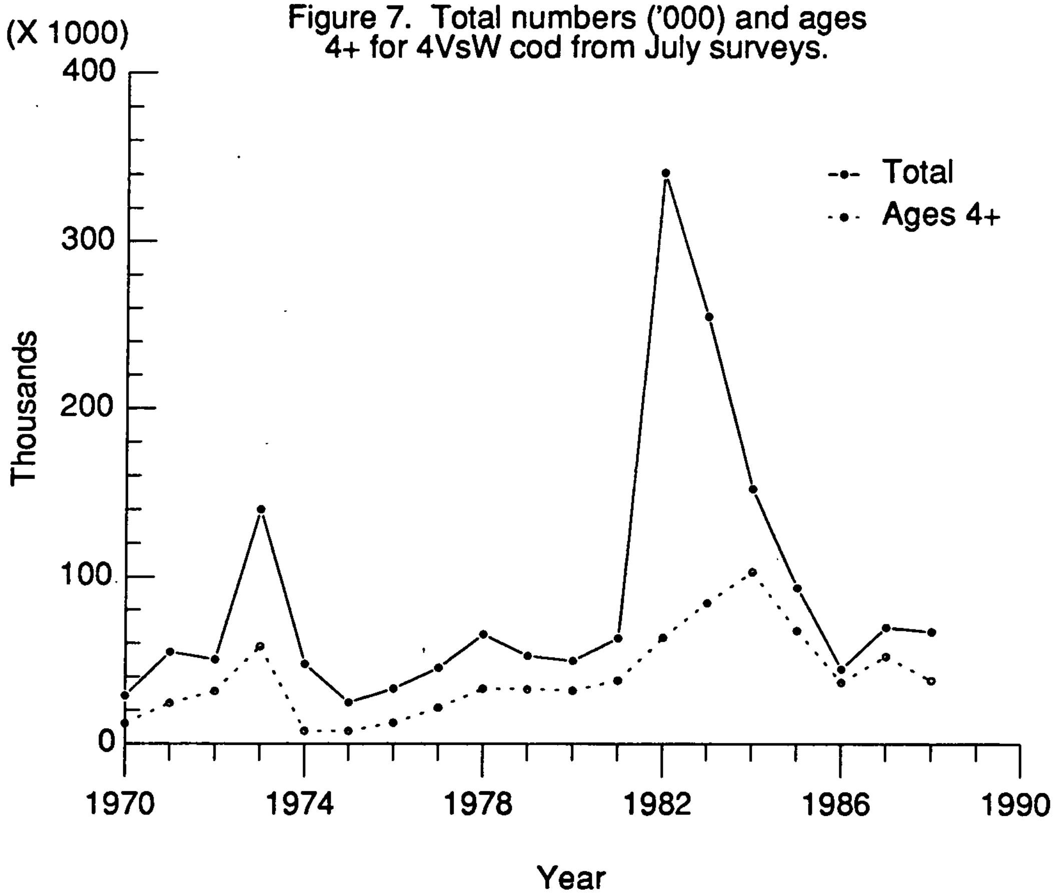


Figure 8. 4VsW cod ages 4+ July survey abundance by area.

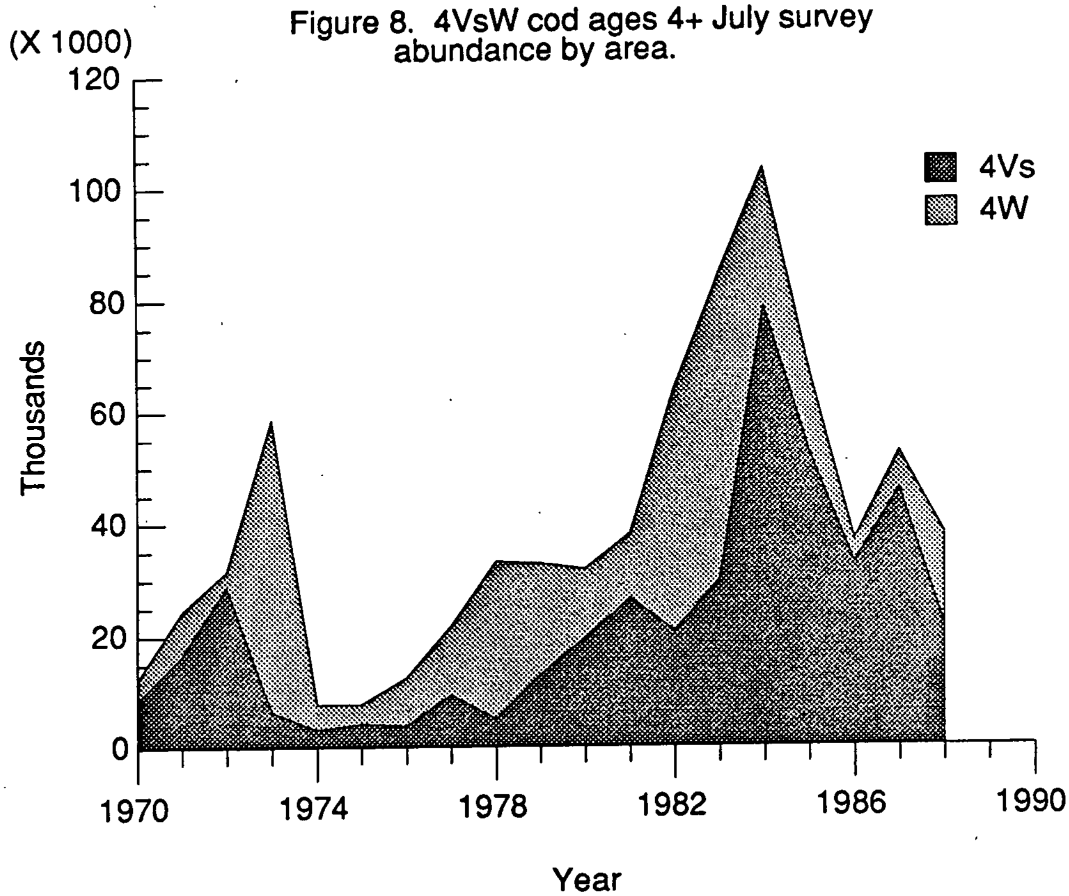


Figure 9. Abundance of cod (all ages) in 4VsW from research vessel surveys.

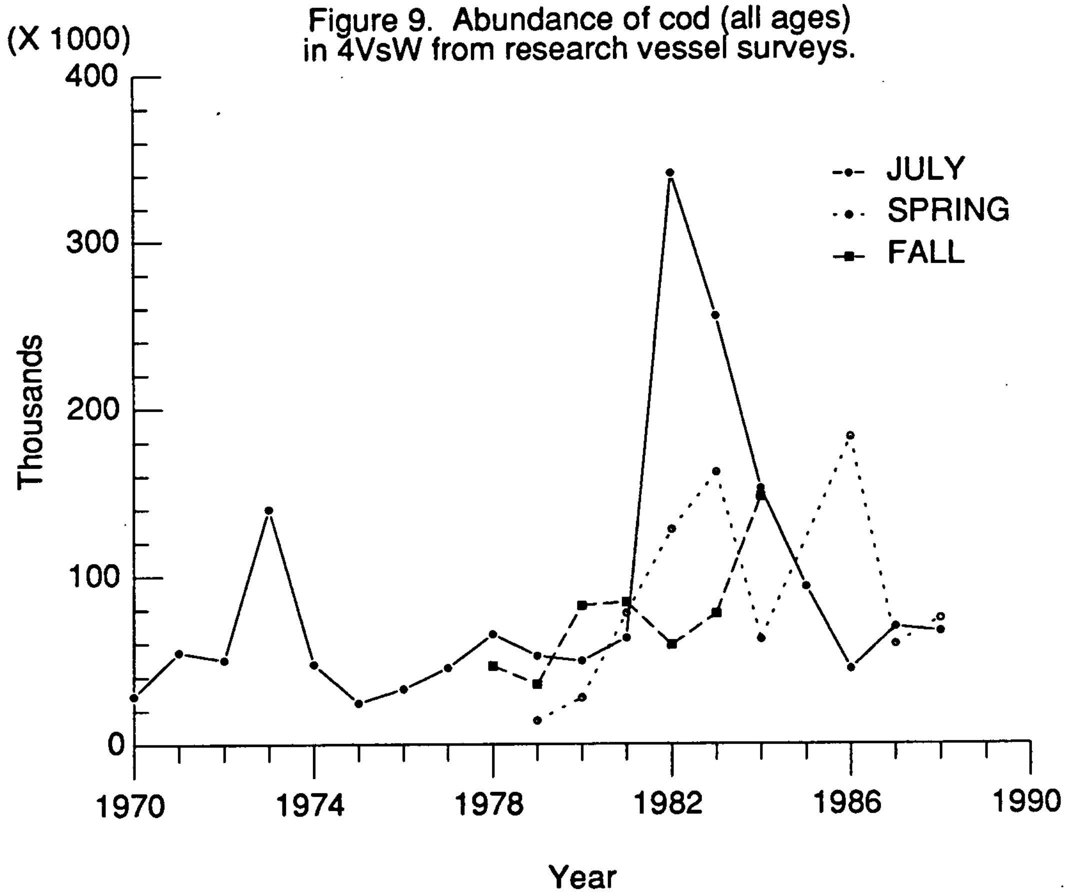


Figure 10. Cod abundance (all ages) in 4Vs from research vessel surveys.

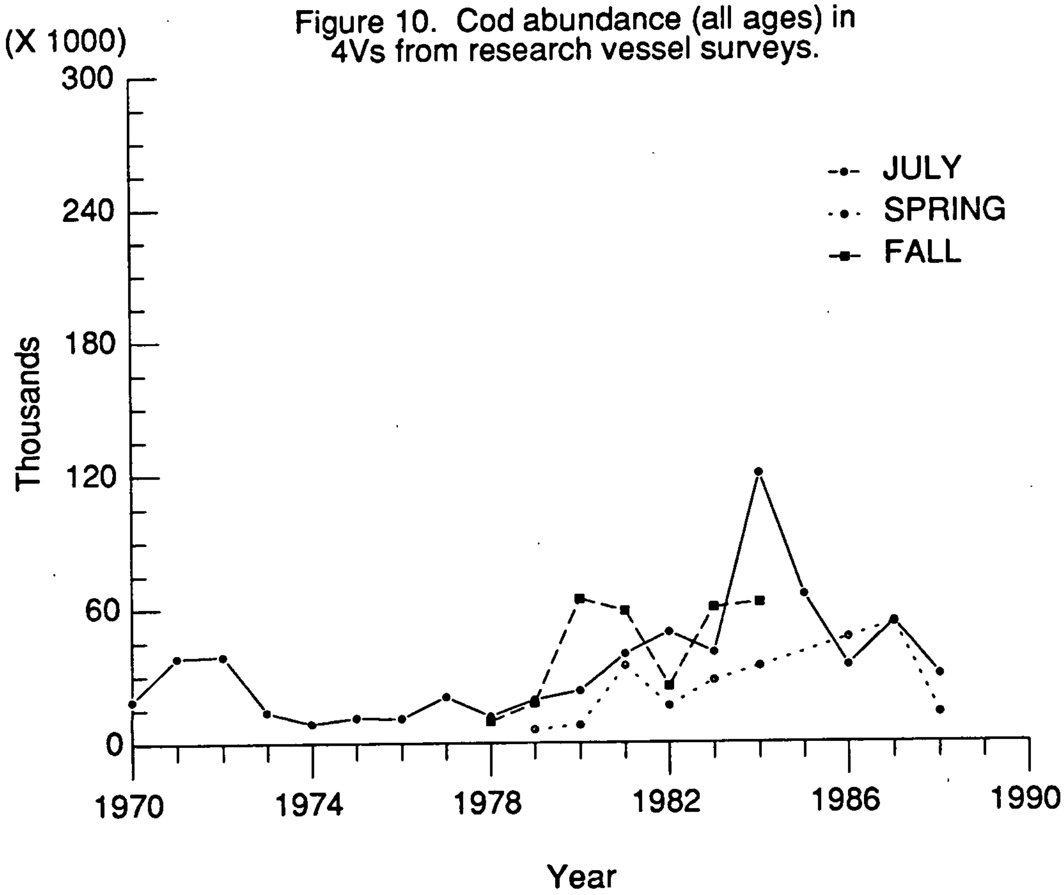


Figure 11. Cod abundance (all ages) in 4W from research vessel surveys.

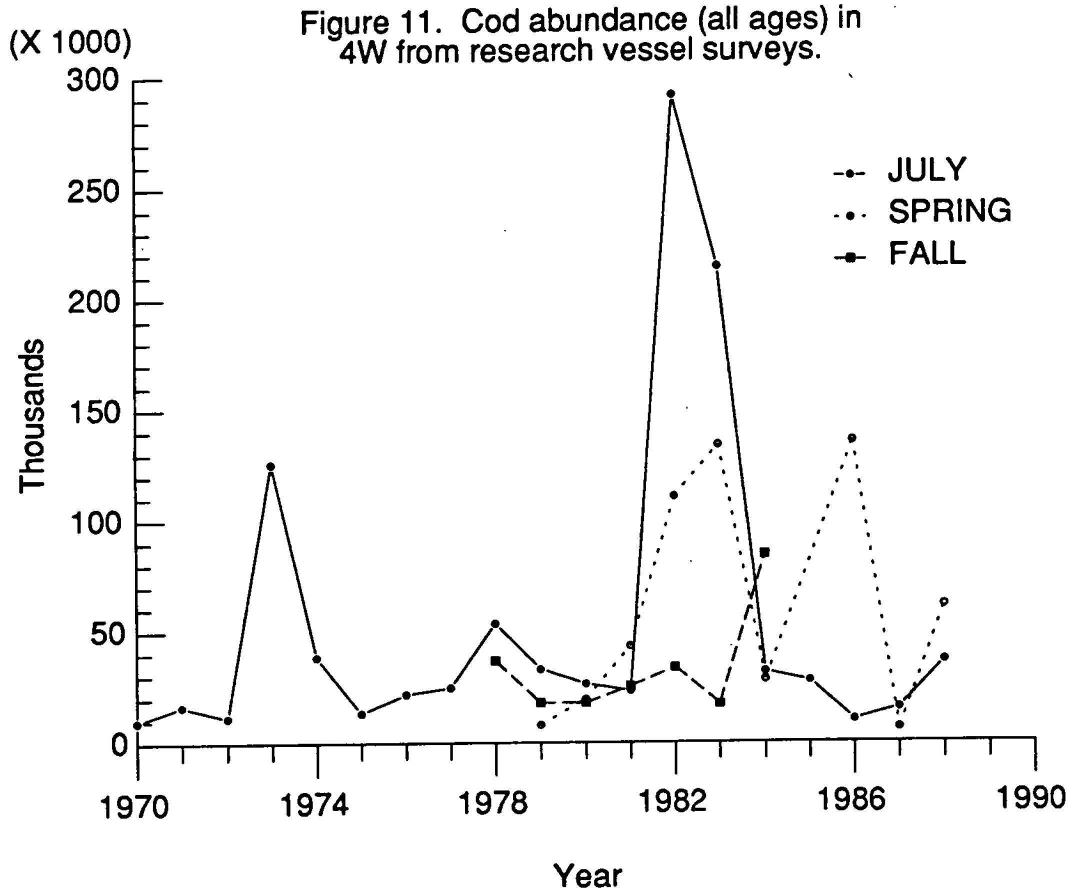


Figure 12. Research vessel catch distribution of 4VsW cod by age groups in spring 1981.

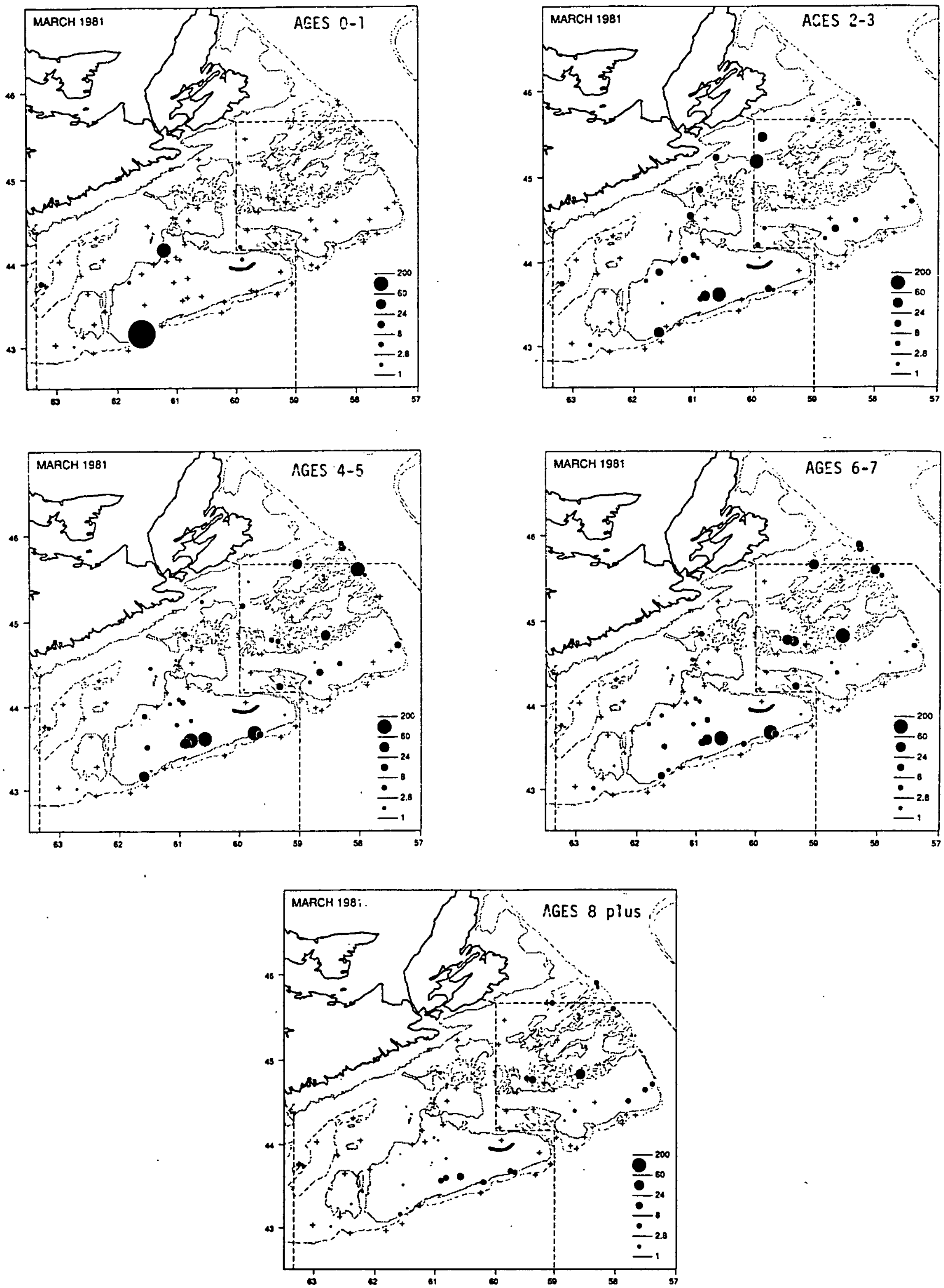


Figure 13. Research vessel catch distribution of 4VsW cod by age groups in July 1981.

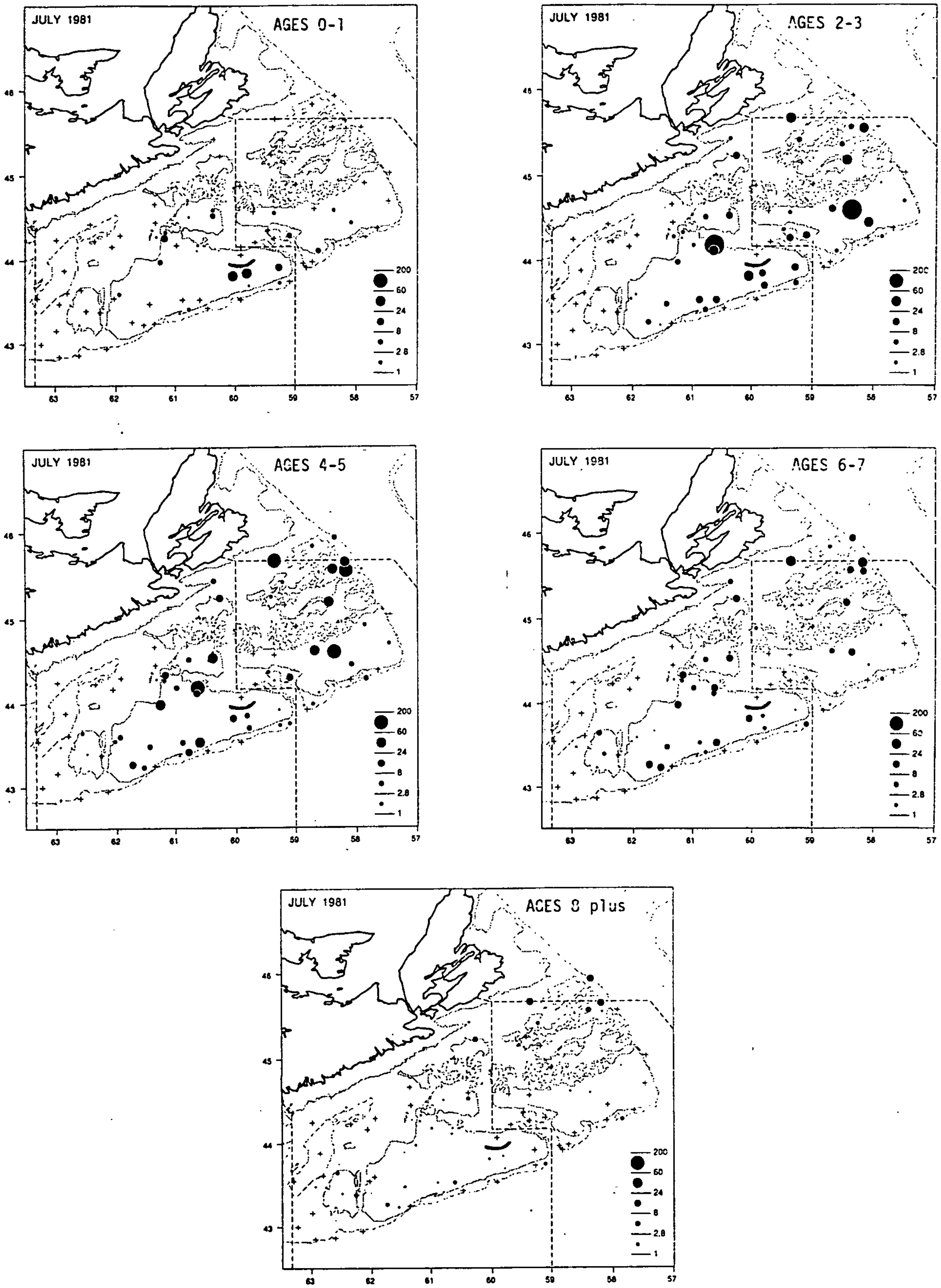


Figure 14. Research vessel catch distribution of 4VsW cod by age groups in fall 1981.

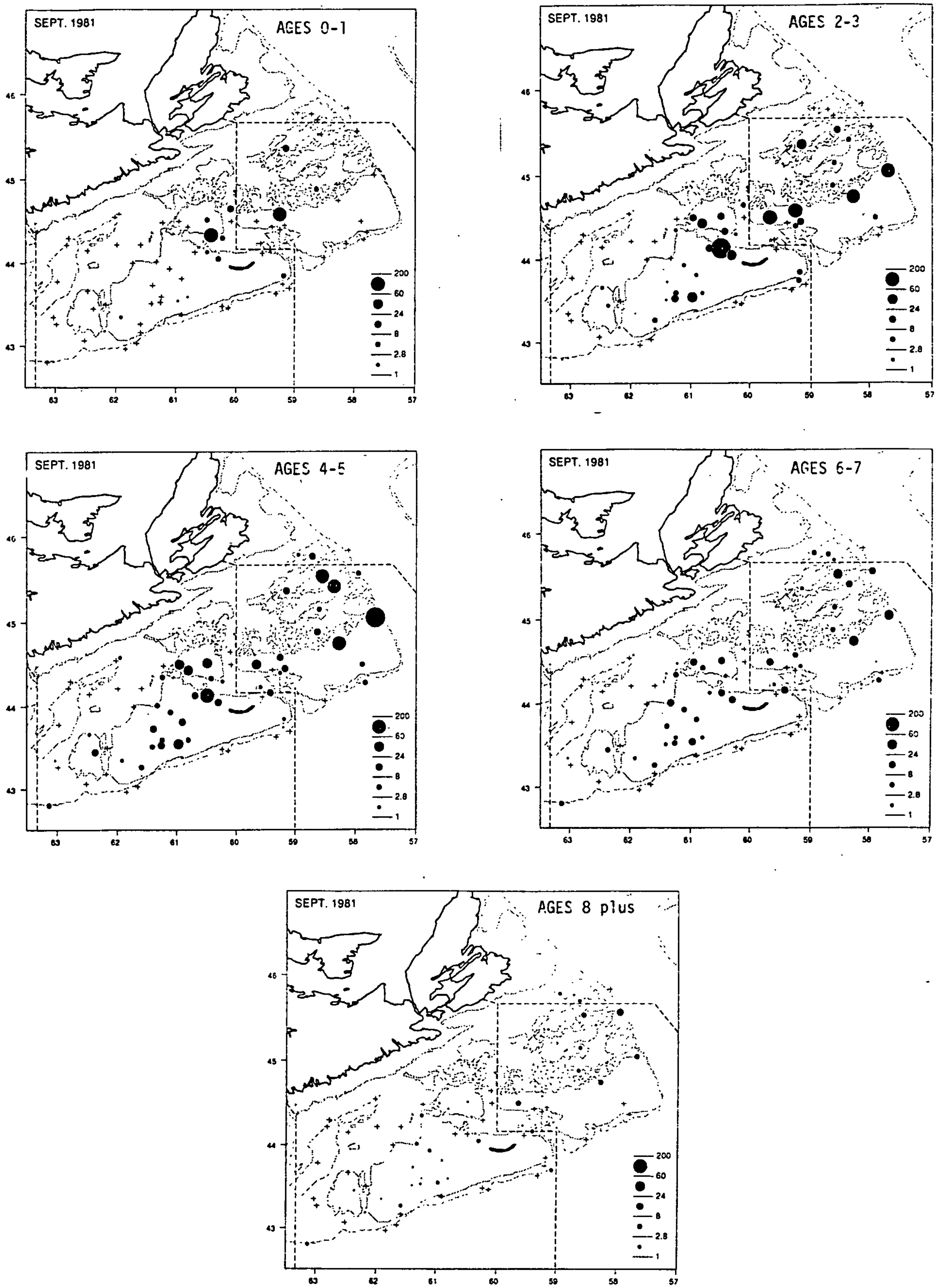


Figure 15. Predicted weight of a 60 cm. 4VsW cod from RV parameters.

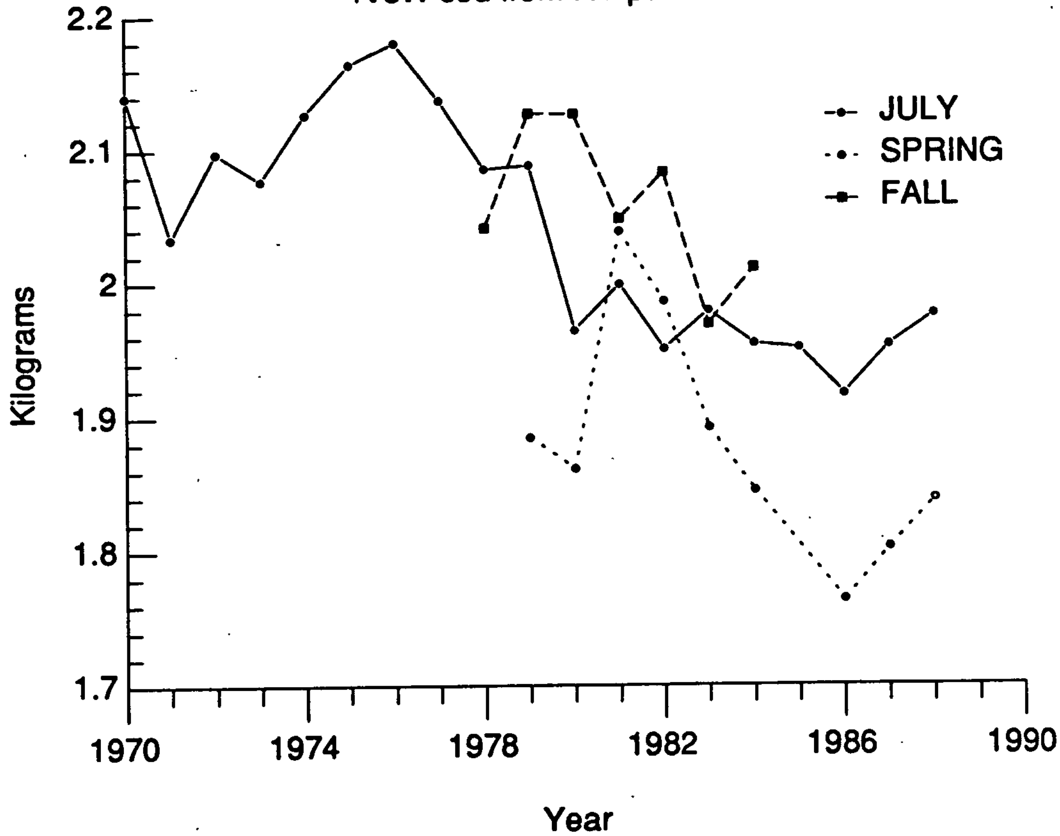


Figure 16. Length at age ratio for 4Vs to 4W cod (tickmarks are at 0.2 intervals).

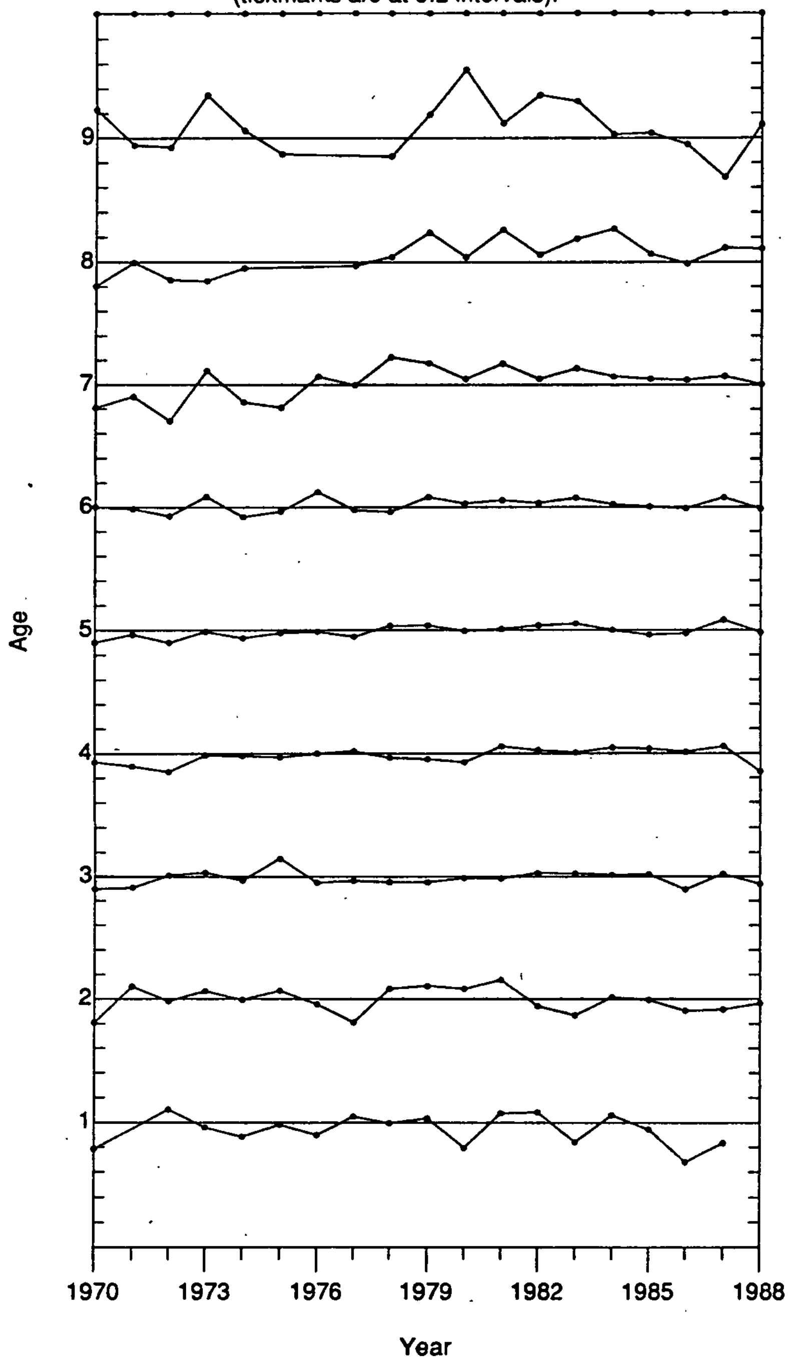


Figure 17. Mean ratio of length at ages 1 to 9 for cod in 4Vs to 4W (RV surveys)

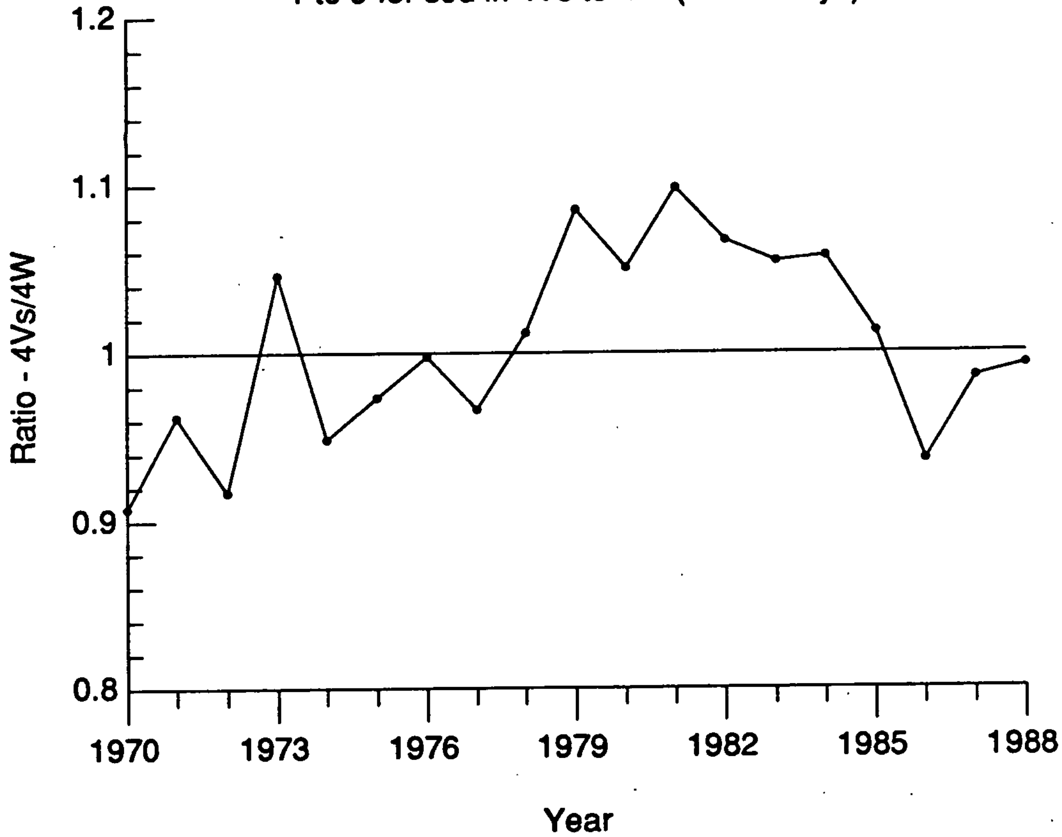


Figure 18. Tuning plots from ADAPT for 4VsW cod.

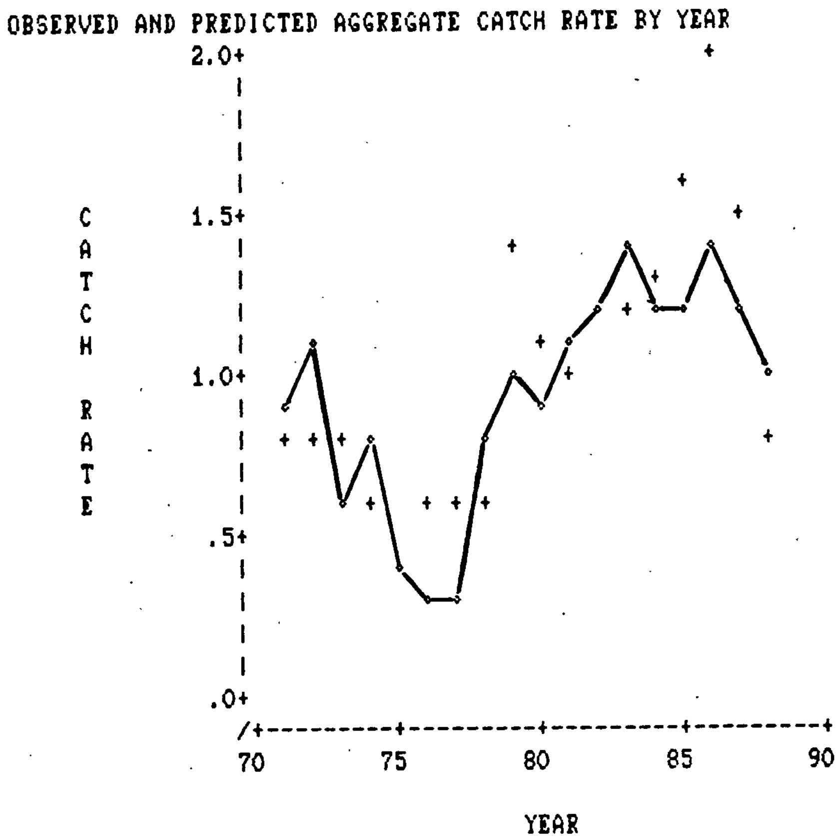
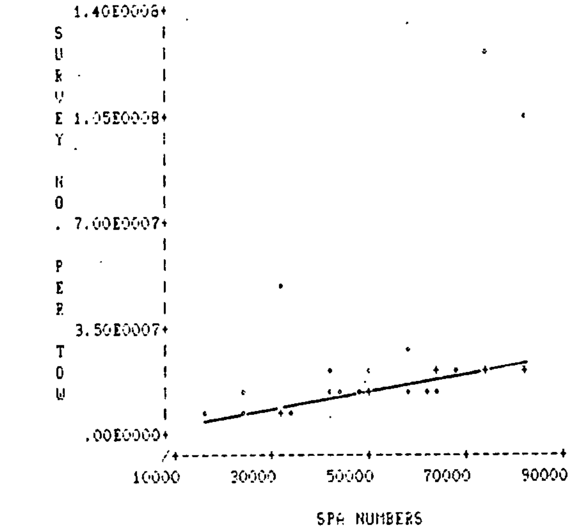


Figure 18.1.

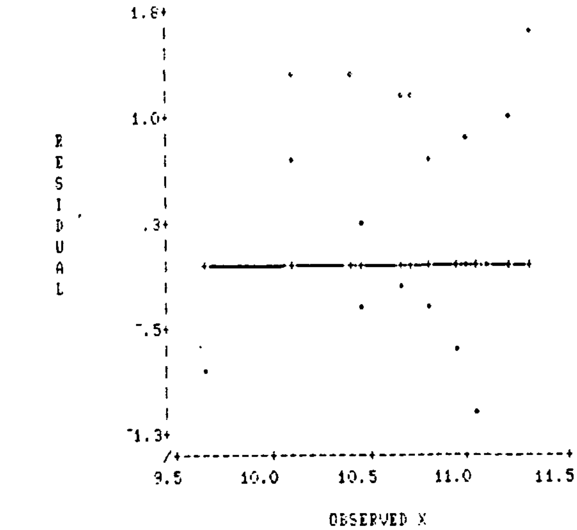
4VsW COD TUNING MAY 1989

4VsW COD
AGE 3 PLOTS

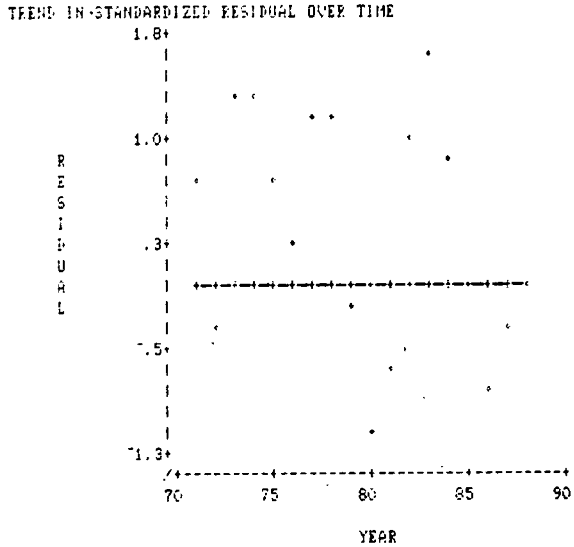
SURVEY NO. PER TOW VS SPA NUMBERS



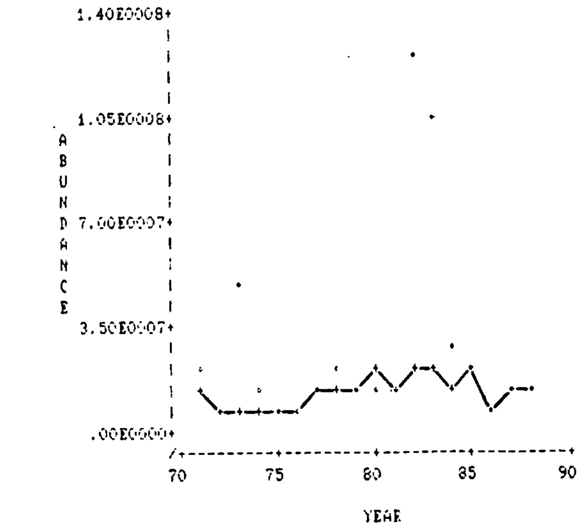
RESIDUAL VS OBSERVED X



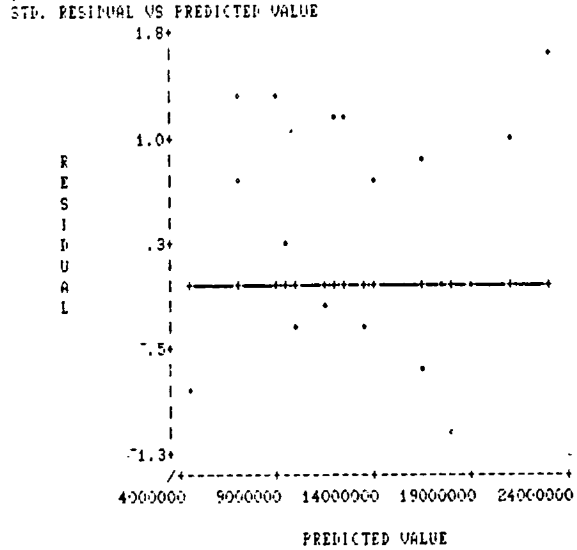
TREND IN STANDARDIZED RESIDUAL OVER TIME



TREND IN POPULATION ABUNDANCE OVER TIME



STD. RESIDUAL VS PREDICTED VALUE



SUMMARY OF DATA FROM PLOT

CARRIER VARIABLE: POPULATION NOS
RESPONSE VARIABLE(S): SURVEY - O:OBSERVED, +:PREDICTED

INDEX	CARRIER	•	+	RANK
71	4.929E4	2.436E7	1.395E7	86
72	3.451E4	8.114E6	9.768E6	75
73	3.206E4	4.714E7	9.074E6	74
74	2.493E4	1.317E7	7.057E6	73
75	2.471E4	8.964E6	6.993E6	76
76	3.441E4	1.006E7	9.739E6	72
77	4.476E4	1.66E7	1.267E7	79
78	4.239E4	2.134E7	1.2E7	78
79	4.116E4	1.096E7	1.165E7	77
80	6.385E4	1.265E7	1.807E7	87
81	5.8E4	1.318E7	1.641E7	71
82	7.43E4	1.253E8	2.103E7	81
83	8.159E4	1.059E8	2.309E7	84
84	5.859E4	3.054E7	1.636E7	88
85	6.757E4	1.873E7	1.912E7	80
86	1.574E4	3.65E6	4.455E6	85
87	4.782E4	1.185E7	1.353E7	82
88	6.133E4	1.737E7	1.736E7	83

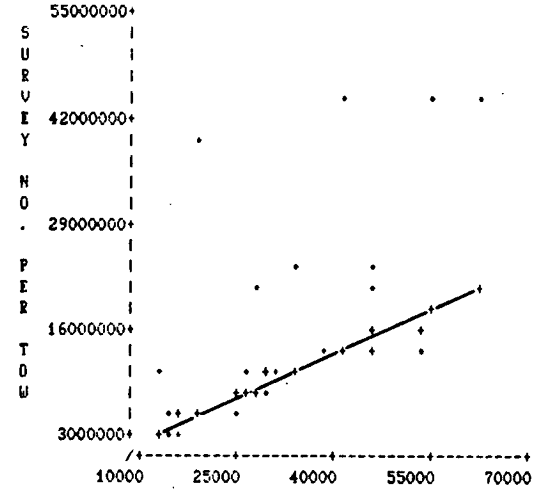
Figure 18.2.

4VsW COD TUNING MAY 1989

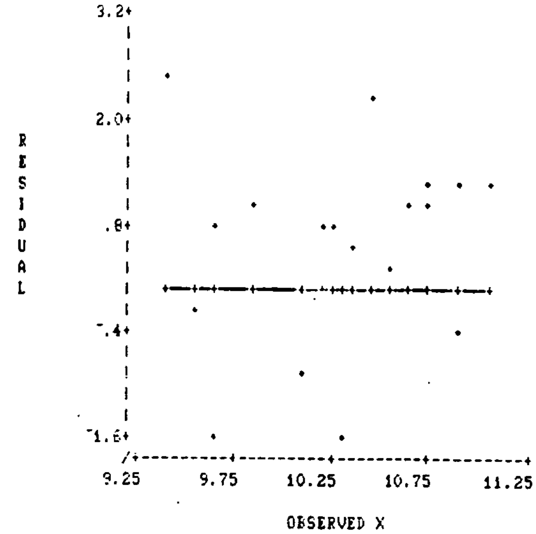
4VsW COD

AGE 4 PLOTS

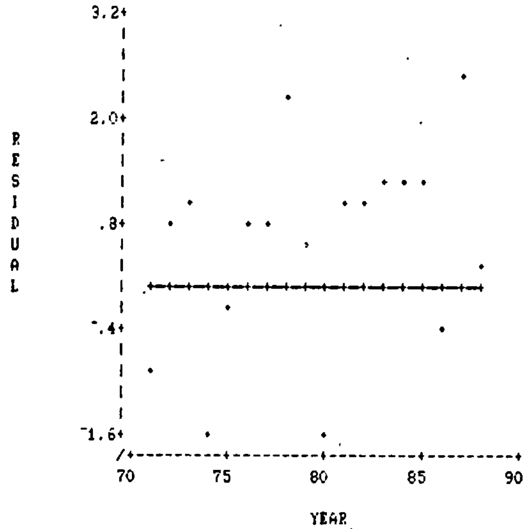
SURVEY NO. PER TOW VS SPA NUMBERS



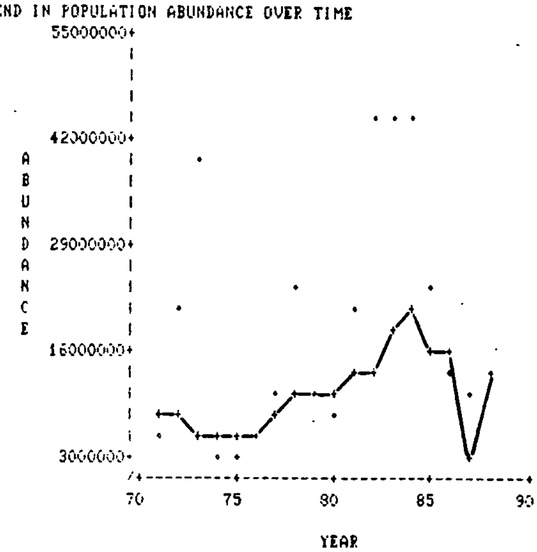
RESIDUAL VS OBSERVED X



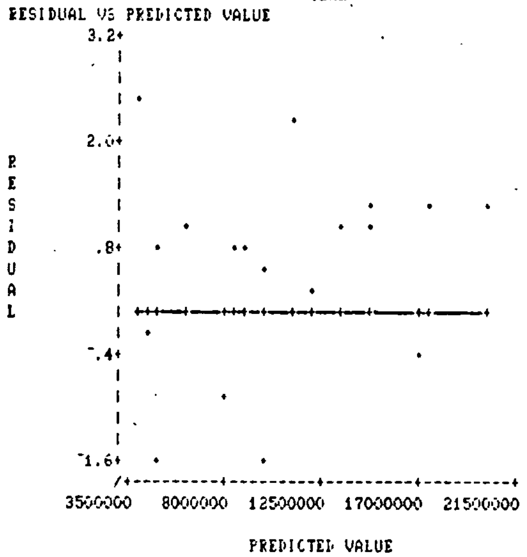
TREND IN STANDARDIZED RESIDUAL OVER TIME



TREND IN POPULATION ABUNDANCE OVER TIME



STD. RESIDUAL VS PREDICTED VALUE



SUMMARY OF DATA FROM PLOT

CARRIER VARIABLE: POPULATION NOS

RESPONSE VARIABLE(S): SURVEY - o:OBSERVED, +:PREDICTED

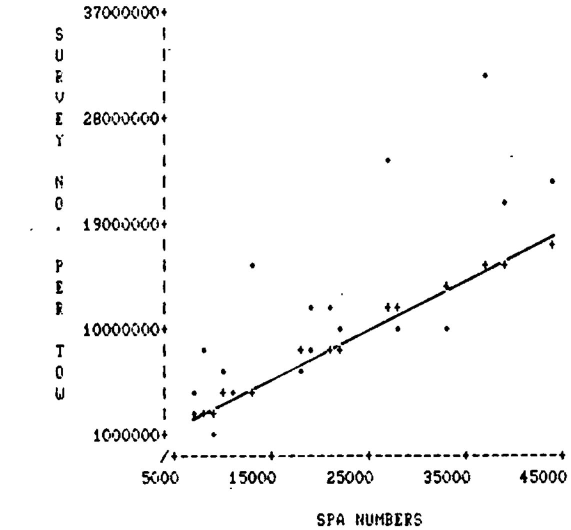
INDEX	CARRIER	•	+	RANK
71	2.486E4	5.482E6	7.959E6	87
72	2.806E4	2.154E7	8.986E6	75
73	1.939E4	3.829E7	6.208E6	76
74	1.549E4	3.851E6	4.961E6	74
75	1.405E4	4.203E6	4.439E6	73
76	1.515E4	6.2E6	4.851E6	71
77	2.639E4	1.078E7	8.45E6	77
78	3.438E4	2.336E7	1.101E7	72
79	3.07E4	1.133E7	9.83E6	80
80	3.012E4	7.007E6	9.645E6	79
81	4.579E4	2.012E7	1.466E7	78
82	4.169E4	4.377E7	1.335E7	88
83	5.513E4	4.587E7	1.765E7	82
84	6.226E4	4.549E7	1.994E7	81
85	4.649E4	2.279E7	1.489E7	85
86	5.287E4	1.469E7	1.693E7	86
87	1.236E4	1.15E7	3.96E6	83
88	3.824E4	1.404E7	1.225E7	84

Figure 18.3.

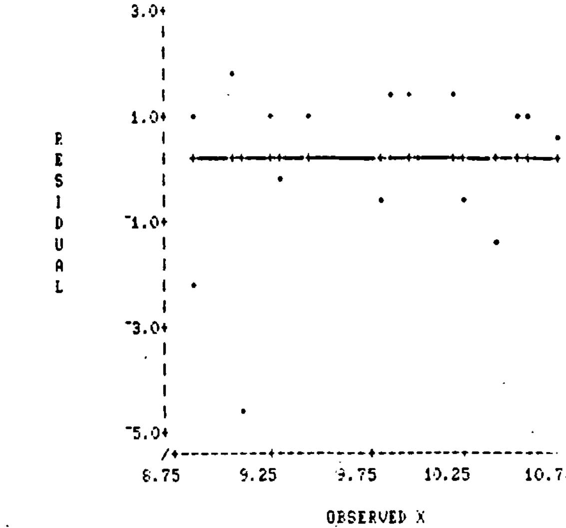
4VsW COD TUNING MAY 1989

4VsW COD
AGE 5 PLOTS

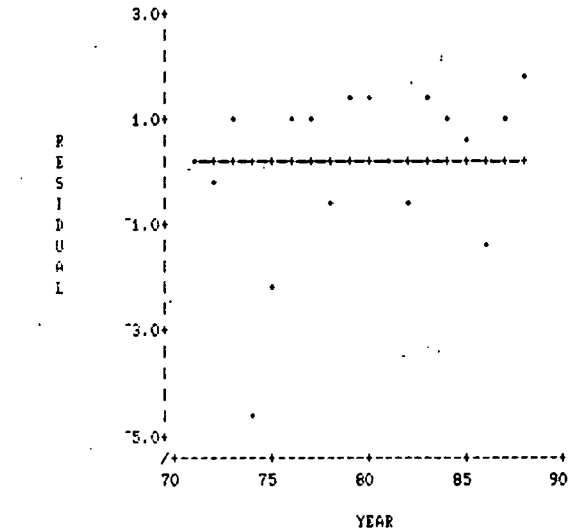
SURVEY NO. PER TOW VS SPA NUMBERS



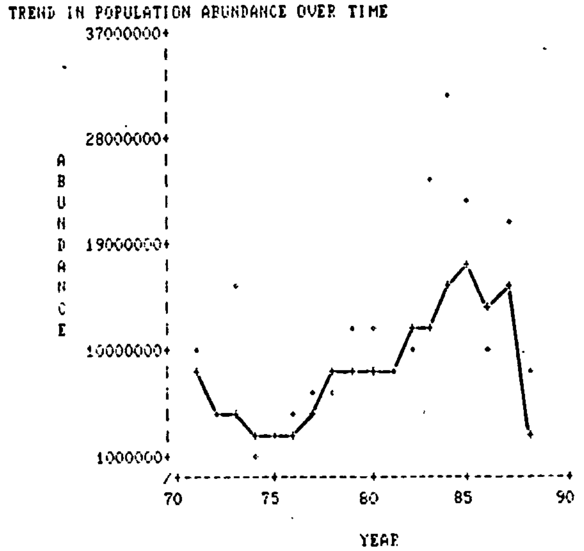
RESIDUAL VS OBSERVED X



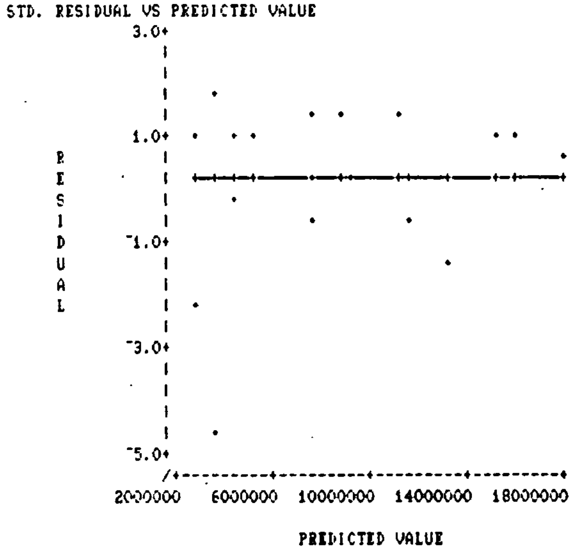
TREND IN STANDARDIZED RESIDUAL OVER TIME



TREND IN POPULATION ABUNDANCE OVER TIME



STD. RESIDUAL VS PREDICTED VALUE



SUMMARY OF DATA FROM PLOT

CARRIER VARIABLE: POPULATION NOS
RESPONSE VARIABLE(S): SURVEY - o:OBSERVED, +:PREDICT:

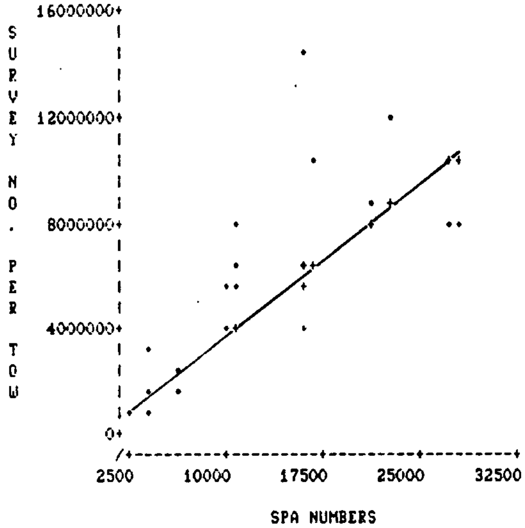
INDEX	CARRIER	•	+	RANK
71	2.214E	1.079E7	9.036E6	75
72	1.118E	3.969E6	4.562E6	76
73	1.268E	1.535E7	5.174E6	88
74	8933	1.378E6	3.645E6	74
75	6980	2.044E6	2.848E6	77
76	7053	3.92E6	2.878E6	72
77	1.032E	6.721E6	4.212E6	73
78	1.846E	6.461E6	7.535E6	78
79	2.128E	1.234E7	8.683E6	81
80	1.88E4	1.186E7	7.671E6	80
81	1.853E	7.665E6	7.562E6	79
82	2.831E	9.827E6	1.155E7	71
83	2.724E	2.355E7	1.112E7	83
84	3.68E4	3.082E7	1.501E7	82
85	4.403E	2.22E7	1.797E7	86
86	3.28E4	9.258E6	1.338E7	84
87	3.876E	2.111E7	1.592E7	87
88	8431	7.783E6	3.44E6	85

Figure 18.4.

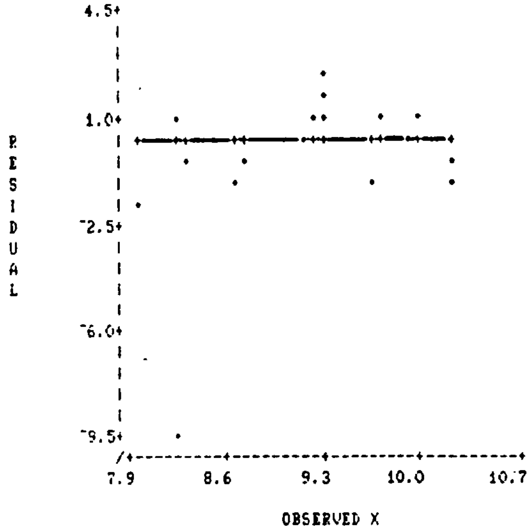
4VsW COD TUNING MAY 1989

4VsW COD
AGE 6 PLOTS

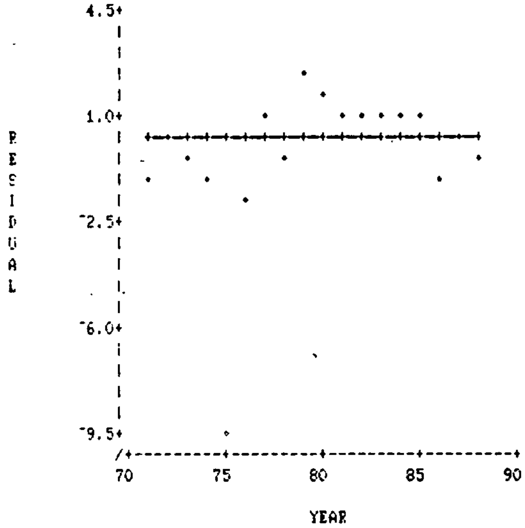
SURVEY NO. PER TOW VS SPA NUMBERS



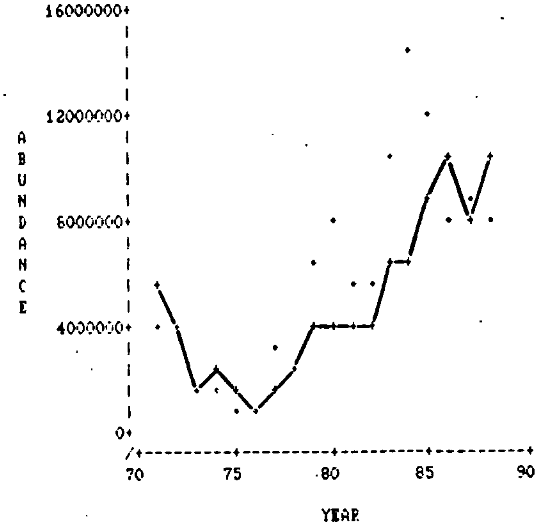
RESIDUAL VS OBSERVED X



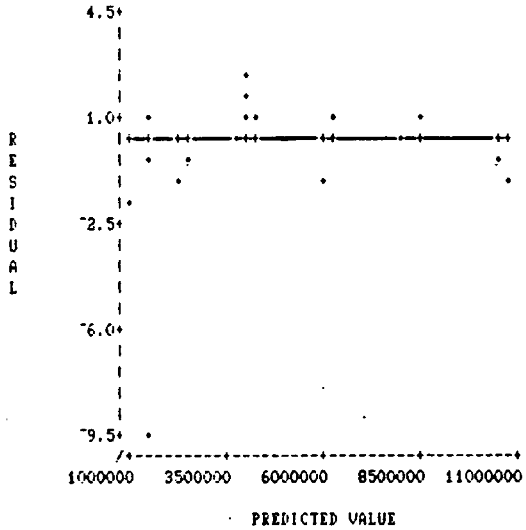
TREND IN STANDARDIZED RESIDUAL OVER TIME



TREND IN POPULATION ABUNDANCE OVER TIME



STD. RESIDUAL VS. PREDICTED VALUE



SUMMARY OF DATA FROM PLOT

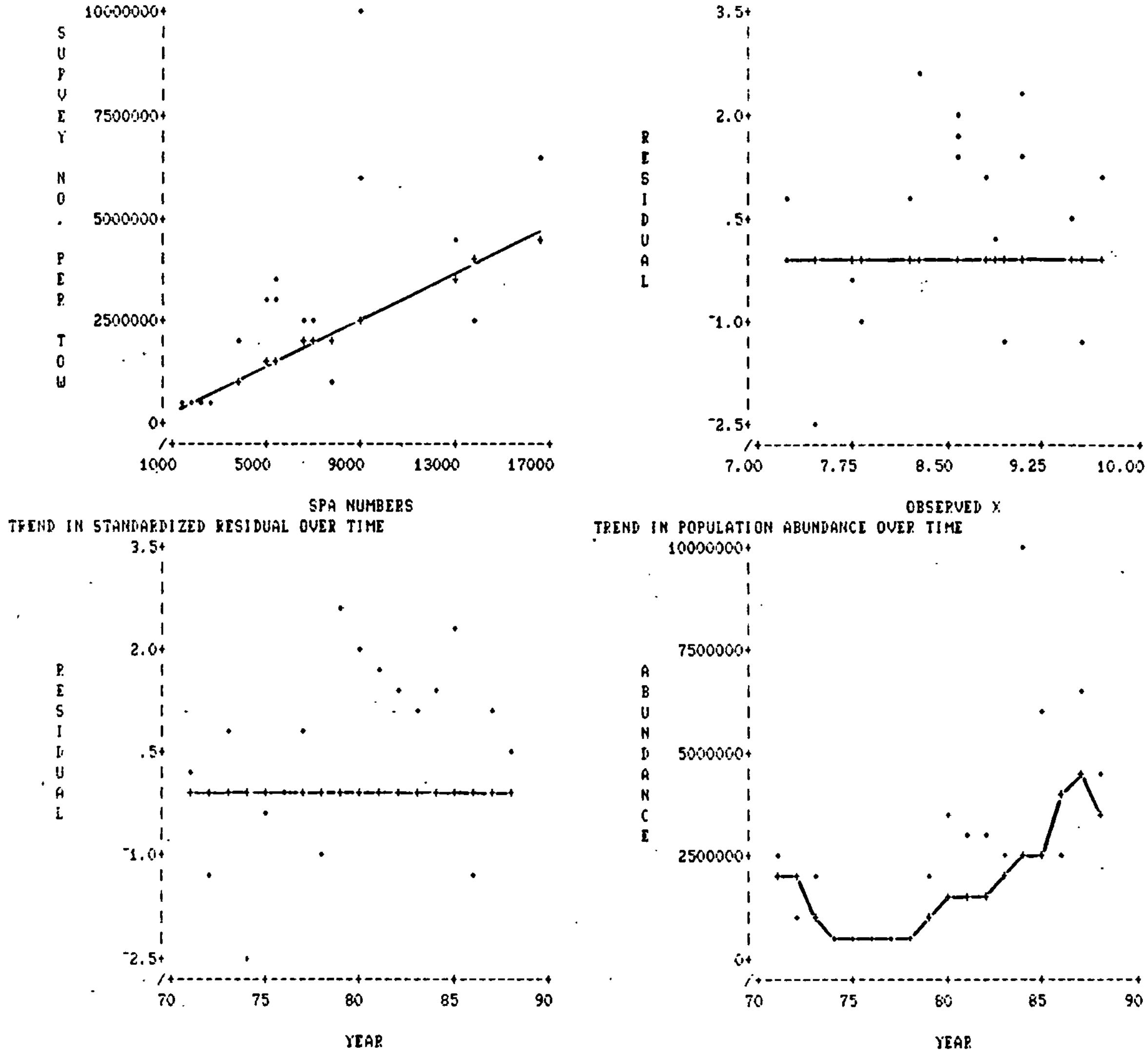
CARRIER VARIABLE: POPULATION NOS
RESPONSE VARIABLE(S): SURVEY - o:OBSERVED, +:PREDICTED

INDEX	CARRIER	o	+	RANK
71	1.566E	3.944E6	5.974E6	76
72	9632	4.09E6	3.674E6	75
73	4060	1.274E6	1.549E6	77
74	6028	1.53E6	2.299E6	73
75	3730	4.477E5	1.423E6	74
76	2854	7.647E5	1.088E6	78
77	3925	2.951E6	1.497E6	72
78	6445	2.383E6	2.458E6	81
79	1.063E	6.182E6	4.056E6	79
80	1.08E4	8.263E6	4.12E6	80
81	1.021E	5.501E6	3.895E6	82
82	1.089E	5.309E6	4.153E6	71
83	1.65E4	1.054E7	6.293E6	84
84	1.623E	1.431E7	6.191E6	83
85	2.242E	1.219E7	8.55E6	87
86	2.789E	7.758E6	1.064E7	85
87	2.112E	8.596E6	8.056E6	88
88	2.733E	8.129E6	1.042E7	86

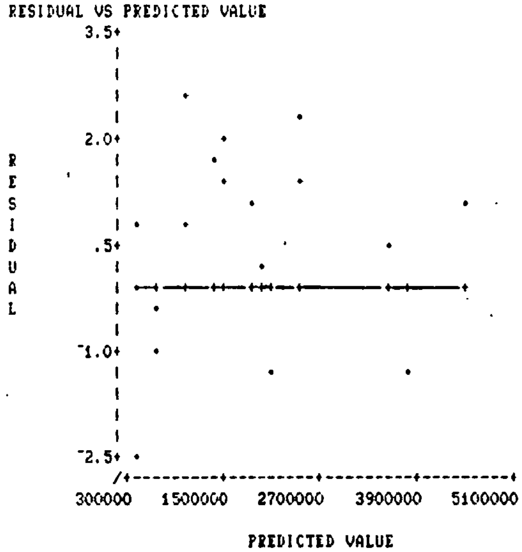
Figure 18.5.

4VsW COD TUNING MAY 1989

4VsW COD
AGE 7 PLOTS



STD. RESIDUAL VS PREDICTED VALUE



SUMMARY OF DATA FROM PLOT
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CARRIER VARIABLE: POPULATION NOS
RESPONSE VARIABLE(S): SURVEY - o:OBSERVED. +:PREDICTED

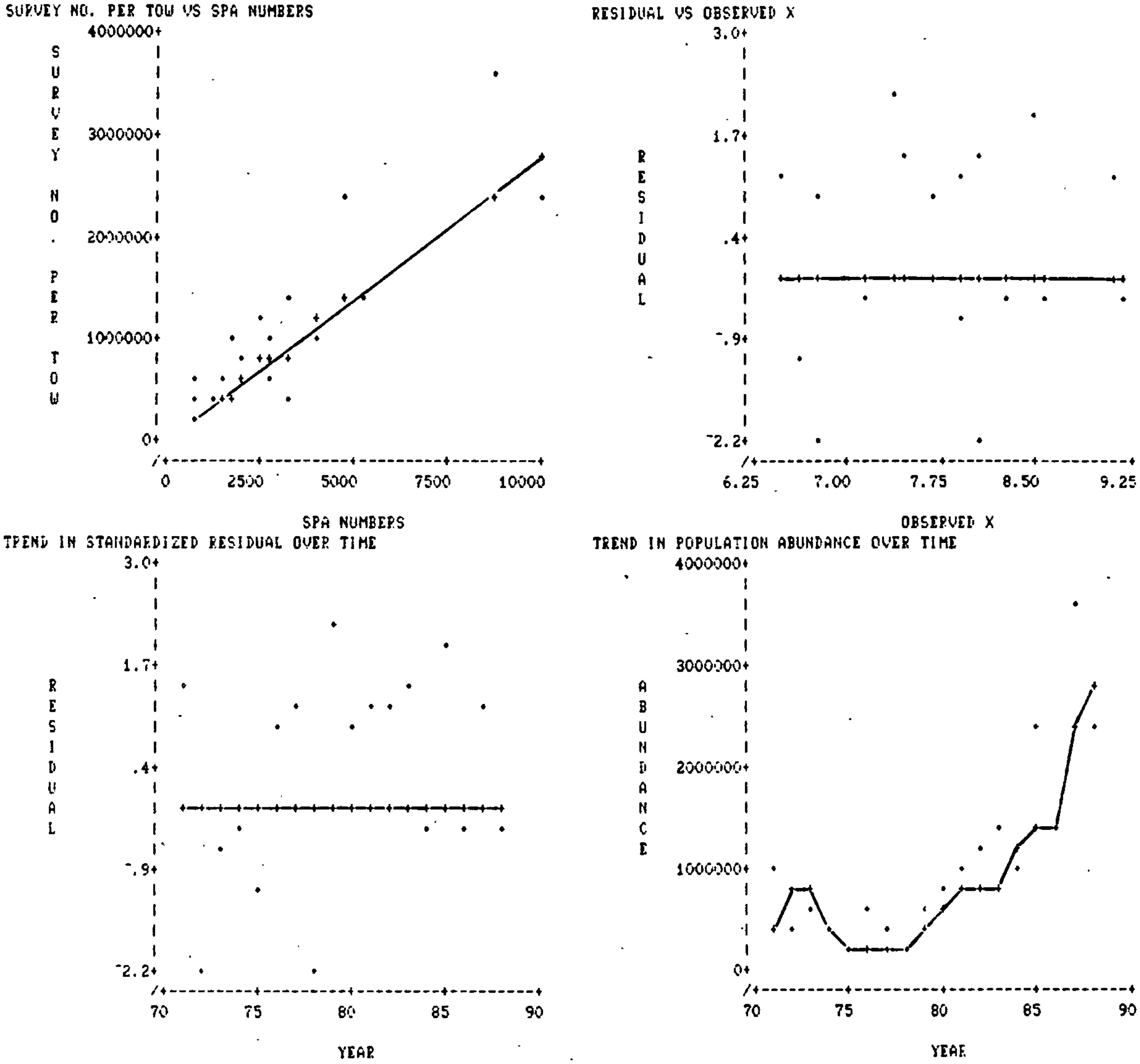
INDEX	CARRIER	•	+	RANK
71	7085	2.362E6	1.936E6	76
72	7837	1.107E6	2.142E6	77
73	3639	1.983E6	9.945E5	74
74	1747	2.539E5	4.773E5	75
75	2320	5.483E5	6.34E5	78
76	1374	3.668E5	3.754E5	73
77	1393	6.353E5	3.808E5	79
78	2472	6.074E5	6.754E5	81
79	3836	1.841E6	1.048E6	80
80	5421	3.274E6	1.481E6	82
81	5191	2.825E6	1.418E6	83
82	5443	2.86E6	1.487E6	71
83	6684	2.355E6	1.827E6	72
84	9086	9.836E6	2.483E6	85
85	9004	6.102E6	2.46E6	84
86	1.387E	2.73E6	3.789'6	88
87	1.657E	6.461E6	4.529E6	86
88	1.309E	4.653E6	3.576E6	87

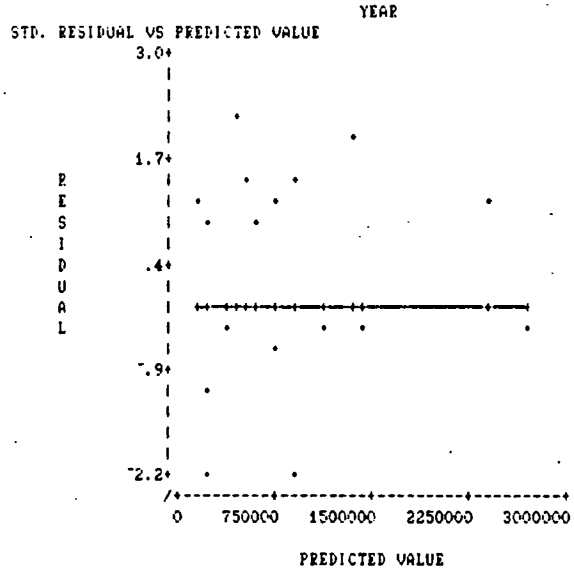
Figure 18.6.

4VsW COD TUNING MAY 1989

4VsW COD

AGE 8 PLOTS





SUMMARY OF DATA FROM PLOT

CARRIER VARIABLE: POPULATION NOS

RESPONSE VARIABLE(S): SURVEY - o:OPSERVED, +:PREDICTED

INDEX	CARRIER	+	+	RANK
71	1774	1.007E6	4.886E5	77
72	3170	3.735E5	6.735E5	75
73	2789	6.154E5	7.686E5	78
74	1289	3.161E5	3.553E5	76
75	755.9	1.443E5	2.083E5	74
76	863.4	6.158E5	2.379E5	79
77	633.8	4.224E5	1.747E5	71
78	861.1	1.262E5	2.373E5	80
79	1565	6.891E5	4.313E5	82
80	2113	8.891E5	5.823E5	81
81	2676	1.042E6	7.375E5	73
82	2601	1.221E6	7.166E5	83
83	3136	1.313E6	8.643E5	72
84	4070	9.702E5	1.122E6	84
85	4816	2.401E6	1.328E6	85
86	5291	1.305E6	1.458E6	86
87	8683	3.512E6	2.393E6	87
88	9890	2.326E6	2.725E6	88

Figure 19. Age 3+ population ('000) and mean biomass for 4VsW cod.

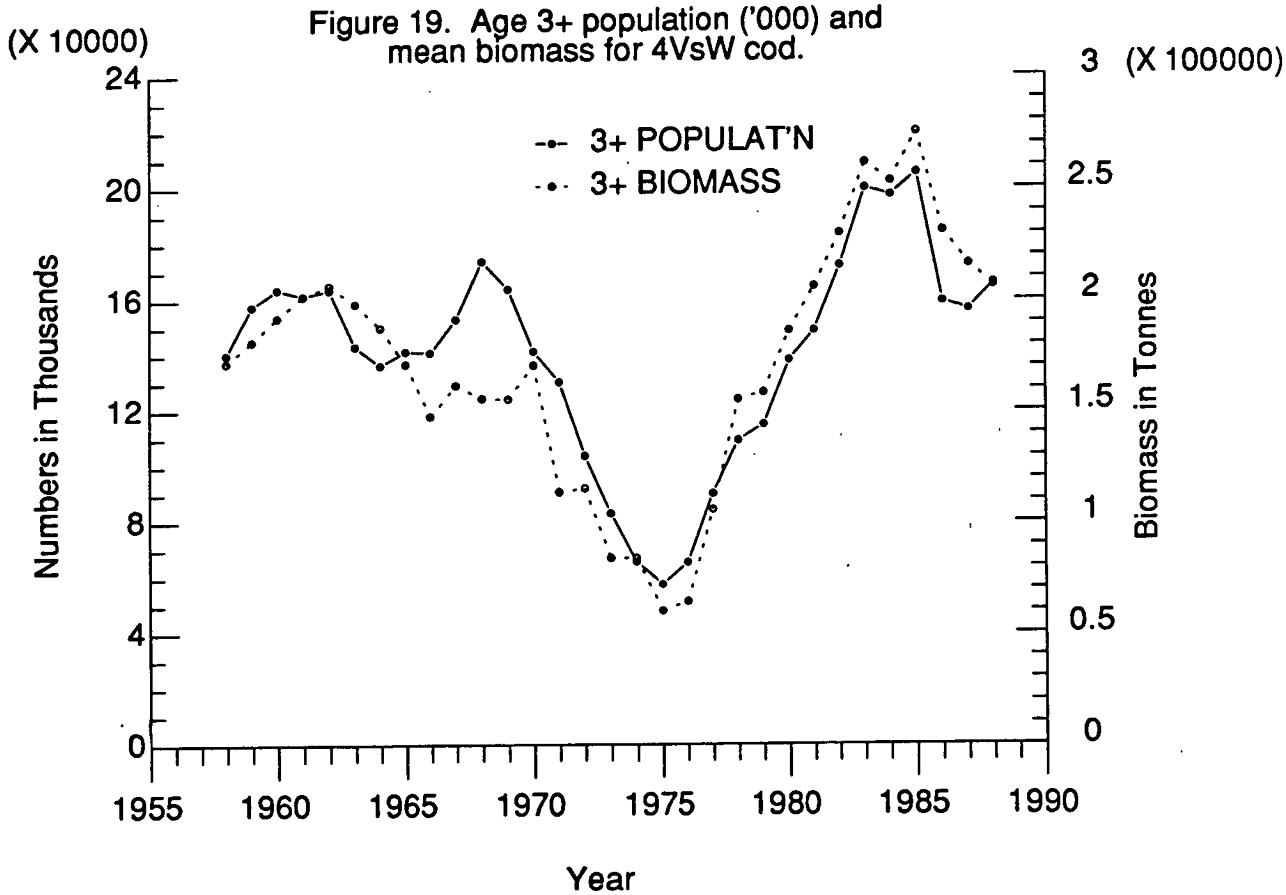


Figure 20. Age 1 recruits to 4VsW cod.

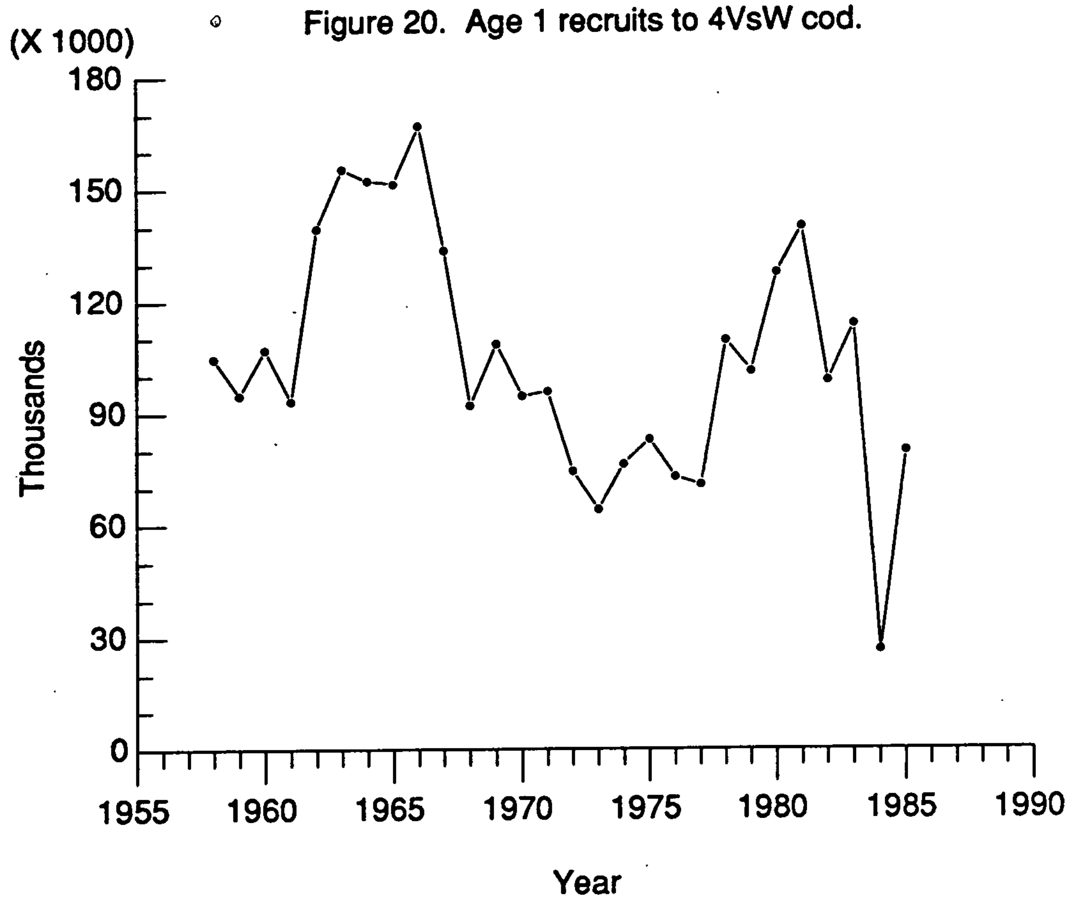
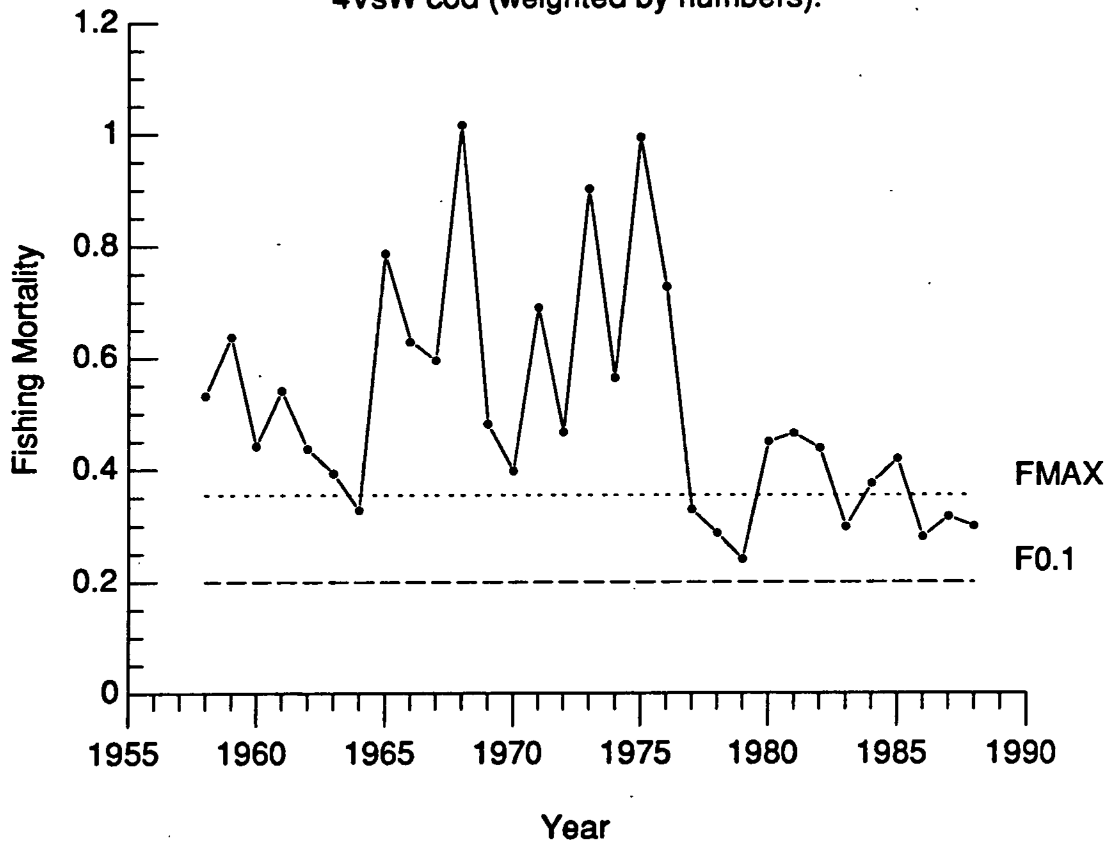


Figure 21. Age 7+ fishing mortality for 4VsW cod (weighted by numbers).



```
∇ INPUT;ANS
  c←⎕EX 'K'
  ⍎(0=⎕NC 'STOCK∆NAME')/'''STOCK NAME?''⋄STOCK∆NAME←⍞'
  'CATCH MATRIX FOR ',STOCK∆NAME
  c←⎕
  'FIRST YEAR AND YOUNGEST AGE IN CATCH MATRIX ? '
  ANS←⎕
  YR←((1↑ANS)-1)+⍳¯1↑⍴c
  AG←((¯1↑ANS)-1)+⍳1↑⍴c
  'ENTER PARTIAL RECRUITMENT VECTOR FOR ALL AGES'
  PR←⎕
  'ASSUMED AGES OF FULL RECRUITMENT (START WITH FIRST FULLY RECRUITED AGE) ? '
  AGE←AG⍳⎕
  'PRESENCE OR ABSENCE OF PLUS GROUP (P/A) ? '
  NUM←'P'=⍞
  'NATURAL MORTALITY ? IS 0.2 CHANGE m IF YOU DONT LIKE THIS'
⍝ m←⎕
  'ENTER STARTING ESTIMATES OF AGE-SPECIFIC FS (TO BE ESTIMATED) FOR LAST YEAR '
  ' EXCLUDE VALUE FOR PLUS ( IF ANY) GROUP '
  FLY←⎕
  'AGES IN CALIBRATION INDEX ? '
  ROWS←,AG⍳AGES←⎕
  FRST←1↑ROWS ⋄ LAST←¯1↑ROWS
⍝ 'ENTER FIRST AND LAST AGES TO CALIBRATE'
⍝ FAG←⎕
⍝ FRST←FAG[1]
⍝ LAST←FAG[2]
  'STARTING ESTIMATES OF YEAR-SPECIFIC FS FOR OLDEST'
  ' NON-PLUS GROUP AGE (ENTER 0 IF NOT DESIRED)'
  FAG←⎕
  FVECT←FLY[¯1+FRST+⍳1+LAST-FRST],1↓⌽FAG
  CVECT←,c[(¯1+FRST+⍳1+LAST-FRST);¯1↑⍴c]
  →(FAG=0)/S1
  CVECT←CVECT,1↓⌽,c[LAST;]
S1:NVECT←(CVECT×(FVECT+m))÷(FVECT×(1-*-FVECT+m))
  lbnd←CVECT×*m÷2
  ubnd←(⍴NVECT)⍴10000000
  'RV INDEX OF ABUNDANCE'
  '              SAME YEARS AS CATCH AT AGE MATRIX '
  '              SAME AGES AS CALIBRATION BLOCK'
  'ENTER 0 IF NO RV INDEX'
  INDEX∆TYPE← 0 0 ⍝ Indicator of indices available (RV,CPUE)
  i∆rv←⎕
  →(0=+/+/i∆rv)/cpue ⍝ No RV index so go to cpue input
  'FIRST AGE IN SURVEY'
  FINS←(1↑AG)-FINS←⎕
  i∆rv←i∆rv[FINS+ROWS;]
  INDEX∆TYPE[1]←1
  'ESTIMATES OF STANDARD ERROR OF INDEX  (ENTER 1 IF LOG MODEL)? '
  ise∆rv←⎕
  ⍎(0≠⍴⍴ise∆rv)/'ise∆rv←ise∆rv[FINS+ROWS;]'
  'INDEX FOR WHAT MONTH ( NO. FROM 1 TO 12 ) ? '
  MNTH←⎕÷12
  'STARTING AGE - SPECIFIC COEFFICIENTS FOR RV INDEX'
  ' '
  ' MATRIX OF AGE BY AGE COEFFICIENTS (1 OR 2 COLUMNS)'
  (1≠+/+/ise∆rv)/' MODEL IS      I = [B0] + B1 × POP '
  (1=+/+/ise∆rv)/' LOG MODEL IS    LN(I) = LN( [B0] + B1 × POP ) '
  ' '
  K←⎕
  lbnd←lbnd,(⍴,K)⍴(-¯1↑⍴K)↑ ¯9000 0 ⍝ MIN SLOPE =0, MIN INTER.=¯9000
  ubnd←ubnd,(⍴,K)⍴9000 ⍝ MAX SLOPE AND INTER. = 9000
cpue:'CPUE INDEX OF ABUNDANCE'
  '              SAME YEARS AS CATCH AT AGE MATRIX'
  'ENTER 0 IF NO CPUE INDEX'
  i∆cpue←⎕
  →(0=+/+/i∆cpue)/exit ⍝ No cpue index so go to exit
  INDEX∆TYPE[2]←1
l1:'ESTIMATES OF STANDARD ERROR OF CPUE?  (1 FOR LOG MODEL OPTION) '
  ise∆cpue←⎕
  →((⍴i∆cpue)≠⍴ise∆cpue)/l1 ⍝ must be same length as i∆cpue
  'ENTER MEAN WEIGHTS AT AGE - SAME YEARS AND AGES AS CATCH'
  MWT←⎕
  'STARTING COEFFICIENTS FOR CPUE INDEX (AGE AGGREGATED)'
  ''
  →(0=⎕NC 'K')/norv
  'ENTER ',(⍕¯1↑⍴K),' VALUE(S) FOR COEFFICIENT(S)'
  K←K,⎕
  →exit1
norv:
  'ENTER 1 (SLOPE) OR 2 (INTERCEPT AND SLOPE) COEFFICIENTS'
  K←(1,⍴,K)⍴K←,⎕
exit1:lbnd←lbnd,((|1-¯1↑⍴K)↑¯9000),0
  ubnd←ubnd,((|1-¯1↑⍴K)↑9000),9000
exit:initial←NVECT,,K
  alpha←1E¯3×NVECT
  limit←100
  'Penalty constraints ON initially (Y/N)? Default is OFF'
  USE∆CONSTRAINTS←0
  ⍎(('Y'=ANS)∨'y'=ANS←⎕INKEY)/'USE∆CONSTRAINTS←1'
  'Penalty functions turned ',(2 3 ⍴'OFFON ')[1+USE∆CONSTRAINTS;]
  ' '
  'Ready to run minipop'
∇
```

```
     ∇ minipop;BOOL;J;DIAG;O;LAMBDA;HESS;N;F;PAR;RSS;de;CAUSE;I;V;NPHI;PHI;pnlty;dpnlty;SHESS;NORM;I;Δts;ANS
[1]  ⍝ NON-LINEAR LEAST SQUARES USING MARQUARDT ALGORITHM
[2]   Δts←¯7↓TIMEFMT ⎕TS
[3]   'Do you wish to document your input ?'
[4]   ⍎(('Y'=ANS)∨'y'=ANS←⎕INKEY)/'miniDOC'
[5]   page Δts
[6]   rssvec←⍳0
[7]   P←⍴par←PAR←,initial
[8]   RSS←e+.×e←OBJΔFN PAR ⍝ RESIDUAL SUM OF SQUARES
[9]   N←⍴,e
[10]  pnlty←alpha PNLTYΔFN PAR ⍝ PENALTY FOR CONSTRAINTS
[11]  NPHI←PHI←RSS+pnlty
[12]  LAMBDA←0.01
[13]  BOOL←(P×P)⍴1,P⍴0 ⍝ USED TO CREATE DIAG MATRIX
[14]  con←10
[15]  J←1
[16]  PRNT
[17]  rssvec←rssvec,RSS
[18] L3:→(limit<J←J+1)/L6 ⍝MAIN LOOP
[19]  PAR←par
[20]  PHI←NPHI
[21]  de←DIFFΔOBJ
[22]  Q←2×e+.×de ⍝ GRADIENT
[23]  HESS←2×(⍉de)+.×de ⍝ HESSIAN
[24]  dpnlty←DIFFΔPNLTY ⍝ DIFFERENCE FOR PENALTY
[25]  Q←Q+dpnlty[1;]
[26]  DIAG← 1 1 ⍉HESS←HESS+(2⍴P)⍴BOOL\dpnlty[2;]
[27]  LAMBDA←9.9999999999999E¯7⌈LAMBDA×0.01
[28]  I←1
[29]  SHESS←HESS+(2⍴P)⍴BOOL\DIAG×LAMBDA←LAMBDA×10 ⍝ MARQUARDT METHOD
[30]  NORM←(+⌿SHESS*2)*0.5 ⍝ COLUMN NORMS
[31]  SHESS←SHESS÷(⍴SHESS)⍴NORM ⍝ SCALE HESSIAN
[32]  par←PAR+V←(Q⌹SHESS)÷NORM ⍝ STEP DIRECTION; STEP SIZE=1
[33]  →(~FRGNΔFN par)/L4
[34]  RSS←e+.×e←OBJΔFN par
[35]  pnlty←alpha PNLTYΔFN par
[36]  →(PHI≥NPHI←RSS+pnlty)/L6
[37] L4:LAMBDA←LAMBDA×100
[38] L5:par←PAR+V←V×0.1*I ⍝INNER LOOP  REDUCE STEP SIZE
[39]  →(10<I←I+1)/L6
[40]  →(~FRGNΔFN par)/L5
[41]  RSS←e+.×e←OBJΔFN par
[42]  pnlty←alpha PNLTYΔFN par
[43]  →(PHI≥NPHI←RSS+pnlty)/L6
[44]  →L5
[45] L6:PRNT
[46]  rssvec←rssvec,RSS
[47]  msr←RSS÷N-P
[48]  →(1=^/CAUSE←(10≥I),(limit≥J),(1E¯3<con←(((N-P)×|Q+.×V)÷P×RSS)*0.5),(1E¯4<|(NPHI-PHI)÷PHI),(9.9999999999999E¯6>∧.<|(par-PAR)÷1E¯20+|PAR))/L3
[49]  ⎕PUT(~CAUSE)/[1]exit
[50]  ⍎(USEΔCONSTRAINTS)/'USEΔCONSTRAINTS←0 ⋄ ''TURNING CONSTRAINTS OFF''⋄→L3'
[51]  page Δts
[52]  OUTPUT
     ∇
```

```
    ∇ miniDOC;l;sp
  OTCFF
  QPUT 'Input Documentation for ',STOCKΔNAME,' Run at',(8ρ' '),Δts
  QPUT 78ρ'-'
  QPUT 78ρ'-'
  QPUT ' '
  QPUT '      This Analysis was Performed Using the Following Criteria : '
  QPUT 78ρ'-'
  QPUT ' '
  QPUT '1)   Catch at Age extends from ',(⍕YR[1]),' to ',(⍕¯1↑YR),' and Ages ',(⍕AG[1]),' to ',⍕¯1↑AG
  ⍎(~((NUM='P')∨NUM='p'))/'QPUT ''      The Catch at Age did NOT contain a PLUS Group''⋄→stp1 '
  QPUT ' '
  QPUT '      Age ',(⍕¯1↑AG),' is a PLUS Group '
  QPUT ' '
  QPUT '      Ages ',(⍕AGES),' were assumed fully recruited'
  QPUT ' '
 stp1:⍎(∧/PR=1)/'QPUT ''2)      No Partial Recruitment Values were Imposed''⋄→stp2'
  QPUT '2)   Partial Recruitment values Imposed: '
  QPUT ' '
  QPUT '                        Ages      PR'
  QPUT 'X20,I2,X7,F5.3' ⎕FMT((((ρAG),1)ρAG),(((ρPR),1)ρPR))
  QPUT ' '
 stp2:QPUT '3)   Natural Mortality was set at ',(⍕m)
  QPUT ' '
  QPUT '4)   F''s over Ages ',(⍕FRST),' to ',(⍕LAST),' will be derived starting from initial estimates: '
  QPUT ' '
  sp←(FRST,FRST+⍳(LAST-FRST)) ⋄ l←(LAST-FRST)+1
  s←(ρNVECT)ρinitial
  FVECT←(⍟s÷(s-CVECT×*m÷2)×*-m)-m
  QPUT '                         Ages      F '
  QPUT 'X20,I2,X7,F5.3' ⎕FMT(((l,1)ρsp),((ρFVECT),1)ρFVECT)
  QPUT ' '
  ⍎(FAG=0)/'QPUT ''5)   No Initial Estimates of F at the oldest ages were used''⋄→stp3'
  QPUT '5)  Estimates of F at the Oldest Ages were derived from the following initial estimates'
  QPUT '                          Year      F '
  QPUT 'X20,I4,X7,F4.2' ⎕FMT(((ρYR),1)ρYR,((ρFAG),1)ρFAG)
 stp3:→(0=INDEXΔTYPE[1])/stp4
  ' '
  QPUT '6)   Research Survey Estimates of Abundance for ages ',(⍕FRST),' to ',(⍕LAST),' were given'
  ⍎(0=ρρiseΔrv)/'QPUT''      No standard errors were applied. Log transformation used'''
  ⍎(0≠ρρiseΔrv)/'QPUT''      Standard errors of abundance index applied to residuals'''
 stp4:→(0=INDEXΔTYPE[2])/stp5
  ''
  QPUT '7)   Commercial CPUE with standard errors was calibrated on fishable biomass'
 stp5:' '
  QPUT '8)   The Lower Limit for Estimated Numbers at Age was the CATCH'
  QPUT '     Upper limit for Estimated Numbers at age was ',⍕1↑ubnd
  →(0=INDEXΔTYPE[1])/stp6
  sp←(¯1↑ρK)↑(ρCVECT)↓lbnd
  ''
  QPUT '9)   The Lower Limit for RV survey slope was ',⍕¯1↑sp
  ⍎(2=ρsp)/'QPUT''                              and for intercept was '',⍕1↑sp'
  sp←(¯1↑ρK)↑(ρCVECT)↓ubnd
  QPUT '     The Upper Limit for RV survey slope was ',⍕¯1↑sp
  ⍎(2=ρsp)/'QPUT ''                              and for intercept was '',⍕1↑sp'
 stp6:→(0=INDEXΔTYPE[2])/exit
  sp←(-¯1↑ρK)↑lbnd
  QPUT '10)  The Lower Limit for CPUE slope was ',⍕¯1↑sp
  (2=ρsp)/'                    and for intercept was ',⍕1↑sp
  sp←(-¯1↑ρK)↑ubnd
  QPUT '     The Upper Limit for CPUE slope was ',⍕¯1↑sp
  ⍎(2=ρsp)/'QPUT''                         and for intercept was '',⍕1↑sp'
 exit:QPUT 78ρ'-'
    ∇
```

```
    ∇ R←OBJ∆FN A
[1]   s←(⍴NVECT)⍴A ⍝ survivors at designated age
[2]   FVECT←(⍟s÷(s-CVECT×⋆m÷2)×⋆-m)-m
[3]   →(^/PR=1)/NOPR ⍝ skips PR if no PR was imposed
[4]   FRF←(+/((1↑AGE)-FRST)↓FVECT×s)÷+/((1↑AGE)-FRST)↓s ⍝ fully recruited F
[5]   ⍎(FRST=LAST)/'FRF←FVECT'
[6]   FLY←PR×FRF
[7]  NOPR:FLY[¯1+FRST+⍳1+LAST-FRST]←FVECT
[8]   →(FAG=0)/S1
[9]   FAG←(⌽(⍴FAG)↑⌽FVECT)
[10] S1:k←((INDEX∆TYPE[2]+INDEX∆TYPE[1]×⍴ROWS),(¯1↑⍴K))⍴(-(INDEX∆TYPE[2]+INDEX∆TYPE[1]×⍴ROWS)×¯1↑⍴K)↑A
[11] ⍝ k is the current calibration coefficients
[12]  ITERCOHORT
[13]  INTERFACE POP
[14]  R←,RESI k ⍝ calculate index residuals
    ∇


    ∇ ITERCOHORT:CATCH;J;MORT;FI;FC;ITER;I;Y;X;FCNEW;DIFF1
[1]   CATCH←c
[2]   J←¯1↑⍴CATCH
[3]   MORT←(⍴CATCH)⍴m
[4]   F←(⍴CATCH)⍴0
[5]   FI←FLY
[6]   →(NUM=0)/S3
[7]   FI←FI,¯1↑FI
[8]  S3:→(FAG=0)/S2
[9]   FC←FAG
[10]  →S1
[11] S2:FC←(¯1↑⍴CATCH)⍴(¯1↑FI)
[12] S1:ITER←0
[13] OK9:I←⍴FI
[14]  F[(⍳I);J]←I⍴FI
[15]  F[I;]←J⍴FC
[16]  ITER←ITER+1
[17]  →(ITER≥20)/0
[18]  POP←(⍴CATCH)⍴0
[19]  POP[(⍳I);J]←((,CATCH[(⍳I);J])×FI+(,MORT[(⍳I);J]))÷FI×1-⋆-FI+(,MORT[(⍳I);J])
[20]  POP[I;]←((,CATCH[I;])×FC+(,MORT[I;]))÷FC×1-⋆-FC+(,MORT[I;])
[21]  →(NUM=0)/SK1
[22]  I←I-1
[23]  POP[I;]←((,CATCH[I;])×FC+(,MORT[I;]))÷FC×1-⋆-FC+(,MORT[I;])
[24]  F[I;]←J⍴FC
[25] SK1:Y←J-1
[26] AA:X←MORT[⍳I-1;Y]
[27]  POP[⍳I-1;Y]←(CATCH[⍳I-1;Y]×⋆X÷2)+(POP[1↓⍳I;Y+1]×⋆X)
[28]  →(1≤Y←Y-1)/AA
[29]  F[⍳I-1;⍳J-1]←(⍟(¯1 ¯1 ↓POP[⍳((1↑⍴POP)-NUM);])÷ 1 1 ↓POP[⍳((1↑⍴POP)-NUM);])- ¯1 ¯1 ↓MORT[⍳((1↑⍴POP)-NUM);]
[30]  →(FAG≠0)/0
[31]  FCNEW←(+/[1]POP[AGE;]×F[AGE;])÷+/[1]POP[AGE;]
[32]  DIFF1←|(FCNEW-FC)÷FCNEW
[33]  FC←(¯1↓FCNEW),¯1↑FC
[34]  →((⌈/¯1↓DIFF1)>0.01)/OK9
    ∇


    ∇ INTERFACE POPN;pr;FRF
[1]  ⍝ Produces 1 or 2 global variables POPIND and FBIOM
[2]   →(0=INDEX∆TYPE[1])/CPUE
[3]   POPIND←POPN×⋆-(F+m)×1↑MNTH ⍝ Adjusts SPA population to the survey month
[4]   POPIND←POPIND[ROWS;] ⍝ selects calibration block
[5]   →(1=INDEX∆TYPE[1])/CPUE
[6]   POPIND2←POPN×⋆-(F+m)×1↑1↓MNTH ⍝ Adjusts SPA population to the survey month
[7]   POPIND2←POPIND2[ROWS;] ⍝ selects calibration block
[8]   →(2=INDEX∆TYPE[1])/CPUE
[9]   POPIND3←POPN×⋆-(F+m)×¯1↑MNTH ⍝ Adjusts SPA population to the survey month
[10]  POPIND3←POPIND3[ROWS;] ⍝ selects calibration block
[11] CPUE:→(0=INDEX∆TYPE[2])/EXIT
[12]  FRF←(+/(POPN×F×OTBpartCAT)[AGE;])÷+/POPN[AGE;] ⍝ Calculates fully recruited Ffor OTB partial F matrix
[13]  pr←1⌊F÷(⍴F)⍴FRF ⍝ calculates PR matrix
[14]  pr[AGE;]←1 ⍝ Sets defined fully recruited ages to 1
[15]  FBIOM←+/POPN×pr×MWT
[16] EXIT:
    ∇
```

```
    ∇ R←RESI K
  R←⍳0
  →(0=INDEX∆TYPE[1])/cpue ⍝ NO RV SURVEY
  R←R,,POPIND RESI∆RV K[⍳⍴ROWS;]
  ⍎(1<INDEX∆TYPE[1])/' R←R,,POPIND2 RESI∆RV2 K[(⍴ROWS)+⍳⍴ROWS;]'
  ⍎(2<INDEX∆TYPE[1])/' R←R,,POPIND3 RESI∆RV3 K[(2×⍴ROWS)+⍳⍴ROWS;]'
  →(0=INDEX∆TYPE[2])/res ⍝ NO CATCH RATE SERIES
 cpue:K←(⊖K)[1;] ⍝ get bottom row of K
  R←R,,FBIOM RESI∆CPUE K
 res:
    ∇


    ∇ R←POPIND RESI∆RV K
  →(1=¯1↑⍴K)/noint
  K← 3 2 1 ⍉(⌽2,⍴POPIND)⍴,K
  ihat∆rv←(K[1;;]+K[2;;]×POPIND) ⍝ WITH INTERCEPT
  →res
 noint:K←⍉(⌽⍴POPIND)⍴,K
  ihat∆rv←K×POPIND ⍝ WITHOUT INTERCEPT
 res:→(^/1=,ise∆rv)/LOG
  R←(,MASKRV)/,(i∆rv-ihat∆rv)÷ise∆rv
  →0
 LOG:R←(,MASKRV)/,(⍟i∆rv)-⍟ihat∆rv
    ∇


    ∇ R←FBIOM RESI∆CPUE K
  →(1=⍴,K)/noint
  ihat∆cpue←(K[1]+K[2]×FBIOM) ⍝ WITH INTERCEPT
  →res
 noint:ihat∆cpue←K×FBIOM ⍝ WITHOUT INTERCEPT
 res:⍎(^/1=ise∆cpue)/'R←(⍟i∆cpue)-⍟ihat∆cpue ⋄→0'
  R←(i∆cpue-ihat∆cpue)÷ise∆cpue
    ∇


    ∇ R←POPIND RESI∆RV2 K
  →(1=¯1↑⍴K)/noint
  K← 3 2 1 ⍉(⌽2,⍴POPIND2)⍴,K
  ihat∆rv2←(K[1;;]+K[2;;]×POPIND2) ⍝ WITH INTERCEPT
  →res
 noint:K←⍉(⌽⍴POPIND2)⍴,K
  ihat∆rv2←K×POPIND2 ⍝ WITHOUT INTERCEPT
 res:→(^/1=ise∆rv2)/log
  R←(,MASK2)/,(i∆rv2-ihat∆rv2)÷(0=ise∆rv2)+ise∆rv2
  →0
 log:R←(,MASK2)/,(⍟i∆rv2)-⍟ihat∆rv2
    ∇

    ∇ R←POPIND RESI∆RV3 K
  →(1=¯1↑⍴K)/noint
  K← 3 2 1 ⍉(⌽2,⍴POPIND3)⍴,K
  ihat∆rv3←(K[1;;]+K[2;;]×POPIND3) ⍝ WITH INTERCEPT
  →res
 noint:K←⍉(⌽⍴POPIND3)⍴,K
  ihat∆rv3←K×POPIND3 ⍝ WITHOUT INTERCEPT
 res:→(^/1=,ise∆rv3)/log
  R←(,MASK3)/,(i∆rv3-ihat∆rv3)÷(0=ise∆rv3)+ise∆rv3
  →0
 log:R←(,MASK3)/,(⍟i∆rv3)-⍟ihat∆rv3

    ∇
```

```
    ∇ R←DIFF∆OBJ;DELTA;I;TPAR
[1]  ⍝ CALCULATES ONE SIDED DIFFERENCE OF OBJECTIVE FUNCTION
[2]   I←1
[3]   R←(N,0)ρ1
[4]  ⍝ DELTA←(0.01×par)+0.01×par=0
[5]   DELTA←1E¯7×1E¯7+|par ⍝ see NASH pg 180 formula 18.5 (GNW3)
[6]  L1:TPAR←((I-1)↑par),(par[I]+DELTA[I]),I↓par
[7]   R←R,(e-OBJ∆FN TPAR)÷(par[I]+DELTA[I])-par[I]
[8]  ⍝ ensures actual DELTA[I] is in denominator, conditions rounding error
[9]   →L1×P≥I←I+1
    ∇

    ∇ R←DIFF∆PNLTY;I;R1;DELTA;TPAR;fpnlty;bpnlty
[1]  ⍝ CALCULATES FIRST AND SECOND DIFFERENCES OF PENALTY FUNCTION
[2]   I←1
[3]   R← 2 0 ρ0
[4]   DELTA←(0.01×PAR)+0.01×PAR=0
[5]  L1:TPAR←((I-1)↑PAR),(PAR[I]+DELTA[I]),I↓PAR
[6]   R1←(pnlty-fpnlty←alpha PNLTY∆FN TPAR)÷DELTA[I]
[7]   TPAR←((I-1)↑PAR),(PAR[I]-DELTA[I]),I↓PAR
[8]   bpnlty←alpha PNLTY∆FN TPAR
[9]   R←R,,R1,(fpnlty+bpnlty-2×pnlty)÷DELTA[I]
[10]  →L1×P≥I←I+1
    ∇

    ∇ R←FRGN∆FN A
[1]   R←^/(A>lbnd),A<ubnd
[2]  ⍝ THIS FUNCTION SHOULD RETURN A 1 IF THE PARAMETERS
[3]  ⍝ ARE IN THE FEASIBLE REGION AND 0 OTHERWISE
[4]  ⍝ R←1 DEFAULT RETURNS 1
    ∇

    ∇ R←alpha PNLTY∆FN A
[1]   R←USE∆CONSTRAINTS×+/alpha÷(ρNVECT)↑A
[2]  ⍝ State variable 'USE∆CONSTRAINTS' controls penalty function
[3]  ⍝ 1 → constraints on; 0 → constraints off
    ∇

    ∇ PRNT;TMP;FMT
[1]   QPUT ' '
[2]   QPUT 'ITERATION NUMBER ',⍕J
[3]   QPUT ' ' ⋄ QPUT 'PENALTY FUNCTION TURNED ',(2 3 ρ'OFFON ')[1+USE∆CONSTRAINTS;] ⋄ QPUT ' '
[4]   TMP← 3 6 ρ'LAMBDARSS   NPHI  '
[5]   QPUT '10A1,E15.6' ⎕FMT(3 10 ↑TMP;⍎¯1↓,TMP,',')
[6]   QPUT ' '
[7]   QPUT ' F''s IN LAST YEAR : '
[8]   QPUT 6 3 ⍕FLY
[9]   QPUT ' '
[10]  →(FAG=0)/NXT
[11]  QPUT ' F''s AT OLDEST AGES : '
[12]  QPUT 6 3 ⍕FAG
[13] NXT:→(0=INDEX∆TYPE[1])/NXT1
[14]  QPUT ' '
[15]  QPUT 'ESTIMATED JULY RV SURVEY CALIBRATION PARAMETERS'
[16]  QPUT ' AGE       ',((2=¯1↑ρK)/'INTERCEPT      '),' SLOPE           NUMBERS'
[17]  FMT←'I4,F14.5,I14'
[18]  ⍎(2=¯1↑ρK)/'FMT←''I4,2F14.5,I14'''
[19]  TMP←⍉(INDEX∆TYPE[2]×¯1↑ρK)↓(ρ,K)↑⌽par
[20]  TMP←(ρ(-INDEX∆TYPE[2],0)↓K)ρTMP
[21]  QPUT FMT ⎕FMT(((ρAGES),1)ρAGES),TMP[⍳ρROWS;],((ρNVECT)↑par)
[22]  →(1=INDEX∆TYPE[1])/NXT1 ⋄ QPUT 'ESTIMATED MARCH RV SURVEY CALIBRATION PARAMETERS'
[23]  QPUT FMT ⎕FMT(((ρAGES),1)ρAGES),TMP[(ρROWS)+⍳ρROWS;],((ρNVECT)↑par)
[24]  →(2=INDEX∆TYPE[1])/NXT1 ⋄ QPUT 'ESTIMATED SEPT. RV SURVEY CALIBRATION PARAMETERS'
[25]
[26]  QPUT FMT ⎕FMT(((ρAGES),1)ρAGES),TMP[(2×ρROWS)+⍳ρROWS;],((ρNVECT)↑par)
[27] NXT1:→(0=INDEX∆TYPE[2])/DONE
[28]  QPUT ''
[29]  QPUT 'ESTIMATED CPUE CALIBRATION PARAMETER(S) '
[30]  QPUT((2=¯1↑ρK)/'     INTERCEPT'),'         SLOPE'
[31]  FMT←'F14.5'
[32]  ⍎(2=¯1↑ρK)/'FMT←''2F14.5'''
[33]  QPUT FMT ⎕FMT(1,¯1↑ρK)ρ(-¯1↑ρK)↑par
[34] DONE:QPUT 78ρ'-'
    ∇
```

```
    ∇ OUTPUT;TIT dx;dy;ag;yr
  ⎕PUT ' '
  ⎕PUT 'RSS Trajectory by Iteration ',STOCK∆NAME,'           ',∆ts
  dx←'ITERATION NUMBER'
  dy←'RESIDUAL SS'
  20 40 PLOT rssvec VS(⍳⍴rssvec)
  I←1
  ⎕PUT ' '
  ⎕PUT ' CALIBRATION COEFFICIENTS BY AGE FOR ',STOCK∆NAME,'        ',∆ts
  ⎕PUT ' '
  →((¯1↑⍴k)=1)/S2
 S1:⎕PUT 'AGE ',(2 0 ⍕AGES[I]),' :  I = ',(10 3 ⍕k[I;1]),'       +',(10 3 ⍕k[I;2]),' × POP'
  →((⍴ROWS)≥I←I+1)/S1
  →NEXT
 S2:→(INDEX∆TYPE[1]=0)/NEXT
  ⎕PUT 'AGE ',(2 0 ⍕AGES[I]),' :  I = ',(10 3 ⍕k[I;1]),' × POP'
  →((⍴ROWS)≥I←I+1)/S2
 NEXT:⎕PUT ' '
  ⎕PUT ' MEAN SQUARE RESIDUALS : ',⍕msr
  ⎕PUT '             MEAN RESIDUAL : ',⍕+/e÷⍴e
  ⎕PUT '  SUM OF ALL RESIDUALS : ';⍕+/e
  page ∆ts
  DATAGEN par
  TIT←'POPULATION NUMBERS (000S)'
  0 OUT POP,[1]+/[1]POP
  TIT←'FISHING MORTALITY'
  page ∆ts
  3 OUT F
  ag←AG
  yr←YR
  →(INDEX∆TYPE[1]=0)/CPUE
  →(∧/1=,ise∆rv)/LOGS
  AG←AGES
  TIT←'WEIGHTED RESIDUALS FOR RV INDEX'
  page ∆ts
  3 OUT RESID∆RV
  ⎕PUT ⎕TCNL,'SUM OF RV RESIDUALS : ',(⍕+/,RESID∆RV),'  MEAN RESIDUAL : ',⍕+/,RESID∆RV÷+/,MASKRV

  →(INDEX∆TYPE[1]<2)/CPUE
  TIT←'WEIGHTED RESIDUALS FROM MARCH RV INDEX'
  YR←MASK2[1;]/yr
  3 OUT RESID∆RV2←(((0≠ise∆rv2)×i∆rv2-ihat∆rv2)÷ise∆rv2)[;MASK2[1;]/⍳1↓⍴MASK2]
  ⎕PUT ⎕TCNL,'SUM OF RV RESIDUALS : ',(⍕+/,RESID∆RV2),'  MEAN RESIDUAL : ',⍕+/,RESID∆RV2÷+/,MASK2
  →(INDEX∆TYPE[1]<3)/CPUE
  TIT←'WEIGHTED RESIDUALS FROM SEPTEMBER RV INDEX'
  YR←MASK3[1;]/yr
  3 OUT RESID∆RV3←(((0≠ise∆rv3)×i∆rv3-ihat∆rv3)÷ise∆rv3)[;MASK3[1;]/⍳1↓⍴MASK3]
  ⎕PUT ⎕TCNL,'SUM OF RV RESIDUALS : ',(⍕+/,RESID∆RV3),'  MEAN RESIDUAL : ',⍕+/,RESID∆RV3÷+/,MASK3
  →CPUE

 LOGS:AG←AGES
  TIT←'LOG RESIDUALS FOR RV INDEX'
  page ∆ts
  3 OUT RESID∆RV
  ⎕PUT ⎕TCNL,'SUM OF RV RESIDUALS : ',(⍕+/,RESID∆RV),'  MEAN RESIDUAL : ',⍕+/,RESID∆RV÷+/,MASKRV
  →(INDEX∆TYPE[1]<2)/CPUE
  TIT←'LOG RESIDUALS FROM MARCH RV INDEX'
  YR←MASK2[1;]/yr
  3 OUT RESID∆RV2←((⍟i∆rv2)-⍟ihat∆rv2)[;MASK2[1;]/⍳1↓⍴MASK2]
  ⎕PUT ⎕TCNL,'SUM OF RV RESIDUALS : ',(⍕+/,RESID∆RV2),'  MEAN RESIDUAL : ',⍕+/,RESID∆RV2÷+/,MASK2
  →(INDEX∆TYPE[1]<3)/CPUE
  TIT←'LOG RESIDUALS FROM SEPTEMBER RV INDEX'
  YR←MASK3[1;]/yr
  3 OUT RESID∆RV3←((⍟i∆rv3)-⍟ihat∆rv3)[;MASK3[1;]/⍳1↓⍴MASK3]
  ⎕PUT ⎕TCNL,'SUM OF RV RESIDUALS : ',(⍕+/,RESID∆RV3),'  MEAN RESIDUAL : ',⍕+/,RESID∆RV3÷+/,MASK3

 CPUE:→(INDEX∆TYPE[2]=0)/NOCPUE
  YR←yr
  ⎕PUT ''
  AG←,0
  TIT←'RESIDUALS FROM CPUE INDEX'
  3 OUT(1,⍴RESID∆CPUE)⍴RESID∆CPUE
  ⎕PUT ⎕TCNL,'SUM OF CPUE RESIDUALS : ',(⍕+/,RESID∆CPUE),'  MEAN RESIDUAL : ',⍕+/,RESID∆CPUE÷⍴,i∆cpue
 NOCPUE:page ∆ts
  ⎕PUT ' '
  ⎕PUT 'ESTIMATED PARAMETERS AND STANDARD ERRORS'
  PAR∆SE
  TIT←'Parameter Correlation Matrix'
  AG←YR←⍳1↑⍴corr
  3 OUT corr
  AG←ag ⋄ YR←yr
  '' ⋄ 5⍴⎕TCBEL
  'Output Age-by-Age Plots? (Y/N) Default is NO'
  ⍎(~('Y'=ANS)∨'y'=ANS←⎕INKEY)/'→0'
  PLOTRVSPA i∆rv
    ∇
```

```
    ∇ DATAGEN PAR;RESID
      RESID←OBJ∆FN PAR
      →(INDEX∆TYPE[1]=0)/CPUE
      →(∧/1=,ise∆rv)/LOG
      RESID∆RV←(i∆rv-ihat∆rv)÷ise∆rv
      →CPUE
    LOG:RESID∆RV←(⍟i∆rv)-⍟ihat∆rv
    CPUE:⍎(INDEX∆TYPE[2]≠0)/' RESID∆CPUE←(-⍴,i∆cpue)↑RESID'

    ∇
```

```
    ∇ INDEX PRINTRVSPA DATA;⎕PP;HDR;RANK;FMT;PS;LBLS;I;Z
     ⍝ PRINT DATA ARRAY USED FOR PLOTS
     ⍝ DATA←→ARRAY SUITABLE FOR USE WITH THE"PLOT"FUNCTION
     ⍝ (INDEX)←→DEFAULT IS ⍳¯1↑⍴DATA
      ⎕PP←4
      N←¯1+1↑⍴DATA
      PS←(N↑ps),(N,9)⍴' '
      PS←¯3⌽PS
      LBLS←(10↑' INDEX'),[1](10↑' CARRIER'),[1]PS
      LBLS←LBLS,[1]10↑' RANK'
      Z←((2 2 +⍴DATA),10)⍴' '
      QPUT 'SUMMARY OF DATA FROM PLOT'
      QPUT '------- -- ---- ---- ----'
      QPUT ''
      QPUT 'CARRIER VARIABLE: POPULATION NOS'
      QPUT 'RESPONSE VARIABLE(S): SURVEY - ○:OBSERVED, +:PREDICTED'
      QPUT ''
      ⍎(0=⎕NC 'INDEX')/'INDEX←⍳¯1↑⍴DATA'
      RANK←INDEX[⍋DATA[1;]]
      Z[1;;]←(2 10 ⍴20↑LBLS[1;]),[1](¯2↑(⍴DATA),10)↑⍕(¯2↑(⍴DATA),1)⍴INDEX
      I←1
    LP:Z[I+1;;]←(2 10 ⍴20↑LBLS[1+I;]),[1](¯2↑(⍴DATA),10)↑⍕(¯2↑(⍴DATA),1)⍴DATA[I;]
      →((1↑⍴DATA)≥I←I+1)/LP
      Z[I+1;;]←(2 10 ⍴20↑LBLS[1+I;]),[1](¯2↑(⍴DATA),10)↑⍕(¯2↑(⍴DATA),1)⍴RANK
      QPUT(1 10 ×⌽2+⍴DATA)⍴ 2 1 3 ⍉Z
    ∇
```

```
    ∇ PAR∆SE;N;P;HESS;de;NORM
      QPUT 'APPROXIMATE STATISTICS ASSUMING LINEARITY NEAR SOLUTION'
      QPUT ' '
      N←⍴,e
      P←⍴,par
      de←DIFF∆O[illegible]
      HESS←2×(⍉de)+.×de
      NORM←(+/HESS*2)*0.5
      HESS←⌹HESS÷(⍴HESS)⍴NORM
      HESS←2×msr×HESS÷⍉(⌽⍴HESS)⍴NORM
      par∆se←(1 1 ⍉HESS)*¯0.5
      corr←HESS÷HESS×par∆se∘.×par∆se
      par∆se←÷par∆se
      QPUT 'ORTHOGONALITY OFFSET.........',,'F16.6' ⎕FMT con
      QPUT 'MEAN SQUARE RESIDUALS .......',,'F16.6' ⎕FMT msr
      QPUT ' '
      QPUT '    PAR. EST.          STD. ERR.         T-STATISTIC '
      QPUT '    ---------          ---------         ----------- '
      QPUT 'E16.6,X3' ⎕FMT(par;par∆se;par÷par∆se)
    ∇
```

```
∇ PLOTRVSPA INDEX;DATA;SCALE;ITER;dx;dy;SYM;RESID
  SCALE← 20 40
  ITER←1
  YR←(YR[1]-1)+⍳¯1↑⍴INDEX
  ''
  RESID←RESID∆RV
  →(INDEX∆TYPE[2]=0)/S1
  page ∆ts
  QPUT 'AGGREGATE CATCH RATE RESIDUAL VS PREDICTED VALUE '
  dy←'CPUE RESIDUAL'
  dx←'PREDICTED CPUE'
  SCALE PLOT RESID∆CPUE VS ihat∆cpue

  QPUT 'OBSERVED AND PREDICTED AGGREGATE CATCH RATE BY YEAR'
  dy←'CATCH RATE'
  dx←'YEAR'
  SCALE PLOT ihat∆cpue AND i∆cpue VS YR


 S1:page ∆ts
  ' '
  QPUT 'AGE ',(⍕AGES[ITER]),' PLOTS '
  →(0=⍴⍴ise∆rv)/LN1
  DATA←INDEX[ITER;]AND ihat∆rv[ITER;]VS POPIND[ITER;]
  QPUT 'SURVEY NO. PER TOW VS SPA NUMBERS'
  ' '
  dy←'SURVEY NO. PER TOW'
  dx←'SPA NUMBERS'
  ' '
  SCALE PLOT DATA
  ' '
  QPUT 'TREND IN STANDARDIZED RESIDUAL OVER TIME'
  ' '
  dy←'RESIDUAL'
  dx←'YEAR'
  SCALE PLOT(RESID[ITER;])AND((⍴YR)⍴0)VS YR
  ' '
  QPUT 'STD. RESIDUAL VS PREDICTED VALUE'
  ' '
  dx←'PREDICTED VALUE'
  SCALE PLOT RESID[ITER;]AND((⍴ihat∆rv[ITER;])⍴0)VS ihat∆rv[ITER;]
  ' '
  QPUT 'RESIDUAL VS OBSERVED X'
  ' '
  dx←'OBSERVED X'
  SCALE PLOT RESID[ITER;]AND((⍴POPIND[ITER;])⍴0)VS⍟POPIND[ITER;]
  →S2
 LN1:
  DATA←(⍟INDEX[ITER;])AND(⍟ihat∆rv[ITER;])VS(⍟POPIND[ITER;])
  QPUT 'LN SURVEY NO. PER TOW VS LN SPA NUMBERS'
  ' '
  dy←'LN SURVEY NO PER TOW'
  dx←'LN SPA NUMBERS
  ' '
  SCALE PLOT DATA
  ' '
  QPUT 'TREND IN  LN RESIDUAL OVER TIME'
  ' '
  dy←'LN RESIDUAL'
  dx←'YEAR'
  SCALE PLOT(RESID[ITER;])AND((⍴YR)⍴0)VS YR
  ' '
  QPUT 'LN RESIDUAL VS LN PREDICTED VALUE'
  ' '
  dx←'LN PREDICTED VALUE'
  SCALE PLOT RESID[ITER;]AND((⍴ihat∆rv[ITER;])⍴0)VS⍟ihat∆rv[ITER;]
  ' '
  QPUT 'LN RESIDUAL VS OBSERVED LN X'
  ' '
  dx←'OBSERVED LN X'
  SCALE PLOT RESID[ITER;]AND((⍴POPIND[ITER;])⍴0)VS⍟POPIND[ITER;]
 S2:
  ' '
  QPUT 'TREND IN POPULATION ABUNDANCE OVER TIME'
  ' '
  dy←'ABUNDANCE'
  dx←'YEAR'
  SCALE PLOT INDEX[ITER;]AND ihat∆rv[ITER;]VS YR
  YR PRINTRVSPA DATA
  ' '
  ITER←ITER+1
  →(ITER=(1↑⍴INDEX)+1)/0
  →S1
∇
```

```
    ∇ Z←A AND B
      Z←((⍳1+1↑⍴B)≠⎕IO+1)\B←(¯2↑ 1 1 ,⍴B)⍴B
      Z[⎕IO+1;]←A
    ∇

    ∇ AXES;I;Y
      I←0 ⎕GINIT 'HERCULES'
      1 ⎕GLINE 1 4 2 ⍴ 200 50 200 850 200 850 1000 850
      I←0
     YTIC:Y←50+100×I
      1 ⎕GLINE 1 2 2 ⍴195,Y,200,Y
      I←I+1
      →(I<9)/YTIC
      I←1
     XTIC:Y←100+100×I
      1 ⎕GLINE 1 2 2 ⍴Y,850,Y,860
      I←I+1
      →(I≤9)/XTIC
    ∇

    ∇ VECT←AGES A∆PLUS MATRIX;FIRSTAGE;LASTAGE
      FIRSTAGE←1↑AGES
      LASTAGE←1↓AGES
      →(∨/(2=⍴AGES,AGES),(LASTAGE<FIRSTAGE),(LASTAGE>AG[⍴AG]))/ERROR
      →(FIRSTAGE<AG[1])/ERROR
      →(∧/(0≤LASTAGE-FIRSTAGE),(2=⍴AGES))/OK
     ERROR:→0,0↑⍞←'INVALID. FORMAT IS FIRSTAGE LASTAGE a∆plus MATRIX'
     OK:MATRIX←((FIRSTAGE-AG[1]),0)↓MATRIX
      MATRIX←⊖+\⊖MATRIX
      VECT←((1+LASTAGE-FIRSTAGE),1↓⍴MATRIX)↑MATRIX
    ∇

    ∇ X←DAT
      X←1↓ 3 0 ⍕100⊤⌽3↑⎕TS
      X[3 6]←'/'
    ∇

    ∇ Z←FTIE FNM;MAP;FS;LIB;⎕ELX;⎕SEG;⎕IO
     ⍝ Ties the named APL file and returns the tie number chosen.
     ⍝ Behaves like VM in that FTIE is a 'slippery' tie
      ⎕IO←1 ⋄ ⎕ELX←'⎕ERROR(∧\⎕DM≠⎕TCNL)/⎕DM'
      ⎕SEG←⍬ ⋄ FS←(0 1 =⎕PEEK 162)/ 1 10 ⍝ Look at file-id setting
      MAP←∧\FNM∊' 0123456789' ⍝ Map leading blanks and numbers
      LIB←MAP/FNM ⋄ FNM←(8 11 [1 10 ⍳FS])↑(~MAP)/FNM
      →(~∧/LIB=' ')/L1 ⋄ LIB←⍕¯48+⎕PEEK 97 ⍝ Get default drive if needed
     L1:LIB←(FS,0)⍕⎕FI LIB
      Z←(⎕FNAMES∧.=LIB,' ',FNM)/⎕FNUMS ⋄ →(0≠⍴Z)/0
      (LIB,' ',FNM)⎕FTIE Z←((⍳21)∊⎕FNUMS)⍳0
    ∇
```

```
    ∇ A OUT B;C;D;E;W;Y;PW;TEST
[1]  ⍝ TRANSLATED R.C. McCRAE - I.P. SHARP ASSOCIATES 85.1.7
[2]   →(1≠⍴⍴B)/CHECK1 ⍝                    || MOD.  83.8.03   M. JOLY
[3]   B←(1,⍴B)⍴B
[4]  CHECK1:A←,⍉(2,¯1↑⍴B)⍴(5⌈2+(A≠0)+A+(0>(⌊/[1]B))+⌈10⍟1⌈⌈/[1]|B),(¯1↑⍴B)⍴A
[5]   PW←(20+⍴TIT)⌈⎕PW⌊4++/((⍴A)⍴ 1 0)/A
[6]   Y←YR
[7]   QPUT ' '
[8]   QPUT(((¯8+PW)↑((⌊0.5×PW-⍴TIT)⍴' '),TIT),DAT)
[9]  SK1:QPUT ' '
[10]  C←¯1+(⎕PW<4++\A[¯1+2×⍳0.5×⍴A])⍳1
[11]  D←(2×C⌊⍴Y)↑A
[12]  D[2×⍳C⌊⍴Y]←0
[13]  QPUT('    |',D⍕(C⌊⍴Y)↑Y)
[14]  QPUT('---+',(+/A[¯1+2×⍳C])⍴'-')
[15]  →(1≠1↑⍴B)/MAT
[16]  QPUT((1 4 ⍴'   |'),((2×C)↑A)⍕(1,C)↑B)
[17]  →CHECK
[18] MAT:QPUT((2 0 ⍕((⍴AG),1)⍴AG),(((⍴AG),2)⍴' |'),((2×C)↑A)⍕((⍴AG),C)↑B)
[19]  →((⍴AG)=1↑⍴B)/CHECK
[20]  QPUT('---+',(+/A[¯1+2×⍳C])⍴'-')
[21]  E←(2 0 ⍕((TEST,1)⍴AG)),(((TEST←(1↑⍴B)-⍴AG),2)⍴'+|')
[22]  QPUT E,((2×C)↑A)⍕(((⍴AG)-1↑⍴B),C)↑B
[23] CHECK:A←(2×C)↓A
[24]  B←(0,C)↓B
[25]  Y←C↓Y
[26]  →(0≠⍴A)/SK1
    ∇


    ∇ A PLOT B;C;D;E;F;G;H;I;K;L;M;N;⎕IO;P;S;T;U;V;X;PVAL;COM;Q;CRTT;ps
[1]   ⎕IO←1 ⋄ CRTT←5E¯11
[2]   S←⍎(,(0=⎕NC 4 2 ⍴'dxdyJ ps')⌿ 4 3 ⍴'dx←dy←0⍴ ps←'),'''∘+∆×∇⎕'''
[3]   →(∧/ 1 2 ≠⍴⍴B)⍴L2
[4]   →((2=⍴⍴B)∧1≠1↑⍴B)/L1
[5]   B←(2,U)⍴(⍳U←⍴B),B
[6]  L1:→(1≠⍴⍴A)⍴L2
[7]   →(2 6 =⍴A)/L3,L7
[8]  L2:→0,0⍴⍞←'PARAMETRES NON VALIDES',∆cr
[9]  L3:M←L4,(K←⌊1E¯3+(L←A[2])÷10),(⌈/B[1;]),⌊/B[1;] ⋄ →L5
[10] L4:H←I[P] ⋄ C←D[P]
[11]  M←L6,(E←⌊1E¯3+(G←A[1])÷5),(⌈/,T),⌊/,T← 1 0 ↓B
[12] L5:S← 10000 5000 2500 1000 500 100 50 25
[13]  →(0=M[2])/L2
[14]  →(0≠U←-/¯2↑M)/L5A
[15]  →0,0⍴⍞←'PAS DE VARIATION DANS X OU Y',∆cr
[16] L5A:S←S×10*¯4+⌈10⍟U←U÷M[2]
[17]  P←(M[3]≤(I←M[4]-S|M[4])+M[2]×D←V-S|V←1.25×U)⍳1 ⋄ →M
[18] L6:X←⌊1.5+(B[1;]-H)×10÷C
[19]  T←⌊0.5+(T-I←I[P])×5÷D←D[P] ⋄ →L8
[20] L7:K←⌊1E¯3+(L←A[4])÷10
[21]  E←⌊1E¯3+(G←A[1])÷5
[22]  X←(F←(0≤X)∧X≤L+1)/X←⌊1.5+(B[1;]-H←A[5])×10÷C←A[6]
[23]  T←F/⌊0.5+((T← 1 0 ↓B)-I←A[2])×5÷D←A[3]
[24] L8:M←(⌊10⍟|D)-0,⍳B←10
[25]  M←M[11⌊(∧/(CRTT×D⌈⌈/P)≥M∘.|P←|I+D×¯1+⍳E+1)⍳1]
[26]  S← 10 ¯3 ⋄ →((B<P←1+⌊10⍟⌈/P)∨M<¯7)/L9
[27]  S←10,0⌈(B-P⌈1)⌊-M
[28] L9:Q←(V\S⍕⍉(D×¯1+⍳E+1)∘.+,I),'|+'[1+V←⌽0=5|¯1+⍳1+P←G]
[29]  U←((-⌊(U-×/⍴dy)÷2)⌽(U←G+1)↑dy),Q
[30]  X←,((⍴T)[1]⍴⍳⍴ps)∘.+1000×X ⋄ T←,T
[31] L10:PVAL←(U[1+G-P;]),(L+1)⍴' '
[32]  →(0=⍴S←(T=P)/X)/L12
[33]  S←(S≠0,¯1↓S)/S←S[⍋S]
[34]  PVAL[(¯1↑⍴U)+⌊S÷1000]←ps[1000|S]
[35] L12:QPUT '      ',PVAL
[36]  →(0≤P←P-1)/L10
[37]  QPUT(16⍴' '),'/',(L+1)⍴'+---------'
[36]  M←(⌊10⍟|C)-0,⍳10
[39]  M←M[11⌊(∧/(CRTT×C⌈⌈/P)≥(10*M)∘.|P←|B←H+C×¯1+⍳K+1)⍳1]
[40]  S←10-3 ⋄ →((B<P←1+⌊10⍟⌈/P)∨M<¯7)/L13
[41]  S←10,0⌈(B-P⌈1)⌊-M
[42] L13:QPUT(6⍴' '),S⍕B
[43]  →(0=×/⍴dx)⍴0
[44]  QPUT ⎕TCLF,((18+⌊0.5×L-×/⍴dx)⍴' '),dx
    ∇
```

```
    ∇ OPUT X;⎕IO;NTIE
     ⎕IO←1 ⍝   VERSION 2.0              || MOD. 84.1.31  M. JOLY
     →(0∊⍴X)/0
     X←⍕X
     →('→'=1↑∆SORTIE)/TOFILE
     →((3 3 ⍴'CRTPRTRS1')∧.=∆SORTIE)/LCRT,LPRT,LRS1
    ERR1:⎕ERROR 'INVALID OUTPUT DESTINATION IN ∆SORTIE'
    LCRT:⎕←X ⋄ →0
    LPRT: 3 0 3 ⎕ARBIN,X,⎕TCNL ⋄ →0
    LRS1: 1 0 0 1 ⎕ARBIN,(X,⎕TCNL),⎕TCLF ⋄ →0
    TOFILE:
     (1↓∆SORTIE)⎕NTIE NTIE←-((⍳20)⍳0,|⎕NNUMS)⍳0
     (X,⎕TCNL)⎕NAPPEND NTIE
     ⎕NUNTIE NTIE
    ∇


    ⍫TIMEFMT


    ∇ Z←A VS B
     Z←((¯2↑ 1 1 ,⍴B)⍴B)÷(¯2↑ 1 1 ,⍴A)⍴A
    ∇


    ∇ page ∆ts
     OPUT ⎕TCFF,'                    4VsW COD TUNING MAY 1989'
     OPUT STOCK∆NAME,(45⍴' '),∆ts
    ∇
```