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An evaluation of the population dynamics of 4X haddock during 1962-88 with yield projected to 1989

by

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Abstract

This evaluation of the 4X haddock population is similar to that conducted last year in terms of the pessimistic view it presents of the resource status. It is different with respect to the technique used (the ADAPT framework) to calibrate the SPA. The 1987 fully recruited fishing mortality is estimated to be 0.59. Total stock biomass is currently about 47,000 t which is comparable to 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. Older age groups are disappearing from the fishery at a rate that cannot be explained by commercial exploitation. This has resulted in an apparent dome-shaped partial recruitment vector in recent years. Projections to 1989 indicate an $F_{0.1}$ yield of 4,600 t under the assumption of a flat-topped PR while the projection assuming the "50% rule" level is 7,000 t. Under the assumption of a dome-shaped PR, $F_{0.1}$ yield projections in 1989 are 9,400 t. Biomass of the stock is at a very low level, comparable to that observed in the early 1970s. Growth overfishing is occurring and recuitment overfishing is a distinct possibility. For these reasons, effort in the 1989 fishery should be reduced to its lowest possible level, even below $F_{0.1}$.

Résumé

La présente évaluation de la population d'aiglefin de la division 4X offre une vision aussi pessimiste que celle de l'an dernier en ce qui concerne l'état de la ressource. Elle diffère toutefois de l'étude de l'an dernier par la technique utilisée (cadre de référence ADAPT) pour calibrer l'ASP. Le taux de mortalité par pêche de plein recrutement pour 1987 a été évalué a 0,59. A 47 000 t environ, la biomasse totale actuelle atteint un bas niveau comparable à ceux du début des années 1970. Les faibles classes d'âge de recrutement depuis 1984, en particulier celle de 1986, donneront vraisemblablement lieu à une diminuation de la biomasse et du rendement au cours des trois à cinq prochaines années. Les classes d'âge les plus anciennes disparaissent du stock de pêche à un taux que l'exploitation commerciale ne peut seule expliquer. De ce fait, on a connu un vecteur de recrutment partiel en forme de dôme au cours des dernières années. Les projections pour 1989 révèlent un taux $F_{0,1}$ de 4 600 t, dans l'hypothèse d'une courbe RP plat, et un taux $F_{0.1}$ de 7 000 t si l'on suit la "règle de 50 %". Dans l'hypothèse d'une courbe RP en forme de dôme, les projections donnent un taux $F_{0,1}$ de 9 400 t pour 1989. La biomasse a atteint un niveau très bas, comparable à ceux du début des années 1970. Il y a surpêche à la croissance et il se peut fort bien qu'il y ait également surpêche au recrutement. C'est pourquoi il conviendrait de réduire l'effort de pêche de 1989 à son plus bas niveau possible, voire de l'amener en dessous de $F_{0,1}$.

Introduction

Since 1974, stock assessment of the population abundance and fishing mortality rates of the NAFO Division 4X haddock resource (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. In this and last year's (O'Boyle and Wallace, 1987) assessment, the survey data was left untransformed i.e. arithmetic scale, when used in the calibration models.

O'Boyle and Wallace (1987) used a cohort minimization procedure to determine the current year's fishing mortality. It was subsequently shown that this procedure is in fact a special case of a more general formulation (Gavaris, 1988). Consequently, the cohort minimization procedure as used in the last assessment was dropped and the more flexible ADAPT framework approach utilized.

Trends in Reported Landings

Annual Trends

The long-term (1930-83) annual catch of 4X haddock has averaged about 20,000 t. This level was exceeded first during the late 1960s and then during the early 1980s when landings peaked above 30,000 t (Figure 2). The former peak, fueled by the strong 1963 year-class, was instrumental in the imposition of a quota system. Total catch has been below the long-term average since 1984 and below the TAC since 1982 with the only exception occurring in 1986 (Table 1). O'Boyle and Wallace (1987) reviewed the historical changes in fleet composition and size by country and the attendant problems of misreporting and discarding during fleet expansion in the period 1977-81. Misreporting practices apparently remain in effect as was indicated in recent discussions in Yarmouth (August 1988) with industry representatives. No estimate of misreporting of landings by area and species and/or discarding are incorporated into this assessment due to lack of firm documentation of their degree.

The recent quota allocation of the stock is given in Table 2. 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 made on a 4-month period basis. In addition to TACs, a variety of by-catch and trip limit regulations have been utilized.

During the 1977-81 period, the TACs were consistently overrun while the resource was recovering from the low abundance observed in the mid-1970s. The main fleet component which expanded during this period was that of mobile gear less than 65 ft. During 1982-84, landings by this fleet were below its allocation but exceeded the allocation during 1985-86. The 1987 landings for this fleet were again below the 1987 allocation. Since 1981, the landings of mobile gear greater than 100 ft has dropped to negligible amounts (Table 3).

Age Composition of the Commercial Catch

Sampling Intensity

Sampling for this resource has been good since 1981 with rates of approximately one sample per 200-300 t landed (Table 3). Coverage of the mobile gear during the second and third quarter of 1987 was not as good as in previous years but adequate to construct the catch at age according to previous practices (Tables 4a, 4b). In contrast to the 1987 evaluation of the haddock resource, the catch for the first half of 1988 had to be estimated from Atlantic Quota Reports. This was due to problems in the data processing protocols in the Statistics Branch which increased the time lag for this year between the receipt of data and its incorporation into the catch/effort database. The quota report statistics were compared to the landings available from the Statistics Branch during the first half of the year from 1982-86. Landings from quota reports generally appear to be lower than those from Statistics Branch among the mobile and fixed gear sectors less than 65 ft (Figure 3). The magnitude of the discrepancies were not quantified. No adjustment to the 1988 catch was made to compensate for this small bias.

Construction of the catch-at-age matrix prior to and after 1978 is discussed in O'Boyle (1981) and O'Boyle and Wallace (1986) respectively. The 1987 catch at age was constructed using the sampling stratum-sample availability table shown in Table 4a. The same type of information for the first half of 1988 is given in Table 4b. This is in keeping with the practice followed since 1982.

Catch and Weight at Age

The catch and weight at age from 1962-87 are given in Table 5a. The pulse of the 1963 year-class through the fishery during the late 1960s is particularly evident. 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) were the predominant contributors. During 1986-87, only three age groups (4-6) have contributed significantly to the annual landings, both in terms of numbers and biomass. The 1987 fishery was dominated by the 1981 and 1982 year-classes which contributed 26 and 42% by weight to the total yield. During the first half of 1988, age groups 5 and 6 (1982 and 1983 year-classes) jointly dominated the fishery accounting for about 70% of the landings (Table 5b).

The 1987 catch-at-age contained a greater proportion of four year olds and lesser proportion of age 5 fish than was projected by O'Boyle and Wallace (1987). All other age groups showed relatively good agreement (Figure 4).

Trends in the average weight and age of haddock in the catch were examined in order to provide an indication of the level of exploitation being sustained by the stock. These trends are shown for the estimates obtained during 1962-87 relative to the levels expected in populations exploited at $F_{0.1}$ and F_{max} (Figure 5). Since 1972, the average age in the catch has been below that expected, not only of a population exploited at $F_{0.1}$, but also at F_{max}. The average weight in 1987 was 1.3 kg and below the F_{max} level. A steady decline in average weight has occurred since 1980. Collectively, these trends suggest high exploitation rates in the 4X haddock fishery. Trends in these parameters can also result from variation in year-class size although the long-term average level of these parameters is more dependent on the long-term exploitation rate.

Stock Abundance Trends

Commercial Catch Rates

A multiplicative model (Gavaris, 1980) was conducted on catch/effort data for otter trawlers in unit areas 4Xmnop and 4Xqr separately. The separation is based on differences (O'Boyle et al., 1983) in the age/size composition of haddock in the two areas. An analysis was also conducted on the longliner data for 4Xmnop. All analyses used as categories year, month, tonnage class and unit area. The model assumptions were met for the 4Xmnop otter trawler analysis (Table 6a, Figure 6). However, the analysis of catch rates of haddock by otter trawlers in 4Xqr (Table 6b, Figure 7) and longliners in 4Xmnop (Table 6c, Figure 8) violated the model assumptions in terms of non-normality of the residual distribution and were than not used in the multiplcative model discussed below.

The catch and effort data for 1968-87 for otter trawlers operating in 4Xmnop were fitted by the full model,

$$\ln \text{(catch/effort)} = \text{year} + \text{tonnage class} + \text{unit area} + \text{month}. \quad (1)$$

The estimates for the parameters of this model are contained in Table 6 and the catch rates series is shown in Figure 6. Catch rates peaked during 1978-81, declined sharply to 1983 and have remained relatively stable thereafter. Ideally, catch/effort analysis should be conducted on the otter trawler data combined for all unit areas. This will be explored in time for the 1989 assessment. Landings at age of 4X haddock by the total fishery and otter trawl alone in the first quarter show that otter trawler landings comprise most of the catch among most age groups and that a declining trend in landings has occurred since 1979 (Table 7).

Groundfish Bottom Trawl Surveys

The July research survey conducted on the Scotian Shelf from 1970 to 1987 was also used to evaluate the status of the resource. The estimated numbers and weights at age, all weighted by stratum area, from these surveys are shown in Tables 8 and 9 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 9). Generally low levels of total abundance occurred during the early 1970s and high total abundance in the early-mid 1980s as indicated by the median smoothed estimates. Catch rates dropped sharply during 1985-88 for ages 2-5 and 6-9. Indeed the low 1987 survey estimate is confirmed by that in 1988. Catch rates expressed as biomass/tow generally paralleled the trends seen in numbers (Figure 10).

Sequential Population Analysis

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. For these reasons the practice of calibrating the SPA with survey data alone was continued.

Calibration Model

Contrary to O'Boyle and Wallace (1987) the following model was used:

$$U_{a,t} = q_a \cdot N_{a,t} \cdot \epsilon_{a,t} \qquad (2)$$

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
$\epsilon_{a,t}$ is the error in the age a, year t estimate of the survey numbers per tow derived from the relationship.

The intercept was dropped after analyses of residuals of preliminary runs indicated that it was not required. The error term is assumed to be multiplicative, as per O'Boyle and Wallace (1987). Attempts to use the standard error to weight the analysis 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 Methodology

The ADAPT method was used (Gavaris, 1988). The input conditions, data, and model framework are given in Table 10. The software was documented in Annex 1. Initial conditions to start this analysis were based on the SPA of O'Boyle and Wallace (1987).

As in the previous assessment, the 1988 first half of the year catch at age was included in the analysis to allow use of the 1987 survey data. The inaccuracy in the 1988 catch data is a cause for concern. Prior to the next assessment, a retrospective analysis will be conducted to evaluate the benefits of including the half year data in the analysis.

A major difference in the model structure of this and last year's calibration is that here, the age 2-12 fishing mortalities in the last year were all independently determined. O'Boyle and Wallace (1987) only determined those for ages 2-7. Fishing mortalities on ages 8-13+ were set equal to that on age 7, thus implicitly assuming a flat-topped partial recruitment ogive. The method used this year allows the model to find the optimum partial recruitment pattern in the last year.

Results and Discussion

Model Fit

The model formulation (Table 10) required seven iterations to reach a stable optimum and the parameters remained constant after removal of the penalty function. All of the parameters associated with the age 2-7 slopes were significantly different from zero although some of parameter estimates associated with the population sizes of the older ages were non-significant (Table 11). Also, the parameter estimates were generally uncorrelated among themselves. The age by age diagnostic plots for ages 2 to 7 (Figure 11) indicate that the residuals were randomly distributed across year, SPA population numbers, and the predicted values.

Population Trends

The population and fishing mortality matrices for 1970-87 are given in Table 12. Trends in age one beginning of year numbers (Figure 12) show that relative to the 1970-87 geometric mean of 25 million, recruitment was poor during the early 1970s, above average during the mid to late 1980s and more recently poor to below average. The size of the 1985-86 year-classes will have a significant negative impact on yield for the next three to five years. Comparison of the 1980-87 age one population numbers (000s) from the current assessment to the one performed by O'Boyle and Wallace (1987) shows close agreement (Table 13), supporting their pessimistic view of the resource. Prior to 1986, only the size of the 1982 year-class has been changed substantially. A major revision was made to the sizes of the 1985-86 year-classes at age one. The estimates for last year were set at the second lowest value from the 1970-87 SPA (Table 12), based on low abundances observed in the 1987 RV survey. The 1988 survey indicated that these year-classes were even weaker.

The recruitment trends alluded to above are reflected in the mid-year population numbers and biomass which have both declined during 1979-1988 (Figure 13). Present levels are equivalent to the lowest abundances on record that were seen during the early 1970s (Table 12).

Interpretation of the exploitation on the fully recruited age groups is difficult given the presence of an apparent strong dome in 1987 availability. Nevertheless, the age 5-6 fishing mortalities during 1970-87 estimated this year (Figure 14) show a general, gradual increase rather than significant interannual variability as was the case in last year's assessment. The age 5-6 estimate of fishing mortality in 1987 is 0.59. This generates 0.67 in 1986, compared to the 0.56 determined in last year's assessment (Table 14).

Yield Projections to 1989

The results of the calibration indicate that since 1985, fish that were abundant in the survey and commercial catch at ages 2-7 disappear from the population at the older age groups at a rate that cannot be explained by commercial exploitation. These observations are consistent with those made by industry representatives and result in a dome-shaped partial recruitment, contrary to previous assumptions. This necessitated an analysis of the $F_{0.1}$ yield options assuming long-term exploitation under flat-topped and dome-shaped exploitation of the older age groups.

A von Bertalanffy growth model was parameterized for input to the yield per recruit analysis. Age 2-12 annual weights (g) at age were calculated as the mean from the 1962-87 commercial fishery. These were converted to lengths (cm) at age using the following formula:

$$W = (0.0077585 \cdot L^{3.07669}) \qquad (3)$$

These coefficients were estimated from the summer survey data for strata 70-85 during 1970-82. They differ from those of strata 90-95 but only used to convert the weight data to and from length in order to run the growth model.

The von Bertalanffy model was fit to the length (cm) at age data using software of Rivard (1982). The resulting equation was:

$$L = 76.573\ (1-e^{-0.175037(Age\ +\ 1.11515)}) \qquad (4)$$

This was used to estimate length for ages 1 and 13-16 which were then converted to weights at ages using equation 3.

The partial recruitment was taken as the average of 1985-87, assuming that ages 5-6 are fully recruited.

Natural mortality was assumed to be 0.2.

A Thompson and Bell yield per recruit analysis was then conducted using the software of Rivard (1982) with the following input parameters:

Age	Weight at age (kg)	PR flat-topped (1970-84)	PR dome-shaped (1985-87)
1	0.223	0.001	0.001
2	0.473	0.041	0.022
3	0.790	0.263	0.127
4	1.148	0.604	0.387
5	1.523	0.847	1.000
6	1.894	1.000	1.000
7	2.250	1.000	0.356
8	2.581	1.000	0.156
9	2.883	1.000	0.130
10	3.155	1.000	0.094
11	3.396	1.000	0.194
12	3.607	1.000	0.402
13	3.791	1.000	0.200
14	3.951	1.000	0.200
15	4.088	1.000	0.200
16	4.206	1.000	0.200

The resulting parameters for the flat-topped and domed exploitation patterns are:

	Flat-topped	Dome-shaped
$F_{0.1}$	0.242	0.567
Y/R (kg)	0.516	0.531
Avg wt (kg)	1.723	1.472

A strong dome in the exploitation does not substantially change the yield per recruit, although the average size of a fish would decline.

A yield per recruit analysis using the historical flat-topped partial recruitment was last conducted in 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 0.242 which was not considered sufficiently different from the 0.25 value to warrant a change.

The 1988 population parameters used for projection of the 1989 yield are:

Age	1988 beginning of year population number (000's)	Weight (kg)	PR
1	25,290	0.250	0.001
2	5,042	0.564	0.022
3	2,974	0.749	0.127
4	8,978	1.032	0.387
5	9,187	1.382	1.000
6	6,168	1.870	1.000
7	971	2.471	0.356
8	1,274	2.864	0.156
9	911	3.612	0.130
10	559	3.731	0.094
11	643	3.726	0.194
12	109	3.803	0.402

Yield was projected to 1989 under the assumption of a weight at age and partial recruitment averaged over 1985-87, full recruitment at ages 5-6, and natural mortality equal to 0.2. Age one recruitment in 1989 was set at the 1970-87 geometric mean of 25,290 with 1988 catch assumed to be 12,400 t.

Two projections were conducted. The first option assumed that the apparent dome in the partial recruitment is transitory and thus employed the $F_{0.1}$ appropriate for flat-topped exploitation. The second option assumed that the dome-shaped PR is a lasting phenomenon and thus used the $F_{0.1}$ appropriate for this pattern of exploitation. Both used the PR as observed in the 1987 fishery thus implicitly assuming that the low availability of the older age groups will continue in the short term.

	Year	F_{5-6}	Catch kt	Avg. population biomass kt
Option 1				
Flat-topped	1988	0.55	12.4	47.2
	1989	0.25 ($F_{0.1}$)	4.6	50.5
	1989	0.40 (F_{50})	7.0	49.3
Option 2				
Dome-shaped	1988	0.55	12.4	47.2
	1989	0.57 ($F_{0.1}$)	9.4	48.0

If the flat-topped assumption is wrong (i.e. exploitation will continue in the long-term to be a dome) then fishing at $F_{0.1}$ will occur at 0.242 rather than 0.567. This will result in a long-term loss in yield per recruit of 30% (1-0.371/0.531) but with 1.6 times the average catch rates.

If the dome-shaped assumption is wrong (i.e. exploitation will continue in the long-term to be flat-topped) then fishing will occur at 0.567 rather than 0.242. This will result in a long-term increase of 11% (1-0.575/0.516) in the yield per recruit but at 50% of the average catch rate. However, given that the current fishery is being exploited near 0.567, the industry would not observe any long-term decline in catch rates under this scenario.

The choice of the yield option must take into account factors other than long-term yield and catch rate. Current biomass is as low as that observed in the early 1970s. In 1972-73, ICNAF imposed TACs of 9,000 t and closed the fishery in 1974. The strategy followed was F_{max} not $F_{0.1}$ which was introduced in 1977. Given the poor recruitment entering the fishery, biomass can be expected to decline, even under $F_{0.1}$. Although not quantified, there may be a danger of stock collapse due to recruitment overfishing. If fishing is allowed to continue at a high rate, most fish will not survive to older ages, reducing our ability to measure availability at age and thus to recommend the most appropriate long-term exploitation strategy.

Option one is the preferred yield projection, assuming no long-term negative effect on recruitment. However, the recent low levels of biomass and recruitment are of major concern.

Concluding Remarks

This assessment supports the pessimistic view of the 4X haddock resource provided by O'Boyle and Wallace (1987). Although the techniques are slightly different, the results are the same. This resource is being exploited very heavily. Current biomass levels are comparable to those observed in the early 1970s. Growth overfishing is occurring and recruitment overfishing is a distinct possibility. This will be evaluated in time for the next assessment. Another concern raised in this assessment is the apparent disappearance of the older fish from the fishery. Studies are also required to confirm this observation. If it is a longer term feature than assumed here, it will have implications on the yield model used to provide the biological basis for management.

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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[2]	10[2]	-	-	15036	15000
1987	13538 (82)	-	17[3]	-	-	-	13555	15000
1988[1]	6021 (51)	-	-	-	-	-	6021	12400

Long-term averages:

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

1. 1 January - 29 June 1988 (Atlantic Quota Report, June 29 1988)

2. NAFO SCS DOC 87/20

3. NAFO SCS Doc. 88/18

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	AQR Date	Fleet	Allocation	Reported[1] Catch	%	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	24/08	FG. < 65'	4140	1865	45	
		MG. < 45' 1/1-30/4	1200	1040	87	05/03
		1/5-31/8	1800	1536	85	
		1/9-31/12	1090	0	0	
		MG.45-65' 1/1-30/4	1000			05/03
		1/5-31/8	1500			
		1/9-31/12	850	2729	111	
		FG. 65-100'	80	0	0	
		MG. 65-100'	80	14	18	
		MG. > 100'	660	387	59	
		Total	12400	7571	61	

[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 port sample collected.

	Tonnage Class					
	TC 1-3			TC 4+		
Year	MG (OT)	FG (LL)	Misc.[2]	MG (OT)	FG(LL)	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 (75.4)	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[1]	4126 (94)	1544 (221)	0	351	0	0

1. 1 January-29 June 1988 (Atlantic Quota Report).

2. Gillnets (set, drift), traps, unspecified.

Table 4a. Summary of commercial sampling for the haddock fishery in 1987. The 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 key formation.

Quarter	4Xm-p TC 1-3	4Xm-p TC 4+	4Xq-r TC 1-3	4Xq-r TC 4+
Otter Trawls				
1	3026 (4749-266)	219 (1121-77)	108	0
2	1965 (3174-84)	163	667 (1132-55)	5
3	442	42	1271 (1801-124)	3
4	89	69 (200-25)	384	0
Longliners				
1	2161 (1797-151)	0	26	0
2	366 (711-89)	0	58	0
3	1201 (412-51)	0	42	0
4	995 (699-86)	0	5	0
Miscellaneous				
1	31	0	0	0
2	40	0	1	0
3	85 (321-91)	0	0	0
4	74	0	0	0

Table 4b. Summary of commercial sampling for the haddock fishery in 1988. The 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 key formation.

Mobile Gear
4Xm-r

Quarter	TC 1-3	TC 4+
1	2271 (4635-328)	80
2	1855 (5214-414)	271

Fixed Gear
4Xm-r

Quarter	TC 1-3	TC 4+
1	1239 (1542-143)	0
2	305	0

Table 5a. Annual landings numbers (a), weight at age (b), percent by numbers (c), and percent by weight (d) of NAFO Division 4X (excluding 4Xs) haddock. Note that age 13 represents all individuals 13 and over.

A.

TOTAL ANNUAL LANDINGS (000S) AT AGE OF HADDOCK CAUGHT IN 4XNHOPQR

	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
1	0	0	0	0	0	0	0	0	0	0	41	150	1	37	18	2	0	0	16	1	0	0	2	0	0	0
2	139	713	155	70	219	22	665	10	1055	788	22	3077	694	2175	1296	1285	75	81	161	1182	491	64	708	198	290	39
3	4524	2013	1272	3038	18341	515	297	2016	724	1617	3434	113	4653	4568	1644	3126	3354	1158	2445	2215	3639	3294	1108	1956	1170	913
4	1415	7185	4286	1981	9796	20380	1164	1968	1502	788	1841	2247	309	5164	4261	2019	7014	6709	3008	6219	2474	5476	4680	2261	4378	2868
5	1778	3087	9337	3153	3167	9148	17448	1621	379	1422	509	1067	1779	485	3682	3193	2094	3881	5413	4199	4628	3733	3439	4516	3923	4186
6	1708	1649	3018	5409	2149	1039	4684	11243	524	404	645	527	509	1103	434	2881	2832	1070	3499	3195	1703	2232	2396	1463	1476	1931
7	1648	1415	1492	1973	3747	735	713	3220	4536	69	90	600	189	247	807	360	1040	1244	527	1163	1457	940	948	464	246	252
8	973	593	1370	1000	840	1052	518	455	1863	3316	57	322	269	172	154	389	137	263	623	357	340	395	340	132	116	56
9	645	478	612	745	409	187	672	249	133	1020	1166	259	186	62	71	107	107	57	169	323	183	187	110	53	40	2
10	232	152	416	288	424	102	190	194	96	163	512	614	269	32	95	72	26	68	34	97	94	119	77	16	28	2
11	205	113	297	203	88	90	131	172	175	181	26	55	552	165	39	23	9	11	21	14	45	69	36	6	9	5
12	64	59	168	114	62	23	65	94	27	146	193	13	24	229	103	8	6	1	3	23	16	25	20	1	4	0
13	100	43	36	113	84	81	89	69	37	105	92	6	4	11	157	87	48	18	10	9	14	25	12	1	2	0

B.

MEAN ANNUAL WEIGHT (KG) AT AGE OF HADDOCK CAUGHT IN 4XNHOPQR

	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
1	0.290	0.290	0.290	0.290	0.290	0.290	0.290	0.290	0.290	0.290	0.290	0.270	0.180	0.230	0.230	0.280	0.290	0.290	0.160	0.230	0.000	0.000	0.250	0.000	0.000	0.000
2	0.560	0.500	0.500	0.360	0.310	0.320	0.370	0.560	0.570	0.500	0.450	0.510	0.460	0.520	0.520	0.460	0.440	0.510	0.522	0.593	0.493	0.394	0.527	0.553	0.523	0.615
3	0.750	0.780	0.750	0.650	0.670	0.620	0.620	0.750	0.900	0.960	0.900	0.750	0.820	0.820	0.810	0.710	0.870	0.870	0.882	0.887	0.907	0.758	0.785	0.787	0.726	0.733
4	1.150	1.050	1.000	1.000	0.850	0.850	0.900	0.880	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
5	1.400	1.450	1.300	1.200	1.230	1.050	1.100	1.150	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
6	1.600	1.700	1.700	1.560	1.500	1.450	1.300	1.350	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
7	2.200	1.850	1.950	1.950	1.800	1.800	1.700	1.600	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
8	2.120	2.350	2.040	2.200	2.180	2.050	2.050	2.000	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
9	1.900	2.250	2.500	2.300	2.500	2.360	2.300	2.450	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
10	2.400	2.200	2.400	2.630	2.500	2.700	2.520	2.500	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
11	2.860	2.700	2.420	2.500	2.750	2.700	3.000	2.700	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
12	2.700	3.200	3.000	2.700	2.600	2.890	2.900	3.300	2.850	3.000	3.700	3.400	3.800	3.700	4.000	3.940	3.620	6.000	4.963	4.823	4.033	3.780	4.114	4.300	3.110	0.000
13	3.990	3.250	3.610	3.300	3.000	2.800	2.950	3.060	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	0.000

C.

PERCENT LANDINGS AT AGE BY NUMBERS

	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
1	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	1	4	1	0	1	0	2	0	10	8	0	34	7	15	10	9	0	1	1	6	3	0	5	2	2	0
3	34	12	6	17	47	2	1	9	7	16	40	1	49	32	13	23	20	8	15	12	24	20	8	18	10	9
4	11	41	19	11	25	61	4	9	14	8	21	25	3	36	33	15	42	46	19	33	16	33	34	20	37	28
5	13	18	42	17	8	27	66	8	3	14	6	12	19	3	29	24	13	27	34	22	31	23	25	41	34	41
6	13	9	13	30	5	3	18	53	5	4	7	6	5	8	3	21	17	7	22	17	11	13	17	13	13	19
7	12	8	7	11	10	2	3	15	41	1	1	7	2	2	6	3	6	9	3	6	10	6	7	4	2	2
8	7	3	6	6	2	3	2	2	17	33	1	4	3	1	1	3	1	2	4	2	2	2	2	1	1	1
9	5	3	3	4	1	1	3	1	1	10	14	3	2	0	1	1	1	0	1	2	1	1	1	0	0	0
10	2	1	2	2	1	0	1	1	1	2	6	7	3	0	1	1	0	0	0	1	1	1	1	0	0	0
11	2	1	1	1	0	0	0	1	2	2	0	1	6	1	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	1	1	0	0	0	0	0	1	2	0	0	2	1	0	0	0	0	0	0	0	0	0	0	0
13	1	0	1	1	0	0	0	0	0	1	1	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0

D.

PERCENT LANDINGS AGE BY WEIGHT

	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	2	0	0	0	0	1	0	4	2	0	13	2	7	4	3	0	0	0	2	1	0	2	1	1	0
3	18	7	3	8	31	1	1	5	4	10	24	1	29	22	7	11	11	4	8	6	14	10	4	10	6	5
4	9	33	13	8	21	52	3	6	10	6	19	23	3	36	27	12	35	36	14	25	13	25	25	16	31	21
5	13	20	38	15	10	29	60	7	3	12	6	16	23	4	32	27	14	29	34	23	32	26	25	42	36	42
6	14	12	16	33	8	4	19	53	5	4	9	9	9	14	5	31	25	10	29	23	15	19	24	19	18	26
7	19	11	9	15	17	4	4	18	46	1	1	11	4	4	13	5	10	14	5	10	16	10	11	8	4	5
8	11	6	9	8	5	6	3	3	22	40	1	6	5	3	3	6	2	4	7	4	4	5	5	3	2	1
9	6	5	5	7	3	1	5	2	2	14	21	5	4	1	1	2	2	1	2	4	3	2	2	1	1	0
10	3	1	3	3	3	1	2	2	2	3	11	14	6	1	2	1	0	1	1	1	2	2	1	0	1	0
11	3	1	2	2	1	1	1	2	3	4	1	2	14	3	1	0	0	0	0	0	1	1	1	0	0	0
12	1	1	2	1	0	0	1	1	0	3	5	0	1	5	2	0	0	0	0	0	0	0	0	0	0	0
13	2	1	0	1	1	1	1	1	1	2	2	0	0	0	4	2	1	0	0	0	0	0	0	0	0	0

Table 5b. Landings of NAFO Division 4X haddock (excluding 4Xs) for the first half of 1988. Numbers, weight, percent numbers, and percent weight at age are shown.

Age	Numbers x 10^3	S^2	C.V.	Weight (kg)	% by Number	% by Weight
1	0	0	0	-	0	0
2	9	4.3	.231	.401	.22	.06
3	162	311.8	.109	.744	4.01	2.00
4	628	1900.6	.069	1.019	15.55	10.63
5	1532	4745.6	.045	1.360	37.93	34.60
6	1238	4166.6	.052	1.705	30.65	35.05
7	404	1297.0	.089	2.173	10.00	14.58
8	49	155.2	.254	2.566	1.21	2.09
9	13	12.1	.268	3.428	.32	.74
10	2	1.8	.662	3.395	.05	.11
11	2	1.0	.507	4.135	.05	.14
12	0	-	-	-	0	0
13+	0	-	-	-	0	0

Table 6. Multiplicative analysis of commercial catch/effort data for various fleet-area components. A. Otter Trawlers in 4XMNOP, B. Otter Trawlers in 4XQR, and C. Longliners in 4XMNOP. Categories: 1-year; 2-tonnage class; 3-unit area; 4-month.

A. REGRESSION OF MULTIPLICATIVE MODEL

MULTIPLE R............. .712
MULTIPLE R SQUARED..... .506

ANALYSIS OF VARIANCE

SOURCE OF VARIATION	DF	SUMS OF SQUARES	MEAN SQUARES	F-VALUE
INTERCEPT	1	9.345E0002	9.345E0002	
REGRESSION	37	1.761E0002	4.758E0000	23.667
TYPE 1	19	6.172E0001	3.248E0000	16.156
TYPE 2	4	5.844E0001	1.461E0001	72.665
TYPE 3	3	1.399E0001	4.664E0000	23.199
TYPE 4	[illegible]	3.016E0001	2.742E0000	13.636
RESIDUALS	854	1.717E0002	2.011E-001	
TOTAL	892	1.282E0003		

REGRESSION COEFFICIENTS

CATEGORY	CODE	VARIABLE	COEFFICIENT	STD. ERROR	NO. OBS.
1	68	INTERCEPT	-0.357	0.133	892
2	4				
3	1				
4	2				
1	69	1	-0.058	0.107	36
	70	2	-0.147	0.119	25
	71	3	-0.384	0.123	22
	72	4	-0.432	0.130	19
	73	5	-0.654	0.147	13
	74	6	-0.035	0.273	3
	75	7	0.014	0.104	46
	76	8	-0.017	0.105	44
	77	9	0.325	0.096	69
	78	10	0.570	0.102	53
	79	11	0.418	0.095	79
	80	12	0.441	0.094	89
	81	13	0.477	0.097	75
	82	14	0.232	0.098	71
	83	15	0.002	0.101	59
	84	16	-0.048	0.106	47
	85	17	-0.016	0.111	38
	86	18	-0.063	0.116	34
	87	19	-0.085	0.114	35
2	2	20	-0.533	0.058	242
	3	21	-0.102	0.056	241
	5	22	0.274	0.051	292
	6	23	-0.896	0.457	1
3	2	24	-0.619	0.097	329
	3	25	-0.646	0.098	291
	4	26	-0.430	0.099	248
4	1	27	-0.223	0.061	96
	3	28	0.131	0.060	101
	4	29	0.004	0.069	72
	5	30	-0.218	0.065	80
	6	31	-0.104	0.062	96
	7	32	-0.322	0.069	69
	8	33	-0.415	0.077	50
	9	34	-0.356	0.075	52
	10	35	-0.364	0.073	56
	11	36	-0.524	0.082	42
	12	37	-0.464	0.081	45

PREDICTED CATCH RATE

STANDARDS USED VARIABLE NUMBERS: 4 1 2

YEAR	TOTAL CATCH	PROP.	CATCH RATE MEAN	CATCH RATE S.E.	EFFORT
68	5703	0.389	0.767	0.102	7434
69	8425	0.729	0.724	0.095	11639
70	1474	1.391	0.662	0.094	2228
71	3373	0.639	0.521	0.077	6468
72	2241	0.619	0.497	0.076	4513
73	3127	0.323	0.397	0.066	7881
74	521	0.099	0.717	0.201	726
75	336	5.468	0.778	0.103	432
76	2567	0.861	0.754	0.099	3403
77	3834	1.490	1.063	0.130	3607
78	2121	2.776	1.358	0.170	1561
79	3958	1.940	1.167	0.139	3390
80	3203	2.386	1.194	0.142	2682
81	3274	2.950	1.238	0.145	2644
82	1675	3.273	0.969	0.117	1729
83	2103	2.518	0.769	0.096	2734
84	294	15.010	0.732	0.094	402
85	514	6.357	0.756	0.098	680
86	147	14.818	0.721	0.094	204
87	219	10.968	0.704	0.095	311

AVERAGE C.V. FOR THE MEAN: .139

Table 6. (Continued)

B. REGRESSION OF MULTIPLICATIVE MODEL

MULTIPLE R............. .705
MULTIPLE R SQUARED..... .497

ANALYSIS OF VARIANCE

SOURCE OF VARIATION	DF	SUMS OF SQUARES	MEAN SQUARES	F-VALUE
INTERCEPT	1	7.819E0002	7.819E0002	
REGRESSION	33	5.734E0001	1.738E0000	9.535
TYPE 1	18	2.563E0001	1.424E0000	7.814
TYPE 2	3	1.316E0001	4.387E0000	24.074
TYPE 3	1	3.799E0000	3.799E0000	20.849
TYPE 4	11	8.383E0000	7.621E¯001	4.182
RESIDUALS	319	5.813E0001	1.822E¯001	
TOTAL	353	8.974E0002		

REGRESSION COEFFICIENTS

CATEGORY	CODE	VARIABLE	COEFFICIENT	STD. ERROR	NO. OBS.
1	68	INTERCEPT	¯0.683	0.206	353
2	3				
3	5				
4	8				
1	69	1	¯0.062	0.251	9
	70	2	¯0.527	0.263	6
	71	3	¯1.168	0.315	4
	72	4	¯1.048	0.333	3
	74	5	¯0.674	0.252	7
	75	6	¯0.652	0.224	15
	76	7	¯0.720	0.219	19
	77	8	¯0.262	0.213	25
	78	9	¯0.411	0.211	29
	79	10	¯0.535	0.211	27
	80	11	¯0.566	0.210	29
	81	12	¯0.526	0.213	25
	82	13	¯0.659	0.213	24
	83	14	¯0.667	0.210	31
	84	15	¯0.916	0.210	29
	85	16	¯1.175	0.209	30
	86	17	¯1.000	0.213	23
	87	18	¯0.937	0.228	13
2	2	19	¯0.391	0.047	171
	4	20	0.073	0.319	2
	5	21	0.246	0.203	7
3	6	22	¯0.220	0.048	158
4	1	23	¯0.017	0.238	4
	2	24	0.525	0.170	8
	3	25	0.702	0.164	9
	4	26	0.204	0.123	17
	5	27	¯0.026	0.086	53
	6	28	0.147	0.084	56
	7	29	0.036	0.088	48
	9	30	0.201	0.086	54
	10	31	0.327	0.090	44
	11	32	0.230	0.167	8
	12	33	0.550	0.276	4

PREDICTED CATCH RATE

STANDARDS USED   VARIABLE NUMBERS: 3 5 8

YEAR	TOTAL CATCH	PROP.	CATCH RATE MEAN	CATCH RATE S.E.	EFFORT
68	3661	0.043	0.542	0.111	6757
69	2401	0.100	0.512	0.088	4665
70	1195	0.086	0.321	0.061	3723
71	1109	0.059	0.167	0.042	6653
72	924	0.054	0.187	0.051	4953
74	1696	0.097	0.278	0.049	6109
75	2254	0.220	0.286	0.037	7879
76	1545	0.558	0.267	0.032	5779
77	1353	1.044	0.423	0.046	3196
78	2173	1.001	0.365	0.038	5953
79	2213	1.065	0.322	0.034	6869
80	3315	0.877	0.313	0.032	10603
81	3815	0.612	0.325	0.035	11734
82	3588	0.805	0.285	0.031	12601
83	2725	1.045	0.277	0.029	9841
84	3290	0.576	0.220	0.023	14934
85	2139	0.588	0.170	0.018	12579
86	2284	0.610	0.202	0.023	11264
87	1271	0.452	0.215	0.030	5919

AVERAGE C.V. FOR THE MEAN: .143

Table 6. (Continued)

C. REGRESSION OF MULTIPLICATIVE MODEL

MULTIPLE R............. .664
MULTIPLE R SQUARED..... .441

ANALYSIS OF VARIANCE

SOURCE OF VARIATION	DF	SUMS OF SQUARES	MEAN SQUARES	F-VAL.E
INTERCEPT	1	6.241E0003	6.241E0003	
REGRESSION	35	7.811E0001	2.232E0000	6.811
TYPE 1	18	2.011E0001	1.117E0000	3.410
TYPE 2	3	6.704E0000	2.235E0000	6.820
TYPE 3	3	1.061E0001	3.538E0000	10.798
TYPE 4	11	2.112E0001	1.920E0000	5.860
RESIDUALS	302	9.895E0001	3.277E-001	
TOTAL	338	6.418E0003		

REGRESSION COEFFICIENTS

CATEGORY	CODE	VARIABLE	COEFFICIENT	STD. ERROR	NO. OBS.
1	68	INTERCEPT	-5.111	0.640	338
2	2				
3	1				
4	8				
1	69	1	-0.109	0.823	1
	71	2	0.621	0.688	3
	72	3	0.772	0.685	3
	73	4	1.527	0.659	5
	74	5	0.792	0.622	15
	75	6	0.745	0.620	17
	76	7	0.467	0.617	17
	77	8	1.319	0.612	20
	78	9	0.883	0.609	30
	79	10	0.792	0.613	19
	80	11	0.634	0.615	25
	81	12	0.658	0.613	25
	82	13	0.452	0.610	26
	83	14	0.560	0.611	38
	84	15	0.649	0.617	24
	85	16	0.448	0.616	24
	86	17	0.363	0.614	27
	87	18	0.504	0.617	18
2	0	19	-0.338	0.453	2
	3	20	0.124	0.072	121
	4	21	0.704	0.162	18
3	2	22	-0.286	0.149	170
	3	23	-0.013	0.152	78
	4	24	0.194	0.161	68
4	1	25	0.175	0.177	74
	2	26	0.250	0.178	85
	3	27	0.314	0.186	43
	4	28	0.325	0.203	23
	5	29	0.114	0.292	6
	6	30	1.297	0.290	6
	7	31	1.342	0.294	6
	9	32	-0.183	0.210	17
	10	33	-0.216	0.206	20
	11	34	-0.040	0.217	18
	12	35	-0.056	0.199	26

PREDICTED CATCH RATE

STANDARDS USED VARIABLE NUMBERS: 2 1 8

YEAR	TOTAL CATCH	PROP.	CATCH RATE MEAN	CATCH RATE S.E.	EFFORT
68	559	0.026	0.006	0.003	96647
69	748	0.017	0.005	0.003	144129
71	1384	0.024	0.012	0.005	114243
72	1865	0.023	0.014	0.006	131919
73	2541	0.072	0.031	0.010	81620
74	2501	0.131	0.015	0.004	164960
75	1657	0.232	0.014	0.004	114501
76	2298	0.257	0.011	0.003	209997
77	1395	0.496	0.026	0.007	54310
78	2917	0.326	0.017	0.004	174974
79	2285	0.247	0.015	0.004	150243
80	2526	0.368	0.013	0.003	194465
81	2465	0.546	0.013	0.003	185317
82	2604	0.340	0.011	0.003	240395
83	2735	0.646	0.012	0.003	225748
84	1621	1.091	0.013	0.003	122616
85	1076	1.031	0.011	0.003	99609
86	1637	0.713	0.010	0.002	164520
87	1201	0.767	0.011	0.003	105510

AVERAGE C.V. FOR THE MEAN: [illegible]

Table 7. Landings at age of 4X haddock by total fishery and otter trawl in the 1st quarter.

LANDINGS AT AGE (000S) OF 4X HADDOCK REPORTED BY FISHERY IN FIRST QUARTER

	1968	1969	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	0	0
2	3	0	12	9	0	0	1	10	4	4	0	0	0	9	1	0	2	2	0	0	1
3	5	180	190	638	657	12	87	90	167	338	598	212	179	260	168	346	14	180	25	74	11
4	110	316	375	310	537	993	21	265	1049	453	1237	2137	624	1761	340	1713	747	466	778	726	212
5	4279	820	135	345	162	480	217	59	975	1187	415	1161	1479	1952	1179	1192	1100	1878	1484	1898	821
6	2229	4438	107	159	243	206	140	170	126	1059	577	275	899	1291	512	662	972	673	849	1146	902
7	234	1077	753	0	33	177	36	36	247	120	352	234	183	647	511	276	438	232	154	160	316
8	153	262	262	904	13	31	26	34	46	138	39	65	96	152	111	98	142	74	67	35	39
9	152	130	9	312	354	53	50	8	23	37	57	12	58	114	81	64	25	30	26	1	10
10	76	18	23	54	107	136	37	5	29	28	6	5	7	45	44	37	37	8	15	2	2
11	1	27	11	42	8	8	105	37	19	10	1	2	6	3	23	20	13	3	8	1	2
12	5	3	1	37	53	2	12	27	12	4	0	0	0	10	8	7	12	0	4	0	0
13	10	1	5	13	12	1	6	0	28	9	2	0	1	4	2	1	3	0	2	0	0
14	1	3	0	0	0	0	0	0	2	21	1	0	1	1	4	1	1	0	0	0	0
15	0	0	0	0	0	0	0	0	1	0	7	0	0	1	0	2	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	2	1	1	0	2	0	0	0	0	0

LANDINGS AT AGE (000S) OF 4X HADDOCK REPORTED BY OTB IN FIRST QUARTER

	1968	1969	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	0	0
2	3	0	10	9	0	0	1	10	2	4	0	0	0	9	1	0	2	2	0	0	1
3	5	172	151	549	657	12	85	46	132	304	543	193	129	241	156	274	14	170	22	70	11
4	104	302	298	267	517	992	19	184	810	412	1066	1950	545	1512	281	1142	377	386	681	611	198
5	4038	783	107	297	162	478	144	40	726	1021	265	1017	1255	1745	950	833	489	1355	997	1358	676
6	2095	4238	85	136	188	204	73	45	112	790	276	212	739	944	337	434	565	373	464	523	532
7	219	1028	598	0	33	175	2	9	152	81	158	161	139	410	272	139	185	104	39	62	139
8	143	250	208	777	13	27	0	4	23	100	31	51	59	50	41	39	60	10	30	6	19
9	142	124	7	269	241	51	8	1	19	13	13	4	28	44	15	23	9	18	3	0	6
10	71	17	18	46	52	118	4	0	14	10	0	2	1	20	10	12	18	0	4	0	1
11	1	26	9	36	8	5	22	1	4	7	0	1	0	2	1	6	6	0	2	0	1
12	5	3	1	32	13	2	3	1	8	2	0	0	0	3	2	1	4	0	0	0	0
13	9	1	4	11	6	0	0	0	11	4	0	0	0	1	0	0	0	0	0	0	0
14	1	3	0	0	0	0	0	0	0	13	0	0	1	1	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0

Table 8. 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 9. 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 10. ADAPT Input Summary for 4X Haddock

Parameters:

Year class estimates

N_i, 1987 i = 2 to 12

Calibration constants for RV surveys

K_i i = 2 to 7

Structure:

- natural mortality assumed equal to 0.2
- error in catch at age assumed negligible
- F for age 12 calculated as the weighted F for ages 6 - 8
- intercepts were not included

Input:

- $C_{i,t}$ i = 2 to 12, t = 1970 to 1987 and first half of 1988
- $RV_{i,t}$ i = 2 to 7, 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 = 114
number of parameters = 17

Table 11. Final parameter estimates and T-statistics for age 2-12 numbers and age 2-7 slopes from ADAPT. Correlation matrix shows interrelationships among the 17 parameters.

ESTIMATED PARAMETERS AND STANDARD ERRORS
APPROXIMATE STATISTICS ASSUMING LINEARITY NEAR SOLUTION

ORTHOGONALITY OFFSET......... 0.013050
MEAN SQUARE RESIDUALS 0.351978

PARAMETER	PAR. EST.	STD. ERR.	T-STATISTIC
$N_{2,88}$	3.68173E0003	1.53765E0003	2.39439E0000
$N_{3,88}$	1.20080E0004	3.95550E0003	3.03577E0000
$N_{4,88}$	1.44555E0004	3.76150E0003	3.84300E0000
$N_{5,88}$	1.22312E0004	2.69508E0003	4.53835E0000
$N_{6,88}$	3.34106E0003	3.85034E0002	8.67732E0000
$N_{7,88}$	1.84031E0003	7.66590E0002	2.40064E0000
$N_{8,88}$	1.17705E0003	5.82962E0002	2.01908E0000
$N_{9,88}$	6.85483E0002	4.54303E0002	1.50887E0000
$N_{10,88}$	7.88015E0002	5.45328E0002	1.44503E0000
$N_{11,88}$	1.38388E0002	2.79973E0002	4.94292E¯001
$N_{12,88}$	6.67982E0002	5.04096E0002	1.32511E0000
q_2	4.09173E¯004	5.97014E¯005	6.85366E0000
q_3	5.31114E¯004	7.56257E¯005	7.02292E0000
q_4	5.80188E¯004	8.20393E¯005	7.07207E0000
q_5	7.55502E¯004	1.08142E¯004	6.98619E0000
q_6	8.30346E¯004	1.24379E¯004	6.67591E0000
q_7	7.84201E¯004	1.28385E¯004	6.10820E0000

Parameter Correlation Matrix

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	1.000	.048	.038	.028	.014	.018	.018	.019	.019	.019	.023	¯.175	¯.181	¯.018	¯.017	¯.019	¯.022
2	.048	1.000	.049	.036	.018	.024	.024	.024	.026	.024	.030	¯.144	¯.148	¯.159	¯.022	¯.025	¯.029
3	.038	.049	1.000	.049	.025	.036	.036	.033	.036	.034	.041	¯.114	¯.117	¯.133	¯.169	¯.034	¯.040
4	.028	.036	.049	1.000	.043	.058	.057	.054	.056	.052	.062	¯.082	¯.085	¯.100	¯.141	¯.200	¯.064
5	.014	.018	.025	.043	1.000	.081	.081	.083	.084	.086	.090	¯.040	¯.042	¯.049	¯.076	¯.147	¯.264
6	.018	.024	.036	.058	.081	1.000	.085	.086	.088	.088	.094	¯.054	¯.057	¯.070	¯.113	¯.187	¯.239
7	.018	.024	.036	.057	.081	.085	1.000	.086	.088	.088	.094	¯.053	¯.056	¯.072	¯.113	¯.185	¯.239
8	.019	.024	.033	.054	.083	.086	.086	1.000	.088	.089	.095	¯.055	¯.058	¯.067	¯.098	¯.176	¯.253
9	.019	.026	.036	.056	.084	.088	.088	.088	1.000	.091	.097	¯.058	¯.060	¯.073	¯.110	¯.177	¯.257
10	.019	.024	.034	.052	.086	.088	.088	.089	.091	1.000	.095	¯.056	¯.058	¯.067	¯.101	¯.166	¯.270
11	.023	.030	.041	.062	.090	.094	.094	.095	.097	.095	1.000	¯.069	¯.072	¯.085	¯.121	¯.189	¯.272
12	¯.175	¯.144	¯.114	¯.082	¯.040	¯.054	¯.053	¯.055	¯.058	¯.056	¯.069	1.000	.075	.055	.050	.055	.064
13	¯.181	¯.148	¯.117	¯.085	¯.042	¯.057	¯.056	¯.058	¯.060	¯.058	¯.072	.075	1.000	.056	.052	.058	.067
14	¯.018	¯.159	¯.133	¯.100	¯.049	¯.070	¯.072	¯.067	¯.073	¯.067	¯.085	.055	.056	1.000	.061	.069	.081
15	¯.017	¯.022	¯.169	¯.141	¯.076	¯.113	¯.113	¯.098	¯.110	¯.101	¯.121	.050	.052	.061	1.000	.103	.122
16	¯.019	¯.025	¯.034	¯.200	¯.147	¯.187	¯.185	¯.176	¯.177	¯.166	¯.189	.055	.058	.069	.103	1.000	.205
17	¯.022	¯.029	¯.040	¯.064	¯.264	¯.239	¯.239	¯.253	¯.257	¯.270	¯.272	.064	.067	.081	.122	.205	1.000

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

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
2	.152	.410	¯1.975	.366	.575	¯.559	¯.840	.688	¯.571	.029	¯.289	.982	.964	¯.495	.688	¯.216	.485	¯.393	.000
3	¯.502	.268	¯.688	¯1.125	.954	¯.920	¯.452	1.029	¯.481	.097	.159	¯.245	.236	.317	.493	.748	.138	¯.397	.369
4	¯.206	.222	¯.490	¯.384	¯.529	¯.038	¯.710	.942	¯1.094	¯.107	.156	¯.040	¯.372	¯.090	.909	1.198	.650	.035	¯.053
5	¯.316	.198	¯.434	¯.023	.175	¯1.208	.250	.542	¯.910	¯.264	.396	¯.359	.113	¯.309	.346	1.004	.948	¯.165	.017
6	.164	.251	¯.478	¯.570	.073	¯.066	¯.491	.859	¯.385	.065	.399	¯.326	.127	¯.276	.390	.457	.208	.280	¯.681
7	¯.435	.297	¯.130	¯.112	.161	.272	¯.328	.580	.022	.632	.580	.144	.130	.098	.081	¯.003	¯.635	¯.967	¯.386

Table 12. Cohort analysis calibrated with RV catch per tow using RV-SPA relationship generated from ADAPT.

POPULATION NUMBERS (000S)

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
1	25366	6300	47520	44283	23732	48628	57619	29986	43803	30841	37159	37146	25034	39961	28387	18250	4489	6158
2	11833	20768	5158	38869	36120	19429	39780	47158	24549	35863	25250	30409	30412	20496	32717	23240	14942	3675
3	5395	8733	16290	4203	29039	28945	13939	31396	37447	20031	29289	20528	23827	24455	16723	26146	18847	11970
4	7222	3762	5687	10230	3339	19565	19565	9925	22876	27624	15352	21767	14802	16215	17041	12689	19636	14372
5	2526	4554	2367	2990	6343	2454	11346	12163	6299	12383	16546	9847	12194	9881	8321	9718	8343	12115
6	3381	1725	2442	1478	1483	3583	1571	5957	7069	3262	6627	8649	4263	5796	4712	3701	3870	3281
7	15934	2294	1047	1415	733	753	1936	893	2271	3225	1703	2259	4190	1949	2726	1690	1706	1832
8	4544	8941	1816	775	616	429	393	855	406	918	1515	917	798	2112	745	1374	963	1174
9	469	2035	4320	1435	344	261	196	183	348	208	514	677	428	345	1372	303	1005	684
10	2174	264	743	2482	940	113	157	96	53	188	119	268	262	185	114	1024	200	787
11	775	1693	68	145	1476	527	64	43	13	20	92	66	131	129	44	23	824	138
12	91	476	1222	32	69	709	282	17	14	3	6	57	42	67	43	3	14	666
Total	79709	61545	88680	108339	104234	125396	146846	138671	145147	134565	134171	132590	116383	121591	112945	98159	74838	50695

FISHING MORTALITY

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
1	.000	.000	.001	.004	.000	.001	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.001
2	.104	.043	.005	.092	.021	.132	.037	.031	.003	.002	.007	.044	.018	.003	.024	.009	.022	.012
3	.161	.229	.265	.030	.195	.192	.140	.117	.104	.066	.097	.127	.185	.161	.076	.086	.071	.088
4	.261	.263	.443	.278	.108	.345	.275	.255	.414	.313	.244	.379	.204	.467	.362	.219	.283	.248
5	.181	.423	.271	.501	.371	.246	.444	.343	.458	.425	.449	.637	.544	.541	.610	.721	.733	.475
6	.188	.300	.345	.501	.477	.416	.364	.765	.585	.450	.876	.525	.583	.554	.826	.574	.548	1.018
7	.378	.034	.100	.632	.335	.450	.618	.590	.706	.556	.419	.841	.485	.761	.485	.362	.174	.164
8	.603	.527	.035	.614	.659	.585	.567	.699	.467	.381	.606	.562	.637	.232	.701	.113	.142	.054
9	.376	.808	.354	.222	.912	.305	.513	1.042	.416	.361	.452	.750	.640	.912	.093	.216	.045	.003
10	.050	1.149	1.434	.319	.380	.376	1.098	1.768	.786	.511	.380	.512	.506	1.243	1.384	.017	.169	.003
11	.287	.126	.545	.544	.533	.425	1.135	.895	1.353	.961	.290	.265	.476	.893	2.427	.336	.012	.041
12	.394	.410	.191	.576	.480	.436	.511	.737	.608	.487	.755	.588	.543	.526	.701	.427	.390	.000

Table 13. Comparison of numbers (mil.) 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
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	91.9	-	-	-	-	-	-
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	-
Present Document	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

Table 14. Comparison of population parameters generated by O'Boyle and Wallace(1987) and the current assessment.

Year	Mid-Year Age 1-12 Population Biomass (kt)		Fully Recruited ages (5-6) Fishing Mortality	
	1987	1988	1987	1988
1970	55.1	55.4	0.193	0.185
1971	46.2	46.5	0.390	0.389
1972	50.3	50.6	0.309	0.309
1973	52.4	52.8	0.501	0.501
1974	54.7	55.0	0.393	0.391
1975	67.8	68.1	0.351	0.347
1976	77.5	79.1	0.440	0.434
1977	80.8	83.6	0.487	0.481
1978	91.8	97.0	0.528	0.525
1979	92.1	99.7	0.432	0.430
1980	84.9	94.6	0.668	0.571
1981	79.5	91.2	0.725	0.585
1982	71.1	82.8	0.690	0.554
1983	64.6	73.9	0.759	0.546
1984	63.5	69.6	1.014	0.688
1985	63.6	65.1	0.801	0.680
1986	61.3	57.1	0.558	0.674
1987	-	47.0	0.430	0.591
1988	-	-	-	0.550

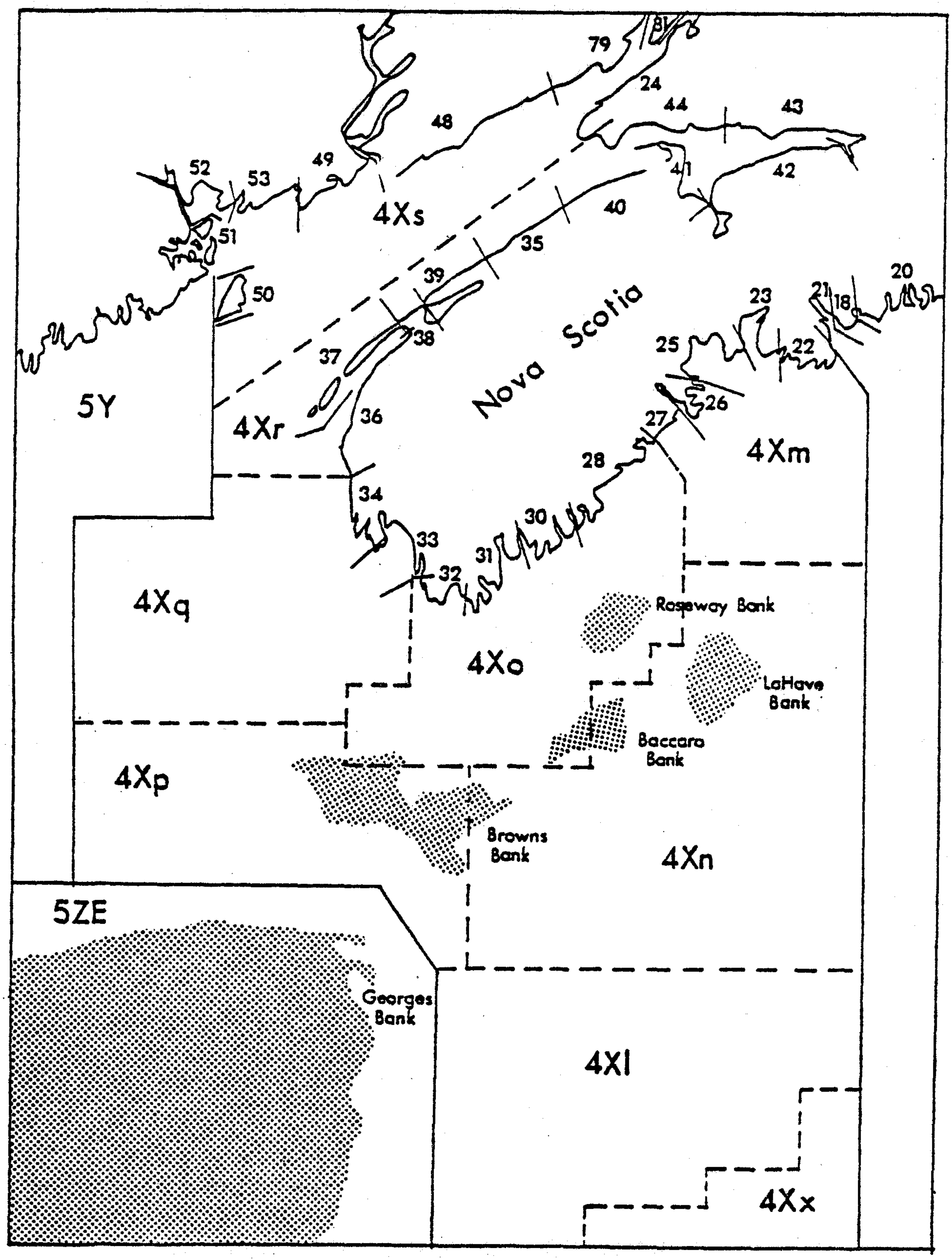


Figure 1. Canadian fisheries statistical unit areas in NAFO Division 4X

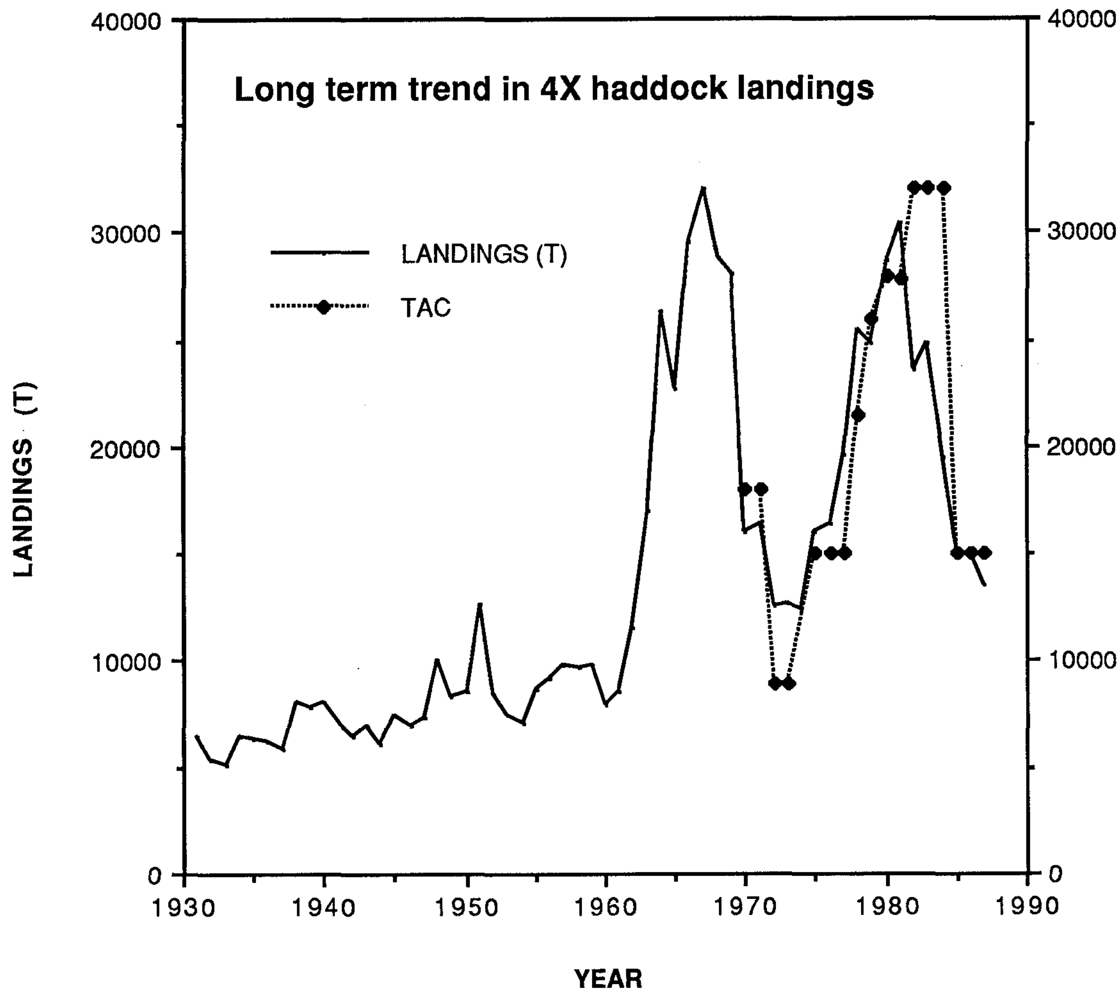


Figure 2. Long term trends in 4X haddock landings, along with annual TAC since 1970.

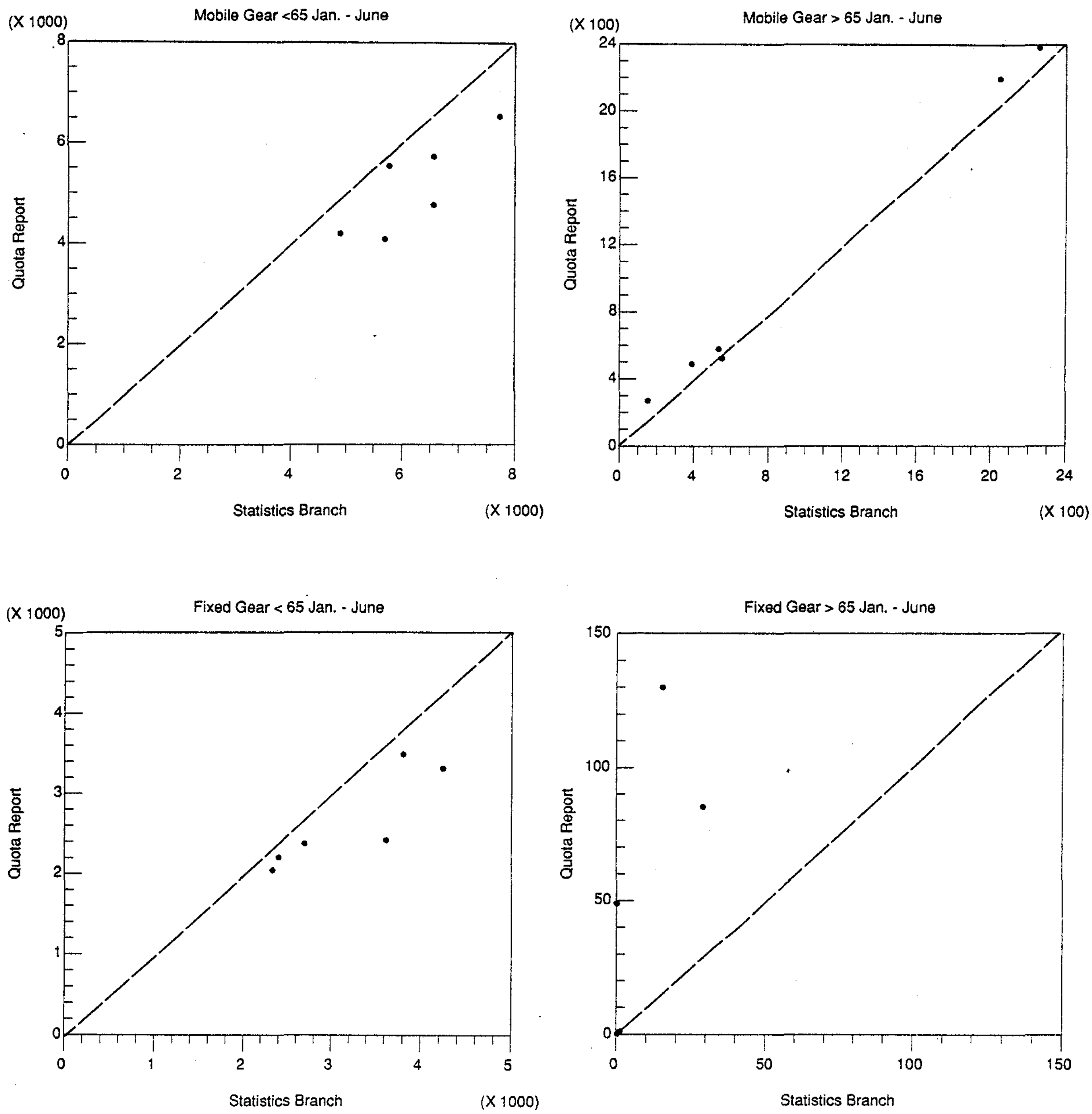


Figure 3. Comparison of landings from Statistics Branch and Quota Management during the first half of the year (1982-87).

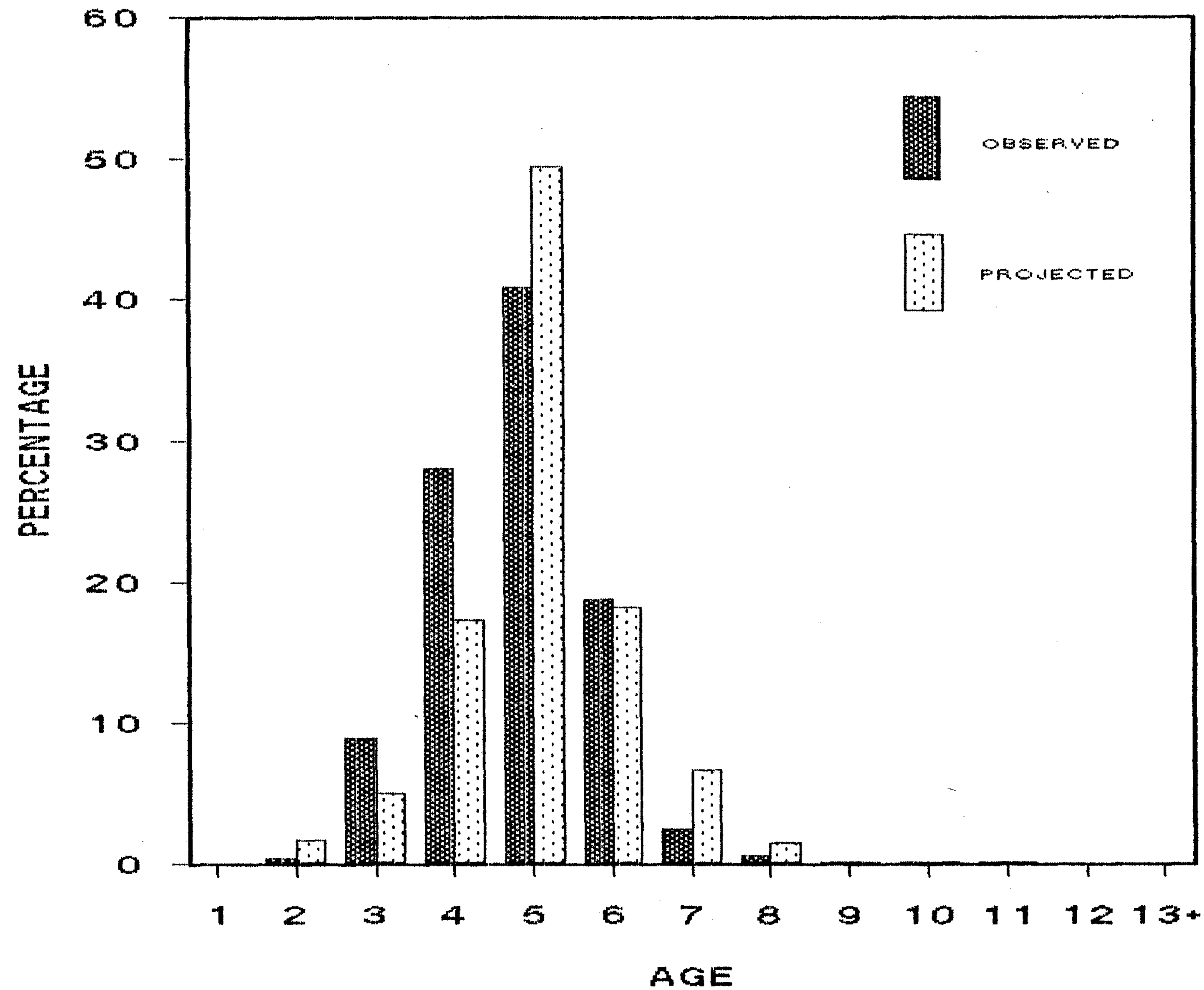


Figure 4. Comparison of observed 1987 catch numbers at age with those projected using 15,000 t in 1987, by O'Boyle and Wallace (1987).

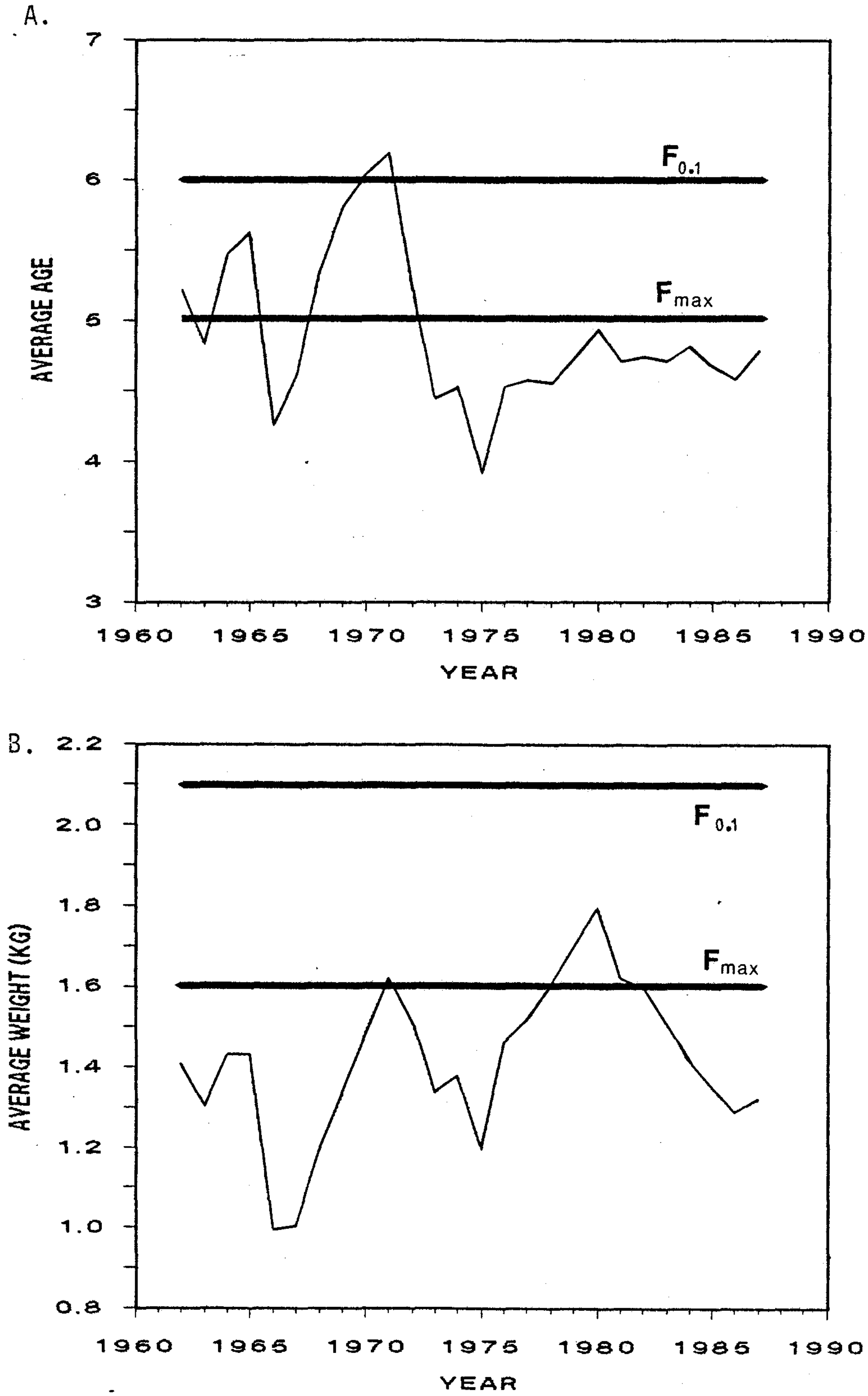


Figure. 5. Age-size characteristics of landings of 4X haddock.
A. Average age of 4X haddock in landings.
B. Average weight (kg) of 4X haddock in landings.
Top and bottom line in each figure indicates levels of these parameters in populations harvested at $F_{0.1}$ and F_{MAX} respectively.

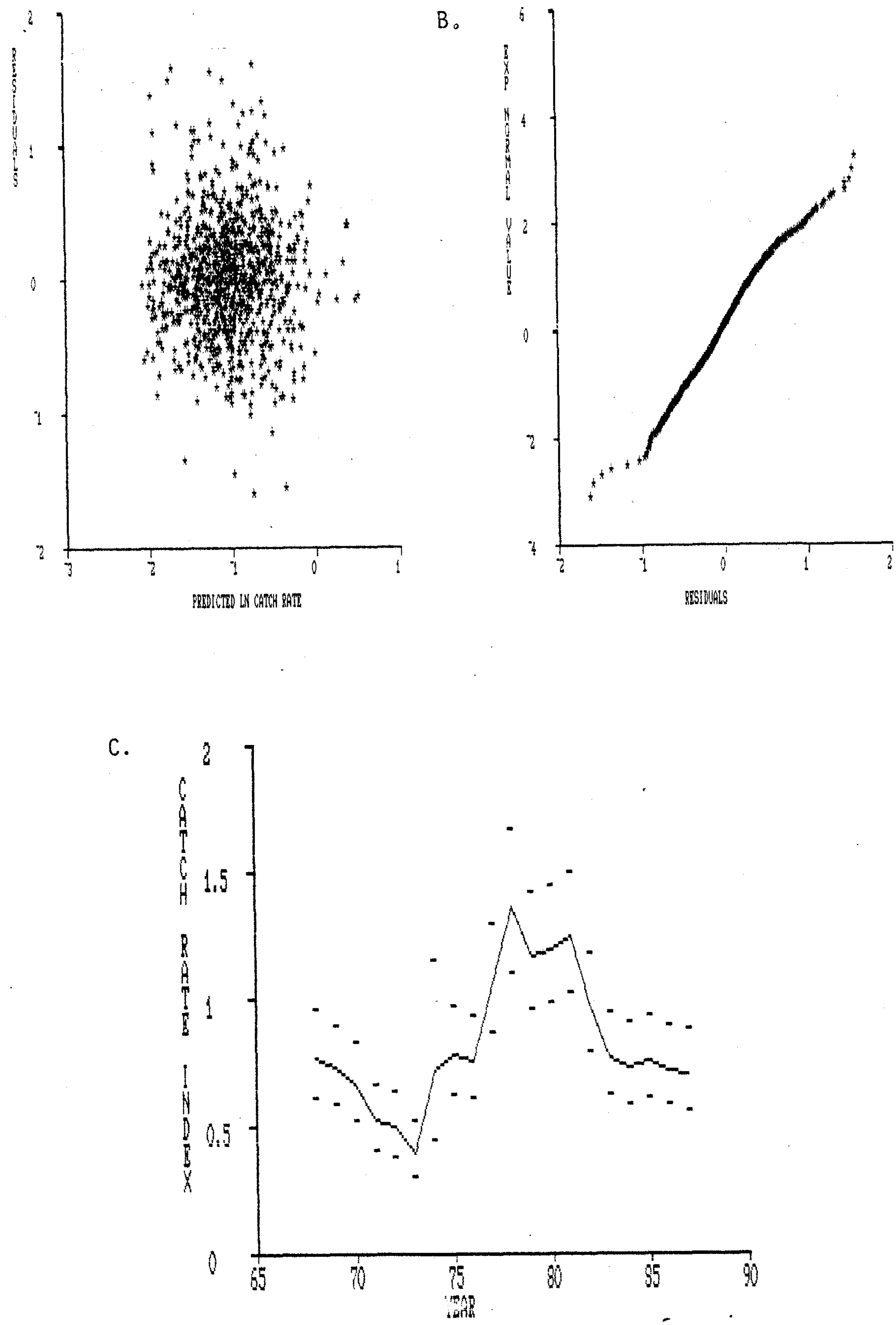


Figure 6. Trends in catch rates (t per hour fished) of haddock by otter trawlers in 4Xmnop using the multiplicative model.
A. Residuals versus predicted LN catch rate.
B. Normal probability plot.
C. Standardized catch rate.

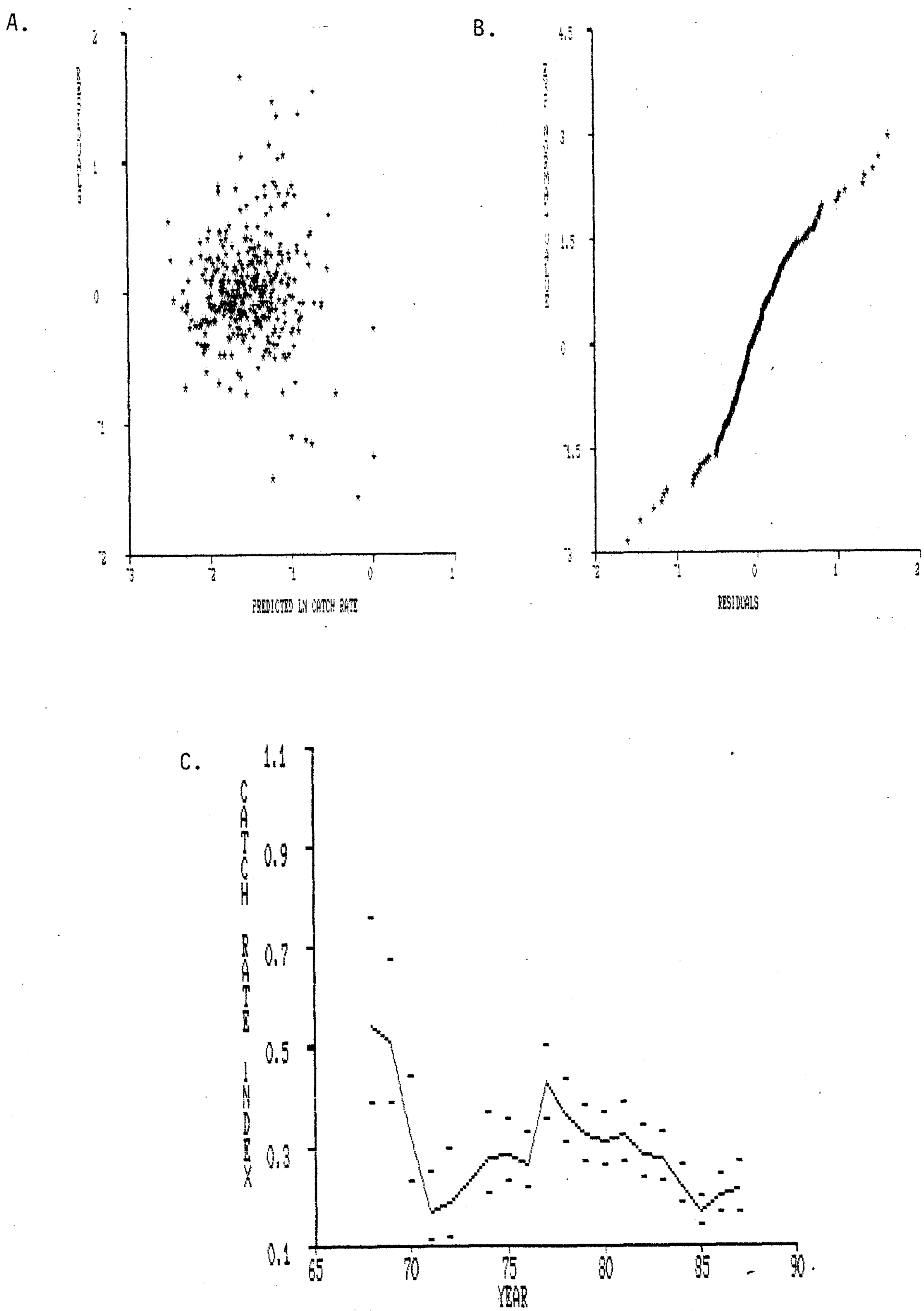


Figure 7. Trends in catch rates (t per hour fished) of haddock by otter trawlers in 4Xqr using the multiplicative model.
A. Residuals versus predicted LN catch rate.
B. Normal probability plot.

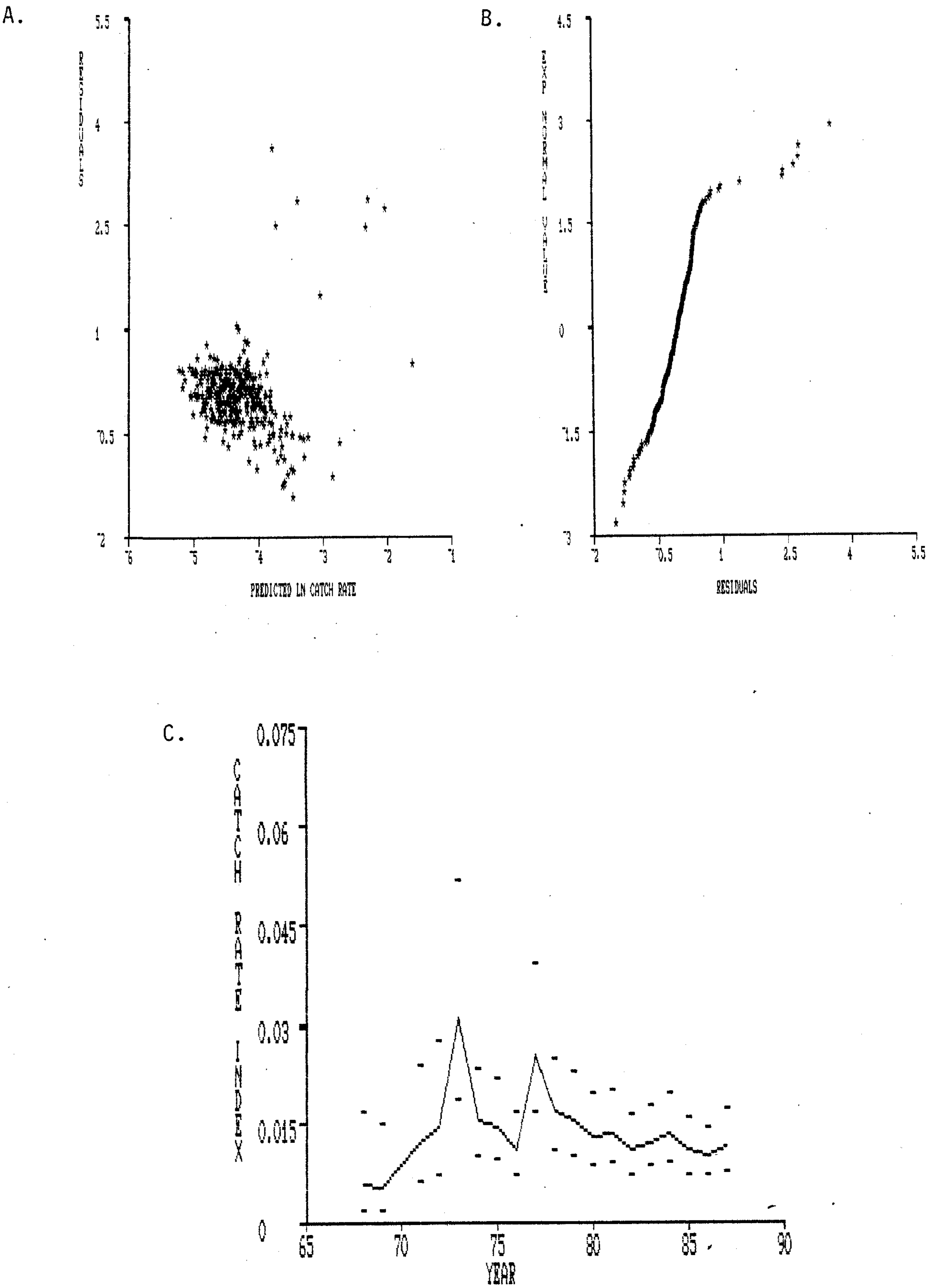


Figure 8. Trends in catch rates (t per 000's lines fished) of haddock by longliners in 4Xmnop using the multiplicative model.
A. Residuals versus predicted LN catch rate.

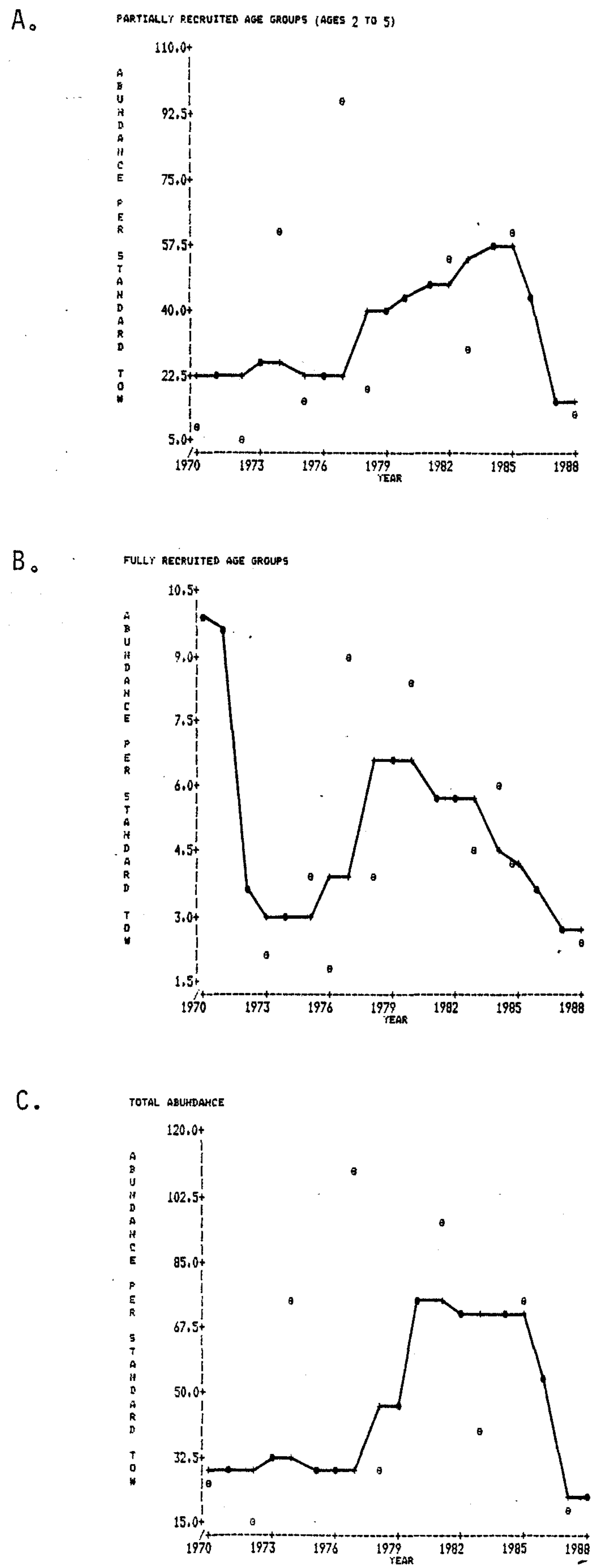
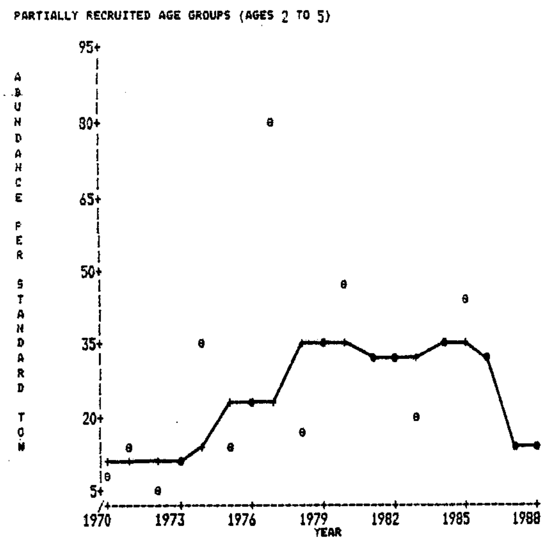
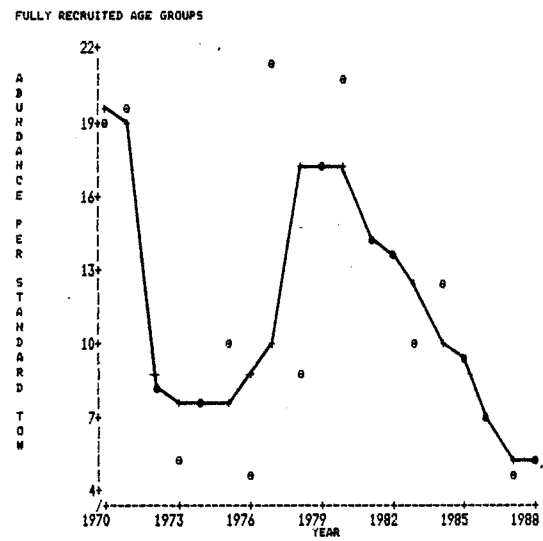


Figure 9. Survey arithmetic mean catch rate (Nos/tow) of haddock from 4X during 1970-88 for ages 2-5 (a), 6-9 (b), and all age groups combined (c). The solid line in each figure indicates the trend in the median smoothed estimates.

A.



B.



C.

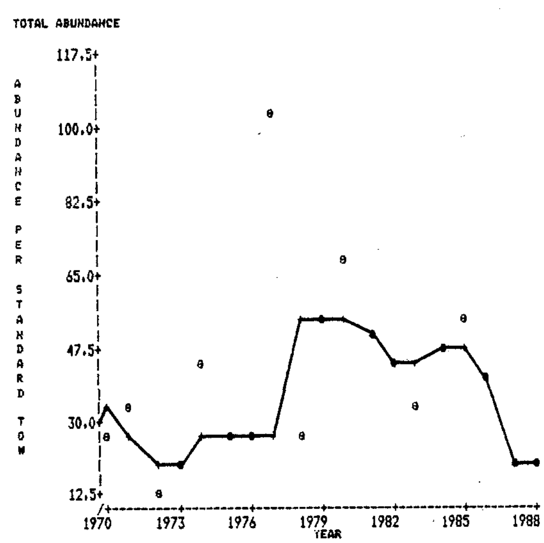


Figure 10. Survey arithmetic mean catch rate (biomass/tow) of haddock from 4X during 1970-88 for ages 2-5 (a), 6-9 (b), and all age groups combined (c). The solid line in each figure indicates the trend in the median smoothed estimates.

SUMMARY OF DATA FROM PLOT

CARRIER VARIABLE: POPULATION NOS Age 2
RESPONSE VARIABLE(S): SURVEY - +:OBSERVED, O:PREDICTED

INDEX	CARRIER	O	+	RANK
1 1970	9911	4.719	4.055	1987
2 1971	1.802E	11.12	7.375	1972
3 1972	4578	0.26	1.873	1970
4 1973	3.279E	19.35	13.42	1986
5 1974	3.174E	23.08	12.99	1975
6 1975	1.601E	3.744	6.55	1971
7 1976	3.465E	6.119	14.18	1983
8 1977	4.122E	33.57	16.87	1985
9 1978	2.18E4	5.039	8.921	1978
A 1979	3.187E	13.43	13.04	1980
B 1980	2.238E	6.856	9.156	1988
C 1981	2.638E	28.8	10.79	1981
D 1982	2.678E	28.74	10.96	1982
E 1983	1.82E4	4.538	7.448	1984
F 1984	2.871E	23.38	11.75	1974
G 1985	2.057E	6.779	8.415	1979
H 1986	1.313E	8.723	5.372	1973
I 1987	3248	0.897	1.329	1976
J 1988	2.378E	1.863	9.731	1977

SUMMARY OF DATA FROM PLOT

CARRIER VARIABLE: POPULATION NOS Age 3
RESPONSE VARIABLE(S): SURVEY - +:OBSERVED, O:PREDICTED

INDEX	CARRIER	O	+	RANK
1 1970	4372	1.405	2.322	1988
2 1971	6800	4.722	3.612	1973
3 1972	1.242E	3.314	6.596	1970
4 1973	3675	0.634	1.952	1971
5 1974	2.306E	31.8	12.25	1987
6 1975	2.303E	4.876	12.23	1976
7 1976	1.143E	3.866	6.073	1972
8 1977	2.61E4	38.8	13.86	1984
9 1978	3.136E	10.3	16.65	1986
A 1979	1.715E	10.04	9.109	1981
B 1980	2.463E	15.33	13.08	1979
C 1981	1.696E	7.055	9.009	1982
D 1982	1.904E	12.81	10.11	1983
E 1983	1.981E	14.45	10.52	1985
F 1984	1.424E	12.38	7.561	1975
G 1985	2.212E	24.83	11.75	1974
H 1986	1.609E	9.808	8.546	1980
I 1987	1.012E	3.615	5.375	1977
J 1988	2536	1.948	1.347	1978

SUMMARY OF DATA FROM PLOT

CARRIER VARIABLE: POPULATION NOS Age 4
RESPONSE VARIABLE(S): SURVEY - +:OBSERVED, O:PREDICTED

INDEX	CARRIER	O	+	RANK
1 1970	5519	2.605	3.202	1974
2 1971	2871	2.081	1.666	1971
3 1972	3909	1.389	2.268	1972
4 1973	7741	3.06	4.491	1970
5 1974	2790	0.954	1.619	1988
6 1975	1.424E	7.952	8.26	1977
7 1976	1.483E	4.228	8.602	1973
8 1977	7613	11.33	4.417	1985
9 1978	1.599E	3.107	9.278	1983
A 1979	2.049E	10.68	11.89	1987
B 1980	1.185E	8.036	6.875	1982
C 1981	1.552E	8.651	9.007	1980
D 1982	1.169E	4.678	6.784	1984
E 1983	1.099E	5.828	6.375	1975
F 1984	1.228E	17.69	7.125	1986
G 1985	9936	19.1	5.764	1976
H 1986	1.482E	16.46	8.596	1981
I 1987	1.107E	6.652	6.423	1978
J 1988	7525	4.14	4.366	1979

SUMMARY OF DATA FROM PLOT

CARRIER VARIABLE: POPULATION NOS Age 5
RESPONSE VARIABLE(S): SURVEY - +:OBSERVED, O:PREDICTED

INDEX	CARRIER	O	+	RANK
1 1970	2022	1.114	1.528	1972
2 1971	3166	2.914	2.392	1975
3 1972	1798	0.88	1.359	1973
4 1973	1986	1.467	1.501	1970
5 1974	4546	4.093	3.434	1971
6 1975	1892	0.427	1.429	1978
7 1976	7792	7.562	5.887	1974
8 1977	8862	11.51	6.696	1986
9 1978	4291	1.305	3.242	1984
A 1979	8599	4.987	6.496	1985
B 1980	1.133E	12.73	8.562	1981
C 1981	6043	3.188	4.565	1983
D 1982	7902	6.685	5.97	1988
E 1983	6415	3.558	4.846	1976
F 1984	5187	5.537	3.919	1982
G 1985	5679	11.71	4.291	1987
H 1986	4840	9.432	3.657	1979
I 1987	8171	5.233	6.173	1977
J 1988	6855	5.267	5.179	1980

SUMMARY OF DATA FROM PLOT

CARRIER VARIABLE: POPULATION NOS Age 6
RESPONSE VARIABLE(S): SURVEY - +:OBSERVED, O:PREDICTED

INDEX	CARRIER	O	+	RANK
1 1970	2696	2.639	2.239	1973
2 1971	1289	1.376	1.07	1974
3 1972	1776	0.915	1.475	1976
4 1973	981.6	0.461	0.8151	1971
5 1974	999	0.892	0.8295	1987
6 1975	2502	1.945	2.077	1972
7 1976	1130	0.574	0.9383	1979
8 1977	3394	6.65	2.818	1985
9 1978	4472	2.527	3.714	1975
A 1979	2233	1.978	1.854	1986
B 1980	3538	4.377	2.937	1984
C 1981	5667	3.398	4.706	1970
D 1982	2701	2.547	2.243	1982
E 1983	3733	2.351	3.099	1977
F 1984	2590	3.176	2.151	1980
G 1985	2356	3.089	1.956	1983
H 1986	2502	2.558	2.077	1988
I 1987	1612	1.771	1.338	1978
J 1988	4403	1.851	3.656	1981

SUMMARY OF DATA FROM PLOT

CARRIER VARIABLE: POPULATION NOS Age 7
RESPONSE VARIABLE(S): SURVEY - +:OBSERVED, O:PREDICTED

INDEX	CARRIER	O	+	RANK
1 1970	1.137E	5.775	9.009	1988
2 1971	2001	2.112	1.585	1975
3 1972	878.6	0.605	0.6959	1974
4 1973	871.2	0.611	0.69	1977
5 1974	536.3	0.494	0.4248	1973
6 1975	515.7	0.531	0.4085	1972
7 1976	1201	0.679	0.9516	1983
8 1977	563.5	0.789	0.4463	1980
9 1978	1339	1.073	1.06	1976
A 1979	2075	3.061	1.644	1985
B 1980	1187	1.662	0.9401	1981
C 1981	1231	1.115	0.9749	1978
D 1982	2810	2.51	2.226	1986
E 1983	1113	0.962	0.8812	1987
F 1984	1828	1.554	1.448	1984
G 1985	1218	0.952	0.9644	1971
H 1986	1372	0.57	1.087	1979
I 1987	1482	0.442	1.174	1982
J 1988	493.4	0.263	0.3908	1970

Figure 11. Age by age diagnostic plots from ADAPT tuning of SPA with RV ages 2 to 7.

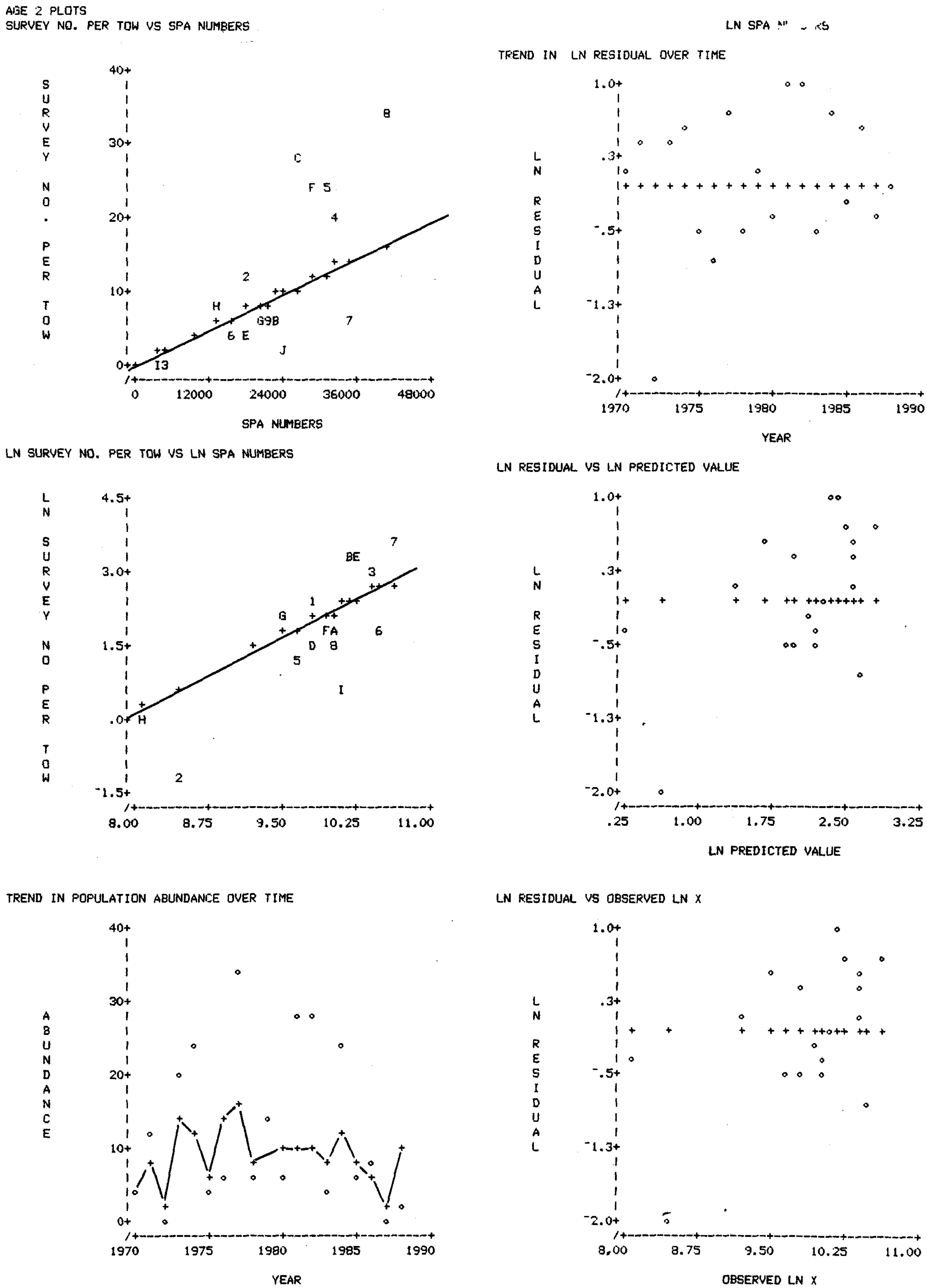
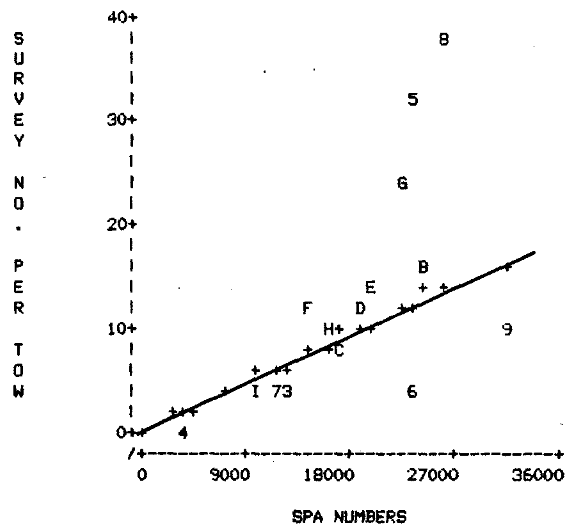


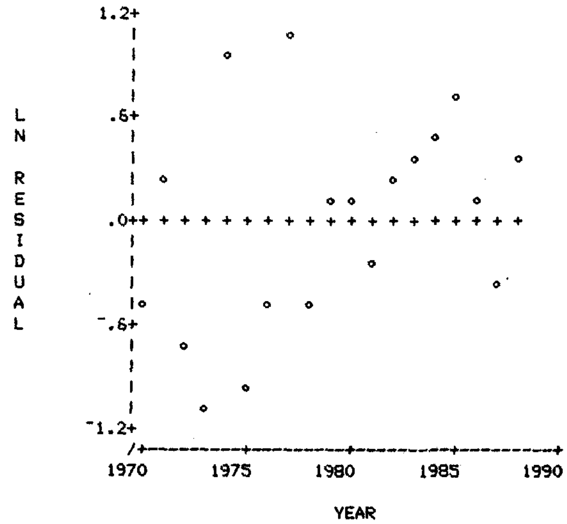
Figure 11. (continued)

AGE 3 PLOTS

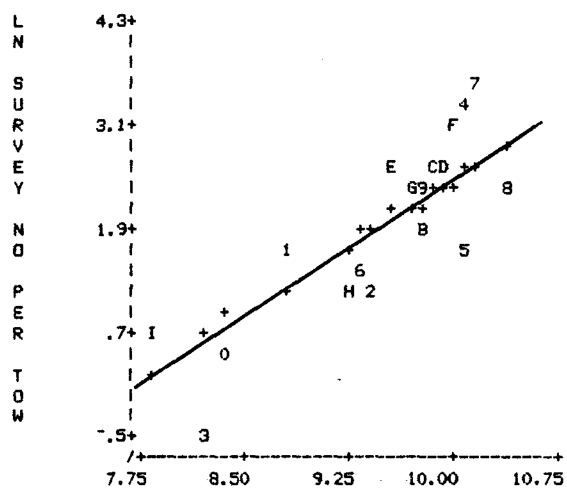
SURVEY NO. PER TOW VS SPA NUMBERS



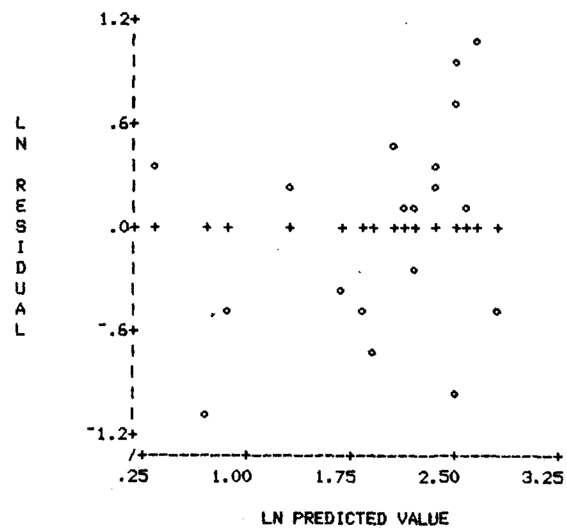
TREND IN LN RESIDUAL OVER TIME



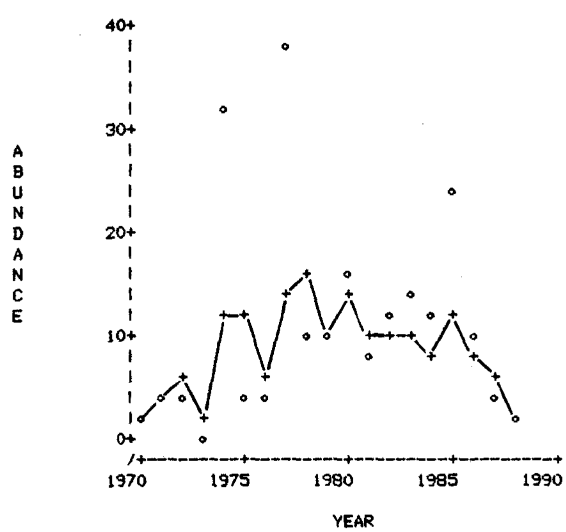
LN SURVEY NO. PER TOW VS LN SPA NUMBERS



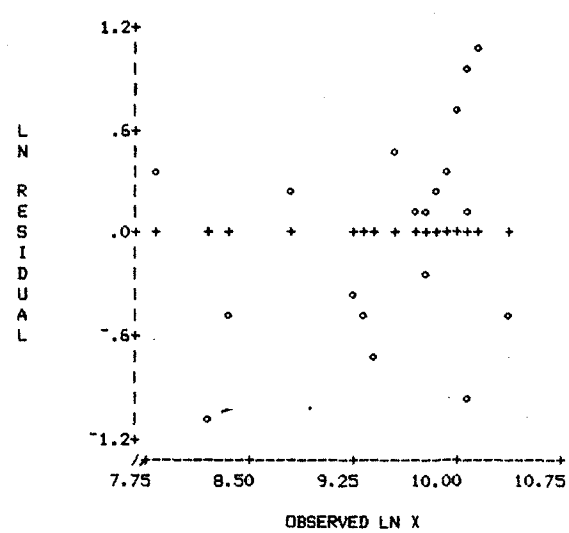
LN RESIDUAL VS LN PREDICTED VALUE



TREND IN POPULATION ABUNDANCE OVER TIME

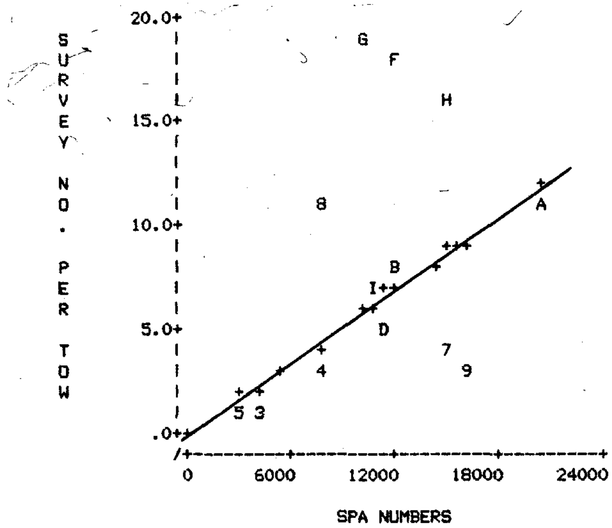


LN RESIDUAL VS OBSERVED LN X

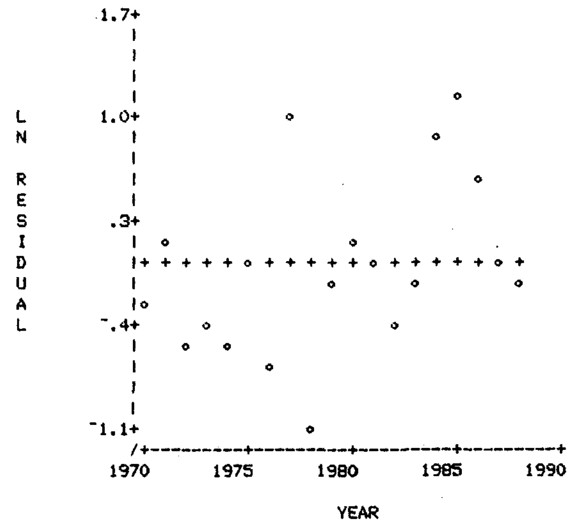


AGE 4 PLOTS

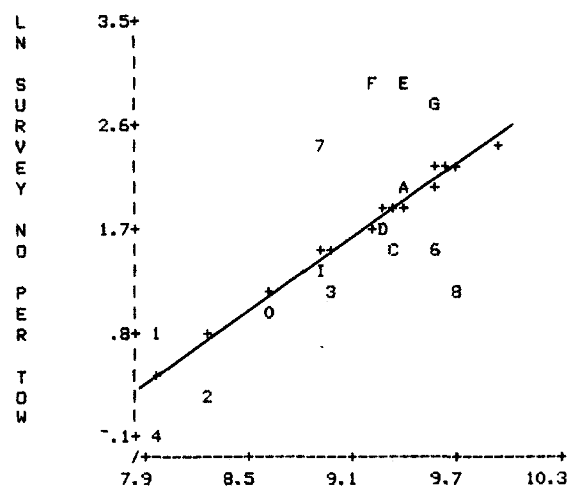
SURVEY NO. PER TOW VS SPA NUMBERS



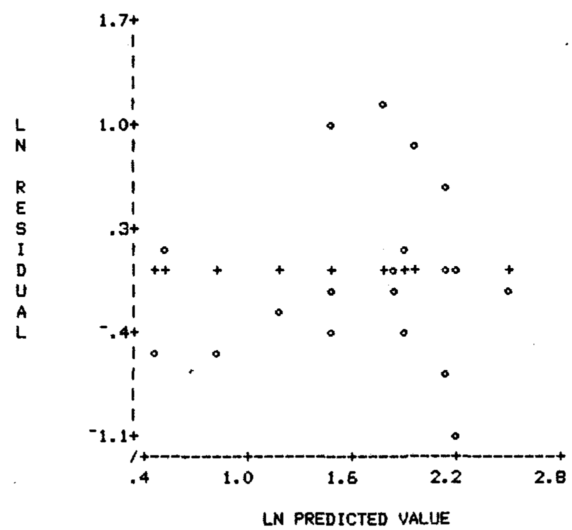
TREND IN LN RESIDUAL OVER TIME



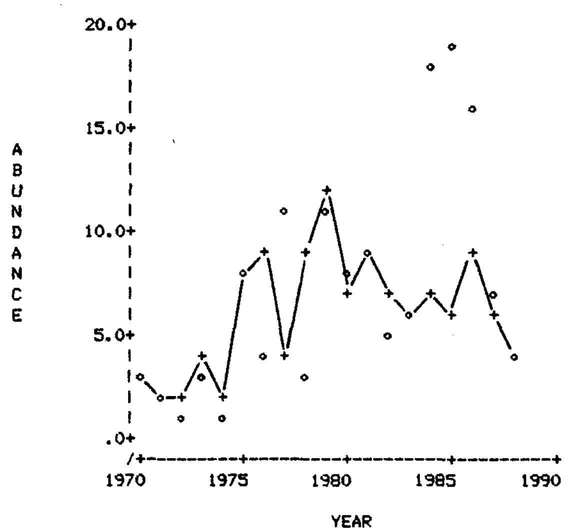
LN SURVEY NO. PER TOW VS LN SPA NUMBERS



LN RESIDUAL VS LN PREDICTED VALUE



TREND IN POPULATION ABUNDANCE OVER TIME



LN RESIDUAL VS OBSERVED LN X

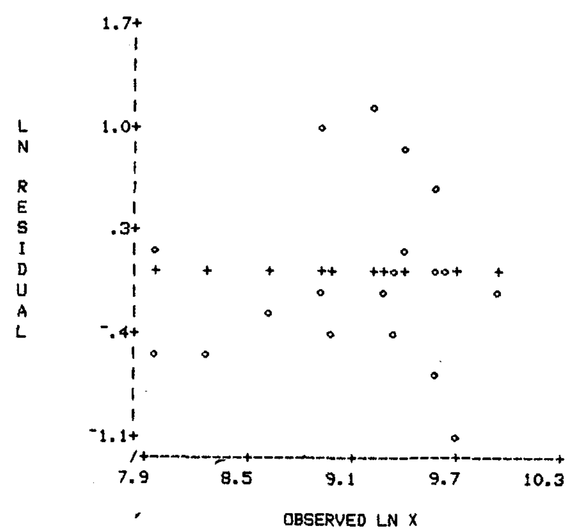
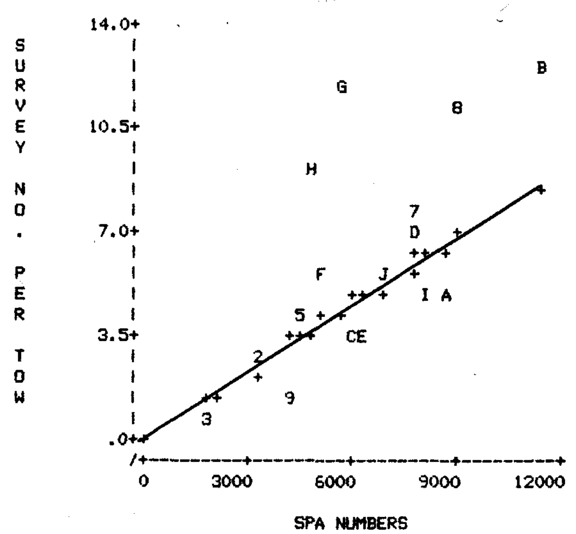


Figure 11. (continued)

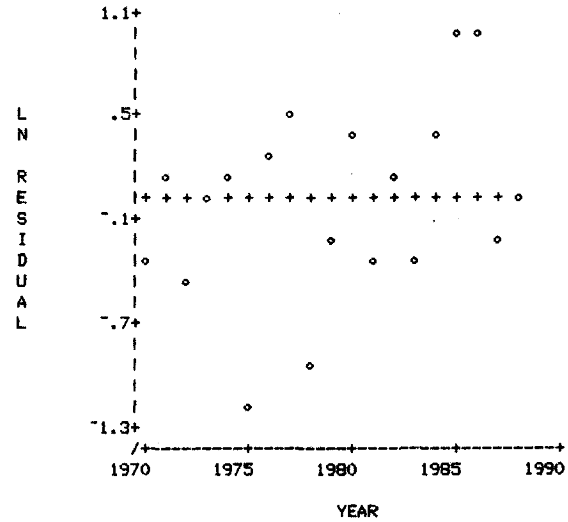
AGE 5 PLOTS

SURVEY NO. PER TOW VS SPA NUMBERS

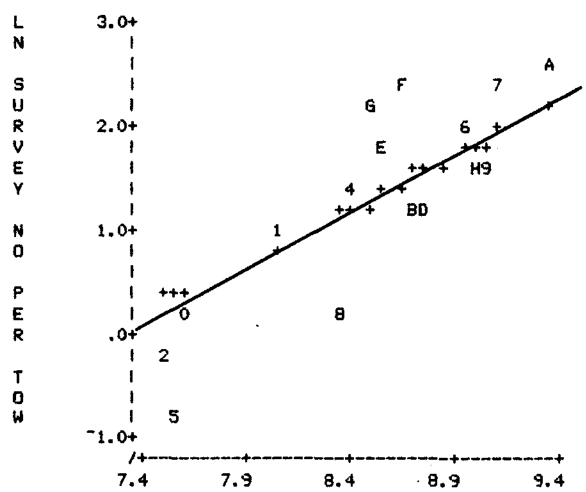


LN SPA NUMBERS

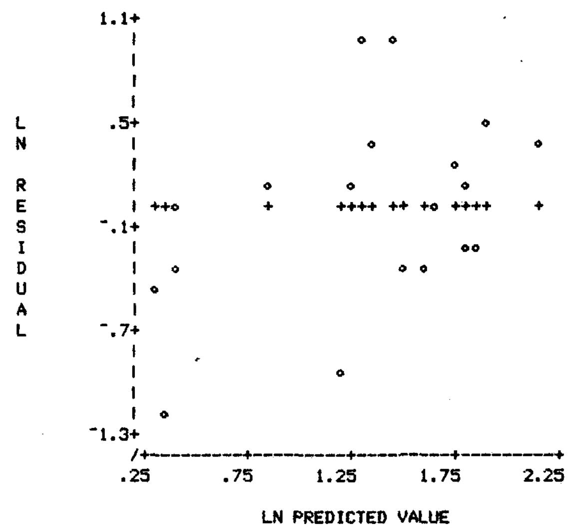
TREND IN LN RESIDUAL OVER TIME



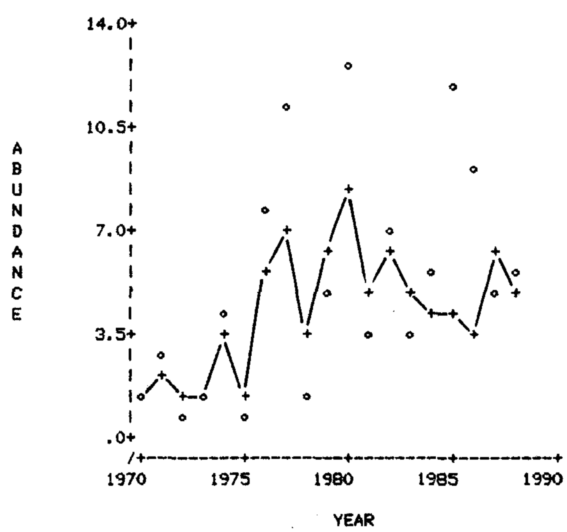
LN SURVEY NO. PER TOW VS LN SPA NUMBERS



LN RESIDUAL VS LN PREDICTED VALUE



TREND IN POPULATION ABUNDANCE OVER TIME



LN RESIDUAL VS OBSERVED LN X

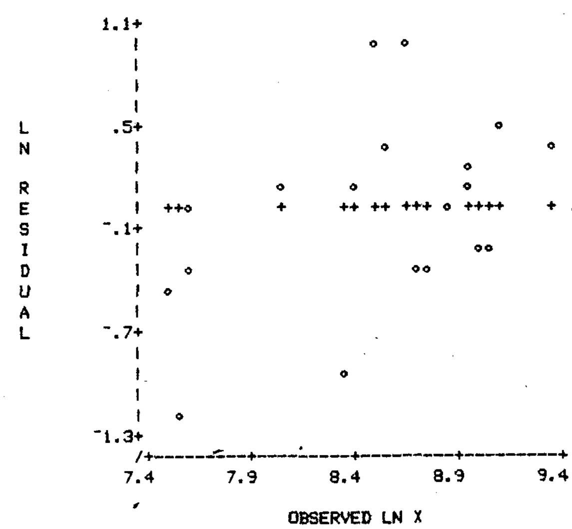


Figure 11. (continued)

AGE 6 PLOTS

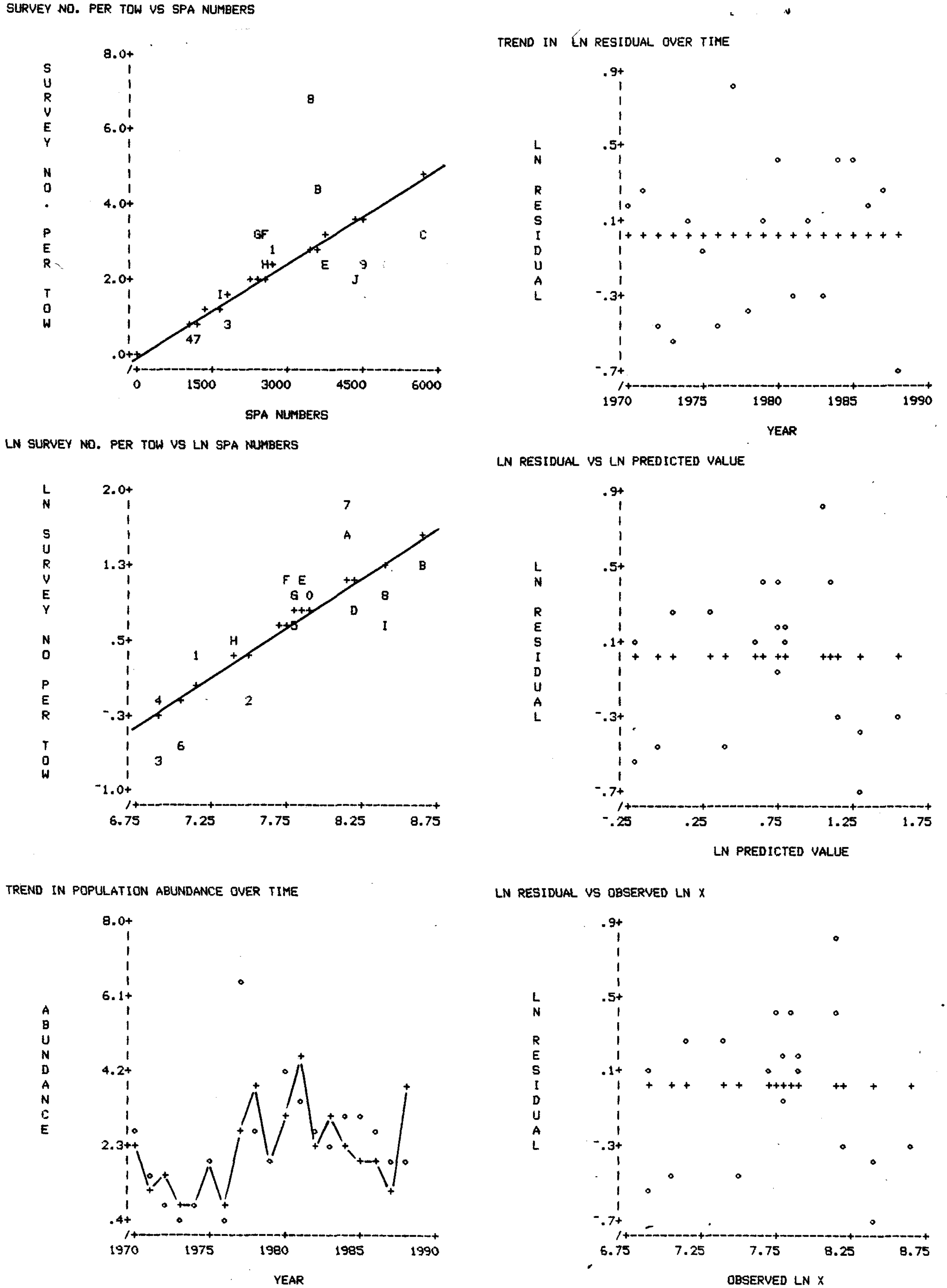


Figure 11. (continued)

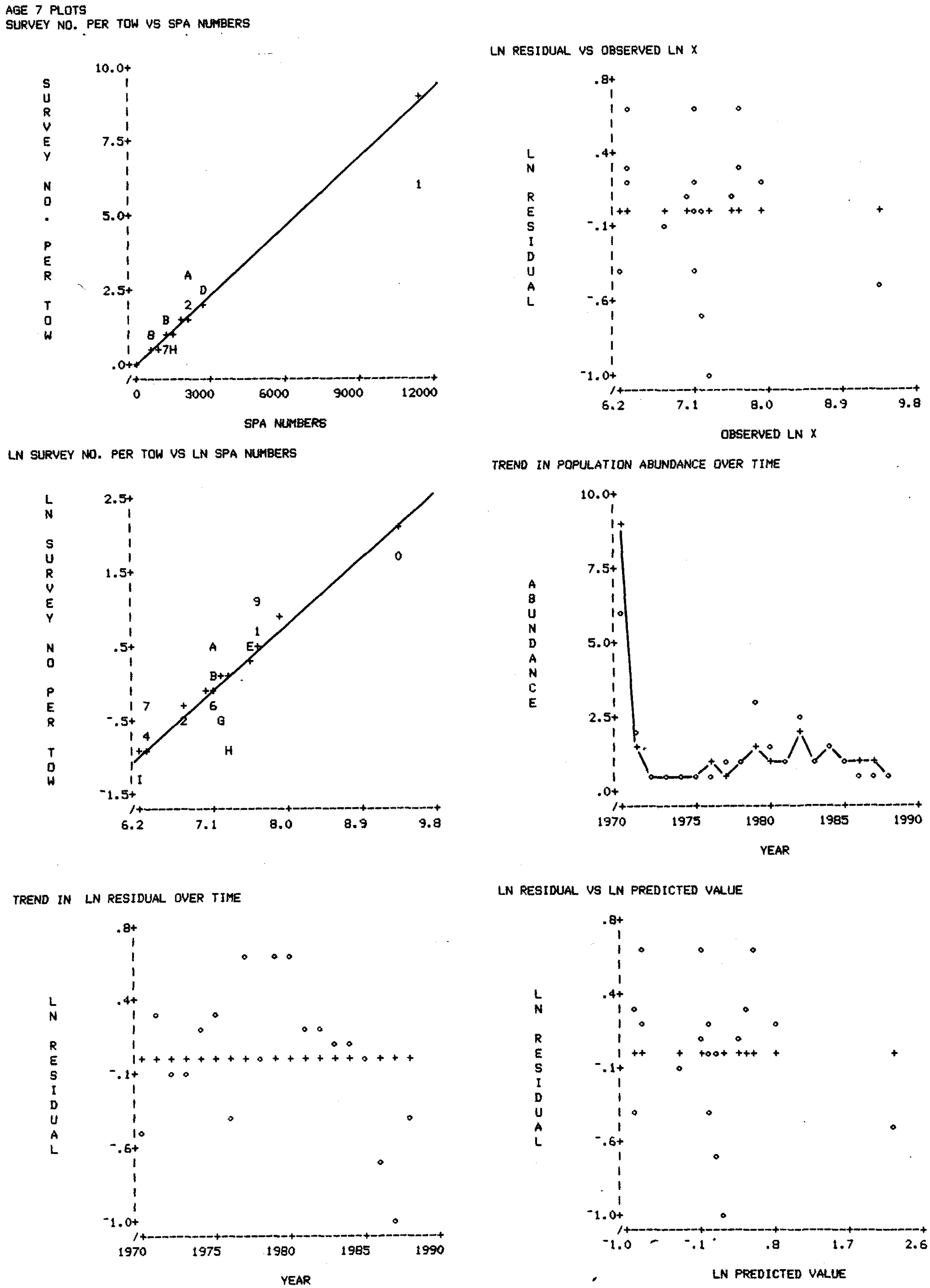


Figure 11. (continued)

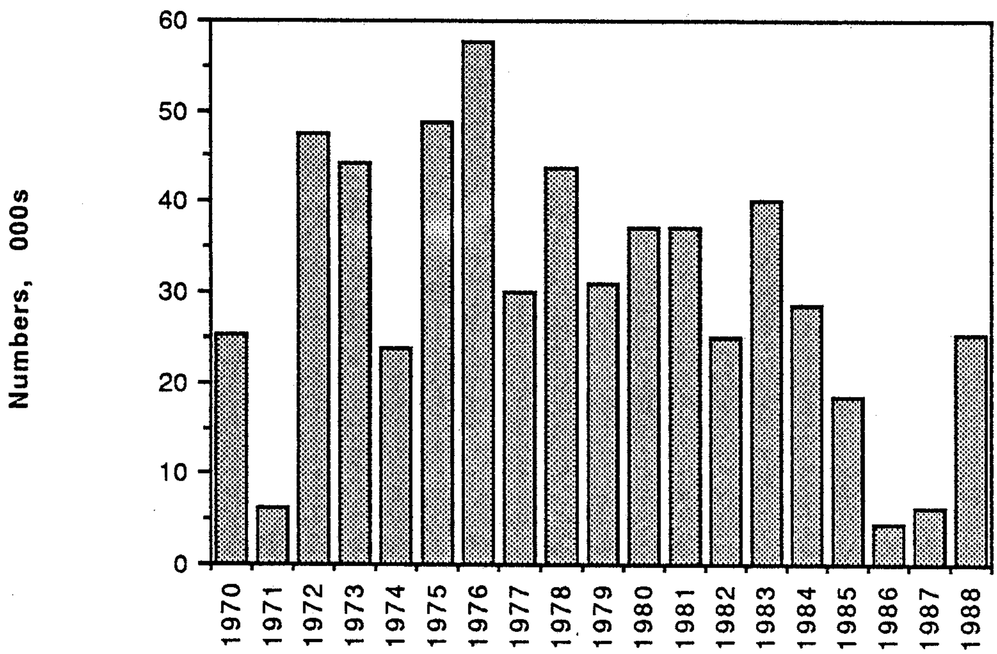


Figure 12. Trends in age one population numbers of the 4X haddock resource. Note that the 1988 age one estimate is the geometric mean for 1970-87.

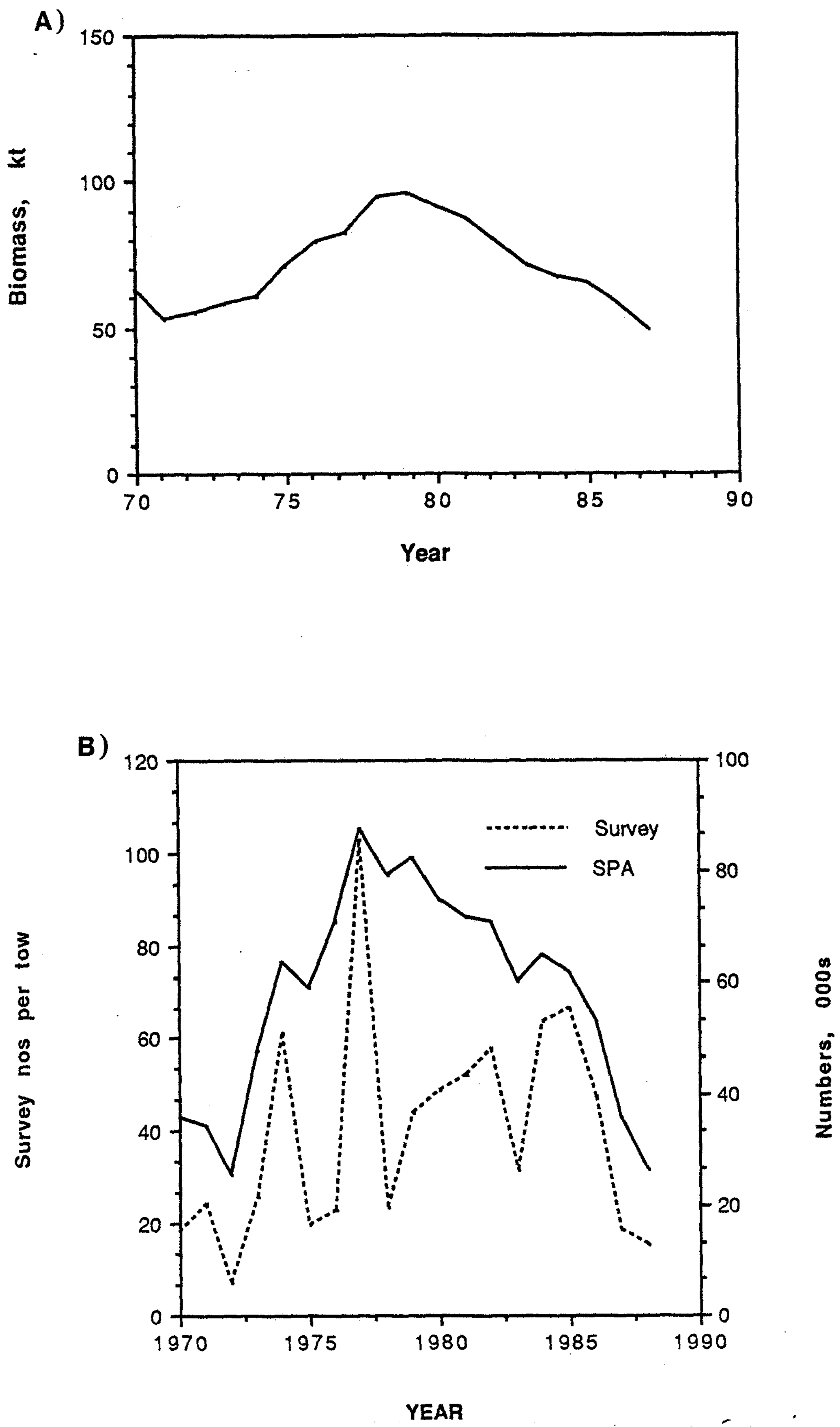


Figure 13. Trends in A) mid-year population biomass and B) age 2-7 survey and SPA age 2-7 abundance for 4X haddock resource.

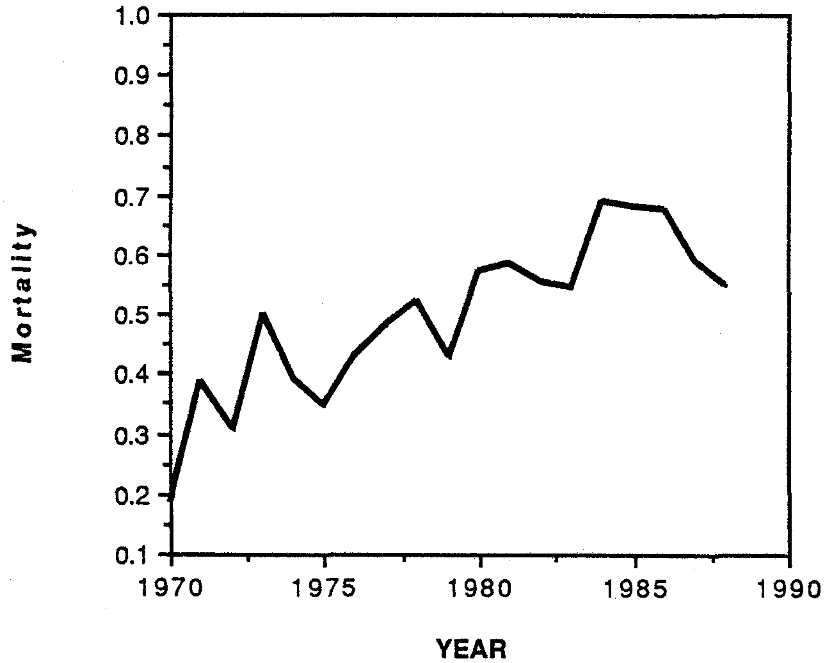
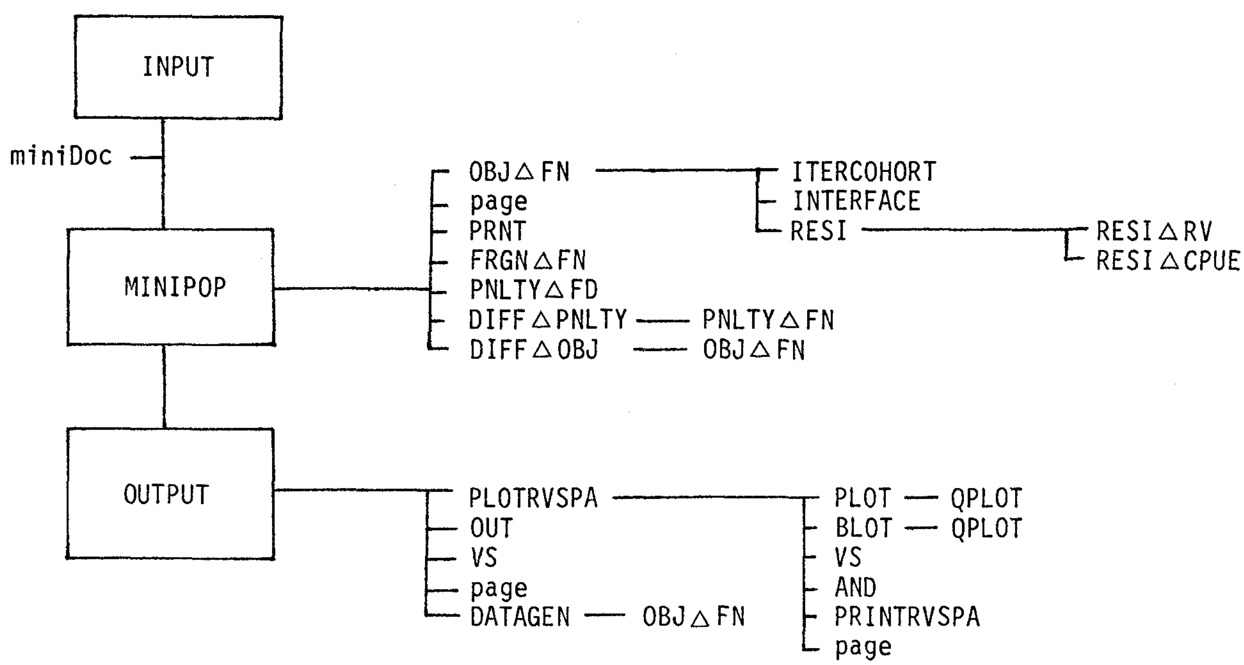


Figure 14. Trends in age 5-6 fish mortality of the 4X haddock resource.

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


      ∇BLOT[⎕]∇
 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
  ⎕IO←1 ⋄ CRTT←5E¯11
  S←⍎(,(0=⎕NC 2 2 ⍴'dxdy')≠ 2 3 ⍴'dx←dy←'),''' '''
  ps←'+0123456789ABCDEFGHIJKLMNOPRSTUVWXYZ'
  →(∧/ 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: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]≤(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↑⌊(∧/(CRTT×D⌈⌈/P)≥M∘.|P←|I+D×¯1+⍳E+1)⍳1]
  S← 10 ¯3 ⋄ →((8<P←1+⌊10⍟⌈/P)∨M<¯7)/L9
  S←10,0⌈(8-P⌈1)⌊-M
 L9:Q←(V⍀S⍕⊖(D×¯1+⍳E+1)∘.+,I),'|+'[1+V←⌽0=S|¯1+⍳1+P←G]
  U←((-⌊(U-×/⍴dy)÷2)⌽(U←G+1)↑dy),Q
  XPS←(⍴T)⍴1
  XPS[1;]←(¯1↑⍴T)⍴1+⍳⍴ps
  X←,XPS+1000×(⍴T)⍴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:QPUT '      ',PVAL
  →(0≤P←P-1)/L10
  QPUT(16⍴' '),'/',(L+1)⍴'+---------'
  M←(⌊10⍟|C)-0,⍳10
  M←M[1↑⌊(∧/(CRTT×C⌈⌈/P)≥(10*M)∘.|P←|B←H+C×¯1+⍳K+1)⍳1]
  S←10-3 ⋄ →((8<P←1+⌊10⍟⌈/P)∨M<¯7)/L13
  S←10,0⌈(8-P⌈1)⌊-M
 L13:QPUT(8⍴' '),S⍕B
  →(0=×/⍴dx)⍴0
  QPUT ⎕TCLF,((18+⌊0.5×L-×/⍴dx)⍴' '),dx


      ∇DATAGEN[⎕]∇
 DATAGEN PAR;RESID
  RESID←OBJ∆FN PAR
 S1:RESID∆RV←((⍴ROWS),1+¯1↑⍴c)⍴RESID
  RESID∆CPUE←(-⍴,i∆cpue)↑RESID


      ∇DIFF∆OBJ[⎕]∇
 R←DIFF∆OBJ;DELTA;I;TPAR
 ⍝ CALCULATES ONE SIDED DIFFERENCE OF OBJECTIVE FUNCTION
  I←1
  R←(N,0)⍴1
  DELTA←(0.01×par)+0.01×par=0
 L1:TPAR←((I-1)↑par),(par[I]+DELTA[I]),I↓par
  R←R,(e-OBJ∆FN TPAR)÷DELTA[I]
  →L1×P≥I←I+1


      ∇DIFF∆PNLTY[⎕]∇
 R←DIFF∆PNLTY;I;R1;DELTA;TPAR;fpnlty;bpnlty
 ⍝ CALCULATES FIRST AND SECOND DIFFERENCES OF PENALTY FUNCTION
  I←1
  R← 2 0 ⍴0
  DELTA←(0.01×PAR)+0.01×PAR=0
 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,,R1,(fpnlty+bpnlty-2×pnlty)÷DELTA[I]
  →L1×P≥I←I+1


      ∇FRGN∆FN[⎕]∇
 R←FRGN∆FN A
  R←∧/(A>lbnd),A<ubnd
 ⍝ THIS FUNCTION SHOULD RETURN A 1 IF THE PARAMETERS
 ⍝ ARE IN THE FEASIBLE REGION AND 0 OTHERWISE
 ⍝ 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[⎕]∇
 INTERFACE POPN;pr;FRF;TAKE
 ⍝ Produces 1 or 2 global variables POPIND and FBIOM
  →(0=INDEX∆TYPE[1])/CPUE
  POPN[1;¯1↑⍴POPN]←*((+/⍟¯4↓,POPN[1;])÷⍴¯4↓,POPN[1;])
  TAKE←1↑⍴POPN
  C88←TAKE↑C88← 1E¯10 9 162 628 1532 1238 404 49 13 2 2 1E¯10
  POP88←0,¯1↓,((TAKE,¯1)↑POPN)×*-((TAKE,¯1)↑F)+m
  POP88MID←(POP88-C88×*m÷4)×*-m÷2
  POPIND←POPN×*-(F+m)×MNTH ⍝ Adjusts SPA population to the survey month
  POPIND←POPIND,[2]POP88MID
  POPIND←POPIND[ROWS;] ⍝ selects calibration block
 CPUE:→(0=INDEX∆TYPE[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[⎕]∇
 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


     ∇OBJ∆FN[⎕]∇
 R←OBJ∆FN 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←((INDEX∆TYPE[2]+⍴ROWS),(¯1↑⍴K))⍴(-(INDEX∆TYPE[2]+⍴ROWS)×¯1↑⍴K)↑A
 ⍝ k is the current calibration coefficients
  ITERCOHORT
  INTERFACE POP
  R←,RESI k ⍝ calculate index residuals


     ∇OUT[⎕]∇
 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
  ' '
  ((¯8+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 ',STOCKΔNAME,'          ',Δts
  dx←'ITERATION NUMBER'
  dy←'RESIDUAL SS'
  20 40 PLOT rssvec VS(⍳⍴rssvec)
  I←1
  ' '
  ' CALIBRATION COEFFICIENTS BY AGE FOR ',STOCKΔNAME,'       ',Δts
  ' '
  →((¯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 Δts
  DATAGEN par
  TIT←'POPULATION NUMBERS (000S)'
  0 OUT POP,[1]+/[1]POP
  TIT←'FISHING MORTALITY'
  page Δts
  3 OUT F
  TIT←'Standardized Residuals for RV index (s.e.=1 for log model)'
  ag←AG
  yr←YR←(YR[1]-1)+⍳¯1↑⍴RESIDΔRV
  AG←AGES
  page Δts
  3 OUT RESIDΔRV
  ' '
  'AVG. RESIDUALS BY AGE  : ', 8 3 ⍕(+/[2]RESIDΔRV)÷+/[2]MASKRV
  'AVG. RESIDUALS BY YEAR : ', 8 3 ⍕(+/[1]RESIDΔRV)÷+/[1]MASKRV
  'AVG. TOTAL RESIDUAL    : ', 8 3 ⍕(+/+/RESIDΔRV)÷+/+/MASKRV
  ' '
  TIT←'PERCENT STANDARDIZED SUM OF SQUARES OF RESIDUALS FOR RV INDEX'
  2 OUT 100×(RESIDΔRV*2)÷(⍴RESIDΔRV)⍴+/+/(RESIDΔRV*2)
  →(INDEXΔTYPE[2]=0)/NOCPUE
  ''
  AG←,0
  TIT←'Standardized residuals for CPUE index'
  3 OUT(1,⍴RESIDΔCPUE)⍴RESIDΔCPUE
NOCPUE:page Δts
  ' '
  'ESTIMATED PARAMETERS AND STANDARD ERRORS'
  PARΔSE
  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 iΔrv
```

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

```
     ∇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
  S←⍎(,(0=⎕NC 4 2 ⍴'dxdyJ ps')⌿ 4 3 ⍴'dx←dy←0⍴ ps←'),'''∘←Δ×∇⎕'''
  →(^/ 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',Δcr
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: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',Δcr
L5A:S←S×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↑⌊(^/(CRTT×D⌈⌈/P)≥M∘.|P←|I+D×¯1+⍳E+1)⍳1]
  S← 10 ¯3 ⋄ →((8<P←1+⌊10⍟⌈/P)∨M<¯7)/L9
  S←10,0⌈(8-P⌈1)⌊-M
L9:Q←(V⍀S⍕⍉(D×¯1+⍳E+1)∘.+,I),'|+'[1+V←⌽0=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↑⌊(^/(CRTT×C⌈⌈/P)≥(10*M)∘.|P←|B←H+C×¯1+⍳K+1)⍳1]
  S←10-3 ⋄ →((8<P←1+⌊10⍟⌈/P)∨M<¯7)/L13
  S←10,0⌈(8-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;DPP;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
  DPP←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↑ρK)/noint
 K← 3 2 1 ⍉(Φ2,ρPOPIND)ρ,K
 ihatΔrv←(K[1;;]+K[2;;]×POPIND) ⍝ WITH INTERCEPT
 →res
noint:K←⍉(ΦρPOPIND)ρ,K
 ihatΔrv←K×POPIND ⍝ WITHOUT INTERCEPT
⍝res:R←(iΔrv-ihatΔrv)×WEIGHT
res:R←((⍟iΔrv)-⍟ihatΔrv)×MASKRV
```

```
    ∇RESIΔCPUE[⎕]∇
R←FBIOM RESIΔCPUE K
 →(1=ρ,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 ,ρB)ρB)⍪(¯2↑ 1 1 ,ρA)ρA
```

```
    ∇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←ρpar←PAR←,initial
 RSS←e+.×e←OBJΔFN PAR ⍝ RESIDUAL SUM OF SQUARES
 N←ρ,e
 pnlty←alpha PNLTYΔFN PAR ⍝ PENALTY FOR CONSTRAINTS
 NPHI←PHI←RSS+pnlty
 LAMBDA←0.01
 BOOL←(P×P)ρ1,Pρ0 ⍝ 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+(2ρP)ρBOOL\dpnlty[2;]
 LAMBDA←9.9999999999999E¯7⌈LAMBDA×0.01
 I←1
 SHESS←HESS+(2ρP)ρBOOL\DIAG×LAMBDA←LAMBDA×10 ⍝ MARQUARDT METHOD
 NORM←(+/SHESS*2)*0.5 ⍝ COLUMN NORMS
 SHESS←SHESS÷(ρSHESS)ρNORM ⍝ 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
```