Assessment of the Voisey stock unit Arctic charr population in 1991

by

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Abstract

Reported landings of Arctic charr from the Voisey assessment unit totaled 11 t in 1991, a decrease of 45% from 1990. Landings have fluctuated between 11 and 21 t for the past eight years largely in response to varying levels of effort. Standardized catch rates in 1991 were the lowest on record. Catch at age data from the 1991 fishery indicated that the 1981 and 1982 year classes were the most abundant in the fishery representing 47% of the catch in numbers of fish. A standardized catch rate, derived using a multiplicative model, was used in an age disaggregated formulation of ADAPT to estimate fishing mortality and stock size in 1991. The assessment indicated that fishing mortality on age 9+ fish was about 0.32 with an estimated population size of about 57,000 fish, about the same as in the past two years, but among the lowest on record. Caution is noted regarding low recruitment estimates in recent years. The projected reference level catch for 1992 ($F_{0.1}$ = 0.4) suggests a reduction of the current TAC by about 20% to 13.4 t.

Résumé

Les débarquements déclarés d'omble chevalier provenant de l'unité d'évaluation de la baie Voisey ont atteint 11 t en 1991, ce qui représente une diminution de 45 % par rapport à 1990. Les débarquements ont fluctué entre 11 et 21 t au cours des huit dernières années, cela principalement à cause d'un niveau variable d'effort. Les taux de prises normalisés de 1991 ont été les plus bas de tous. Les données sur les prises selon l'âge en 1991 révèlent que les classes d'âge de 1981 et 1982 étaient les plus abondantes, représentant 47 % des prises en nombre de poissons. On a eu recours à un modèle multiplicatif pour établir un taux de prise normalisé, que l'on a appliqué à une formule de la méthode ADAPT décomposée par âge afin d'estimer la mortalité due à la pêche et la grosseur des stocks en 1991. Selon cette estimation, la mortalité due à la pêche parmi les poissons de 9 ans et plus était d'environ 0,32 et la population se chiffrait approximativement à environ 57 000 poissons, soit le même nombre qu'il y a environ deux ans et le plus bas enregistré. Les faibles estimations de recrutement des dernières années inspirent la prudence. D'après la projection du niveau de référence des prises de 1992 ($F_{0.1}$ = 0,4), il conviendrait de réduire de 20 % le TPA actuel, qui serait ramené à 13,4 t.

1. Introduction

Arctic charr catch statistics from the Voisey stock unit, made up of Voisey Bay and Antons subareas (Fig. 1), have been available since 1974. It was first assessed as a single unit in 1985 (Dempson and LeDrew 1986). Annual landings have ranged from 4 to 41 t (mean = 20 t, 1974-91), and from 1977 to 1991 have contributed 16% of the commercial catch of charr from the Nain fishing region. In 1991, 20% of the commercial charr catch was taken in the Voisey unit. The recommended Total Allowable Catch (TAC) in 1991 was maintained at 17 t; the same value since 1987.

This paper summarizes information from the 1991 fishery and provides an estimate of current stock size derived from a formulation of the adaptive framework (Gavaris 1988).

2. Trends in catch and effort data - conventional series

Catch and effort data for the Voisey stock unit are summarized in Table 1 for the period 1974-91. The highest catch of 41 t occurred in 1979, the lowest catch of 4 t was in 1975. The TACs listed in Table 1 for 1979 to 1984 applied only to the Voisey Bay subarea. The quota area catch in Table 1 summarizes the landings for from Voisey Bay for those years. Since 1985, the TAC has applied to the entire stock unit.

Landings in 1991 totaled 11 t; a decrease of 45% from 1990 when the TAC was obtained. Landing have fluctuated between 11 and 21 t for the past eight years (Fig. 2) largely in response to varying levels of effort. In 1991, effort decreased by only 13% from 1990, while catch per unit effort (CUE) declined 36% to the lowest value recorded (Table 1).

2.1 Timing of the fishery

In 1991, severe ice conditions contributed to the disruption of normal fishing activities along much of the northern Labrador coast. In many areas, fisherpersons were delayed or prevented from accessing traditional fishing berths. In the Nain stock unit, mean timing of the 1991 commercial catch was approximately three weeks later in comparison with the previous 14 years. For the Voisey Unit, the mean timing of the 1991 fishery was about one week later than the average for the past 14 years, but the greatest impact was in the contracted fishery that occurred (Fig. 3). Peak movements of charr out of the bays early in the summer, or return runs back to rivers in mid to late summer could easily be missed with such a short fishery. This may have contributed to reduced catches and catch rates during the past year.

3. Catch and average weights at age

Catch at age data are available since 1977 and are summarized in Table 2. Catch at age, along with the estimated standard error and coefficient of variation for the 1991 data are provided in Table 3. The 1981 and 1982 year classes (year of hatching) represented by 9 and 10 year old fish in 1991 were the most abundant representing 47% of the catch (Table 2). These year classes

were also the most abundant last year. Mean age of the catch in 1991 was 9.3 years and has ranged from 8.2 y in 1979 to 9.3 in both 1990 and 1991. A summary of the percent at age in the catch is provided in Table 4.

Weights at age were derived from length-weight relationships obtained from sampling the commercial fishery as explained in past years (Dempson 1991). Gutted head-on weights were converted to whole weight using the conversion factor 1.22 (Dempson 1984). A comparison of recorded total landings with the cross product total (sum of the matrix of estimated numbers at age x matrix of weights at age) agreed quite well with the discrepancy between the two of about 0.6% for 1991. Weight at age data are provided in Table 5.

4. Standardization of catch rates

A multiplicative model (Gavaris 1980) was used to account for differences in catch rates between year and week. The regression of ln catch rate for the period 1977 to 1991 was initially fitted using SAS REG procedures (SAS 1985) to avail of the various diagnostics available. Diagnostics included leverage estimates (diagonal elements of the hat matrix) and influence statistics using the DFFITS calculation (Freund and Littell 1986; Myers 1986). Cumulative probability plots of residuals were used in assessing normality of residuals. Standardized catch rates were obtained using the STANDAR (APL) version of the multiplicative analysis program.

The regression of ln catch rate of charr for the 1977-91 period in this model explained 48% of the variation (Table 6). Normal probability plots confirmed the general log normal distribution of the data (Fig. 4). Observations with high leverage were identified in 1982, 1984 and 1991 (Fig. 4) but appear to have little influence as indicated by the generally well balanced DIFFITS values. Both year and week classification variables were significant (Table 6). A comparison of the standardized and unstandardized catch rates for the Voisey stock unit is provided in Fig. 5. Standardized catch rates and estimated effort are provided in Table 7. As indicated earlier, the lowest catch rate recorded was in 1991.

A catch rate index at age was derived using the catch at age along with the estimated effort obtained from the standardization of commercial catch rates (Table 8).

5. Estimation of stock size

Last year, several formulations of the adaptive framework (Gavaris 1988) were run to estimate population size in 1990. These included age aggregated and age dissagregated formulations. The ADAPT process is based on established methods for nonlinear parameter estimation. The minimization procedure is applied to determine a set of parameter values such that the predicted abundance indices by age group are closest to the observed values (further details provided in CAFSAC 1988 p. 32).

Several age disaggregated formulations were attempted this year. Previously, it had been established that intercepts were not significant and thus were not included in the current analysis. Initially, calibrations were

attempted on ages 6 to 12. Results of this run indicated that both the age 6 and 7 population numbers were not significant, similar to results obtained last year. Additional formulations calibrating on ages 7 to 12 yielded significant results.

The resulting formulation is as follows:

Parameters:

- Year-class estimates

  Ni, 1991 i = 7 to 12

- Calibration coefficients for commercial catch rates

  Ki i = 7 to 12

Structure:

- Natural mortality assumed to be 0.2;
- Error in catch at age assumed negligible;
- Fishing mortality (F) for age groups 13-14 set equal to the weighted F for age groups 9-12;
- Model did not include an intercept.

Input:

Ci,t	i = 6 to 14,	t = 1977-91
C/Ei,t	i = 7 to 12,	t = 1977-91

Objective function:

- Minimize:

$$\Sigma\Sigma\{obs(C/Ei,t) - pred(C/Ei,t)\}^2$$
$$it$$

Summary:

- Number of observations = 90
- Number of parameters = 12

5.1 Assessment Results

Abundances were estimated with coefficients of variation (CV) ranging from 0.23 to 0.38 for ages 7 to 12 (Table 9). CVs on the slopes ranged from 0.10 to 0.11. The mean square residual was 0.147. Correlations among estimated

parameters were generally low (Table 10). Residuals displayed some patterns (Table 9) with positive year effects for 1985, 1989, and 1990, and negative effects for 1982, 1987, and 1989.

A summary of estimated population numbers and fishing mortality are given in Table 11. Fishing mortality in 1991 was estimated to be about 0.32 on 9+ fish. Population size estimated for 1991 was low and is influenced by the virtual absence of age 6 fish; a pattern observed in previous years. As stated above, however, age 6 was excluded from the calibration process. Using a geometric mean from 1982-89 to estimate age 6 fish in 1991 results in a total estimated population size of about about 57,000 fish (Fig. 6).

Results of the above formulation suggest that population size during the past three years has remained somewhat stable, but among the lowest levels recorded. Estimates, however, are sensitive to recruitment in the recent years. Excluding 1991, the results suggest, and caution is advised, that recruitment levels during the past few years have declined resulting in overall lower population sizes.

5.2 Retrospective analysis

Variability in recruitment estimates for the terminal year prompted a retrospective examination using the current ADAPT formulation. The retrospective analysis repeated the current assessment by going back as far as 1986. Resulting population sizes are illustrated in Fig. 7. As observed in the figure, dramatic differences in the estimated stock size can occur as new information is added. The population size in the terminal year is often underestimated, primarily because of the poor estimation of the recruiting year class. As mentioned above, this age class is omitted from the ADAPT calibration process due to lack of fit to the model. The addition of one or more years of data, however, tend to smooth out the problem.

As in past assessments, and assessments on other Labrador charr stocks (Nain unit), recruitment values in the terminal year are normally derived from an average. Fig. 7 also illustrates the retrospective pattern of population sizes when average recruitment is used. As expected, there is less variability in the estimation of terminal year population sizes, and more consistency as new information is added. A comparison of population sizes for 1987 and 1988 from the current ADAPT run was made with the population size estimated at that time using the traditional calibration process. The comparison showed that stock size was overestimated by only 6 to 7.5%.

6. Prognosis

Parameters used for projections of reference level catches were derived from the above ADAPT results and are summarized in Table 12. Weights at age were averages of 1988-91 data. Natural mortality was assumed to be 0.2 and $F_{0.1}$ was 0.4. Partial recruitment values for the projection were derived from averaging fishing mortalities over the period 1982-89. Recruitment for the projection was based on the geometric mean population numbers for age 6 fish (1982-89).

Results of the projection suggest that the reference level catch for 1992 should be reduced from the current 17 t TAC by about 20% to 13.4 t. Maintaining the current reference level catch at 17 t would increase fishing mortality to over over 0.52. The suggestion of low recruitment levels in recent, and possibly subsequent years, is noted.

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Table 1. Catch (kg) and effort (person-weeks fished) statistics for the Voisey assessment units from 1974 to 1991. Quota area catch (QAC) refers to the landings from those subareas specifically under TAC regulation only, prior to the derivation of assessment units in 1985.

Year	TAC[1]	QAC	Catch	Effort	CUE	% Offshore	Unit as % of Nain Region Total
1974			29180			31	24
1975			3727			94	8
1976			14652	57	257	21	11
1977			24108	75	321	9	13
1978			36991	102	363	11	17
1979	22500	21880	40590	116	350	47	23
1980	22500	11557	19694	82	240	42	12
1981	16100	16325	23810	90	265	33	10
1982	16100	2688	13309	60	222	45	7
1983	16100	2953	25593	80	320	89	17
1984	16100	8133	20873	101	207	62	17
1985	23400		15648	57	275	91	15
1986	23400		16655	82	203	82	17
1987	17000		21242	101	210	41	22
1988	17000		14037	52	270	60	19
1989	17000		11019	32	344	100	13
1990	17000		19895	69	288	64	23
1991	17000		10971	60	183	26	20

[1]TAC applied only to Voisey Bay subarea from 1979 to 1984.

Table 2. Estimated catch at age from the commercial Arctic charr fishery in the Voisey stock unit, 1977-91.

CATCH AT AGE

AGE	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
6	318	619	475	154	68	316	1045	291	1	44	8
7	2085	4374	4914	803	915	755	2947	2891	1917	851	1312
8	4030	5372	7928	3386	2571	1566	3410	3254	3066	3230	2813
9	2086	2330	3382	4140	4803	2346	3449	2238	3242	3888	4420
10	1237	1236	1163	1424	2359	1226	1611	1392	433	1400	2029
11	600	1141	634	500	941	657	1084	753	324	686	966
12	389	380	212	238	406	65	827	414	233	244	280
13	212	380	159	159	41	13	147	355	64	149	38
14	108	334	55	28	19	27	45	83	55	123	57
6+	11065	16166	18922	10832	12123	6971	14565	11671	9335	10615	11923
7+	10747	15547	18447	10678	12055	6655	13520	11380	9334	10571	11915

AGE	1988	1989	1990	1991
6	140	68	17	9
7	1638	911	1110	909
8	2319	1445	2865	1047
9	1465	1520	2945	1625
10	1440	1135	1827	1257
11	771	702	1083	691
12	289	245	588	362
13	28	107	440	155
14	43	183	136	89
6+	8133	6316	11011	6144
7+	7993	6248	10994	6135

Table 3. Summary of the catch at age in 1991 with an estimate of the standard error and coefficient of variation (C.V.) for the Voisey stock unit.

Age	Catch at age	Standard error	C.V. (%)
6	9	6.1	67.6
7	909	106.1	11.7
8	1047	123.1	11.8
9	1625	142.0	8.7
10	1257	132.2	10.5
11	691	96.3	13.9
12	362	70.9	19.6
13	155	44.6	28.8
14	89	33.8	38.0

Table 4. Summary of the percent at age in the commercial catch of Arctic charr from the Voisey stock unit, 1977-91.

PERCENT AT AGE FOR THE VOISEY STOCK UNIT

	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
6	2.9	3.8	2.5	1.4	0.6	4.5	7.2	2.5	0.0	0.4	0.1	1.7
7	18.8	27.1	26.0	7.4	7.5	10.8	20.2	24.8	20.5	8.0	11.0	20.1
8	36.4	33.2	41.9	31.3	21.2	22.5	23.4	27.9	32.8	30.4	23.6	28.5
9	18.9	14.4	17.9	38.2	39.6	33.7	23.7	19.2	34.7	36.6	37.1	18.0
10	11.2	7.6	6.1	13.1	19.5	17.6	11.1	11.9	4.6	13.2	17.0	17.7
11	5.4	7.1	3.4	4.6	7.8	9.4	7.4	6.5	3.5	6.5	8.1	9.5
12	3.5	2.4	1.1	2.2	3.3	0.9	5.7	3.5	2.5	2.3	2.3	3.6
13	1.9	2.4	0.8	1.5	0.3	0.2	1.0	3.0	0.7	1.4	0.3	0.3
14	1.0	2.1	0.3	0.3	0.2	0.4	0.3	0.7	0.6	1.2	0.5	0.5

	1989	1990	1991
6	1.1	0.2	0.1
7	14.4	10.1	14.8
8	22.9	26.0	17.0
9	24.1	26.7	26.4
10	18.0	16.6	20.5
11	11.1	9.8	11.2
12	3.9	5.3	5.9
13	1.7	4.0	2.5
14	2.9	1.2	1.4

Table 5. Average weight at age (kg-round) from the commercial Arctic charr fishery, Vosiey stock unit, 1977-91.

AVERAGE WEIGHT AT AGE

AGE	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
6	1.53	1.53	1.53	1.03	0.93	1.20	1.33	1.25	1.05	1.07	1.03	1.23
7	1.77	1.77	1.77	1.24	1.26	1.46	1.54	1.53	1.39	1.21	1.41	1.50
8	2.07	2.07	2.07	1.60	1.77	1.70	1.64	1.71	1.63	1.44	1.73	1.69
9	2.60	2.60	2.60	1.89	2.04	2.02	1.89	1.93	1.77	1.64	1.80	1.78
10	2.78	2.78	2.78	2.19	2.17	2.20	2.04	2.06	1.98	1.72	1.95	1.89
11	2.94	2.94	2.94	2.42	2.30	2.49	2.18	2.14	1.99	1.90	2.02	1.98
12	3.24	3.24	3.24	2.49	2.37	2.33	2.10	2.32	2.18	1.90	1.92	1.88
13	2.60	2.60	2.60	2.70	3.36	2.83	2.20	1.91	2.26	1.97	2.31	2.23
14	2.76	2.76	2.76	3.73	2.76	3.42	2.55	1.82	2.26	1.45	1.58	1.45

AGE	1989	1990	1991
6	1.27	1.12	1.11
7	1.43	1.48	1.47
8	1.68	1.70	1.64
9	1.79	1.83	1.79
10	1.95	1.94	1.84
11	2.06	2.01	2.01
12	1.90	1.98	2.01
13	2.04	1.90	2.01
14	1.90	2.29	2.15

MEAN AGE OF INDIVIDUALS IN CATCH

AGE	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
	8.62	8.50	8.20	8.86	9.09	8.84	8.63	8.66	8.51	8.97	8.98	8.77

AGE	1989	1990	1991
	9.18	9.28	9.31

MEAN WEIGHT OF INDIVIDUALS IN CATCH

AGE	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
	2.28	2.21	2.17	1.83	1.98	1.94	1.78	1.79	1.68	1.58	1.79	1.73

AGE	1989	1990	1991
	1.78	1.81	1.77

Table 6. Results of the analysis of variance of log transformed catch rates from the Voisey stock unit, 1977-91.

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: CUE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	24	14.77779945	0.61574164	3.89	0.0001	0.477910	7.2537
ERROR	102	16.14390046	0.15827353		ROOT MSE		CUE MEAN
CORRECTED TOTAL	126	30.92169991			0.39783606		5.48456548

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE III SS	F VALUE	PR > F
YY	14	8.22209606	3.71	0.0001	14	5.91618102	2.67	0.0023
WK	10	6.55570338	4.14	0.0001	10	6.55570338	4.14	0.0001

PARAMETER ESTIMATES

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB > |T|
INTERCEP	1	5.67894421	0.17266160	32.891	0.0001
YY78	1	0.20171088	0.19388653	1.040	0.3006
YY79	1	0.24789399	0.19445667	1.275	0.2053
YY80	1	-0.0128248	0.20017558	-0.064	0.9490
YY81	1	-0.0219671	0.19019559	-0.115	0.9083
YY82	1	-0.391577	0.19642786	-1.993	0.0489
YY83	1	0.36543103	0.20782234	1.758	0.0817
YY84	1	-0.132252	0.19086736	-0.693	0.4899
YY85	1	0.10729802	0.19388653	0.553	0.5812
YY86	1	-0.205329	0.19019559	-1.080	0.2829
YY87	1	-0.151795	0.21873477	-0.694	0.4893
YY88	1	-0.0286212	0.19019559	-0.150	0.8807
YY89	1	0.19265331	0.21605827	0.892	0.3747
YY90	1	0.08763313	0.20647681	0.424	0.6722
YY91	1	-0.46912	0.19642786	-2.388	0.0188
WK25	1	0.10000191	0.21554098	0.464	0.6437
WK26	1	-0.353662	0.16264521	-2.174	0.0320
WK27	1	-0.252579	0.15129331	-1.669	0.0981
WK28	1	-0.18483	0.15124652	-1.222	0.2245
WK29	1	-0.0762424	0.14827986	-0.514	0.6082
WK30	1	0.04574518	0.14827986	0.309	0.7583
WK32	1	0.04392585	0.15036790	0.292	0.7708
WK33	1	-0.20927	0.15744275	-1.329	0.1868
WK34	1	-0.707512	0.16659550	-4.247	0.0001
WK35	1	-0.813801	0.26298319	-3.094	0.0025

Table 7. Commercial catch rate index for the Voisey stock unit, 1977-91.

Year	Standardized catch rate	Standard error	Effort
1977	312	54	77
1978	382	64	97
1979	400	67	101
1980	308	53	64
1981	306	50	78
1982	211	35	63
1983	449	81	57
1984	274	45	76
1985	348	58	45
1986	255	41	65
1987	267	53	80
1988	304	49	46
1989	377	71	29
1990	340	61	58
1991	195	33	56

Table 8. Catch rate index at age for the Voisey stock unit, 1977-91.

VOISEY STOCK UNIT CATCH RATE AT AGE INDEX

	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
6	4.1	6.4	4.7	2.4	0.9	5.0	18.3	3.8	0.0	0.7	0.1	3.0
7	27.1	45.1	48.7	12.5	11.7	12.0	51.7	38.0	42.6	13.1	16.4	35.6
8	52.3	55.4	78.5	52.9	33.0	24.9	59.8	42.8	68.1	49.7	35.2	50.4
9	27.1	24.0	33.5	64.7	61.6	37.2	60.5	29.4	72.0	59.8	55.3	31.8
10	16.1	12.7	11.5	22.2	30.2	19.5	28.3	18.3	9.6	21.5	25.4	31.3
11	7.8	11.8	6.3	7.8	12.1	10.4	19.0	9.9	7.2	10.6	12.1	16.8
12	5.1	3.9	2.1	3.7	5.2	1.0	14.5	5.4	5.2	3.8	3.5	6.3
13	2.8	3.9	1.6	2.5	0.5	0.2	2.6	4.7	1.4	2.3	0.5	0.6
14	1.4	3.4	0.5	0.4	0.2	0.4	0.8	1.1	1.2	1.9	0.7	0.9

	1989	1990	1991
6	2.3	0.3	0.2
7	31.4	19.1	16.2
8	49.8	49.4	18.7
9	52.4	50.8	29.0
10	39.1	31.5	22.4
11	24.2	18.7	12.3
12	8.4	10.1	6.5
13	3.7	7.6	2.8
14	6.3	2.3	1.6

Table 9. Parameter estimates and residuals from ADAPT for the Voisey stock unit, ages 7-12, 1977-91.

ESTIMATED PARAMETERS AND STANDARD ERRORS
APPROXIMATE STATISTICS ASSUMING LINEARITY NEAR SOLUTION

ORTHOGONALITY OFFSET,..... 0.019720
MEAN SQUARE RESIDUALS 0.146783

AGE	PARAMETER	ESTIMATE	STD. ERR.	T-STATISTIC	C.V.
7	ABUNDANCE	1.17152E4	4.44297E3	2.63679E0	0.38
8	ABUNDANCE	7.06945E3	1.94485E3	3.63495E0	0.28
9	ABUNDANCE	7.76181E3	1.83955E3	4.21941E0	0.24
10	ABUNDANCE	5.19551E3	1.22011E3	4.25823E0	0.23
11	ABUNDANCE	2.09245E3	5.02061E2	4.16773E0	0.24
12	ABUNDANCE	1.14280E3	2.83615E2	4.02940E0	0.25
7	RV SLOPE	1.60655E-3	1.70961E-4	9.39720E0	0.11
8	RV SLOPE	4.36605E-3	4.53826E-4	9.62053E0	0.10
9	RV SLOPE	7.40449E-3	7.68217E-4	9.63853E0	0.10
10	RV SLOPE	7.33830E-3	7.64984E-4	9.59275E0	0.10
11	RV SLOPE	8.83085E-3	9.28480E-4	9.51108E0	0.11
12	RV SLOPE	7.90422E-3	8.31103E-4	9.51052E0	0.11

LOG RESIDUALS FOR ABUNDANCE INDEX

	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
7	-0.105	0.009	0.370	-0.533	-0.512	-0.625	0.614	0.179	0.326	-0.490
8	0.343	0.097	0.078	-0.103	-0.197	-0.434	0.394	-0.147	0.148	-0.148
9	-0.120	-0.254	-0.202	0.036	0.189	-0.042	0.587	-0.241	0.445	0.055
10	-0.184	-0.097	-0.208	0.176	0.014	-0.229	0.428	0.364	-0.861	-0.078
11	-0.206	0.305	-0.066	-0.008	0.308	-0.597	0.269	0.060	0.042	-0.513
12	-0.236	0.105	-0.248	0.554	0.834	-1.320	0.595	-0.071	0.311	0.222

	1987	1988	1989	1990	1991
7	-0.260	0.360	0.309	0.360	0.000
8	-0.115	0.240	0.013	0.138	-0.307
9	0.062	-0.256	0.210	-0.024	-0.446
10	-0.072	0.222	0.458	0.335	-0.267
11	-0.112	-0.000	0.374	0.212	-0.068
12	-1.021	0.045	-0.066	0.305	-0.010

SUM OF INDEX 1 RESIDUALS : 0.0001445195 MEAN RESIDUAL : 0.0000016058

Table 10. Parameter correlation matrix for the Voisey stock unit ADAPT run calibrated using ages 7-12, 1977-91.

PARAMETER CORRELATION MATRIX

	1	2	3	4	5	6	7	8	9	10
1	1.000	0.051	0.040	0.033	0.024	0.019	-0.268	-0.022	-0.017	-0.015
2	0.051	1.000	0.060	0.048	0.035	0.028	-0.190	-0.213	-0.025	-0.022
3	0.040	0.060	1.000	0.027	0.046	0.060	-0.150	-0.173	-0.217	-0.065
4	0.033	0.048	0.027	1.000	0.066	0.073	-0.122	-0.134	-0.171	-0.242
5	0.024	0.035	0.046	0.066	1.000	0.082	-0.088	-0.101	-0.128	-0.184
6	0.019	0.028	0.060	0.073	0.082	1.000	-0.070	-0.081	-0.104	-0.133
7	-0.268	-0.190	-0.150	-0.122	-0.088	-0.070	1.000	0.084	0.063	0.055
8	-0.022	-0.213	-0.173	-0.134	-0.101	-0.081	0.084	1.000	0.072	0.062
9	-0.017	-0.025	-0.217	-0.171	-0.128	-0.104	0.063	0.072	1.000	0.079
10	-0.015	-0.022	-0.065	-0.242	-0.184	-0.133	0.055	0.062	0.079	1.000
11	-0.014	-0.021	-0.092	-0.101	-0.275	-0.193	0.053	0.060	0.076	0.090
12	-0.015	-0.022	-0.130	-0.139	-0.119	-0.286	0.056	0.063	0.080	0.084

	11	12
1	-0.014	-0.015
2	-0.021	-0.022
3	-0.092	-0.130
4	-0.101	-0.139
5	-0.275	-0.119
6	-0.193	-0.286
7	0.053	0.056
8	0.060	0.063
9	0.076	0.080
10	0.090	0.084
11	1.000	0.095
12	0.095	1.000

Table 11. Estimated population numbers and fishing mortality from ADAPT for the Voisey stock unit, calibrated using ages 7-12, 1977-91.

POPULATION NUMBERS

	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
6	40971	32422	19036	17243	19404	25936	29910	27496	18544	18833
7	21883	33257	25985	15156	13978	15825	20948	23542	22249	15182
8	11885	16029	23270	16828	11682	10616	12273	14484	16659	16481
9	5853	6084	8263	11879	10714	7238	7275	6963	8915	10865
10	3670	2905	2873	3705	5979	4426	3803	2835	3676	4365
11	1574	1885	1260	1300	1745	2761	2514	1656	1062	2618
12	1135	746	511	458	612	577	1666	1078	674	576
13	1111	577	267	227	160	134	414	616	508	341
14	314	718	129	75	42	94	98	206	183	358
6+	88396	94623	81594	66869	64314	67605	78900	78877	72469	69619

	1987	1988	1989	1990	1991
6	22017	20166	12071	14283	1055
7	15380	18019	16384	9821	11678
8	11660	11405	13270	12590	7037
9	10571	7001	7239	9557	7715
10	5378	4656	4406	4552	5160
11	2307	2567	2509	2580	2073
12	1522	1015	1404	1419	1133
13	251	993	569	928	629
14	145	171	788	369	361
6+	69230	65991	58640	56099	36843

FISHING MORTALITY

	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
6	0.009	0.021	0.028	0.010	0.004	0.014	0.039	0.012	0.000	0.003	0.000
7	0.111	0.157	0.234	0.060	0.075	0.054	0.169	0.146	0.100	0.064	0.099
8	0.470	0.463	0.472	0.252	0.279	0.178	0.367	0.285	0.227	0.244	0.310
9	0.501	0.550	0.602	0.486	0.684	0.444	0.742	0.439	0.514	0.503	0.620
10	0.466	0.635	0.593	0.553	0.573	0.365	0.631	0.782	0.139	0.438	0.540
11	0.547	1.105	0.812	0.554	0.906	0.305	0.647	0.698	0.411	0.342	0.621
12	0.476	0.828	0.613	0.854	1.322	0.133	0.795	0.553	0.481	0.631	0.227
13	0.237	1.302	1.074	1.492	0.334	0.114	0.499	1.014	0.150	0.658	0.183
14	0.472	0.708	0.630	0.528	0.687	0.381	0.699	0.582	0.400	0.472	0.563

	1988	1989	1990	1991
6	0.008	0.006	0.001	0.009
7	0.106	0.063	0.133	0.090
8	0.255	0.128	0.290	0.179
9	0.263	0.264	0.416	0.263
10	0.418	0.335	0.586	0.311
11	0.403	0.370	0.623	0.454
12	0.378	0.214	0.613	0.431
13	0.032	0.233	0.743	0.315
14	0.323	0.294	0.516	0.315

Table 12. Parameters used as input for catch projections of Voisey stock unit Arctic charr.

Age	Mean weight (kg.)	Age disaggregated	
		Population numbers 1991	PR
6	1.21	21142	0.021
7	1.47	11678	0.241
8	1.68	7037	0.602
9	1.80	7715	0.895
10	1.91	5160	1.0
11	2.02	2073	1.0
12	1.94	1133	1.0
13	2.05	629	1.0
14	1.95	361	1.0

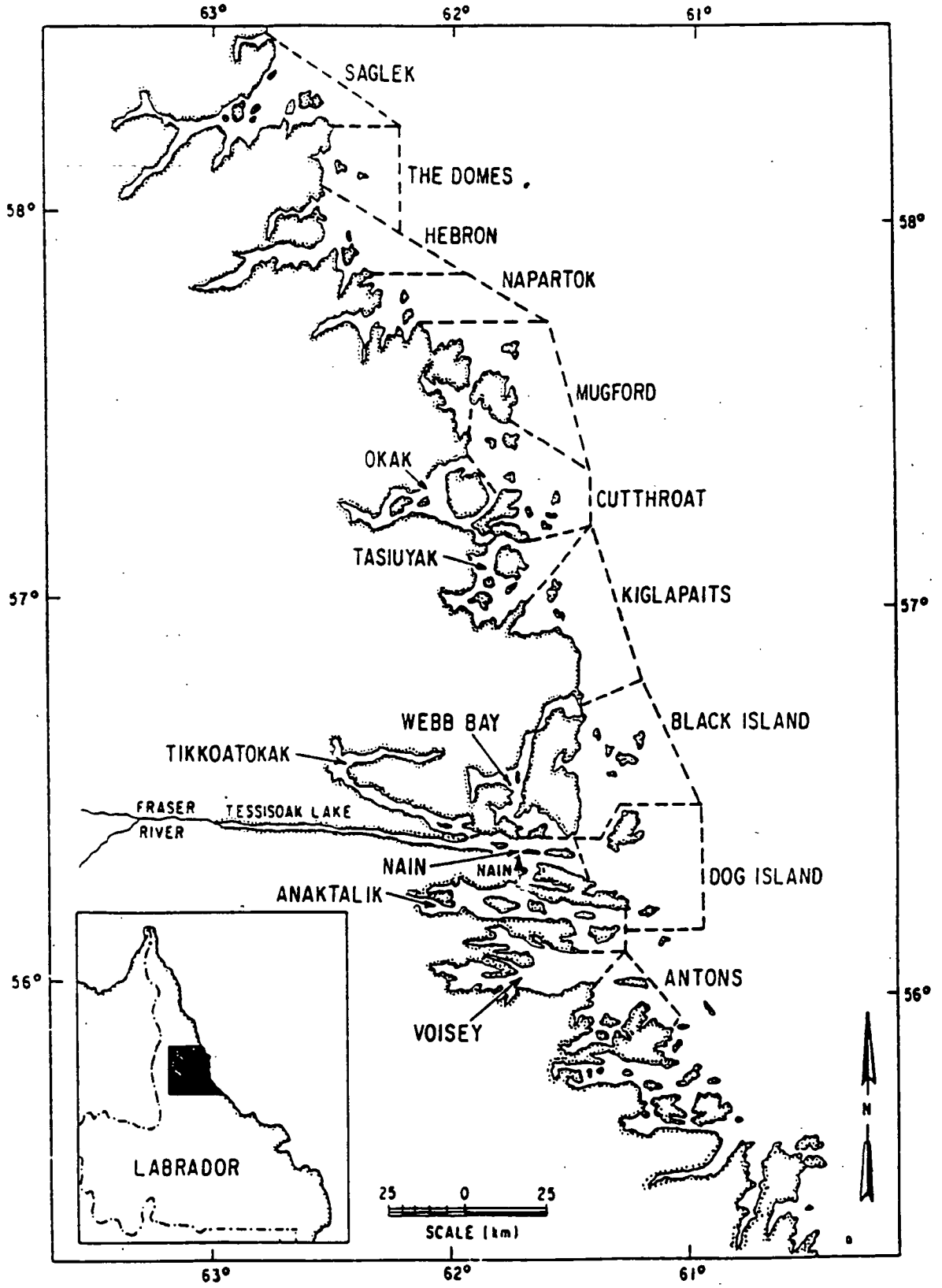


Figure 1. Geographical separation of the Nain Fishing Region subareas.

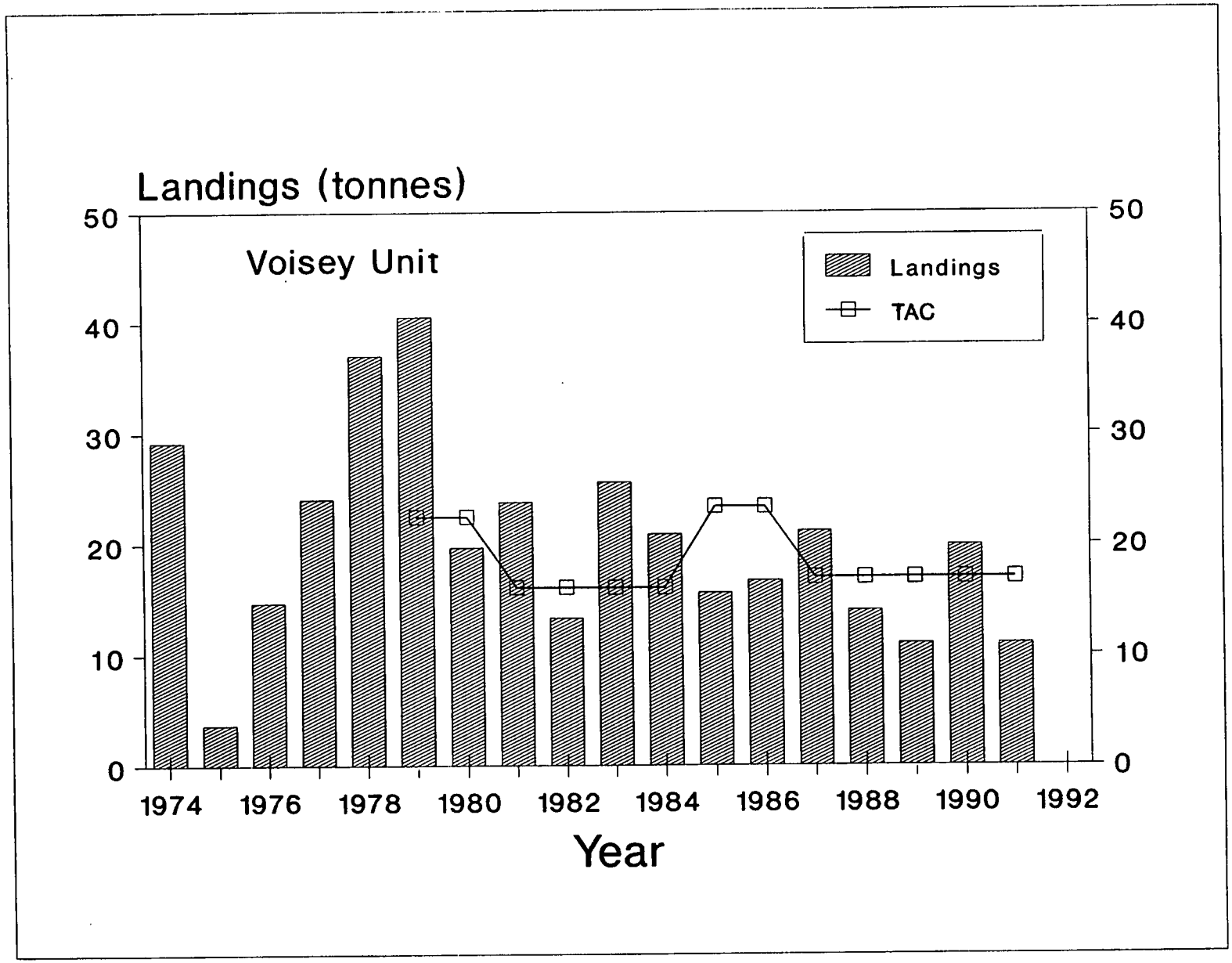


Fig. 2. Summary of Arctic charr landings from the Voisey stock unit in relation to the TAC.

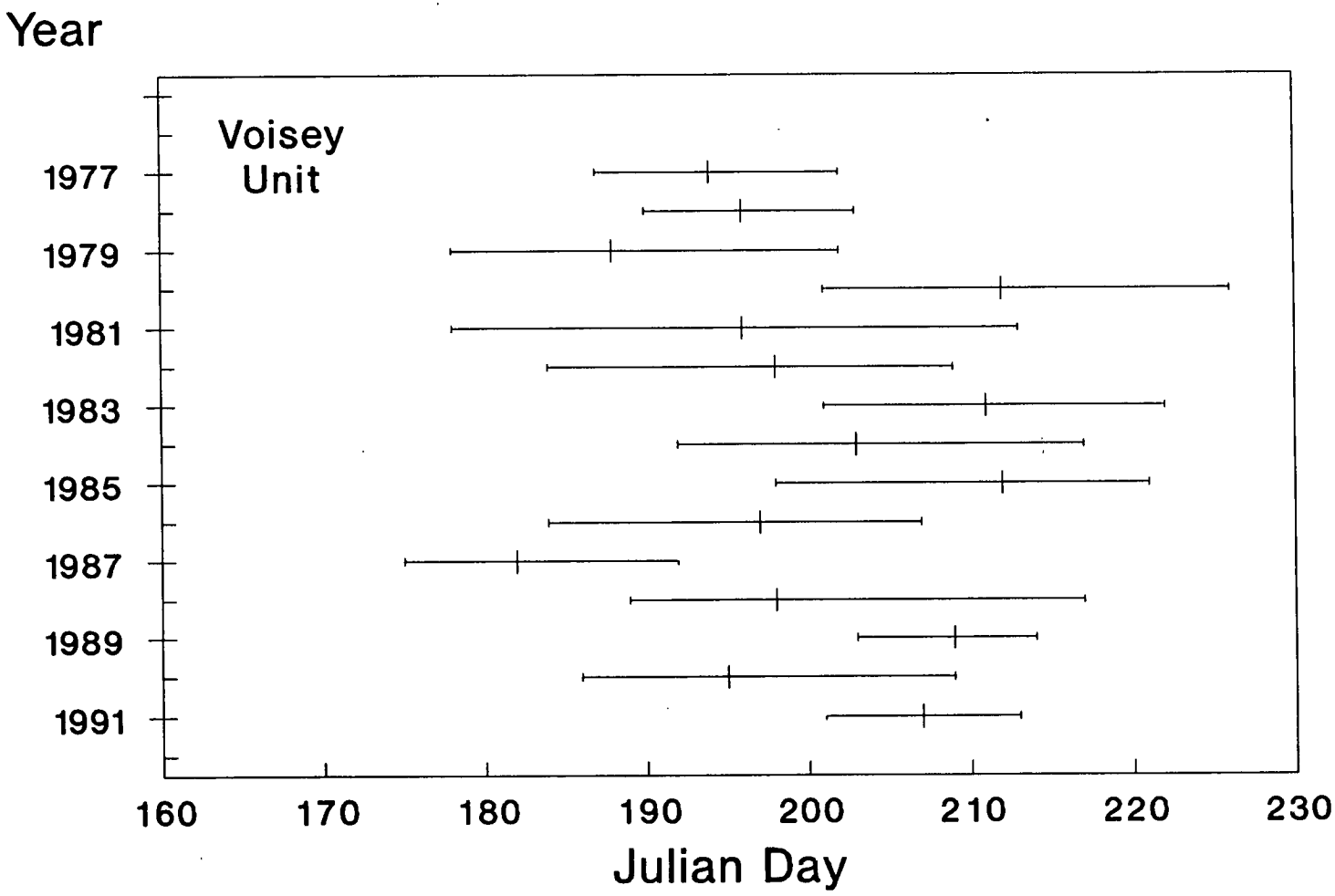
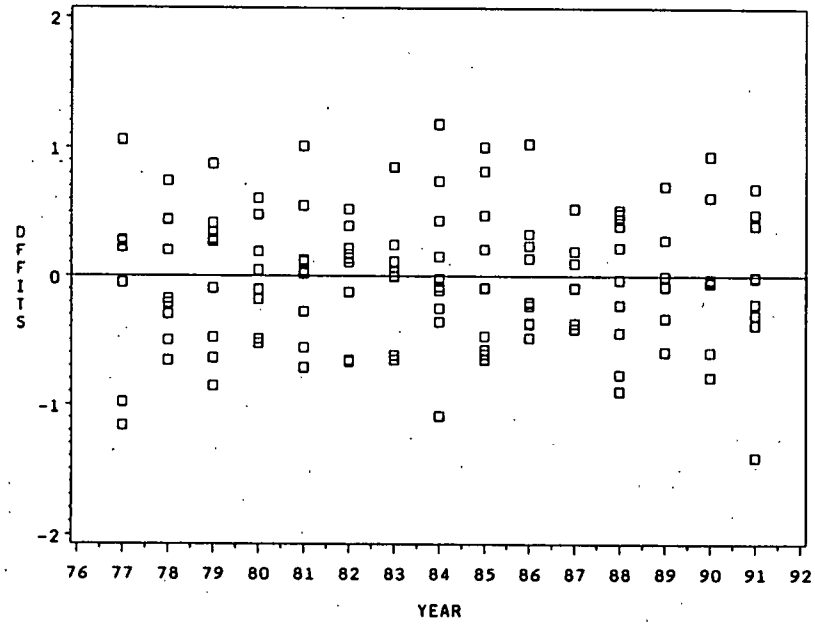
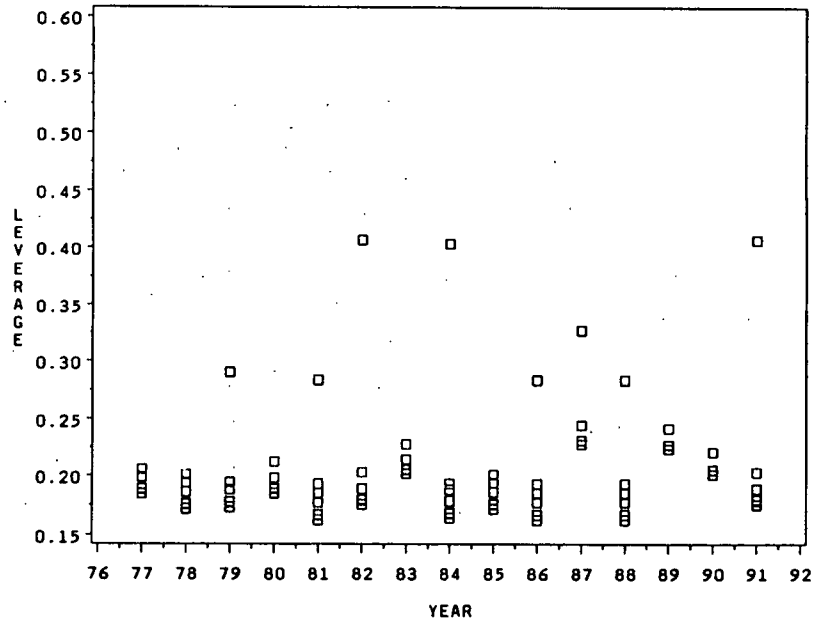
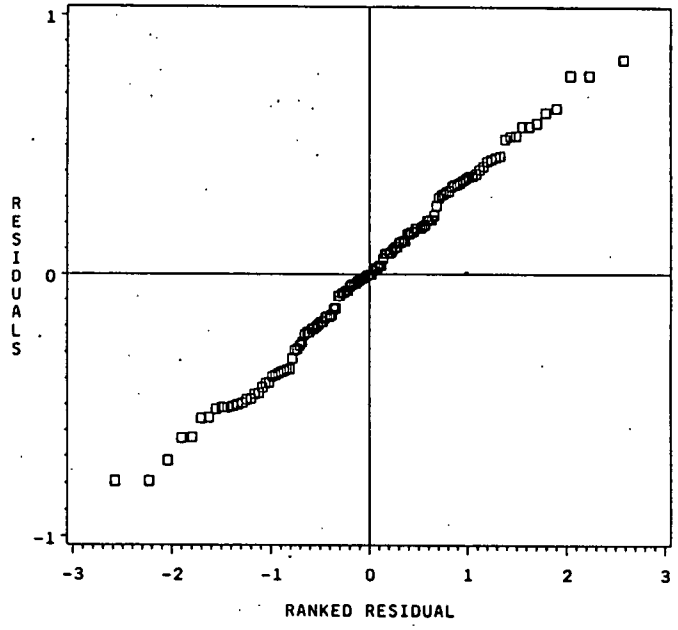


Fig. 3. Catch timing of the Voisey stock unit commercial Arctic charr fishery, 1977-91. The median point, along with the 25th and 75th percentiles are illustrated.







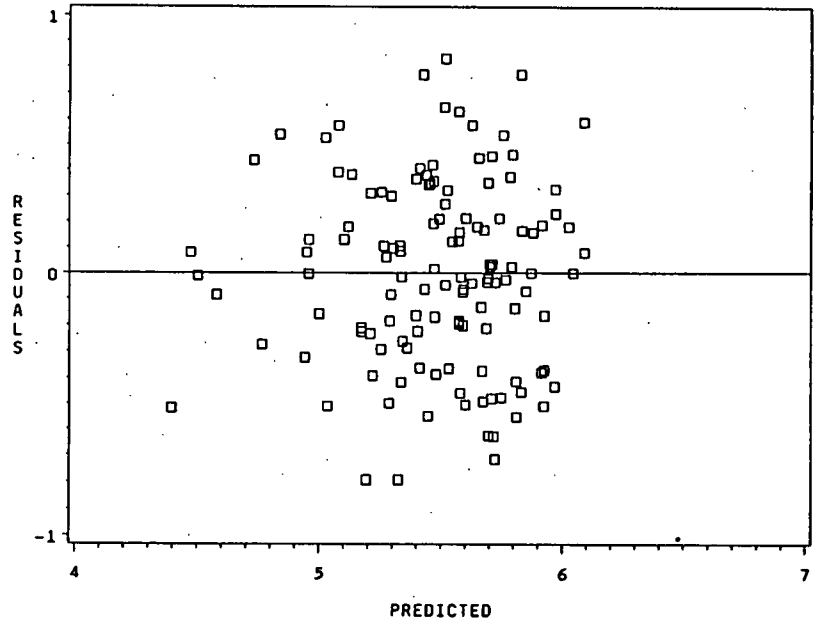


Fig. 4. Residual plots and influence diagnostics for the Voisey stock unit catch rate series, 1977-91.

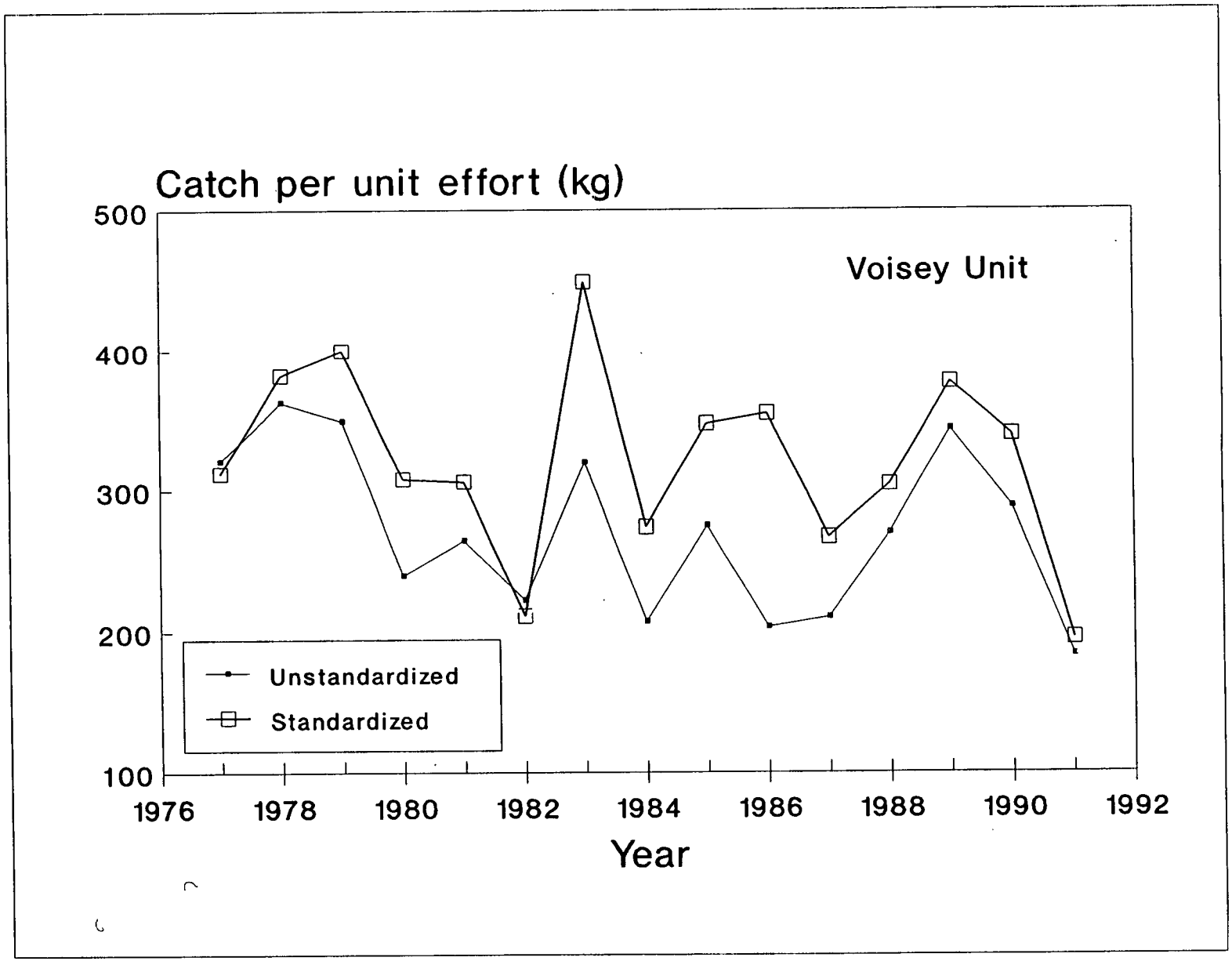
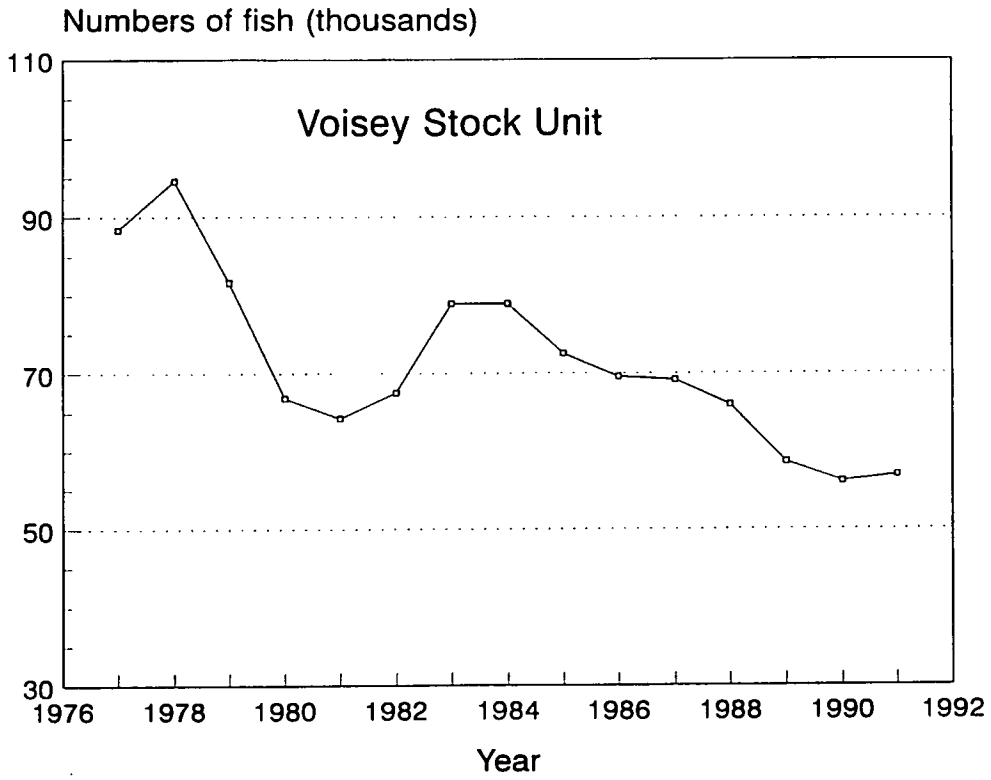


Fig. 5. Comparison of standardized and unstandardized commercial catch rates for the Voisey stock unit, 1977-91.



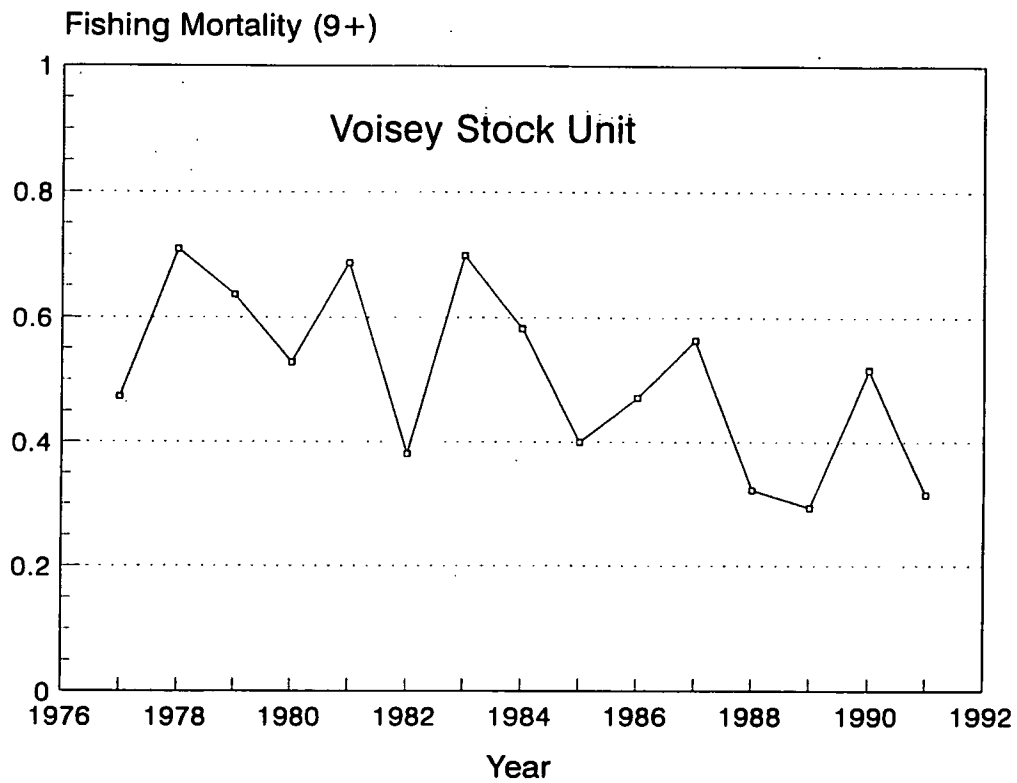
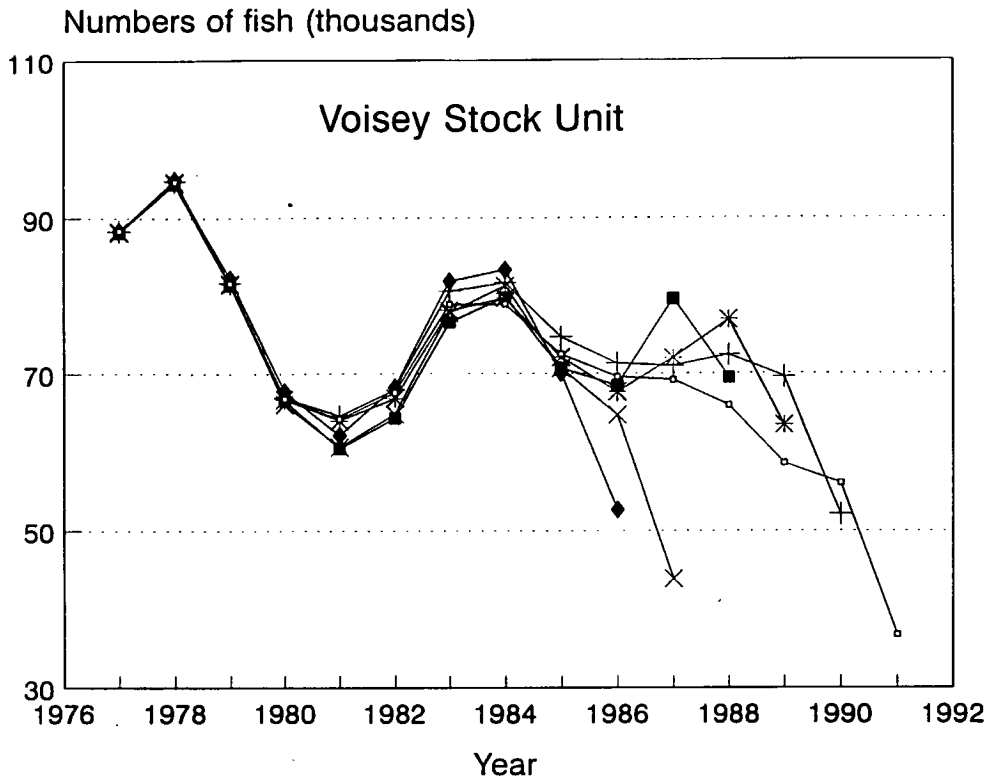


Fig. 6. Estimated population numbers and fishing mortality from the Voisey stock unit Arctic charr population, 1977-91.



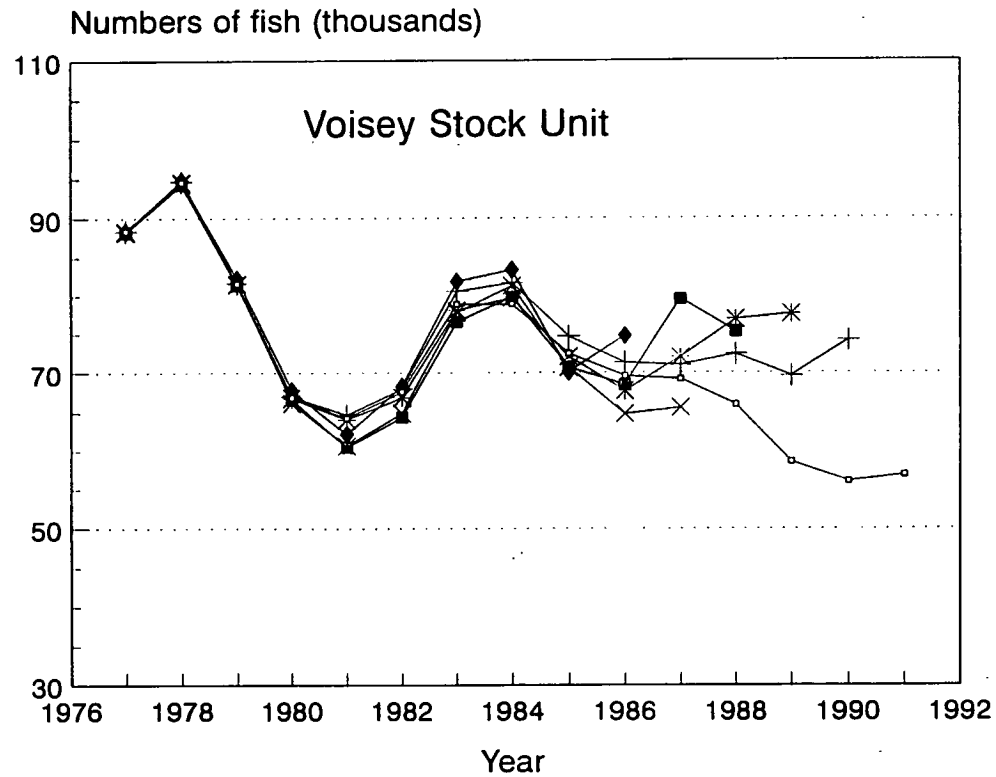


Fig. 7. Comparison of the Voisey stock unit population numbers derived through retrospective ADAPT runs from 1977-86 to 1977-91. Lower figure illustrates population numbers when a correction for recruitment (mean) is used in the terminal year.