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An evaluation of the population dynamics of 4X haddock during 1962-88 with yield projected to 1990

by

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Abstract

This evaluation of the 4X haddock population is similar to the previous two assessments in terms of the pessimistic view it presents of the resource status. It is similar to the 1988 assessment in terms of the calibration technique used to generate the models -- the ADAPT framework. The 1988 nominal catch of 4X haddock was 10,976 t. The major gear components in the fishery (MG < 65'; FG < 65') caught their allocations although misreporting appears to remain a widespread problem. The 1988 fully recruited fishing mortality is estimated to be 0.49. Total stock biomass is currently about 34,000 t which is below the low levels observed during the early 1970s. Poor recruiting year classes since 1984 and the especially low 1986 year class will probably result in a lower biomass and yield in the upcoming three to five years. Projections to 1990 indicate an $F_{0.1}$ yield of 4,600 t. The 1990 fishery should be reduced to its lowest possible level, even below $F_{0.1}$.

RESUME

Les résultats peu encourageants de cette évaluation de la population d'aiglefin de la zone 4X vont dans le même sens que ceux des deux dernières évaluations de ce stock. Nous avons utilisé la même technqiue d'étalonnage que celle de 1988 pour élaborer les modèles, la méthode ADAPT. Les prises nominales d'aiglefin de la zone 4X ont été de 10 976 t en 1988. Les bateaux de moins de 65 pieds équipés d'engins de pêche mobiles et les bateaux de même taille équipés d'engins de pêche fixes, lesquels représentent les deux principaux types d'équipement utilisé pour cette pêche, ont pêché les quantités de poisson qui leur étaient allouées, mais les inexactitudes en matière de prises déclarées semblent encore constituer un problème largement répandu. La mortalité par pêche de 1988 dans le groupe de poissons pleinement recruté est estimée à 0,49. La biomasse totale du stock est actuellement d'environ 34 000 t, ce qui est inférieur aux valeurs du début des années 1970. Comme les niveaux de recrutement ont été faibles depuis 1984, et particulièrement en 1986, la biomasse et la production seront probablement inférieures au cours des 3 à 5 prochaines années. Selon les projections, la production au niveau $F_{0.1}$ devrait être de 4 600 t en 1990. En 1990, cette pêche devrait être au niveau le plus bas qu'elle peut atteindre, peut-être même en deçà du niveau $F_{0.1}$.

Introduction

Since 1974 population estimates and fishing mortality rates of the NAFO Division 4X haddock stock (Figure 1) have been derived using Sequential Population Analysis (SPA). Calibration of these analyses since 1980 has been conducted using the Canadian summer groundfish trawl survey data series. The survey data was not transformed from the arithmetic scale when used in the calibration models.

In keeping with the previous assessment of this stock (O'Boyle et al. 1988), the ADAPT framework approach was utilized (Gavaris 1988). O'Boyle et al. (1988) noted the difficulties in determining the partial recruitment level of the older age groups. This evaluation re-examined the assumptions used in that analysis.

The Fishery

Annual Trends in Reported Landings

The long-term (1930-83) annual catch of 4X haddock has averaged about 20,000 t. This level was surpassed once during the late 1960s and again during the early 1980s when landings peaked above 30,000 t (Figure 2). The former peak, fuelled by the strong 1963 year class, resulted in high exploitation rates and low spawning stock biomass and was thus instrumental in the imposition of a quota system and spawning area closure (Halliday, 1988) under ICNAF authority. Total catch has been below the TAC since 1982 (except for 1986) and below the long-term average since 1984 (Table 1). Haddock caught in unit area 4Xs apparently belong to the Division 5Y spawning stock (Halliday 1974) and therefore were not included in the analysis. O'Boyle and Wallace (1987) reviewed the historical changes in fleet composition and size and the attendant problems of misreporting and discarding during the 1977-81 fleet expansion period. Discussions with industry representatives during 1988 indicated that substantial misreporting continues. Objective information on the extent of this problem is very difficult to obtain. Comparison of trip statistics to information collected by MFD port samplers may shed some light on the misreporting levels and allow evaluation of the impact on the assessment.

The quota allocations of the stock since 1976 are given in Table 2. The general tendency with time has been for finer and finer subdivisions of the TAC by fleet sector and season. During 1982-87, the fishery was regulated on the basis of five gear sectors - 1) mobile gear less than 65 ft, 2) mobile gear 65-100 ft, 3) mobile gear greater than 100 ft, 4) fixed gear less than 65 ft and 5) fixed gear 65-100 ft. In 1988, the gear sectors less than 65 ft were further subdivided into under and above 45 ft groups. Since 1986, the allocation to the mobile gear less than 65 ft has been further subdivided into three 4-month periods to extend the fishery over the year. In addition to TACs, a variety of by-catch and trip limit regulations have been utilized. These fine-scale fleet allocations have resulted in significant enforcement problems, and stimulated implementation of an aggregate groundfish (cod, haddock, pollock) allocation in 1989 for the under 65' fleet.

During 1977-81, the TACs were consistently exceeded. The resource was recovering from the low abundance of the mid-1970s. The main fleet component which expanded during this period was that of mobile gear less than 65 ft. During 1982-84, this fleet's landings fell short of its allocation but has exceeded this every year since then. Landings by the mobile gear fleet greater than 100 ft, which once composed the major portion of the fishery, have dropped to small amounts (Table 3).

Landings Sampling Intensity

During the 1977-81 period of the inshore fleet expansion, sampling fell behind the exploitation and thus the landings per sample ratio increased relative to previous levels. Since then, sampling for this resource has been generally good with rates of approximately one sample per 200-300 t landed (Table 3). Sampling of the fishery during 1988 was adequate to construct the catch at age, which was done following previous practices. As in previous years, due to the lack of verified data, no adjustments were made to the total landings to account for misreporting. This included the 2,000 t that were reported from 5Z in the first quarter of 1988 that were considered to have originated from 4X. Conversely, port samplers reported that during the third quarter of 1988 most of the 4X landings were actually from 5Z. Adjustments for misreporting to this year's data alone were considered inappropriate.

Construction of the catch-at-age matrix for the period prior to and after 1978 is discussed in O'Boyle (1981) and O'Boyle and Wallace (1986) respectively. The 1988 catch-at-age was constructed using the sampling stratum-sample availability table shown in Table 4. This is in keeping with the practice followed since 1982.

Catch Numbers and Weight at Age

The catch numbers and weight at age data for 1970-88 are given in Table 5. In recent years, there has been a tendency for the landings to be dominated by fewer and fewer age groups. In 1982-83, five age groups (3-7) each contributed over 10% to the total yield. In the following two years, four age groups (4-7) dominated. During 1986-88, only three age groups (4-6) have contributed significantly to the annual landings. The 1988 fishery was dominated by the 1982 and 1983 year-classes -- these contributing 33% and 39% respectively by weight to the total yield (Table 5).

The 1988 observed catch-at-age showed relatively good agreement to the catch-at-age projected by O'Boyle et al. (1988) with differences of less than 5% in all age groups (Figure 3) except that of age seven (1981 year class).

Trends in the average weight and age of haddock in the catch were examined in order to provide an indication of the long-term (1962-88) level of exploitation experienced by the stock. Data for the 1962-69 period was obtained from O'Boyle and Wallace (1987). These trends are shown relative to the levels expected in populations exploited at $F_{0.1}$ and F_{max} (Figure 4). The average age in the 1988 catch slightly exceeded the F_{max} level, with an average age of 5.2. The average weight at age is below the F_{max} level of 1.6 kg. Trends in these parameters are to be expected as year-class size varies. However, the long-term average level of these parameters is more dependent on the long-term exploitation rate. Since 1972, both the average weight and age in the catch have been below that expected, not only of a population exploited at $F_{0.1}$ but also at F_{max}, indicating that the resource is being heavily exploited.

Abundance Indices

Commercial Catch Rates

A multiplicative analysis (Gavaris, 1980) was conducted on the otter trawler catch-effort data for all 4X unit areas combined. This analysis used year, month, tonnage class, and unit area as categories (Table 6). The overall fit of the model to the data was good, as indicated by the residual analysis (Fig. 5). Catch rates peaked during 1978-81, declined sharply to 1983, and have remained relatively stable thereafter (Figure 5). Due to concerns with the reliability of this catch/effort data and unquantifiable effects of the regulatory system, it has not been used as an index of 4X haddock abundance.

Groundfish Bottom Trawl Surveys

The July research survey conducted on the Scotian Shelf from 1970 to 1988 was used to evaluate the status of the resource. The estimated numbers and weights at age from these surveys, all weighted by stratum area, are shown in Tables 7 and 8 along with associated standard errors and coefficients of variation. Conversion factors for the different vessels used in these surveys are contained in O'Boyle and Wallace (1987). The arithmetic mean catch rates, smoothed by the Med 3R method (Tukey, 1977), from 1970-88 for ages 2-5, ages 6-9, and all age groups combined exhibit large inter-annual variability (Figure 6). Generally low levels of total abundance occurred during the early 1970s and high total abundance in the early-mid 1980s. Abundance dropped sharply during 1985-88 for ages 2-5 and 6-9. The 1988 survey results confirmed the low abundance indicated in last year's evaluation. In particular, the 1985-86 year-classes continue to be estimated as being poor. At age 2, they exhibit catch per tow in 1987-88 comparable to that of the 1970 year -class which has been the lowest on record (Table 7). As the survey does not provide reliable estimates of abundance until at least age 2, it is too early to provide indications of the 1987 and 1988 year-class size. Catch rates expressed as biomass/tow generally paralleled the trends seen in numbers (Figure 7).

Total mortality (Z) estimates calculated using the age groups considered to be fully recruited (ages 5-7/6-8) to the survey gear varied around 0.5 during 1970-83 but rose thereafter to a value of 1.3 by 1987/88 (Figure 8). If natural mortality has been constant at 0.2, these calculations indicate that recent exploitation rates have attained values in the order of 0.7-1.2, which are significantly higher than $F_{0.1}$ or F_{max}.

Sequential Population Analysis Methods

Calibration Model

The following model as per O'Boyle et al. (1988) was used:

$$U_{a,t} = q_a \cdot N_{a,t} \cdot \varepsilon_{a,t}$$

where $U_{a,t}$ is the summer survey catch numbers at age a in year t;
q_a is the age a catchability of the survey or slope of the relationship;
$N_{a,t}$ is the mid-year age a, year t SPA abundance estimate; and
$\varepsilon_{a,t}$ is the error in the age a, year t estimate of the survey numbers per tow derived from the relationship.

An intercept term was not included in the model and the error term was assumed to be multiplicative. Attempts to use the standard error to weight the analysis have always proved unsuccessful. The reasons for this are unclear and require further investigation. For the moment, as per previous practice, the log transform was used to stabilize the variance.

Calibration Data

The survey series represents an unbiased but variable view of abundance relative to the stable but biased view generated from the commercial catch data. Misreporting, discarding and the like contribute to the bias in the commercial catch rate series. As well, the regulatory system (closed areas, seasons, trip limits, etc.) may have distorted the catch rates artificially. For these reasons the practice of calibrating the SPA with survey data alone was continued.

Again, as per previous practice, the mid-year population numbers from SPA used in the calibration model were calculated by assuming the total catch-at-age is caught uniformly throughout the year. This is not the case and may influence the calibration, although not enough to invalidate the overall result. Work is currently underway to provide seasonal catch at age for use in this assessment.

O'Boyle et al. (1988) used an ADAPT formulation that used the first half of 1988's catch at age data. This allowed use of the most up-to-date information in the September assessment. The current assessment used only full year data. Preliminary analysis were conducted to compare the results of full and half year formulations for each year from 1980 - 1987. The implicit assumption of a constant exploitation pattern throughout the year could not be met and the comparison was deemed inappropriate. Upon completion of the catch at age data by gear sector and quarter the half year - full year comparison will be re-examined.

Calibration Methodology

The ADAPT method was used (Gavaris 1988). The input conditions, data, and model framework are given in Table 9. The software is documented in Annex 1. Fourteen parameters were estimated: ages 2 to 8 in 1988 and the slopes of the regression relating SPA to RV population numbers at ages 2, 3, 4, 5, 6, 7, and 8.

Natural mortality was assumed equal to 0.2. The fishing mortality on the oldest age group in each year and ages 8+ in the last year depends on the partial recruitment model assumed. O'Boyle et al. (1988) set the age 12 F in each year to the average F for ages 7-10. The Fs on ages 8+ in the most recent year were determined as parameters from the calibration. Here, as in that assessment, the abundance of the older age groups tends to decline faster than can be ascribed by the landings, suggesting a decline in the partial recruitment of those age groups. However, such a pattern would be inconsistent with historical observations. Attempts were made with differing calibration models to see whether or not a dome or flat-topped PR provided a better model fit. The dome-shaped model was marginally better although the information content in the data on the older age groups is low. Such a model created large inconsistent age-specific exploitation patterns throughout the time series. For example, these runs generated fully-recruited fishing mortalities in the early 1980s which were substantially lower than those calculated from the survey data. Also, the age 10 - 11 PR estimates were below 0.05. These are, at best, an order of magnitude below historical PRs observed for these age groups. This assessment adopted the flat-top model based on the model fit and thus historical consistency. Further work is required to resolve this issue. It is possible that whereas the partial recruitment model is accurate, problems in the catch at age are compromising the ability to fit it to the data. The adoption of a flat-topped partial recruitment required re-evaluation of the yield-per-recruit analysis presented in O'Boyle et al. (1988).

In the last assessment of this stock (O'Boyle et al., 1988), ages 2 to 12 of the catch at age were used. In this assessment the age 12 data were dropped due to the presence of zero values in 1987-88.

Results and Discussion

Model Fit

The model formulation (Table 9) required six iterations to reach a stable optimum; the parameters remained constant after removal of the penalty function. All of the parameters associated with the age 4-8 slopes were significantly different from zero and the parameter estimates were generally uncorrelated among themselves (Table 10). The age by age diagnostic plots for ages 2 to 8 (Figure 9) from the ADAPT calibration show that the overall model fit was satisfactory and that the residuals were randomly distributed across year, SPA population numbers, and the predicted values. Nevertheless, local residual patterns were evident, such as the very high values for ages 4+ in 1984-86. These may be indicative of data problems, particularly in the catch at age.

Population Trends

The population and fishing mortality matrices for 1970-88 age are given in Table 11. In relation to the 1970-87 geometric mean of 24 million, recruitment was low in the early-1970s, strong during the mid- to late 1970s, and average in the early 1980s (Figure 10). The size of the 1985-86 year classes were estimated to be very low; these will have a significant impact on yield for the next three to five years. Comparison of the 1980-87 age one population numbers (millions) from the current assessment to the one performed by O'Boyle et al. (1988), show close agreement (Table 12), supporting their pessimistic view of the resource.

The recruitment trends alluded to above are reflected in the mid-year population numbers and biomass which have both declined during 1979-88 (Figure 11) following the passage of the early 1980's recruitment pulse through the population. Present levels are equivalent to the lowest abundances on record that were seen during the early 1970s (Table 13). This assessment provides a more pessimistic view than that of O'Boyle et al. (1988) and this is due, in part, to the change in the partial recruitment model. Nevertheless, most of the current biomass is in the younger age groups and thus yield projection is relatively unaffected by this difference.

This assessment produced a 1987 age 5-6 fishing mortality of 0.731, compared to the value of 0.591 generated last year. The pattern of consistently underestimating F in the current year is strong for this stock and indeed was the original one which stimulated the work on the retrospective analysis for all the CAFSAC assessed stocks. The fishing mortality table (Table 11) shows a number of high Fs during 1983-86 which appear anomalous. These are likely an artifact of the partial recruitment pattern assumed in 1988. A dome-shaped PR provides more reasonable values. The question as to what indeed is the recent year's PR is thus an important issue. As mentioned earlier, it is considered that the PR is flat-topped but that data problems, particularly in the total catch, are influential. Simulation studies have indicated that large-scale misreporting of total catch could cause the so-called retrospective pattern (unpublished).

Notwithstanding the above, it is evident that the population is experiencing high exploitation rates. Indeed, the estimates based on the survey data alone (Figure 8) indicate fully recruited fishing mortalities of at least four times $F_{0.1}$ in recent years, which is consistent with this assessment (Figure 12).

Yield Projections to 1990

A Thompson and Bell yield-per-recruit analysis was conducted using the software of Rivard (1982). The weights at age for ages 1-16 were taken from O'Boyle et al. (1988). The partial recruitment was taken as the average of 1982-87, assuming that ages 6+ are fully recruited. Natural mortality was assumed to be 0.2. The input parameters are given in Table 14. The resulting parameters were $F_{0.1}$ = 0.268, Y/R = 0.525 kg and average weight = 1.916 kg. A yield-per-recruit analysis using the historical flat-topped partial recruitment was last conducted in 1981 (O'Boyle 1981) and is the basis for the $F_{0.1}$ value of 0.25 used in recent evaluations. The calculations conducted here indicates a value of 0.27 which was not considered sufficiently different from the 0.25 value to warrant a change. These results confirm that the recent fishery has been exploiting the stock above $F_{0.1}$ and indeed F_{max} and is thus resulting in a loss of growth production.

The 1988 population parameters used for projection of 1990 yield are:

Age	1989 Beginning of Year Population Numbers ('000s)	Weight (kg)	PR
1	23,983	.223	.0001
2	19,636	.543	.0124
3	3,968	.749	.098
4	2,073	1.060	.256
5	5,832	1.413	.602
6	4,558	1.847	1.0
7	2,316	2.417	1.0
8	118	2.897	1.0
9	104	3.703	1.0
10	5	3.746	1.0
11	1	3.837	1.0

The weight at age is the 1986-88 average. The partial recruitment is the 1986-88 average, assuming full recruitment at age 6+. Natural mortality was assumed to be 0.2. Age-one recruitment in 1989-90 was set at the 1970-87 geometric mean (23,983) with the 1989 catch assumed to be 4,600 t.

The projection results were:

Year	F6+	Catch ('000s) t	Average Population Biomass ('000s) t
1988	0.49	10.7	33.3
1989	0.27	4.6	37.7
1990	0.25	4.6	45.4

The 1989 TAC of 4600 t will be at roughly $F_{0.1}$ with a similar TAC in 1990 required. Given the low stock abundance however, we must also consider the recruitment dynamics of this resource.

The possibility that the 4X haddock stock is suffering from recruitment overfishing was examined. Recruitment overfishing requires the identification of a spawning stock biomass below which year-class strength is directly related to mature female biomass. Stock-recruitment (S/R) relationships generally suffer from large variability and unequal distribution of data across the range of spawning stock biomass. Midyear female spawning stock biomass was estimated by first calculating the expected length at age (Figure 13) from a Von Bertallanfy growth analysis (Table 15), conducted by O'Boyle et al. (1988). Then using the maturity ogives derived for 4X female haddock (Figure 14) by Waiwood and Buzeta (1989) the percent maturity at length equivalent to mid-year ages were generated (Table 16). This information was then used to calculate the mid-year spawning stock biomass (Figure 15). The mature female biomass is at an historical low of 11,396 t and has been declining steadily since 1980. Spawning stock biomass may be approaching a critically low level. Recruitment has been declining since 1983 (Figure 10). The relationship between recruitment and spawning stock biomass (Figure 16) appears to approximate a Ricker S/R curve (Ricker 1975) although the origin is not at zero. Therefore, statements on whether or not recruitment overfishing is occurring cannot be definitive. It is clear that caution must be exercised as data for the relationship between spawning stock biomass and recruitment below current levels does not exist. The fear is that recruitment overfishing is currently occurring and that stock collapse may be imminent.

Concluding Remarks

This assessment presents a pessimistic view of the 4X haddock resource consistent with the previous two assessments of O'Boyle and Wallace (1987) and O'Boyle et al. (1988). The resource is being heavily exploited with the belief that misreporting is widespread. Current biomass levels are at an historical low and growth overfishing is occurring. Although a strong case for recruitment overfishing cannot be made conclusively, it is within the harvesting capabilities of the fleets to fish the stock to economic and possibly biological extinction. Stock collapse may be imminent. This assessment indicates that the 1990 fishery for haddock should be maintained at the lowest possible level, even below the $F_{0.1}$ catch of 4,600 t.

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Table 1. Reported nominal catch (t round) of haddock from NAFO Division 4X (excluding unit area 4Xs) by country. The numbers in brackets represent the number of commercial samples collected in that year.

YEAR	CANADA (MQ)	CANADA (Nfld)	USA	USSR	SPAIN	OTHER	TOTAL	TAC
1970	15560 (26)	-	1638	2	370	12	17582	18000
1971	16067 (29)	-	654	97	347	1	17166	18000
1972	12391 (36)	-	409	10	470	1	13281	9000
1973	12535 (30)	-	265	14	134	6	12954	9000
1974	12243 (25)	-	660	35	97	-	13035	-
1975	15985 (56)	-	2111	39	7	2	18144	15000
1976	16293 (45)	-	972	-	95	5	17365	15000
1977	19555 (79)	-	1648	2	-	12	21217	15000
1978	25299 (62)	114	1135	2	-	27	26577	21500
1979	24275 (49)	268	70	3	-	15	24631	26000
1980	28209 (56)	71	257	38	-	37	28612	28000
1981	30148 (82)	117	466	-	-	15	30746	27850
1982	23201 (92)	28	854	-	-	4	24087	32000
1983	24428(119)	44	494	17	-	7	24990	32000
1984	19402 (97)	23	206	-	-	-	19631	32000
1985	14902 (86)	-	25	-	-	1	14928	15000
1986	14986 (78)	-	40[1]	10[1]	-	-	15036	15000
1987	13538 (82)	-	17[2]	-	-	-	13555	15000
1988	10921 (79)	-	2[3]	53[3]	-	-	10976	12400

Long-term averages:

1930 - 60 = 16854 t
1961 - 83 = 24217 t
1930 - 83 = 20127 t

1 - NAFO SCS Doc. 87/20
2 - NAFO SCS Doc. 88/18
3 - NAFO Circular Letters

Table 2. Recent Canadian fishery allocations and the respective reported catch (t) of 4X haddock. Information from Atlantic Quota Reports (AQR)

Year	AQR Date	Fleet	Allocation	Reported[1] Catch	%	CLOSURE DATES
1976		All Vessels	13300	15715	118	
1977		All Vessels	13400	20220	151	
1978		All Vessels	21500	25518	119	
1979		vessels < 125'	17500	17949	103	
		vessels > 125'	8500	6471	76	
		Total	26000	24420		
1980		vessels < 125'	22500	23585	105	
		vessels > 125'	5500	5095	93	
		Total	28000	28680		
1981	31/12	vessels ≤ 125'	22350	25102	112	24/10 - 31/12
		vessels > 125'	5500	5380	98	02/02 - 31/12
		Total	27850	30482		
1982	31/12	FG. < 65'	8850	8168	92	
		MG. > 65'	15000	12909	86	
		FG. 65-100'	100	124	124	23/05 - 31/12
		MG. 65-100'	1000	567	57	
		MG. ≥ 100'	7050	2829	40	
		Total	32000	24597		
1983	31/12	FG. < 65'	9050	9179	104	
		MG. > 65'	15000	12991	87	
		FG. 65-100'	100	108	108	12/04 - 31/12
		MG. 65-100'	800	177	18	
		MG. > 100'	7050	2438	35	
		Total	32000	24893		
1984	31/12	FG. < 65'	8850	6958	79	
		MG. > 65'	15000	12359	82	
		FG. 65-100'	100	3	3	
		MG. 65-100'	1000	44	4	
		MG. > 100'	7050	648	9	
		Total	32000	20012		
1985	31/12	FG. < 65'	4000	4496	112	16/11 - 31/12
		MG. > 65'	10000	10214	102	13/08 - 31/12
		FG. 65-100'	100	1	1	
		MG. 65-100'	100	61	61	
		MG. > 100'	800	541	68	
		Total	15000	15313		

Table 2. (Continued).

Year	Report Date	Fleet		Allocation	Reported Catch[1]	%	CLOSURE DATES
1986	31/12	FG. <65'		5000	5446	109	
		MG. >65'	1/1-30/4	2700			13/03
			1/5-31/8	4000			18/07
			1/9-31/12	2300	9202	102	
		FG. 65-100'		100	0	0	
		MG. 65-100'		100	118	118	15/02 , 15/11
		MG. >100'		800	680	85	
		Total		15000	15446		
1987	31/12	FG. <65'		5000	4747	95	
		MG. >65'	1/1-30/4	2700	2998	111	13/03
			1/5-31/8	4000	3481	87	18/07
			1/9-31/12	2300	1380	60	
		FG. 65-100		100	49	49	
		MG. 65-100		100	121	121	15/02 , 15/11
		MG. >100		800	487	61	
		Total		15000	13263	88	
1988	31/12	FG.< 65'		4126	3455	84	
		FG. 65-100'		75	0	0	
		MG.< 45'	1/1-30/4	1200	1037	86	Trip limits
			1/5-31/8	1800	1540	86	Trip limits
			1/9-31/12	978	839	86	21/10
		MG.45-65'	1/1-31/8	2500	2708	108	Trip limits
			1/9-31/12	976	962	99	21/10
		MG. 65-100'		85	15	17	
		MG.> 100'		660	408	62	
		Total		12400	10964		
1989	29/03	FG.< 65'		1540	901	59	
		FG.65-100'		25	0	0	
		MG.< 45'	1/1-30/4	450	1281	285	22/2; 16/3
			1/5-31/8	670	0	-	
			1/9-31/12	400	0	-	
		MG.45-65'	1/1-30/4	370	1375	372	22/2; 16/3
			1/5-31/8	560	0	-	
			1/9-31/12	320	0	-	
		MG.65-100'		25	0	0	
		MG. >100'		240	36	15	
		Total		4600	3593		

[1] These figures are based on hail information and thus are unofficial and not comparable to those in Table 1.

Table 3. Reported nominal catch (t round) of haddock from NAFO Division 4X (excluding unit areas 4Xs) landed in the Maritimes split by tonnage class and gear type. The numbers in brackets represent the mean weight landed per age/size sample collected.

	Tonnage Class					
	TC 1-3			TC 4+		
Year	MG (OT)	FG (LL)	Misc.[1]	MG (OT)	FG	Misc.
1970	4894 (1224)	3281	767	6501 (296)	114	3
1971	4289 (858)	3475 (1158)	499	7711 (367)	94	0
1972	2742 (686)	4396 (440)	439	4750 (216)	63	0
1973	1822 (304)	6090 (677)	324	4228 (282)	70	0
1974	3949 (494)	6364 (530)	251	1622 (324)	55	0
1975	6085 (320)	5193 (577)	271	4408 (157)	26	0
1976	4347 (1087)	5305 (884)	445 (223)	6144 (186)	46	6
1977	6178 (1030)	4328 (481)	550	8343 (130)	117	35
1978	9413	6814 (568)	1084 (542)	7888 (164)	97	0
1979	10171 (5086)	5127 (394)	600 (600)	8317 (252)	57	0
1980	13043 (1186)	6911 (384)	1127 (376)	7045 (294)	82	0
1981	14765 (328)	7846 (302)	993 (331)	6475 (809)	70	0
1982	11670 (243)	7581 (345)	945 (79)	2972 (297)	32	0
1983	12563 (224)	8533 (225)	754 (75)	2535 (195)	15	0
1984	11828 (208)	6769 (226)	193 (193)	609 (76)	0	0
1985	9834 (173)	4360 (182)	142	565 (113)	1	0
1986	9201 (192)	5336 (184)	240	209 (209)	0	0
1987	7952 (169)	4854 (270)	231 (21)	501 (84)	0	0
1988	7074 (131)	3353 (152)	118 (118)	376 (188)	0	0

1 - Gillnets (set, drift), traps, unspecified.

Table 4. Summary of commercial sampling for the 4X haddock fishery in 1988. Tons landed is followed by sampling information in parentheses. The first number represents the number of fish measured and the second, the number of otoliths read. The boxes represent the aggregation used in age/length formation.

Otter Trawls

Quarter	4Xmnop TC 1 - 3	4Xmnop TC 4+	4Xqr TC 1 - 3	4Xqr TC 4+
1	2203 (4635-328)	77	81	0
2	1476 (2743-205)	222	763 (2471-209)	16
3	1126 (505-53)	17	688 (1214-126)	4
4	612 (301-28)	40 (400-49)	125 (195-25)	0

Longliners

Quarter	4Xmnop TC 1 - 3	4Xmnop TC 4+	4Xqr TC 1 - 3	4Xqr TC 4+
1	1368 (1542-143)	0	19	0
2	176	0	29	0
3	1075 (1475-145)	0	29	0
4	650 (1630-163)	0	7	0

Miscellaneous*

Quarter	4Xmnop TC 1 - 3	4Xmnop TC 4+	4Xqr TC 1 - 3	4Xqr TC 4+
1	25	0	0	0
2	22	0	5	0
3	45 (16-10)	0	2	0
4	19	0	0	0

* - Longline samples applied to miscellaneous landings.

Table 5. Annual landings numbers (A), weight at age (B), percent by number (C), and percent by weight (D) of NAFO Division 4X haddock. Note that age 13 represents all individuals 13 and over.

(A)

Total Annual Landings (000S) at Age of 4Xmnopqr Haddock

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
1	0	0	41	150	1	37	18	2	0	0	16	1	0	0	2	0	0	0	0
2	1055	788	22	3077	694	2175	1296	1285	75	81	161	1182	491	64	708	198	290	39	28
3	724	1617	3434	113	4653	4568	1644	3126	3354	1158	2445	2215	3639	3294	1108	1956	1170	913	312
4	1502	788	1841	2247	309	5164	4261	2019	7014	6709	3008	6219	2474	5476	4680	2261	4378	2868	1341
5	379	1422	509	1067	1779	485	3682	3193	2094	3881	5413	4199	4628	3733	3439	4516	3923	4186	2852
6	524	404	645	527	509	1103	434	2881	2832	1070	3499	3195	1703	2232	2396	1463	1476	1931	1934
7	4536	69	90	600	189	247	807	360	1040	1244	527	1163	1457	940	948	464	246	252	452
8	1863	3316	57	322	269	172	154	389	137	263	623	357	340	395	340	132	116	56	76
9	133	1020	1166	259	186	62	71	107	107	57	169	323	183	187	110	53	40	2	14
10	96	163	512	614	269	32	95	72	26	68	34	97	94	119	77	16	28	2	3
11	175	181	26	55	552	165	39	23	9	11	21	14	45	69	36	6	9	5	4
12	27	146	193	13	24	229	103	8	6	1	3	23	16	25	20	1	4	0	0
13+	37	105	92	6	4	11	157	87	48	18	10	9	14	25	12	1	2	0	0

(B)

Mean Annual Weight (kg) at Age of 4Xmnopqr Haddock

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
1	.290	.290	.290	.270	.180	.230	.230	.280	.290	.290	.160	.230	.000	.000	.250	.000	.000	.000	.000
2	.570	.500	.450	.510	.460	.520	.520	.460	.440	.510	.522	.593	.493	.394	.527	.553	.523	.615	.491
3	.900	.960	.900	.750	.820	.820	.810	.710	.870	.870	.882	.887	.907	.758	.785	.787	.726	.733	.788
4	1.050	1.250	1.350	1.250	1.100	1.200	1.190	1.220	1.330	1.330	1.326	1.260	1.294	1.141	1.069	1.043	1.050	1.003	1.126
5	1.160	1.400	1.600	1.800	1.700	1.550	1.600	1.720	1.850	1.840	1.777	1.721	1.653	1.714	1.411	1.392	1.397	1.356	1.487
6	1.430	1.500	1.750	2.000	2.300	2.250	2.100	2.200	2.330	2.360	2.355	2.219	2.130	2.146	1.932	1.942	1.867	1.800	1.875
7	1.650	1.750	1.900	2.200	2.500	2.850	2.950	2.940	2.700	2.830	2.906	2.654	2.577	2.607	2.287	2.460	2.480	2.473	2.297
8	1.950	1.950	2.100	2.300	2.600	3.000	3.500	3.300	3.390	3.300	3.278	3.134	2.947	2.869	2.683	2.901	2.615	3.077	3.000
9	2.300	2.300	2.300	2.500	2.800	3.200	3.600	3.570	3.770	4.030	3.811	3.608	3.470	3.108	3.054	3.341	3.399	4.095	3.614
10	2.820	2.650	2.800	2.700	2.950	3.450	3.800	3.770	4.170	4.150	4.332	3.688	4.033	3.550	3.431	3.244	3.540	4.410	3.287
11	2.800	3.250	3.000	3.300	3.200	3.500	4.100	3.690	4.030	4.960	4.200	4.546	3.946	3.630	3.841	4.162	3.037	3.980	4.495
12	2.850	3.000	3.700	3.400	3.600	3.700	4.000	3.940	3.620	6.000	4.963	4.823	4.033	3.780	4.114	4.300	3.110	.000	.000
13+	3.600	3.000	3.300	4.200	3.900	4.400	4.200	3.910	4.630	5.680	5.711	4.680	4.908	4.064	4.000	5.700	4.410	.000	.000

(C)

Percent Landings at Age by Numbers

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
1	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	10	8	0	34	7	15	10	9	0	1	1	6	3	0	5	2	2	0	0
3	7	16	40	1	49	32	13	23	20	8	15	12	24	20	8	18	10	9	4
4	14	8	21	25	3	36	33	15	42	46	19	33	16	33	34	20	37	28	19
5	3	14	6	12	19	3	29	24	13	27	34	22	31	23	25	41	34	41	41
6	5	4	7	6	5	8	3	21	17	7	22	17	11	13	17	13	13	19	28
7	41	1	1	7	2	2	6	3	6	9	3	6	10	6	7	4	2	2	6
8	17	33	1	4	3	1	1	3	1	2	4	2	2	2	2	1	1	1	1
9	1	10	14	3	2	0	1	1	1	0	1	2	1	1	1	0	0	0	0
10	1	2	6	7	3	0	1	1	0	0	0	1	1	1	1	0	0	0	0
11	2	2	0	1	6	1	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	1	2	0	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0
13+	0	1	1	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0

(D)

Percent Landings at Age by Weight

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	4	2	0	13	2	7	4	3	0	0	0	2	1	0	2	1	1	0	0
3	4	10	24	1	29	22	7	11	11	4	8	6	14	10	4	10	6	5	2
4	10	6	19	23	3	36	27	12	35	36	14	25	13	25	25	16	31	21	14
5	3	12	6	16	23	4	32	27	14	29	34	23	32	26	25	42	36	42	39
6	5	4	9	9	9	14	5	31	25	10	29	23	15	19	24	19	18	26	33
7	46	1	1	11	4	4	13	5	10	14	5	10	16	10	11	8	4	5	9
8	22	40	1	6	5	3	3	6	2	4	7	4	4	5	5	3	2	1	2
9	2	14	21	5	4	1	1	2	2	1	2	4	3	2	2	1	1	0	0
10	2	3	11	14	6	1	2	1	0	1	1	1	2	2	1	0	1	0	0
11	3	4	1	2	14	3	1	0	0	0	0	0	1	1	1	0	0	0	0
12	0	3	5	0	1	5	2	0	0	0	0	0	0	0	0	0	0	0	0
13+	1	2	2	0	0	0	4	2	1	0	0	0	0	0	0	0	0	0	0

Table 6. Multiplicative analysis of commercial catch/effort data for otter trawlers in 4Xmnopqr. Categories: 1 - year, 2 - tonnage class, 3 - unit area, 4 - month.

REGRESSION OF MULTIPLICATIVE MODEL

MULTIPLE R............. .718
MULTIPLE R SQUARED..... .515

ANALYSIS OF VARIANCE

SOURCE OF VARIATION	DF	SUMS OF SQUARES	MEAN SQUARES	F-VALUE
INTERCEPT	1	1.707E0003	1.707E0003	
REGRESSION	40	2.960E0002	7.401E0000	33.141
TYPE 1	20	7.734E0001	3.867E0000	17.317
TYPE 2	4	7.459E0001	1.865E0001	83.503
TYPE 3	5	3.423E0001	6.846E0000	30.656
TYPE 4	11	3.273E0001	2.976E0000	13.325
RESIDUALS	1246	2.782E0002	2.233E-001	
TOTAL	1287	2.282E0003		

REGRESSION COEFFICIENTS

CATEGORY	CODE	VALUE	VARIABLE	COEFFICIENT	STD. ERROR	NO. OBS.
1	68		INTERCEPT	-0.746	0.138	1287
2	2					
3	1					
4	1					
1	69	1969	1	-0.008	0.103	45
	70	1970	2	-0.169	0.114	31
	71	1971	3	-0.447	0.120	26
	72	1972	4	-0.538	0.127	22
	73	1973	5	-0.764	0.152	13
	74	1974	6	-0.039	0.170	10
	75	1975	7	-0.079	0.098	61
	76	1976	8	-0.112	0.098	63
	77	1977	9	0.261	0.091	95
	78	1978	10	0.418	0.094	83
	79	1979	11	0.252	0.090	107
	80	1980	12	0.253	0.090	118
	81	1981	13	0.296	0.092	101
	82	1982	14	0.083	0.093	96
	83	1983	15	-0.086	0.093	90
	84	1984	16	-0.164	0.097	77
	85	1985	17	-0.299	0.098	68
	86	1986	18	-0.269	0.103	57
	87	1987	19	-0.216	0.106	48
	88	1988	20	-0.210	0.114	36
2	3	TC3	21	0.407	0.033	429
	4	TC4	22	0.488	0.056	120
	5	TC5	23	0.766	0.044	306
	6	TC6	24	-0.268	0.478	1
3	2	4Xn	25	-0.822	0.093	341
	3	4Xo	26	-0.882	0.094	301
	4	4Xp	27	-0.668	0.095	259
	5	4Xq	28	-0.850	0.098	198
	6	4Xr	29	-1.086	0.100	158
4	2	Feb	30	0.250	0.060	149
	3	Mar	31	0.372	0.065	110
	4	Apr	32	0.149	0.069	92
	5	May	33	-0.080	0.063	138
	6	Jun	34	0.103	0.062	159
	7	Jul	35	-0.115	0.066	121
	8	Aug	36	-0.185	0.070	98
	9	Sept	37	-0.035	0.067	112
	10	Oct	38	-0.008	0.068	100
	11	Nov	39	-0.232	0.083	51
	12	Dec	40	-0.170	0.084	49

PREDICTED CATCH RATE

STANDARDS USED VARIABLE NUMBERS: 2 4 2

YEAR	TOTAL CATCH	PROP.	CATCH RATE MEAN	CATCH RATE S.E.	EFFORT
68	9364	0.254	0.347	0.033	26959
69	11826	0.540	0.345	0.032	34299
70	11395	0.189	0.293	0.030	38874
71	12000	0.185	0.222	0.024	54105
72	7492	0.192	0.202	0.024	37034
73	6050	0.167	0.161	0.023	37625
74	5571	0.039	0.331	0.053	16818
75	10493	0.222	0.321	0.027	32658
76	10491	0.293	0.311	0.026	33759
77	14521	0.492	0.452	0.033	32154
78	17301	0.467	0.529	0.039	32730
79	18488	0.544	0.448	0.032	41291
80	20088	0.525	0.448	0.031	44794
81	21240	0.566	0.468	0.033	45410
82	14642	0.573	0.378	0.027	38735
83	15098	0.539	0.319	0.022	47269
84	12437	0.508	0.295	0.022	42096
85	10399	0.435	0.258	0.019	40327
86	9401	0.380	0.266	0.021	35394
87	8453	0.352	0.280	0.023	30171
88	7450	0.215	0.281	0.026	26467

AVERAGE C.V. FOR THE MEAN: .090

Table 7. 4X Haddock mean numbers at age per standard tow (A), standard error of the mean (B), and coefficients of variation by age (C) in 1970-88 summer RV surveys.

A. CANADIAN SUMMER SURVEY - STRATIFIED MEAN NUMBERS PER STANDARD TOW

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
0	0.000	0.000	0.000	0.000	0.000	0.000	0.069	0.025	0.012	0.523	0.029	0.678	0.271	0.349	0.307	0.000	0.121	0.000	0.082
1	5.899	0.117	5.822	6.781	11.530	6.970	6.425	6.401	6.325	1.748	21.946	41.014	13.052	6.858	4.684	6.637	3.838	0.943	7.172
2	4.719	11.116	0.260	19.354	23.084	3.744	6.119	33.567	5.039	13.428	6.856	28.799	28.737	4.538	23.382	6.779	8.723	0.897	1.863
3	1.405	4.722	3.314	0.634	31.804	4.876	3.866	38.796	10.300	10.040	15.330	7.055	12.807	14.449	12.381	24.828	9.808	3.615	1.948
4	2.605	2.081	1.389	3.060	0.954	7.952	4.228	11.334	3.107	10.680	8.036	8.651	4.678	5.828	17.691	19.104	16.462	6.652	4.140
5	1.114	2.914	0.880	1.467	4.093	0.427	7.562	11.511	1.305	4.987	12.726	3.188	6.685	3.558	5.537	11.710	9.432	5.233	5.267
6	2.639	1.376	0.915	0.461	0.892	1.945	0.574	6.650	2.527	1.978	4.377	3.398	2.547	2.351	3.176	3.089	2.558	1.771	1.851
7	5.775	2.112	0.605	0.611	0.494	0.531	0.679	0.789	1.073	3.061	1.662	1.115	2.510	0.962	1.554	0.952	0.570	0.442	0.263
8	0.807	5.181	0.882	0.464	0.585	0.422	0.127	1.031	0.029	1.162	1.348	0.243	0.334	0.322	0.557	0.095	0.241	0.003	0.075
9	0.343	0.757	1.241	0.275	0.344	0.176	0.024	0.143	0.000	0.248	0.640	0.437	0.205	0.292	0.444	0.000	0.069	0.000	0.140
10	0.283	0.093	0.043	0.375	0.246	0.110	0.037	0.129	0.000	0.030	0.240	0.279	0.060	0.209	0.080	0.040	0.017	0.000	0.000
11	0.084	0.045	0.006	0.025	0.338	0.301	0.000	0.015	0.029	0.000	0.043	0.142	0.038	0.090	0.033	0.000	0.017	0.000	0.000
12	0.031	0.061	0.005	0.000	0.000	0.269	0.254	0.069	0.039	0.000	0.000	0.036	0.000	0.069	0.030	0.030	0.000	0.000	0.000
13	0.000	0.000	0.000	0.015	0.000	0.000	0.109	0.279	0.193	0.165	0.050	0.005	0.000	0.070	0.041	0.034	0.078	0.457	0.148

B. CANADIAN SUMMER SURVEY - STRATIFIED AR, STANDARD ERROR OF MEAN NUMBERS PER STANDARD TOW

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
0	0.000	0.000	0.000	0.000	0.000	0.000	0.055	0.000	0.000	0.249	0.032	0.464	0.266	0.235	0.122	0.000	0.055	0.000	0.063
1	1.488	0.055	2.584	2.382	6.582	2.813	1.592	1.829	2.226	0.896	14.040	23.825	5.132	2.255	2.152	1.707	0.475	0.249	2.869
2	1.394	2.831	0.130	7.648	8.187	1.091	1.393	12.202	1.554	1.575	2.871	12.613	8.186	1.627	11.221	1.340	2.444	0.367	1.043
3	0.330	1.437	0.933	0.230	10.049	1.418	0.565	23.918	3.064	0.804	5.911	3.348	3.424	4.399	4.506	8.115	2.620	0.843	0.460
4	0.765	0.703	0.265	0.616	0.255	2.173	0.688	6.787	0.822	2.370	2.500	1.557	1.061	1.025	6.052	8.775	3.813	1.150	0.675
5	0.447	0.998	0.148	0.170	1.052	0.138	1.146	5.104	0.385	1.391	3.858	0.470	1.365	0.567	1.408	3.965	2.029	0.830	0.702
6	1.066	0.484	0.148	0.084	0.263	0.572	0.077	2.569	0.799	0.493	1.238	0.509	0.439	0.349	0.628	0.507	0.693	0.302	0.414
7	1.915	0.797	0.100	0.100	0.138	0.179	0.089	0.232	0.277	0.773	0.381	0.219	0.511	0.145	0.300	0.195	0.219	0.100	0.095
8	0.290	1.742	0.155	0.110	0.170	0.138	0.000	0.367	0.000	0.279	0.245	0.063	0.095	0.063	0.100	0.032	0.089	0.000	0.045
9	0.126	0.259	0.214	0.071	0.100	0.071	0.000	0.032	0.000	0.110	0.130	0.118	0.063	0.071	0.095	0.000	0.045	0.000	0.134
10	0.130	0.055	0.000	0.095	0.071	0.063	0.000	0.045	0.000	0.000	0.055	0.122	0.032	0.055	0.032	0.000	0.000	0.000	0.000
11	0.032	0.000	0.000	0.000	0.071	0.105	0.000	0.000	0.000	0.000	0.000	0.055	0.000	0.000	0.000	0.000	0.000	0.000	0.000
12	0.000	0.032	0.000	0.000	0.000	0.084	0.089	0.045	0.000	0.000	0.000	0.000	0.000	0.032	0.000	0.000	0.000	0.000	0.000
13	0.000	0.000	0.000	0.000	0.000	0.000	0.032	0.063	0.071	0.055	0.045	0.000	0.000	0.032	0.000	0.032	0.063	0.358	0.130

C. CANADIAN SUMMER SURVEY - COEFFICIENTS OF VARIATION

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
0	0	0	0	0	0	0	79	0	0	48	109	68	98	67	40	0	45	0	77
1	25	47	44	35	57	40	25	29	35	51	64	58	39	33	46	26	12	26	40
2	30	25	50	40	35	29	23	36	31	12	42	44	28	36	48	20	28	41	56
3	23	30	28	36	32	29	15	62	30	8	39	47	27	30	36	33	27	23	24
4	29	34	19	20	27	27	16	60	26	22	31	18	23	18	34	46	23	17	16
5	40	34	17	12	26	32	15	44	29	28	30	15	20	16	25	34	22	16	13
6	40	35	16	18	29	29	13	39	32	25	28	15	17	15	20	16	27	17	22
7	33	38	17	16	28	34	13	29	26	25	23	20	20	15	19	20	38	23	36
8	36	34	18	24	29	33	0	36	0	24	18	26	28	20	18	33	37	0	60
9	37	34	17	26	29	40	0	22	0	44	20	27	31	24	21	0	65	0	96
10	46	59	0	25	29	57	0	35	0	0	23	44	53	26	40	0	0	0	0
11	38	0	0	0	21	35	0	0	0	0	0	39	0	0	0	0	0	0	0
12	0	52	0	0	0	31	35	65	0	0	0	0	0	46	0	0	0	0	0
13	0	0	0	0	0	0	29	23	37	33	89	0	0	45	0	93	81	78	88

Table 8. 4X Haddock mean biomass (kg) at age (A) per standard tow and average weight (kg) per fish by age (B) in 1970-88 summer RV surveys.

A. CANADIAN SUMMER SURVEY - STRATIFIED AR, MEAN WEIGHT (KG) PER STANDARD TOW

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.000	0.004	0.001	0.002	0.002	0.000	0.000	0.000	0.000
1	0.554	0.011	0.467	0.635	1.087	0.765	0.629	0.694	0.434	0.132	1.798	3.408	0.778	0.475	0.482	0.499	0.292	0.071	0.731
2	1.894	2.880	0.052	5.543	7.224	1.397	2.226	15.385	2.077	4.837	2.745	11.382	6.411	1.178	6.872	1.681	2.372	0.178	0.717
3	1.034	3.609	2.055	0.314	21.331	3.630	2.724	31.641	8.886	8.087	11.376	5.561	8.501	8.242	5.748	12.648	5.026	1.705	1.298
4	2.643	2.266	1.682	3.939	0.924	9.576	5.075	13.907	4.260	13.972	10.428	9.906	5.805	6.326	14.310	15.194	12.369	5.485	3.863
5	1.491	4.125	1.364	2.500	7.019	0.732	12.069	19.908	2.360	8.378	23.005	5.533	10.383	5.723	6.965	14.330	12.099	7.085	7.183
6	4.057	2.185	1.690	1.002	1.969	4.331	1.216	13.678	5.310	4.442	9.473	7.397	5.179	4.576	5.901	6.519	4.422	3.165	3.701
7	11.214	3.694	1.136	1.347	1.217	1.488	1.777	2.208	2.723	7.890	4.199	2.891	6.136	2.326	3.410	2.621	1.448	0.995	0.696
8	1.904	11.022	2.028	1.111	1.543	1.226	0.310	3.096	0.096	3.357	3.689	0.708	1.001	0.847	1.351	0.275	0.691	0.008	0.291
9	0.860	1.971	3.327	0.703	0.908	0.533	0.073	0.541	0.000	0.989	2.081	1.408	0.663	0.809	1.378	0.000	0.237	0.000	0.493
10	0.881	0.354	0.140	1.032	0.668	0.372	0.118	0.394	0.000	0.096	0.796	1.117	0.273	0.616	0.277	0.127	0.076	0.000	0.000
11	0.289	0.163	0.022	0.083	1.200	0.998	0.000	0.048	0.075	0.000	0.162	0.566	0.130	0.225	0.124	0.000	0.076	0.000	0.000
12	0.073	0.205	0.026	0.000	0.000	0.862	0.872	0.234	0.133	0.000	0.000	0.160	0.000	0.258	0.124	0.114	0.000	0.000	0.000
13	0.000	0.000	0.000	0.056	0.000	0.000	0.408	1.053	0.583	0.685	0.204	0.027	0.000	0.385	0.128	0.008	0.309	0.340	0.189

B. CANADIAN SUMMER SURVEY - AVERAGE WEIGHT (KG) OF AN INDIVIDUAL

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.004	0.000	0.006	0.004	0.006	0.007	0.000	0.000	0.000	0.000
1	0.094	0.094	0.080	0.094	0.094	0.110	0.098	0.108	0.069	0.076	0.082	0.083	0.060	0.069	0.103	0.075	0.076	0.075	0.102
2	0.401	0.259	0.200	0.286	0.313	0.373	0.364	0.458	0.412	0.360	0.400	0.395	0.223	0.260	0.294	0.248	0.272	0.198	0.385
3	0.736	0.764	0.620	0.495	0.671	0.744	0.705	0.816	0.863	0.805	0.742	0.788	0.664	0.570	0.464	0.509	0.512	0.472	0.666
4	1.015	1.089	1.211	1.287	0.969	1.204	1.200	1.227	1.371	1.308	1.298	1.145	1.241	1.085	0.809	0.795	0.751	0.825	0.933
5	1.338	1.416	1.550	1.704	1.715	1.714	1.596	1.729	1.808	1.680	1.808	1.736	1.553	1.608	1.258	1.224	1.283	1.354	1.364
6	1.537	1.588	1.847	2.174	2.207	2.227	2.118	2.057	2.101	2.246	2.164	2.177	2.033	1.946	1.858	2.110	1.729	1.787	1.999
7	1.942	1.749	1.878	2.205	2.464	2.802	2.617	2.798	2.538	2.578	2.526	2.593	2.445	2.418	2.194	2.753	2.540	2.251	2.646
8	2.359	2.127	2.299	2.394	2.638	2.905	2.441	3.003	3.310	2.889	2.737	2.914	2.997	2.630	2.425	2.895	2.867	2.667	3.880
9	2.507	2.604	2.681	2.556	2.640	3.028	3.042	3.783	0.000	3.988	3.252	3.222	3.234	2.771	3.104	0.000	3.435	0.000	3.521
10	3.113	3.806	3.256	2.752	2.715	3.382	3.189	3.054	0.000	3.200	3.317	4.004	4.550	2.947	3.462	3.175	4.471	0.000	0.000
11	3.440	3.622	3.667	3.320	3.550	3.316	0.000	3.200	2.586	0.000	3.767	3.986	3.421	2.500	3.758	0.000	4.471	0.000	0.000
12	2.355	3.361	5.200	0.000	0.000	3.204	3.433	3.391	3.410	0.000	0.000	4.444	0.000	3.739	4.133	3.800	0.000	0.000	0.000
13	0.000	0.000	0.000	3.733	0.000	0.000	3.743	3.774	3.021	4.152	4.080	5.400	0.000	5.500	3.122	0.235	3.962	0.744	1.277

Table 9. ADAPT input summary for 4X haddock.

Parameters:

- Year-class estimates

  $N_{t,1988}$ i = 2 to 8

- Calibration constants for RV surveys

  K_i i = 2 to 8

Structure:

- Natural mortality assumed equal to 0.2
- Error in catch at age assumed negligible
- F for age 11 calculated as the weighted F for ages 7-8
- F for ages 9-11 in 1988 calculated as the weighted F for ages 7-8
- Intercepts not included

Input:

- $C_{i,t}$ i = 2 to 11 t = 1970 to 1988
- $RV_{i,t}$ i = 2 to 8 t = 1970 to 1988
- Survey numbers were related to July SPA numbers

Objective function:

- Minimize

$$\sum_{i}\sum_{t}(\text{obs.}(\ln RV_{i,t}) - \text{pred.}(\ln RV_{i,t}))^2$$

Summary:

- Number of observations = 133
- Number of parameters = 14

Table 10. (A) Final parameter estimates and T-statistics for ages 2-8 and ages 2-8 slopes; (B) correlation matrix showing interrelationships among the 14 parameters from ADAPT run and (C) standardized residuals form RV index under assumption of log model (s.e. = 1).

(A)

ESTIMATED PARAMETERS AND STANDARD ERRORS
APPROXIMATE STATISTICS ASSUMING LINEARITY NEAR SOLUTION

ORTHOGONALITY OFFSET......... 0.011853
MEAN SQUARE RESIDUALS 0.542941

Parameter	PAR. EST.	STD. ERR.	T-STATISTIC
$n_{2,88}$	4.88597E0003	3.70896E0003	1.31734E0000
$n_{3,88}$	2.88692E0003	1.49709E0003	1.92836E0000
$n_{4,88}$	8.63952E0003	3.79187E0003	2.27843E0000
$n_{5,88}$	8.77020E0003	3.47647E0003	2.52273E0000
$n_{6,88}$	4.99690E0003	2.08326E0003	2.39860E0000
$n_{7,88}$	6.47852E0002	1.55660E0002	4.16196E0000
$n_{8,88}$	2.12629E0002	9.92183E0001	2.14305E0000
q_2	4.30828E¯004	7.73806E¯005	5.56765E0000
q_3	5.60798E¯004	9.82804E¯005	5.70610E0000
q_4	6.21396E¯004	1.07811E¯004	5.76376E0000
q_5	8.46227E¯004	1.46632E¯004	5.77108E0000
q_6	1.05921E¯003	1.83672E¯004	5.76682E0000
q_7	1.24566E¯003	2.19471E¯004	5.67575E0000
q_8	8.48077E¯004	1.48679E¯004	5.70408E0000

Parameter Correlation Matrix

(B)

I	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	1.000	.040	.032	.024	.014	.002	.001	¯.236	¯.014	¯.008	¯.005	¯.003	¯.001	¯.001
2	.040	1.000	.045	.033	.020	.003	.002	¯.169	¯.178	¯.012	¯.008	¯.004	¯.001	¯.001
3	.032	.045	1.000	.043	.026	.004	.003	¯.136	¯.140	¯.156	¯.010	¯.005	¯.001	¯.001
4	.024	.033	.043	1.000	.036	.006	.005	¯.101	¯.103	¯.119	¯.165	¯.007	¯.002	¯.002
5	.014	.020	.026	.036	1.000	.015	.013	¯.058	¯.060	¯.072	¯.111	¯.184	¯.005	¯.004
6	.002	.003	.004	.006	.015	1.000	.033	¯.010	¯.010	¯.012	¯.020	¯.063	¯.237	¯.100
7	.001	.002	.003	.005	.013	.033	1.000	¯.006	¯.007	¯.009	¯.018	¯.055	¯.125	¯.229
8	¯.236	¯.169	¯.136	¯.101	¯.058	¯.010	¯.006	1.000	.058	.035	.023	.012	.003	.002
9	¯.014	¯.178	¯.140	¯.103	¯.060	¯.010	¯.007	.058	1.000	.036	.023	.012	.003	.002
10	¯.008	¯.012	¯.156	¯.119	¯.072	¯.012	¯.009	.035	.036	1.000	.027	.014	.004	.003
11	¯.005	¯.008	¯.010	¯.165	¯.111	¯.020	¯.018	.023	.023	.027	1.000	.022	.007	.006
12	¯.003	¯.004	¯.005	¯.007	¯.184	¯.063	¯.055	.012	.012	.014	.022	1.000	.021	.018
13	¯.001	¯.001	¯.001	¯.002	¯.005	¯.237	¯.125	.003	.003	.004	.007	.021	1.000	.050
14	¯.001	¯.001	¯.001	¯.002	¯.004	¯.100	¯.229	.002	.002	.003	.006	.018	.050	1.000

Standardized Residuals for RV index (s.e.=1 for log model)

(C)

I	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
2	.095	.369	¯1.980	.324	.526	¯.613	¯.890	.749	¯.591	.092	¯.225	1.060	1.037	¯.505	.722	¯.229	.472	¯.411	.000
3	¯.562	.208	¯.730	¯1.132	.910	¯.972	¯.508	.977	¯.414	.076	.225	¯.173	.331	.402	.482	.785	.124	¯.410	.380
4	¯.278	.147	¯.568	¯.436	¯.547	¯.093	¯.776	.871	¯1.159	¯.019	.128	.055	¯.289	.067	1.033	1.181	.695	.016	¯.029
5	¯.468	.079	¯.556	¯.150	.085	¯1.260	.159	.433	¯1.028	¯.373	.529	¯.404	.286	¯.177	.681	1.290	.928	¯.096	.043
6	¯.028	¯.043	¯.728	¯.827	¯.194	¯.274	¯.648	.658	¯.621	¯.185	.166	¯.117	.012	.055	.803	1.330	.902	.337	¯.597
7	¯.920	¯.110	¯.653	¯.587	¯.322	¯.226	¯.728	.268	¯.351	.182	.107	¯.293	.605	¯.080	1.006	1.050	1.038	.133	¯.119
8	¯1.087	.008	¯.362	.035	.590	.574	¯.578	1.003	¯1.820	.888	.541	¯.736	¯.166	.286	1.139	.131	2.400	¯2.389	¯.457

Table 11. Cohort analysis calibrated with RV catch per tow using RV-SPA relationships generated from ADAPT.

POPULATION NUMBERS (000S)

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
1	25109	6019	47115	44189	23775	48521	51622	29039	39102	27490	32755	32841	24015	36729	27318	17564	4343	5957	0
2	11889	20558	4928	38538	36043	19464	39692	42248	23773	32014	22507	26803	26887	19662	30071	22364	14380	3556	4877
3	5422	8779	16118	4015	28768	28882	13968	31324	33427	19396	26138	18281	20875	21569	16040	23980	18131	11511	2876
4	7244	3784	5725	10089	3185	19343	19513	9949	22818	24333	14832	19187	12963	13799	14678	12130	17862	13786	8598
5	2616	4572	2385	3021	6227	2328	11164	12120	6318	12335	13852	9422	10082	8375	6342	7783	7885	10663	8691
6	3231	1799	2456	1492	1508	3489	1467	5809	7034	3278	6587	6443	3915	4067	3479	2081	2286	2906	4943
7	16216	2171	1107	1427	745	774	1858	808	2149	3197	1716	2227	2384	1664	1310	680	380	535	632
8	4522	9172	1715	825	626	439	410	791	336	818	1492	928	771	633	512	215	137	88	211
9	1105	2016	4509	1353	384	269	204	197	296	151	432	657	437	324	161	111	56	8	21
10	813	784	728	2637	873	146	164	102	64	145	72	201	246	192	96	32	43	10	5
11	557	578	495	133	1603	471	91	48	19	29	58	28	77	116	50	9	12	10	6
	78723	60233	87282	107719	103737	124126	140153	132436	135336	123187	120440	117020	102652	107130	100058	86950	65516	49030	30860

FISHING MORTALITY

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
1	.000	.000	.001	.004	.000	.001	.000	.000	.000	.000	.001	.000	.000	.000	.000	.000	.000	.000	.001
2	.103	.043	.005	.092	.022	.132	.037	.034	.003	.003	.008	.050	.020	.004	.026	.010	.023	.012	.006
3	.160	.228	.268	.032	.197	.192	.139	.117	.118	.068	.109	.144	.214	.185	.079	.094	.074	.092	.127
4	.260	.262	.439	.283	.113	.350	.276	.254	.415	.363	.254	.443	.237	.577	.434	.231	.316	.261	.188
5	.174	.421	.269	.495	.379	.262	.453	.344	.456	.427	.565	.678	.708	.678	.914	1.025	.798	.569	.445
6	.198	.285	.343	.495	.467	.430	.396	.794	.589	.447	.884	.794	.655	.933	1.432	1.501	1.251	1.326	.558
7	.370	.036	.094	.625	.329	.435	.654	.678	.765	.562	.415	.861	1.125	.979	1.608	1.401	1.260	.734	1.474
8	.608	.510	.037	.564	.644	.568	.536	.784	.599	.439	.619	.554	.668	1.168	1.325	1.141	2.666	1.218	.503
9	.143	.819	.337	.238	.766	.294	.487	.921	.510	.539	.566	.783	.622	1.017	1.402	.748	1.560	.334	1.234
10	.140	.261	1.502	.298	.416	.277	1.021	1.500	.595	.727	.734	.763	.549	1.155	2.188	.789	1.272	.260	1.234
11	.422	.420	.060	.603	.473	.483	.632	.730	.743	.537	.510	.770	1.014	1.031	1.528	1.339	1.633	.802	1.234

Table 12. Comparison of numbers (millions) at age 1 generated by CAFSAC assessments since 1977.

Assessment	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
O'Boyle unpublished assessment #1 1977	30.8	7.0	60.4	49.3	28.9	33.4	-	-	-	-	-	-	-	-	-	-	-	-	-
O'Boyle unpublished assessment #2 1978	20.8	7.0	60.2	35.3	14.6	26.9	44.8	-	-	-	-	-	-	-	-	-	-	-	-
Res. Doc. 78/19	33.0	10.8	75.0	56.4	34.7	43.5	83.0	29.4	-	-	-	-	-	-	-	-	-	-	-
Res. Doc. 80/2	26.4	7.2	50.3	53.3	28.9	56.2	73.5	41.3	50.3	-	-	-	-	-	-	-	-	-	-
Res. Doc. 81/24	25.4	6.5	48.6	47.2	26.2	50.6	81.8	42.0	76.1	45.3	100.0	-	-	-	-	-	-	-	-
Res. Doc. 82/53	25.5	6.1	47.9	46.3	25.0	54.1	63.0	39.0	61.9	31.8	97.0	-	-	-	-	-	-	-	-
Res. Doc. 83/73	25.4	6.4	47.74	44.6	24.6	50.1	59.4	33.5	57.0	28.2	88.0	75.5	30.7	-	-	-	-	-	-
Res. Doc. 84/100	25.3	6.3	47.4	44.5	24.2	49.0	52.6	30.2	41.3	28.1	37.9	39.4	24.5	20.0	-	-	-	-	-
Res. Doc. 85/109	25.3	6.3	47.4	44.4	24.0	49.1	52.1	30.2	41.8	33.9	39.8	58.5	28.6	48.6	12.3	-	-	-	-
Res. Doc. 86/98	25.3	6.2	47.3	44.2	23.7	48.8	52.1	29.6	39.9	29.4	37.9	48.3	37.5	50.2	23.2	27.4	18.7	-	-
Res. Doc. 87/97	25.3	6.2	47.3	44.1	23.7	48.6	51.6	29.1	39.1	27.5	34.1	36.9	29.1	50.5	27.8	19.5	20.0	-	-
Res. Doc. 88/72	25.4	6.3	47.5	44.3	23.7	48.6	57.6	30.0	43.8	30.8	37.2	37.1	25.0	40.0	28.4	18.3	4.5	6.2	-
Present Document	25.1	6.0	47.1	44.2	23.8	48.5	51.6	29.0	39.1	27.5	32.8	32.8	24.0	36.7	27.3	17.6	4.3	6.0	*24.0

* - $\bar{Y}_{GM}$

Table 13. Comparison of population parameters generated by O'Boyle et al. (1988) and the current assessment.

Year	Mid-Year Age 1-11 Population Biomass (kt) 1988	1989	Fully Recruited Ages (5-6) Fishing Mortality 1988	1989
1970	62.5	60.1	0.185	0.187
1971	51.6	49.8	0.389	0.383
1972	51.7	52.9	0.309	0.306
1973	58.3	58.2	0.501	0.495
1974	60.3	60.2	0.391	0.396
1975	69.8	69.1	0.347	0.363
1976	79.6	77.8	0.434	0.447
1977	83.8	80.8	0.481	0.490
1978	97.1	91.7	0.525	0.526
1979	100.3	92.4	0.430	0.432
1980	95.3	85.0	0.571	0.668
1981	92.2	78.7	0.585	0.725
1982	83.9	68.1	0.554	0.693
1983	74.5	57.2	0.546	0.762
1984	69.9	53.1	0.688	1.098
1985	68.1	50.1	0.680	1.126
1986	59.9	43.0	0.674	0.900
1987	50.6	34.8	0.591	0.731
1988	-	33.7	-	0.486

Table 14. Yield per recruit analysis for 4X haddock.

AGE	WEIGHT-AT-AGE	PARTIAL RECRUITMENT
1	.223	.000
2	.473	.012
3	.790	.111
4	1.148	.291
5	1.523	.690
6	1.894	1.000
7	2.250	1.000
8	2.581	1.000
9	2.883	1.000
10	3.115	1.000
11	3.396	1.000
12	3.607	1.000
13	3.791	1.000
14	3.951	1.000
15	4.088	1.000
16	4.206	1.000

NATURAL MORTALITY RATE : 0.2
F0.1 COMPUTED AS .2680 AT Y/R OF .5246
FMAX COMPUTED AS .8693 AT Y/R OF .5972

YIELD PER RECRUIT ANALYSIS

	FISHING MORTALITY	CATCH (NUMBER)	YIELD (KG)	AVG. WEIGHT (KG)	YIELD PER UNIT EFFORT
	.1000	.154	.339	2.209	1.732
	.2000	.237	.478	2.019	1.221
F0.1---	.2680	.274	.525	1.916	1.000
	.3000	.288	.539	1.874	.919
	.4000	.323	.569	1.762	.727
	.5000	.349	.584	1.674	.597
	.6000	.369	.592	1.603	.504
	.7000	.385	.595	1.545	.435
	.8000	.399	.597	1.496	.381
FMAX---	.8693	.407	.597	1.466	.351
	.9000	.411	.597	1.454	.339
	1.0000	.421	.597	1.417	.305
	1.1000	.430	.595	1.385	.277
	1.2000	.438	.594	1.357	.253
	1.3000	.445	.592	1.331	.233
	1.4000	.452	.591	1.308	.216
	1.5000	.458	.589	1.286	.201

Table 15. Data used in derivation of Von Bertalanffy growth model for yield per recruit analyses.

Age	Weight at Age (kg) 1962-87 AVG.	Length at Age (cm) [1] $w = \frac{(0.0077585L^{3.07669})}{1000}$	Predicted[2] Length at Age	Predicted Weight at Age
1.5	-	-	28.125	0.223
2.5	0.486	36.236	35.905	0.473
3.5	0.787	42.380	42.435	0.790
4.5	1.121	47.536	47.916	1.148
5.5	1.482	52.052	52.518	1.523
6.5	1.876	56.201	56.380	1.894
7.5	2.291	59.974	59.623	2.250
8.5	2.611	62.577	62.345	2.581
9.5	2.954	65.143	64.629	2.883
10.5	3.205	66.891	66.547	3.155
11.5	3.415	68.286	68.157	3.396
12.5	3.478	68.689	69.508	3.607
13.5	-	-	70.643	3.791
14.5	-	-	71.595	3.951
15.5	-	-	72.394	4.088
16.5	-	-	73.065	4.206

1 - From summer survey (Strata 70-85)

2 - $L = 76.573\ [1 - e^{-0.175037^{(t+1.11515)}}]$

Table 16. Percent maturity at age for 4X haddock females using length-maturity relationship[1] from Waiwood and Buzeta (1989).

Age	Percent Maturity
1.5	0.80
2.5	15.90
3.5	49.20
4.5	75.40
5.5	88.90
6.5	94.90
7.5	97.50
8.5	98.70
9.5	99.30
10.5	99.60
11.5	99.70
12.5	99.80
13.5	99.90
14.5	100.00
15.5	100.00
16.6	100.00

[1] Probit = 13.41908 $\log_{10}$ L(cm) - 16.86306

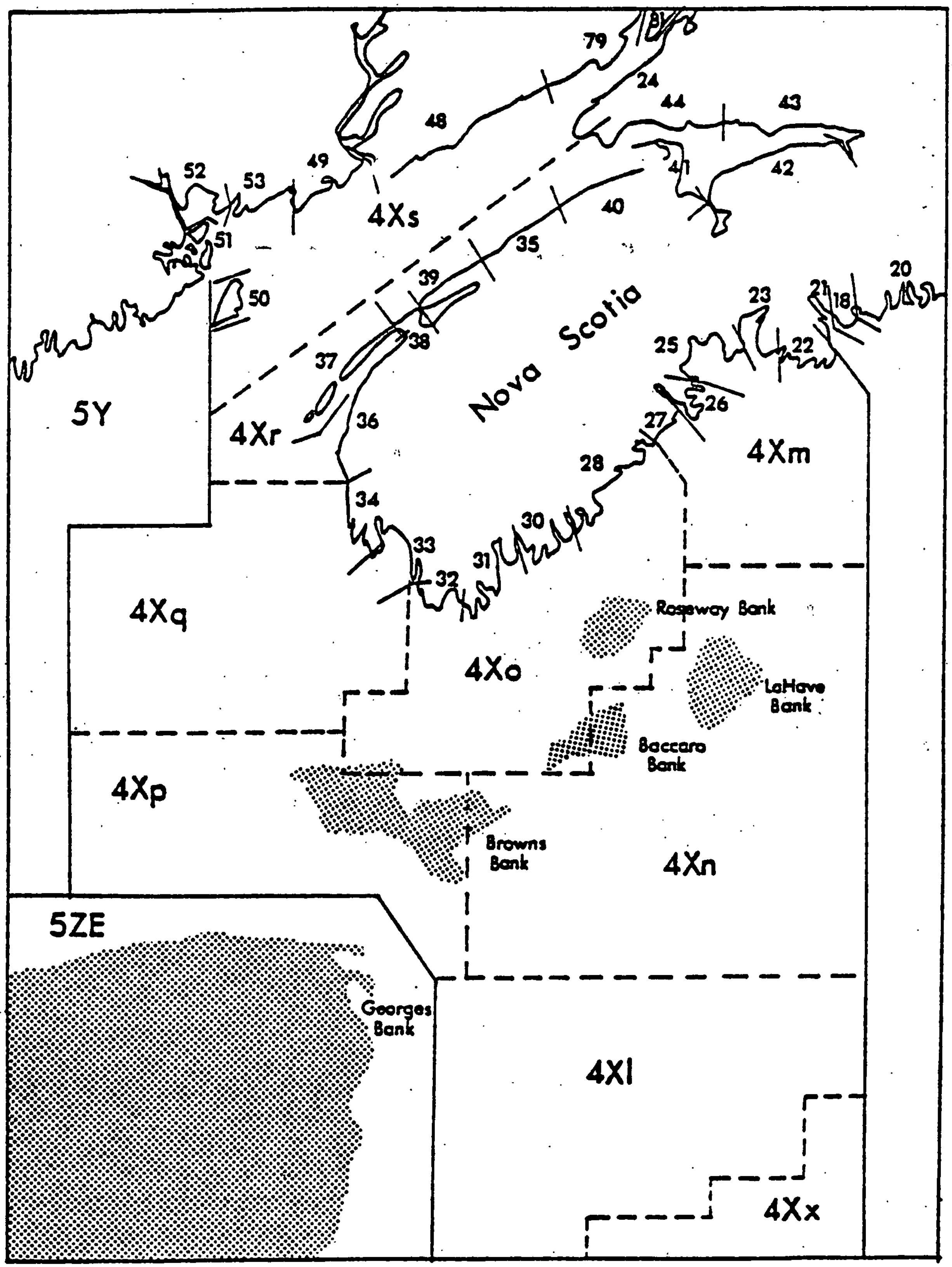


Figure 1. Canadian fisheries statistical unit areas in NAFO Division 4X

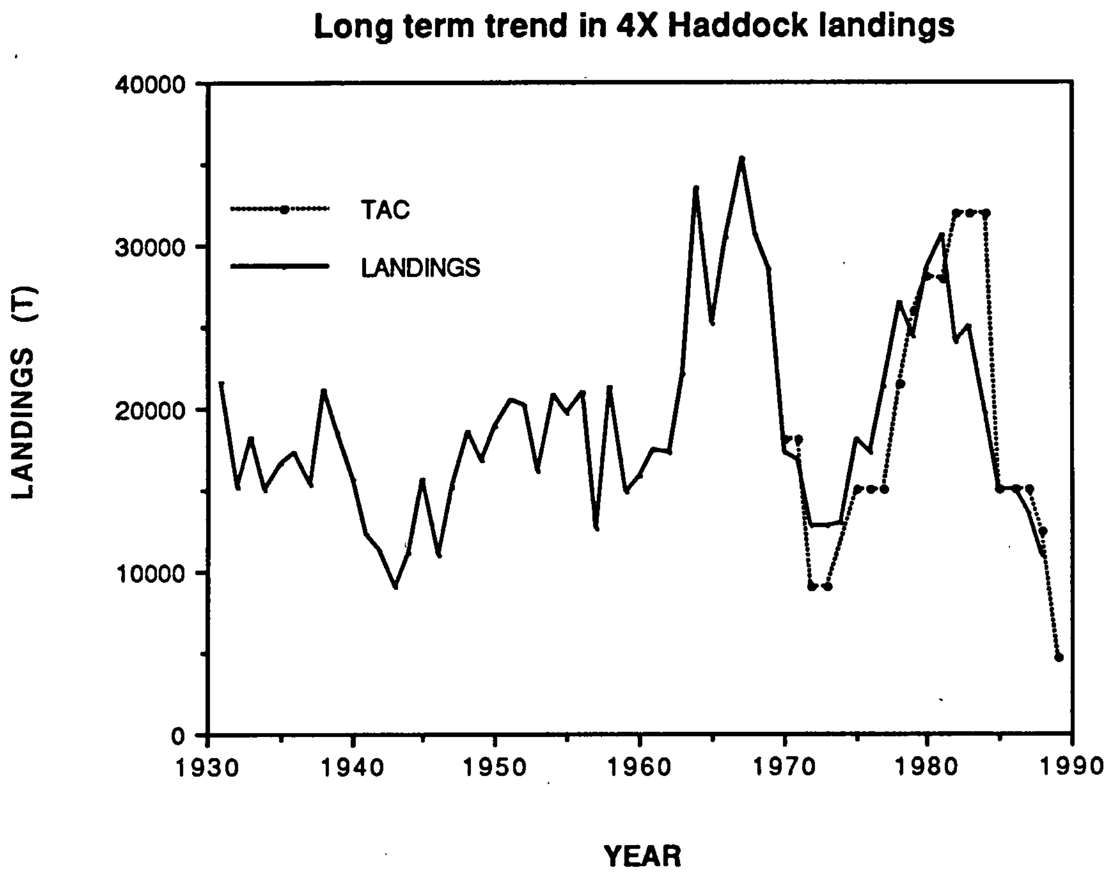


Figure 2. Long-term trends in 4X haddock landings, along with TACs since 1970.

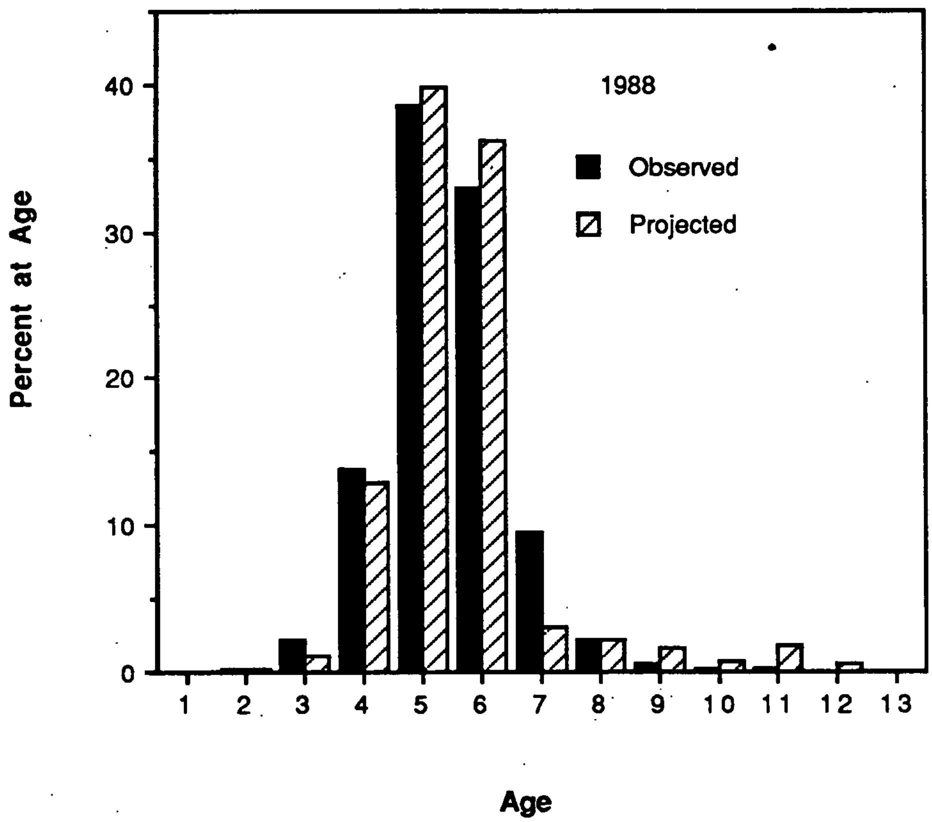
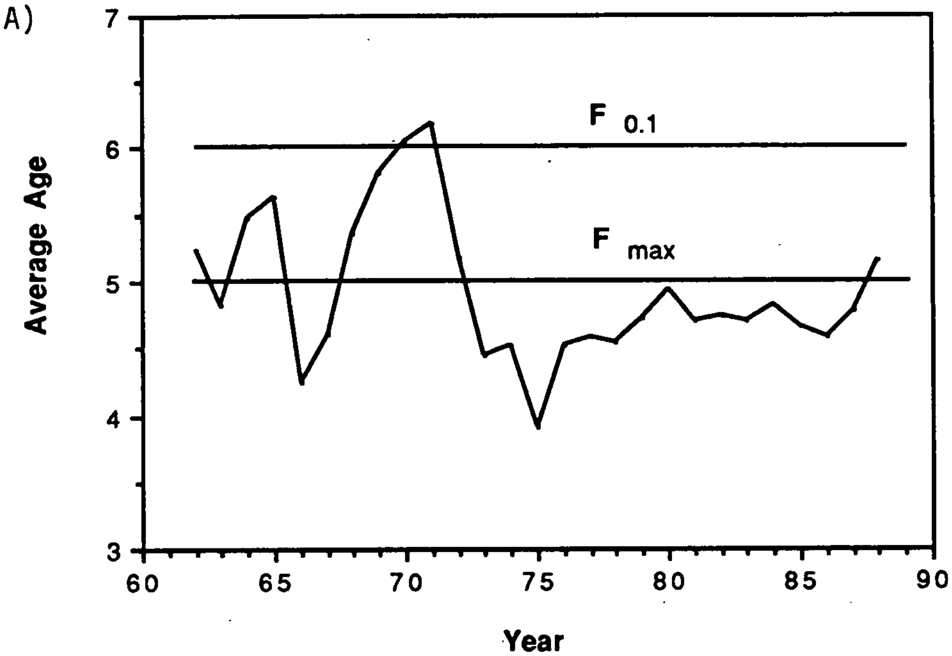


Figure 3. Comparison of observed 1988 catch numbers at age with those projected using 12,400 t in 1988, by O'Boyle et al. (1988).

(A)



(B)

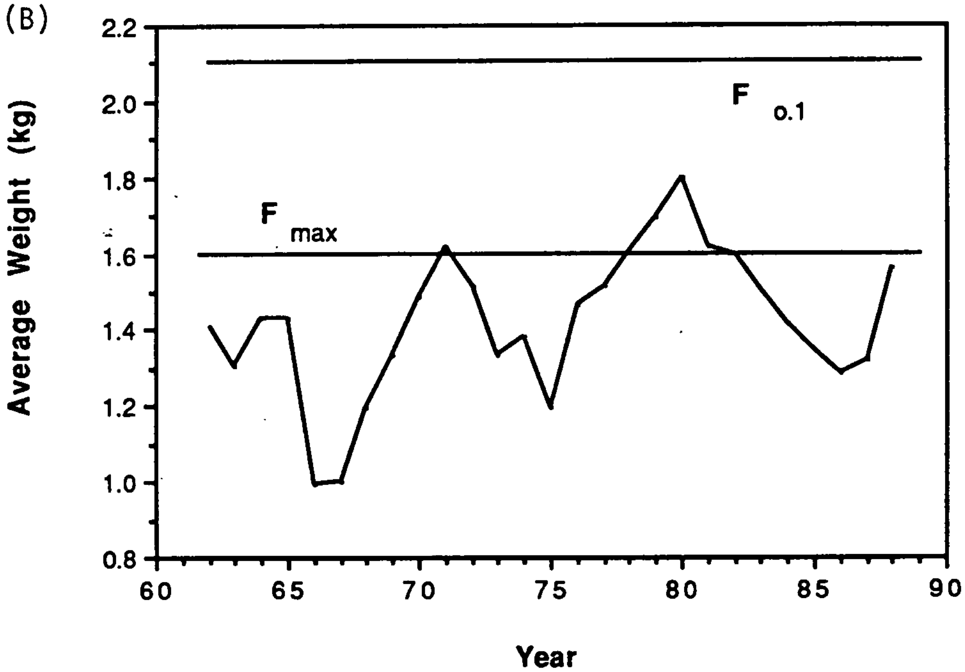


Figure 4. Age-size characteristics of landings of 4X haddock. (A) Average age of 4X haddock in landings; (B) Average weight (kg) of 4X haddock in landings. Top and bottom line in each figure indicates levels of these parameters in equilibrium populations harvested at $F_{0.1}$ and F_{max}, respectively.

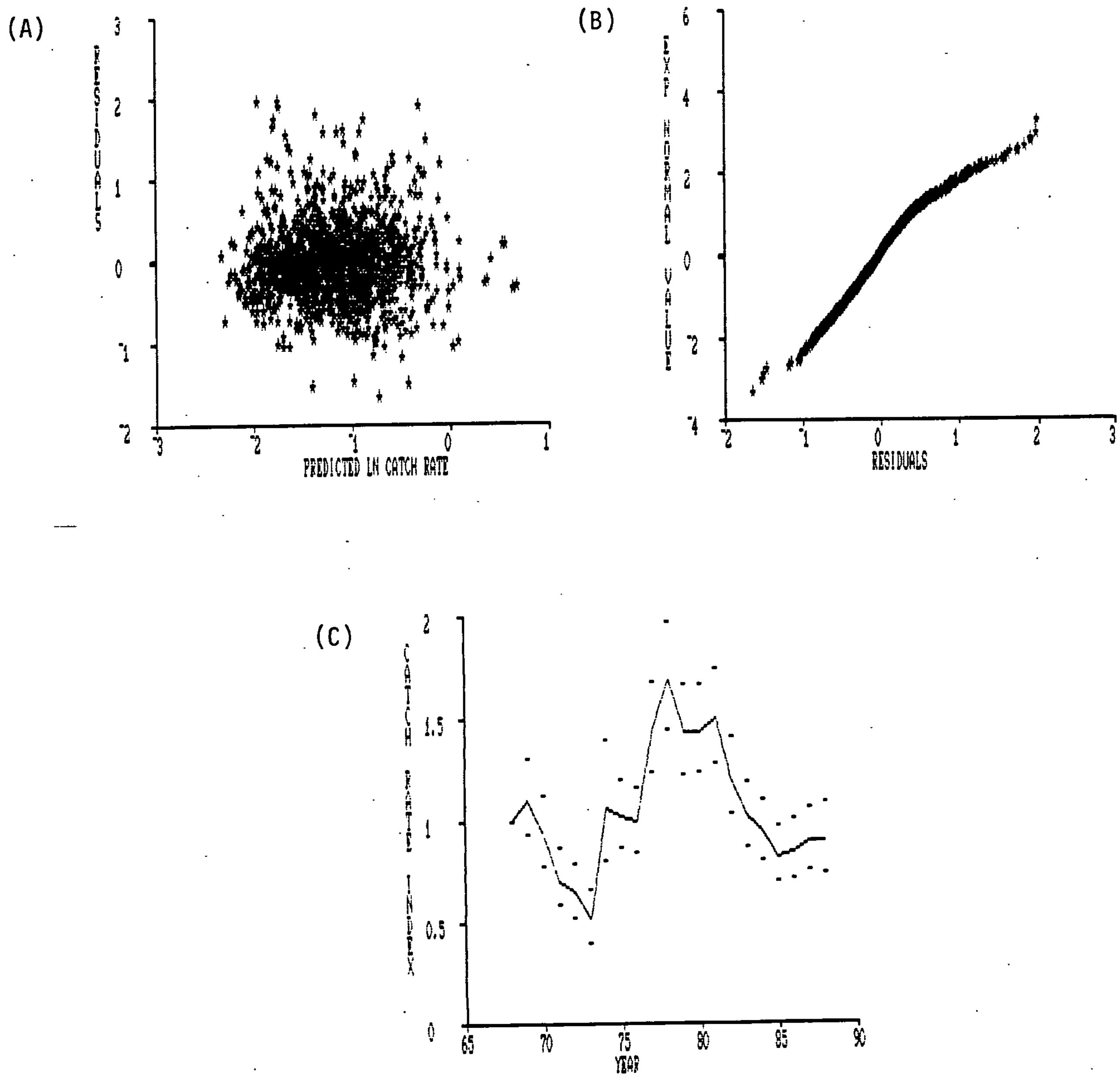


Figure 5. Trends in catch rates (t per hour) of haddock by otter trawlers in 4Xmnopqr using the multiplicative model. (A) Residuals versus predicted LN catch rate; (B) Normal probability plot; (C) Standardized catch rate.

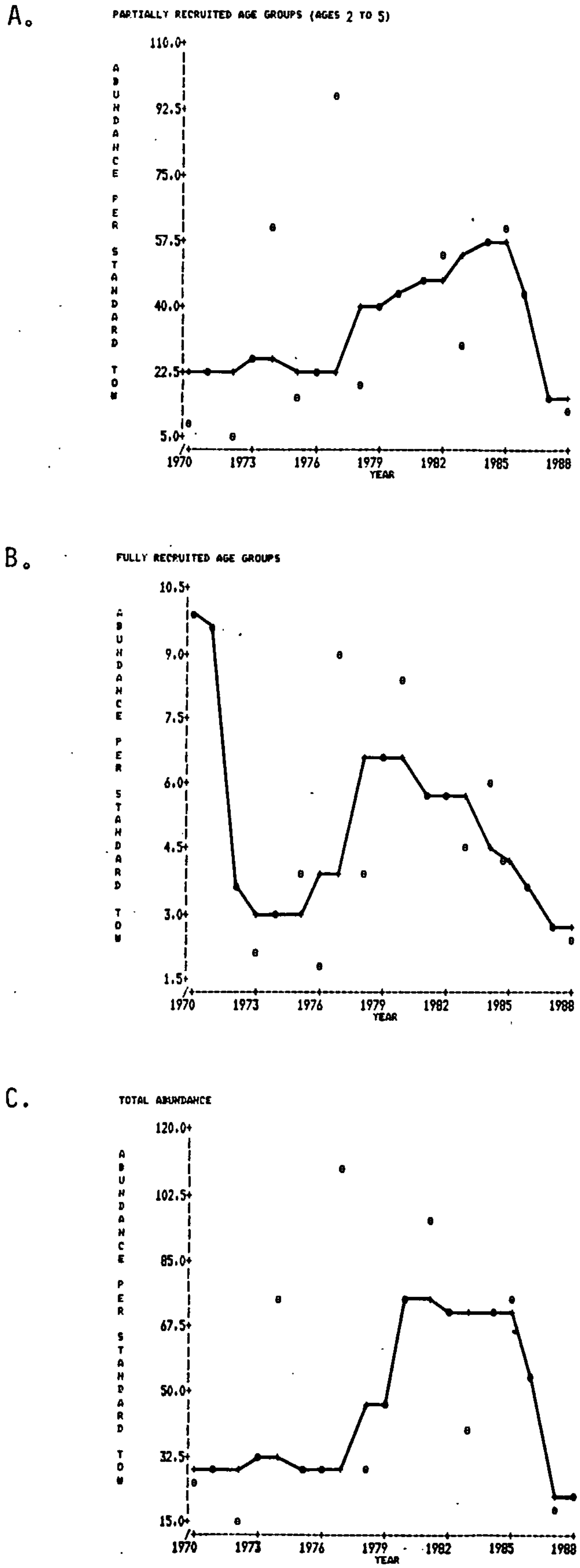


Figure 6. Survey arithmetic mean catch rate (Nos/tow) of haddock from 4X during 1970-88 for ages 2-5 (a), 6-9 (b), and all age groups combined (c). The solid line in each figure indicates the trend in the median smoothed estimates.

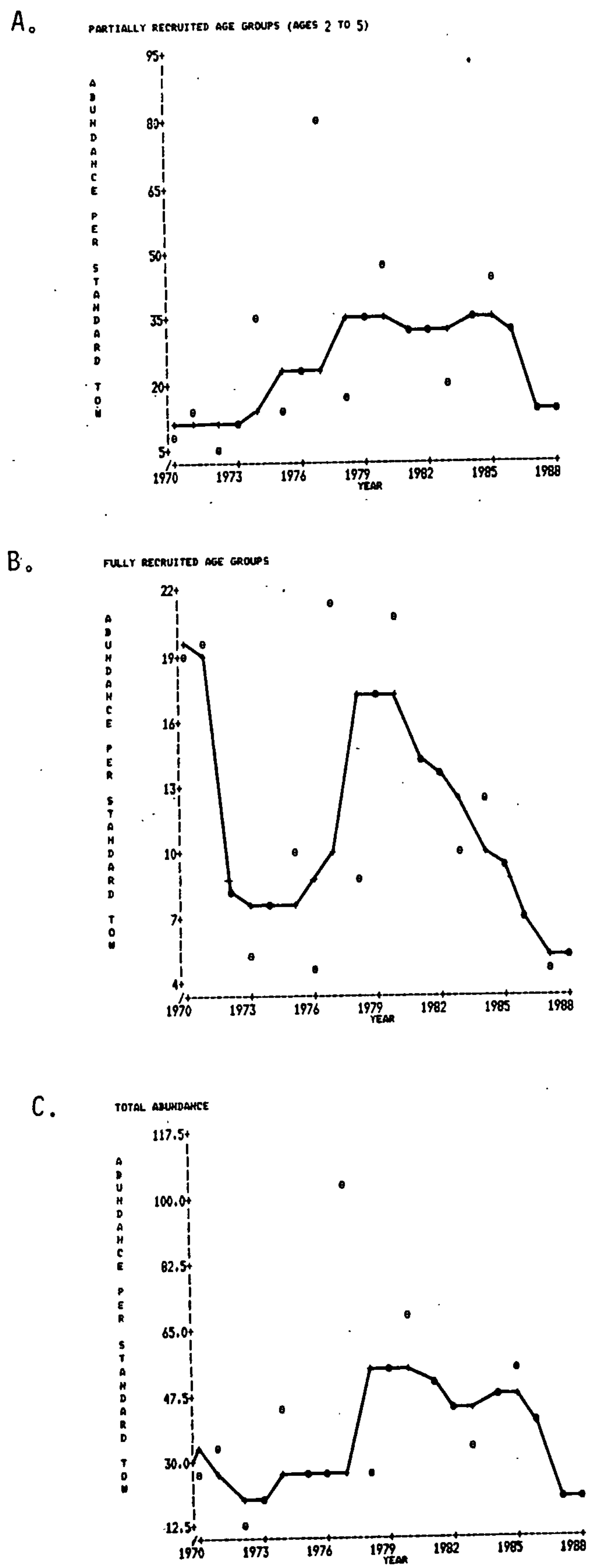


Figure 7. Survey arithmetic mean catch rate (biomass/tow) of haddock from 4X during 1970-88 for ages 2-5 (a), 6-9 (b), and all age groups combined (c). The solid line in each figure indicates the trend in the median smoothed estimates.

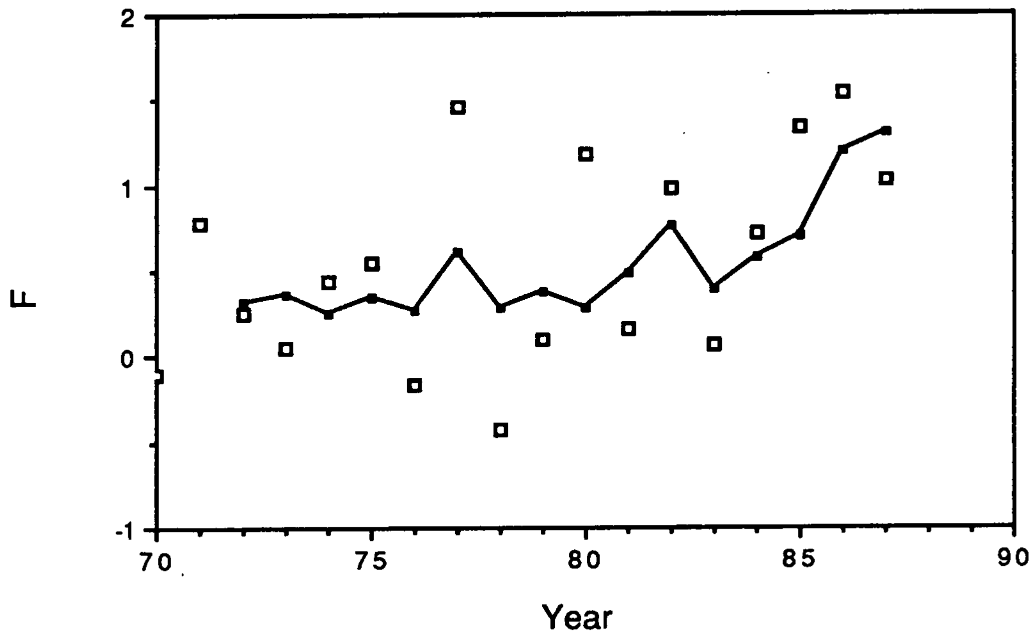


Figure 8. Total mortality (Z) estimates calculated for fully recruited ages (5-7/6-8) from the RV survey data. Natural mortality assumed equal to 0.2. Open squares are annual estimates and line connects 3-yr. running means.

Figure 9. Age by age diagnostic plots from ADAPT tuning of SPA with RV ages 2 to 8.

SUMMARY OF DATA FROM PLOT

CARRIER VARIABLE: POPULATION NOS Age 2

RESPONSE VARIABLE(S): SURVEY - +:OBSERVED, 0:PREDICTED

INDEX	CARRIER	+	0	RANK
1 1970	9961	4.719	4.292	1987
2 1971	1.704E	11.12	7.685	1988
3 1972	4373	0.26	1.884	1972
4 1973	3.249E	19.35	14	1970
5 1974	3.167E	23.08	13.65	1986
6 1975	1.604E	3.744	6.91	1975
7 1976	3.457E	6.119	14.89	1983
8 1977	3.685E	33.57	15.88	1971
9 1978	2.111E	5.039	9.096	1985
A 1979	2.044E	13.43	12.25	1980
B 1980	1.994E	6.856	8.589	1978
C 1981	2.317E	28.8	9.981	1981
D 1982	2.364E	20.74	10.19	1982
E 1983	1.746E	4.538	7.522	1984
F 1984	2.635E	23.38	11.25	1979
G 1985	1.979E	6.779	8.525	1974
H 1986	1.263E	0.723	5.441	1973
I 1987	3142	0.897	1.354	1976
J 1988	4324	1.863	1.863	1977

CARRIER VARIABLE: POPULATION NOS Age 3

RESPONSE VARIABLE(S): SURVEY - +:OBSERVED, 0:PREDICTED

INDEX	CARRIER	+	0	RANK
1 1970	4396	1.405	2.465	1988
2 1971	6841	4.722	3.836	1973
3 1972	1.226E	3.314	6.878	1970
4 1973	3507	0.634	1.967	1971
5 1974	2.282E	31.8	12.8	1987
6 1975	2.298E	4.876	12.89	1976
7 1976	1.146E	3.866	6.426	1972
8 1977	2.604E	38.8	14.6	1984
9 1978	2.777E	10.3	15.58	1981
A 1979	1.659E	10.04	9.302	1986
B 1980	2.182E	15.33	12.24	1982
C 1981	1.496E	7.055	8.389	1979
D 1982	1.64E4	12.81	9.195	1983
E 1983	1.723E	14.45	9.663	1985
F 1984	1.363E	12.38	7.642	1980
G 1985	2.019E	24.83	11.33	1974
H 1986	1.545E	9.808	8.666	1975
I 1987	9710	3.615	5.445	1977
J 1988	2376	1.948	1.333	1978

CARRIER VARIABLE: POPULATION NOS Age 4

RESPONSE VARIABLE(S): SURVEY - +:OBSERVED, 0:PREDICTED

INDEX	CARRIER	+	0	RANK
1 1970	5538	2.605	3.441	1974
2 1971	2891	2.081	1.796	1971
3 1972	3943	1.389	2.45	1972
4 1973	7614	3.06	4.731	1970
5 1974	2653	0.954	1.648	1988
6 1975	1.404E	7.952	8.723	1973
7 1976	1.478E	4.228	9.184	1977
8 1977	7634	11.33	4.744	1983
9 1978	1.594E	3.107	9.904	1985
A 1979	1.752E	10.68	10.88	1982
B 1980	1.138E	8.036	7.073	1984
C 1981	1.318E	8.651	8.192	1987
D 1982	1.005E	4.678	6.243	1980
E 1983	8768	5.828	5.449	1981
F 1984	1.014E	17.69	6.3	1986
G 1985	9435	19.1	5.863	1975
H 1986	1.322E	16.46	8.215	1976
I 1987	1.053E	6.632	6.545	1978
J 1988	6856	4.14	4.26	1979

CARRIER VARIABLE: POPULATION NOS Age 5

RESPONSE VARIABLE(S): SURVEY - +:OBSERVED, 0:PREDICTED

INDEX	CARRIER	+	0	RANK
1 1970	2103	1.114	1.78	1975
2 1971	3182	2.914	2.693	1972
3 1972	1814	0.88	1.535	1973
4 1973	2014	1.467	1.705	1970
5 1974	4441	4.093	3.758	1971
6 1975	1778	0.427	1.505	1984
7 1976	7626	7.562	6.453	1985
8 1977	8824	11.51	7.467	1978
9 1978	4309	1.305	3.646	1986
A 1979	8555	4.987	7.239	1974
B 1980	8863	12.73	7.5	1983
C 1981	5645	3.188	4.777	1981
D 1982	5937	6.685	5.024	1982
E 1983	5017	3.558	4.245	1988
F 1984	3311	5.537	2.802	1987
G 1985	3808	11.71	3.223	1976
H 1986	4405	9.432	3.727	1979
I 1987	6809	5.233	5.762	1977
J 1988	5965	5.267	5.048	1980

CARRIER VARIABLE: POPULATION NOS Age 6

RESPONSE VARIABLE(S): SURVEY - +:OBSERVED, 0:PREDICTED

INDEX	CARRIER	+	0	RANK
1 1970	2562	2.639	2.714	1985
2 1971	1256	1.376	1.436	1986
3 1972	1790	0.915	1.896	1973
4 1973	994.8	0.461	1.054	1974
5 1974	1022	0.892	1.082	1976
6 1975	2416	1.945	2.559	1987
7 1976	1036	0.574	1.098	1984
8 1977	3252	6.65	3.445	1971
9 1978	4440	2.527	4.703	1972
A 1979	2247	1.978	2.38	1983
B 1980	3499	4.377	3.707	1979
C 1981	3607	3.398	3.821	1982
D 1982	2377	2.547	2.517	1975
E 1983	2100	2.251	2.225	1970
F 1984	1343	3.176	1.422	1988
G 1985	771.4	3.089	0.817	1977
H 1986	980.3	2.558	1.038	1980
I 1987	1193	1.771	1.264	1981
J 1988	3176	1.851	3.364	1978

CARRIER VARIABLE: POPULATION NOS Age 7

RESPONSE VARIABLE(S): SURVEY - +:OBSERVED, 0:PREDICTED

INDEX	CARRIER	+	0	RANK
1 1970	1.163E	5.775	14.49	1986
2 1971	1092	2.112	2.357	1988
3 1972	932.8	0.605	1.162	1985
4 1973	882.4	0.611	1.099	1987
5 1974	547	0.494	0.6813	1984
6 1975	534.5	0.531	0.6658	1977
7 1976	1129	0.679	1.407	1975
8 1977	484.5	0.789	0.6036	1974
9 1978	1224	1.073	1.524	1983
A 1979	2049	3.061	2.553	1973
B 1980	1199	1.667	1.493	1972
C 1981	1200	1.115	1.494	1982
D 1982	1100	2.51	1.371	1976
E 1983	836.6	0.962	1.042	1980
F 1984	456.4	1.554	0.5685	1981
G 1985	267.4	0.952	0.333	1978
H 1986	162	0.57	0.2018	1971
I 1987	310.6	0.442	0.3869	1979
J 1988	237.9	0.263	0.2963	1970

CARRIER VARIABLE: POPULATION NOS Age 8

RESPONSE VARIABLE(S): SURVEY - +:OBSERVED, 0:PREDICTED

INDEX	CARRIER	+	0	RANK
1 1970	2823	0.807	2.418	1986
2 1971	6061	5.181	5.192	1987
3 1972	1493	0.882	1.279	1985
4 1973	528.4	0.464	0.4526	1988
5 1974	382.4	0.585	0.3275	1984
6 1975	280.3	0.422	0.2401	1978
7 1976	267.1	0.127	0.2288	1976
8 1977	445.8	1.031	0.3818	1975
9 1978	211	0.029	0.1807	1983
A 1979	563.8	1.162	0.4829	1974
B 1980	924.9	1.348	0.7922	1977
C 1981	597.9	0.243	0.5121	1982
D 1982	464.8	0.334	0.3981	1973
E 1983	285.1	0.322	0.2442	1979
F 1984	210.3	0.557	0.1802	1981
G 1985	98.29	0.095	0.08419	1980
H 1986	25.77	0.241	0.02208	1972
I 1987	38.56	3E-3	0.03303	1970
J 1988	139.7	0.075	0.1197	1971

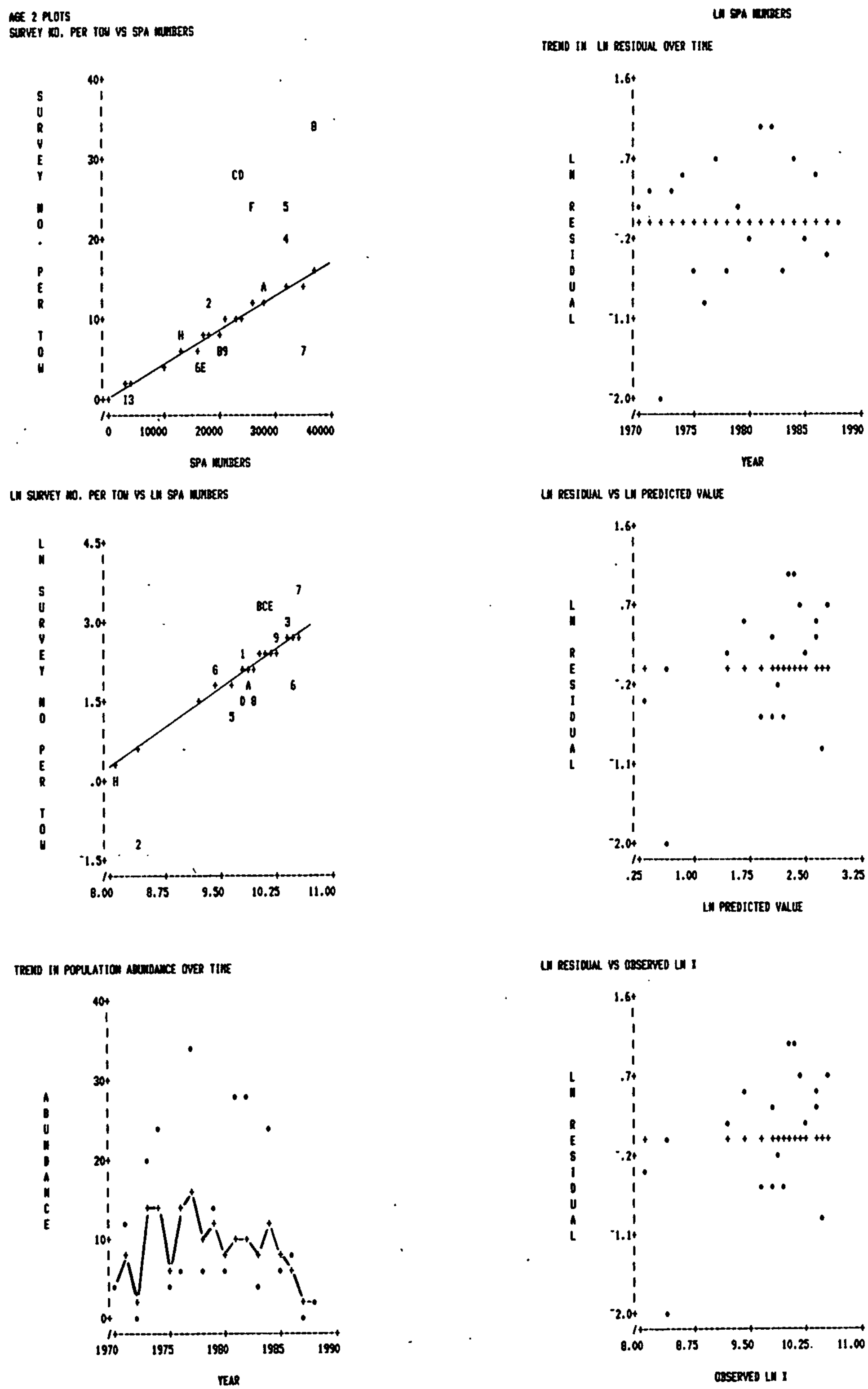


Figure 9. (Continued)

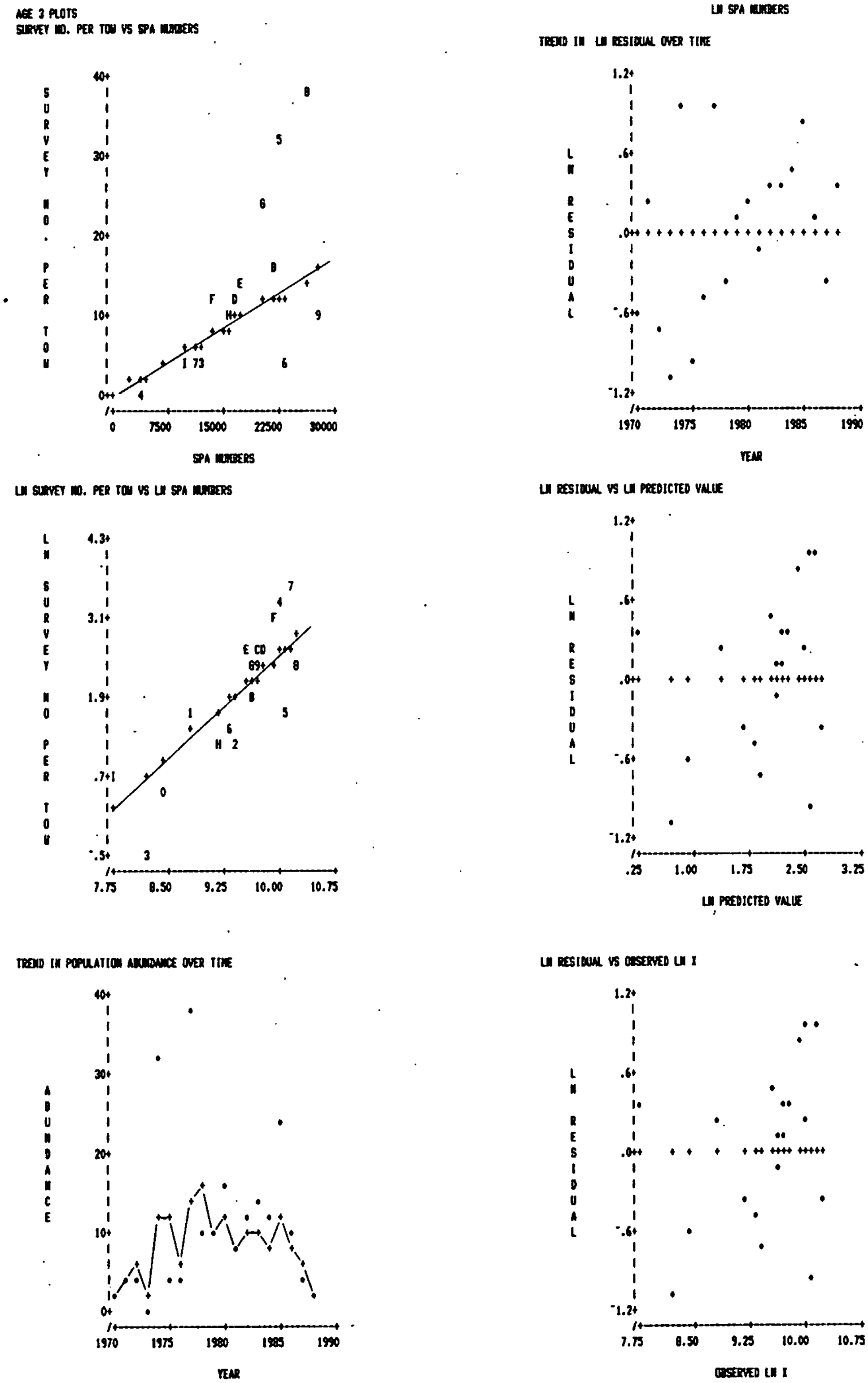


Figure 9. (Continued)

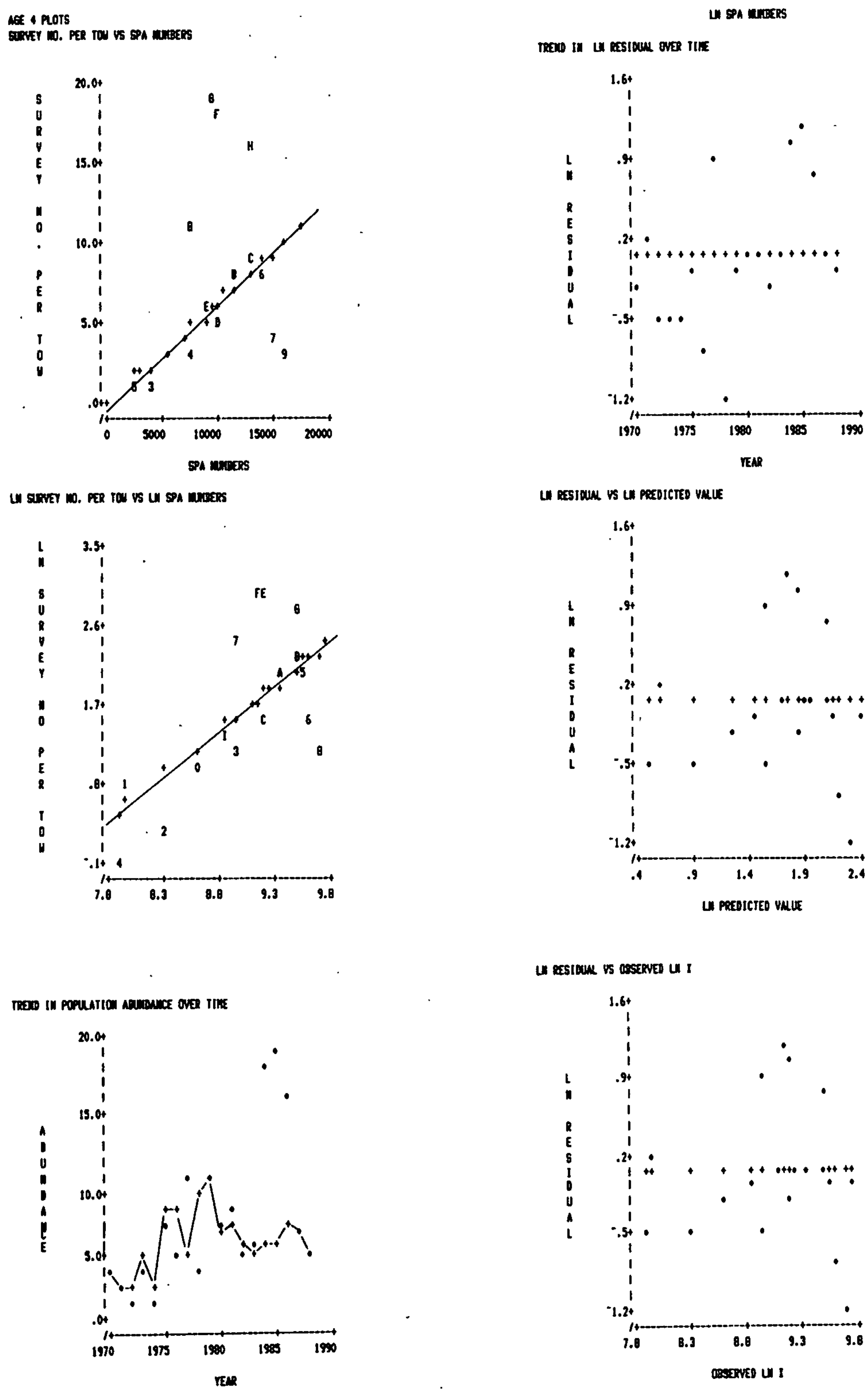
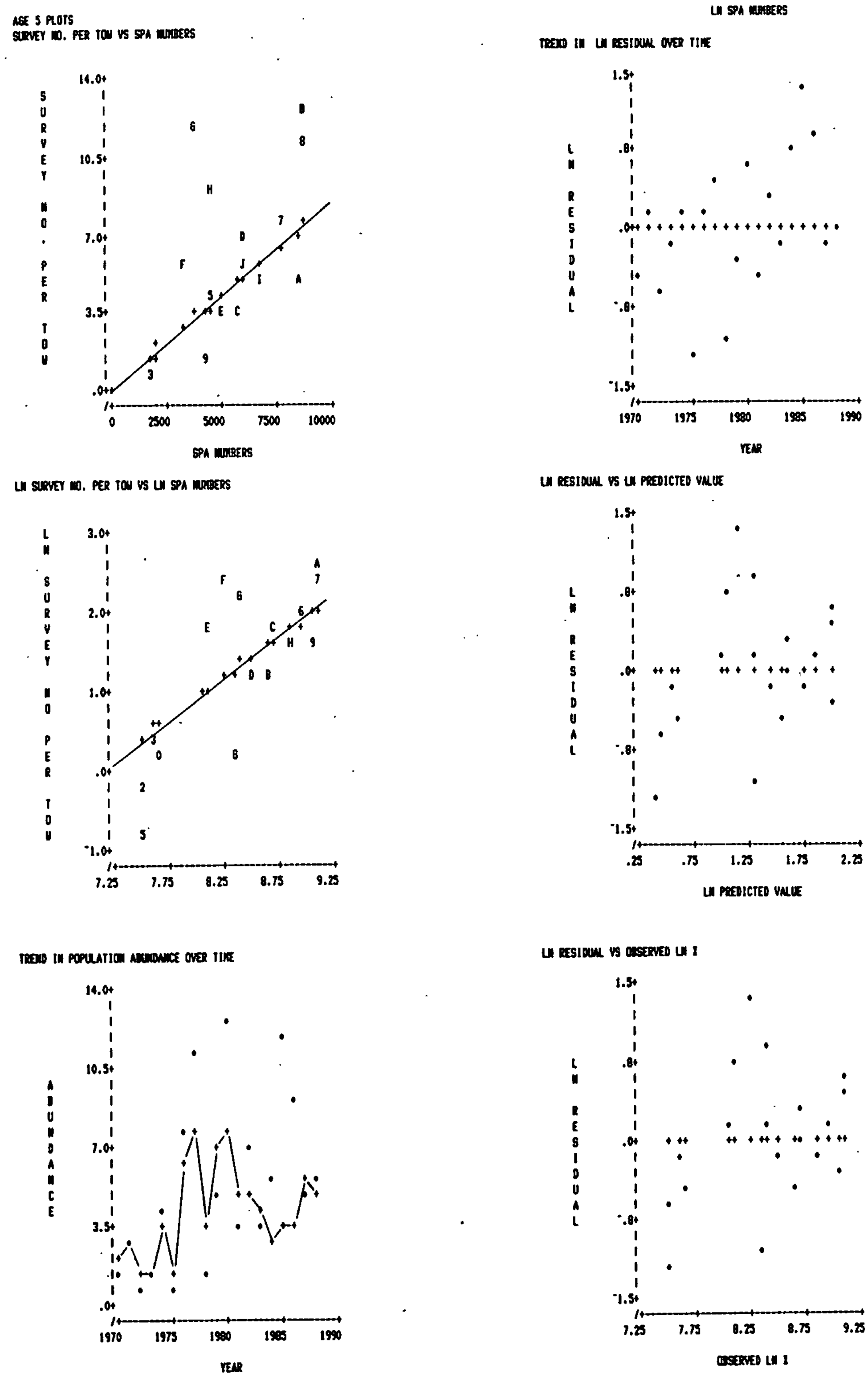


Figure 9. (Continued)



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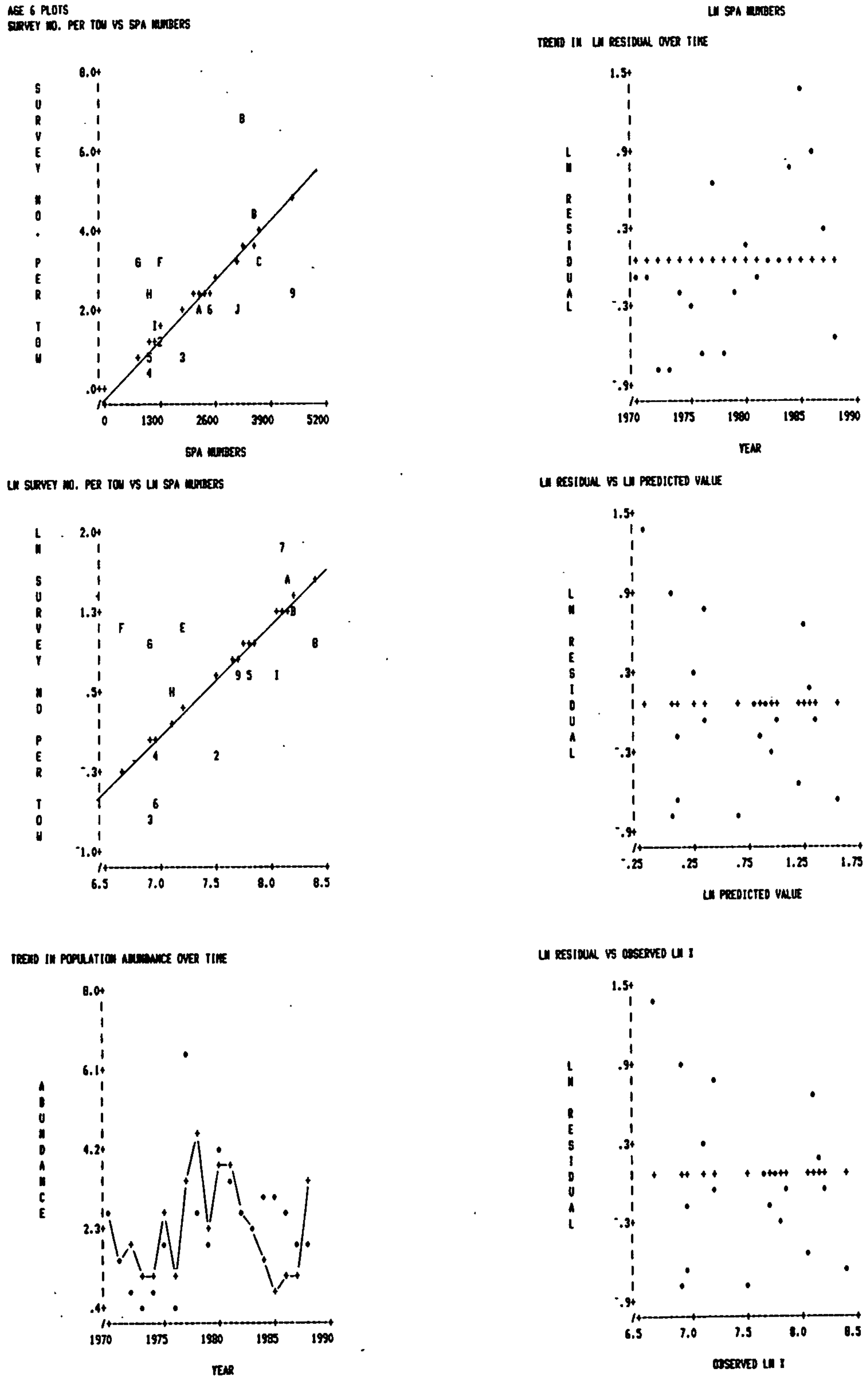

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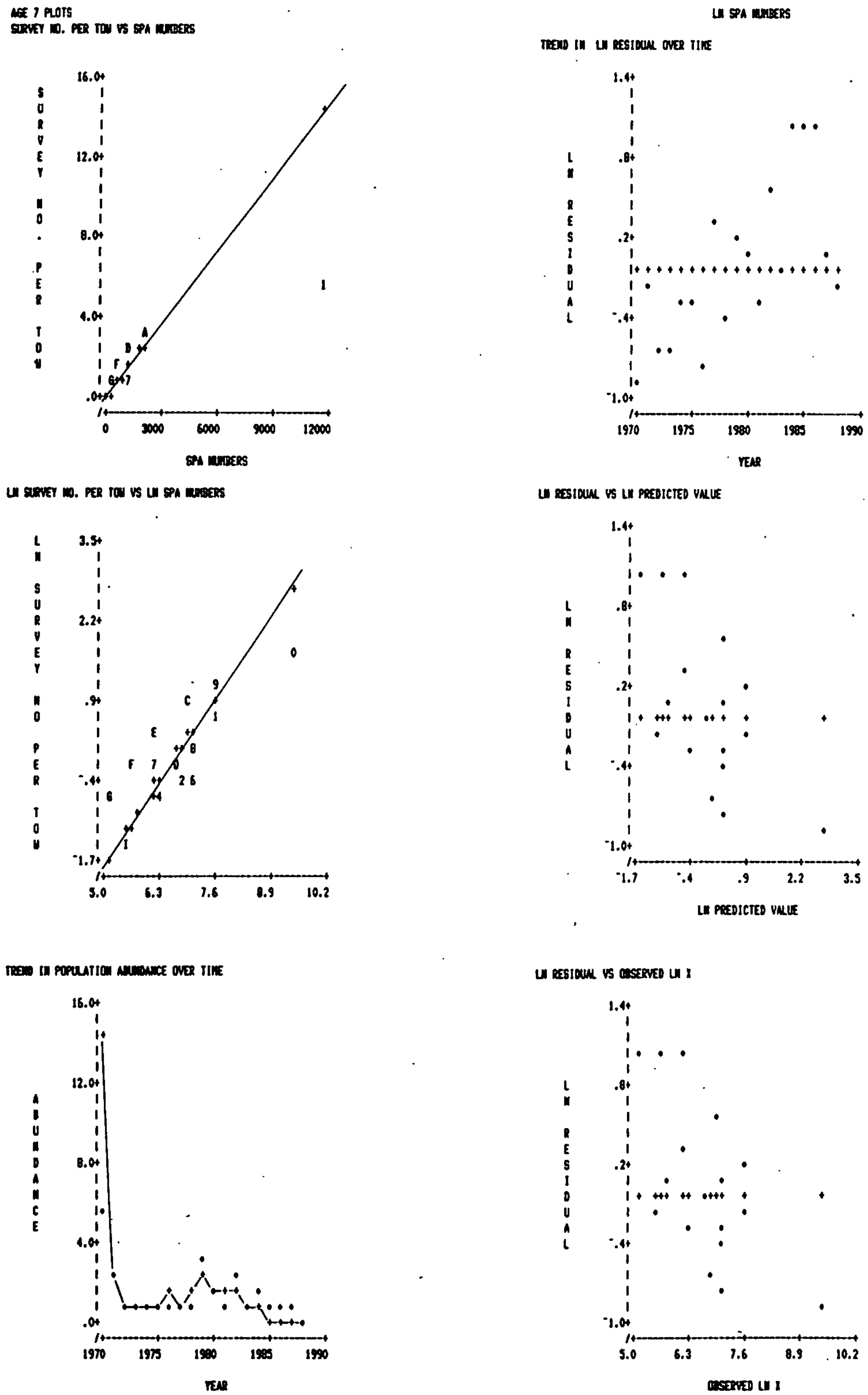

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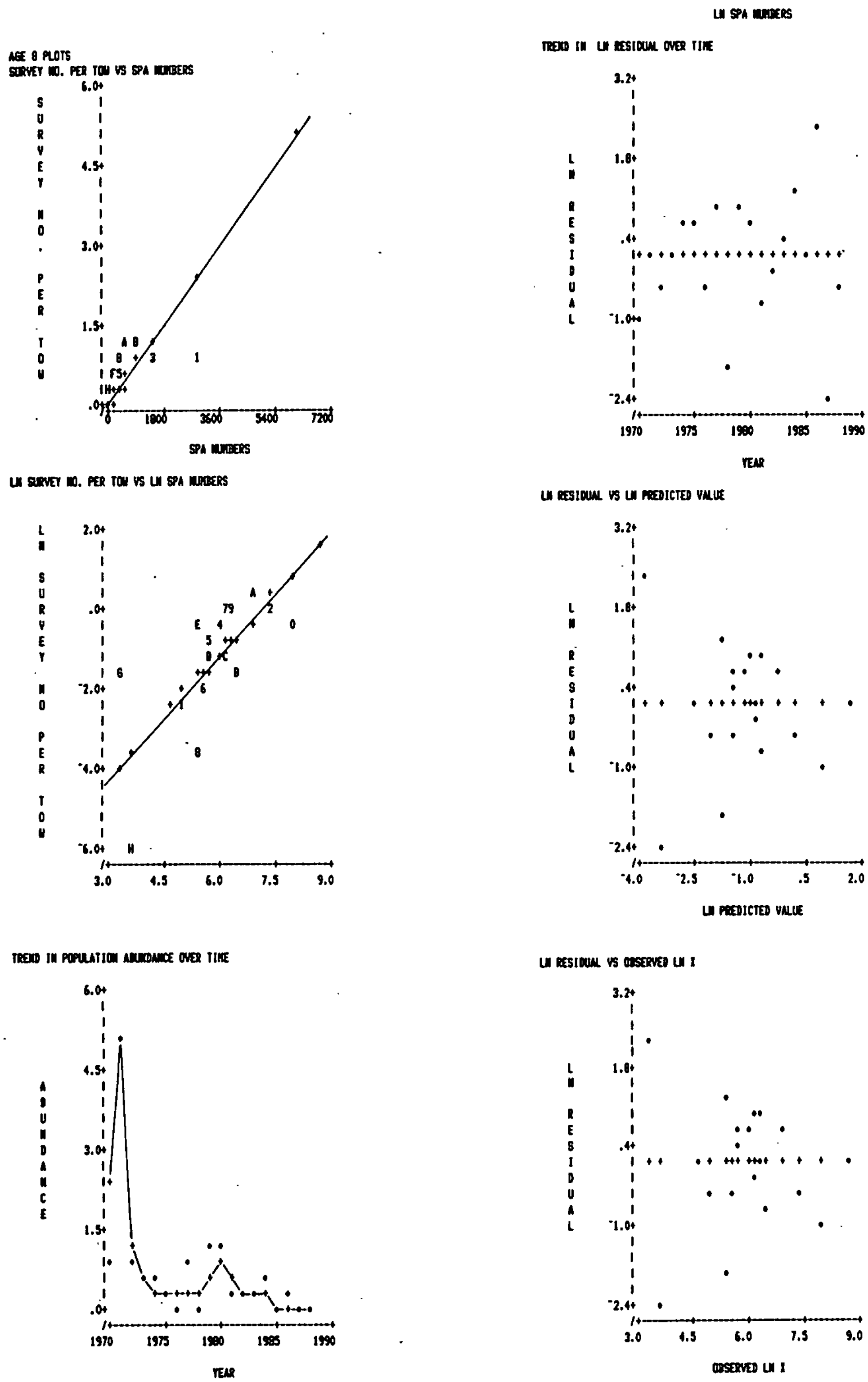


Figure 9. (Continued)

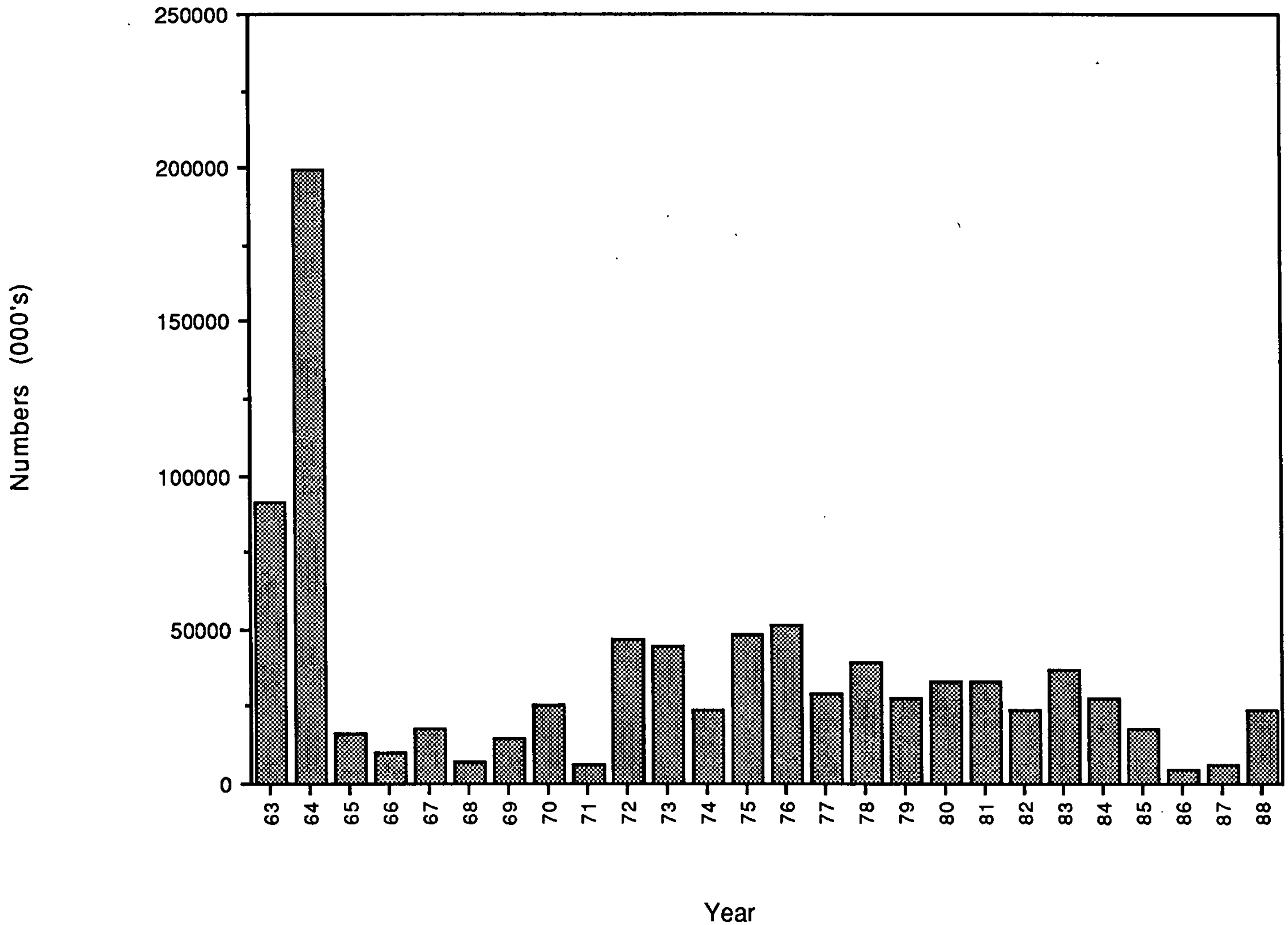


Figure 10. Trends in age one population numbers of the 4X haddock resource for 1963 - 1988. 1988 age one estimate is the geometric mean for 1970 - 87.

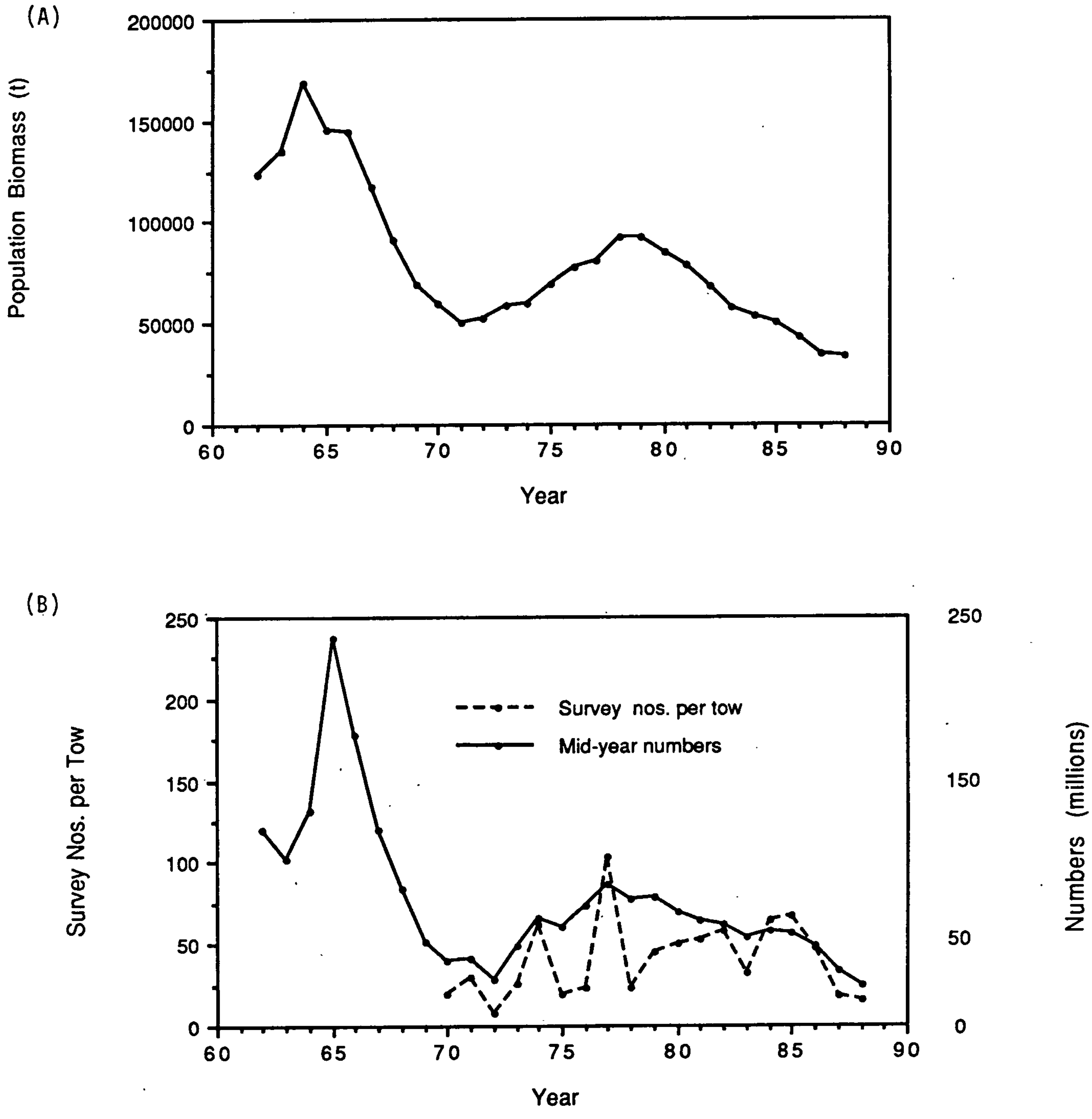


Figure 11. Trends in (A) mid-year population biomass and (B) age 2-8 survey and age 2-8 SPA mid-year numbers for the 4X haddock resource.

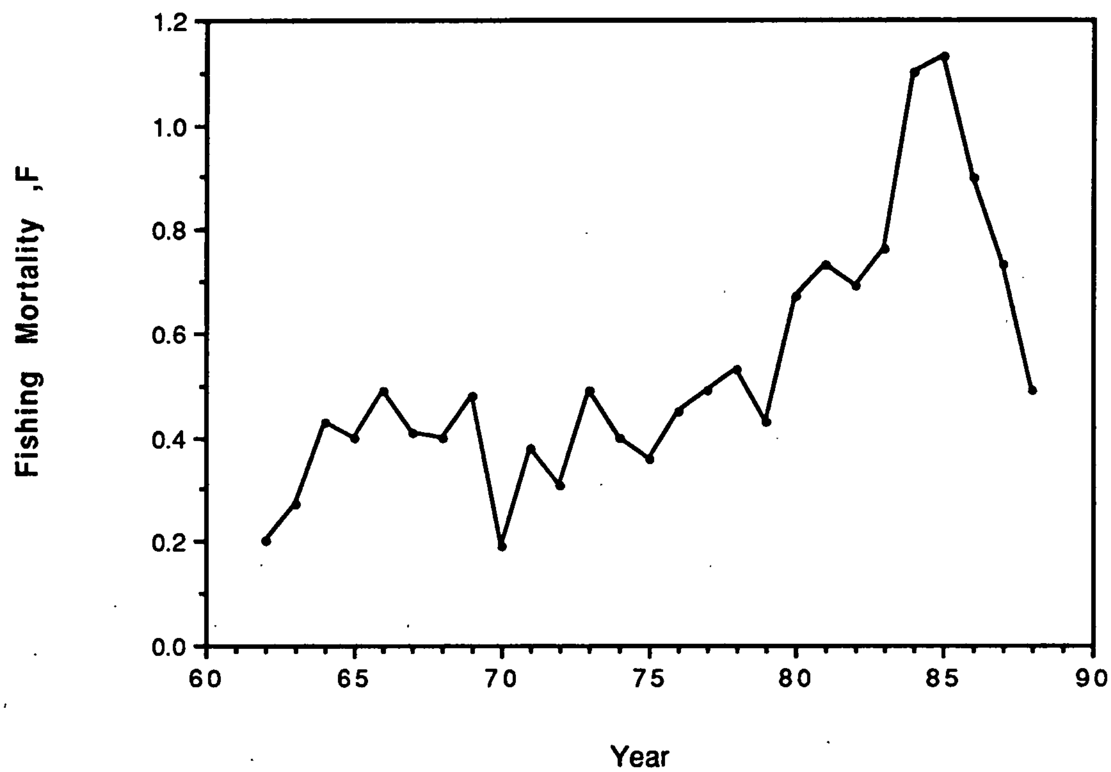


Figure 12. Trends in age 5-6 fishing mortality of the 4X haddock resource.

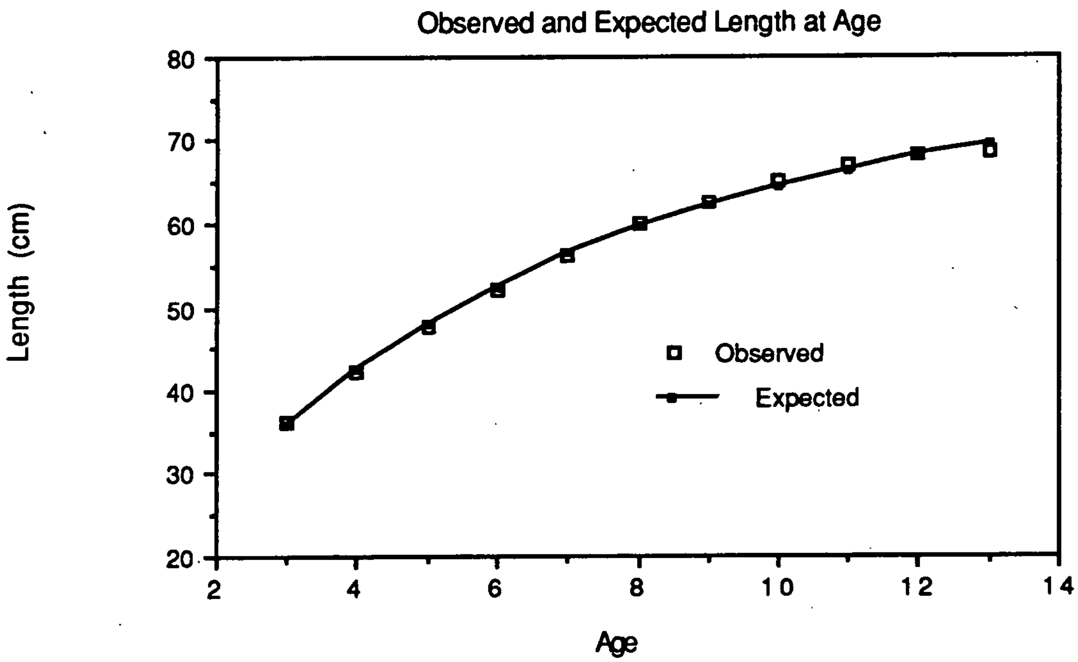


Figure 13. Observed and predicted lengths at age from Von Bertallanffy growth model.

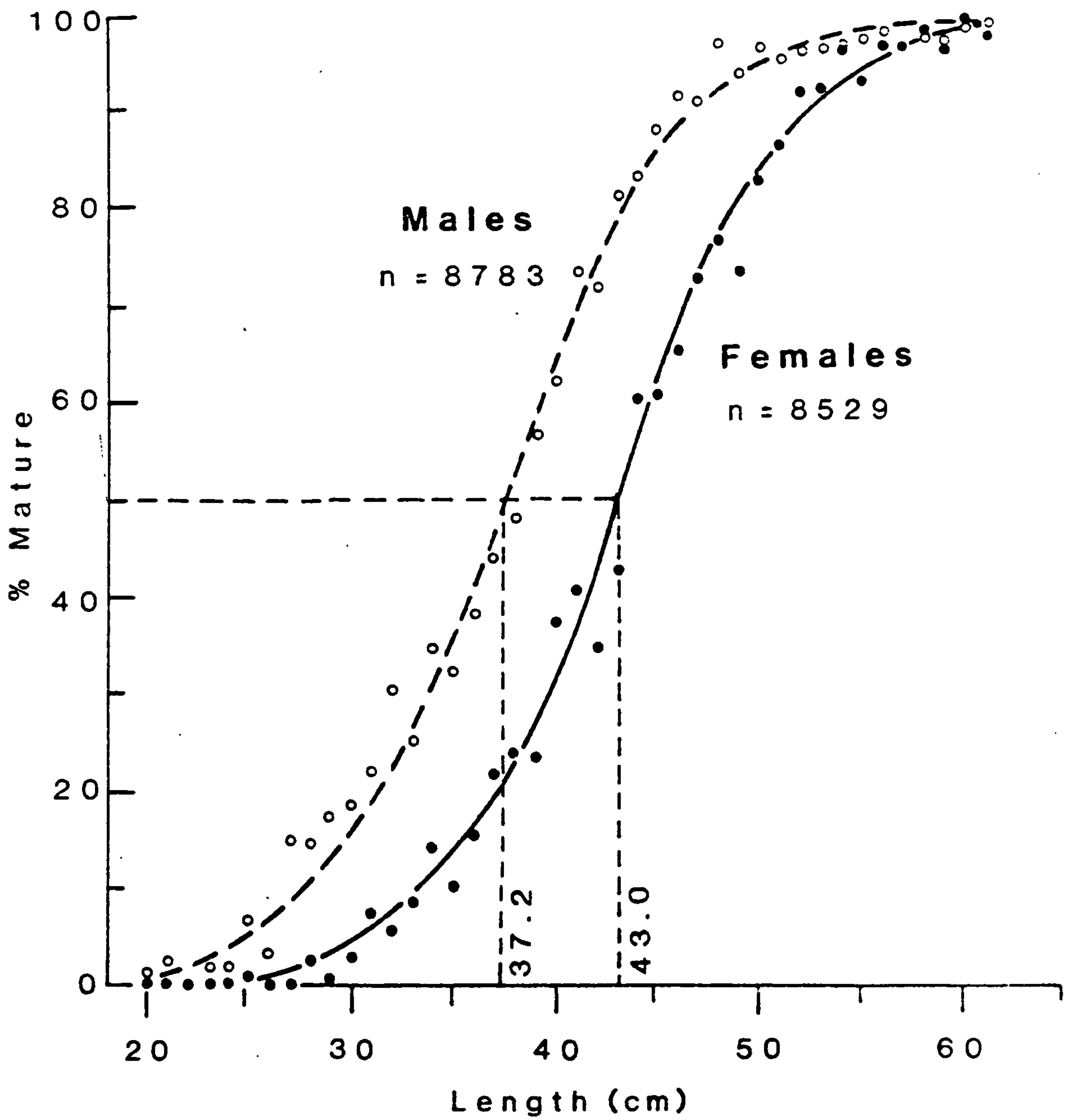


Figure 14. Maturity ogives for 4X haddock females and males. Taken from Waiwood and Buzeta (1989).

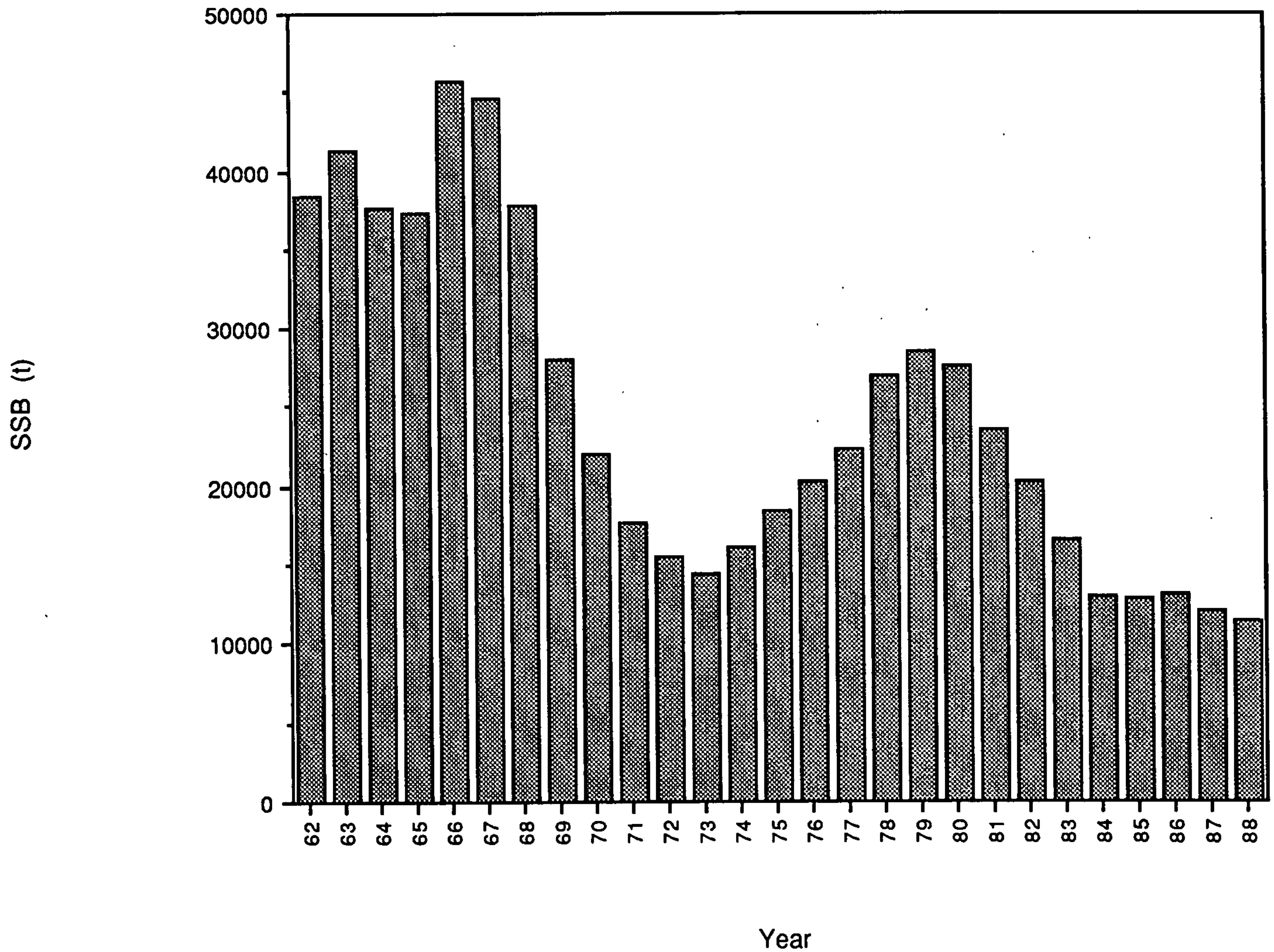


Figure 15. Trends in spawning stock biomass for 1962 - 88.

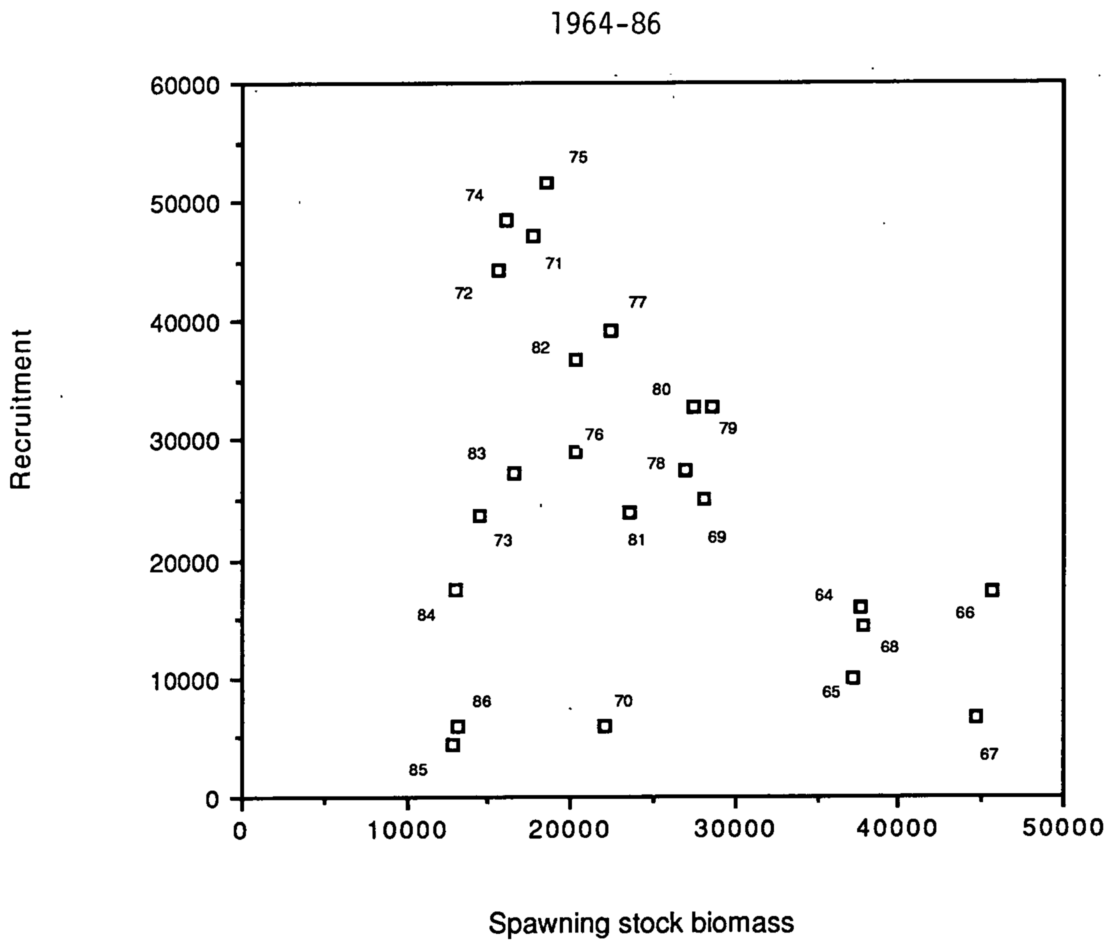
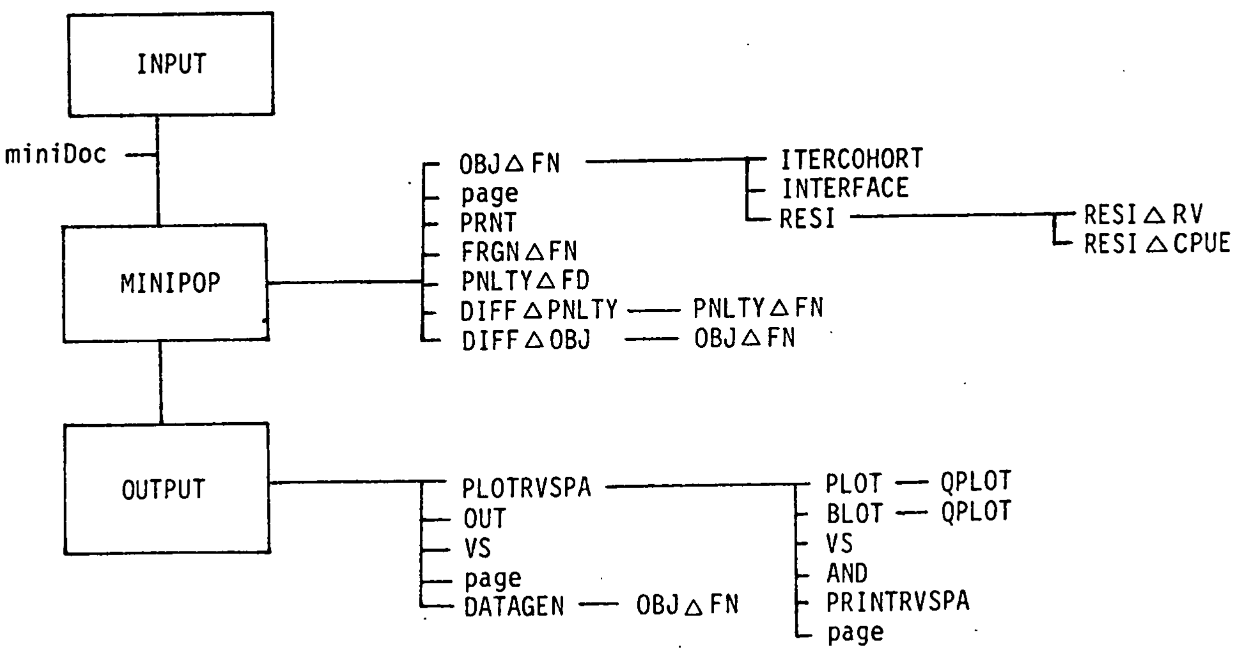


Figure 16. Relationship between spawning stock biomass and recruitment (at age 1) for the 4X haddock resource, 1964 - 86. The 1962 and 1963 year classes were not included in this analysis.

ANNEX 1.

List of functions used in the calibration of the 4X haddock assessment

AND	PLOT
BLOT	PLOTRVSPA
DATAGEN	PNLTY△FN
DIFF△OBJ	PRINTRVSPA
DIFF△PNLTY	PRNT
FRGN△FN	QPUT
INPUT	RESI
INTERFACE	RESI△CPUE
ITERCOHORT	RESI△RV
OBJ△FN	VS
OUT	miniDOC
OUTPUT	minipop
PAR△SE	page



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


      ∇BLOT[⎕]∇
[0]  A BLOT B;C;D;E;F;G;H;I;K;L;M;N;⎕IO;P;S;T;U;V;X;PVAL;COM;Q;CRTT
[1]   ⎕IO←1 ⋄ CRTT←5E¯11
[2]   S←⍎(,(0=⎕NC 2 2 ⍴'dxdy')≠ 2 3 ⍴'dx←dy←'),''' '''
[3]   ps←'+0123456789ABCDEFGHIJKLMNOPRSTUVWXYZ'
[4]   →(∧/ 1 2 ≠⍴⍴B)⍴L2
[5]   →((2=⍴⍴B)∧1≠1↑⍴B)/L1
[6]   B←(2,U)⍴(⍳U←⍴B),B
[7]  L1:→(1≠⍴⍴A)⍴L2
[8]   →(2 6 =⍴A)/L3,L7
[9]  L2:→0,0⍴⍞←'PARAMETRES NON VALIDES',Δcr
[10] L3:M←L4,(K←⌊1E¯3+(L←A[2])÷10),(⌈/B[1;]),⌊/B[1;] ⋄ →L5
[11] L4:H←I[P] ⋄ C←D[P]
[12]  M←L6,(E←⌊1E¯3+(G←A[1])÷5),(⌈/,T),⌊/,T← 1 0 ↓B
[13] L5:S← 10000 5000 2500 1000 500 100 50 25
[14]  →(0=M[2])/L2
[15]  →(0≠U←-/¯2↑M)/L5A
[16]  →0,0⍴⍞←'PAS DE VARIATION DANS X OU Y',Δcr
[17] L5A:S←S×10*¯4+⌈10⍟U←U÷M[2]
[18]  P←(M[3]≤(I←M[4]-S|M[4])+M[2]×D←V-S|V←1.25×U)⍳1 ⋄ →M
[19] L6:X←⌊1.5+(B[1;]-H)×10÷C
[20]  T←⌊0.5+(T-I←I[P])×5÷D←D[P] ⋄ →L8
[21] L7:K←⌊1E¯3+(L←A[4])÷10
[22]  E←⌊1E¯3+(G←A[1])÷5
[23]  X←(F←(0≤X)∧X≤L+1)/X←⌊1.5+(B[1;]-H←A[5])×10÷C←A[6]
[24]  T←F/⌊0.5+((T← 1 0 ↓B)-I←A[2])×5÷D←A[3]
[25] L8:M←(⌊10⍟|D)-0,⍳B←10
[26]  M←M[1⍳⌊(∧/(CRTT×D⌈⌈/P)≥M∘.|P←|I+D×¯1+⍳E+1)⍳1]
[27]  S← 10 ¯3 ⋄ →((S<P←1+⌊10⍟⌈/P)∨M<¯7)/L9
[28]  S←10,0⌈(S-P⌈1)⌊-M
[29] L9:Q←(V\S⍕⊖(D×¯1+⍳E+1)∘.+,I),'|+'[1+V←⊖0=S|¯1+⍳1+P←G]
[30]  U←((-⌊(U-×/⍴dy)÷2)⌽(U←G+1)↑dy),Q
[31]  XPS←(⍴T)⍴1
[32]  XPS[1;]←(¯1↑⍴T)⍴1+⍳⍴ps
[33]  X←,XPS+1000×(⍴T)⍴X
[34]  T←,T
[35] L10:PVAL←(U[1+G-P;]),(L+1)⍴' '
[36]  →(0=⍴S←(T=P)/X)/L12
[37]  S←(S≠0,¯1↓S)/S←S[⍋S]
[38]  PVAL[(¯1↑⍴U)+⌊S÷1000]←ps[1000|S]
[39] L12:⎕PUT '      ',PVAL
[40]  →(0≤P←P-1)/L10
[41]  ⎕PUT(16⍴' '),'/',(L+1)⍴'+---------'
[42]  M←(⌊10⍟|C)-0,⍳10
[43]  M←M[1⍳⌊(∧/(CRTT×C⌈⌈/P)≥(10*M)∘.|P←|B←H+C×¯1+⍳K+1)⍳1]
[44]  S←10-3 ⋄ →((S<P←1+⌊10⍟⌈/P)∨M<¯7)/L13
[45]  S←10,0⌈(S-P⌈1)⌊-M
[46] L13:⎕PUT(8⍴' '),S⍕B
[47]  →(0=×/⍴dx)⍴0
[48]  ⎕PUT ⎕TCLF,((18+⌊0.5×L-×/⍴dx)⍴' '),dx


      ∇DATAGEN[⎕]∇
[0]  DATAGEN PAR;RESID
[1]   RESID←OBJΔFN PAR
[2]  S1:RESIDΔRV←((⍴ROWS),1↓¯1↑⍴c)⍴RESID
[3]   RESIDΔCPUE←(-⍴,⍳Δcpue)↑RESID


      ∇DIFFΔOBJ[⎕]∇
[0]  R←DIFFΔOBJ;DELTA;I;TPAR
[1]  ⍝ CALCULATES ONE SIDED DIFFERENCE OF OBJECTIVE FUNCTION
[2]   I←1
[3]   R←(N,0)⍴1
[4]   DELTA←(0.01×par)+0.01×par=0
[5]  L1:TPAR←((I-1)↑par),(par[I]+DELTA[I]),I↓par
[6]   R←R,(e-OBJΔFN TPAR)÷DELTA[I]
[7]   →L1×P≥I←I+1


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


      ∇FRGNΔFN[⎕]∇
[0]  R←FRGNΔFN A
[1]   R←∧/(A)lbnd),A<ubnd
[2]  ⍝ THIS FUNCTION SHOULD RETURN A 1 IF THE PARAMETERS
[3]  ⍝ ARE IN THE FEASIBLE REGION AND 0 OTHERWISE
[4]  ⍝ R←1 DEFAULT RETURNS 1
```

```
     ∇INPUT[⎕]∇
   INPUT;ANS
    c←⎕EX 'K'
    ⍎(0=⎕NC 'STOCK∆NAME')/'''STOCK NAME?''⋄STOCK∆NAME←⍞'
    'CATCH MATRIX FOR ',STOCK∆NAME
    c←⎕
    'FIRST YEAR AND YOUNGEST AGE IN CATCH MATRIX ? '
    ANS←⎕
    YR←((1↑ANS)-1)+⍳¯1↑⍴c
    AG←((¯1↑ANS)-1)+⍳1↑⍴c
    'ENTER PARTIAL RECRUITMENT VECTOR FOR ALL AGES'
    PR←⎕
    'ASSUMED AGES OF FULL RECRUITMENT (START WITH FIRST FULLY RECRUITED AGE) ? '
    AGE←AG⍳⎕
    'PRESENCE OR ABSENCE OF PLUS GROUP (P/A) ? '
    NUM←'P'=⍞
    'NATURAL MORTALITY ? '
    m←⎕
    'ENTER STARTING ESTIMATES OF AGE-SPECIFIC FS (TO BE ESTIMATED) FOR LAST YEAR '
    ' EXCLUDE VALUE FOR PLUS ( IF ANY) GROUP '
    FLY←⎕
    'AGES IN CALIBRATION INDEX ? '
    ROWS←AG⍳AGES←⎕
    FRST←1↑ROWS ⋄ LAST←¯1↑ROWS
    'ENTER FIRST AND LAST AGES TO CALIBRATE'
    FAG←⎕
    FRST←FAG[1]
    LAST←FAG[2]
    'STARTING ESTIMATES OF YEAR-SPECIFIC FS FOR OLDEST'
    ' NON-PLUS GROUP AGE (ENTER 0 IF NOT DESIRED)'
    FAG←⎕
    FVECT←FLY[¯1+FRST+⍳1+LAST-FRST],1↓⌽FAG
    CVECT←,c[(¯1+FRST+⍳1+LAST-FRST);¯1↑⍴c]
    →(FAG=0)/S1
    CVECT←CVECT,1↓⌽,c[LAST;]
   S1:NVECT←(CVECT×(FVECT+m))÷(FVECT×(1-*-FVECT+m))
    lbnd←CVECT
    ubnd←(⍴NVECT)⍴10000000
    'RV INDEX OF ABUNDANCE'
    '                SAME YEARS AS CATCH AT AGE MATRIX '
    '                SAME AGES AS CALIBRATION BLOCK'
    'ENTER 0 IF NO RV INDEX'
    INDEX∆TYPE← 0 0 ⍝ Indicator of indices available (RV,CPUE)
    i∆rv←⎕
    →(0=+/+/i∆rv)/cpue ⍝ No RV index so go to cpue input
    INDEX∆TYPE[1]←1
    'ESTIMATES OF STANDARD ERROR OF INDEX  (ENTER 1 IF LOG MODEL)? '
    ise∆rv←(⍴i∆rv)⍴,⎕
    MASKRV←(⍴ise∆rv)⍴1
    MASKRV[1;19]←0
    WEIGHTRV←(÷ise∆rv)×MASKRV
    'INDEX FOR WHAT MONTH ( NO. FROM 1 TO 12 ) ? '
    MNTH←⎕÷12
    'STARTING AGE - SPECIFIC COEFFICIENTS FOR RV INDEX'
    ' '
    ' MATRIX OF AGE BY AGE COEFFICIENTS (1 OR 2 COLUMNS)'
    (1≠+/+/ise∆rv)/' MODEL IS     I = [B0] + B1 × POP '
    (1=+/+/ise∆rv)/' LOG MODEL IS    LN(I) = LN( [B0] + B1 × POP ) '
    ' '
    K←⎕
    lbnd←lbnd,(⍴,K)⍴(-¯1↑⍴K)↑ ¯9000 0 ⍝ MIN SLOPE =0, MIN INTER.=¯9000
    ubnd←ubnd,(⍴,K)⍴9000 ⍝ MAX SLOPE AND INTER. = 9000
   cpue:'CPUE INDEX OF ABUNDANCE'
    '                SAME YEARS AS CATCH AT AGE MATRIX'
    'ENTER 0 IF NO CPUE INDEX'
    i∆cpue←⎕
    →(0=+/+/i∆cpue)/exit ⍝ No cpue index so go to exit
    INDEX∆TYPE[2]←1
   l1:'ESTIMATES OF STANDARD ERROR OF CPUE?  (NO LOG MODEL OPTION) '
    ise∆cpue←⎕
    →((⍴i∆cpue)≠⍴ise∆cpue)/l1 ⍝ must be same length as i∆cpue
    'ENTER MEAN WEIGHTS AT AGE - SAME YEARS AND AGES AS CATCH'
    MWT←⎕
    'STARTING COEFFICIENTS FOR CPUE INDEX (AGE AGGREGATED)'
    ''
    →(0=⎕NC 'K')/norv
    'ENTER ',(⍕¯1↑⍴K),' VALUE(S) FOR COEFFICIENT(S)'
    K←K⍪⎕
    →exit1
   norv:
    'ENTER 1 (SLOPE) OR 2 (INTERCEPT AND SLOPE) COEFFICIENTS'
    K←(1,⍴,K)⍴K←,⎕
   exit1:lbnd←lbnd,((⍳1-¯1↑⍴K)↑¯9000),0
    ubnd←ubnd,((⍳1-¯1↑⍴K)↑9000),9000
   exit:initial←NVECT,,K
    alpha←1E¯3×NVECT
    limit←100
    WEIGHT←WEIGHTRV×(+/+/MASKRV)÷+/+/WEIGHTRV
    'Penalty constraints ON initially (Y/N)? Default is OFF'
    USE∆CONSTRAINTS←0
    ⍎(('Y'=ANS)∨'y'=ANS←⎕INKEY)/'USE∆CONSTRAINTS←1'
    'Penalty functions turned ',(2 3 ⍴'OFFON ')[1+USE∆CONSTRAINTS;]
    ' '
    'Ready to run minipop'
```

```
     ∇INTERFACE[0]∇
 INTERFACE POPN;pr;FRF;TAKE
 ⍝ Produces 1 or 2 global variables POPIND and FBIOM
  →(0=INDEXΔTYPE[1])/CPUE
  POPN[1;¯1↑⍴POPN]←*((+/⍟¯4↓,POPN[1;])÷⍴¯4↓,POPN[1;])
  POPIND←POPN×*-(F+m)×MNTH ⍝ Adjusts SPA population to the survey month
  POPIND←POPIND[ROWS;] ⍝ selects calibration block
 CPUE:→(0=INDEXΔTYPE[2])/EXIT
  FRF←(+⌿(POPN×F)[AGE;])÷+⌿POPN[AGE;] ⍝ Calculates fully recruited F
  pr←1⌈F÷(⍴F)⍴FRF ⍝ calculates PR matrix
  pr[AGE;]←1 ⍝ Sets defined fully recruited ages to 1
  FBIOM←+⌿POPN×pr×MWT
 EXIT:
```

```
     ∇ITERCOHORT[0]∇
 ITERCOHORT;CATCH;J;MORT;FI;FC;ITER;I;Y;X;FCNEW;DIFF1
  CATCH←c
  J←¯1↑⍴CATCH
  MORT←(⍴CATCH)⍴m
  F←(⍴CATCH)⍴0
  FI←FLY
  →(NUM=0)/S3
  FI←FI,¯1↑FI
 S3:→(FAG=0)/S2
  FC←FAG
  →S1
 S2:FC←(¯1↑⍴CATCH)⍴(¯1↑FI)
 S1:ITER←0
 OK9:I←⍴FI
  F[(⍳I);J]←I⍴FI
  F[I;]←J⍴FC
  ITER←ITER+1
  →(ITER≥20)/0
  POP←(⍴CATCH)⍴0
  POP[(⍳I);J]←((,CATCH[(⍳I);J])×FI+(,MORT[(⍳I);J]))÷FI×1-*-FI+(,MORT[(⍳I);J])
  POP[I;]←((,CATCH[I;])×FC+(,MORT[I;]))÷FC×1-*-FC+(,MORT[I;])
  →(NUM=0)/SK1
  I←I-1
  POP[I;]←((,CATCH[I;])×FC+(,MORT[I;]))÷FC×1-*-FC+(,MORT[I;])
  F[I;]←J⍴FC
 SK1:Y←J-1
 AA:X←MORT[⍳I-1;Y]
  POP[⍳I-1;Y]←(CATCH[⍳I-1;Y]×*X÷2)+(POP[1+⍳I;Y+1]×*X)
  →(1≤Y←Y-1)/AA
  F[⍳I-1;⍳J-1]←(⍟(¯1 ¯1 ↓POP[⍳((1↑⍴POP)-NUM);])÷ 1 1 ↓POP[⍳((1↑⍴POP)-NUM);])- ¯1 ¯1 ↓MORT[⍳(
(1↑⍴POP)-NUM);]
  →(FAG≠0)/0
  FCNEW←(+/[1]POP[AGE;]×F[AGE;])÷+/[1]POP[AGE;]
  DIFF1←|(FCNEW-FC)÷FCNEW
  FC←(¯1↓FCNEW),¯1↑FC
  →((⌈/¯1↓DIFF1)>0.01)/OK9
```

```
     ∇OBJΔFN[0]∇
 R←OBJΔFN A
  s←(⍴NVECT)⍴A ⍝ survivors at designated age
  FVECT←(⍟s÷(s-CVECT×*m÷2)×*-m)-m
  →(∧/PR=1)/NOPR ⍝ skips PR if no PR was imposed
  FRF←(+/((1↑AGE)-FRST)↓FVECT×s)÷+/((1↑AGE)-FRST)↓s ⍝ fully recruited F
  FLY←PR×FRF
 NOPR:FLY[¯1+FRST+⍳1+LAST-FRST]←FVECT
  →(FAG=0)/S1
  FAG←(⌽(⍴FAG)↑⌽FVECT)
 S1:k←((INDEXΔTYPE[2]+⍴ROWS),(¯1↑⍴K))⍴(-(INDEXΔTYPE[2]+⍴ROWS)×¯1↑⍴K)↑A
 ⍝ k is the current calibration coefficients
  ITERCOHORT
  INTERFACE POP
  R←,RESI k ⍝ calculate index residuals
```

```
     ∇OUT[0]∇
 A OUT B;C;D;W;Y;PW
  A←,⍉(2,¯1↑⍴B)⍴(5⌈4+(A≠0)+A+⌊10⍟1⌈⌈/[1]B),(¯1↑⍴B)⍴A
  PW←(20+⍴TIT)⌈(⎕PW)⌊4++/((⍴A)⍴ 1 0)/A
  Y←YR
  ' '
  ((¯B+PW)↑((⌊0.5×PW-⍴TIT)⍴' '),TIT),DAT
 SK1:' '
  C←¯1+(⎕PW<4++\A[¯1+2×⍳0.5×⍴A])⍳1
  D←(2×C⌊⍴Y)↑A
  D[2×⍳C⌊⍴Y]←0
  '    |',D⍕(C⌊⍴Y)↑Y
  '———+',(+/A[¯1+2×⍳C])⍴'-'
  (2 0 ⍕((⍴AG),1)⍴AG),(((⍴AG),2)⍴' |'),((2×C)↑A)⍕((⍴AG),C)↑B
  ((((1↑⍴B)-⍴AG),4)⍴'   |'),((2×C)↑A)⍕(((⍴AG)-1↑⍴B),C)↑B
  A←(2×C)↓A
  B←(0,C)↓B
  Y←C↓Y
  →(0≠⍴A)/SK1
```

```
      ∇OUTPUT[⎕]∇
 OUTPUT;TIT;dx;dy;ag;yr
  ' '
  'RSS Trajectory by Iteration ',STOCK∆NAME,'          ',∆ts
  dx←'ITERATION NUMBER'
  dy←'RESIDUAL SS'
  20 40 PLOT rssvec VS(⍳⍴rssvec)
  I←1
  ' '
  ' CALIBRATION COEFFICIENTS BY AGE FOR ',STOCK∆NAME,'       ',∆ts
  ' '
  →((¯1↑⍴k)=1)/S2
S1:'AGE ',(2 0 ⍕AGES[I]),' :  I = ',(10 3 ⍕k[I;1]),'      +',(10 3 ⍕k[I;2]),' × POP'
  →((⍴ROWS)≥I←I+1)/S1
  →NEXT
S2:'AGE ',(2 0 ⍕AGES[I]),' :  I = ',(10 3 ⍕k[I;1]),' × POP'
  →((⍴ROWS)≥I←I+1)/S2
NEXT:' '
  ' MODEL MEAN SQUARE RESIDUALS : ',⍕msr
  page ∆ts
  DATAGEN par
  TIT←'POPULATION NUMBERS (000S)'
  0 OUT POP,[1]+/[1]POP
  TIT←'FISHING MORTALITY'
  page ∆ts
  3 OUT F
  TIT←'Standardized Residuals for RV index (s.e.=1 for log model)'
  ag←AG
  yr←YR←(YR[1]-1)+⍳¯1↑⍴RESID∆RV
  AG←AGES
  page ∆ts
  3 OUT RESID∆RV
  ' '
  'AVG. RESIDUALS BY AGE  : ', 8 3 ⍕(+/[2]RESID∆RV)÷+/[2]MASKRV
  'AVG. RESIDUALS BY YEAR : ', 8 3 ⍕(+/[1]RESID∆RV)÷+/[1]MASKRV
  'AVG. TOTAL RESIDUAL    : ', 8 3 ⍕(+/+/RESID∆RV)÷+/+/MASKRV
  ' '
  TIT←'PERCENT STANDARDIZED SUM OF SQUARES OF RESIDUALS FOR RV INDEX'
  2 OUT 100×(RESID∆RV*2)÷(⍴RESID∆RV)⍴+/+/(RESID∆RV*2)
  →(INDEX∆TYPE[2]=0)/NOCPUE
  ''
  AG←,0
  TIT←'Standardized residuals for CPUE index'
  3 OUT(1,⍴RESID∆CPUE)⍴RESID∆CPUE
NOCPUE:page ∆ts
  ' '
  'ESTIMATED PARAMETERS AND STANDARD ERRORS'
  PAR∆SE
  TIT←'Parameter Correlation Matrix'
  AG←YR←⍳1↑⍴corr
  3 OUT corr
  AG←ag ⋄ YR←yr
  ''
  'Output Age-by-Age Plots? (Y/N) Default is NO'
  ⍎(~('Y'=ANS)∨'y'=ANS←⎕INKEY)/'→0'
  PLOTRVSPA ⍳∆rv


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


      ∇PLOT[⎕]∇
 A PLOT B;C;D;E;F;G;H;I;K;L;M;N;⎕IO;P;S;T;U;V;X;PVAL;COM;Q;CRTT;ps
  ⎕IO←1 ⋄ CRTT←5E¯11
  B←⍎(,(0=⎕NC 4 2 ⍴'dxdyJ ps')⌿ 4 3 ⍴'dx←dy←Q⍴ ps←'),'''∘←∆×∇⎕'''
  →(^/ 1 2 ≠⍴⍴B)⍴L2
  →((2=⍴⍴B)^1≠1↑⍴B)/L1
  B←(2,U)⍴(⍳U←⍴B),B
L1:→(1≠⍴⍴A)⍴L2
  →(2 6 =⍴A)/L3,L7
L2:→0,0⍴⎕←'PARAMETRES NON VALIDES',∆cr
L3:M←L4,(K←⌊1E¯3+(L←A[2])÷10),(⌈/B[1;]),⌊/B[1;] ⋄ →L5
L4:H←I[P] ⋄ C←D[P]
  M←L6,(E←⌊1E¯3+(G←A[1])÷5),(⌈/,T),⌊/,T← 1 0 ↓B
L5:B← 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←B×10*¯4+⌈10⍟U←U÷M[2]
  P←(M[3]≤(I←M[4]-S|M[4])+M[2]×D←V-S|V←1.25×U)⍳1 ⋄ →M
L6:X←⌊1.5+(B[1;]-H)×10÷C
  T←⌊0.5+(T-I←I[P])×5÷D←D[P] ⋄ →L8
L7:K←⌊1E¯3+(L←A[4])÷10
  E←⌊1E¯3+(G←A[1])÷5
  X←(F←(0≤X)^X≤L←1)/X←⌊1.5+(B[1;]-H←A[5])×10÷C←A[6]
  T←F/⌊0.5+((T← 1 0 ↓B)-I←A[2])×5÷D←A[3]
L8:M←(⌊10⍟|D)-0,⍳B←10
  M←M[1⍳1⌊(^/(CRTT×⌈⌈/P)≥M∘.|P←|I←D×¯1+⍳E←1)⍳1]
  S← 10 ¯3 ⋄.→((B<P←1←⌊10⍟⌈/P)∨M<¯7)/L9
  S←10,0⌈(B-P⌈1)⌊-M
L9:Q←(V⌽S⍕Q(D×¯1+⍳E←1)∘.+,I),'|←'[1+V←Q0=5|¯1+⍳1+P←G]
  U←((-⌊(U-×/⍴dy)÷2)⌽(U←G+1)↑dy),Q
  X←,((⍴T)[1]⍴⍳⍴ps)∘.+1000×X ⋄ T←,T
L10:PVAL←(U[1+G-P;]),(L+1)⍴' '
  →(0=⍴S←(T=P)/X)/L12
  S←(S≠0,¯1↓S)/S←S[⍋S]
  PVAL[(¯1↑⍴U)+⌊S÷1000]←ps[1000|S]
L12:⍞PUT '      ',PVAL
  →(0≤P←P-1)/L10
  ⍞PUT(16⍴' '),'/',(L+1)⍴'+---------'
  M←(⌊10⍟|C)-0,⍳10
  M←M[1⍳1⌊(^/(CRTT×C⌈⌈/P)≥(10*M)∘.|P←|B←H←C×¯1+⍳K←1)⍳1]
  S←10-3 ⋄ →((B<P←1←⌊10⍟⌈/P)∨M<¯7)/L13
  S←10,0⌈(B-P⌈1)⌊-M
L13:⍞PUT(8⍴' '),S⍕B
  →(0=×/⍴dx)⍴0
  ⍞PUT ⎕TCLF,((18+⌊0.5×L-×/⍴dx)⍴' '),dx
```

```
∇PLOTRVSPA[⎕]∇
PLOTRVSPA INDEX;DATA;DATALN;SCALE;ITER;dx;dy;SYM;RESID;ZZ
 SCALE← 20 40
 'OVERALL STANDARDIZED RESIDUALS VERSUS PREDICTED X'
 ' '
 dy←'RV STAND. RESIDUAL'
 dx←'PRED. RV INDEX'
 SCALE PLOT(,RESIDΔRV)AND((⍴,RESIDΔRV)⍴0)VS,ihatΔrv
 ' '
 ITER←1
 YR←(YR[1]-1)+⍳¯1↑⍴INDEX
 ''
 RESID←RESIDΔRV
 →(INDEXΔTYPE[2]=0)/S1
 page Δts
 'AGGREGATE CATCH RATE RESIDUAL VS PREDICTED VALUE '
 dy←'CPUE RESIDUAL'
 dx←'PREDICTED CPUE'
 SCALE PLOT RESIDΔCPUE VS ihatΔcpue

S1:page Δts
 ' '
 'AGE ',(⍕AGES[ITER]),' PLOTS '
 DATA←(0,INDEX[ITER;])AND(0,ihatΔrv[ITER;])VS(0,POPIND[ITER;])
 'SURVEY NO. PER TOW VS SPA NUMBERS'
 ' '
 dy←'SURVEY NO. PER TOW'
 dx←'SPA NUMBERS'
 ' '
 SCALE BLOT DATA
 DATA←INDEX[ITER;]AND ihatΔrv[ITER;]VS POPIND[ITER;]
 ' '
 →LN1
 'TREND IN STANDARDIZED RESIDUAL OVER TIME'
 ' '
 dy←'RESIDUAL'
 dx←'YEAR'
 SCALE PLOT(RESID[ITER;])AND((⍴YR)⍴0)VS YR
 '  '
 'STD. RESIDUAL VS PREDICTED VALUE'
 ' '
 dx←'PREDICTED VALUE'
 SCALE PLOT RESID[ITER;]AND((⍴ihatΔrv[ITER;])⍴0)VS ihatΔrv[ITER;]
 ' '
 'RESIDUAL VS OBSERVED X'
 ' '
 dx←'OBSERVED X'
 SCALE PLOT RESID[ITER;]AND((⍴POPIND[ITER;])⍴0)VS POPIND[ITER;]
 →S2
LN1:
 DATALN←(⍟INDEX[ITER;])AND(⍟ihatΔrv[ITER;])VS(⍟POPIND[ITER;])
 'LN SURVEY NO. PER TOW VS LN SPA NUMBERS'
 ' '
 dy←'LN SURVEY NO PER TOW'
 dx←'LN SPA NUMBERS'
 ' '
 SCALE BLOT DATALN
 ' '
 'TREND IN  LN RESIDUAL OVER TIME'
 ' '
 dy←'LN RESIDUAL'
 dx←'YEAR'
 SCALE PLOT(RESID[ITER;])AND((⍴YR)⍴0)VS YR
 '  '
 'LN RESIDUAL VS LN PREDICTED VALUE'
 ' '
 dx←'LN PREDICTED VALUE'
 SCALE PLOT RESID[ITER;]AND((⍴ihatΔrv[ITER;])⍴0)VS⍟ihatΔrv[ITER;]
 ' '
 'LN RESIDUAL VS OBSERVED LN X'
 ' '
 dx←'OBSERVED LN X'
 SCALE PLOT RESID[ITER;]AND((⍴POPIND[ITER;])⍴0)VS⍟POPIND[ITER;]
S2:
 ' '
 'TREND IN POPULATION ABUNDANCE OVER TIME'
 ' '
 dy←'ABUNDANCE'
 dx←'YEAR'
 SCALE PLOT INDEX[ITER;]AND ihatΔrv[ITER;]VS YR
 ZZ←YR PRINTRVSPA DATA
 (' ',' ',((¯1↑⍴DATA)↑2↓ps)),[2]⍕ZZ
 ' '
 ITER←ITER+1
 →(ITER=(1↑⍴INDEX)+1)/0
 →S1
```

```
∇PNLTYΔFN[⎕]∇
R←alpha PNLTYΔFN A
 R←USEΔCONSTRAINTS×+/alpha÷(⍴NVECT)↑A
⍝ State variable 'USEΔCONSTRAINTS' controls penalty function
⍝ 1 → constraints on; 0 → constraints off
```

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

```
      ∇PRNT[⎕]∇
  PRNT;TMP;FMT
   ' '
   'ITERATION NUMBER ',⍕J
   ' ' ⋄ 'PENALTY FUNCTION TURNED ',(2 3 ⍴'OFFON ')[1+USE∆CONSTRAINTS;] ⋄ ' '
   TMP← 3 6 ⍴'LAMBDARSS   NPHI  '
   '10A1,E15.6' ⎕FMT(3 10 ↑TMP;⍎¯1↓,TMP,',')
   ' '
   ' F''s IN LAST YEAR : '
   6 3 ⍕FLY
   ' '
   →(FAG=0)/NXT
   ' F''s AT OLDEST AGES : '
   6 3 ⍕FAG
 NXT:→(0=INDEX∆TYPE[1])/NXT1
   ''
   'ESTIMATED RV SURVEY CALIBRATION PARAMETERS'
   ' 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
   FMT ⎕FMT(((⍴AGES),1)⍴AGES),TMP,((⍴NVECT)↑par)[((FRST-1)↓⍳LAST)⍳ROWS]
 NXT1:→(0=INDEX∆TYPE[2])/DONE
   ''
   'ESTIMATED CPUE CALIBRATION PARAMETER(S) '
   ((2=¯1↑⍴K)/'      INTERCEPT'),'        SLOPE'
   FMT←'F14.5'
   ⍎(2=¯1↑⍴K)/'FMT←''2F14.5'''
   FMT ⎕FMT(1,¯1↑⍴K)⍴(-¯1↑⍴K)↑par
 DONE:78⍴'-'
```

```
      ∇QPUT[⎕]∇
  QPUT X;⎕IO;NTIE
   ⎕IO←1 ⍝   VERSION 2.0              || MOD. 84.1.31  M. JOLY
   →(0∊⍴X)/0
   X←⍕X
   →('→'=1↑∆SORTIE)/TOFILE
   →((3 3 ⍴'CRTPRTRS1')∧.=∆SORTIE)/LCRT,LPRT,LRS1
  ERR1:⎕ERROR 'INVALID OUTPUT DESTINATION IN ∆SORTIE'
  LCRT:⎕←X ⋄ →0
  LPRT: 3 0 3 ⎕ARBIN,X,⎕TCNL ⋄ →0
  LRS1: 2 0 0 3 ⎕ARBIN,X,⎕TCNL ⋄ →0
  TOFILE:
   (1↓∆SORTIE)⎕NTIE NTIE←-((⍳20)⍳0,|⎕NNUMS)⍳0
   (X,⎕TCNL)⎕NAPPEND NTIE
   ⎕NUNTIE NTIE
```

```
      ∇RESI[⎕]∇
  R←RESI K
   R←⍳0
   →(0=INDEX∆TYPE[1])/cpue ⍝ NO RV SURVEY
   R←R,,POPIND RESI∆RV((-INDEX∆TYPE[2]),0)↓K
   →(0=INDEX∆TYPE[2])/res ⍝ NO CATCH RATE SERIES
  cpue:K←(⊖K)[1;] ⍝ get bottom row of K
   R←R,,FBIOM RESI∆CPUE K
  res:
```

```
      ∇RESIΔRV[⎕]∇
 R←POPIND RESIΔRV K
  →(1=¯1↑⍴K)/noint
  K← 3 2 1 ⍉(⌽2,⍴POPIND)⍴,K
  ihatΔrv←(K[1;;]+K[2;;]×POPIND) ⍝ WITH INTERCEPT
  →res
 noint:K←⍉(⌽⍴POPIND)⍴,K
  ihatΔrv←K×POPIND ⍝ WITHOUT INTERCEPT
 ⍝res:R←(iΔrv-ihatΔrv)×WEIGHT
 res:R←((⍟iΔrv)-⍟ihatΔrv)×MASKRV


      ∇RESIΔCPUE[⎕]∇
 R←FBIOM RESIΔCPUE K
  →(1=⍴,K)/noint
  ihatΔcpue←(K[1]+K[2]×FBIOM) ⍝ WITH INTERCEPT
  →res
 noint:ihatΔcpue←K×FBIOM ⍝ WITHOUT INTERCEPT
 res:R←(iΔcpue-ihatΔcpue)÷iseΔcpue


      ∇VS[⎕]∇
 Z←A VS B
  Z←((¯2↑ 1 1 ,⍴B)⍴B)⍪(¯2↑ 1 1 ,⍴A)⍴A


      ∇minipop[⎕]∇
 minipop;BOOL;J;DIAG;Q;LAMBDA;HESS;N;P;PAR;RSS;de;CAUSE;I;V;NPHI;PHI;pnlty;dpnlty;SHESS;NORM
;I;Δts;ANS
 ⍝ NON-LINEAR LEAST SQUARES USING MARQUARDT ALGORITHM
  Δts←¯7↓TIMEFMT ⎕TS
  'Do you wish to document your input ?'
  ⍎(('Y'=ANS)∨'y'=ANS←⎕INKEY)/'miniDOC'
  page Δts
  rssvec←⍳0
  P←⍴par←PAR←,initial
  RSS←e+.×e←OBJΔFN PAR ⍝ RESIDUAL SUM OF SQUARES
  N←⍴,e
  pnlty←alpha PNLTYΔFN 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←DIFFΔOBJ
  Q←2×e+.×de ⍝ GRADIENT
  HESS←2×(⍉de)+.×de ⍝ HESSIAN
  dpnlty←DIFFΔPNLTY ⍝ DIFFERENCE FOR PENALTY
  Q←Q+dpnlty[1;]
  DIAG← 1 1 ⍉HESS←HESS+(2⍴P)⍴BOOL\dpnlty[2;]
  LAMBDA←9.9999999999999E¯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
  →(~FRGNΔFN par)/L4
  RSS←e+.×e←OBJΔFN par
  pnlty←alpha PNLTYΔFN 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
  →(~FRGNΔFN par)/L5
  RSS←e+.×e←OBJΔFN par
  pnlty←alpha PNLTYΔFN par
  →(PHI≥NPHI←RSS+pnlty)/L6
  →L5
 L6:PRNT
  rssvec←rssvec,RSS
  msr←RSS÷N-P
  →(1=∧/CAUSE←(10≥I),(limit≥J),(1E¯3<con←(((N-P)×Q+.×V)÷P×RSS)*0.5),(1E¯4<|(NPHI-PHI)÷PHI),(
9.9999999999999E¯6∨.<|(par-PAR)÷1E¯20+|PAR))/L3
  (~CAUSE)/[1]exit
  ⍎(USEΔCONSTRAINTS)/'USEΔCONSTRAINTS←0 ⋄ ''TURNING CONSTRAINTS OFF''⋄→L3'
  page Δts
  OUTPUT
```

```
    ∇miniDOC[⎕]∇
miniDOC;l;sp
 ⎕TCFF
 'Input Documentation for ',STOCK∆NAME,' Run at',(8⍴' '),∆ts
 78⍴'-'
 78⍴'-'
 ' '
 '     This Analysis was Performed Using the Following Criteria : '
 78⍴'-'
 ' '
 '1)   Catch at Age extends from ',(⍕YR[1]),' to ',(⍕¯1↑YR),' and Ages ',(⍕AG[1]),' to ',⍕¯
1↑AG
 ⍎(~(NUM=1))/'''     The Catch at Age did NOT contain a PLUS Group''⋄→stp1 '
 ' '
 '     Age ',(⍕¯1↑AG),' is a PLUS Group '
 ' '
 '     Ages ',(⍕AGES),' were assumed fully recruited'
 ' '
stp1:⍎(^/PR=1)/'''2)     No Partial Recruitment Values were Imposed''⋄→stp2'
 '2)   Partial Recruitment values Imposed: '
 ' '
 '                       Ages      PR'
 'X20,I2,X7,F5.3' ⎕FMT((((⍴AG),1)⍴AG),(((⍴PR),1)⍴PR))
 ' '
stp2:'3)   Natural Mortality was set at ',(⍕m)
 ' '
 '4)   F''s over Ages ',(⍕FRST),' to ',(⍕LAST),' will be derived starting from initial esti
mates: '
 ' '
 sp←(FRST,FRST+⍳(LAST-FRST)) ↑ 1+(LAST-FRST)+1
 '                        Ages     F '
 'X20,I2,X7,F5.3' ⎕FMT(((1,1)⍴sp),((⍴FVECT),1)⍴FVECT)
 ' '
 ⍎(FAG=0)/'''5)  No Initial Estimates of F at the oldest ages were used''⋄→stp3'
 '5)  Estimates of F at the Oldest Ages were derived from the following initial estimates'
 '                         Year     F '
 'X20,I4,X7,F4.2' ⎕FMT(((⍴YR),1)⍴YR,((⍴FAG),1)⍴FAG)
stp3:→(0=INDEX∆TYPE[1])/stp4
 ' '
 '6)   Research Survey Estimates of Abundance for ages ',(⍕FRST),' to ',(⍕LAST),' were give
n'
 (0=⍴⍴ise∆rv)/'      No standard errors were applied. Log transformation used'
 (0≠⍴⍴ise∆rv)/'      Standard errors of abundance index applied to residuals'
stp4:→(0=INDEX∆TYPE[2])/stp5
 ''
 '7)   Commercial CPUE with standard errors was calibrated on fishable biomass'
stp5:' '
 '8)   The Lower Limit for Estimated Numbers at Age was the CATCH'
 '     Upper limit for Estimated Numbers at age was ',⍕1↑ubnd
 →(0=INDEX∆TYPE[1])/stp6
 sp←(¯1↑⍴K)↑(⍴CVECT)↓lbnd
 ''
 '9)   The Lower Limit for RV survey slope was ',⍕¯1↑sp
 (2=⍴sp)/'                         and for intercept was ',⍕1↑sp
 sp←(¯1↑⍴K)↑(⍴CVECT)↓ubnd
 '     The Upper Limit for RV survey slope was ',⍕¯1↑sp
 (2=⍴sp)/'                         and for intercept was ',⍕1↑sp
stp6:→(0=INDEX∆TYPE[2])/exit
 sp←(-¯1↑⍴K)↑lbnd
 '10)  The Lower Limit for CPUE slope was ',⍕¯1↑sp
 (2=⍴sp)/'                   and for intercept was ',⍕1↑sp
 sp←(-¯1↑⍴K)↑ubnd
 '     The Upper Limit for CPUE slope was ',⍕¯1↑sp
 (2=⍴sp)/'                   and for intercept was ',⍕1↑sp
exit:78⍴'-'
```

```
    ∇page[⎕]∇
page ∆ts
 ⎕TCFF,'              ADAPTIVE FRAMEWORK TUNING WORKSHOP'
 STOCK∆NAME,(45⍴' '),∆ts
```