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Stock Status of 4VsW cod in 1989 using a Half-year SPA Formulation

by

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Abstract

The catch of 4VsW cod in 1989 was 36,662 t., a reduction of over 1500 t. from 1988 but still over the TAC. The catch at age from 1971 to 1989 was reconstructed on a half-year basis. The management system switched, in mid-year, to regulating the fishery by condition of license rather than the previous method of issuing Variation Orders.

The July surveys and the March surveys were used as the indices of population abundance for calibration purposes. The commercial catch rates continued to decline in 1989 to a level inconsistent with other indications of the stock size.

The SPA was calibrated using ADAPT and the half-year catch at age. It had been suggested that the half-year formulation might have resolved the problems with the retrospective view of the assessment, however this was not the case.

The 1989 fishery produced a mean fully-recruited F of 0.38, almost double $F_{0.1}$. The 1990 and 1991 TAC's of 35,200 t. are projected to generate F's of 0.39 and 0.36 respectively. The $F_{0.1}$ catch in 1991 would be 20,700 t. The population biomass is projected to grow in 1990 and 1991 even if the catches remain at 35,200 t.

Résumé

En 1989, les prises de morue de 4VsW se sont établies à 36 662 t, ce qui représente une diminution de 1 500 t par rapport à 1988, mais reste supérieur au TPA. On a recalculé les prises selon l'âge de 1971 à 1989, en les compilant par demi-année. En cours d'année, on a modifié le régime de gestion, de sorte que la pêche est désormais régie par les conditions des permis plutôt que par des ordonnances de variation.

Les campagnes d'évaluation de juillet et de mars ont servi à établir les indices d'abondance de la population aux fins d'étalonnage. Les taux de prises commerciales ont continué de fléchir en 1989, atteignant un niveau atypique des autres indications sur la grosseur du stock.

L'ASP a été étalonnée au moyen de la méthode ADAPT et des prises selon l'âge par demi-année. Certains pensaient que la formule par demi-année pourrait permettre de résoudre les problèmes découlant du caractère rétrospectif de l'évaluation, mais cela n'a pas été le cas.

Dans la pêche de 1989, le plein recrutement moyen F était de 0,38, soit près du double de $F_{0.1}$. En se fondant sur un TPA de 35 200 t pour 1990 et 1991, on a établi des projections respectives de F = 0,39 et F = 0,36 pour ces deux années. En 1991, les prises seraient de 20 700 t à $F_{0.1}$. On prévoit que la biomasse de population augmentera en 1990 et 1991, même si les prises restent de 35 200 t.

Introduction and Description of the Fishery

The 1989 total catch of 4VsW cod was 36,662 t., a reduction of over 1500 t. from 1988, but still 1400 t. over the TAC (Table 1 and Figure 1). The foreign catch, primarily bycatch in the USSR and Cuba silver hake fishery, increased to over 200 t., the highest since 1985.

Twenty percent of the total catch was taken in 4W (Table 2), the highest proportion since 1983. The greatest change was in the OTB gears, dominated by the offshore trawlers, which increased the proportion of their catch taken in 4W four-fold (3.3% to 12.5%).

The allocations to each gear sector were adjusted during the course of the fishing season (Table 3) and the final allocations were close to the reported catches for all gear sectors except FG <45' which had an 1850 t. overrun. Management measures employed within season changed in May of 1989 with Variation Orders, issued by the Regional Director-General being largely superceded by Conditions of License issued by local Fisheries Officers. While this change made it possible for managers to institute changes in trip limits and by-catch limits very effectively, it is much more difficult to determine what management measures were in effect at any given time.

Catch at Age

The 1989 catch at age was constructed from 6 age-length keys (Table 4), quarterly keys for the mobile gears and half-year keys for the longline/handline gears. The catch assigned to age-length keys accounted for 97.7% of the total and the age composition from keys (Table 5) was adjusted upwards by 2.3%. The parameters of the length-weight relationship (a/b) were obtained from the results of the March 1989 and July 1989 research vessel surveys. The 1989 catch at age was compared to the projected catch at age from the last assessment (Figure 2). The agreement between the two curves is fairly good although the catch of the 1983 yearclass (age 6) was not as poor as projected. The 1980 yearclass (age 9) still shows up strongly and indeed, better than projected.

The entire catch at age from 1971 to 1988 was reconstructed, where necessary, (MacEachern and Fanning, 1990) on a half-year basis to better estimate the mid-year numbers for calibration purposes. As well several deficiencies identified since the last assessment were addressed. The 1984 catch at age was recalculated with a/b values from the July 1984 RV survey as the parameter values used previously generated weights at length substantially below those indicated by the July 1984 survey. The 1988 catch at age was also reconstructed to correct the a/b values and to include 700 t. of additional catch. In the 1988 assessment the long term mean values for a/b were used (Fanning and MacEachern, 1989) to reduce interannual variation, however subsequent investigation has indicated that yearly changes in the length-weight relationship are not random but rather show distinct trends. Because of this the mean values were not appropriate and the annual estimates of a/b were used instead. The resulting half-year catches at age (Table 6) were compared, by MacEachern and Fanning (1990) to the full-year catches at age in the previous assessment (Fanning and MacEachern, 1989). Except for the years where the input values (a/b or total catch) were changed, the differences were minimal.

The weights at age in the commercial catch (Table 7) have been variable in recent years. Ages 3-7 may be showing a slight increasing trend over the last 3 years, however the weights of the older ages have generally continued to decline in the same period.

Indices

July Research Vessel (RV) Survey

The July stratified RV survey from 1971 to the present, has been used as the primary index of abundance of this stock. A conversion factor of 0.8 was applied to adjust A.T. Cameron and Lady Hammond (1971-1982) mean catch per tow to Alfred Needler (1983-1989) equivalents (Fanning, 1985). The total catch rate in numbers has remained constant for the last 3 years however the age 4+ population has continued to decline and is now the lowest since 1977 (Table 8; Figure 3). The age 2 catch (1987 yearclass) was the largest since 1983 (1981 yearclass). The coefficients of variation for the July RV survey are given in Table 9.

Spring RV Survey

A spring stratified RV survey has been conducted in 4VsW from 1979 to the present with the exception of 1985. As part of an experiment in survey design the spring survey strata were changed in 1986 to produce fewer, larger strata (Figure 4) and allocation of sets was based on both stratum size and historical fish distribution. The new design and allocation scheme has been retained since then. Because cod have rarely been caught in strata 60 and 61 in any season these two strata were eliminated entirely from the new stratification scheme. As was done for the July survey the catches from the years 1978-84 were adjusted by a conversion factor of 0.8 to account for the change in RV vessel from A.T. Cameron to Alfred Needler (Fanning, 1985).

The spring survey in 4VsW has been unable to sample the entire survey area in several years due to ice, and in three years one or more entire strata were unsampled (Table 10). Since the new stratification scheme was adopted in 1986 there has only been one occasion that a stratum was unsampled. The strata north and east of Canso (43,44,45,46 and 401,402) are most likely to be affected by ice cover. The mean catch per tow by strata (Table 11) shows that strata 45 and 402, which overlap in area, are significant contributors to the overall catch. To investigate the magnitude of potential biases introduced by being unable to sample all strata, several methods of weighting the available data were examined. The first assumption investigated was that the mean in the missing strata was equal to the mean in the remaining area, effectively the stratum was removed from the survey. The second approach was that the adjacent, sampled strata could be used to estimate the unsampled area, effectively pooling strata 43,44,45 in 1980, 43,44,45,46 in 1982 and 401,402 in 1989. Strata were pooled using unweighted means and means weighted by number of samples. The different ways of pooling strata had virtually no effect on the survey catch per tow and the difference between ignoring missing strata and pooling was minimal except for age 2 in 1989. The unadjusted means were used as the index of abundance for the assessment.

The total catch numbers (Table 12, Figure 5) in 1989 are substantially higher than the previous 2 years however the age 4+ numbers are down, similar to the July survey results (Figure 6). The catch of the 1987 yearclass was the highest in the series at age 2, consistent with the indications of a relatively strong yearclass from the July RV survey. The coefficients of variation for the Spring surveys are given in Table 13.

Commercial Catch Rates

Commercial catch rates were estimated using a multiplicative model to standardize the otter trawler series from 1968 to 1989. The model and the gear categories have been the same since 1987 (Fanning and MacEachern, 1989 and references therein) with the addition of each new years data. The APL software STANDARD (Anon, 1986) was used to calculate the standardized catch rate. The results (Table 14, Figure 7) indicate a continuation of the declining catch rates seen since 1986.

The commercial catch rate was not used as an index of population abundance to calibrate this assessment. The catch rates, as calculated from the Fisheries Statistics, have apparently declined since 1986 to a degree inconsistent with other indicators of population size. One possibility is that increased in-house management of Enterprise Allocations by companies has resulted in increased effort being expended searching for particular size and species mixes in each trip. However, the total fishing effort, for an entire trip, is recorded, by the statistics system, as directed for the main species caught. This will deflate the trip-based catch rate for the main species while the set-based catch rate may be considerably higher.

The International Observer Program (IOP) collects catch and effort at sea and the data is recorded on a set-by-set basis. A multiplicative model was used to analyse the IOP catch and effort data for Maritimes stern trawlers (TC 4-5) from 1982 to 1989 (Table 15). Comparison of the two catch rate series (Figure 7) indicates that, in general, the set-based catch rates (IOP) have remained relatively high from 1984 while the trip-based catch rates peaked in 1986, and have returned to a low level in 1989.

The difficulties with the commercial catch rates identified above have prompted a research recommendation to review the available catch rate data and particularly, to examine the effects of aggregation i.e. trip-by-trip cf. set-by-set, on the apparent trends in the catch rate series. Until some understanding of these effects is gained the commercial catch rates will be difficult to use for calibration purposes.

Sequential Population Analysis (SPA)

One problem which arises when calibrating an SPA is to estimate the size of the population at the time of year appropriate to the calibration index. In the case of RV surveys they are generally conducted in the same month each year. Since the major RV survey for Scotia-Fundy stocks is in July (i.e. midyear) the practice has been to "fish down" the SPA population by applying half of the estimated annual total mortality to the beginning of year numbers. This assumes that a greater proportion of the catch is taken in the first half of the year. Deviations from this assumption can introduce a misalignment of the SPA population and the calibration index which may vary from year to year depending on the seasonal distribution of catches. With the catch at age available with an appropriate seasonal breakdown, half-yearly in this case, it was possible to estimate the midyear population size directly from the catch without assuming a specific seasonal pattern of catches. The underlying SPA model equation is unchanged when using the catch at age on a half-year basis.

Calibration

The ADAPT software used to estimate the population size in 1989 is given in Appendix 1. There were several changes in the ADAPT formulation (Table 16) from the previous assessment (Fanning and MacEachern, 1989). The SPA was calibrated using the July and March RV mean catch per tow rather than the July RV population numbers and the standardized commercial catch rates. All residuals were given equal weight and were calculated as differences of logarithms, rather than arithmetic differences weighted by the standard error of the respective index. The ages in the calibration block were changed from 3-8 to 4-9 and the fully recruited age groups were assumed to be 7-9 rather than 7-10. The value of natural mortality was 0.1 per half-year. There were several revisions to the ADAPT software required which were complicated by the fact that some operations require the full-year catch at age and others operate on the half-year catch at age. This is done by shifting the rows in the various matrices between full-year and half-year intervals (see Appendix 1, Table 1 for an example).

Results

The results of the ADAPT formulation used in this assessment are comparable to those of the last assessment. The calibration statistics (Table 17A) show significant estimates for all ages and all slopes in the calibration. The parameter correlation matrix has the typical blocked pattern with negative correlations between the population estimates and the slope estimates for corresponding ages. The correlations are all small in absolute value (maximum absolute values observed were -.24 and -.18 between the youngest age and the two corresponding slopes). The residuals (Table 17B) continue to show strong "survey effects" with the residuals for all ages having the same sign in a given year e.g. July RV 1974, 1985, 1986, 1987 and March RV 1979, 1981, 1986. Further work to examine, and possibly correct for, the survey effect was recommended.

Although a half-year catch at age was used to calibrate the SPA from 1971-1989, only a full-year catch at age was available for long-term (1958-1989) perspective. The beginning of year numbers and total annual F from the half-year ADAPT analysis were used as inputs into a full-year SPA to estimate the longterm population numbers and fishing mortality. The biomass (Figure 8) and population numbers (Table 18, Figure 8) have both continued to decline from their high values of 1985-1986. The fishing mortality (Table 19, Figure 9) continued to vary between 0.3 and 0.5 as it has since 1980. The variation in fishing mortality has been greatly reduced relative to the years prior to the extension of jurisdiction by Canada (1977). The recruitment at age 1 (Figure 10) shows the 83, 84, and 85 yearclasses to be the smallest in the available time series. The 1986 yearclass was not calibrated with ADAPT but estimates using mean PR at age 3 range from the largest in the time series (mean PR from 1986-88) to 90 million (mean PR from 1983-88) which is still above the geometric mean (GM) of 77 million.

Retrospective

The assessment of this stock has produced a strong trend in the retrospective view of the stock status. As additional years of data are added to a given model formulation the population size estimated for preceding years has been consistently smaller than was estimated without the additional data (Figure 11). This problem has existed in all the model formulations examined and is still unresolved. This is particularly concerning as the estimate of fully recruited F in 1989 (0.38) is the highest terminal year estimate since 1982 in the retrospective series.

Yield per Recruit

No new yield per recruit was estimated for this assessment and the $F_{0.1}$value from previous assessments of 0.2 was retained.

Prognosis

Catch projections were made based on 1990 beginning of year numbers, mean weights at age from 1986-89 and mean PR from 1986-88. The 1988-90 year-classes were assumed to be the GM of the 1970-85 year-classes (77 million fish). The RV surveys indicate that the 1986 year-class is comparable to the 1981 or 1982 year-classes which average 90 million fish. The 1987 year-class appears to be even larger than the 1986. For projection purposes the 1986 and 1987 year-classes were set to 90 million fish. The projection input data are:

Age	January 1990 Population numbers (000)	Average Weight (kg)	Partial Recruitment
1	77,000	0.067	0.0001
2	63,042	0.279	0.001
3	60,323	0.593	0.01
4	48,787	0.949	0.16
5	20,714	1.289	0.53
6	15,098	1.688	0.81
7	6,944	2.197	1.00
8	10,924	2.622	1.00
9	2,170	3.317	1.00
10	2,251	4.353	1.00
11	1,167	5.502	1.00
12	607	6.199	1.00
13	278	8.054	1.00
14	70	11.809	1.00
15	49	12.000	1.00

If the 1990 catch is equal to the TAC of 35,200 t. it will generate a fishing mortality in 1990 of 0.39 and the projected 1991 catch at $F_{0.1}$will be 21,000 t. There are several alternatives for 1991 catches given below.

Option 1: $F_{0.1}$in 1991;
Option 2: 50% rule (F=0.3) in 1991;
Option 3: Constant catch at 35,200 t. in 1991

Option	F		4+ Biomass ('000 t)		Catch ('000 t)	
	1990	1991	1990	1991	1990	1991
1	.39	.20	139	162	35.2	20.7
2	.39	.30	139	157	35.2	30.0
3	.39	.36	139	154	35.2	35.2

The assessment of this stock indicates a substantial decline from the population size indicated in the last assessment (Fanning and MacEachern, 1989). There were several corroborative indications in the 1990 fishery, the fixed gear sector had considerable difficulty catching cod in 4VsW, and the offshore had very poor catches in the fall. There have also been reports of substantial numbers of small fish discarded in the mobile gear fishery which would support the view of one or more good year-classes beginning to recruit.

Management Considerations

Multiyear Management

The current prognoses assume that the 1986 and 1987 year-classes are comparable to the very large 1981 year-class. This assumption is based on survey estimates as these two year-classes have not yet recruited to the fishery. Whether they are as large as assumed or are only above average will have little effect in the 1991 fishery, however the size of those year-classes will be the major factor affecting fishing mortality in 1992 and 1993. Because of these concerns reliable estimates of the effects of 2 or 3 year management plans cannot be made. It is assumed that, given the current estimates of biomass, the current catch continued for 3 years would not present an undue risk of stock collapse or fishery failure. There is a chance, if the 1986 and 1987 year-classes are not as large as presently estimated, that the biomass will decline and a significant reduction in catches will be needed by 1993.

Alternative Advice

The three options presented in the Prognosis section are just three points on a curve defined by fishing mortality and catch. The entire curve (Figure 12a) shows the individual points in context with the change in biomass projected to occur. As the stock is not considered to be at a critical biomass level the change in biomass is adequate to evaluate the consequences of a particular catch level. When a stock is critically low the total biomass, rather than the change in biomass, would be more useful to evaluate catch advice. An alternative view of the same information (Figure 12b) uses the catch as the independent axis, which may be more useful from a fisheries managers perspective.

Literature Cited

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Fanning L.P. and W.J. MacEachern. 1989. Stock Status of 4VsW cod in 1988. CAFSAC Res. Doc. 89/57.

MacEachern W.J. and L.P. Fanning. 1990. Reconstruction of the 4VsW cod catch at age on a half-year basis (1971-1989). CAFSAC Res. Doc. 90/87.

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	19611	24130	60000
1975	9939	1867	546	15611	3042	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	52104	-	303	-	110	29	52546	42578	9968	55000
1985	56553	-	870	-	21	11	57455	48189	9266	55000
1986	51467	-	-	-	28	34	51529	44028	7501	48000
1987	45430	-	-	-	25	48	45503	39755	5748	44000
1988[1]	38101	-	-	-	89[2]	19[2]	38209	33648	4561	38000
1989[1]	36445	-	-	-	168[2]	49[2]	36662	29323	7339	35200
1990										35200

[1] Preliminary Interzonal

[2] IOP

Table 2. Total catch of 4VsW cod by gear[1] and (Sub)Division from NAFO.

YEAR	4Vs					4W					4VsW				
	TRAWLS	LL	SDN	MIS	TOTAL	TRAWLS	LL	SDN	MIS	TOTAL	TRAWLS	LL	SDN	MIS	TOTAL
1964	25452	42	2	0	25496	32855	708	88	4110	37761	58307	750	90	4110	63257
1965	36607	84	22	0	36713	28931	1416	159	3767	34273	65538	1500	181	3767	70986
1966	27006	143	14	14	27177	36460	1474	38	3376	41348	63466	1617	52	3390	68525
1967	26481	99	27	0	26607	22407	2405	71	2668	27551	48888	2504	98	2668	54158
1968	48715	48	18	0	48781	24686	2970	89	3902	31647	73401	3018	107	3902	80428
1969	22265	43	7	1	22316	21946	3567	13	2323	27849	44211	3610	20	2324	50165
1970	28617	21	1	0	28639	23655	3817	62	1261	28795	52272	3838	63	1261	57434
1971	24088	40	0	0	24128	22006	4819	26	1584	28435	46094	4859	26	1584	52563
1972	33570	595	4	2364	36533	15888	3793	7	5424	25112	49458	4388	11	7788	61645
1973	21654	82	3	1662	23401	25144	3748	20	1780	30692	46798	3830	23	3442	54093
1974	19105	337	0	169	19611	18931	2969	5	2225	24130	38036	3306	5	2394	43741
1975	10522	444	0	728	11694	16336	3185	11	1291	20823	26858	3629	11	2019	32517
1976	10068	68	0	1417	11553	8021	2913	14	1906	12854	18089	2981	14	3323	24407
1977	2819	50	4	0	2873	2305	3487	68	1657	7517	5124	3537	72	1657	10390
1978	10044	294	19	0	10357	8277	4552	839	1380	15048	18321	4846	858	1380	25405
1979	14869	438	86	0	15393	14579	5825	3245	988	24637	29448	6263	3331	988	40030
1980	28941	2116	321	0	31378	6729	6588	3440	1117	17874	35670	8704	3761	1117	49252
1981	27662	4274	171	0	32107	9813	8229	2433	1136	21611	37475	12503	2604	1136	53718
1982	32247	7069	794	0	40110	6431	6655	1943	615	15644	38678	13724	2737	615	55754
1983	28024	4475	671	0	33170	11555	5052	1936	667	19210	39579	9527	2607	667	52380
1984	37576	4123	879	0	42578	3839	3512	2144	473	9968	41415	7635	3023	473	52546
1985	39978	7449	718	44	48189	3768	3386	1229	883	9266	43746	10835	1947	927	57455
1986	35514	8277	237	0	44028	2758	3075	600	1068	7501	38272	11352	837	1068	51529
1987	33157	6276	311	11	39755	1803	2666	538	741	5748	34960	8942	849	752	45503
1988[2]	26888	6092	612	56	33648	1218	2155	383	805	4561	28106	8247	995	861	38209
1989[2]	22560	6320	402	41	29323	3503	2920	323	593	7339	26063	9240	725	634	36662

[1] Gear designations include the following:
TRAWLS - Side/stern bottom, side/stern midwater, pair trawls and shrimp trawls;
LL - Set/drift longlines, Hand lines, jigs, dory vessel lines;
SDN - Scottish, danish and pair seines;
MIS - Miscellaneous gears not included above.

[2] Preliminary Interzonal and International Observer Program data.

Table 3. 4VsW cod - 1989 allocations and catches.

Gear Sector	Allocations at Specific Dates Jan 1	May 15	July 1	Oct 15	Dec 31	Total Catch (Quota Report)*
Vessels >100'	23160	22960	22890	22840	22935	23002
MG 65-100'	625	738	738	824	479	401
FG 65-100'	520	607	677	641	891	813
MG 45-64'						
(Jan-Apr)	945	1145	1145	1145	1145	1362
(May-Aug)	945	945	945	945	945	706
(Sep-Dec)	945	745	745	745	745	792
MG <45'						
(Jan-Apr)	305	455	455	455	455	602
(May-Aug)	610	460	460	460	460	271
(Sep-Dec)	300	300	300	300	300	437
FG 45-64'						
(Jan-May)	250	250	250	250	250	371
(Jun-Aug)	1455	1455	1455	1148	1148	668
(Sep-Dec)	280	280	280	280	280	613
FG <45'						
(Jan-Mar)	185	185	--	--	--	--
(Apr-May)	490	490	--	--	--	--
(Jan-May)	--	--	600	600	600	1505
(Jun-Aug)	3195	3195	3350	3350	3350	3796
(Sep-Dec)	990	990	910	1217	1217	1716
Totals	35200				35200	37055

* - preliminary

Table 4. Data used to generate 1989 age length keys for 4VsW cod.

Key	Gear	Period Covered	Length-Weight Coefficient a	b	Source	Number Measured	Aged	Catch
1	OTB, OTM, PTB, SNU	Q_1 - Jan-Mar	0.0068	3.0601	Mar 4Vs	3375	413	7741
2	OTB, OTM, PTB, SNU	Q_2 - Apr-June	0.0096	2.9867	Jul 4Vs	5165	435	5939
3	OTB, OTM, PTB, SNU	Q_3 - July-Sept	0.0060	3.1075	Jul4VsW	2833	189	3314
4	OTB, OTM, PTB, SNU	Q_4 - Oct-Dec	0.0096	2.9867	Jul 4Vs	6370	517	9576
5	LL, LH	H_1 - Jan-June	0.0060	3.1075	Jul4VsW	4531	747	3630
6	LL, LH	H_2 - July-Dec	0.0060	3.1075	Jul4VsW	3609	542	5611

Table 5. 4VsW cod catch at age ('000) by key in 1989.

	OTB, OTM, PTB, SNU				LL, LHP		
Age	Q_1	Q_2	Q_3	Q_4	H_1	H_2	Total
1	0	0	0	0	0	0	0
2	0	7	0	0	0	0	7
3	1	115	152	380	3	6	657
4	90	369	667	1276	24	63	2489
5	343	986	747	1603	96	257	4032
6	711	596	311	1232	173	251	3274
7	1308	774	182	721	298	331	3614
8	564	285	42	551	135	189	1766
9	769	321	40	433	186	238	1987
10	204	80	10	114	84	89	581
11	76	22	0	47	39	63	247
12	67	12	0	14	24	37	154
13	2	4	0	0	10	13	29
14	2	0	0	1	4	8	15
15	27	0	0	0	4	26	57
16	0	1	0	7	1	25	34
Total	4164	3572	2151	6379	1081	1596	18943

Table 6. 4VsW cod catch at age by half year intervals in thosands of fish.

	71.0	71.5	72.0	72.5	73.0	73.5	74.0	74.5	75.0	75.5	76.0	76.5	77.0	77.5
1	1472	512	710	1336	623	595	787	486	945	593	363	150	0	1
2	9514	3310	6651	9214	5231	4990	4518	2803	5267	3304	2029	837	4	19
3	7133	2510	5458	6343	4196	3805	8011	5313	4543	2859	1922	938	91	441
4	3746	1379	8390	3599	3144	2659	6906	4789	1908	1255	2416	2291	239	990
5	4811	1801	5343	2041	5264	4370	4033	2821	2858	1930	1943	1957	516	1075
6	3725	1403	4906	1621	1822	1502	1323	924	1967	1330	1038	1047	483	362
7	2484	935	2486	822	1846	1524	393	276	1755	1188	637	650	297	193
8	1426	537	1413	467	2593	2139	592	416	371	252	222	225	136	63
9	511	193	261	86	923	761	115	81	296	201	67	69	111	7
10	267	100	350	116	213	176	90	63	409	277	26	27	29	4
11	116	43	51	17	302	249	8	5	103	69	6	6	39	3
12	126	47	6	2	4	4	1	1	73	50	23	24	41	3
13	113	43	27	9	12	9	0	0	24	17	0	0	11	0
14	58	22	0	0	12	9	0	0	4	2	2	2	3	0
15	29	11	2	1	10	8	0	0	4	2	0	0	2	0
16	38	14	5	2	26	21	0	0	11	8	1	1	6	0
3+	24583	9038	28698	15126	20367	17236	21472	14689	14326	9440	8303	7237	2004	3141
4+	17450	6528	23240	8783	16171	13431	13461	9376	9783	6581	6381	6299	1913	2700
5+	13704	5149	14850	5184	13027	10772	6555	4587	7875	5326	3965	4008	1674	1710
6+	8893	3348	9507	3143	7763	6402	2522	1766	5017	3396	2022	2051	1158	635

	78.0	78.5	79.0	79.5	80.0	80.5	81.0	81.5	82.0	82.5	83.0	83.5	84.0
1	8	26	3	9	15	16	2	1	3	0	0	0	0
2	20	74	10	83	15	77	41	217	1	137	2	4	0
3	96	1072	545	1217	341	1424	882	2318	705	1768	1898	1609	71
4	834	3244	3586	2973	1176	3697	4239	4897	3582	4085	5007	3672	2527
5	1473	3344	5198	4327	3201	3736	3406	3875	7150	2973	4320	3164	3977
6	1011	1571	2465	2591	3669	2508	2496	2155	2733	948	4210	2068	3328
7	372	395	612	598	1692	1358	1533	1424	1976	592	1097	808	2498
8	127	120	153	224	748	373	706	715	884	431	653	359	698
9	66	41	30	46	193	120	213	184	437	242	362	263	316
10	42	33	4	19	50	42	55	80	158	160	83	141	110
11	18	13	1	9	30	20	38	31	94	59	54	95	41
12	14	13	1	3	23	3	13	19	37	28	22	30	17
13	15	13	1	2	2	2	8	14	30	24	10	14	13
14	5	5	0	0	0	0	1	1	9	46	11	4	6
15	1	0	0	0	1	0	2	3	13	6	4	2	7
16	2	0	0	0	7	0	2	0	3	16	2	9	0
3+	4076	9864	12596	12009	11133	13283	13594	15716	17811	11378	17733	12238	13609
4+	3980	8792	12051	10792	10792	11859	12712	13398	17106	9610	15835	10629	13538
5+	3146	5548	8465	7819	9616	8162	8473	8501	13524	5525	10828	6957	11011
6+	1673	2204	3267	3492	6415	4426	5067	4626	6374	2552	6508	3793	7034

	84.5	85.0	85.5	86.0	86.5	87.0	87.5	88.0	88.5	89.0	89.5
1	0	0	0	0	0	0	0	0	0	0	0
2	1	0	4	0	3	0	0	0	8	7	0
3	359	68	88	74	50	34	4	22	163	120	551
4	3251	968	1285	1675	2535	411	466	234	1278	488	2056
5	5124	3996	4155	3266	4374	2863	2831	834	1565	1439	2672
6	2350	4495	3028	5405	3816	2574	3311	1880	2651	1495	1839
7	1331	3005	1279	2281	1308	3379	2670	2487	1588	2404	1265
8	552	1692	738	978	593	1514	1219	1897	1398	994	802
9	228	795	268	719	404	579	526	1162	569	1289	729
10	180	278	174	276	171	319	285	383	243	372	218
11	112	183	101	178	107	102	131	191	69	138	113
12	46	123	50	50	55	54	77	85	68	104	52
13	21	26	42	38	28	30	31	47	17	16	13
14	11	12	8	7	4	4	7	7	2	6	9
15	1	6	11	13	6	8	6	8	2	31	27
16	5	13	2	13	5	6	6	6	5	2	33
3+	13571	15660	11229	14973	13456	11877	11570	9243	9618	8898	10379
4+	13212	15592	11141	14899	13406	11843	11566	9221	9455	8778	9828
5+	9961	14624	9856	13224	10871	11432	11100	8987	8177	8290	7772
6+	4837	10628	5701	9958	6497	8569	8269	8153	6612	6851	5100

Table 7. 4VsW cod mean weights at age in the commercial catch. 20/ 2/91

	70	71	72	73	74	75	76	77	78	79	80	81	82	83
1	.02	.01	.05	.08	.13	.10	.10	.10	.20	.07	.07	.07	.07	.12
2	.15	.11	.18	.22	.33	.27	.28	.28	.62	.53	.57	.62	.58	.39
3	.45	.32	.44	.45	.62	.53	.57	.81	.95	.76	.80	.83	.81	.81
4	.91	.64	.81	.79	1.02	.89	.96	1.09	1.25	1.06	1.15	1.14	1.07	1.08
5	1.50	1.07	1.29	1.21	1.53	1.34	1.46	1.67	1.68	1.70	1.60	1.69	1.58	1.55
6	2.19	1.56	1.85	1.72	2.13	1.87	2.03	2.36	2.47	2.39	2.21	2.13	2.39	2.10
7	2.94	2.09	2.48	2.28	2.82	2.47	2.66	3.17	3.61	3.13	3.08	2.97	2.78	3.10
8	3.73	2.65	3.14	2.90	3.58	3.12	3.35	4.58	5.23	3.71	4.31	3.94	4.07	3.53
9	4.51	3.21	3.83	3.54	4.41	3.81	4.07	4.14	5.59	4.77	5.26	5.70	5.49	4.38
10	5.28	3.75	4.52	4.22	5.28	4.53	4.80	5.33	6.54	6.84	6.92	7.16	7.08	5.76
11	6.02	4.28	5.20	4.90	6.19	5.27	5.55	4.65	7.92	7.96	7.56	7.67	8.74	6.99
12	6.71	4.77	5.87	5.59	7.13	6.01	6.29	4.91	9.21	9.41	10.19	9.26	9.10	9.04
13	7.36	5.23	6.52	6.28	8.09	6.76	7.02	7.14	10.40	10.63	7.92	11.87	11.43	10.63
14	7.95	5.65	7.14	6.96	9.05	7.51	7.74	8.59	9.75	10.03	8.13	8.65	10.59	11.71
15	8.49	6.04	7.73	7.62	10.01	8.24	8.43	10.60	8.68	11.45	14.45	9.84	12.48	12.69

	84	85	86	87	88	89
1	.07	.07	.07	.07	.07	.07
2	.54	.64	.26	.21	.36	.29
3	.77	.70	.69	.50	.53	.65
4	1.08	1.04	.96	.95	.91	.97
5	1.51	1.46	1.27	1.33	1.31	1.24
6	2.12	1.98	1.68	1.61	1.85	1.61
7	2.77	2.49	2.42	1.97	2.10	2.29
8	3.64	3.17	2.77	2.76	2.60	2.36
9	4.01	3.93	3.40	4.07	3.21	2.59
10	5.09	5.11	5.02	4.32	4.24	3.83
11	6.84	6.37	5.29	6.75	5.33	4.64
12	7.81	6.12	6.84	6.64	6.03	5.29
13	10.53	9.94	10.05	7.54	6.51	8.12
14	10.08	11.17	9.42	12.59	12.02	13.21
15	13.10	11.26	11.73	13.11	8.45	7.99

Table 8. 4VsW cod mean catch per tow at age in the July survey. 20/ 2/91

	70	71	72	73	74	75	76	77	78	79	80	81
0	.028	.007	.000	.000	.248	.020	.000	.000	.050	.292	.014	.024
1	.424	.441	1.780	1.843	1.484	.949	.675	.213	.875	.348	.198	1.328
2	4.732	2.202	2.773	12.585	9.452	2.430	3.703	2.754	3.745	3.042	2.013	3.653
3	1.662	10.223	3.405	19.785	5.529	3.763	4.222	6.970	8.956	4.599	5.312	5.531
4	2.576	2.301	9.039	16.073	1.616	1.764	2.602	4.527	9.805	4.757	2.941	8.444
5	1.277	4.530	1.666	6.444	.578	.858	1.645	2.821	2.712	5.181	4.977	3.217
6	.424	1.655	1.717	.535	.642	.188	.321	1.239	1.000	2.595	3.468	2.309
7	.500	.992	.465	.833	.107	.230	.154	.267	.255	.773	1.374	1.186
8	.159	.423	.157	.258	.133	.061	.258	.177	.053	.289	.373	.437
9	.030	.183	.142	.123	.064	.117	.000	.042	.026	.118	.097	.144
10	.070	.020	.044	.147	.046	.005	.178	.000	.023	.024	.076	.162
11	.080	.039	.000	.048	.018	.000	.024	.028	.000	.013	.027	.042
12	.029	.017	.000	.000	.017	.020	.000	.018	.000	.001	.000	.007
13	.051	.059	.000	.000	.000	.000	.041	.000	.000	.005	.000	.007
14	.000	.000	.000	.058	.000	.000	.000	.000	.000	.000	.000	.000
15	.000	.000	.000	.008	.016	.000	.000	.000	.000	.000	.000	.007
16	.000	.000	.000	.000	.000	.000	.000	.000	.015	.000	.000	.000
0+	12.040	23.090	21.188	58.740	19.951	10.405	13.825	19.054	27.514	22.036	20.869	26.497
1+	12.013	23.084	21.188	58.740	19.703	10.385	13.825	19.054	27.464	21.744	20.855	26.473
2+	11.589	22.642	19.408	56.897	18.219	9.435	13.150	18.840	26.589	21.397	20.657	25.145
3+	6.857	20.441	16.635	44.311	8.767	7.006	9.447	16.087	22.844	18.355	18.644	21.493
4+	5.195	10.218	13.229	24.526	3.239	3.243	5.225	9.117	13.888	13.756	13.333	15.962

	82	83	84	85	86	87	88	89	90
0	.003	.020	.070	.000	.027	.044	.069	.028	.003
1	.733	13.721	.406	1.287	.357	.645	.059	.246	.128
2	62.940	13.307	7.272	1.683	1.325	1.506	4.703	8.860	5.067
3	52.596	44.468	12.817	7.881	1.532	4.974	7.291	7.384	18.240
4	18.371	19.253	19.094	9.564	6.164	4.826	5.895	5.012	8.644
5	4.125	9.884	12.938	9.319	3.886	8.858	3.267	3.473	3.867
6	2.228	4.423	6.005	5.117	3.256	3.608	3.412	1.350	1.408
7	1.201	.988	4.128	2.561	1.146	2.712	1.953	2.000	.602
8	.512	.551	.407	1.008	.548	1.474	.976	.474	.288
9	.114	.140	.332	.484	.241	.341	.218	.324	.106
10	.116	.076	.099	.115	.154	.024	.052	.013	.071
11	.063	.039	.234	.111	.035	.080	.116	.003	.000
12	.000	.018	.006	.068	.000	.043	.016	.019	.000
13	.000	.018	.006	.000	.023	.009	.000	.008	.000
14	.005	.000	.009	.000	.000	.000	.018	.000	.000
15	.000	.000	.000	.013	.000	.026	.000	.000	.000
16	.000	.000	.000	.000	.000	.000	.000	.000	.000
0+	143.007	106.906	63.824	39.211	18.694	29.170	28.043	29.194	38.424
1+	143.004	106.886	63.754	39.211	18.667	29.126	27.975	29.166	38.422
2+	142.271	93.165	63.349	37.924	18.310	28.481	27.916	28.920	38.294
3+	79.331	79.858	56.076	36.241	16.985	26.975	23.213	20.059	33.227
4+	26.735	35.390	43.259	28.360	15.453	22.001	15.923	12.676	14.987

Table 9. 4VsW cod coefficient of variation in the July survey. 20/ 2/91

	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85
0	.514	1.000	.000	.000	.000	1.000	.000	.000	.471	.552	.644	.760	1.000	1.000	.534	.000
1	.277	.363	.747	.649	.135	.341	.370	.276	.147	.226	.292	.395	.299	.905	.563	.667
2	.063	.303	.295	.771	.032	.266	.165	.174	.425	.257	.397	.316	.854	.395	.285	.326
3	.210	.589	.661	.622	.073	.347	.119	.197	.396	.260	.368	.385	.822	.501	.566	.175
4	.097	.466	.844	.785	.080	.253	.252	.247	.230	.220	.243	.293	.744	.424	.478	.262
5	.078	.582	.677	.708	.313	.187	.227	.397	.292	.191	.233	.256	.362	.390	.491	.341
6	.105	.549	.820	.775	.384	.236	.216	.504	.172	.164	.266	.224	.076	.221	.481	.337
7	.251	.520	.806	.679	.269	.333	.198	.514	.097	.169	.256	.269	.046	.135	.540	.263
8	.291	.344	.624	.327	.457	.402	.000	.492	.318	.177	.339	.271	.025	.184	.357	.214
9	.760	.695	.633	.784	.355	.464	.000	.421	.263	.187	.484	.450	.097	.214	.526	.198
10	.536	.730	.781	.523	.190	1.000	.000	.000	.670	.522	.611	.518	.000	.000	.311	.242
11	.000	.600	.000	.443	1.000	.000	1.000	.471	.000	.404	.688	.662	.000	.000	.713	.469
12	1.000	1.000	.000	.000	.000	1.000	.000	.541	.000	1.000	.000	1.000	.000	.000	1.000	.290
13	.000	.723	.000	.000	.000	.000	.000	.000	.000	.885	.000	1.000	.000	.000	.740	.000
14	.000	.000	.000	.676	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.736	.000
15	.000	.000	.000	.713	1.000	.000	.000	.000	.000	.000	.000	1.000	.000	.000	.000	1.000
16	.000	.000	.000	.000	.000	.000	.000	.000	1.000	.000	.000	.000	.000	.000	.000	.000

	86	87	88	89	90
0	.698	1.000	.588	1.000	1.000
1	.368	.346	.449	.226	.548
2	.490	.293	.458	.620	.514
3	.286	.376	.509	.485	.373
4	.341	.274	.319	.325	.298
5	.347	.240	.307	.241	.346
6	.312	.286	.483	.233	.307
7	.290	.304	.444	.267	.301
8	.286	.281	.393	.250	.308
9	.300	.257	.268	.285	.388
10	.291	.394	.347	.676	.351
11	.542	.395	.358	1.000	1.000
12	.000	.531	.425	.631	1.000
13	1.000	1.000	.000	.733	1.000
14	.000	.000	.638	.000	1.000
15	.000	.585	.000	.000	1.000
16	.000	.000	.000	.000	1.000

Table 10. Number of samples in each stratum in 4VsW Spring surveys.

	79	80	81	82	83	84
43	2	0	6	0	3	4
44	3	4	3	0	2	3
45	4	0	3	1	4	5
46	3	2	3	0	3	3
47	4	4	4	3	4	3
48	4	3	4	4	3	4
49	2	2	2	2	2	2
50	3	3	3	3	3	3
51	2	2	2	2	2	2
52	2	2	2	2	2	2
53	3	3	3	3	3	3
54	3	3	3	3	3	3
55	7	5	6	7	7	7
56	6	4	7	6	6	4
57	2	0	2	2	3	1
58	3	0	3	3	2	3
59	1	4	4	1	4	4
60	2	2	2	2	3	2
61	2	2	2	2	2	2
62	4	4	4	2	5	4
63	2	2	1	2	2	2
64	5	5	5	5	5	5
65	2	4	5	5	7	5
66	3	3	3	3	2	3
43+	74	63	82	63	82	79

	86	87	88	89
401	7	7	1	0
402	13	14	6	8
403	8	9	4	9
404	1	1	1	2
405	2	6	4	6
406	8	11	11	10
407	8	8	6	8
408	14	13	15	12
409	8	14	11	15
410	7	7	7	7
411	1	2	2	2
401+	77	92	68	80

Table 11. Mean catch per tow in each stratum in 4VsW Spring surveys.

	79	80	81	82	83	84
43	.5	.0	13.3	.0	1.3	36.0
44	14.9	15.2	80.7	.0	37.1	62.7
45	8.3	.0	122.7	35.0	154.0	53.7
46	3.4	17.5	9.7	.0	1.8	9.3
47	.3	2.0	13.2	.7	26.5	5.2
48	1.0	.2	9.6	99.5	17.0	3.3
49	3.4	3.9	.0	7.1	31.2	58.1
50	15.6	54.1	.0	46.1	52.4	70.5
51	1.0	1.6	.0	269.3	60.6	1.1
52	33.5	77.0	20.6	8.0	11.5	2.7
53	.0	.5	.0	2.1	.0	.0
54	37.5	16.9	17.3	27.4	195.8	9.6
55	13.9	23.4	138.2	384.6	273.3	128.7
56	1.7	3.2	18.0	210.1	46.4	.3
57	8.7	.0	4.4	96.9	1491.3	2.1
58	.0	.0	.0	24.7	.0	5.4
59	9.2	60.3	17.4	145.0	6.4	7.7
60	1.0	1.1	6.3	12.1	3.4	1.0
61	.0	.3	.0	.4	.0	.5
62	2.2	.4	.2	1.9	.2	.8
63	6.3	3.8	.0	1.0	11.9	10.2
64	12.8	16.4	193.0	10.2	11.6	14.2
65	2.6	5.4	2.3	8.1	1.0	.4
66	1.0	.0	.0	4.3	.5	.0

	86	87	88	89
401	1.0	16.5	2.2	.0
402	105.2	166.8	23.2	115.8
403	47.9	1.2	17.1	1.5
404	123.0	1.9	4.1	48.4
405	25.0	29.0	21.1	30.3
406	3.9	2.4	12.4	63.0
407	51.2	11.0	2.1	7.2
408	73.6	2.1	181.3	50.7
409	839.0	3.4	12.8	66.6
410	.3	10.3	23.1	5.0
411	.0	.0	.0	14.3

Table 12. 4VsW cod mean catch per tow in Spring surveys (no 1985 survey).

	79	80	81	82	83	84	85	86	87	88	89
0	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
1	.260	.863	8.249	2.646	.851	.217	.000	.188	.346	.601	.578
2	2.123	2.709	3.801	22.224	3.169	1.490	.000	10.877	.919	7.965	17.957
3	.892	2.042	5.293	17.907	42.138	1.846	.000	19.439	2.874	9;490	10.396
4	.597	1.665	7.787	11.836	25.520	9.367	.000	23.579	4.496	4.262	4.228
5	1.372	2.518	4.869	7.241	4.960	6.212	.000	11.666	10.138	4.325	4.796
6	1.020	2.900	5.765	1.989	5.846	2.918	.000	13.128	4.818	4.880	1.680
7	.473	1.426	3.205	1.363	1.316	2.535	.000	6.272	3.324	1.434	.704
8	.286	.304	1.532	1.082	.618	.774	.000	1.337	1.204	1.870	.224
9	.065	.064	.177	.280	.289	.504	.000	.735	.237	.463	.255
10	.099	.025	.135	.143	.096	.195	.000	.279	.105	.186	.048
11	.077	.015	.027	.063	.037	.017	.000	.044	.036	.178	.027
12	.022	.002	.023	.031	.043	.086	.000	.050	.029	.041	.017
13	.027	.009	.000	.011	.015	.000	.000	.007	.029	.024	.003
14	.009	.005	.000	.000	.045	.006	.000	.007	.010	.000	.010
15	.010	.000	.000	.005	.000	.000	.000	.000	.000	.033	.020
16	.000	.000	.000	.007	.000	.021	.000	.008	.000	.000	.000
1+	7.332	14.548	40.864	66.828	84.941	26.188	.000	87.616	28.564	35.750	40.945
2+	7.072	13.685	32.615	64.182	84.089	25.970	.000	87.428	28.218	35.149	40.367
3+	4.949	10.975	28.814	41.957	80.920	24.480	.000	76.552	27.299	27.185	22.409
4+	4.057	8.934	23.521	24.051	38.783	22.634	.000	57.113	24.425	17.695	12.014

Table 13. 4VsW cod coefficients of variation in Spring surveys.

	79	80	81	82	83	84	85	86	87	88	89
0	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
1	.305	.306	.932	.038	.402	.491	.000	.338	.288	.288	.582
2	.160	.457	.542	.271	.580	.259	.000	.788	.306	.705	.758
3	.570	.400	.274	.607	.709	.266	.000	.656	.451	.805	.489
4	.285	.307	.278	.601	.516	.409	.000	.419	.555	.509	.484
5	.221	.376	.301	.352	.368	.481	.000	.322	.549	.542	.440
6	.232	.485	.274	.261	.309	.501	.000	.300	.536	.455	.380
7	.389	.550	.228	.242	.297	.429	.000	.311	.451	.430	.338
8	.387	.639	.240	.196	.296	.387	.000	.323	.452	.438	.578
9	.375	.343	.245	.225	.364	.551	.000	.345	.428	.501	.381
10	.438	.769	.345	.409	.641	.414	.000	.260	.538	.495	.293
11	.385	.401	.630	.477	.888	.527	.000	.464	.682	.592	.438
12	.500	1.000	.455	.617	.492	.463	.000	.765	.468	.715	.651
13	.702	.826	.000	.461	.768	.000	.000	.534	.468	1.000	1.000
14	.612	1.000	.000	.000	.564	1.000	.000	.534	1.000	.000	.857
15	1.000	.000	.000	1.000	.000	.000	.000	.000	.000	.777	.857
16	.000	.000	.000	.650	.000	1.000	.000	.622	.000	.000	.000

Table 14. 4VsW cod commercial catch rate standardization for OTB in TC 1-5.

MULTIPLE R............. .641
MULTIPLE R SQUARED..... .410

ANALYSIS OF VARIANCE

SOURCE OF VARIATION	DF	SUMS OF SQUARES	MEAN SQUARES	F-VALUE
INTERCEPT	1	7.535E0001	7.535E0001	
REGRESSION	42	2.588E0002	6.162E0000	20.177
TYPE 1	9	9.085E0001	1.009E0001	33.053
TYPE 2	1	2.209E0000	2.209E0000	7.232
TYPE 3	11	5.957E0001	5.415E0000	17.731
TYPE 4	21	1.426E0002	6.788E0000	22.227
RESIDUALS	1217	3.717E0002	3.054E-001	
TOTAL	1260	7.059E0002		

PREDICTED CATCH RATE

STANDARDS USED VARIABLE NUMBERS: 1 1 1

YEAR	TOTAL CATCH	PROP.	CATCH RATE MEAN	CATCH RATE S.E.	EFFORT
68	68279	0.760	1.360	0.196	50206
69	40540	0.786	1.328	0.184	30516
70	48582	0.795	1.185	0.168	40989
71	41495	0.719	0.838	0.116	49508
72	42805	0.637	0.797	0.095	53676
73	41087	0.762	0.771	0.087	53276
74	32848	0.940	0.574	0.056	57203
75	20982	0.884	0.425	0.043	49314
76	15520	0.909	0.567	0.055	27383
77	4597	0.647	0.566	0.065	8126
78	16135	0.018	0.624	0.125	25854
79	28501	0.093	1.394	0.257	20445
80	35244	0.835	1.069	0.104	32974
81	36810	0.857	1.043	0.098	35302
82	38380	0.934	1.256	0.116	30557
83	37853	0.866	1.216	0.118	31134
84	40768	0.921	1.342	0.128	30379
85	41568	0.815	1.688	0.164	24627
86	36979	0.841	2.039	0.197	18132
87	34107	0.829	1.298	0.129	26268
88	27399	0.876	1.156	0.112	23703
89	25346	0.805	1.155	0.114	21936

AVERAGE C.V. FOR THE MEAN: .116

Table 14. continued

REGRESSION COEFFICIENTS

CATEGORY	CODE	VARIABLE	COEFFICIENT	STD. ERROR	NO. OBS.
gear	1	INTERCEPT	0.165	0.145	1260
area	1				
month	1				
year	68				
gear	2	1	-0.709	0.080	83
	3	2	-0.179	0.067	143
	4	3	-0.029	0.064	159
	5	4	0.144	0.059	216
	6	5	-0.211	0.085	68
	7	6	-0.052	0.102	41
	8	7	0.139	0.072	106
	9	8	0.487	0.079	189
	10	9	0.882	0.086	93
area	2	10	-0.095	0.035	450
month	2	11	0.130	0.077	122
	3	12	0.084	0.074	157
	4	13	-0.176	0.075	148
	5	14	-0.383	0.077	132
	6	15	-0.477	0.084	90
	7	16	-0.564	0.091	67
	8	17	-0.322	0.085	85
	9	18	-0.374	0.084	90
	10	19	-0.394	0.081	106
	11	20	-0.035	0.082	96
	12	21	0.032	0.087	78
year	69	22	-0.024	0.156	27
	70	23	-0.138	0.157	26
	71	24	-0.485	0.158	26
	72	25	-0.537	0.144	45
	73	26	-0.571	0.140	54
	74	27	-0.868	0.135	79
	75	28	-1.167	0.138	61
	76	29	-0.881	0.136	73
	77	30	-0.881	0.159	35
	78	31	-0.769	0.223	9
	79	32	0.031	0.207	12
	80	33	-0.247	0.144	75
	81	34	-0.272	0.141	96
	82	35	-0.086	0.140	103
	83	36	-0.118	0.146	74
	84	37	-0.019	0.144	79
	85	38	0.210	0.145	77
	86	39	0.399	0.144	78
	87	40	-0.052	0.145	70
	88	41	-0.168	0.146	70
	89	42	-0.169	0.146	67

Table 15. 4VsW standardized catch rate from IOP for OTB (TC 4-5).

MULTIPLE R............. .623
MULTIPLE R SQUARED..... .389

ANALYSIS OF VARIANCE

SOURCE OF VARIATION	DF	SUMS OF SQUARES	MEAN SQUARES	F-VALUE
INTERCEPT	1	3.016E0000	3.016E0000	
REGRESSION	19	4.449E0001	2.342E0000	4.514
TYPE 1	7	1.102E0001	1.574E0000	3.034
TYPE 2	11	3.240E0001	2.945E0000	5.677
TYPE 3	1	3.366E-001	3.366E-001	0.649
RESIDUALS	135	7.003E0001	5.187E-001	
TOTAL	155	1.175E0002		

REGRESSION COEFFICIENTS

CATEGORY	CODE	VARIABLE	COEFFICIENT	STD. ERROR	NO. OBS.
year	82	INTERCEPT	0.117	0.250	155
month	1				
TC	5				
year	83	1	-0.093	0.226	23
	84	2	0.528	0.227	22
	85	3	0.657	0.230	21
	86	4	0.532	0.249	16
	87	5	0.459	0.244	17
	88	6	0.250	0.231	21
	89	7	0.574	0.250	16
month	2	8	0.380	0.255	16
	3	9	0.439	0.255	16
	4	10	-0.355	0.264	14
	5	11	-0.452	0.270	13
	6	12	-0.699	0.284	11
	7	13	-0.822	0.293	10
	8	14	-0.572	0.292	10
	9	15	-0.811	0.283	11
	10	16	-0.957	0.264	14
	11	17	-0.154	0.264	14
	12	18	-0.031	0.294	10
gear	4	19	-0.097	0.121	65

PREDICTED CATCH RATE

STANDARDS USED VARIABLE NUMBERS: 1 5

YEAR	TOTAL CATCH	PROP.	CATCH RATE MEAN	CATCH RATE S.E.	EFFORT
82	38380	0.109	1.414	0.349	27142
83	37853	0.112	1.291	0.307	29316
84	40768	0.161	2.402	0.577	16973
85	41568	0.140	2.733	0.654	15212
86	36979	0.074	2.408	0.596	15357
87	34107	0.098	2.238	0.550	15242
88	27399	0.172	1.818	0.435	15067
89	25346	0.166	2.511	0.618	10096

AVERAGE C.V. FOR THE MEAN: .243

Table 16. Summary of the ADAPT framework used to estimate the stock parameters for 4VsW cod in 1989.

Framework: Assumptions and Structure Imposed

The formulation used in this assessment combines July and Spring survey indices using log residuals to estimate the population numbers by half years. The structure imposed is as follows:

Error in catch assumed negligible

Partial recruitment fixed for ages	1	2	3	..	10+
	.0001	.0001	.012	..	1.0

F at the oldest age assumed equal to the mean F for ages 7-9 weighted by population numbers

No intercept was used in the relationship between population numbers and survey indices

Natural mortality was set at 0.2 (0.1 per half year)

Parameters of the ADAPT framework

Yearclass estimates — $N_{i,t}$, i=4, 5, ... 9 ; t=1989.5 i.e. midyear numbers

Survey coefficieants — $K_{1,i}$, i=4, 5, ... 9 July RV
$K_{2,i}$, 1=4, 5, ... 9 Spring RV

Input

Catch at age — $C_{i,t}$, i=1, 2, ... 15 ; t= 1971, 1971.5, ... 1989.5

July RV CPUE — $RV_{1,i,t}$, i=4, 5, ... 9 ; t=1971.5, 1972.5 ... 1989.5

Spring RV CPUE — $RV_{2,i,t}$, i=4, 5, ... 9 ; t=1979, 1980, ... 1989 except 1985

Objective Function

Minimize

$$\sum_{i}\sum_{t}\{(\ln RV_{1,i,t})-(\ln R\hat{V}_{1,i,t})\}^2+\sum_{i}\sum_{t}\{(\ln RV_{2,i,t})-(\ln R\hat{V}_{2,i,t})\}^2$$

Note: 3 July residuals given 0 weight (1974 age 5; 1975 age 6; 1976 age 9)

Summary

Number of observations	111	July RV	(114-3)
	60	Spring RV	
Number of Parameters	18		

Table 17A. 4VsW cod ADAPT summary statistics from half-year SPA.

ESTIMATED PARAMETERS AND STANDARD ERRORS
APPROXIMATE STATISTICS ASSUMING LINEARITY NEAR SOLUTION

ORTHOGONALITY OFFSET......... 0.043892
MEAN SQUARE RESIDUALS 0.356224

AGE	PAR. EST.	STD. ERR.	T-STATISTIC	C.V.
NUMBERS				
4	2.686E0004	1.195E0004	2.248E0000	4.447E-001
5	2.097E0004	7.063E0003	2.969E0000	3.368E-001
6	1.045E0004	3.285E0003	3.181E0000	3.144E-001
7	1.525E0004	4.417E0003	3.453E0000	2.896E-001
8	3.970E0003	1.526E0003	2.602E0000	3.844E-001
9	4.233E0003	1.612E0003	2.625E0000	3.809E-001
JULY RV				
4	2.133E-004	3.025E-005	7.051E0000	1.418E-001
5	2.207E-004	3.183E-005	6.933E0000	1.442E-001
6	1.880E-004	2.709E-005	6.942E0000	1.440E-001
7	1.579E-004	2.223E-005	7.103E0000	1.408E-001
8	1.351E-004	1.911E-005	7.071E0000	1.414E-001
9	1.072E-004	1.563E-005	6.859E0000	1.458E-001
SPRING RV				
4	1.554E-004	3.112E-005	4.993E0000	2.003E-001
5	1.926E-004	3.768E-005	5.111E0000	1.957E-001
6	2.210E-004	4.292E-005	5.149E0000	1.942E-001
7	1.924E-004	3.742E-005	5.142E0000	1.945E-001
8	1.778E-004	3.480E-005	5.110E0000	1.957E-001
9	1.043E-004	2.041E-005	5.108E0000	1.958E-001

Parameter Correlation Matrix

	1	2	3	4	5	6	7	8	9	10	11	12	13
1	1.000	.062	.051	.048	.016	.023	-.182	-.020	-.015	-.012	-.010	-.012	-.239
2	.062	1.000	.072	.071	.031	.029	-.136	-.147	-.022	-.018	-.016	-.017	-.179
3	.051	.072	1.000	.091	.046	.041	-.112	-.117	-.139	-.024	-.022	-.023	-.145
4	.048	.071	.091	1.000	.045	.059	-.110	-.124	-.145	-.180	-.105	-.153	-.136
5	.016	.031	.046	.045	1.000	.076	-.058	-.067	-.088	-.129	-.194	-.079	-.031
6	.023	.029	.041	.059	.076	1.000	-.053	-.061	-.077	-.103	-.144	-.215	-.064
7	-.182	-.136	-.112	-.110	-.058	-.053	1.000	.045	.035	.030	.027	.029	.086
8	-.020	-.147	-.117	-.124	-.067	-.061	.045	1.000	.038	.034	.031	.033	.055
9	-.015	-.022	-.139	-.145	-.088	-.077	.035	.038	1.000	.041	.039	.041	.041
10	-.012	-.018	-.024	-.180	-.129	-.103	.030	.034	.041	1.000	.052	.053	.032
11	-.010	-.016	-.022	-.105	-.194	-.144	.027	.031	.039	.052	1.000	.055	.026
12	-.012	-.017	-.023	-.153	-.079	-.215	.029	.033	.041	.053	.055	1.000	.033
13	-.239	-.179	-.145	-.136	-.031	-.064	.086	.055	.041	.032	.026	.033	1.000
14	-.023	-.181	-.146	-.147	-.077	-.035	.053	.058	.044	.037	.031	.032	.065
15	-.016	-.024	-.160	-.156	-.092	-.079	.038	.042	.051	.044	.041	.043	.045
16	-.013	-.019	-.025	-.190	-.129	-.106	.031	.035	.043	.056	.054	.055	.034
17	-.010	-.016	-.022	-.103	-.207	-.154	.028	.032	.040	.054	.066	.057	.026
18	-.012	-.018	-.024	-.153	-.079	-.219	.029	.033	.041	.053	.055	.070	.034

	14	15	16	17	18
1	-.023	-.016	-.013	-.010	-.012
2	-.181	-.024	-.019	-.016	-.018
3	-.146	-.160	-.025	-.022	-.024
4	-.147	-.156	-.190	-.103	-.153
5	-.077	-.092	-.129	-.207	-.079
6	-.035	-.079	-.106	-.154	-.219
7	.053	.038	.031	.028	.029
8	.058	.042	.035	.032	.033
9	.044	.051	.043	.040	.041
10	.037	.044	.056	.054	.053
11	.031	.041	.054	.066	.055
12	.032	.043	.055	.057	.070
13	.065	.045	.034	.026	.034
14	1.000	.049	.038	.032	.032
15	.049	1.000	.046	.042	.043
16	.038	.046	1.000	.056	.056
17	.032	.042	.056	1.000	.058
18	.032	.043	.056	.058	1.000

Table 17B. 4VsW cod residuals from half-year SPA model with July and Spring surveys.

MEAN SQUARE RESIDUALS : 0.3562239745
MEAN RESIDUAL : 4.452536411E-3
SUM OF ALL RESIDUALS : 0.7613837263

Log residuals from the July RV survey

	71.0	72.0	73.0	74.0	75.0	76.0	77.0	78.0	79.0	80.0	81.0	82.0
4	-.527	.521	1.377	-.873	-.419	-.384	-.248	.204	-.279	-.758	-.124	.767
5	.170	-.143	.853	-1.286	-.798	.025	.027	-.468	.026	.200	-.194	-.339
6	-.456	.116	-.279	-.542	-1.334	-.993	.468	-.436	.225	.435	.218	.256
7	.012	-.996	.400	-.904	-.459	-.426	-.489	-.519	-.020	.468	.161	.481
8	.611	-.968	-.470	-.248	-.560	.796	.694	-1.621	.190	-.056	.160	.116
9	.065	.536	.000	-.536	.920	3.152	-.152	-.569	-.316	-.194	-.352	-.218

	83.0	84.0	85.0	86.0	87.0	88.0	89.0
4	.633	.450	.219	-.444	.140	.051	-.036
5	.567	.602	.052	-.342	.226	.005	-.179
6	.438	.747	.408	-.338	.292	-.195	-.255
7	.093	1.126	.734	-.362	.228	.584	-.087
8	.385	-.113	.542	-.103	.596	-.019	.003
9	-.472	.604	1.034	-.028	.185	-.360	-.218

SUM OF RV RESIDUALS : 1.09019994 MEAN RESIDUAL : 9.82162108E-3

Log residuals from Spring RV survey

	79.0	80.0	81.0	82.0	83.0	84.0	86.0	87.0	88.0	89.0
4	-2.142	-1.083	.018	.554	1.140	-.008	1.154	.339	-.002	.054
5	-1.327	-.487	.204	.197	-.113	-.110	.773	.409	.344	.188
6	-1.037	-.098	.797	-.190	.386	-.287	.742	.271	-.091	-.335
7	-.815	.107	.787	.194	.043	.263	.996	.066	-.136	-1.450
8	-.188	-.695	.956	.427	.072	.107	.369	-.052	.185	-1.208
9	-.928	-.706	-.213	.510	.154	.912	.927	-.309	.199	-.633

SUM OF RV RESIDUALS : 0.2034114428 MEAN RESIDUAL : 3.390190713E-3

Table 18. 4VsW cod population numbers from longterm SPA.

	58	59	60	61	62	63	64	65	66	67	68
1	105745	95815	108304	93543	141167	159009	153142	145910	154128	121467	75721
2	92880	86576	78446	88672	76546	114732	126811	122849	116672	123650	98953
3	68352	75919	70883	64227	72342	57276	72416	87577	82784	79335	97404
4	38694	53380	59896	51685	49469	53776	31557	45961	54763	51949	59283
5	23145	28483	35662	43503	33641	31150	32929	17757	26321	32193	35304
6	17851	16657	15347	23176	27166	21777	15627	16301	9701	11980	17801
7	5749	11244	7766	8471	12934	15106	12923	8545	7800	3906	5883
8	5420	3250	5239	3814	4325	8107	7956	7980	4159	3440	1871
9	4258	3112	1334	2636	1420	1244	4662	4392	2482	1967	1695
10	1635	1664	1754	830	1061	542	706	2870	1671	1258	1009
11	978	562	366	1315	526	437	322	295	917	920	444
12	125	309	172	189	944	278	248	133	86	148	459
13	56	50	26	73	75	705	182	135	26	49	63
14	12	0	17	20	0	0	554	104	24	9	26
15	28	0	0	0	14	0	0	453	6	19	3
1+	364929	377020	385210	382154	421632	464139	460034	461263	461541	432289	395918
2+	259184	281205	276906	288611	280464	305130	306893	315353	307413	310822	320197
3+	166304	194629	198460	199939	203918	190398	180082	192503	190741	187172	221244
4+	97952	118710	127577	135713	131576	133122	107666	104926	107957	107837	123840

	69	70	71	72	73	74	75	76	77	78	79
1	99494	85062	84866	67306	61887	74357	86392	72141	67928	107119	96802
2	59738	80168	68473	67687	53254	49566	59726	69340	58600	55614	87671
3	66498	40678	57827	44457	41062	34353	33957	41144	54177	47957	45448
4	63992	47491	25264	38619	25721	26379	16069	21104	31098	43875	38207
5	32446	39974	25489	16047	20770	15807	11015	10295	13020	24349	32232
6	14759	17292	20356	14886	6457	8288	6740	4686	4900	9220	15577
7	7067	6588	10050	12026	6281	2279	4753	2535	1950	3247	5212
8	1666	3846	3637	5135	6853	2094	1260	1228	911	1153	1964
9	722	902	2462	1202	2503	1329	802	468	601	566	721
10	650	377	525	1379	670	526	911	207	260	385	367
11	500	487	243	98	707	196	292	125	121	183	248
12	226	323	274	55	19	80	149	83	91	61	122
13	185	133	214	68	38	8	64	11	26	35	26
14	21	140	101	34	23	12	7	15	9	11	3
15	6	11	104	10	28	0	10	0	9	4	0
1+	347968	323472	299885	269009	226273	215274	222147	223383	233702	293780	324598
2+	248474	238410	215019	201702	164386	140918	135756	151242	165773	186661	227797
3+	188736	158242	146546	134016	111132	91351	76029	81902	107174	131048	140126
4+	122239	117564	88720	89558	70070	56999	42072	40758	52996	83091	94678

	80	81	82	83	84	85	86	87	88	89
1	114406	126890	75264	94518	40408	53121	49747	471671	16051	2
2	79244	93640	103886	61618	77385	33083	43492	40729	386172	13141
3	71695	64796	76432	84930	50443	63356	27083	35605	33346	316163
4	35615	57101	50155	60340	66361	40910	51731	22061	29117	27134
5	25346	24750	38484	34126	41549	49104	31456	38544	17269	22471
6	17771	14475	13675	22348	21168	25782	32827	18841	26405	11968
7	8178	8960	7643	7866	12617	12193	14302	18533	10101	17519
8	3173	3936	4661	3934	4716	6865	6107	8462	9700	4583
9	1267	1583	1937	2626	2305	2730	3422	3578	4455	4961
10	521	754	937	971	1584	1395	1274	1786	1930	2081
11	279	344	495	479	593	1035	733	638	915	1014
12	194	183	219	267	258	347	590	342	312	514
13	96	135	121	120	172	154	127	388	162	117
14	18	75	91	50	77	110	65	45	263	74
15	3	15	60	24	28	48	72	43	27	207
1+	357806	397638	374059	374218	319663	290234	263027	661267	536223	421948
2+	243400	270748	298795	279700	279255	237113	213279	189596	520173	421946
3+	164157	177108	194910	218082	201870	204029	169788	148867	134001	408805
4+	92462	112312	118477	133153	151427	140673	142705	113262	100655	92642

Table 19. 4VsW cod fishing mortality from longterm SPA.

	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73
1	.00	.00	.00	.00	.01	.03	.02	.02	.02	.00	.04	.02	.02	.03	.03	.02
2	.00	.00	.00	.00	.09	.26	.17	.19	.19	.04	.20	.18	.13	.23	.30	.24
3	.05	.04	.12	.06	.10	.40	.25	.27	.27	.09	.22	.14	.28	.20	.35	.24
4	.11	.20	.12	.23	.26	.29	.38	.36	.33	.19	.40	.27	.42	.25	.42	.29
5	.13	.42	.23	.27	.23	.49	.50	.40	.59	.39	.67	.43	.47	.34	.71	.72
6	.26	.56	.39	.38	.39	.32	.40	.54	.71	.51	.72	.61	.34	.33	.66	.84
7	.37	.56	.51	.47	.27	.44	.28	.52	.62	.54	1.06	.41	.39	.47	.36	.90
8	.35	.69	.49	.79	1.05	.35	.39	.97	.55	.51	.75	.41	.25	.91	.52	1.44
9	.74	.37	.27	.71	.76	.37	.29	.77	.48	.47	.76	.45	.34	.38	.38	1.36
10	.87	1.31	.09	.26	.69	.32	.67	.94	.40	.84	.50	.09	.24	1.48	.47	1.03
11	.95	.98	.46	.13	.44	.37	.69	1.03	1.62	.50	.47	.24	.37	1.28	1.45	1.97
12	.72	2.28	.66	.72	.09	.22	.41	1.42	.37	.66	.71	.33	.21	1.19	.17	.64
13	9.24	.91	.04	9.49	9.52	.04	.36	1.54	.88	.45	.88	.07	.08	1.64	.88	.95
14	8.18	.28	8.49	.18	.28	.28	.00	2.73	.00	.97	1.33	.45	.10	2.11	.00	8.77
15	.50	.50	.50	.50	.50	.50	.50	.50	.50	.50	.50	.50	.50	.54	.40	1.20

	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89
1	.02	.02	.01	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
2	.18	.17	.05	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
3	.56	.28	.08	.01	.03	.04	.03	.06	.04	.05	.01	.00	.01	.00	.01	.00
4	.67	.25	.28	.04	.11	.21	.16	.19	.19	.17	.10	.06	.09	.04	.06	.11
5	.65	.65	.54	.15	.25	.40	.36	.39	.34	.28	.28	.20	.31	.18	.17	.22
6	.36	.78	.68	.21	.37	.44	.48	.44	.35	.37	.35	.39	.37	.42	.21	.36
7	.39	1.15	.82	.33	.30	.30	.53	.45	.46	.31	.41	.49	.32	.45	.59	.26
8	.76	.79	.51	.28	.27	.24	.50	.51	.37	.33	.35	.50	.33	.44	.47	.56
9	.18	1.15	.39	.24	.23	.12	.32	.32	.49	.31	.30	.56	.45	.42	.56	.59
10	.39	1.79	.33	.15	.24	.07	.22	.22	.47	.29	.23	.44	.49	.47	.44	.37
11	.08	1.05	.11	.48	.21	.05	.22	.25	.42	.42	.34	.36	.56	.52	.38	.32
12	.03	2.43	.98	.76	.67	.04	.16	.21	.40	.24	.31	.80	.22	.55	.78	.40
13	.00	1.23	.00	.64	2.14	.14	.05	.20	.68	.25	.25	.67	.85	.19	.58	.32
14	.00	7.83	.34	.48	7.56	.00	.00	.03	1.11	.40	.28	.22	.21	.32	.04	.25
15	.46	1.07	.70	.28	.28	.26	.50	.45	.43	.31	.38	.50	.34	.44	.53	.31

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

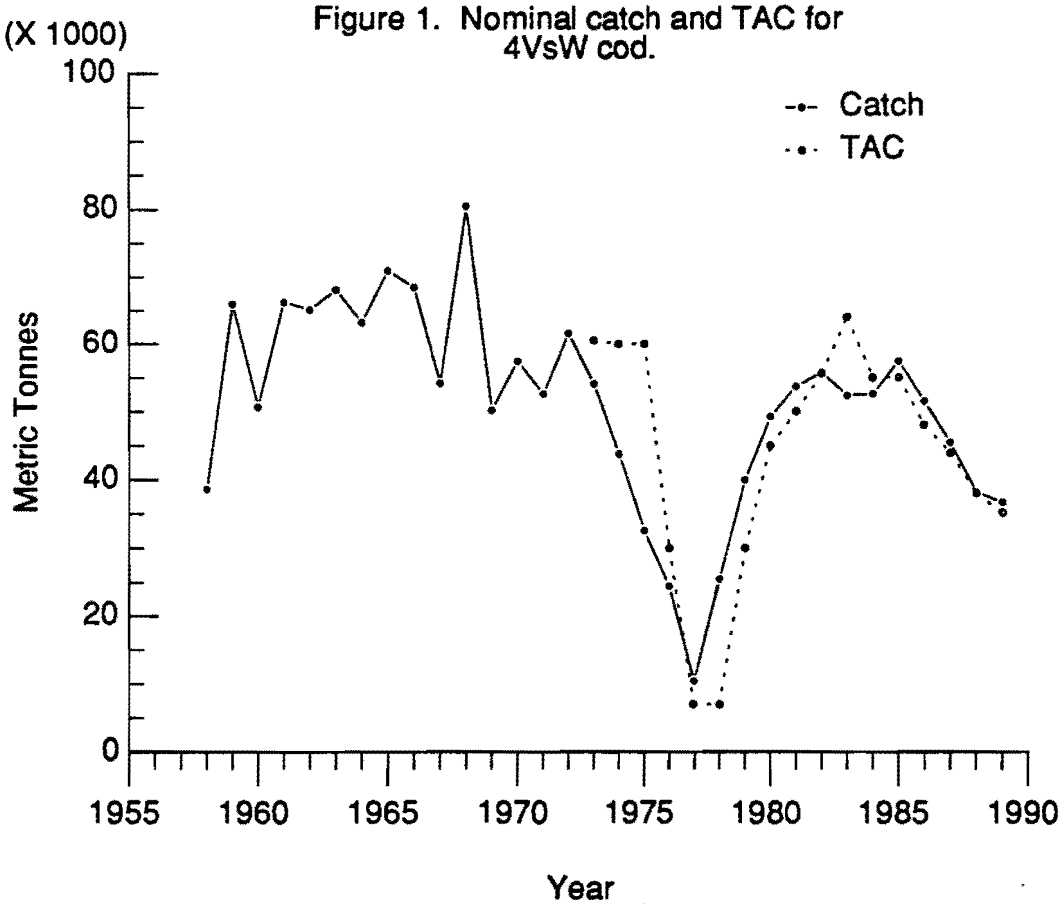


Figure 2. Comparison of projected and observed catch at age for 4VsW cod 1989.

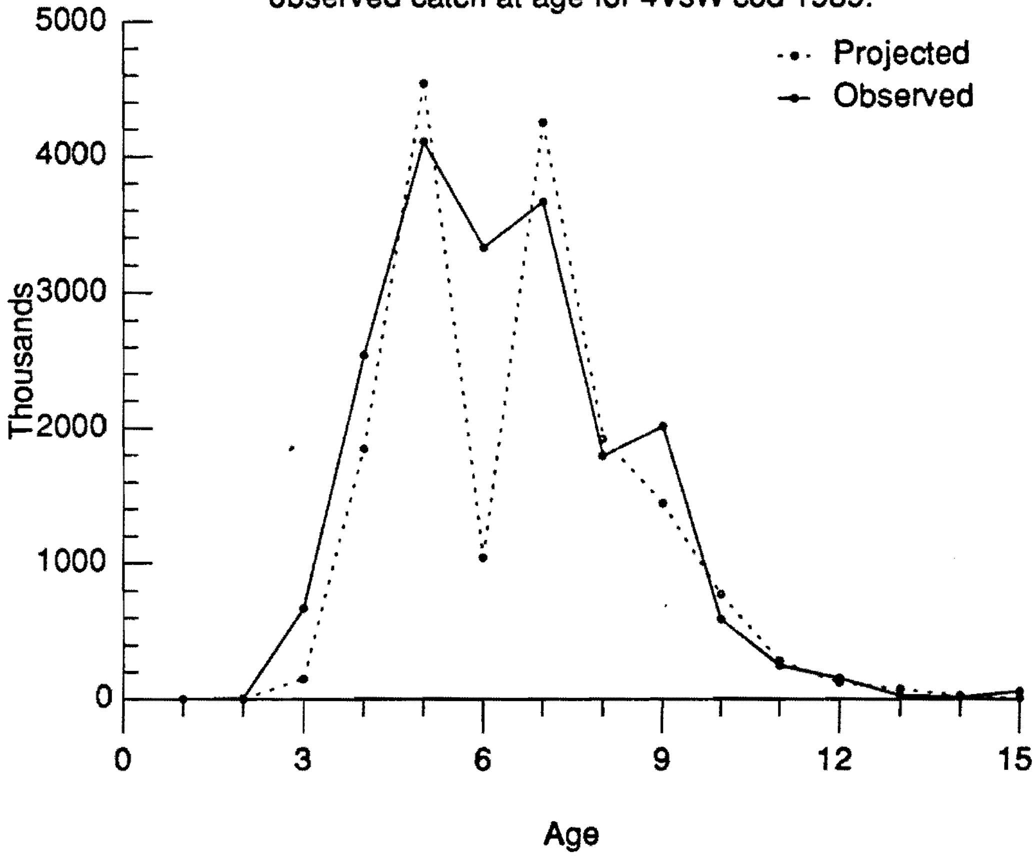


Figure 3. July RV survey mean catch per tow for 4VsW cod.

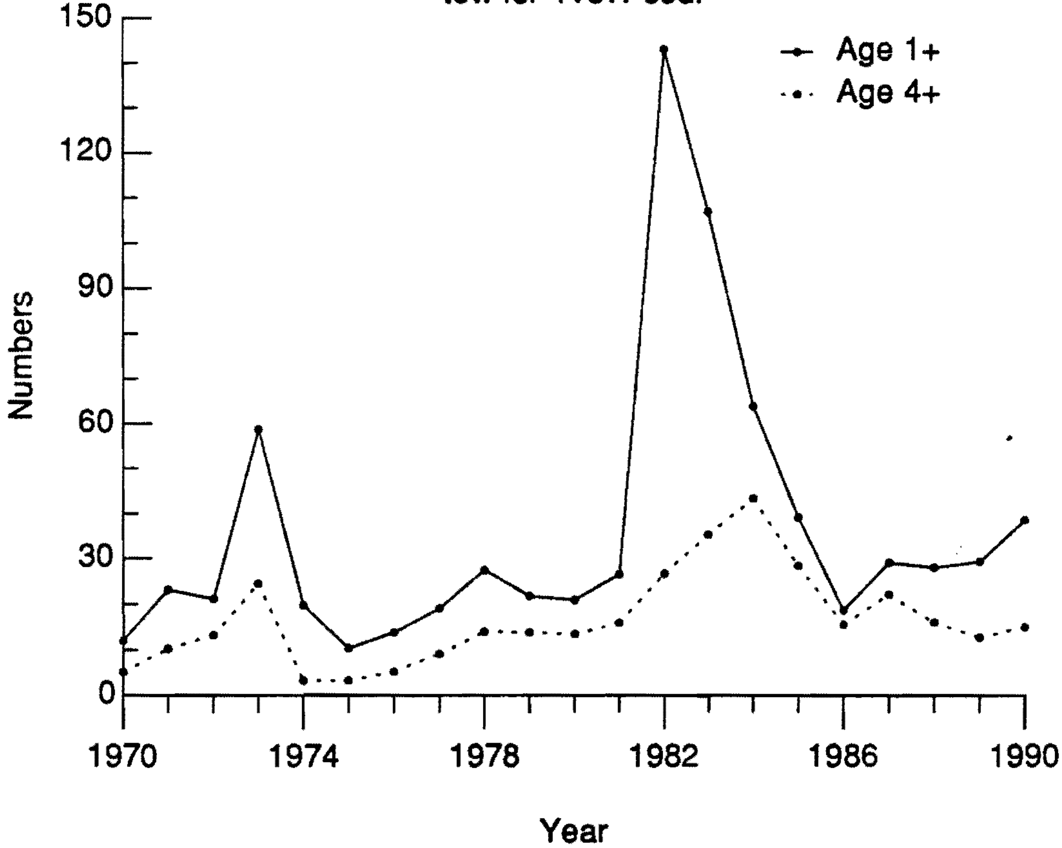
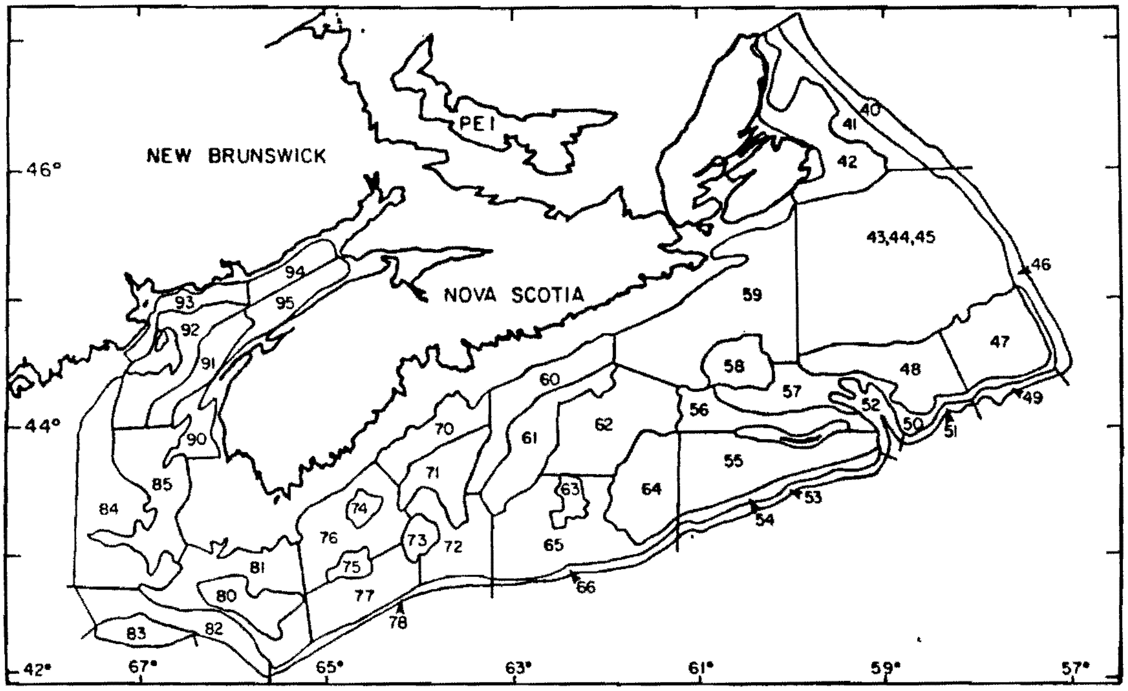
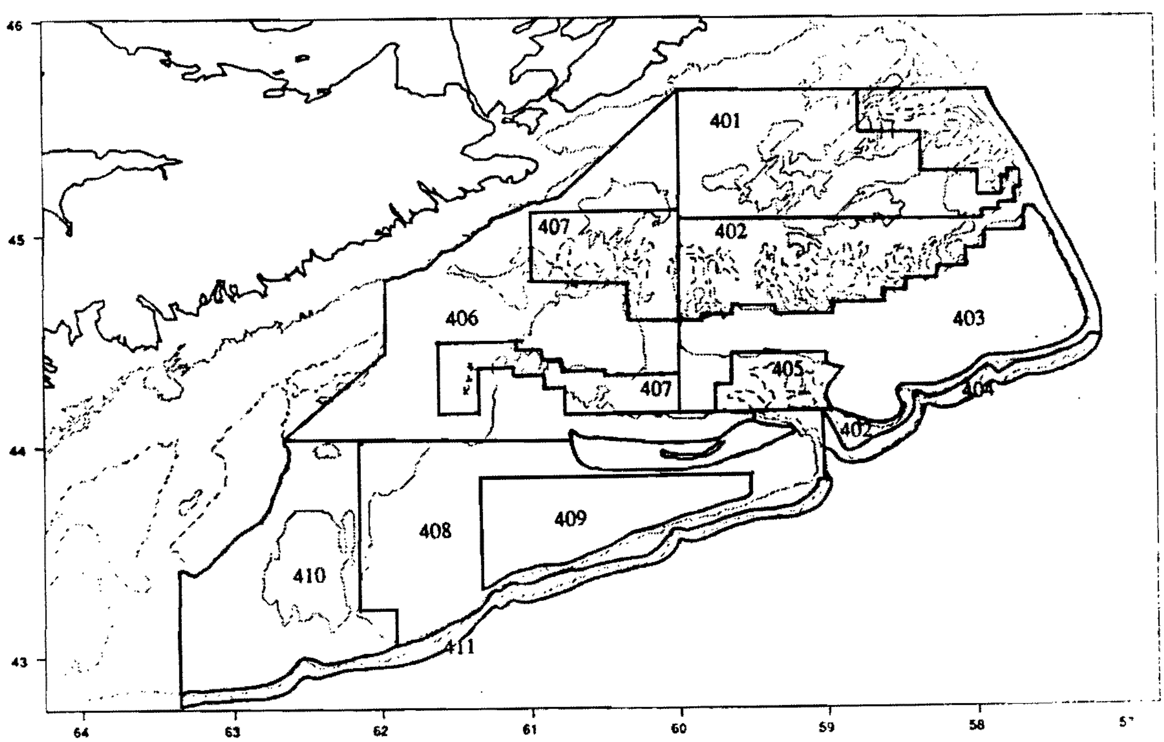


Figure 4. Stratification schemes used in surveying 4VsW cod.



All July surveys and Spring surveys from 1979 to 1984.



Spring surveys from 1986 to the present.

Figure 5. Spring RV survey mean catch per tow for 4VsW cod (No 1985 survey).

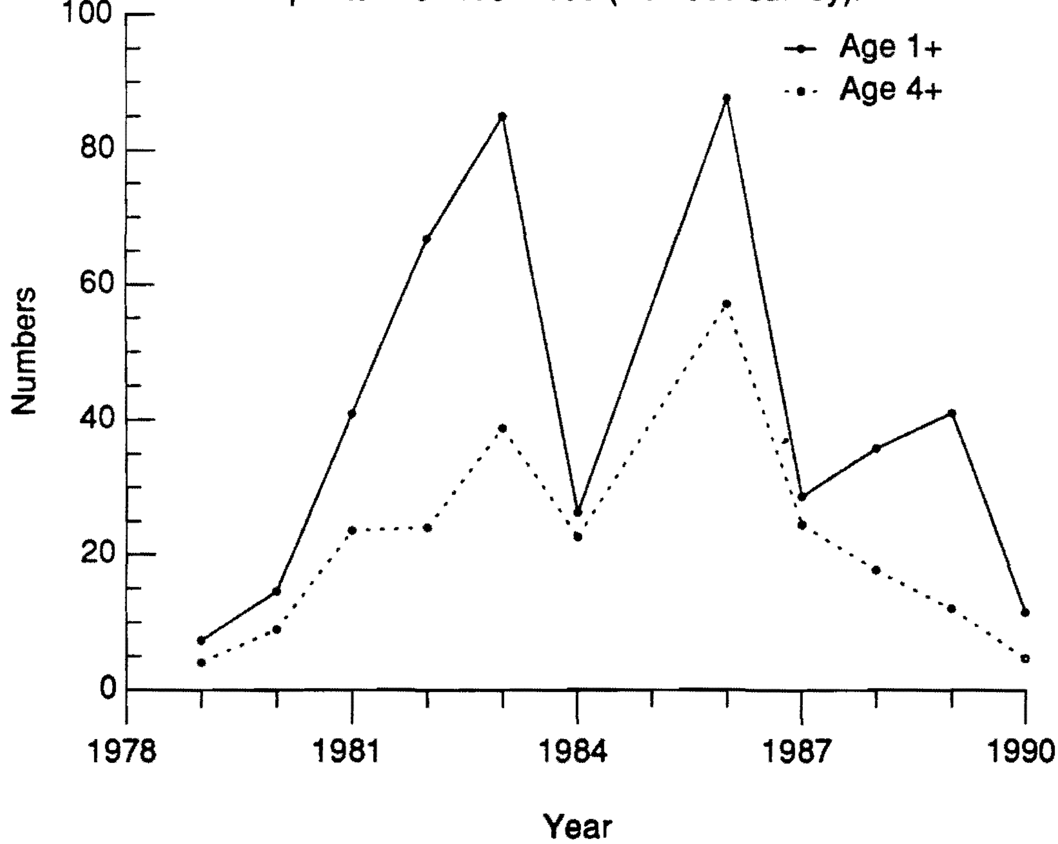


Figure 6. Comparison of ages 4+ catch per tow in July and Spring surveys.

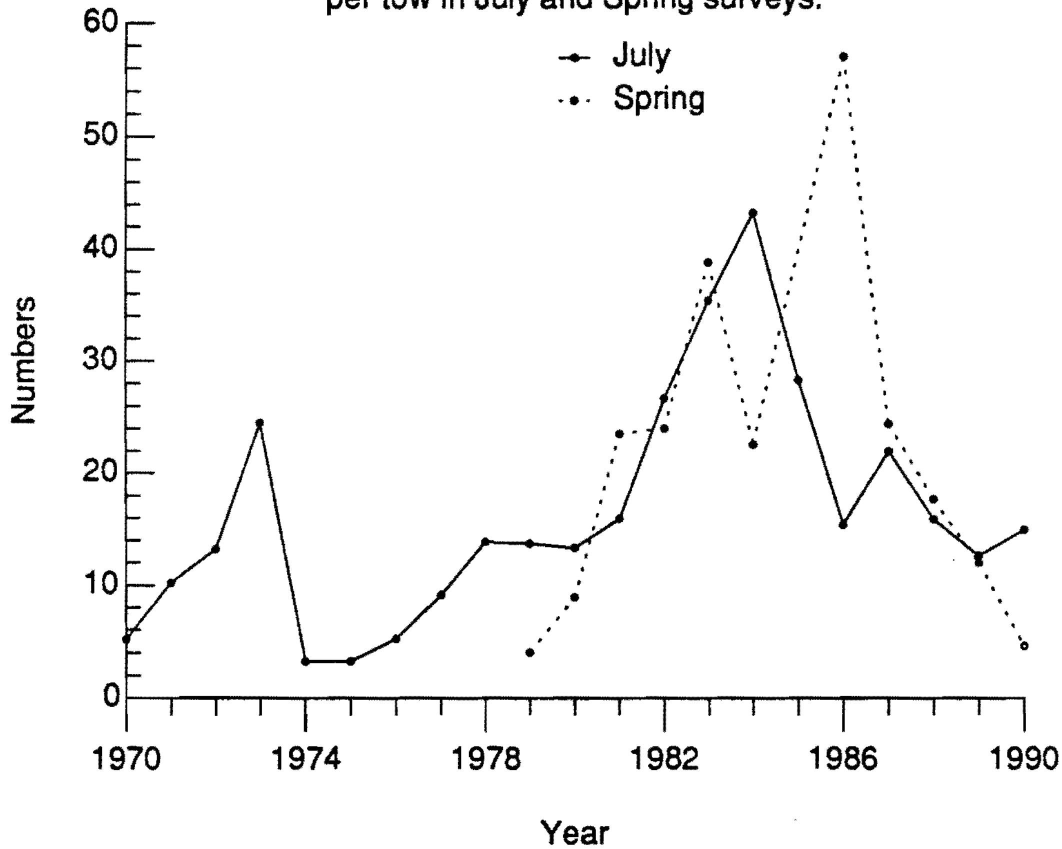
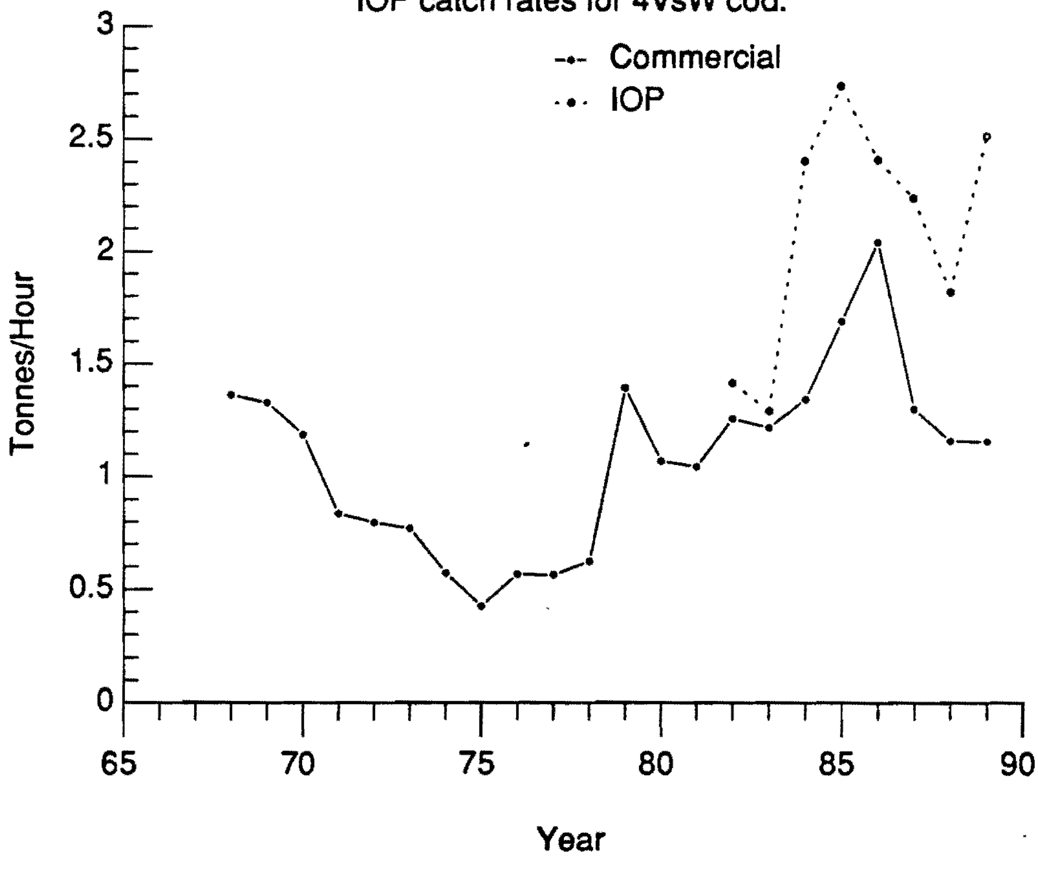


Figure 7. Standardized commercial and
IOP catch rates for 4VsW cod.



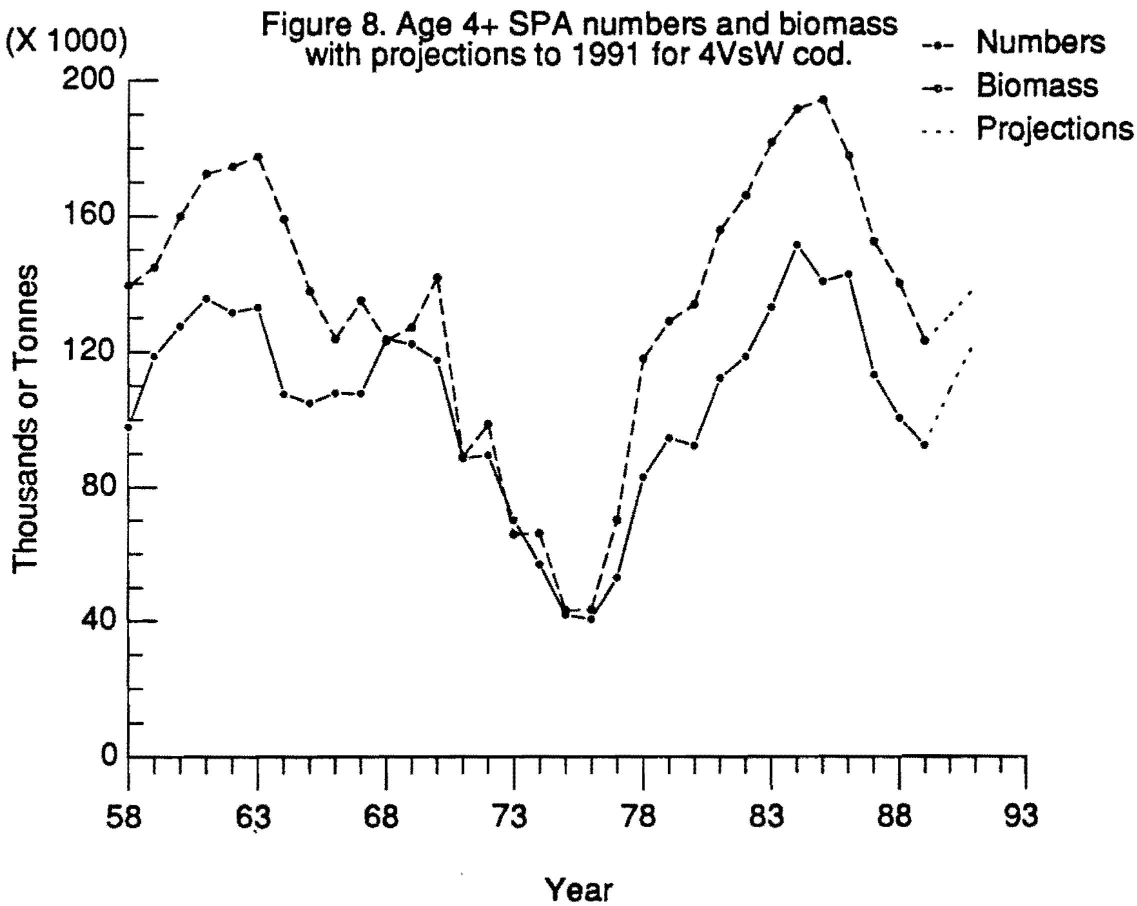


Figure 8. Age 4+ SPA numbers and biomass with projections to 1991 for 4VsW cod.
Numbers
Biomass
Projections
(X 1000)
200
160
120
80
40
0
Thousands or Tonnes
58
63
68
73
78
83
88
93
Year

Figure 9. Mean fully recruited fishing mortality (Ages 7-9) in 4VsW cod.

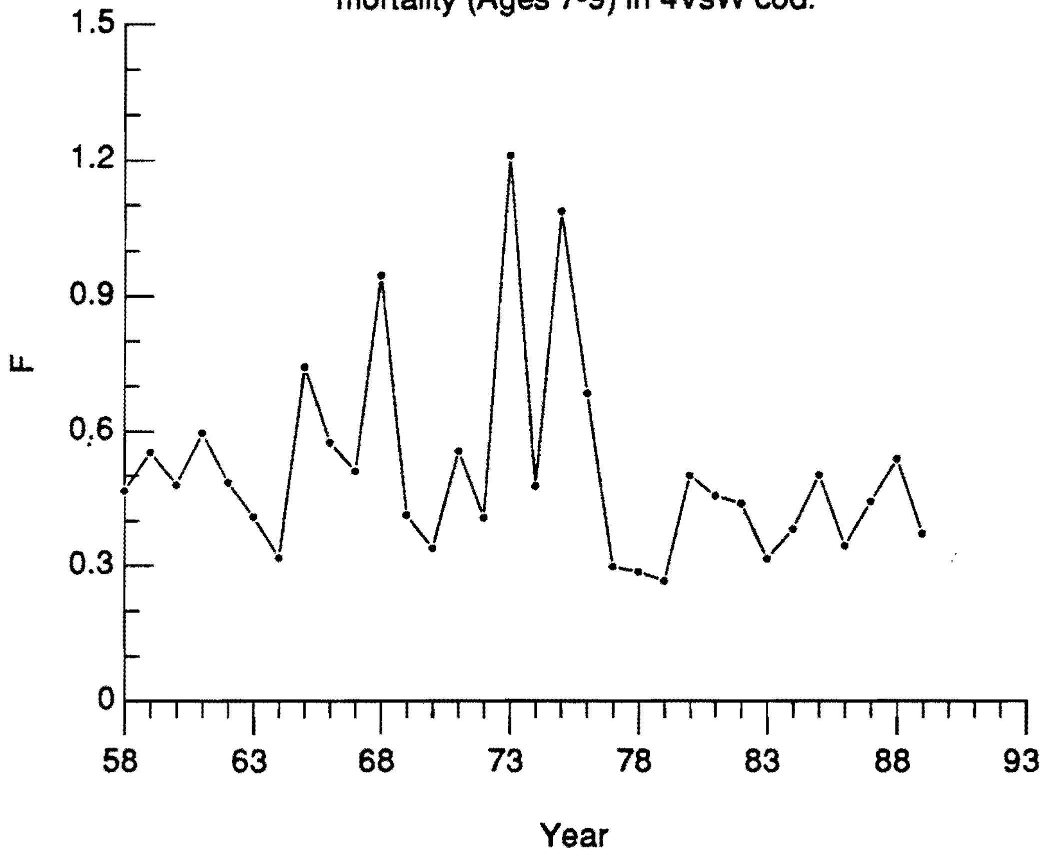


Figure 10. Age 1 recruitment from SPA in 4VsW cod.

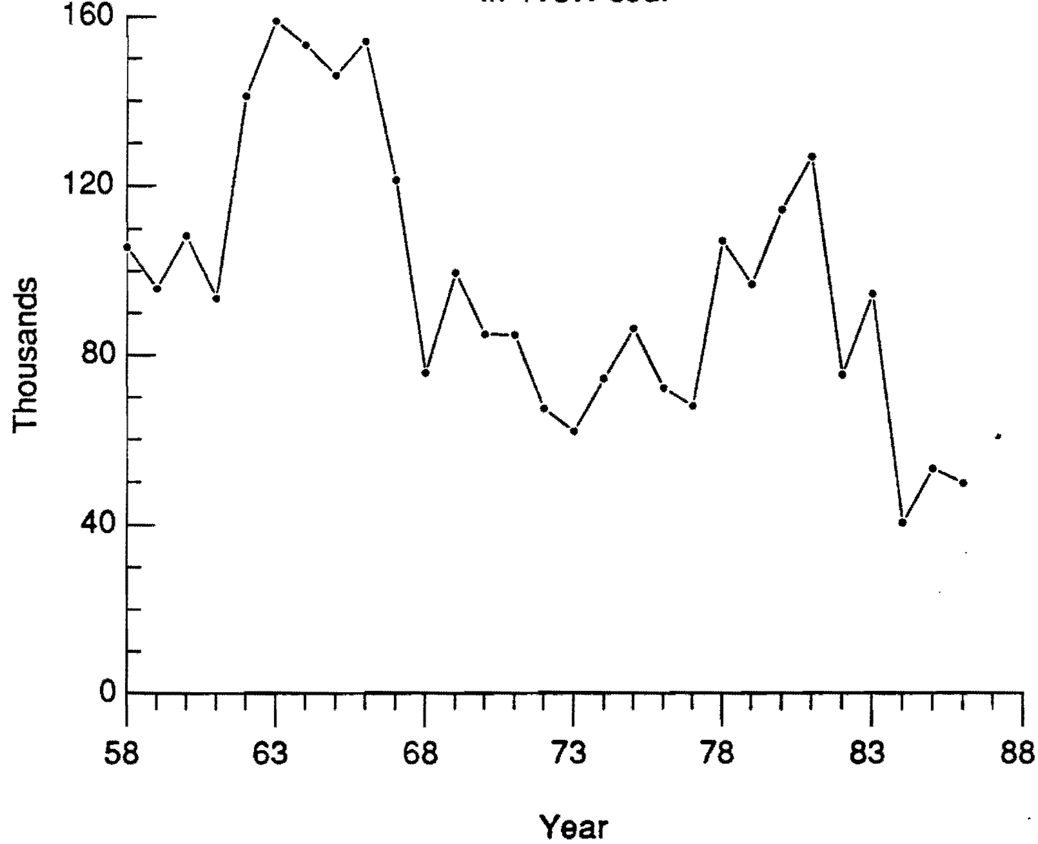
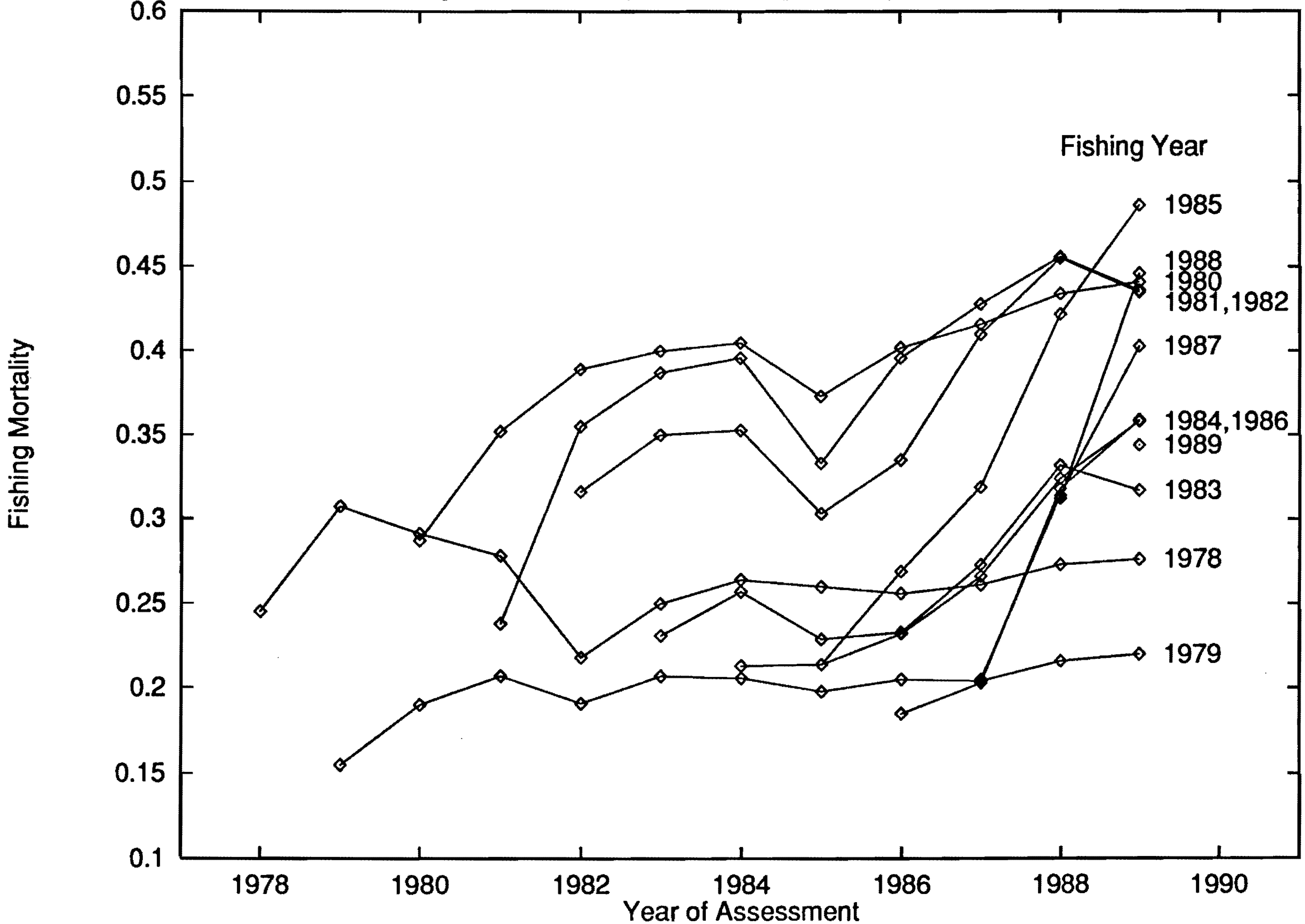


Figure 11. Retrospective fishing mortality in 4VsW cod.



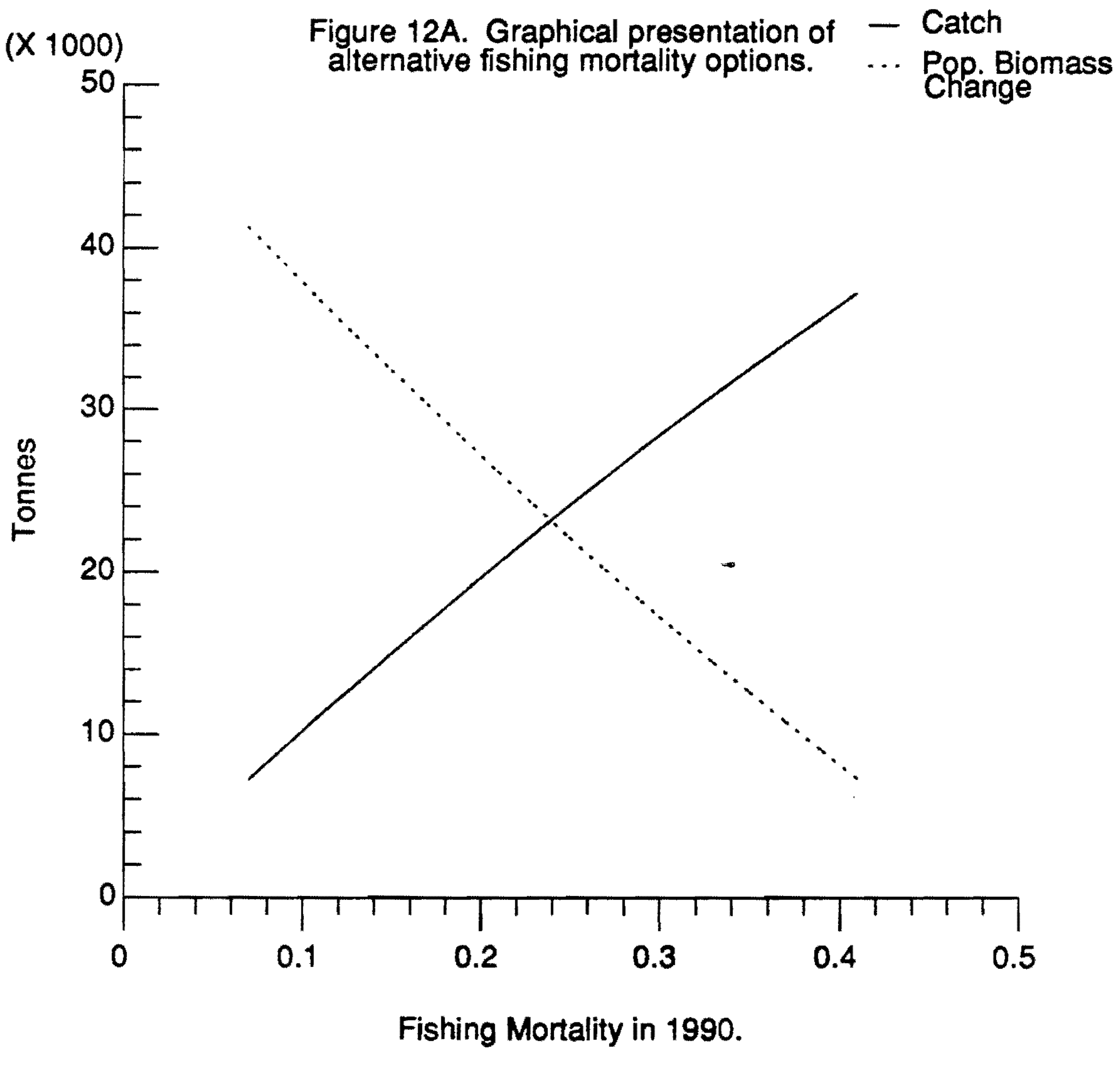
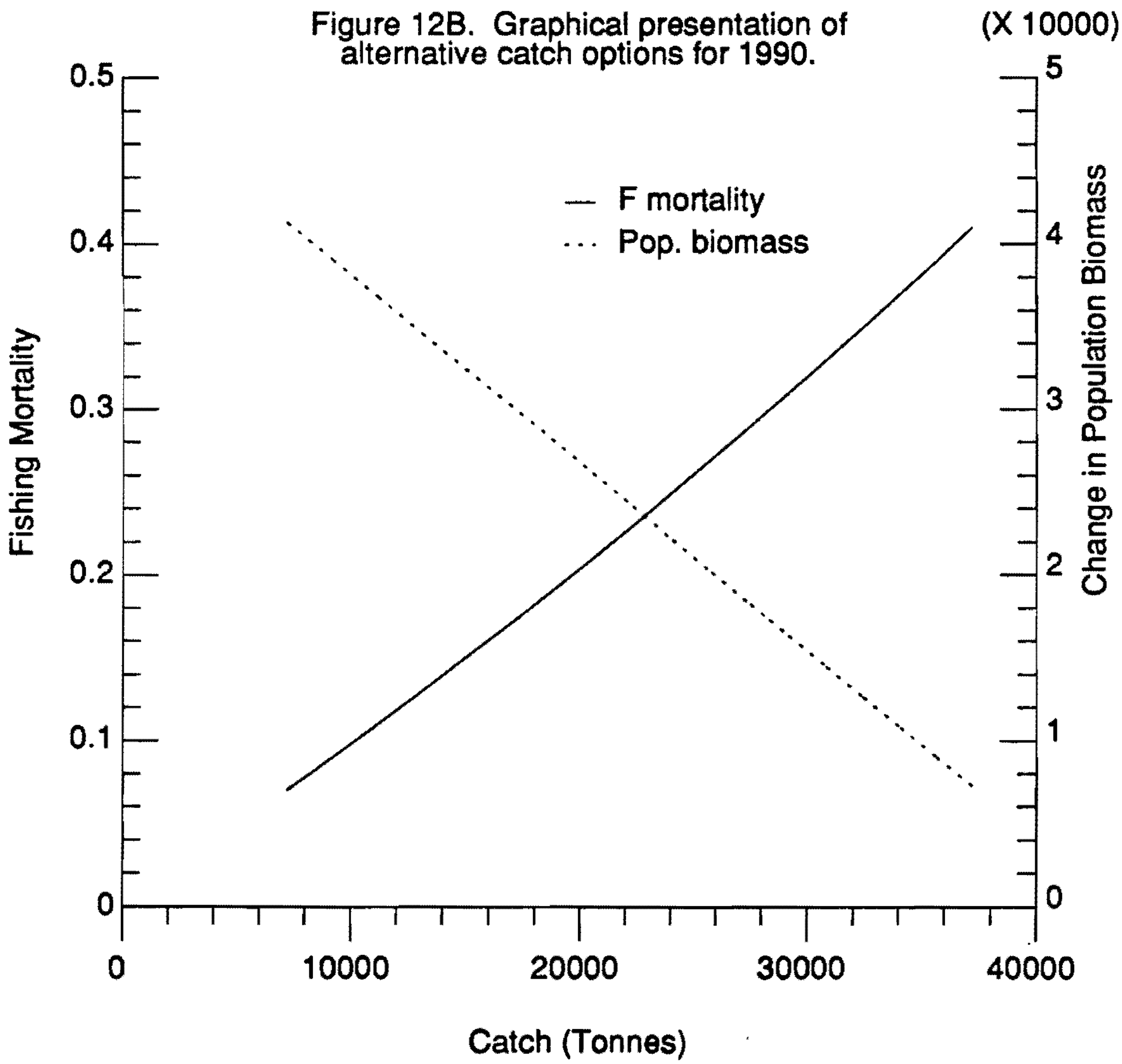


Figure 12A. Graphical presentation of alternative fishing mortality options.
— Catch
··· Pop. Biomass Change
(X 1000)
Tonnes
50
40
30
20
10
0
0
0.1
0.2
0.3
0.4
0.5
Fishing Mortality in 1990.

Figure 12B. Graphical presentation of alternative catch options for 1990.



```
3 NYADAPT 91/01/04 16:31:36

      )FNS
∆AND          AXES          A∆PLUS        CLOSEFILE     CRT
DATAGEN       DEFAULT       DIFF∆OBJ      DIFF∆PNLTY    FRCN∆FN
FTIE          FYSHIFT       GMODE         GRAPH         GRAPHS
NYINTERFACE   NYSHIFT       INPUT         OBJ∆FN        OPENFILE
OUT           OUTPUT        PARASE        PRNT          PLOTRVSPA
PNLTY∆FN      PRINTRVSPA    PRNT          PRT           QPUT
RESI          RESI∆CPUE     RESI∆RV       RESI∆RV2      RESI∆RV3
SCALE         SC∆FILEIT     SC∆FILER      SPA           SPA∆AFORM
SPA∆CFORM     SPA∆E         SPA∆FTOS      SPA∆IC        SPA∆ITERCOHORT
SPA∆SOUT      SPA∆STOP      SPA∆TAIL      TIMEFMT       TMODE
UNBLANK       UNDER         VS            miniDOC       minipop
page          start

    ∇ 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
    ∇

    ∇ CLOSEFILE
      →(∧/∆SORTIE=⍕∆SORTIE)/NAN ⍝ NOT NUMERIC, UNTIE ALL NATIVE FILES
      ⎕NUNTIE ∆SORTIE
      →0
     NAN:⎕NUNTIE ⎕NNUMS
    ∇

    ∇ CRT
      ⎕PW←80
      ∆SORTIE←'CRT'
    ∇

    ∇ DATAGEN PAR;RESID
      RESID←OBJ∆FN PAR
      →(INDEX∆TYPE[1]=0)/CPUE
      →(∧/1=.iseerv)/LOG
      RESID∆RV←(iarv-ihatarv)÷iseerv
      →CPUE
     LOG:RESID∆RV←(⍟iarv)-⍟ihatarv
     CPUE:⍎(INDEX∆TYPE[2]≠0)/' RESID∆CPUE←(-⍴,iacpue)↑RESID'

    ∇

    ∇ R←PRMPT DEFAULT X
     ⍝ PROMPTS THE USER FOR A VALUE WITH AN OPTIONAL DEFAULT VALUE
     ⍝ ORG.WS: UTIL  VERSION: 3  DATE: 86/08/29  AUTHOR: C. BLACK
      ⍎(2=⎕NC 'PRMPT')/'⍞←PRMPT'
      →(0=1↑0⍴X)/NUMERIC
      ' default is...  ',X
      →(0<⍴R←,⍞)/END
      →SUBS
     NUMERIC:' default is...  ',⍕X
      →(0=⍴R←⍞)/SUBS
      R←,⍎R
      →END
     SUBS:R←X
     END:
    ∇

    ∇ R←DIFF∆OBJ;DELTA;I;TPAR
     ⍝ CALCULATES ONE SIDED DIFFERENCE OF OBJECTIVE FUNCTION
      I←1
      R←(N,0)⍴1
      DELTA←1E¯7×1E¯7⌈|par ⍝ see NASH pg 180 formula 18.5 (CNM3)
     L1:TPAR←((I-1)↑par),(par[I]+DELTA[I]),I↓par
      R←R,(e-OBJ∆FN TPAR)÷(par[I]+DELTA[I])-par[I]
     ⍝ ensures actual DELTA[I] is in denominator, conditions rounding error
      →L1×P≥I←I+1
    ∇

    ∇ R←DIFF∆PNLTY;I;R1;DELTA;TPAR;fpnlty;bpnlty
     ⍝ CALCULATES FIRST AND SECOND DIFFERENCES OF PENALTY FUNCTION
      I←1
      R← 2 0 ⍴0
      DELTA←1E¯7×1E¯7⌈|par ⍝ see NASH pg 180 formula 18.5 (CNM3)
     L1:TPAR←((I-1)↑PAR),(PAR[I]+DELTA[I]),I↓PAR
      R1←(pnlty-fpnlty←alpha PNLTY∆FN TPAR)÷DELTA[I]
      TPAR←((I-1)↑PAR),(PAR[I]-DELTA[I]),I↓PAR
      bpnlty←alpha PNLTY∆FN TPAR
      R←R,[1]R1,(fpnlty+bpnlty-2×pnlty)÷DELTA[I]
      →L1×P≥I←I+1
    ∇
```

Appendix 1 (continued)

```
    ∇ R←FRCHAFN A
      R←∧/(A)|bnd),A(ubnd
  ⍝ THIS FUNCTION SHOULD RETURN A 1 IF THE PARAMETERS
  ⍝ ARE IN THE FEASIBLE REGION AND 0 OTHERWISE
  ⍝ R←1 DEFAULT RETURNS 1
    ∇

    ∇ Z←FTIE FNM;MAP;FS;LID;ELX;SRC;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'
      SRC←0 ⋄ FS←(0 1 =⎕PEEK 162)/ 1 10 ⍝ Look at file-id setting
      MAP←∧\FNM∊' 0123456789' ⍝ Map leading blanks and numbers
      LID←MAP/FNM ⋄ FNM←(8 11 [1 10 ⍳FS])↑(~MAP)/FNM
      →(~∧/LID=' ')/L1 ⋄ LID←⍕¯48+⎕PEEK 97 ⍝ Get default drive if needed
  L1:LID←(FS,0)⍕⍎ LID
      Z←(⎕FNAMES∧.=LID,' ',FNM)/⎕FNUMS ⋄ →(0≠⍴Z)/0
      (LID,' ',FNM)⎕FTIE Z←((⍳21)∊⎕FNUMS)⍳0
    ∇

    ∇ R←FYSHIFT M
  ⍝ Compresses the rows of a cohort-aligned half year catch at age
  ⍝ i.e. there is 1 row per age and 2 columns per year
  ⍝ Complementary function to HYSHIFT

      R←((¯1↑⍴M)⍴ 0 1)⊖M
      R←((1↑⍴R)⍴ 1 0)/R
    ∇

    ∇ GMODE
      0 0 ⍴0 ⎕GINIT 'HERCULES'
    ∇

    ∇ X GRAPH Y;DUMMY;⎕ELX;⎕ALX
      ⎕ALX←⎕ELX←'TMODE'
      X←⌊200.5+(X-¯1↑DUMMY)×800÷-/DUMMY←¯2↑(1+⍴X)⍴X[⍋X]
      Y←1000-⌊150.5+(Y-¯1↑DUMMY)×800÷-/¯2↑DUMMY←DUMMY,¯2↑(1+⍴Y)⍴Y[⍋Y]
      AXES
      SCALE DUMMY←0.5
      1 ⎕GLINE((1,(⍴X),2)⍴M(2,⍴X)⍴X,Y)
      ('ROW: ',⍕ROWS[I])⎕GWRITE 50 200 1
      DUMMY←⎕INKEY
      TMODE

    ∇

    ∇ X GRAPHS MAT
      ⍎(0=⎕NC 'ROWS')/'ROWS←⍳1↑⍴MAT'
      ROWS←,ROWS
      I←1
  TOP:X GRAPH 1E¯3×MAT[ROWS[I];]
      →((⍴ROWS)≥I←I+1)/TOP
    ∇

    ∇ HYINTERFACE POPN;pr;FRF
  ⍝ Produces 1 or 2 global variables POPIND and FBIOM
      →(0=INDEX∆TYPE[1])/CPUE
      POPIND←FYSHIFT POPN×*-(F+m)×1↑MNTH ⍝ Adjusts SPA population to the survey month
      POPIND←POPIND[ROWS;RV1HALF] ⍝ selects calibration block
      →(1=INDEX∆TYPE[1])/CPUE
      POPIND2←FYSHIFT POPN×*-(F+m)×1↑1↓MNTH ⍝ Adjusts SPA population to the survey month
      POPIND2←POPIND2[ROWS;RV2HALF] ⍝ selects calibration block
      →(2=INDEX∆TYPE[1])/CPUE
      POPIND3←FYSHIFT POPN×*-(F+m)×¯1↑MNTH ⍝ Adjusts SPA population to the survey month
      POPIND3←POPIND3[ROWS;RV3HALF] ⍝ selects calibration block
  CPUE:→(0=INDEX∆TYPE[2])/EXIT
      FRF←(+⌿(POPN×F×OTBpartCAT)[AGE;])÷+⌿POPN[AGE;] ⍝ Calculates fully recruited Ffor OTB partial F's
      pr←1⌊F÷(⍴F)⍴FRF ⍝ calculates PR matrix
      pr[AGE;]←1 ⍝ Sets defined fully recruited ages to 1
      FBIOM←+⌿POPN×pr×MWT
  EXIT:
    ∇

    ∇ R←HYSHIFT M
  ⍝ Aligns half-year catches from a given cohort along a single diagonal
  ⍝ i.e. there are 2 lines per age and 2 columns per year spaced with 0's
  ⍝ Function is complementary to FYSHIFT

      R←((2×1↑⍴M)⍴ 1 0)\M
      R←((¯1↑⍴R)⍴ 0 ¯1)⊖R
    ∇
```

```
    ∇ INPUT;ANS;iaIN;Kin;SIN
   □←⎕EX 'K'
   ⍎(0=⎕NC 'STOCK∆NAME')/'''STOCK NAME?''⋄STOCK∆NAME←⍞'
   cname←('CATCH MATRIX FOR ',STOCK∆NAME)DEFAULT cname
   c←⍎cname
   ANS←'FIRST YEAR AND YOUNGEST AGE IN CATCH MATRIX ? ' DEFAULT(1↑YR),1↑AG
   YR←((1↑ANS)-1)+⍳¯1↑⍴c
   AG←((¯1↑ANS)-1)+⍳1↑⍴c
   'ENTER PARTIAL RECRUITMENT VECTOR FOR ALL AGES'
   PR←DEFAULT PR
   DOME←¯1↑PR
   'ASSUMED AGES OF FULL RECRUITMENT (START WITH FIRST FULLY RECRUITED AGE) ? '
   AGE←AG⍳DEFAULT AG[AGE]
   MOM←0
   'NATURAL MORTALITY IS 0.2 -- CHANGE SPA∆M IF YOU DONT LIKE THIS'
   c←HYSHIFT c
   INTCATCH←SPA∆IC c×*SPA∆M÷2 ⍝ integrated catch with .5 year m
   TAILCATCH←SPA∆TAIL c×*SPA∆M÷2 ⍝ "Tail" of matrix - oldest age, last year
   SPA∆Z∆MAT←SPA∆Z⍴INTCATCH ⍝ Natural mortality multipliers
   ''
   'ENTER STARTING ESTIMATES OF TERMINAL F FOR LAST YEAR '
   ' WILL BE MULTIPLIED BY INPUT PR'
   FLY←PR×DEFAULT 1↑defaults
   'AGES IN CALIBRATION INDEX ? '
   ROWS←,AG⍳AGES←DEFAULT AGES
   FRST←1↑ROWS ⋄ LAST←¯1↑ROWS
 ⍝ 'STARTING ESTIMATES OF YEAR-SPECIFIC FS FOR OLDEST'
 ⍝ ' NON-PLUS GROUP AGE (ENTER 0 IF NOT DESIRED)'
 ⍝ FAG←D
   c←7 YSHIFT c
   FAG←0
   FVECT←FLY[¯1+FRST+⍳1+LAST-FRST],1↑0FAG
   CVECT←,c[(¯1+FRST+⍳1+LAST-FRST);¯1↑⍴c]
   →(FAG=0)/S1
   CVECT←CVECT,1↓0,c[LAST;]
 S1:NVECT←(CVECT×(FVECT+m))÷(FVECT×(1-*-FVECT+m))
   lbnd←CVECT×*m÷2
   ubnd←(⍴NVECT)⍴10000000

   'NUMBER OF RV SURVEYS?'
   'ENTER 0 IF NO RV INDEX'
   INDEX∆TYPE[1]←DEFAULT INDEX∆TYPE[1]
   SIN←1 ⋄ 0 0 ⍴⎕EX 'K'
 RVLP:→(SIN>INDEX∆TYPE[1])/cpue ⍝ No more surveys -- go to CPUE
   'RV INDEX OF ABUNDANCE'
   '   SAME YEARS AS CATCH AT AGE MATRIX '
   '   AGES FOR CALIBRATION BLOCK WILL BE SELECTED'
   rvname[SIN;]←30↑DEFAULT rvname[SIN;]
   iaIN←⍎rvname[SIN;]
   iaIN←iaIN+iaIN=0 ⍝ SETS ZEROS EQUAL TO ONE FOR LOGGING
   'FIRST AGE IN SURVEY'
   FINS←(1↑AG)-FINS←DEFAULT 0
   ⍎'iarv',(' 23 '[SIN]),'←iaIN[FINS+ROWS;]'
   'ESTIMATES OF STANDARD ERROR OF INDEX  (ENTER 1 IF LOG MODEL)? '
   rvsename[SIN;]←30↑DEFAULT rvsename[SIN;]
   iaIN←⍎rvsename[SIN;]
   ⍎'isearv',(' 23 '[SIN]),'←1'
   ⍎(0≠⍴⍴iaIN)/'isearv',(' 23 '[SIN]),'←iaIN[FINS+ROWS;]'
   'INDEX FOR WHAT MONTH ( NO. FROM 1 TO 12 ) ? '
   MNTH[SIN]←(DEFAULT 6×MNTH[SIN])÷6
   'STARTING AGE - SPECIFIC COEFFICIENTS FOR RV INDEX'
   ' '
   ' MATRIX OF AGE BY AGE COEFFICIENTS (1 OR 2 COLUMNS)'
   (1≠+/+/isearv)/' MODEL IS      I = [B0] + B1 × POP '
   (1=+/+/isearv)/' LOG MODEL IS    LN(I) = LN [B0] + B1 × POP ) '
   ' '
   Kin←DEFAULT 1↓defaults ⍝ GLOBAL TO STORE INPUT F AND K'S
   Kin←((⍴AGES),⍴Kin)⍴Kin
   lbnd←lbnd,(⍴,Kin)⍴(-¯1↑⍴Kin)↑ ¯9000 0 ⍝ MIN SLOPE =0, MIN INTER.=¯9000
   ubnd←ubnd,(⍴,Kin)⍴9000 ⍝ MAX SLOPE AND INTER. = 9000
   ⍎(0=⎕NC 'K')/'K←Kin ⋄ SIN←SIN+1 ⋄ →RVLP'
   K←K,Kin ⋄ SIN←SIN+1 ⋄ →RVLP

 cpue:'AGE-AGGREGATED CPUE INDEX OF ABUNDANCE'
   '                SAME YEARS AS CATCH AT AGE MATRIX'
   'ENTER 0 IF NO CPUE INDEX, 1 OTHERWISE'
   INDEX∆TYPE[2]←DEFAULT INDEX∆TYPE[2]
   →(0=INDEX∆TYPE[2])/exit ⍝ No cpue index so go to exit
   ia∆cpue←⍎cpuename[1;]←30↑DEFAULT cpuename[1;]
 l1:'ESTIMATES OF STANDARD ERROR OF CPUE?  (1 FOR LOG MODEL OPTION) '
   isea∆cpue←⍎cpuename[2;]←30↑DEFAULT cpuename[2;]
   →((⍴ia∆cpue)≠⍴isea∆cpue)/l1 ⍝ must be same length as ia∆cpue
   'ENTER MEAN WEIGHTS AT AGE - SAME YEARS AND AGES AS CATCH'
   MWT←⍎cpuename[3;]←30↑DEFAULT cpuename[3;]
   'STARTING COEFFICIENTS FOR CPUE INDEX (AGE AGGREGATED)'
   ''
   →(0=⎕NC 'K')/norv
   'ENTER ',(⍕¯1↑⍴K),' VALUE(S) FOR COEFFICIENT(S)'
   K←K,DEFAULT(¯1↑⍴K)↑1E¯5
   →exit1
 norv:
   'ENTER 1 (SLOPE) OR 2 (INTERCEPT AND SLOPE) COEFFICIENTS'
   K←(1,⍴,K)⍴K←,D
 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 minpop'
    ∇
```

Appendix 1 (continued)

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

    ∇ OPENFILE FNAME
[1]   ⎕PW←96
[2]   ⎕ELX←'→NOTIE'
[3]   FNAME ⎕NTIE ∆SORTIE←¯1+⌊/0,⎕NNUMS
[4]   ⎕ELX←'⎕DM'
[5]   FNAME,' OPENED FOR APPEND'
[6]   →0
[7]  NOTIE:⎕ELX←'⎕DM'
[8]   →(~∧/'FILE NOT FOUND'=14↑⎕DM)/ERR
[9]   ⎕ELX←'→ERR'
[10]  FNAME ⎕NCREATE ∆SORTIE←¯1+⌊/0,⎕NNUMS
[11]  ⎕ELX←'⎕DM'
[12]  FNAME,' CREATED AND OPEN FOR APPEND'
[13]  →0
[14] ERR:⎕ELX←'⎕DM'
[15]  ⎕DM
    ∇

    ∇ 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)⍴(5Γ2+(A≠0)+A<(0×1/[1]B))+⌈10⍟1⌈⌈/[1]|B),(¯1↑⍴B)⍴A
[5]   PW←(20+⍴TIT)⌈⎕PW|4++/((⍴A)⍴ 1 0)/A
[6]   Y←YR
[7]   QPUT ' '
[9]   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]←1
[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
    ∇
```

```
    ∇ OUTPUT;TIT;dx;dy;ag;yr
  page ∆ts
  DATAGEN par
  POP←FYSHIFT POP
  F←FYSHIFT F
  YR←HYYR
  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=,iso∆rv)/LOGS
  AG←AGES
  TIT←'WEIGHTED RESIDUALS FOR RV INDEX'
  page ∆ts
  QPUT ' MEAN SQUARE RESIDUALS : ',⍕msr
  QPUT '          MEAN RESIDUAL : ',⍕+/e÷⍴e
  QPUT '  SUM OF ALL RESIDUALS : ',⍕+/e
  QPUT ' '
  3 OUT RESID∆RV
  QPUT ⎕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≠|se∆rv2)×|∆rv2-|hat∆rv2)+|se∆rv2)[;MASK2[1;]/⍳1↓⍴MASK2]
  QPUT ⎕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≠|se∆rv3)×|∆rv3-|hat∆rv3)+|se∆rv3)[;MASK3[1;]/⍳1↓⍴MASK3]
  QPUT ⎕TCNL,'SUM OF RV RESIDUALS : ',(⍕+/,RESID∆RV3),'  MEAN RESIDUAL : ',⍕+/,RESID∆RV3÷+/,MASK3
  →CPUE

 LOGS:AG←AGES
  YR←FYYR
  TIT←'LOG RESIDUALS FOR RV INDEX'
  page ∆ts
  QPUT ' MEAN SQUARE RESIDUALS : ',⍕msr
  QPUT '          MEAN RESIDUAL : ',⍕+/e÷⍴e
  QPUT '  SUM OF ALL RESIDUALS : ',⍕+/e
  QPUT ' '
  3 OUT RESID∆RV
  QPUT ⎕TCNL,'SUM OF RV RESIDUALS : ',(⍕+/,RESID∆RV),'  MEAN RESIDUAL : ',⍕+/,RESID∆RV÷+/,MASKR
  →(INDEX∆TYPE[1]<2)/CPUE
  TIT←'LOG RESIDUALS FROM MARCH RV INDEX'
  YR←MASK2[1;]/FYYR
  3 OUT RESID∆RV2←((⍟|∆rv2)-⍟|hat∆rv2)[;MASK2[1;]/⍳1↓⍴MASK2]
  QPUT ⎕TCNL,'SUM OF RV RESIDUALS : ',(⍕+/,RESID∆RV2),'  MEAN RESIDUAL : ',⍕+/,RESID∆RV2÷+/,MA
  →(INDEX∆TYPE[1]<3)/CPUE
  TIT←'LOG RESIDUALS FROM SEPTEMBER RV INDEX'
  YR←MASK3[1;]/yr
  3 OUT RESID∆RV3←((⍟|∆rv3)-⍟|hat∆rv3)[;MASK3[1;]/⍳1↓⍴MASK3]
  QPUT ⎕TCNL,'SUM OF RV RESIDUALS : ',(⍕+/,RESID∆RV3),'  MEAN RESIDUAL : ',⍕+/,RESID∆RV3÷+/,MAS

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

```
    ∇ PARASE;H;P;HESS;de;NORM
      QPUT 'APPROXIMATE STATISTICS ASSUMING LINEARITY NEAR SOLUTION'
      QPUT ' '
      H←ρ,e
      P←ρ,par
      de←DIFF∆OBJ
      HESS←2×(⍉de)+.×de
      NORM←(+/HESS*2)*0.5
      HESS←⌹HESS÷(ρHESS)ρNORM
      HESS←2×merr×HESS÷⍉(⌽ρHESS)ρNORM
      parase←(1 1 ⍉HESS)*¯0.5
      morr←HESS÷HESS×parase∘.×parase
      parase←+parase
      QPUT 'ORTHOGONALITY OFFSET..........',,'F16.6' ⎕FMT oon
      QPUT 'MEAN SQUARE RESIDUALS ........',,'F16.6' ⎕FMT mer
      QPUT ' '
      QPUT ' PAR. EST.        STD. ERR.       T-STATISTIC       C.V. '
      QPUT ' ----------       ---------       -----------       ----- '
      QPUT 'E12.4,X3' ⎕FMT(par;parase;par÷parase;parase÷par)
    ∇

    ∇ A PLOT B;C;D;E;F;G;H;I;K;L;M;N;DIO;P;S;T;U;V;X;PVAL;COM;Q;CRTT;ps
      DIO←1 ◊ CRTT←5E¯11
      S←ε(,(0=⎕NC 4 2 ρ'dxdyJ ps')⌿ 4 2 ρ'dx←dy←0e ps←'),'''←←axv⎕'''
      →(∧/ 1 2 ≠ρρB)ρL2
      →((2=ρρB)∧1≠1↑ρB)/L1
      B←(2,U)ρ(ιU←ρB),B
      L1:→(1≠ρρA)ρL2
      →(2 6 =ρA)/L3,L7
      L2:→0,0⍴⎕←'PARAMETRES NON VALIDES',∆cr
      L3:M←L4,(K←L1E¯3+(L←A[2])+10),(⌈/B[1;]),L/B[1;] ◊ →L5
      L4:H←I[P] ◊ C←B[P]
      M←L6,(E←L1E¯3+(G←A[1])+5),(⌈/,T),L/,T← 1 0 ↓B
      L5:S← 10000 5000 2500 1000 500 100 50 25
      →(0=M[2])/L2
      →(0≠U←-/¯2↑M)/L5A
      →0,0⍴⎕←'PAS DE VARIATION DANS X OU Y',∆cr
      L5A:S←S×10*¯4+⌈10⍟U←U÷M[2]
      P←(M[3],(1+M[4]-S|M[4]))+M[2]×D←U-S|U+1.25×U)ι1 ◊ →M
      L6:H←L1.5+(B[1;]-H)×10÷C
      T←L0.5+ T-I+I[P])×5÷D←B[P] ◊ →L8
      L7:K←L1E¯3+(L←A[4])+10
      E←L1E¯3+(G←A[1])+5
      X←(F←(0≤X)∧X≤L+1)/X←L1.5+(B[1;]-H←A[5])×10÷C←A[6]
      T←F/L0.5+((T← 1 0 ↓B)-I←A[2])×5÷D←A[3]
      L8:H←(L10⊥I)-0,ιD÷10
      H←H[1L(∧/(CRTT×B[/P)≥H∘.|P←I|÷D×¯1+ιE+1)ι1]
      S← 10 ¯3 ◊ →((8(P←1+L10⍟⌈/P)∨H¯7)/L9
      S←10,0⌈(8-P[1])L-M
      L9:Q←(U~Sυe(D×¯1+ιE+1)∘.+,1),'|+'[1+U←0=5|¯1+ι1+P←G]
      U←((-L(U-×/ρdy)÷2)⌽(U←G+1)↑dy),Q
      X←,((ρT)[1]ρtops)∘.+1000×X ◊ T←,T
      L10:PVAL←(U[1+G-P;]),(L+1)ρ' '
      →(0=ρS←(T=P)/X)/L12
      S←(S≠0,¯1↓S)/S←S[⍋S]
      PVAL[(¯1↑ρU)+L S+1000]←ps[1000|S]
      L12:QPUT '      ',PVAL
      →(0≤P←P-1)/L10
      QPUT(16ρ' '),'/',(L+1)ρ'+---------'
      M←(L10⊥|C)-0,ι10
      M←M[1L(∧/(CRTT×C[⌈/P]≥(10∧M)∘.|P←|B←M×C×¯1+ιK+1)ι1]
      S←10-3 ◊ →((8(P←1+L10⍟⌈/P)∨M(¯7)/L13
      S←10,0⌈(8-P[1])L-M
      L13:QPUT(9ρ' '),S⍕B
      →(0=×/ρdx)ρ0
      QPUT DTCLF,((18+L0.5×L-×/ρdx)ρ' '),dx
    ∇

    ∇ PLOTRVSPA INDEX;DATA;SCALE;ITER;dx;dy;SYM;RESID
      SCALE← 20 40
      ITER←1
      YR←(YR[1]-1)+ι¯1↑ρINDEX
      ''
      RESID←RESID∆RV
      →(INDEX∆TYPE[2]=0)/S1
      page ats
      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 ats
      ' '
      QPUT 'AGE ',(⍕AGES[ITER]),' PLOTS '
      →(0=ρρiset∆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((ρYR)ρ0)VS YR
      ' '
      QPUT 'STD. RESIDUAL VS PREDICTED VALUE'
      ' '
      dx←'PREDICTED VALUE'
      SCALE PLOT RESID[ITER;]AND((ρihat∆rv[ITER;])ρ0)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(⍟Ihatarv[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((⍴Ihatarv[ITER;])⍴0)VS⍟Ihatarv[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 Ihatarv[ITER;]VS YR
 YR PRINTRVSPA DATA
 ' '
 ITER←ITER+1
 →(ITER=(1↑⍴INDEX)+1)/0
 →S1
∇

∇ R←alpha PNLTY∆FN A
  R←USE∆CONSTRAINTS×+/alpha×(⍴NVECT)↑A
 ⍝ State variable 'USE∆CONSTRAINTS' controls penalty function
 ⍝ 1 → constraints on; 0 → constraints off
∇
```

```
∇ PRNT;TMP;FMT
 QPUT ' '
 QPUT 'ITERATION NUMBER ',⍕J
 QPUT ' ' ⋄ QPUT 'PENALTY FUNCTION TURNED ',(2 3 ⍴'OFFON ')[1+USE∆CONSTRAINTS;] ⋄ QPUT ' '
 TMP← 2 6 ⍴'LAMBDARSS   MFMI '
 QPUT '10A1,E15.6' ⎕FMT(2 10 ↑TMP;⍕¯16,TMP,',')
 →(~verbose)/0
 QPUT ' '
 QPUT ' F''s IN LAST YEAR : '
 QPUT 6 3 ⍕FLY
 QPUT ' '
 →(FAG=0)/NXT
 QPUT ' F''s AT OLDEST AGES : '
 QPUT 6 3 ⍕FAG
NXT:→(0=INDEX∆TYPE[1])/NXT1
 QPUT ' '
 QPUT 'ESTIMATED JULY RV SURVEY CALIBRATION PARAMETERS'
 QPUT ' AGE      ',((2=¯1↑⍴K)/'INTERCEPT     '),' SLOPE          NUMBERS'
 FMT←'I4,F14.5,I14'
 ⍎(2=¯1↑⍴K)/'FMT←''I4,2F14.5,I14'''
 TMP←⍉(INDEX∆TYPE[2]×¯1↑⍴K)↓(⍴,K)⍴⍉par
 TMP←(⍴(-INDEX∆TYPE[2],0)↓K)⍴TMP
 QPUT FMT ⎕FMT(((⍴AGES),1)⍴AGES),TMP[⍳⍴ROWS;],((⍴NVECT)↑par)
 →(1=INDEX∆TYPE[1])/NXT1 ⋄ QPUT 'ESTIMATED MARCH RV SURVEY CALIBRATION PARAMETERS'
 QPUT FMT ⎕FMT(((⍴AGES),1)⍴AGES),TMP[(⍴ROWS)+⍳⍴ROWS;],((⍴NVECT)↑par)
 →(2=INDEX∆TYPE[1])/NXT1 ⋄ QPUT 'ESTIMATED SEPT. RV SURVEY CALIBRATION PARAMETERS'

 QPUT FMT ⎕FMT(((⍴AGES),1)⍴AGES),TMP[(2×⍴ROWS)+⍳⍴ROWS;],((⍴NVECT)↑par)
NXT1:→(0=INDEX∆TYPE[2])/DONE
 QPUT ''
 QPUT 'ESTIMATED CPUE CALIBRATION PARAMETER(S) '
 QPUT((2=¯1↑⍴K)/'     INTERCEPT'),'        SLOPE'
 FMT←'F14.5'
 ⍎(2=¯1↑⍴K)/'FMT←''2F14.5'''
 QPUT FMT ⎕FMT(1,¯1↑⍴K)⍴(-¯1↑⍴K)↑par
DONE:QPUT 78⍴'-'
∇

∇ PRT
 ⎕PW←100
 ∆SORTIE←'PRT'
∇

∇ QPUT X;DIO
 ⎕IO←1 ⍝   VERSION 2.0              ( MOD. 84.1.31  M. JOL)
 →(0∊⍴X)/0
 X←⍕X
 →(~∧/∆SORTIE=⍕∆SORTIE)/TOFILE ⍝ FILE TIE NUMBER IF NUMERIC
 →((3 3 ⍴'CRTPRTRS1')∧.=∆SORTIE)/LCRT,LPRT,LRS1
ERR:⎕ERROR 'INVALID OUTPUT DESTINATION IN ∆SORTIE'
LCRT:⎕←X ⋄ →0
LPRT: 3 0 3 ⎕ARBIN,X,DTCNL ⋄ →0
LRS1: 1 0 0 1 ⎕ARBIN,(X,DTCNL),DTCLF ⋄ →0
TOFILE:
 (,X,DTCNL),DTCLF)⎕NAPPEND ∆SORTIE
∇
```

```
    ∇ INDEX PRINTPUSPA DATA;⎕PP;HPR;RANK;FMT;PS;LBLS;I;Z
[1]   ⍝ PRINT DATA ARRAY USED FOR PLOTS
[2]   ⍝ DATA←→ARRAY SUITABLE FOR USE WITH THE PLOT FUNCTION
[3]   ⍝ (INDEX)←→DEFAULT IS ⍳¯1↑⍴DATA
[4]    ⎕PP←4
[5]    N←¯1+1↑⍴DATA
[6]    PS←(N↑ps),(N,9)⍴' '
[7]    PS←¯3⌽PS
[8]    LBLS←(10↑' INDEX'),[1](10↑' CARRIER'),[1]PS
[9]    LBLS←LBLS,[1]10↑' RANK'
[10]   Z←((2 2 +⍴DATA),10)⍴' '
[11]   QPUT 'SUMMARY OF DATA FROM PLOT'
[12]   QPUT '------- -- ---- ---- ----'
[13]   QPUT ''
[14]   QPUT 'CARRIER VARIABLE: POPULATION NOS'
[15]   QPUT 'RESPONSE VARIABLE(S): SURVEY - ○:OBSERVED, +:PREDICTED'
[16]   QPUT ''
[17]   ⍎(0=⎕NC 'INDEX')/'INDEX←⍳¯1↑⍴DATA'
[18]   RANK←INDEX[⍋DATA[1;]]
[19]   Z[1;;]←(2 10 ⍴20↑LBLS[1;]),[1](¯2↑(⍴DATA),10)↑⍕(¯2↑(⍴DATA),1)⍴INDEX
[20]   I←1
[21] IP:Z[I+1;;]←(2 10 ⍴20↑LBLS[1+I;]),[1](¯2↑(⍴DATA),10)↑⍕(¯2↑(⍴DATA),1)⍴DATA[I;]
[22]   →((1↑⍴DATA)≥I←I+1)/IP
[23]   Z[I+1;;]←(2 10 ⍴20↑LBLS[1+I;]),[1](¯2↑(⍴DATA),10)↑⍕(¯2↑(⍴DATA),1)⍴RANK
[24]   QPUT(1 10 ×0 2+⍴DATA)⍴, 2 1 3 ⍉Z
    ∇

    ∇ R←RESI K
[1]    R←⍳0
[2]    →(0=INDEX∆TYPE[1])/cpue ⍝ NO RV SURVEY
[3]    R←R,.POPIND RESI∆RV K[⍳⍴ROWS;]
[4]    ⍎(1(INDEX∆TYPE[1])/' R←R,.POPIND2 RESI∆RV2 K[(⍴ROWS)+⍳⍴ROWS;]'
[5]    ⍎(2(INDEX∆TYPE[1])/' R←R,.POPIND3 RESI∆RV3 K[(2×⍴ROWS)+⍳⍴ROWS;]'
[6]    →(0=INDEX∆TYPE[2])/res ⍝ NO CATCH RATE SERIES
[7]  cpue:K←(⍴K)[1;] ⍝ get bottom row of K
[8]    R←R,.FBIOM RESI∆CPUE K
[9]  res:
    ∇

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

    ∇ R←POPIND RESI∆RV K
[1]    →(1=¯1↑⍴K)/noint
[2]    K← 3 2 1 ⍉(⌽2,⍴POPIND)⍴,K
[3]    ihat∆rv←(K[1;;]+K[2;;]×POPIND) ⍝ WITH INTERCEPT
[4]    →res
[5]  noint:K←⍉(⌽⍴POPIND)⍴,K
[6]    ihat∆rv←K×POPIND ⍝ WITHOUT INTERCEPT
[7]  res:→(∧/1=,ise∆rv)/LOG
[8]    R←(,MASK)/,(i∆rv-ihat∆rv)÷ise∆rv+ise∆rv=0
[9]    →0
    ∇

    ∇ R←POPIND RESI∆RV2 K
[1]    →(1=¯1↑⍴K)/noint
[2]    K← 3 2 1 ⍉(⌽2,⍴POPIND2)⍴,K
[3]    ihat∆rv2←(K[1;;]+K[2;;]×POPIND2) ⍝ WITH INTERCEPT
[4]    →res
[5]  noint:K←⍉(⌽⍴POPIND2)⍴,K
[6]    ihat∆rv2←K×POPIND2 ⍝ WITHOUT INTERCEPT
[7]  res:→(∧/1=,ise∆rv2)/log
[8]    R←(,MASK2)/,(i∆rv2-ihat∆rv2)÷(0=ise∆rv2)+ise∆rv2
[9]    →0
[10] log:R←(,MASK2)/,(⍟i∆rv2)-⍟ihat∆rv2
    ∇

    ∇ R←POPIND RESI∆RV3 K
[1]    →(1=¯1↑⍴K)/noint
[2]    K← 3 2 1 ⍉(⌽2,⍴POPIND3)⍴,K
[3]    ihat∆rv3←(K[1;;]+K[2;;]×POPIND3) ⍝ WITH INTERCEPT
[4]    →res
[5]  noint:K←⍉(⌽⍴POPIND3)⍴,K
[6]    ihat∆rv3←K×POPIND3 ⍝ WITHOUT INTERCEPT
[7]  res:→(∧/1=,ise∆rv3)/log
[8]    R←(,MASK3)/,(i∆rv3-ihat∆rv3)÷(0=ise∆rv3)+ise∆rv3
[9]    →0
[10] log:R←(,MASK3)/,(⍟i∆rv3)-⍟ihat∆rv3
[11]
    ∇

    ∇ SCALE XY
[1]   ⍝ XY HAS 4 ELEMENTS: MAX X, MIN X, MAX Y, MIN Y RESPECTIVELY
[2]   ⍝ XR←+8÷-/XY[2 1] ◊ YR←+8÷-/XY[4 3] ⍝ FIND RANGES OF EACH X AND Y TICK
[3]    (⍕XY[3])⎕GWRITE 150 50 1
[4]    (⍕XY[4])⎕GWRITE 150 850 1
[5]    (⍕XY[2])⎕GWRITE 195 900 1
[6]    (⍕XY[1])⎕GWRITE 995 900 1
    ∇

    ∇ TN←X SCAFILEIT TN;CN;CNAME;CNVEC;I;INX;KEY;NAME;LN;TS;T;VAR;CMT;XX
[1]   ⍝ UTILITY TO MANIPULATE STATGRAF FORMAT APL FILES.
[2]   ⍝ WORKSPACE: \APL\MFDUTIL\MFDUTIL.AWS
[3]   ⍝ VERSION: SCAFILEIT.0     G. WHITE  1987-06-01
[4]    ⍎(0≠1↑0⍴TN)/' NAME←TN' ⍝ TN NOT NUMERIC, ASSUME NAME
[5]    →(0=⎕NC 'X')/CREATE ⍝ CREATE EMPTY FILE
[6]    ⍎(0≠1↑0⍴TN)/'NAME ⎕FTIE TN←1+⌈/1,⎕FNUMS'
[7]    X←(¯2↑1,⍴X)⍴X ⍝ MUST BE ARRAY
[8]  LP:KEY←1↑X[1;] ⍝ LOOP OVER ROWS OF X
[9]    →(0=+/'RAU'∊KEY)/ERR1 ⍝ MUST BE  (A)ppend, (R)ead, (U)pdate
[10]   CNAME←1↓X[1;]
[11]   X←1 0 ↓X
[12]   CMT←(I←(CNAME,'⍝')⍳'⍝')↓CNAME,' '
[13]   CNAME←(I-1)↑CNAME
[14]   CNAME←(' '≠CNAME)/CNAME ⍝ COMPONENT NAME
[15]   INX←⎕FREAD TN,1
```

Appendix 1 (continued)

```
[16] ⍝ LOOK FOR NAME IN INDEX
[17]  CN←(INX[;⍳18]∧.=18↑CNAME)⍳1
[18]  →((KEY≠'A')∧CN≥(⎕FSIZE TN)[2])/ERR2 ⍝ NOT FOUND OR DUPLICATE
[19]  →((KEY='A')∧CN<(⎕FSIZE TN)[2])/ERR3 ⍝ DON'T ALLOW DUPLICATION ON APPEND
[20]  →(KEY≠'R')/UPDATE
[21]  CNAME←,INX[CN;⍳18] ⍝ IN CASE NAME WASN'T FULLY SPECIFIED
[22]  ⍎CNAME,'← ⎕FREAD TN,CN'
[23]  →(0=1↑⍴X)↓LP,0
[24] UPDATE:TS←'G(Z9/),G(Z9/),G(99 ),G(Z9:),G(99 )'
[25]  TS←,TS ⎕FMT 1 5 ⍴⎕TS[2 3 1 4 5]- 0 0 1900 0 0
[26]  T←'C' ⋄ ⍎(0=1↑0⍴(VAR←⍎CNAME))/'T←''N'''
[27]  T←80↑(18↑CNAME),T,(6 0 ⍕⍴⍴VAR),'   ',(12↑⍕⍴VAR),TS,CMT
[28]  →(KEY='U')/REPLACE
[29]  INX←INX,[1]T ⍝ APPEND
[30]  XX←VAR ⎕FAPPEND TN
[31]  INX ⎕FREPLACE TN,1
[32]  →(0=1↑⍴X)↓LP,0
[33] REPLACE:INX[CN;]←T
[34]  VAR ⎕FREPLACE TN,CN
[35]  INX ⎕FREPLACE TN,1
[36]  →(0=1↑⍴X)↓LP,0
[37] CREATE:NAME ⎕FCREATE TN←1+⌈/1,⎕FNUMS
[38]  INX← 1 80 ⍴'FDIRECTORY',72⍴' '
[39]  TS←'G(Z9/),G(Z9/),G(99 ),G(Z9:),G(99 )'
[40]  TS←,TS ⎕FMT 1 5 ⍴⎕TS[2 3 1 4 5]- 0 0 1900 0 0
[41]  INX[1;40+⍳15]←TS ⋄ INX[1;55+⍳14]←'FILE DIRECTORY'
[42]  XX←INX ⎕FAPPEND TN
[43]  →0
[44] ERR1:'SG∆FILER: KEY (',KEY,⎕TCNL,') NOT (A)ppend, (R)ead, or (U)pdate'
[45]  →0
[46] ERR2:'SG∆FILER: NAME "',CNAME,'" NOT FOUND OR REPEATED IN FILE INDEX.'
[47]  →0
[48] ERR3:'SG∆FILER: NAME "',CNAME,'" ALREADY IN USE ON APPEND.'
    ∇

    ∇ SG∆FILER;TN;CN;CNAME;CNVEC;INX;KEY;NAME;PROMPT;LN;TS;T;VAR;CMT
[1]  ⍝ UTILITY ROUTINE TO CREATE STATGRAF FORMAT FILES FROM APL DIRECTLY
[2]  ⍝ INTERACTIVE PROMPTS ARE USED THROUGHOUT
[3]  ⍝ WORKSPACE: APL\MFDUTIL\MFDUTIL.AWS
[4]  ⍝ VERSION: SG∆FILER.0  L.P. FANNING MFD-BIO (902)-426-8506
[5]  ⍝            SG∆FILER.1  L.P. FANNING
[6]  ⍝            SG∆FILER.2  L.P. FANNING 1987-07-02
[7]   'AVAILABLE LIBRARIES' ⋄ ' ' ⋄ DLIBS
[8]   'ENTER LIBRARY NUMBER' ⋄ LN←⎕
[9]   ⎕AV[14],'EXISTING APL FILES ' ⋄ ' ' ⋄ ⎕FLIB LN
[10] R1:⍞←'(R)EAD, (A)PPEND OR (C)REATE ? '
[11]  →(0=+/'RAC'∊KEY←⎕INKEY)/R1
[12]  PROMPT←⎕AV[14],'ENTER FILE NAME: '
[13]  NAME←(⍕LN),16↑⍞,0⍴⍞←PROMPT
[14]  →(KEY='C')/CREATE
[15]  NAME ⎕FTIE TN←1+⌈/1,⎕FNUMS
[16] R2:⎕AV[14]
[17]  ⎕← 0 ⍕ ⍎(0<(1↑⍴INX),1)⍴⍳1↑⍴INX),' ',INX←⎕FREAD TN,1   ⍝ [1←]
[18]  →(KEY='A')/APPEND
[19]  'ENTER VECTOR OF CN VALUES SEPARATED BY BLANKS'
[20]  →(0=⍴,CNVEC←⎕)/R2
[21]  →(0<+/0=CNVEC←UP1 CNVEC)/R2
[22] L10:CN←1↑CNVEC
[23]  →(CN≥(⎕FSIZE TN)[2])/DONE
[24]  NAME←,INX[CN;⍳18]
[25]  ⍎NAME,'← ⎕FREAD TN,CN'
[26]  →(0=⍴,CNVEC←1↓CNVEC)/DONE
[27]  →L10
[28] APPEND:CNAME←21↓⍞,0⍴⍞←⎕AV[14],'ENTER VARIABLE NAME: '
[29]  TS←'G(Z9/),G(Z9/),G(99 ),G(Z9:),G(99 )'
[30]  TS←,TS ⎕FMT 1 5 ⍴⎕TS[2 3 1 4 5]- 0 0 1900 0 0
[31]  T←'C' ⋄ ⍎(0=1↑0⍴(VAR←⍎CNAME))/'T←''N'''
[32]  CMT←' ' ⍝ TO BE PROVIDED BY USER
[33]  INX←INX,[1]80↑(18↑CNAME),T,(6 0 ⍕⍴⍴VAR),'   ',(12↑⍕⍴VAR),TS,CMT
[34]  VAR ⎕FAPPEND TN
[35]  INX ⎕FREPLACE TN,1
[36]  →('Y'=1↑⎕INKEY,0⍴⍞←'APPEND MORE (Y/N) ? ')/APPEND
[37]  →DONE
[38] CREATE:NAME ⎕FCREATE TN←1+⌈/1,⎕FNUMS
[39]  INX← 1 80 ⍴'FDIRECTORY',72⍴' '
[40]  TS←'G(Z9/),G(Z9/),G(99 ),G(Z9:),G(99 )'
[41]  TS←,TS ⎕FMT 1 5 ⍴⎕TS[2 3 1 4 5]- 0 0 1900 0 0
[42]  INX[1;40+⍳15]←TS ⋄ INX[1;55+⍳14]←'FILE DIRECTORY'
[43]  INX ⎕FAPPEND TN
[44]  →APPEND
[45] DONE:⎕FUNTIE TN
[46]  ⎕AV[14]
    ∇

    ∇ N←IC SPA S;C;M;A;E
[1]  ⍴E←SPA∆S⍴IC ⍝ MUST BE CALCULATED HERE IF M VARIES
[2]
[3]   S←(1↑⍴IC)SPA∆AFORM S
[4]   N←IC+S×SPA∆E∆MAT
    ∇

    ∇ Z←A SPA∆AFORM X;R
[1]   ⍎(0=⎕NC 'A')/'X←(A,⍴X)⍴X'
[2]   A←1↑R←⍴X
[3]   Z←(A-⍳A)⌽X
[4]   Z←(A,1--/R)↑Z ⍝ DISCARD FILL ELEMENTS
    ∇

    ∇ Z←FILL SPA∆CFORM X;A
[1]   ⍎(0=⎕NC 'FILL')/'FILL←0' ⍝ DEFAULT FILL
[2]   A←1↑⍴X
[3]   ...FILL
[4]   Z←(⍳A)-A)⌽X ⍝ EACH COL. REPRESENTS ONE YC
```

```
    ∇ E←SPA∆E R;T;A
  ⍝ GMW 85/04/30.
  ⍝ →(0≠1↑0ρR)/HLP
   A←1↑R
   T←1↓R
   T←1+(A-⍳A)∘.LT-⍳T ⍝ TIME FROM END OF COHORT
   E←*T×SPA∆M
    ∇

    ∇ S←CO SPA∆FTOS F
  ⍝ GMW  85/05/01
   →(0≠1↑0ρF)/HLP
   ⍎(2=ρρCO)/'CO←SPA∆TAIL CO' ⍝ VECTORIZE ARRAY INPUT
   ⍎(2=ρρF)/' F←SPA∆TAIL F '
   S←CO×(⍟-SPA∆M)÷¯1↓⍟F
   →0
  HLP:S←F,⎕TCNL
   S←S,'S←CO SPA∆FTOS F                   ','SPAFNS.SPA∆FTOS.O',⎕TCNL
   S←S,'----------------',⎕TCNL
   S←S,'SURVIVORS VECTOR FROM CATCH (START OF YR.) AND F.',⎕TCNL,⎕TCNL
   S←S,'  S↔SURVIVORS AT THE END OF THE FINAL YEAR',⎕TCNL
   S←S,'      VECTOR[YEAR-CLASS]',⎕TCNL,⎕TCNL
   S←S,' CO↔CATCH AT AGE ADJUSTED TO START OF THE YEAR',⎕TCNL
   S←S,'      VECTOR[YEAR-CLASS] OR ARRAY[AGE;YEAR]',⎕TCNL,⎕TCNL
   S←S,'  F↔AVERAGE ANNUAL INSTANTANEOUS RATE OF FISHING MORTALITY',⎕TCNL
   S←S,'      VECTOR[YEAR-CLASS] OR ARRAY[AGE;YEAR]',⎕TCNL,⎕TCNL
   S←S,'NOTE: ONLY THE LAST AGE AND YEAR OF INPUT ARRAYS',⎕TCNL
   S←S,'       WILL BE USED IN THE CALCULATIONS.',⎕TCNL,⎕TCNL
   S←S,'REQUIRES: SPA∆M, SPA∆TAIL',⎕TCNL,⎕TCNL
    ∇

    ∇ IC←M SPA∆IC CO;E;A;V
  ⍝ GMW  85/04/30
   →('  =1↑0ρCO)/HLP
   ⍎(0=⎕NC 'M')/'M←SPA∆M' ⍝ DEFAULT
   →(2=ρρM)/MAT
  ⍝ A←1↑1↓ρCO  ⍝ VARIANCE FORM
   A←1↑ρCO
   E←(2ρA)ρ*M×¯1+⍳A ⍝ CUMULATIVE MORTALITY FACTORS
   E←(2ρA)↑(1-⍳A)⌽E,(0 ¯1 +A)ρ0
   IC←E+.×SPA∆CFORM CO
  ⍝ IC←E+.×SPA∆CFORM CO[1;;]    ⍝ FOR VARIANCE FORM
  ⍝ V←(E×E)+.×SPA∆CFORM CO[2;;]
   IC←SPA∆AFORM IC
  ⍝ IC←IC,[0.5]SPA∆AFORM V
   →0
  MAT:'SPA∆IC *** MATRIX FORM FOR M NOT IMPLEMENTED ***'
   →0
  HLP:IC←CO SPA∆IChelp 'SPAFSN.SPA∆IC.¯1'

    ∇ SPA∆ITERCOHORT;F1;D;FF1;FCNEW;age
   age←2×2/AGE
   age←age+(⍴⍴age)⍴ ¯1 0
   F1←2/FLY
   →(NUM=0)/S2
   F1←F1,¯1↑F1
  S3:→(FAG=0)/S2
   FC←FAG
   →S1
  S2:→(2=⎕NC 'TPAR')/S1 ⍝ Do not initialize FC if in DIFF∆OBJ
   FC←(¯1↑ac)ρ(¯1↑F1)
  S1:SURV←TAILCATCH SPA∆FTOS(¯1↑FC),⌽F1
   POP←INTCATCH SPA SURV
   →((FAG≠0)∨2=⎕NC 'TPAR')/0 ⍝ Exit now if in DIFF∆OBJ
   F←POP SPA∆STOF SURV

  ⍝ ALTCF calculations for F at oldest age
  ⍝ FCNEW←(+/F[AGE;])÷⍴AGE ⍝ Unweighted mean F over fully recruited ages
   FCNEW←(+/POP[AGE;]×F[AGE;])÷+/POP[AGE;] ⍝ Numbers weighted mean F
   DIFF1←|(FCNEW-FC)÷FCNEW
   FC←(¯1↓FCNEW),¯1↑FC
   →(0.01<⌈/¯1↓DIFF1)/S1
    ∇

    ∇ Z←SPA∆SOUT S;AGES;YEARS;YC
  ⍝ GMW 85/05/01
   →(0≠1↑0ρS)/HLP
   AGES←⍉((ρYR),ρAG)ρAG
   YEARS←(ρAGES)ρYR
   YC←YEARS-AGES
   AGES←SPA∆TAIL AGES
   YEARS←SPA∆TAIL YEARS
   YC←SPA∆TAIL YC
   Z←AGES
   Z←Z,[1.5]YEARS
   Z←Z,YC
   Z←Z,S
   →0
  HLP:Z←S,⎕TCNL
   Z←Z,'Z←SPA∆SOUT S                  ','SPAFNS.SPA∆SOUT.O',⎕TCNL
   Z←Z,'-------------',⎕TCNL
   Z←Z,'FORM TABLE OF YEAR-CLASS DATA',⎕TCNL,⎕TCNL
   Z←Z,' Z↔AGE, YEAR, YEAR-CLASS, SURVIVORS',⎕TCNL
   Z←Z,'     (NUMERIC ARRAY WITH FOUR COLUMNS)',⎕TCNL,⎕TCNL
   Z←Z,' S↔SURVIVORS, VECTOR[YEAR-CLASS]',⎕TCNL,⎕TCNL
   Z←Z,'USES: SPA∆TAIL',⎕TCNL,'GLOBALS: AG, YR',⎕TCNL,⎕TCNL
    ∇
```

```
    ∇ F←N SPA∆STOF S;NL;MASK
  ⍝ GHW  85/04/30.
   →((⍴1↑0⍴S)/HLP
  ⍝ N←N ∆ACCEPTIF '2=⍴⍴X ⍝ BEGINNING OF YEAR NUMBERS (N)'
  ⍝ S←S ∆ACCEPTIF '(¯1↑⍴/⍴N)=⍴X ⍝ SURVIVORS, ONE FOR EACH COHORT'
  ⍝ (0≥⌊/S)/'SPA∆STOF: *** SURVIVORS LESS THAN OR EQUAL TO ZERO ***',⎕TCBEL
   NL←(1 1 ↓N),[1](¯1+1↓⍴N)↑S ⍝ LAGGED NUMBERS FOR END OF YEAR
   NL←NL,⊖(¯1+1↓⍴N)↓S
   MASK←(N≤0)∨NL≤0
   NL←(N-MASK×N)+NL-MASK×NL ⍝ REPLACE BAD RATIOS WITH ONE
   F←(⍟NL)-SPA∆M
   F←(F×~MASK)+MASK×99.99 ⍝ FLAG BAD ENTRIES
   →0
  HLP:F←8,⎕TCNL
   F←F,'F←N SPA∆STOF S                    ','SPAFNS.SPA∆STOF.O',⎕TCNL
   F←F,'---------------',⎕TCNL
   F←F,'FISHING MORTALITY FROM NUMBERS AND SURVIVORS.',⎕TCNL,⎕TCNL
   F←F,' F←→ AVERAGE INSTANTANEOUS RATE OF FISHING MORTALITY.',⎕TCNL
   F←F,'      ARRAY[AGE;YEAR]',⎕TCNL,⎕TCNL
   F←F,' N←→ BEGINNING OF YEAR NUMBERS ARRAY[AGE;YEAR]',⎕TCNL,⎕TCNL
   F←F,' S←→ SURVIVORS AT THE END OF THE LAST YEAR AND AGE, ',⎕TCNL
   F←F,'      VECTOR[YEAR-CLASS]',⎕TCNL,⎕TCNL
   F←F,'USES: SPA∆M, ∆ACCEPTIF',⎕TCNL,⎕TCNL
    ∇

    ∇ Z←SPA∆TAIL X
  ⍝ GHW  85/04/30.
   →(0≠1↑0⍴X)/HLP
   Z←(,X[1↑⍴X;]),1↓0,X[;1↓⍴X]
   →0
  HLP:Z←X,⎕TCNL
   Z←Z,'Z←SPA∆TAIL X                 ','SPAFNS.SPA∆TAIL.O',⎕TCNL
   Z←Z,'-------------',⎕TCNL
   Z←Z,'RETURNS TERMINAL ENTRIES OF ARRAY X',⎕TCNL,⎕TCNL
   Z←Z,' Z←→ENTRIES FROM LAST ROW AND COLUMN OF ARRAY X.',⎕TCNL
   Z←Z,'     IN YEAR-CLASS ORDER.',⎕TCNL,⎕TCNL
   Z←Z,' X←→ARRAY[AGE;YEAR]',⎕TCNL,⎕TCNL
    ∇


    ∇TIMEFMT


    ∇ TMODE
   0 0 ⍴1 BCINIT 'HERCULES'
    ∇

    ∇ R←NBLANK X;A
   R←(A∨1↓1⌽1,A←' '≠X)/X
    ∇
```

```
    ∇ UNDER V
   QPUT V
   QPUT(V≠' ')\'-'
    ∇

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

    ∇ miniDOC;l;sp
   QPUT ⎕TCFF
   QPUT 78⍴'-'
   QPUT 'Input Documentation for ',STOCK∆NAME,' Run at',(3⍴' '),ats
   QPUT 78⍴'-'
   QPUT ' '
   QPUT '1)   Catch at Age extends from ',(⍕YR[1]),' to ',(⍕¯1↑YR),' and Ages ',⍕AG[1],' to ',[illegible]
   ⍎(~((NUM='P')∨NUM='p'))/'QPUT ''     The Catch at Age did NOT contain a PLUS Group''[illegible]→str1'
   QPUT ' '
   QPUT '     Age ',(⍕¯1↑AG),' is a PLUS Group '
   QPUT ' '
   QPUT '     Ages ',(⍕AG[AGE]),' were assumed fully recruited'
   QPUT ' '
  stp1:⍎(∧/PR=1)/'QPUT ''2)     No Partial Recruitment Values were Imposed''⋄→stp2'
   QPUT ''
   QPUT '2)   Partial Recruitment -* indicates ages used to calculate mean'
   QPUT '                             fully recruited F'
   l←(⍴AG)⍴' ' ⋄ l[AGE]←'*'
   QPUT ' '
   QPUT '       Ages      PR'
   QPUT 'X8,I2,X1,A1,X5,F5.3' ⎕FMT(AG;l;PR)
   QPUT ' '
  stp2:QPUT '3)   Natural Mortality was set at ',(⍕m)
   QPUT ' '
   QPUT '4)   F''s over Ages ',(⍕AG[FRST]),' to ',(⍕AG[LAST]),' will be estimated starting from[illegible]
   QPUT ' '
   sp←(AG[FRST],FRST+⍳(LAST-FRST))
   s←(⍴NVECT)⍴initial
   FVECT←(⍟s÷(s-CVECT×*m÷2)×*-m)-m
   QPUT '                   Ages    F '
   QPUT 'X20,I2,X7,F5.3' ⎕FMT(sp;FVECT)
   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(((⍴YR),1)⍴YR,((⍴FAG),1)⍴FAG)
  stp3:→(0=INDEX∆TYPE[1])/stp4
   QPUT ' '
   QPUT '6)   Research Survey Estimates of Abundance for ages ',[illegible],' to ',[illegible],' were [illegible]
   ⍎(0=⍴⍴isearv)/'QPUT''      No standard errors were applied. Log transformation used'''
   ⍎(0≠⍴⍴isearv)/'QPUT''      Standard errors of abundance index applied to residuals'''
   →(1=INDEX∆TYPE[1])/stp4
   QPUT ' '
```

Appendix 1 (continued)

```
QPUT 'There were ',(⍕INDEX∆TYPE[1]),' RV series used for tuning'
QPUT 'RV  Month   Years '
QPUT ' 1  ',(2⍕MNTHE[1]×12),'      ',⍕(∨/MASKRV)/YR
QPUT ' 2  ',(2⍕MNTHE[2]×12),'      ',⍕(∨/MASK2)/YR
→(2=INDEX∆TYPE[1])/stp4
QPUT ' 3  ',(2⍕MNTHE[3]×12),'      ',⍕(∨/MASK3)/YR

stp4:→(0=INDEX∆TYPE[2])/stp5
QPUT ' '
→(∧/1=isemcpue)/lcpue
QPUT '7)   Commercial CPUE with standard errors was calibrated on fishable biomass'
→stp5
lcpue:QPUT '7)   Commercial CPUE (LOG residuals) was calibrated on fishable biomass'
stp5:QPUT ' '
QPUT '8)   The Lower Limit for Estimated Numbers at Age was the CATCH'
QPUT '     Upper limit for Estimated Numbers at age was ',⍕ituhnd
→(0=INDEX∆TYPE[1])/stp6
sp←(¯1↑⍴K)↑(⍴CVECT)⍴lbnd
QPUT ' '
QPUT '9)   The Lower Limit for RV survey slope was ',⍕¯1↑sp
⍎(2=⍴sp)/'QPUT ''                         and for intercept was '',⍕1↑sp'
sp←(¯1↑⍴K)↑(⍴CVECT)⍴ubnd
QPUT '     The Upper Limit for RV survey slope was ',⍕¯1↑sp
⍎(2=⍴sp)/'QPUT ''                         and for intercept was '',⍕1↑sp'

stp6:→(0=INDEX∆TYPE[2])/exit
sp←(-¯1↑⍴K)↑lbnd
QPUT ' '
QPUT '10)  The Lower Limit for CPUE slope was ',⍕¯1↑sp
⍎(2=⍴sp)/'QPUT ''                      and for intercept was '',⍕1↑sp'
sp←(-¯1↑⍴K)↑ubnd
QPUT '     The Upper Limit for CPUE slope was ',⍕¯1↑sp
⍎(2=⍴sp)/'QPUT ''                      and for intercept was '',⍕1↑sp'
exit:QPUT 70⍴'═'
∇
```

```
∇ minipop;BOOL;J;DIAG;Q;LAMBDA;HESS;N;P;PAR;RSS;de;CAUSE;I;V;NPHI;PHI;pnlty;dpnlty;SHESS;NORM;I;ats;ANS
  ⍝ NON-LINEAR LEAST SQUARES USING MARQUARDT ALGORITHM
  ⍎(2≠⎕NC 'verbose')/'verbose←1'
  ats←'TOTIMEFMT DTS'
  'Do you wish to document your input ?'
  ⍎(('Y'≠↑ANS)∨'y'≠ANS←⍞INKEY)/'miniDOC'
  page ats
  rssvec←⍳0
  P←⍴par←PAR←,initial
  RSS←e←.×e←OBJ∆FN PAR ⍝ RESIDUAL SUM OF SQUARES
  N←⍴e
  pnlty←alpha PNLTY∆FN PAR ⍝ PENALTY FOR CONSTRAINTS
  NPHI←PHI←RSS+pnlty
  LAMBDA←0.01
  BOOL←(P×P)⍴1,P⍴0 ⍝ USED TO CREATE DIAG MATRIX
  con←10
  J←1
  PRNT
  rssvec←rssvec,RSS
L3:→(limit J←J+1)/L6 ⍝MAIN LOOP
  PAR←par
  PHI←NPHI
  de←DIFF∆OBJ
  Q←2×e+.×de ⍝ GRADIENT
  HESS←2×(⍉de)+.×de ⍝ HESSIAN
  dpnlty←DIFF∆PNLTY ⍝ DIFFERENCE FOR PENALTY
  Q←Q+dpnlty[1;]
  DIAG← 1 1 ⍉HESS←HESS+(2⍴P)⍴BOOL\dpnlty[2;]
  LAMBDA←9.99999999999999E¯7⌈LAMBDA×0.01
  I←1
  SHESS←HESS+(2⍴P)⍴BOOL\DIAG×LAMBDA←LAMBDA×10 ⍝ MARQUARDT METHOD
  NORM←(+⌿SHESS*2)*0.5 ⍝ COLUMN NORMS
  SHESS←SHESS÷(⍴SHESS)⍴NORM ⍝ SCALE HESSIAN
  par←PAR+V←(Q⌹SHESS)÷NORM ⍝ STEP DIRECTION; STEP SIZE=1
  →(~FRCN∆FN par)/L4
  RSS←e+.×e←OBJ∆FN par
  pnlty←alpha PNLTY∆FN par
  →(PHI≥NPHI←RSS+pnlty)/L6
L4:LAMBDA←LAMBDA×100
L5:par←PAR+V←V×0.1*I ⍝INNER LOOP  REDUCE STEP SIZE
  →(10<(I←I+1))/L6
  →(~FRCN∆FN par)/L5
  RSS←e+.×e←OBJ∆FN par
  pnlty←alpha PNLTY∆FN par
  →(PHI≥NPHI←RSS+pnlty)/L6
  →L5
L6:PRNT
  rssvec←rssvec,RSS
  ms←RSS÷N-P
  →(I=∧/CAUSE←(10≥I),(limit J),(1E¯3(same(((N-P)×IQ+.×V)÷P×RSS)*0.5),(1E¯4((NPHI-PHI)÷PHI)...(9,99
  QPUT(~CAUSE)/[1]exit
  ⍎(USE∆CONSTRAINTS)/'USE∆CONSTRAINTS←0 ◊ ''TURNING CONSTRAINTS OFF''◊→L3'
  page ats
  OUTPUT
∇
```

```
∇ page ats
  QPUT DTCFF,'             ADAPT3RV TUNING SEPTEMBER 1990'
  QPUT STOCK∆NAME,(45⍴' '),ats
∇

∇ start
  'INPUT' OPFKEY 5
  'minipop' OPFKEY 6
∇
```

Appendix 1.

Table 1. Half-year to full-year shift needed for half-year SPA calculations in ADAPT.

Assume Y is an age by half year matrix where each element (ab) represents the cohort number (a) and the half of the year (b). It can be seen that each cohort goes down the matrix in steps i.e. it goes across two columns before going down a row.

```
      Y
11 12 21 22 31 32
41 42 11 12 21 22
51 52 41 42 11 12
61 62 51 52 41 42
71 72 61 62 51 52
81 82 71 72 61 62
```

The APL function HYSHIFT aligns the cohorts along diagonals and fills the intervening "cohorts" with 0's.

```
    HYSHIFT Y
11  0 21  0 31  0
 0 12  0 22  0 32
41  0 11  0 21  0
 0 42  0 12  0 22
51  0 41  0 11  0
 0 52  0 42  0 12
61  0 51  0 41  0
 0 62  0 52  0 42
71  0 61  0 51  0
 0 72  0 62  0 52
81  0 71  0 61  0
 0 82  0 72  0 62
```

The APL function FYSHIFT performs the complementary function and removes the half-year "cohorts".

```
      X                     FYSHIFT X
11  0 21  0 31  0       11 12 21 22 31 32
 0 12  0 22  0 32       41 42 11 12 21 22
41  0 11  0 21  0       51 52 41 42 11 12
 0 42  0 12  0 22       61 62 51 52 41 42
51  0 41  0 11  0       71 72 61 62 51 52
 0 52  0 42  0 12       81 82 71 72 61 62
61  0 51  0 41  0
 0 62  0 52  0 42
71  0 61  0 51  0
 0 72  0 62  0 52
81  0 71  0 61  0
 0 82  0 72  0 62
```