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Sequential Population Analysis of the Nain Assessment Unit Arctic Charr Population in 1986

by

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Abstract

The Nain assessment unit, made up of Anaktalik Bay, Nain Bay, Tikkoatokak Bay, Webb Bay, Black Island, and Dog Island, was first assessed as a homogeneous unit at the end of the 1985 fishery. Annual landings from this assessment unit have ranged from 34 to 76 t (mean = 54 t) and from 1977 to 1986 have represented 36% of the total commercial production of Arctic charr from the Nain Fishing Region. Total allowable catch in 1986 was 43 t. Landings in 1986 were 37 t or 86% of the TAC. Effort decreased by 27% while catch per unit effort was 23% higher than in 1985. A sequential population analysis was carried out on catch at age data from 1977 to 1986 and suggested a reference level catch in 1987 from 45.5 to 53.5 t.

Résumé

L'unité d'évaluation de Nain, qui est constituée de la baie d'Anaktalik, de la baie de Nain, de la baie de Tikkoatokak, de la baie de Webb, de Black Island et de Dog Island, a été évaluée pour la première fois comme une entité homogène à la fin de la saison de pêche de 1985. Les débarquements annuels dans cette unité d'évaluation ont varié de 34 à 76 t (moyenne = 54 t) et, de 1977 à 1986, ils ont constitué 36 % de la pêche commerciale totale d'omble chevalier dans la zone de pêche de Nain. En 1986, le TPA était de 43 t et les débarquements ont été de 37 t, ou 86 % du TPA. L'effort de pêche a diminué de 27 %, tandis que les prises par unité d'effort ont été supérieures de 23 % à celles de 1985. Une analyse séquentielle de population a été réalisée à partir des données sur les prises par âge pour 1977 à 1986; cette analyse indique que le taux de prise de référence en 1987 devrait se situer entre 45,5 et 53,5 t.

Introduction

The Nain assessment unit (Fig. 1) consists of an inshore zone made up of Anaktalik Bay, Nain Bay, Tikkoatokak Bay, and Webb Bay subareas, and an offshore zone consisting of the Dog Island and Black Island subareas (Dempson et al. 1986). It was first assessed as a homogeneous unit in 1985 (Dempson and LeDrew 1986). Prior to this, individual assessments were conducted separately on Arctic charr populations from Nain-Tikkoatokak Bay and Anaktalik Bay. Commercial removals from the other subareas within the assessment unit were only partially accounted for in the assessment. Annual landings from the Nain assessment unit have ranged from 34 to 76 t (mean = 54 t) (Table 1) and from 1977 to 1986 have represented 36% of the total commercial production from the entire Nain Fishing Region. The TAC recommended for 1986 was 43 t.

This paper summarizes results of the 1986 fishery and provides a forecast of available harvest, or a 'reference level' catch, for 1987.

Stock Assessment

Catch and effort data for the Nain assessment unit are summarized in Table 1 for 1974-86. The highest catch of 76 t occurred in 1977, the lowest of 34 t was in 1975. No quotas were in effect on any subarea during these two years. The quotas listed in Table 1 for 1979-83 applied only to the specific subareas of Anaktalik Bay and Nain-Tikkoatokak Bay. In 1984 and 1985, an offshore component was included in the TAC. The quota area catch in Table 1, therefore, summarizes landings for those subareas specifically under quota restrictions only prior to the derivation of assessment units in 1986. In 1986, the TAC applied to the entire assessment unit.

Landings in 1986 totaled 37 t and were 10% lower than the previous year. Effort decreased by 27%, while catch per unit effort (CUE) was 23% higher than in 1985. The 1986 catch, however, was 86% of the TAC for the assessment unit.

The trend for increased landings and abundance of fish in the offshore zone continued in 1986 (Table 1). This was the first time that over 50% of the catch occurred in the offshore zone. Since 1976 the proportion of the catch taken in the offshore zone has been correlated with total landings ($r = -0.73$, $P = 0.010$); total landings are lower in years when a greater proportion of the catch occurs in the offshore zone. Based on catch data from 1977 to 1985, July 21 was calculated to be the overall mean date of the fishery as estimated by a migratory timing statistic (Dempson and Kristofferson 1987). Thus fish caught after July 22 are classified as 'late'. Fishing in the offshore zone usually occurs later in the season in comparison with fishing in the inshore areas. Therefore, there is also a highly significant relationship between the proportion of the catch taken in the offshore zone and the proportion of the catch which is taken 'later' in the fishing season ($r = 0.92$, $P = 0.0001$). It follows then that as the proportion of the catch taken later in the season increases, total catch should decrease. In fact total catch is negatively correlated to the proportion of the catch taken 'late' ($r = -0.79$, $P = 0.004$). From counting fence operations it is known that charr begin returning to the rivers during the second two weeks of July. It is possible that the availability of fish to the fishery is less when landings are concentrated in the offshore zone later in the fishing season. Thus overall landings may not necessarily be expected to be as high as if catches were concentrated in the inshore zone earlier in the fishing season.

Numbers at age were available since 1977 and are summarized in Table 2. Data were derived from annual commercial sampling programs. Mean age has ranged from 8.5 to 9.8 years with a slight trend to a younger mean age during the past three years. From 1977 to 1986, 66% of the catch has been made up of 8-, 9-, and 10-year-old fish. Only 5% of the fish are older than age 12.

Weights at age were calculated from commercial samples obtained from 1977 to 1986. Gutted head-on weights were converted to whole weight using the conversion factor 1.22 (Dempson 1984). For the yield per recruit analysis, mean weight at age for the period 1977-79 was used. This tends to reflect more of the 'original' characteristics of the stock. For stock projections, mean weight at age for the period 1984-86 was used (Table 3).

Mean weight at age has changed over time. For 7- to 10-year-old Arctic charr the average percentage decrease in weight is 8% (0.16 kg) (average 1977-79 to 1984-86), while the average decline for 11- to 14-year-old fish is 23% (0.66 kg). It is possible that the large catches during the late 1970s, primarily in the inshore subareas of Anaktalik Bay and Tikkoatokak Bay, have effectively removed the larger individuals from the stock. The percentage of the catch of 'large' charr (fish greater than 2.3 kg gutted head-on weight) in Anaktalik Bay from 1977 to 1979 ranged from 20 to 38% but dropped to 11% for 1982-84 (Dempson et al. 1986). Similarly in Tikkoatokak Bay, the percentage of 'large' charr in the catch was between 14 and 20% in 1977-79, but only 5 to 8% in 1982-84. These two subareas dominated the landings from the Nain assessment unit from 1977 to 1979 ranging from 79 to 92% of the total catch. From 1984 to 1986 only 11-33% of the total catch was taken from these two subareas. The change in mean weight at age would appear to reflect the removal of these larger fish.

Total mortality (Z) was calculated using the Paloheimo method (Ricker 1975) and the average value from all years (1977-78 to 1985-86) was 0.57. Average Z of 0.60 for the past three years (1983-84 to 1985-86) was reasonably constant. Assuming a natural mortality rate as in past assessments of 0.2 yields an estimate of fishing mortality of 0.40. An estimate of total mortality was also derived from a catch curve using catch per unit effort at age data from 1984-86. This indicated a Z of 0.62.

As in past years, an estimate of fishing mortality was derived from:

$$\mu = 1 - e^{-F} \text{ (Ricker 1975)}$$

where μ was estimated from tag recaptures. Using last year's value of 10% for an estimate of tagging mortality, tag loss or non-reporting of tags results in a value of μ of

$$\mu = \frac{151}{435} = 0.347.$$

Rate of fishing mortality was calculated to be 0.43 (95% C.L. = 0.35 - 0.52).

An initial cohort analysis was run using partial recruitment values and terminal fishing mortality (F_T) from last year's assessment (Dempson and LeDrew 1986) (F_T = 0.45). An iterative procedure was used to obtain estimates of fishing mortality for the oldest age group (F_B). The iteration process stops when the input and output values differ by 0.005 or less (Rivard 1982). Following this the cohort analysis procedure was rerun using the newly-derived values for F_B.

Partial recruitment rates were calculated using the historical averaging method from the matrix of fishing mortality rates generated from the last sequential population analysis (SPA) and are presented in Table 3.

Yield per recruit was calculated by the method of Thompson and Bell (Ricker 1975) using partial recruitment rates and mean weight at age. $F_{0.1}$ was 0.40 at a yield per recruit of 0.89 kg.

Cohort analyses were performed using a range of terminal fishing mortality (F_T) rates from 0.2 to 0.6 using the newly-derived estimates of partial recruitment. In each run, fishing mortality rates for the oldest age group (F_B) were re-evaluated using the iterative procedure. Regressions of F (weighted mean F for fully-recruited fish) on fishing effort and population biomass on catch per unit effort of fully-recruited fish were used in tuning the analysis to key in on an appropriate value for F_T in 1986. Data from 1977 to 1986 were included in the regression analyses.

Regressions of F on effort showed a decrease in the correlation coefficient with an increase in F_T (Table 4). The distance of the last point (1986) to the regression line decreased as F_T increased. The intercept value, however, was lowest when F_T = 0.25. Two additional indices were used in trying to identify an appropriate value for F_T. The sum of the residuals for the last three years (1984-86) was the lowest when F_T = 0.35, while the sum of squares of the residuals for the last three years was minimal when F_T = 0.3.

With respect of the regressions of population biomass on CUE, the correlation coefficient had the highest value when F_T = 0.3. The residual of the last year to the regression line was lowest when F_T = 0.35, while the residuals for the last three years were also lowest when F_T = 0.3

In summary, regression analyses suggest a value of F_T of 0.3-0.35. Estimates derived from the Paloheimo and catch curve methods (F_T = 0.4), in addition to the tagging results (F_T = 0.43) suggest a slightly higher value of terminal fishing mortality.

Stock projections, therefore, were run with F_T varying from 0.35 to 0.45. Recruitment for the projections was estimated from the geometric mean of population numbers for age 6- and 7-year-old fish for years 1977-84. Weights at age were based on 1984-86 data. Table 5 summarizes the population numbers and fishing mortality matrix for the cohort analysis run with F_T = 0.40.

Results of the projections are summarized in Table 6. The 'reference level' catch in 1987 ranges from 45.5 to 53.5 t with the highest value occurring with F_T = 0.35. The 1987 reference level catch resulting from the cohort analysis run with F_T = 0.40 is virtually identical to the projected available harvest two years in advance from last year's assessment (47.7 t). The reference level catch projected two years in advance (for 1988), with F_T = 0.40, would be 50 t. A reference level catch of 47 t for 1987 would be 9% higher than last year, but still 19% lower than the average catch in this assessment unit over the past 10 years (mean = 58.2 t, 1977-86).

The reference level catch could be apportioned using the proportionate distribution of total landings in the Nain assessment unit inshore and offshore zones during the past five years. These values are:

	Average 1982-86
Inshore	0.620
Offshore	0.380

Applying these values to a reference level catch of 47 t, for example, would result in the following distribution of allowable landings for 1987:

Inshore	29.1 t
Offshore	17.9 t

The inshore component could also be subdivided into respective subareas to avoid concentrating effort in any one location.

References

Dempson, J. B. 1984. Conversion factors for northern Labrador Arctic charr landings statistics. CAFSAC Res. Doc. 84/6.

Dempson, J. B., and A. H. Kristofferson. 1987. Spatial and temporal aspects of the ocean migration of anadromous Arctic char, Salvelinus alpinus. In Life history strategies of diadromous fishes. Am. Fish. Soc. Spec. Publ.

Dempson, J. B., and L. J. LeDrew. 1986. Sequential population analysis of the Nain assessment unit Arctic charr population. CAFSAC Res. Doc. 86/24.

Dempson, J. B., L. J. LeDrew, and G. Furey. 1986. Summary of catch statistics by subarea and assessment unit for the northern Labrador Arctic charr fishery in 1985. CAFSAC Res. Doc. 86/26.

Ricker, W. E. 1975. Computation and interpretation of biological statistics of fish populations. Bull. Fish. Res. Board Can. 191.

Rivard, D. 1982. APL programs for stock assessment (revised). Can. Tech. Rep. Fish. Aquat. Sci. 1091.

Table 1. Summary of catch and effort statistics for the Nain assessment unit, 1974-86. Quotas and landings are in kg round weight, effort is expressed as man-weeks fished. Refer to text for information on quotas and quota area catch.

	Inshore			Offshore				Total				
	Catch	Effort	CUE	Catch	Effort	CUE	% Catch offshore	Catch	Effort*	CUE	Quota	Quota area catch
1974	30,822			6,923			18.1	37,745				
1975	31,076			2,754			8.1	33,830				
1976	50,813	146	348	2,500	52	48	4.7	53,313	196	272		
1977	7,098	183	387	5,347	114	47	7.0	76,255	291	262		
1978	70,465	212	332	3,298	106	31	4.5	73,763	314	235		
1979	54,967	189	291	11,877	152	78	17.8	66,844	336	199	61,000	52,832
1980	52,328	183	286	22,727	215	106	30.3	75,055	390	192	61,000	50,176
1981	49,956	157	318	15,676	131	120	23.9	65,632	278	236	37,160	37,223
1982	43,108	119	362	12,509	117	107	22.2	55,617	235	237	43,660	39,119
1983	33,603	147	229	17,599	149	118	34.4	51,202	289	177	51,000	19,102
1984	24,558	131	187	14,342	128	112	36.9	38,900	244	159	43,200	29,063
1985	21,527	125	172	19,631	130	151	47.7	41,158	252	163	30,500	36,019
1986	16,347	91	180	20,748	101	205	55.9	37,095	185	201	43,000	

*Total effort should be equal to or less than the sum of the inshore and offshore effort.

TABLE 2. ESTIMATED CATCH AT AGE FOR ARCTIC CHARR FROM THE NAIN STOCK UNIT,1977-86.

	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
6	2003	371	430	113	145	145	210	83	174	212
7	9250	6703	4306	1023	1557	641	1689	2009	2862	4183
8	12453	13122	11568	11930	6570	4425	4797	3850	7277	7814
9	7630	7984	9593	16725	15180	7746	6732	5692	4510	5939
10	5052	4406	4208	8541	9784	8624	5389	5085	3706	2894
11	2454	2367	2168	3543	3286	5020	5285	2362	2133	1304
12	988	1688	1573	946	673	2604	3378	1539	1324	635
13	358	312	418	764	232	412	865	575	828	242
14	180	272	312	349	80	259	306	142	442	201
15	1	118	34	39	57	47	1	29	214	206
16	1	97	14	2	10	17	1	1	30	52
17	1	1	1	16	1	25	15	1	41	1
TOTAL	40371	37441	34625	43992	37575	29965	28668	21368	23541	23682
MEAN AGE	8.5	8.8	8.9	9.2	9.3	9.8	9.8	9.4	9.2	8.8

Table 3. Summary of weight (kg-round) at age data, partial recruitment rates and calculated $F_{0.1}$ for the Nain assessment unit Arctic charr populations.

	Weight			
Age	1977-79	1980-83	1984-86	Partial recruitment
6	1.05	1.13	1.15	0.012
7	1.52	1.41	1.40	0.105
8	1.83	1.62	1.75	0.420
9	2.12	1.91	2.01	0.762
10	2.45	2.01	2.12	1.00
11	2.59	2.01	2.12	1.00
12	2.63	2.08	2.09	1.00
13	2.74	2.16	2.13	1.00
14	3.13	2.09	2.10	1.00
15	3.05	2.18	2.10	1.00
16	3.05	2.10	2.10	1.00
17	3.05	2.10	2.10	1.00

$F_{0.1}$ = 0.40 at a Y/R of 0.893 kg

Table 4. Results of regressions (1977-86) of F on effort and population biomass on catch per unit effort for various terminal fishing mortality rates (F_T) for the Nain assessment unit.

Regression	Parameter	Terminal F 0.2	0.25	0.3	0.35	0.4	0.45	0.5	0.6
F (weighted mean for fully-recruited fish) on effort	r	0.85	0.83	0.79	0.73	0.65	NS 0.54	0.42	0.15
	residual - 1986	-0.11	-0.11	-0.11	-0.10	-0.09	-0.08	-0.06	-0.03
	normalized	-0.21	-0.20	-0.19	-0.17	-0.15	-0.12	-0.10	-0.04
	intercept	-0.10	0.00	0.10	0.19	0.27	0.35	0.43	0.58
	normalized	-0.20	0.00	0.17	0.32	0.45	0.58	0.69	0.88
	Σ residuals (1984-86)	-0.15	-0.10	-0.05	-0.01	0.03	0.06	0.10	0.16
	Σ $(residuals)^2$ (1984-86)	0.01	0.01	0.00	0.01	0.02	0.02	0.02	0.03
Population biomass (fully-recruited fish) on CUE	r	0.66	0.82	0.85	0.84	0.81	0.79	0.77	0.74
	residual (t) - 1986	16	8	2	-2	-5	-7	-9	-11
	normalized	0.32	0.17	0.05	-0.04	-0.11	-0.17	-0.21	-0.29
	intercept (t)	26	21	17	14	12	10	9	7
	normalized	0.54	0.45	0.38	0.33	0.29	0.26	0.23	0.19
	Σ residuals (1984-86)	15	3	-6	-12	-17	-20	-23	-27
	Σ $(residuals)^2$ (1984-86)	248	70	39	59	98	142	186	266

Table 5. Summary of the population numbers and fishing mortality matrix for the cohort analysis run at $F_T = 0.40$ on the catch at age data for the Nain assessment unit Arctic charr population.

POPULATION NUMBERS

	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
6	124694	106217	56758	49003	41296	39282	60132	86891	137150	46894
7	82884	100279	86627	46081	40018	33679	32030	49042	71065	112132
8	42931	59490	76036	67028	36802	31355	26994	24696	38334	55594
9	21483	23881	36833	51786	44083	24186	21667	17761	16736	24801
10	13257	10685	12328	21476	27265	22357	12793	11648	9391	9621
11	6637	6283	4761	6286	9855	13470	10501	5598	4936	4335
12	2222	3214	3002	1936	1941	5095	6486	3815	2446	2111
13	826	925	1104	1035	729	980	1815	2254	1731	805
14	419	352	475	525	156	387	429	704	1325	668
15	134	180	42	107	114	55	83	75	448	685
16	3	109	41	4	52	42	3	67	35	173
17	1	1	1	21	1	34	19	1	54	1
6+	295492	311616	278009	245287	202314	170923	172954	202552	283651	257820
7+	170798	205399	221251	196285	161017	131641	112822	115661	146501	210926
8+	87914	105120	134624	150204	120999	97961	80791	66619	75435	98794
9+	44982	45630	58588	83176	84197	66606	53797	41923	37101	43200

FISHING MORTALITY

	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
6	0.018	0.004	0.008	0.003	0.004	0.004	0.004	0.001	0.001	0.005
7	0.132	0.077	0.057	0.025	0.044	0.021	0.060	0.046	0.046	0.042
8	0.387	0.279	0.184	0.219	0.220	0.170	0.219	0.189	0.235	0.168
9	0.498	0.461	0.339	0.442	0.479	0.437	0.421	0.437	0.354	0.305
10	0.547	0.608	0.474	0.579	0.505	0.556	0.627	0.659	0.573	0.400
11	0.525	0.538	0.700	0.975	0.460	0.531	0.812	0.628	0.649	0.400
12	0.676	0.869	0.865	0.776	0.483	0.832	0.857	0.590	0.912	0.400
13	0.652	0.466	0.542	1.692	0.433	0.625	0.748	0.331	0.752	0.400
14	0.644	1.918	1.294	1.325	0.837	1.343	1.549	0.252	0.460	0.400
15	0.008	1.288	2.179	0.518	0.801	2.804	0.013	0.560	0.751	0.400
16	0.524	4.196	0.479	0.827	0.239	0.592	0.516	0.017	2.985	0.400
17	0.553	0.636	0.586	0.693	0.493	0.585	0.742	0.589	0.639	0.400
10+	0.555	0.665	0.602	0.720	0.493	0.593	0.751	0.596	0.648	0.400

Table 6. Summary of projected reference level catch (t) for 1987 and 1988 with F_T in 1986 varying from 0.35 to 0.45.

	F_T in 1986		
Reference level catch	0.35	0.40	0.45
1987	53.5	47.5	45.5
1988	54.9	50.2	49.1

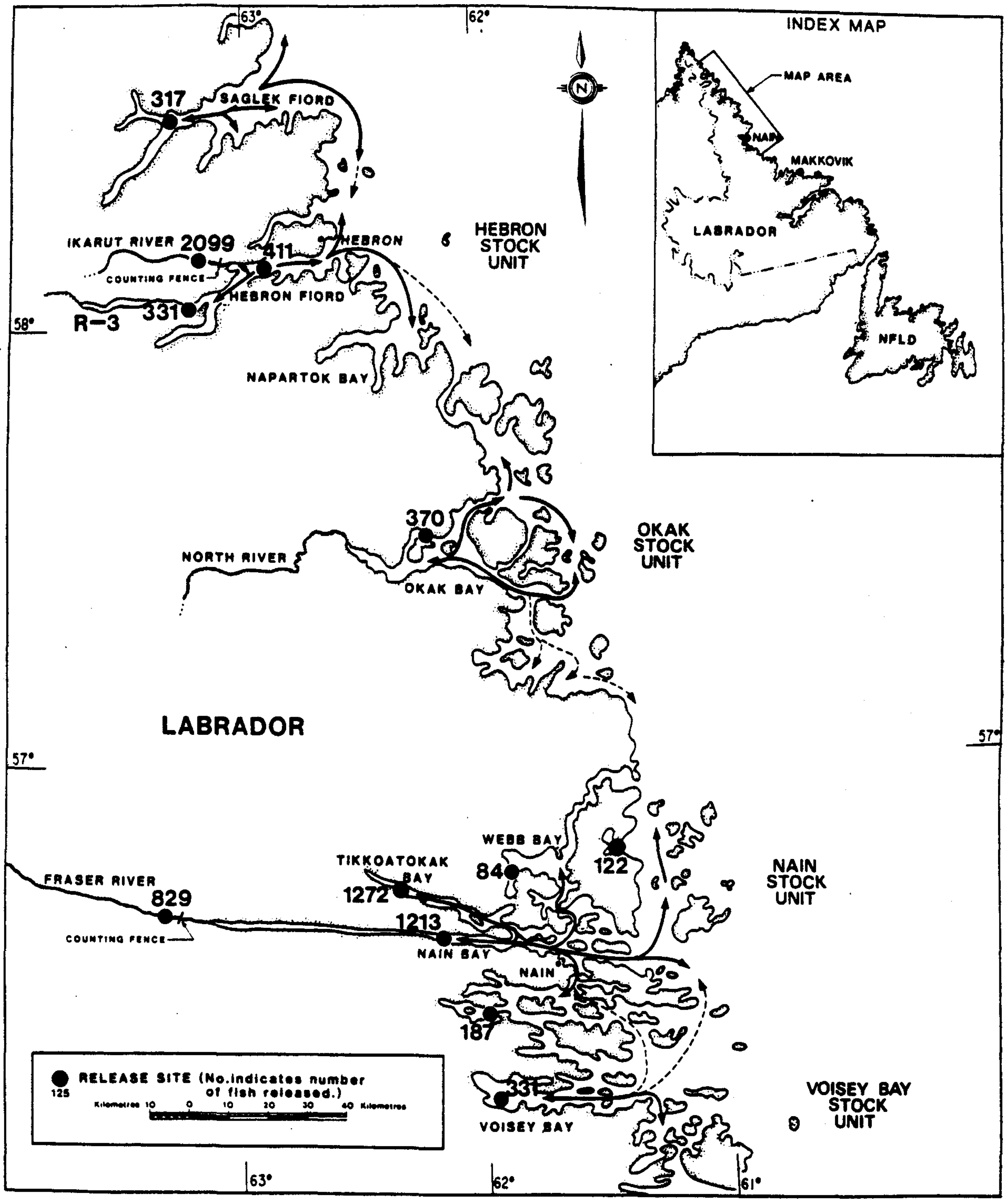

Fig. 1. General patterns of ocean movements of anadromous Arctic charr in northern Labrador showing number of fish tagged and release locations. Stock Unit areas are also indicated.