ECOLOGY AND COMPARATIVE POPULATION DYNAMICS OF ANADROMOUS ATCTIC CHARR, SALVELINUS ALPINUS (LINNAEUS 1758), IN NORTHERN LABRADOR

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ECOLOGY AND COMPARATIVE POPULATION DYNAMICS OF ANADROMOUS ARCTIC CHARR, SALVELINUS ALPINUS (LINNAEUS 1758), IN NORTHERN LABRADOR

by

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ABSTRACT

Biological characteristics and population dynamics of northern Labrador anadromous Arctic charr (Salvelinus alpinus) were investigated. Univariate and multivariate statistical analyses were performed on nine meristic and thirteen morphometric characters of charr samples from various northern Labrador areas. Variation in meristic characters was slight, although significant differences between samples indicated the discrete nature of the stocks. Differences in growth rate, age at maturity, and movement patterns of tagged fish corroborated results of morphological analyses.

Biological characteristics including age, growth, movement patterns and aspects of reproduction were examined in Fraser River Arctic charr. No consistent differences in growth rate were found between male and female charr. Upstream migration from the sea began in mid-July with a tendency for larger fish to enter the river first. Average size and age of upstream migrants were 45.1 cm and 8.3 years respectively.

Biological characteristics of commercially exploited and unexploited Labrador charr populations were examined. Mean age of charr increased with latitude. Commercial exploitation has reduced the proportion of charr greater than 2.3 kg (gutted head-on weight) in commercial catches. Mean length of catches, however, has remained relatively constant in several areas. Total instantaneous mortality rates varied from 0.48 to 0.83 in exploited areas to 0.28 and 0.29 in unexploited populations.

Comparisons between northern Labrador Arctic charr and charr from other regions are discussed with respect to movement patterns, size, age and reproductive characteristics. Labrador charr migrated to sea for the first time at smaller sizes (7.8-19.1 cm) but comparable ages (3-7 years) with Arctic charr from other regions. Egg production in Fraser River charr was intermediate between charr from eastern and central Arctic regions, and those from the Western Arctic. Female Fraser River charr were estimated to produce 245 eggs 100 g^{-1}. Commercially exploited Labrador Arctic charr populations were generally smaller and younger than exploited charr stocks in the Northwest Territories.

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1. INTRODUCTION

Arctic charr, *Salvelinus alpinus* (Linnaeus 1758), have a circumpolar distribution in which they occur as anadromous and resident freshwater populations. They are the most northerly distributed freshwater fish (Walters 1955; Scott and Crossman 1973) and are one of the few species known to occur naturally in an ecosystem as the only fish species present (Johnson 1980). Their North American range extends from as far south as Maine and New Hampshire (McPhail 1961) to approximately the northernmost limit of land, Discovery Harbour, Ellesmere Island (Bigelow 1963). In Labrador, Arctic charr are found along the entire coast, however, they are more abundant north of Hamilton Inlet being largely replaced by brook charr (*Salvelinus fontinalis*) and Atlantic salmon (*Salmo salar*) in southern Labrador. Anadromous Arctic charr are also known to exist in Parker's River, Pistolet Bay, on the northern tip of Newfoundland while relict lacustrine populations are found in Maine, New Hampshire, New Brunswick (Catt 1950), Quebec (Vladykov 1954; Saunders and Power 1969; McAllister and Coad 1974), and insular Newfoundland (Scott and Crossman 1964; Rombough *et al*. 1978).

Relict populations of Arctic charr in Maine, New Hampshire and Quebec were originally regarded as separate species (Rombough *et al*. 1978): *S*. *marstoni*, the Quebec red trout (Vladykov 1954); *S*. *oquassa*, the blueback trout (Waters 1960; Everhart and Waters 1965) and *S*. *aureolus*, the sunapee trout (Kircheis 1976; McCleave, LeBar and Kircheis 1977). However, Saunders and McKenzie (1971), Qadri (1974) and Kornfield *et al*. (1981) have concluded that these forms are actually conspecific but could be given subspecific status on the basis of their geographical isolation (*S. alpinus oquassa*). Behnke (1980) suggested that relict lacustrine populations in eastern North America originated from a northern European *Salvelinus alpinus* which dispersed across the North Atlantic Ocean. Based on morphological comparisons he believes Labrador Arctic charr represent an introgression of this eastern North American form with the eastern Arctic charr (described by McPhail 1961) which dispersed from Asia across the Arctic Ocean to North America with the two forms coming in contact in postglacial times in Labrador. Variability in Labrador charr, possibly resulting from this introgression, was noted by Backus (1957) who stated that these charr differed more in general appearance among themselves than in any comparison made between relict forms from Maine.

Numerous studies have been carried out on the biology of Arctic charr in Alaska, the Yukon and the Northwest Territories (Sprules 1952; Grainger 1953; Thomson 1957; Hunter 1970; McCart and Craig 1973; Yoshihara 1973; Bain 1975; McCart and Bain 1974; Moore and Moore 1974; Craig and Poulin 1975; Moore 1975a, and b; Johnson 1976, 1980). Comparatively fewer studies have dealt with the biology and life history of Arctic charr in Labrador although approximately thirty years ago, Lidicker (1952), as part of the Blue Dolphin Expeditions in Labrador, wrote "Because of the possibility of the increased commercial importance of Arctic char, studies of this species are especially worthwhile, and may lead to a firm foundation on which to base intelligent management of this valuable resource." Since then several reports have concerned biological aspects of the commercial fishery (Andrews and Lear 1956; Coady and Best 1976;

Dempson 1978) while other reports described the fishery (Hunter 1964; Dyke 1967; Coady 1974). Peet (1968, 1971) and Murphy (1972, 1974) provided preliminary biological information on Arctic charr from fish counting fence operations and reconnaissance surveys on several rivers in southern Labrador. Glova and McCart (1978) recently studied charr populations in Nachvak Fiord.

Arctic charr have been harvested traditionally along the entire northern Labrador coast (Coady and Best 1976). However, during the past 10 years, fishing effort has been confined to the region extending from Hamilton Inlet north to Hebron Fiord (Fig. 1). While in excess of 200 metric tons (t) y^{-1} of anadromous charr have been harvested within this 500 km stretch of coastline during the past 4 years, 86% were caught within the Nain fishing region which currently extends from Anton's Point 225 km north to Hebron Fiord (Fig. 1). Owing to the intense fishery that has developed within this limited expanse of Labrador coastline, it was important for proper management to have a better understanding of biological characteristics and dynamics of Arctic charr populations within this region particularly since charr are vulnerable to overexploitation. The concentration of fishing in specific locations has resulted in the decline or collapse of Arctic charr populations in Frobisher Bay (Hunter 1976), Tree River, Northwest Territories (Robertson and Dowler 1973), northern Quebec (Power and Le Jeune 1976), Greenland (Mattox 1973), Novaya Zemlya (Yessipov 1935), Switzerland (Rhulé 1977), England (Kipling 1972) and Nachvak Fiord, Labrador (Andrews and Lear 1956).

Figure 1. Extent of the major Arctic charr fishing regions in Labrador.


68°
66°
64°
62°
60°
58°
56°
54°
60°
58°
56°
54°
52°
ECLIPSE CHANNEL
RYANS BAY
KOMAKTORVIK
NACHVAK
RAMAH
N
ATLANTIC
OCEAN
HEBRON
NAIN
FISHERY
QUEBEC
NAIN
ANTONS
MAKKOVIK
FISHERY
ADLATOK BAY
MAKKOVIK
MIDDLE BROOK
RIGOLET
SAND HILL RIVER
LABRADOR
ST CHARLES RIVER
80
0
80
160
SCALE (KM)
66°
64°
62°
60°
58°
56°

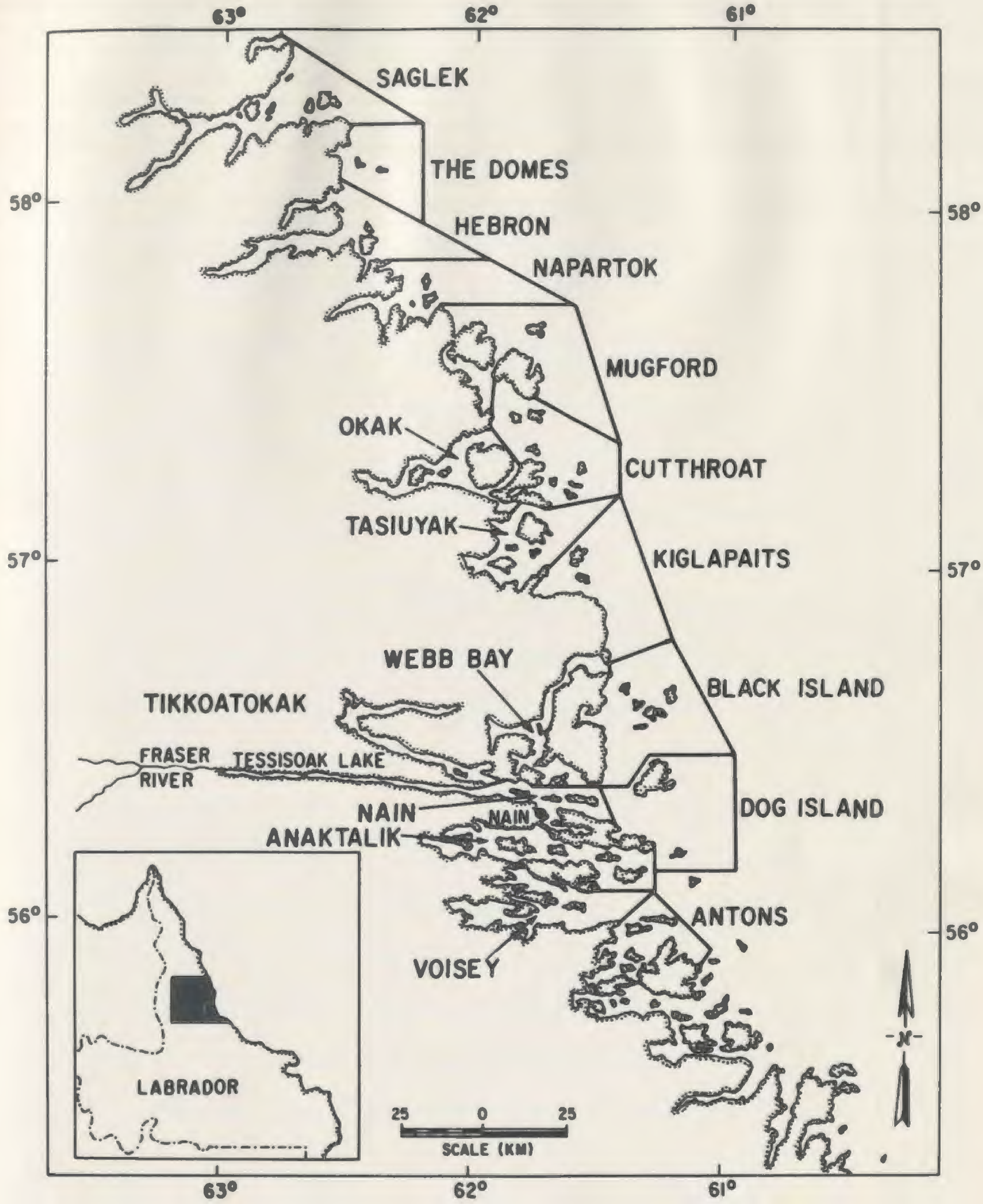
Charr are generally considered to be a localized species which remain in close proximity to their natal rivers (Nielsen 1961a; Grainger 1953). Recent studies, however, have indicated that in certain cases marine migrations may be rather extensive (Jensen and Berg 1977; Johnson 1980) implying considerable mixing of populations at sea. Consequently, the first objective of this study was to determine whether anadromous charr harvested within the Nain fishing region represented one large intermingling population or if there were significant differences in biological and morphological characteristics between charr populations from several neighbouring areas. This would suggest that individual bays were characterized by their own discrete stocks with a minimal amount of interchange between the arbitrarily defined geographical areas (Fig. 2) (Coady and Best 1976; Dempson 1978).

The determination of stock components is a major requirement of any fishery management program. This is because individual stocks may have their own characteristic mortality rates, ages at maturity, and growth rates, and current models of population dynamics generally are not applicable to mixed stock fisheries (Gulland 1979).

A thorough understanding of the biology of the species also is an important consideration of management programs. The second objective of this study, therefore, was to provide a detailed account of the life history of one population within the Nain fishing region, specifically from the Fraser River.

The final objective was to analyze comparatively various aspects of the population dynamics of anadromous Arctic charr from exploited and unexploited areas in northern Labrador. Data of this nature

Figure 2. Coastal breakdown of Nain commercial fishing areas.


63°
62°
61°
58°
57°
56°
SAGLEK
THE DOMES
HEBRON
NAPARTOK
MUGFORD
OKAK
CUTTHROAT
TASIUYAK
KIGLAPAITS
WEBB BAY
BLACK ISLAND
TIKKOATOKAK
FRASER RIVER
TESSISOAK LAKE
NAIN
NAIN
DOG ISLAND
ANAKTALIK
ANTONS
VOISEY
LABRADOR
25 0 25
SCALE (KM)
N

could be used in assessing populations and formulating management strategies on the basis of how populations are affected by and respond to exploitation as determined through changes in population characteristics.

2. DESCRIPTION OF STUDY AREA

The section of the northern Labrador coast with which this study is concerned ranges from Voisey Bay (56°15'N, 61°50°W) northward to the Hebron Fiord (58°09'N, 62°45'W), a distance of 240 km (Fig. 2). The area has been divided into a number of different land regions characterized by climate, physiography and vegetation (Lopoukhine et al. 1978). In general the coastal section is composed of a barren plateau characterized by an irregular coastline that is dissected by a number of large bays and fiords, some of which extend inland approximately 50 km. Nain, presently the only permanent settlement within the region, served as the main focal point and supply centre for all field studies.

In the Nain-Voisey Bay area, coastal mountains are relatively low and bays are sheltered from direct exposure to the sea by numerous offshore islands. The northern extension of the boreal forest occurs within the region and Wheeler (1935), Lopoukhine et al. (1978), and Elliott and Short (1979) have discussed the vegetation in this area.

North of Nain two mountain ranges dominate the coast: the Kiglapaits (1200 m) between Nain and Okak and the Kaumajets (1300 m) between Okak and Hebron. Offshore islands are less numerous along this section of the coast and those that do occur tend to be clustered around the mouths of Okak Bay, Napartok Bay and Hebron Fiord.

Climate conditions prevailing over this region are largely influenced by the geographical position of Labrador, altitude, and the southward flowing cold Labrador current (Lopoukhine et al. 1978). It can be generally classified as subarctic in nature with a mean annual temperature of -5.0°C, 600-700 mm of precipitation annually with snowfall averaging 300 cm per year (Peach 1975). Lopoukhine et al. (1978) indicated that permafrost is widespread along coastal margins but continuous in inland areas. Climatic data for the northern coastal region have been recorded at Hopedale, situated 154 km south of Nain, since 1942. These data, which are summarized in Table 1 for the period 1960-1979, provide a general picture of the annual climatic conditions prevailing over this region.

Rivers in this region generally flow in an easterly direction through steep valleys that are largely the result of glacial erosion (Wheeler 1935). Anderson (in prep.) reports that substrates are primarily sand and gravel and tributaries for many of these streams are inaccessible to migrating fish since they cascade over canyon walls. Freshwater areas begin to freeze during the latter part of October and remain frozen until late April or early May. Sea ice, on the other hand, forms in early December and bays remain ice covered until breakup the following June.

The specific study on the life history characteristics of Arctic charr was conducted at the Fraser River and adjacent Nain Bay (Fig. 2). The Fraser River (56°39'N, 63°10'W), located northwest of Nain, has a drainage area of 1606 km^2, a total length of 116 km and a width at its mouth of 30 m (Anderson in prep.). It flows in an easterly direction from the Quebec-Labrador border for 65 km where

Table 1. Summary of monthly temperature (°C) and precipitation (mm) data at Hopedale, Labrador (55°28'N, 60°13'W) for the period 1960-1979.

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Mean daily temperature	-16.1	-15.7	-11.8	-5.4	1.4	6.3	10.2	10.7	7.0	1.9	-3.2	-11.0	-2.1
Mean daily maximum	-12.1	-11.2	-7.2	-1.4	4.8	10.4	14.3	14.4	10.3	4.6	-0.6	-7.6	1.6
Mean daily minimum	-20.4	-20.2	-16.3	-9.4	-2.0	2.2	6.2	6.9	3.8	-0.8	-6.6	-13.7	-5.9
Extreme maximum	-0.8	0.7	4.2	7.5	12.6	23.4	24.6	24.3	19.7	13.3	6.7	3.5	11.6
Extreme minimum	-30.9	-30.1	-26.8	-19.0	-8.6	-2.6	1.5	3.1	-0.6	-6.7	-13.8	-24.6	-13.3
No. of days with frost	31	28	31	29	25	7	0	0	2	18	28	31	230
Mean total precipitation	81.9	72.1	73.2	56.1	49.5	67.4	80.8	73.6	55.0	73.9	63.7	64.7	811.9

it drains into Tessisoak Lake. This steep walled lake, formed as a result of unequal glacial erosion, extends approximately 56 km inland from Nain Bay (Wheeler 1935, Anderson in. prep.). Below the lake the Fraser River meanders through a series of small ponds and rapid areas where it eventually empties into Nain Bay. Arctic charr is the dominant fish species present, however, the system also contains brook charr (*Salvelinus fontinalis*), lake charr (*S. namaycush*), threespine stickleback (*Gasterosteus aculeatus*), ninespine stickleback (*Pungitius pungitius*) and mottled sculpin (*Cottus bairdi*).

Information regarding oceanographic conditions existing within the bays and fiords included in this study area is generally lacking with the exception of an intensive study of the Hebron Fiord and preliminary data for Nain Bay (Nutt 1953; Nutt and Coachman 1956; Nutt 1963). Of particular interest was the finding that a high Arctic marine environment persists throughout the year in the deeper basins of the Hebron Fiord and that similar conditions exist in Nain Bay, however, only during the winter months.

3. MATERIALS AND METHODS

3.1. STOCK DETERMINATION

3.1.1. Collection and preparation of samples

A total of 1007 Arctic charr were collected in 1978 from seven different marine areas for examination of meristic, morphometric and biological characteristics (Table 2). Samples were obtained from different mesh size gillnets during a period of time when return migration into freshwater was occurring. All samples removed from nets were labeled for location of capture, date and gear mesh size. Specimens were wrapped in plastic, frozen and later transported to St. John's where they were kept in cold storage until later examined.

Prior to examination, fish were removed from freezers, placed on ice and allowed to thaw slowly overnight.

3.1.2. Meristic and morphometric measurements

A total of 22 meristic and morphometric characters were studied on Arctic charr samples collected in northern Labrador (Table 3). Counts and measurements were made following the procedures proposed by Hubbs and Lagler (1970). Morphometric measurements were taken on the left side of the fish to the nearest mm, except the following: head length, postorbital length, pectoral fin length, snout length, orbit length, and length of upper jaw. These characters were measured to the nearest 0.01 mm using a set of Helios vernier calipers.

Table 2. Summary of research samples of northern Labrador Arctic charr available from 1978-1980 for analysis of meristic, morphometric and biological characteristics.

Area	Date	Gear Mesh Size (mm)										
		38	51	64	76	89	102	114	127	140	152	Total
Ramah Bay (58°52'N, 63°15'W)	1978 Aug. 7		13			45		34	77	28	24	221
Saglek Fiord (58°29'N, 63°15'W)	1978 Aug. 8-9		15			72		29	23	9	1	149
	1979 Aug. 4-5		50	11	2			122	5			190
	1980 Aug. 14-15	26		13	7		42	119			2	209
	Total	26	65	24	9	72	42	270	28	9	3	548
Hebron Fiord (58°09'N, 62°45'W)	1978 Aug. 10-11		28			34		30				92
	1979 Aug. 6		21	23	15			96				155
	1980 Aug. 16				99			95			50	244
	Total		49	23	114	34		221			50	491
Napartok Bay (58°01'N, 62°19'W)	1978 Aug. 11							60	33			93
	1979 Aug. 7				6			55	24			85
	1980 Aug. 17	1			51		44	54			8	158
	Total	1			57		44	169	57		8	336
Okak Bay (57°28'N, 62°20'W)	1978 Aug. 12		5			20		138	36			199
	1979 Aug. 8							76				76
	1980 Aug. 19						13	21			4	38
	Total		5			20	13	234	36		4	313
Tikkoatokak Bay (56°42'N, 62°12'W)	1978 Aug. 1-5							124				124
Voisey Bay (56°15'N, 61°50'W)	1978 Aug. 1-5							129				129

Table 3. Meristic and morphometric characters examined on northern Labrador Arctic charr and designated abbreviations.

Variable	Abbreviation
MERISTICS	
Dorsal fin rays	DR
Anal fin rays	AR
Pectoral fin rays	PCTR
Pelvic fin rays	PELR
Branchiostegal rays	BR
Vertebrae	V
Upper gill rakers	UGR
Lower gill rakers	LGR
Total gill rakers	TGR
MOROPHOMETRICS	
Total length	TL
Fork length	FL
Standard length	ST
Opercular girth	GOP
Maximum girth	GMX
Predorsal length	PRDL
Dorsal to adipose length	DADL
Head length	HL
Postorbital length	PORBL
Pectoral fin length	PCTL
Snout length	SNL
Orbit length	ORBL
Length of upper jaw	UJL

The first gill arch on the left side of the fish was removed and all rakers on both limbs, including rudiments, were counted. Vertebrae and fin ray counts were taken from radiographs using General Electric Model 11CE2-2 and 11CE5 X-ray machines and Kodak Industrial Film (Ready Pack AA-2). Charr samples were filleted to expose the vertebral column and therefore increase the clarity of radiographs. All vertebral centra were counted including those articulating with the fourth and fifth hypurals but excluding the urostyle, as illustrated by Vladykov (1954). Similarly, fins were removed and spread out on X-ray trays to allow for easy counting. Fin ray counts also included rudimentary rays. Radiographs were read twice, however, any discrepancies between the first and second reading necessitated a third count. If agreement could not be reached following the third reading, the sample was rejected from further analysis.

3.1.3. Statistical analyses

Statistical analyses of meristic and morphometric data were confined to samples from the following four areas: Voisey Bay, Tikkoatokak Bay, Okak Bay and Hebron Fiord (Fig. 2).

The significance of interpopulation differences in each meristic variable and in growth comparisons of length at age between areas was tested by analysis of variance (ANOVA). Statistical analyses were performed on transformed ($\sqrt{x + 0.5}$, Sokal and Rohlf 1969) meristic data. However, as the standard one-way ANOVA is sensitive to a lack of homogeneity of within-group variances (Brown and Forsythe 1974a), the Biomedical computer Program BMDP7D (Dixon and Brown 1979) was used to calculate a modified F-statistic, the Brown-Forsythe statistic (F*), which does not assume equality of variances (Brown and Forsythe 1974a). Multiple range tests (Brown and Forsythe 1974b) were conducted to identify which areas differed significantly at the $P < 0.05$ level. Multivariate techniques were not applied to meristic data since discrete data do not generally conform to the assumption of multivariate normality required in the analyses (Misra, pers. comm.).

Morphometric data excluding fork length, standard length and total length variables were analyzed by the Biomedical Computer Program BMDP7M (Stepwise Linear Discriminant Analysis; Jennrich and Sampson 1979). This program initially performs a multivariate analysis of variance (MANOVA) to determine the equality of character mean vectors (group population centroids). The multivariate test is Wilk's lambda statistic:

$$\Lambda = \frac{|W|}{|T|}$$

where W is the determinant of the pooled within-group deviation score cross-products matrix and T is the determinant of the total sample deviation score cross-products matrix (Cooley and Lohnes 1962). This has an approximate F distribution (Rao 1952; Morrison 1967):

$$F = \left[\frac{1-\Lambda}{\Lambda}\right] \frac{n_2}{n_1}$$

with n_1 and n_2 degrees of freedom where:

$$n_1 = p\,(g - 1),$$

$$n_2 = s\left[(N-1) - \frac{p + (g - 1) + 1}{2}\right] - \frac{p\,(g - 1) - 2}{2}, \text{ and}$$

$$s = \sqrt{\frac{p^2\,(g - 1)^2 - 4}{p^2 + (g - 1)^2 - 5}}, \text{ with}$$

p the number of variables, g the number of groups and N the total sample size of the groups being compared. The relative success of the method can be judged by the subsequent stepwise discriminating procedure which classifies individuals into groups and is analogous to a multivariate multiple range test (Pimental 1979). The stepwise procedure adds variables into the classification function one at a time so that each new character contributes only that amount of information which is unique to it and is not already carried by the earlier variables (Blackith and Reyment 1971) until group separation ceases to improve (Jennrich and Sampson 1979). The program also employes a jackknife validation procedure which has been shown to reduce bias (Lachenbruch and Mickey 1968) by classifying each case into a group according to the classification information from all data except the specimen being classified (Jennrich and Sampson 1979). Homogeneity of within-group variance-covariance matrices was examined by Box's test utilizing the SPSS Discriminant Analysis program (Klecka 1975).

In order to reduce the effect of different mean fish size on intergroup comparisons, yet still maintain the biological integrity of the data, charr samples selected for morphometric analyses were those captured in 114 mm mesh gillnets and, therefore, subject to the same degree of gear selectivity. Additionally, these data were stratified by selecting charr which were in the fork length interval 44.0-59.9 cm.

3.1.4. Tagging

In conjunction with analyses of meristic and morphometric characters, tagging experiments were carried out to examine distribution patterns and determine the extent of intermingling of coastal populations. Locations and dates of tagging experiments are listed in Table 4.

Tagging operations at the Fraser River were carried out on upstream migrating charr obtained from a counting fence facility. Charr tagged in Tikkoatokak Bay during May, 1979 and in Nain Bay during June, 1980, were captured by angling using barbless spinners while charr tagged in remaining locations were captured in surface shore-set gillnets. Upon removal from gillnets charr were placed in a holding tank from which they were individually removed, measured for fork length to the nearest mm, tagged using a numbered Carlin tag with double stainless steel thread, and released. Charr tagged at the Fraser River and those captured by angling were placed into a partially submerged measuring trough where they were measured for fork length, tagged and released. Tags were inserted into the musculature below the anterior end of the dorsal fin.

Recaptures were obained from the commercial fishery, the local recreational fishery or from charr returning back through the Fraser River counting fence. A reward of $5.00 was paid for each returned tag.

Table 4. Summary by area and year of Arctic charr tag recaptures in northern Labrador.

Location	Date	No. tagged	Recaptures year	Recaptures No.	Area of recapture* 1	2	3	4	5	5A	6	7	8	9	10	11	12	13	14	15	16	Unknown
Voisey Bay	1979 June	39	1979	6	2	4																
			1980	2							1		1									
	1980 July	100	1980	8	2	5					1											
	TOTAL	139		16	4	9					2		1									
Anaktalik Bay	1979 June	29	1979	1			1															
			1980	4			2						1									1
	1980 June	91	1980	9			3		1				3									2
	TOTAL	120		14			6		1				4.									3
Nain Bay	1979 June-July	98	1979	7						6	1											
			1980	15					2		9		4									
	1980 June	98	1980	22	2		1	1		1	7		9									1
	TOTAL	193		44	2		1	1	2	7	17		13									1
Fraser River	1975 July-August	287	1976	38					22	10	5											1
			1977	16					6	6	4											
			1978	14					4	1	9											
			1979	13						4	8											1
			1980	5							2		1									2
	1976 August	100	1977	11					8	3												
			1978	4					2	1	1											
			1979	5						3	2											
			1980	1							1											
	1977 August	200	1978	15			2		6		7											
			1979	17					1	5	11											
			1980	8	1				1	1	2		3									
	1978 August	31	1979	9	1				1	3	4											
			1980	1				1														
	1979 August	190	1979	5						5												
			1980	38			2	4	7	1	10		9	2								3
	TOTAL	808		200	2		4	5	58	43	66		13	2								7
Tikkoatokak Bay	1979 May	72	1979	24					1		21		1	1								
			1980	10					1		9											
	1979 June-July	84	1979	10				1	1	1	7											
			1980	3							2											1
	1980 June	110	1980	26							15		11									
	TOTAL	266		73				1	3	1	54		12	1								1

Table 4 (Cont'd).

Location	Date	No. tagged	Recaptures year	No.	Area of recapture* 1	2	3	4	5	5A	6	7	8	9	10	11	12	13	14	15	16	Unknow
Okak Bay	1978 August	50	1979	1												1						
			1980	1										1								
	1979 August	19	1979	1												1						
	1980 August	100	1980	0																		
	TOTAL	169		3										1		2						
Napartok Bay	1978 August	50	1979	1															1			
	1979 August	53	1979	1															1			
	1980 August	123	1980	2															2			
	TOTAL	226		4															4			
Hebron Fiord	1978 August	100	1980	1																		1
	1979 August	50	1980	1																1		
	1980 August	149		0																		
	TOTAL	299		2																1		1
Saglek Fiord	1978 August	100	1979	1																	1	
			1980	1																1		
	1979 August	52		0																		
	1980 August	150		0																		
	TOTAL	302		2																1	1	

* 1 - Anton's; 2 - Voisey Bay; 3 - Anaktalik Bay; 4 - Dog Island; 5 - Nain Bay; 5A - Fraser River; 6 - Tikkoatokak Bay; 7 - Webb Bay; 8 - Black Island; 9 - Kiglapaits; 10 - Tasiuyak; 11 - Okak Bay; 12 - Cutthroat; 13 - Mugford; 14 - Napartok Bay; 15 - Hebron Fiord; 16 - Saglek Fiord

3.2. LIFE HISTORY

3.2.1. Age determination

Age of charr was determined from sagittal otoliths which had been removed from the fish and stored dry in envelopes. In the laboratory the lateral surface of the otolith was ground by hand on a small carborundum stone to remove surface irregularities. They were then immersed in glycerine and viewed on a black background under reflected light using a binocular miscroscope. The small dark central core of the otolith was considered to represent embryonic and early larval growth (Nordeng 1961). Alternating sets of wide opaque and narrow hyaline zones were interpreted in a manner similar to Coady and Best (1976), as summer and winter growth respectively. Age was assigned to a fish on the basis of the actual number of hyaline rings observed on the otolith.

3.2.2. Biological sampling

Upstream migrations of Arctic charr were monitored in the Fraser River from July to September, 1975-1979, using a 76 m portable counting fence (Coady and Best 1976; Anderson and McDonald 1978) located approximately 5 km upstream from where the river empties into Tessisoak Lake (Fig. 2). The aluminum conduit fence which was fitted with a downstream and an upstream wooden trap, provided a virtually nonselective device for enumerating and sampling migrant charr. The fence was installed in July as soon as water levels would permit and traps were subsequently checked several times each day. Upstream migrating charr were counted and most measured for fork length (cm) and whole weight (to nearest 100 grams), then released. Each year a varying number of charr were selected randomly throughout the duration of the run in order to obtain detailed information on the biological characteristics of the population. These data included: fork length, whole weight, sex and state of maturity. Otoliths were also removed and stored dry for later age determination. In 1979 ovaries were removed from sampled fish, weighed to 0.1 g and a mean egg diameter calculated. Egg size was determined by measuring the total length of 10 eggs placed on a measuring board, then calculating the mean.

High water levels throughout the summer of 1978 resulted in the counting fence operating for only three days. However, 201 adult charr were angled or captured in gillnets set off the mouth of the river during August to obtain biological characteristics of the run for that year.

Sex and maturity were determined by gross inspection of the gonads of sampled fish. In 1975, 1976 and 1977 fish were classified only as mature and immature. Beginning in 1978 state of maturity was classified as follows:

Stage

1. Immature. Juvenile fish with no gonadal development. Females have small opaque ovaries, granular in appearance with egg diameter less than 1 mm. Males, small transparent testes.

2. Maturing. Some gonadal development, but fish will not spawn this year. Ovaries and testes larger than in stage 1 with the former becoming yellowish in colour. Egg diameter 1-2 mm.

3. Mature. Fish will spawn this year. Ovaries well developed with blood vessels visible along surface. Egg diameter 2.0-3.5 mm. Testes are white and distended.

4. Ripe. Gonads fill body cavity and sexual products are easily expressed. Egg diameter greater than 3.5 mm.

5. Spent. Ovaries are flaccid and reddish-violet in colour; generally contain small recruitment eggs (Vladykov 1956) with some ripe eggs either still attached to ovary or loose in body cavity. Testes are shrunken and inflamed in appearance.

6. Mature Previous Spawner. A previous spawner that will also mature this year. Females with developed ovaries and evidence of previous spawn in body cavity; males, developed testes with evidence of previous maturation from development of secondary sexual characteristics such as a kype and a notched upper jaw (Bain 1975).

7. Mature Nonspawner. Fish not spawning during that particular year as determined by the lack of gonadal development, but having evidence of previous maturation as indicated in stage 6.

Length and age at which 50% of the sample was mature were derived from probit analysis (Bliss 1952) following the technique outlined by Fleming (1960). Those fish in maturity stages 3-7 were classified as mature for the analyses. Sex ratios were compared to deviations from a 1:1 ratio by chi-squared analyses (Elliott 1977).

Age and size compositions of the upstream runs were estimated by constructing an age-length key from the random age sample of fish, applying this to the length-frequency data (stratified by 2 cm intervals) for the same season then apportioning the total number of charr counted into respective age and size categories (Ricker 1975, Westrheim and Ricker 1978). Mean length and weight at age for males and females were calculated by combining data for years 1975-1979. Growth differences in length at age between sexes were compared by Student's t-test (Sokal and Rohlf 1969). Growth increments were also calculated from tag return samples from which otoliths were available for age determination.

Weight-length relationships were described using the general formula:

$$W = aL^b$$

where W = whole weight (kg), L = fork length (cm) and a and b are constants. A logarithmic transformation yields a straight line relationship:

$$\log W = \log a + b \log L$$

from which the parameters a and b can be estimated by linear regression (Le Cren 1951; Ricker 1975). Condition factors (Le Cren 1951) were calculated from the equation:

$$K = \frac{W \cdot C}{L^3}$$

where C is a constant which converts K to a value in the range of unity.

Investigations concerning the biology of juvenile Arctic charr were made from seine net collections of small charr from the Fraser River and adjacent Nain Bay.

3.3. COMPARATIVE POPULATION DYNAMICS

3.3.1. Catch and effort data

Purchase slips are supplied to northern Labrador fish plants by the Economics Branch of Department of Fisheries and Oceans. These records are filled out at the time of catch receipt and include information such as name and licence number of fisherman, area where fish were caught, date, number of nets used, species and number of pounds of fish in each size category. Since 1977, numbers of Arctic charr and Atlantic salmon caught were also added to catch records (Dempson 1978).

Analysis of these data provided weekly breakdowns of landings by size and area. Weights are listed in kilograms and have been converted to round condition by the conversion factor: gutted head-on weight x 1.24 = round fresh weight (Coady and Best 1976). Calculated mean weights were used in estimating total numbers of fish caught by area and week. Catch per unit effort estimates were derived following the method initiated by Coady and Best (1976) and are expressed in terms of kg per man-week fished.

3.3.2. Commercial sampling

The procedures for commercial sampling were the same as those described by Dempson (1978) where random samples of catches from specific areas, and caught in gillnets of 114 and 127 mm mesh sizes, were obtained throughout the fishing season, measured for fork length (cm) and gutted head-on weight (kg), and otoliths removed for age determination. The commercial season generally opens July 1, however, in 1979 fishing began June 20.

Age composition of the catch was estimated by extrapolating relative age proportions from the sample to the total number of charr caught in an area. In 1980, a random-stratified procedure was used where age-length keys were constructed from a random sample of fish and applied to length-frequency data from the same area. The total numbers of charr caught were then apportioned into respective age and size categories.

Growth differences in length at age between areas were compared by analysis of variance. The same method applied to the univariate analyses of meristic data (Section 3.1.3.) was used here. Multiple range tests (Brown and Forsythe 1974b) were conducted to identify which areas differed significantly.

Weight-length relationships from commercial data were calculated in the same manner as those for Fraser River charr (Section 3.2.2.) except gutted head-on weight was used in place of whole weight. Differences between areas were compared by analysis of covariance (Snedecor and Cochran 1967).

3.3.3. Research sampling

Research samples were obtained from surveys conducted in several northern Labrador areas during 1978, 1979 and 1980. In addition to length, weight and age data, sex and maturity information were also collected. Monofilament gillnets of various mesh size were used to capture the fish.

Size and age at maturity were derived in the same way as Fraser River charr (Section 3.2.2.) using probit analysis. Research samples from 1978 to 1980 were pooled in order to have sufficient sample sizes for the analyses. Sex ratios were compared by chi-squared analyses (Elliott 1977). Growth differences between sexes in each area were compared by Student's t-test (Sokal and Rohlf 1969) after combining data for the three years.

3.3.4. Estimation of mortality rate

Estimates of total instantaneous mortality (Z) were calculated from least squares regressions fitted to the descending limb of catch curves, based on the number caught in each fully recruited age class. This method assumes year-class strength and annual survival rate in adults are constant, and all age classes beyond modal age are equally vulnerable to the fishing gear used in obtaining samples (Ricker 1975). In order to eliminate fluctuations resulting from variable recruitment of fish to the exploited phase of the population, age compositions from commercial samples were combined for 1977-1980 (Beverton and Holt 1956; Ricker 1975).

Estimates of natural mortality were similarly derived by combining age-frequency data from 1978 to 1980 obtained from research sampling in the unexploited Hebron and Saglek fiords.

4. RESULTS

4.1. STOCK DETERMINATION

4.1.1. Analysis of meristic and morphometric data

Results of univariate analyses of meristic variables are shown in Table 5. Interpopulation variation in meristic characters was slight, however, of the nine variables examined, six differed significantly ($P < 0.01$) in their means but not between all areas. Multiple range tests indicated that Voisey Bay and Tikkoatokak Bay charr did not differ significantly in any of the meristic characters examined. Voisey Bay charr differed from Okak Bay charr in lower gill rakers counts, while Tikkoatokak Bay charr differed from Okak charr in lower gill raker and pectoral fin ray counts. Arctic charr from the Hebron Fiord were clearly separate from all other areas, differing signifiantly in at least four characters (Table 5). Highest meristic counts were observed in eight of nine variables from Hebron Fiord charr, the most northerly of the four major areas examined in this section of the study. This trend, however, did not continue into the Saglek Fiord and Ramah Bay areas (Appendix 1).

Univariate statistics for morphometric characters are summarized in Table 5. Multivariate analysis of morphometric data indicated that there were significant differences ($P < 0.01$) in the character mean vectors between all areas (Table 6). Part of the reason Okak Bay charr differed from the other areas could be related to differences in size of fish included in the analysis. After selecting fish from within a specific length interval, Okak Bay charr still had significantly different fork lengths from Voisey Bay, Tikkoatokak Bay and Hebron

Table 5. Univariate statistics for meristic and morphometric characters from northern Labrador Arctic charr. Analysis of variance results including Levene's test of heteroscedasticity and multiple comparison tests of meristic characters. Statistical analyses based on transformed ($\sqrt{x + 0.5}$; Sokal and Rohlf 1969) meristic data. Significance levels are $P < 0.05$(*) and $P < 0.01$(**). Underlined areas are not significantly different. DR = dorsal rays; AR = anal rays, PCTR = pectoral rays; PELR = pelvic rays; BR = branchiostegal rays; V = vertebrae; UGR = upper gill rakers; LGR = lower gill rakers; TGR = total gill rakers.

Meristic characters	Voisey Bay (V)				Tikkoatokak Bay (T)				Okak Bay (O)				Hebron Fiord (H)				Levene's test	df	F*		Multiple comparison test
	N	$\bar{x}$	S.D.	Range	N	$\bar{x}$	S.D.	Range	N	$\bar{x}$	S.D.	Range	N	$\bar{x}$	S.D.	Range					
DR	91	14.65	0.69	13-16	90	14.71	0.74	13-16	133	14.50	0.74	12-17	68	14.77	0.95	12-17	NS	3,281	2.06	NS	
AR	91	13.74	0.83	12-16	91	13.46	0.67	12-15	135	13.36	0.82	11-15	68	13.26	0.75	12-15	NS	3,349	0.90	NS	
PCTR	93	13.57	0.68	12-16	90	13.31	0.77	12-15	136	13.66	0.86	11-16	68	13.91	0.88	10-16	NS	3,323	7.46	**	TVOH
PELR	93	9.07	0.41	8-10	91	9.05	0.31	8-10	135	9.10	0.40	8-10	68	9.16	0.37	9-10	NS	3,346	1.27	NS	
BR	128	10.62	0.78	8-12	124	10.53	0.64	9-12	190	10.72	0.63	9-12	91	10.96	0.73	9-13	**	3,439	6.97	**	TVOH
V	122	65.05	0.97	62-68	121	64.93	1.03	62-67	176	64.81	0.93	63-68	89	65.54	1.29	63-72	*	3,370	9.42	**	OTVH
UGR	124	9.47	0.83	7-11	120	9.33	0.77	7-11	187	9.43	0.84	7-13	88	10.06	0.76	8-12	**	3,476	16.21	**	TOVH
LGR	124	14.85	0.88	13-17	120	14.67	1.00	12-17	187	14.47	1.00	12-17	88	15.16	1.23	12-18	**	3,379	9.39	**	OTVH
TGR	125	24.31	1.29	21-28	123	24.01	1.35	21-27	187	23.91	1.44	20-28	89	25.21	1.62	22-30	NS	3,422	18.07	**	OTVH
Morphometric characters																					
TL	119	53.40	3.69	47.0-62.4	99	54.09	4.52	46.0-63.4	98	51.31	3.65	46.5-62.6	25	55.27	4.46	47.1-61.9					
FL	119	50.48	3.52	44.1-58.9	99	51.17	4.35	44.1-59.8	98	48.43	3.51	44.0-59.3	25	52.36	4.48	44.1-59.7					
ST	119	45.97	3.19	40.4-53.4	99	46.55	4.01	39.9-54.6	98	43.85	3.19	34.4-53.9	25	47.21	3.93	39.5-53.3					
GOP	118	25.65	2.28	20.4-31.2	99	25.41	2.81	20.2-32.8	86	24.07	2.15	20.3-29.4	25	25.31	2.37	21.4-29.2					
GMX	119	30.98	3.01	24.4-39.7	99	29.87	3.28	24.8-41.0	86	28.98	2.36	24.4-35.0	25	29.38	2.65	25.3-33.9					
PRDL	119	21.08	1.64	17.6-24.7	99	20.99	1.79	17.7-25.2	86	19.96	1.44	17.4-23.6	25	21.83	2.07	17.9-25.2					
DADL	119	11.09	1.16	8.7-13.4	99	10.99	1.23	8.7-14.4	86	10.87	0.96	8.7-13.4	25	12.09	1.29	9.8-14.3					
HL	119	9.73	0.93	8.0-14.6	99	9.87	0.98	8.0-12.0	87	9.53	0.87	8.0-11.9	25	10.29	1.06	8.5-12.7					
PORBL	119	5.53	0.47	4.5-6.9	99	5.68	0.54	4.7-6.9	85	5.38	0.56	4.3-6.9	25	5.74	0.48	5.0-6.7					
PCTL	119	6.39	0.72	4.9-8.0	99	6.68	0.96	3.7-8.9	86	6.68	0.88	2.7-8.8	25	6.97	0.97	5.1-9.0					
SNL	119	2.70	0.38	1.9-4.1	99	2.88	0.48	2.1-4.2	86	2.67	0.43	1.2-4.0	25	2.91	0.44	2.2-4.0					
ORBL	119	1.38	0.12	1.1-1.8	99	1.40	0.15	1.1-1.8	86	1.42	0.20	1.0-1.9	25	1.49	0.20	1.3-1.9					
UJL	119	5.04	0.65	3.9-7.3	99	5.16	0.73	3.9-7.4	86	4.99	0.67	4.0-7.1	24	5.37	0.86	4.2-7.6					

Table 6. Summary of multivariate analysis of variance of Arctic charr morphometric characters (above diagonal) and percent correctly classified by discriminant analysis (below diagonal). Significance levels are $P<0.05(*)$ and $P<0.01(**)$.

	Voisey	Tikkoatokak		Okak		Hebron	
		df	f	df	f	df	f
Voisey		4,212	18.70**	3,199	31.75**	4,137	19.30**
Tikkoatokak	75			5,178	11.14**	4,118	10.93**
Okak	77	73				3,105	18.57**
Hebron	78	78		78			

Fiord fish. Differences in size were not found in the latter three areas.

The stepwise procedure selected characters which were most useful in discriminating between groups. In order of importance, these were: maximum girth, dorsal to adipose length, predorsal length, left pectoral fin length and snout length. Approximately 77% of the individuals were correctly classified into their respective areas by the discriminant analysis. Four of six area comparisons, Voisey-Okak, Voisey-Hebron, Tikkoatokak-Okak and Tikkoatokak-Hebron had heterogenous variance-covariance matrices.

Morphological data from Napartok Bay, Saglek Fiord and Ramah Bay are presented in Appendix 1.

4.1.2. Distribution patterns

A total of 1526 tags were applied to Fraser River, Voisey Bay, Anaktalik Bay, Tikkoatokak Bay and Nain Bay charr since 1975. Recaptures totalling 347 (23%) are summarized by year and area in Table 4. Approximately 80% have been recovered within a 50 km distance from the release site, or in the case of Fraser River charr, within 50 km from the freshwater-marine transition area at the head of Nain Bay.

Distributions of Nain Bay, Tikkoatokak Bay and Fraser River recaptures are illustrated in Figs. 3, 4 and 5 respectively. Except for the interchange of charr between Nain Bay (Fraser River) and Tikkoatokak Bay, migrations to outer offshore areas appear more

Figure 3. Recaptures of charr tagged in Nain Bay during 1979 and 1980. Each (X) represents five tag recaptures and each (•) corresponds to one tag return.

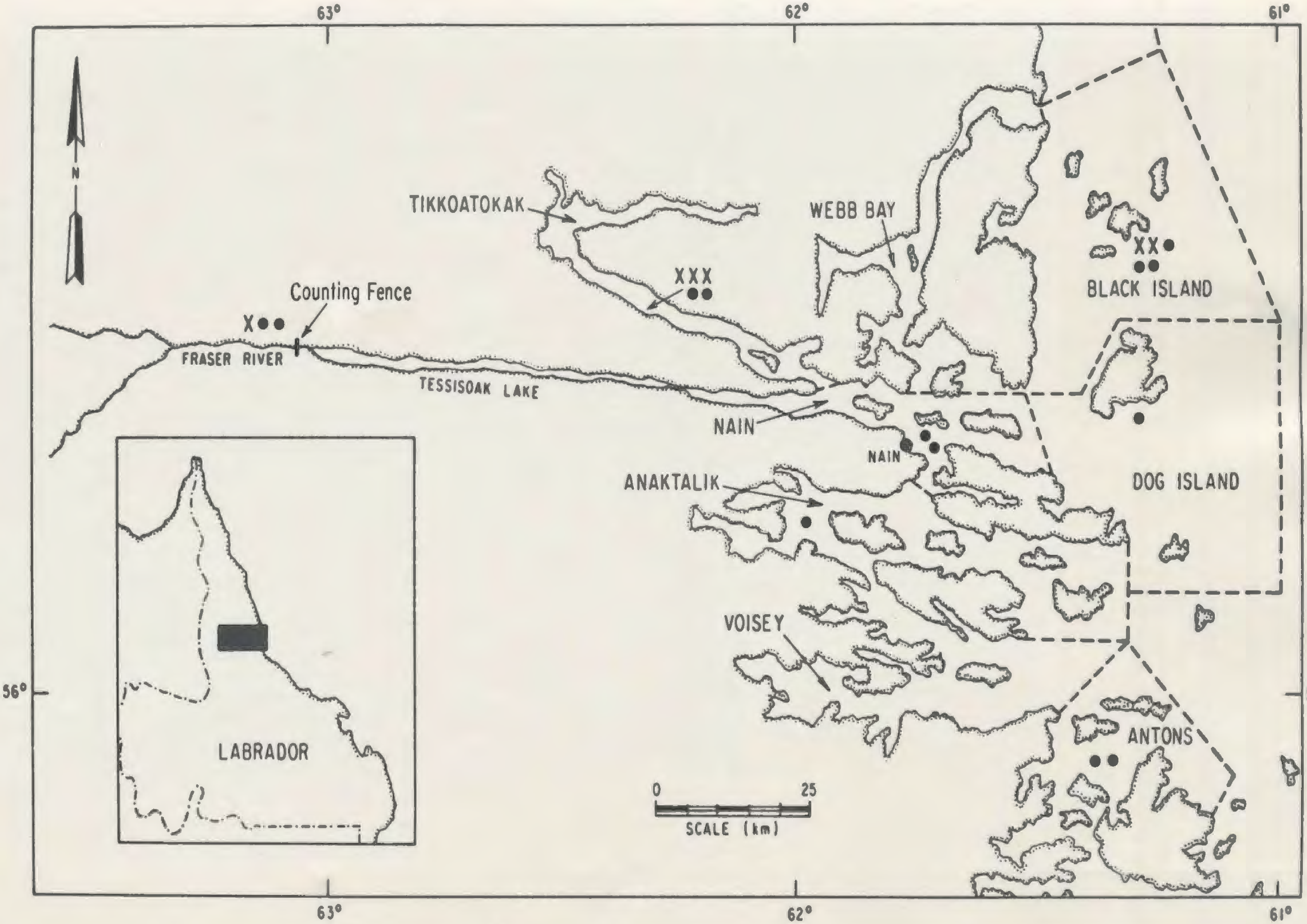

63°
62°
61°
56°
N
TIKKOATOKAK
WEBB BAY
XXX
Counting Fence
X
FRASER RIVER
TESSISOAK LAKE
NAIN
NAIN
XX
BLACK ISLAND
DOG ISLAND
ANAKTALIK
VOISEY
ANTONS
LABRADOR
0
25
SCALE (km)

Figure 4. Recaptures of Arctic charr tagged in Tikkoatokak Bay during 1979 and 1980. Each (X) represents five tag recaptures and each (•) corresponds to one tag return.

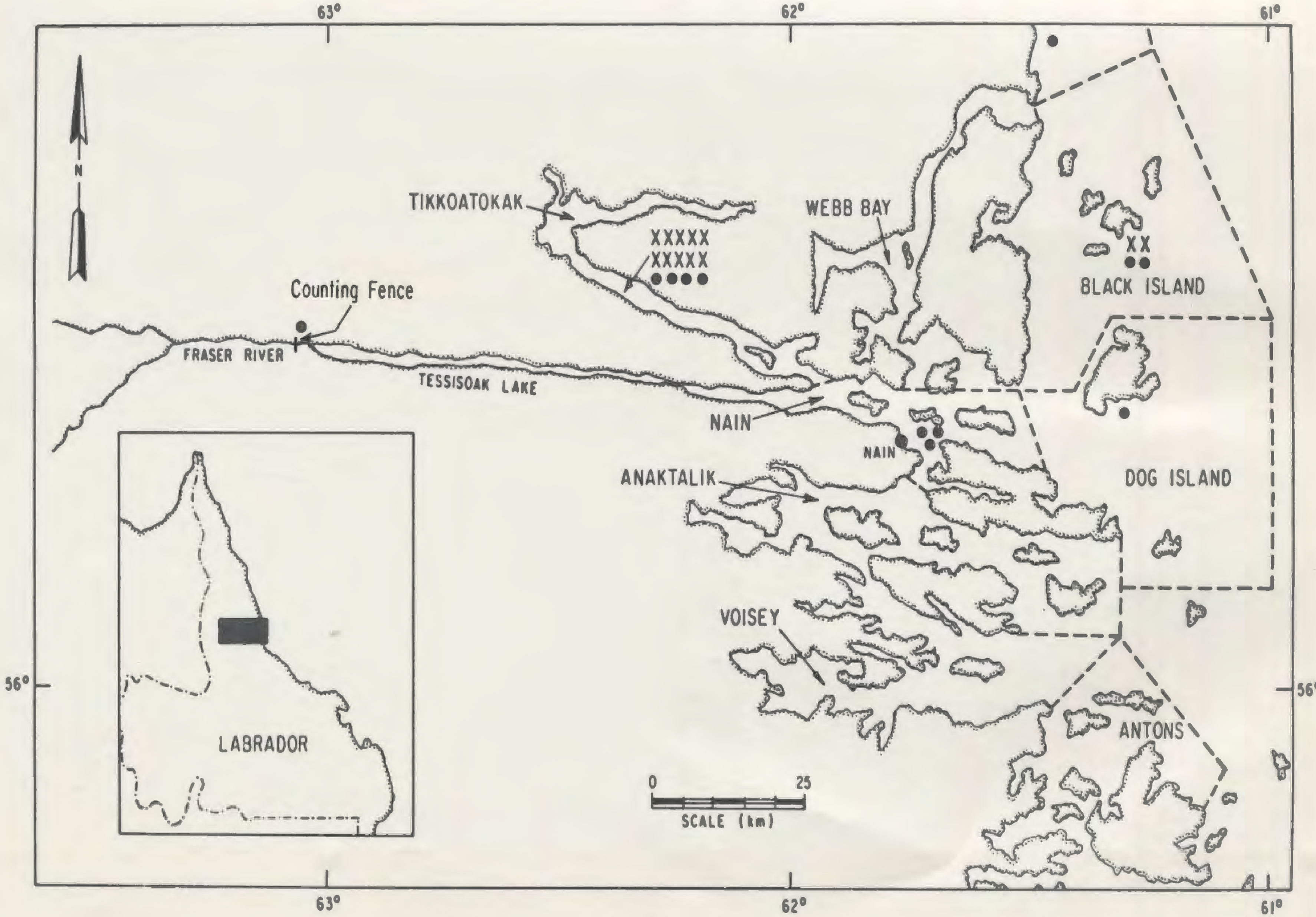

63°
62°
61°
56°
N
TIKKOATOKAK
XXXXX
XXXXX
WEBB BAY
XX
BLACK ISLAND
Counting Fence
FRASER RIVER
TESSISOAK LAKE
NAIN
NAIN
ANAKTALIK
DOG ISLAND
VOISEY
ANTONS
LABRADOR
0
25
SCALE (km)

Figure 5. Recaptures of Arctic charr tagged at the Fraser River from 1975 to 1979. Each (X) represents five tag recaptures and each (•) corresponds to one tag return.

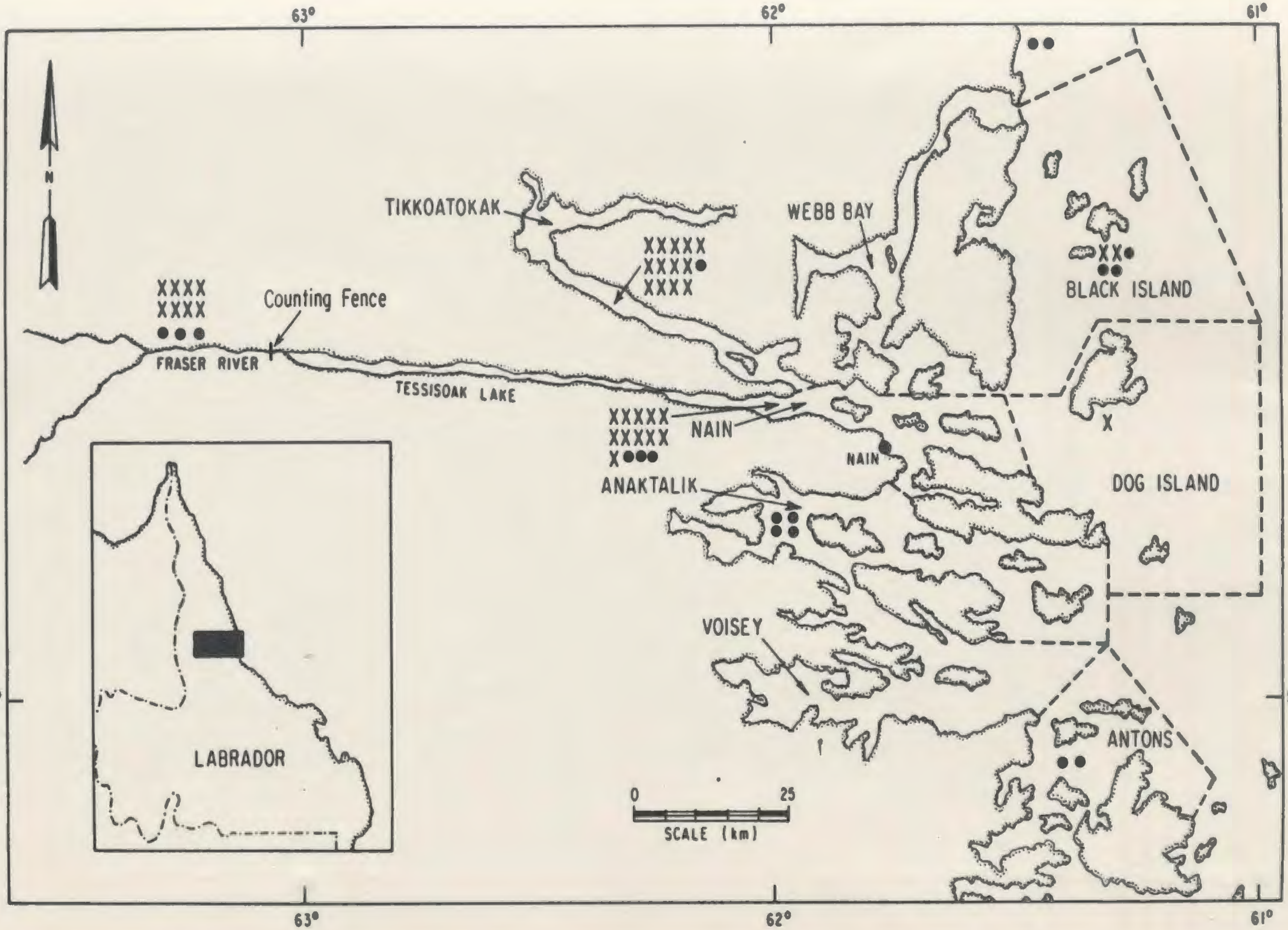

63°
62°
61°
N
XXXX
XXXX
FRASER RIVER
Counting Fence
TESSISOAK LAKE
TIKKOATOKAK
XXXXX
XXXX
XXXX
WEBB BAY
XX
BLACK ISLAND
XXXXX
XXXXX
X
NAIN
NAIN
X
DOG ISLAND
ANAKTALIK
VOISEY
ANTONS
LABRADOR
56°
56°
0
25
SCALE (km)
63°
62°
61°

Figure 6. Recaptures of Arctic charr tagged in the Voisey, Anaktalik, Okak, Napartok, Hebron and Saglek areas during the period 1978-1980.


63°
62°
61°
58°
57°
56°
SAGLEK
THE DOMES
HEBRON
NAPARTOK
MUGFORD
OKAK
CUTTHROAT
TASIUYAK
KIGLAPAITS
BLACK ISLAND
WEBB BAY
TIKKOATOKAK
FRASER RIVER
TESSISOAK LAKE
NAIN
NAIN
ANAKTALIK
DOG ISLAND
ANTONS
VOISEY
VOISEY BAY X
ANAKTALIK BAY □
OKAK BAY △
NAPARTOK BAY ●
HEBRON FIORD ■
SAGLEK FIORD ▲
LABRADOR
25 0 25
SCALE (km)
N

common than interchange of charr between inner bays. The latter accounts for 4.5% of the tag recoveries if Nain and Tikkoatokak Bay are considered as one area and recaptures in offshore areas are excluded. Offshore movements, however, occurred in 1980 only. It is assumed that late ice conditions prevailing within the bays during spring of 1980 influenced the abundance of capelin (*Mallotus villosus*), which is the predominant food item for Arctic charr in the Nain region (Andrews and Lear 1956, Dempson *et al*. 1979), resulting in a directed offshore feeding migration. Except for one Fraser River charr caught in the Anton's region in 1979, all other distant recaptures occurred during 1980 (Table 4). This offshore movement was similarly evidenced in the 1980 recaptures of Nain Bay, Tikkoatokak Bay and Anaktalik Bay charr (Table 4). It should be noted, that Nain Bay has been closed to commercial fishing since 1978 and recaptures of these tags in that area only arise from the spring domestic fishery or recreational fishing during the summer.

In addition to the tagging studies carried out within the heavily exploited Nain area, a total of 996 charr have also been tagged in Okak Bay, Napartok Bay, Hebron Fiord and Saglek Fiord (Table 4). The latter two areas have been virtually unexploited since 1969 while Napartok Bay has been lightly fished since 1976. Okak Bay, on the other hand, has been one of the more important charr producing areas within the Nain fishing region for many years (Coady and Best 1976; Dempson 1978).

Recaptures of Arctic charr tagged in these northern areas are too few at the present time to draw any conclusions. However, it appears that the distribution of these fish also is relatively localized. No Hebron or Saglek charr have been recaptured in any of the southern areas, nor have any Napartok Bay or Okak Bay charr been recaptured within the heavily exploited bays in the immediate vicinity of Nain. Recaptures of these charr as well as Voisey Bay and Anaktalik Bay charr are illustrated in Fig. 6.

Results of the morphological analyses and tag recapture patterns indicate that separate populations of Arctic charr exist along a limited section of the northern Labrador coast. Individual bays and fiords appear to have their own characteristic stocks although it is likely that a large degree of interchange occurs between rivers within each area. Fraser River (Nain Bay) and Tikkoatokak Bay charr are defined as one stock complex distinctly different from Voisey Bay, Okak Bay and Hebron Fiord charr each of which similarly should be treated as a separate population. Tag recaptures of Fraser River, Nain Bay, Tikkoatokak Bay, Anaktalik Bay and Voisey Bay charr in the offshore areas of Dog Island and Black Island suggest these latter two areas are composed of a composite of stocks from the Nain area but not of stocks originating from Okak Bay or areas to the north.

4.2. LIFE HISTORY

4.2.1. Age and growth

4.2.1.1. Juvenile growth pattern

During the first summer of life juvenile Arctic charr in the Fraser River reached an average size of 3.9 cm (SD = 0.7) (Table 7).

Although no eleutheroembryos or alevins were obtained it was assumed that these charr emerged from the gravel and began exogenous feeding when they were 2.0-2.5 cm in length. This was the size of emergent alevins in the Kigdlut-iluat River, Greenland (Nielsen 1961b) and Sagavanirktok River, Alaska, (Yoshihara 1973). Smallest age 0 charr found in the Fraser River were 2.4 cm while the largest young-of-the year were 5.6 cm when captured in August.

Growth rate was relatively slow throughout the first two years of freshwater life with length increments averaging 2.5 cm annually (Table 7). During the next two years rate of growth increased to 3.5 cm per year yielding an overall rate of increase in length from age 0 to age 4 of 3.0 cm per year. Fraser River charr averaged 12.5 cm and 16.0 cm at age 3 and age 4 respectively. Annual growth throughout this juvenile phase can be expressed by the following linear equation:

$$\text{Length (cm)} = 3.540 + 3.020\ (\text{age}) \qquad r^2 = 0.993.$$

Length at age in 0, 1, and 2 year old juveniles ranged by 3.2, 4.7 and 6.0 cm respectively (Table 7). However, growth appeared more variable at ages 3 and 4 with variation in individual length ranging by 11.8 and 13.6 cm (Table 7).

Weight gain in juveniles (age 0-5) increased exponentially and can be expressed by the following equation:

$$\text{Weight (grams)} = 0.913e^{0.980\ (\text{age})} \qquad r^2 = 0.993$$

Table 7. Comparison of mean length at age between male and female Arctic charr, with age-weight relationship from Fraser River, 1975-1979. Significance levels are P<0.05 (*) and P<0.01 (**).

	Fork Length (cm)							Fork Length (cm)				Round Weight (g)			
	Male			Female				Sexes combined[1]				Sexes combined			
Age	N	Mean	S.D.	N	Mean	S.D.	t	N	Mean	S.D.	Range	N	Mean	S.D.	Range
0	14	4.5	0.5	14	4.4	0.4	0.16	72	3.9	0.7	2.4-5.6	72	1	0.3	0.1-1
1	31	6.6	0.9	29	6.6	1.0	0.04	71	6.5	0.9	4.1-8.8	71	2	1.0	0.5-3
2	22	9.0	1.2	18	9.0	1.5	0.02	96	9.0	1.5	6.2-12.2	96	7	3.8	1.5-16
3	22	13.6	1.7	7	12.5	1.7	1.52	78	12.5	2.0	7.1-18.9	78	20	9.1	3.7-43
4	27	16.0	2.5	11	18.0	2.1	2.41*	51	16.0	2.8	8.9-22.5	51	38	17.5	10.3-76
5	31	22.8	5.8	32	23.8	4.0	0.77	70	22.8	5.1	12.1-35.0	70	132	89.3	18-45
6	50	32.1	7.4	49	34.3	6.5	1.56	99	33.1	7.0	17.0-48.8	99	472	328.6	63-1500
7	54	39.3	8.8	106	40.6	6.1	1.03	160	40.2	7.2	13.9-57.8	160	840	482.1	140-2700
8	66	41.9	9.0	95	44.6	4.7	2.21*	161	43.5	6.9	17.5-64.2	161	1061	591.1	155-3100
9	53	51.6	9.5	67	47.1	6.0	3.03**	120	49.1	8.0	32.3-69.1	120	1605	902.6	320-4600
10	22	50.2	8.5	38	50.2	5.9	0.01	60	50.2	6.9	36.5-64.0	60	1660	756.0	500-4000
11	14	56.9	8.9	26	52.9	5.7	1.71	40	54.3	7.1	41.0-68.4	40	2204	1172.9	400-5800
12	8	55.7	11.1	21	53.3	5.7	0.59	29	54.0	7.4	40.8-72.8	29	1855	814.0	700-3900
13	2	46.6	3.4	6	61.8	2.8		8	58.0	7.5	44.2-66.5	8	2587	826.7	1200-3650
14				8	55.9	4.1		8	55.9	4.1	48.9-62.5	8	2212	617.5	1300-3100
15				3	60.8	2.7		3	60.8	2.7	57.7-62.7	3	2120	964.4	2100-2900
16	1	52.8						1	52.8			1	1550		
17				1	50.1			1	50.1			1	1500		
18				2	53.2	8.3		2	53.2	8.3	47.3-59.0	2	1850	919.2	1200-2500
Total	417			533				1130				1130			

[1]Includes unsexed fish.

At age 3 juvenile charr weighed 20 grams while by age 5 weight had increased to 132 grams. With respect to both length and weight most rapid growth occurred between the ages of 4 and 6.

4.2.1.2. Age-length and age-weight relationship

Empirical growth of Fraser River charr is summarized in Table 7. Length increments from age 4 to 11 averaged 5.5 cm annually compared with 3.0 cm per year for juvenile charr between ages 0 and 4. Largest increases in length were between ages 5-6, 6-7, and 4-5.

Since significant differences in mean lengths of male and female charr were found in only 3 of 13 comparisons (Table 7) data from both sexes were combined. Age 8, 10, and 12 year old Arctic charr were 43.5, 50.2 and 54.0 cm in length respectively with corresponding weights of 1061, 1660 and 1855 grams. The longest charr sampled for age from the Fraser River was 72.8 cm (3200 g, age 12), the heaviest 5800 g (64.0 cm, age 11) and the oldest 18 years. Except for juveniles which were obtained from seine nets, remaining samples were obtained primarily from the counting fence. An accurate representation of length at age is therefore provided since samples were not affected by the selectivity of other types of sampling gear.

Growth rates of individual fish were quite variable as indicated by the distribution of length at age shown in Table 8 and as illustrated in the empirical growth curve (Fig. 7) and length frequency distribution stratified by age-class (Fig. 8). Variation in individual growth was

Table 8. Age-length key for Fraser River Arctic charr samples, 1975-1979.

Length interval (cm)	Age 0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
0.0-1.9																			
2.0-3.9	42																		
4.0-5.9	30	21																	
6.0-7.9		47	27	1															
8.0-9.9		3	41	6	1														
10.0-11.9			26	26	5														
12.0-13.9			2	26	3	3		1											
14.0-15.9				14	14	5													
16.0-17.9				4	13	3	1		1										
18.0-19.9				1	12	10													
20.0-21.9					2	9													
22.0-23.9					1	10	5												
24.0-25.9						9	10	4	2										
26.0-27.9						9	12	3											
28.0-29.9						6	11	7											
30.0-31.9						3	6	4	1										
32.0-33.9						2	9	11	6	3									
34.0-35.9						1	14	13	8	6									
36.0-37.9							8	18	12	1	2								
38.0-39.9							7	10	16	3	1								
40.0-41.9							3	15	18	6	4	1	2						
42.0-43.9							4	23	17	14	7	3	1						
44.0-45.9							4	20	21	10	6	3		1					
46.0-47.9							2	12	21	12	1	2	3						1
48.0-49.9							3	6	19	13	7	1	2	1	1				
50.0-51.9								8	8	14	7	6	2					1	
52.0-53.9								2	1	10	6	1	4		2		1		
54.0-55.9								2	2	3	5	5	6						
56.0-57.9								1	2	6	2	4	3		3	1			
58.0-59.9									2	7	5	5		1	1				1
60.0-61.9									2	2	5	4	2	2					
62.0-63.9									1	5	1	1	1	2	2	1	2		
64.0-65.9									1	3	1	3							
66.0-67.9										1				1					
68.0-69.9										1		1	1						
70.0-71.9																			
72.0-73.9												1							
N	72	71	96	78	51	70	99	160	161	120	60	40	29	8	8	3	1	1	2
Mean length (cm)	3.9	6.5	9.0	12.5	16.0	22.8	33.1	40.2	43.5	49.1	50.2	54.3	54.0	58.0	55.9	60.8	52.8	50.1	53.2
S.D.	0.7	0.9	1.5	2.0	2.8	5.1	7.0	7.2	6.9	8.0	6.9	7.1	7.4	7.5	4.1	2.7			8.3
Condition Factor		1.01	1.01	1.01	1.22	0.99	1.12	1.15	1.17	1.23	1.24	1.27	1.15	1.31	1.24	0.95	1.05	1.19	1.18

Figure 7. Empirical growth curve for Fraser River Arctic charr. Vertical lines represent length range and shaded rectangular areas correspond to one standard deviation on either side of the mean.

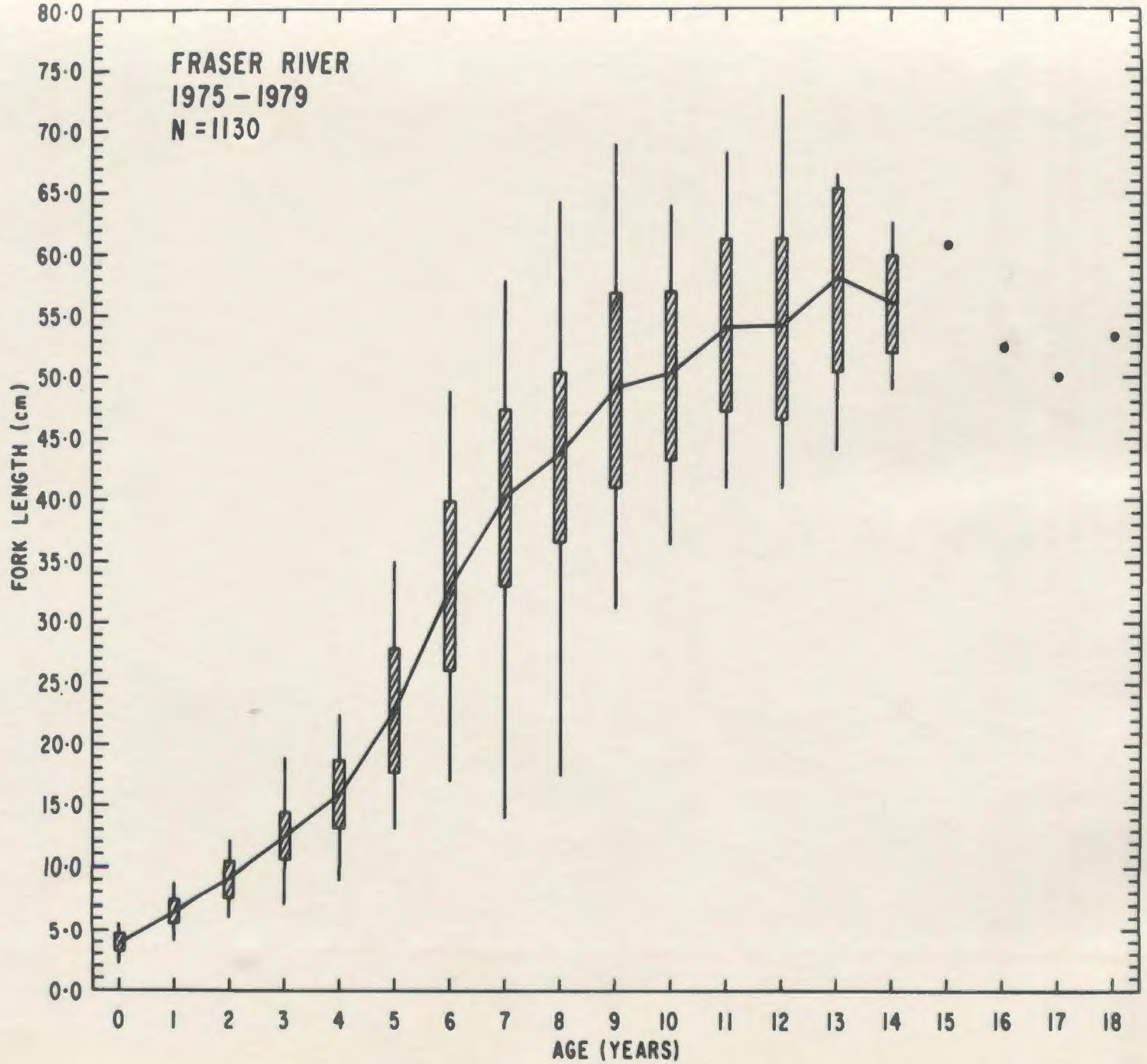
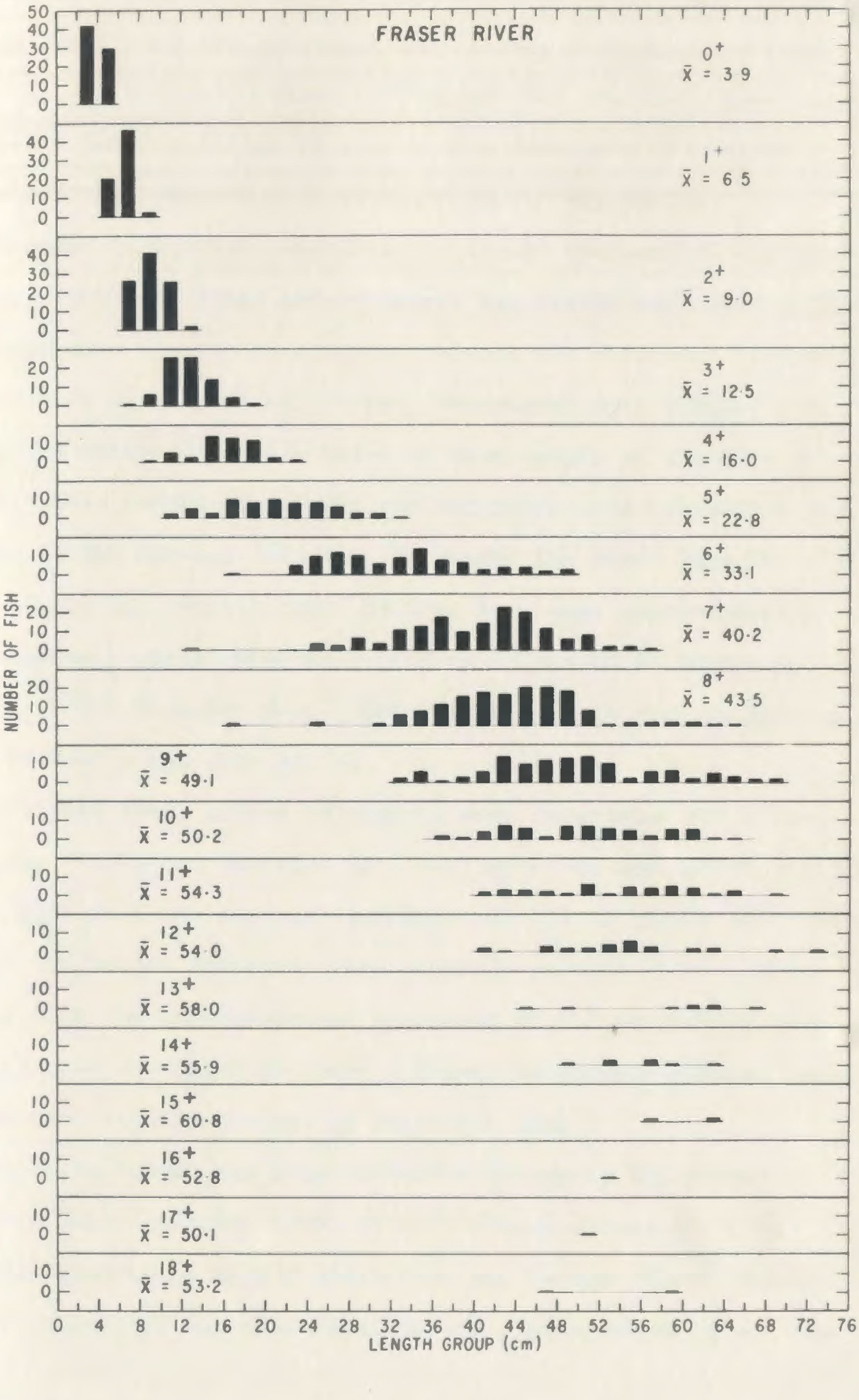

FRASER RIVER
1975 – 1979
N = 1130
FORK LENGTH (cm)
AGE (YEARS)
0·0
5·0
10·0
15·0
20·0
25·0
30·0
35·0
40·0
45·0
50·0
55·0
60·0
65·0
70·0
75·0
80·0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18

Figure 8. Length-frequency distribution stratified by age classes for Fraser River Arctic charr, 1975-1979.


FRASER RIVER
0+ X̄ = 3.9
1+ X̄ = 6.5
2+ X̄ = 9.0
3+ X̄ = 12.5
4+ X̄ = 16.0
5+ X̄ = 22.8
6+ X̄ = 33.1
7+ X̄ = 40.2
8+ X̄ = 43.5
9+ X̄ = 49.1
10+ X̄ = 50.2
11+ X̄ = 54.3
12+ X̄ = 54.0
13+ X̄ = 58.0
14+ X̄ = 55.9
15+ X̄ = 60.8
16+ X̄ = 52.8
17+ X̄ = 50.1
18+ X̄ = 53.2
NUMBER OF FISH
LENGTH GROUP (cm)

more extensive when weights were examined. While the mean coefficient of variation (C.V.) for length at age between 0-12 year old charr was 16.6%, the C.V. with respect to weight for similarly aged charr was 50.4%. This variation in growth is undoubtedly influenced by the age at first seaward migration and age at maturation.

In order to further elucidate the annual increments in growth occurring in Fraser River Arctic charr, tag return data were examined. Only those data from which accurate release and recapture information was available were utilized. First, recaptures were grouped into 5 cm length intervals on the basis of fork length at the time of release. Mean length at release and recapture were calculated in addition to the average increment in length for charr from the six groups (Table 9). Arctic charr 35.0-44.9 cm grew approximately 5.1 cm annually while those 45.0-54.9 cm increased in length by approximately 2.7 cm per year. Charr over 55.0 cm grew an average of 1.3 cm over a one year period.

Following this, growth increments were determined for those recaptures from which otoliths were available for age determination. Between ages 6-10 the average increment was 3.7 cm (Table 10). As expected the larger increases were found in younger charr. This compares with the average growth increment of 4.2 cm derived from empirical data for age 6-10 charr. Growth increments between years were not consistently greater in empirical data.

Growth in length was also estimated following the method of Manzer and Taylor (Ricker 1975) as utilized by Jensen and Berg (1977) for anadromous Arctic charr from the Vardnes River, Norway. A linear regression was calculated for l_{t+1} on l_t where l_t was the

Table 9. Annual growth increments in Fraser River Arctic charr summarized by 5 centimeter length intervals as derived from tag recaptures.

Length interval (cm)	N	Release: Mean Length (cm)	Release: S.D.	Recapture: Mean Length (cm)	Recapture: S.D.	Growth Increment: Mean (cm)	Growth Increment: S.D.
35.0-39.9	1	37.0	-	42.5	-	5.5	-
40.0-44.9	19	43.3	1.1	48.4	2.2	5.1	2.2
45.0-49.9	23	48.0	1.3	50.6	1.3	2.6	1.3
50.0-54.9	21	52.2	1.1	55.0	2.0	2.8	1.6
55.0-59.9	7	57.0	0.7	58.3	0.9	1.3	0.6
60.0-64.9	4	61.1	1.4	62.5	2.2	1.4	1.1
Total	75	49.4	5.3	52.5	4.5	3.1	2.0

Table 10. Annual growth increments in Fraser River Arctic charr summarized by age group as derived from tag recaptures.

Age	Release			Recapture			Growth Increment	
	N	Mean Length (cm)	S.D.	Age	Mean Length (cm)	S.D.	Length (cm)	S.D.
6	2	42.7	1.8	7	47.0	2.1	4.3	0.3
7	11	45.5	4.0	8	50.7	3.5	5.2	2.5
8	16	49.5	4.0	9	53.1	3.5	3.6	2.0
9	13	49.3	4.3	10	52.4	4.2	3.1	1.5
10	4	51.1	4.3	11	53.2	4.2	2.1	0.7
11	8	52.6	3.7	12	54.0	3.3	1.4	1.4
12	2	52.4	6.6	13	54.6	5.8	2.3	0.8
13	1	57.8	-	14	59.3	-	1.5	-
14	2	50.9	1.9	15	51.9	1.2	1.0	0.7

fork length of tagged charr at the time of release in the Fraser River during the upstream migration, and l_{t+1} was the fork length of the same charr caught approximately one year later. These results are presented in Table 11. Estimates of L_∞ (the theoretical maximum length of fish) and K (a constant determining the rate of change in length increments), two of the parameters describing the von Bertalanffy growth function, which is:

$$l_t = L_\infty \left(1-e^{-K(t-t_o)}\right)$$

were derived from these data. K was estimated from the slope of the line which is equal to e^{-Kt} while $L_\infty = \text{Mean} \dfrac{(l_{t+i})}{1-k}$, where $k = e^{-K}$ (Ricker 1975).

From this highly significant regression ($P < 0.01$) estimates can be made of annual growth of fish of a specific size in addition to deriving an estimate of the instantaneous rate of increase G, where $G = \ln (l_{t+1}/l_t)$. The following table outlines the estimated growth in length with the corresponding rate of increase for several size classes of Fraser River charr:

l_t(cm)	l_{t+1}(cm)	Increment (cm)	G
35.0	41.3	6.3	0.17
40.0	45.2	5.2	0.12
45.0	49.1	4.1	0.09
50.0	53.0	3.0	0.06
55.0	56.9	1.9	0.03
60.0	60.9	0.9	0.01

The Manzer-Taylor relationship was compared with empirical data by substituting into the equation for l_t the mean lengths of fish age 6-10 and calculating the average increment (mean of the difference

Table 11. Linear regressions of l_{t+i} on l_t with estimates of L_∞ and K derived from recaptured Fraser River Arctic charr.

	N	Regression equation	r	$\bar{l}_t$	$\bar{l}_{t+i}$	L_∞	K
One year's growth							
	75	$l_{t+i} = 13.84 + 0.78\, l_t$	0.93	49.4	52.5	64.0	0.24
Two year's growth							
	27	$l_{t+i} = 20.37 + 0.71\, l_t$	0.87	45.0	52.2	69.5	0.17

between l_{t+1} and l_t ages 6-10). This value was 4.3 cm while the mean increment from observed data was 4.2 cm.

For Arctic charr recaptured after two, three, four and five years, similar regressions were computed. Results for recaptures after two years are summarized in Table 11. These charr grew approximately 7.2 cm; for three years (N = 17) the increase in length was 10.1 cm; for four years (N = 14) the increase was 10.5 cm; and recaptures after five years (N = 4) had an increase in length of 13.5 cm.

4.2.1.3. Weight-length relationship

The weight-length relationship for Fraser River Arctic charr was calculated from 6097 upstream migrating fish. These fish were obtained from a counting fence and ranged in length from 14.7 to 73.3 cm. Mean length of the sample was 44.6 cm and mean weight (round condition) was 1.33 kg. The regression equation, listed in Table 12, had a slope coefficient of 2.62 indicating allometric growth in this population.

Condition factors are often used in comparing fish from different years, populations, or areas in terms of the overall well being or degree of fitness (Le Cren 1951). Condition factors calculated for Fraser River charr by age class are listed in Table 8. Values ranged from 0.99 to 1.31.

Table 12. Weight-length relationships derived from various research samples of northern Labrador Arctic charr.

Area	N	Fork Length (cm)		Round weight (kg)		Weight-length regression	r
		Mean	Range	Mean	Range		
Fraser River	6097	44.6	14.7-73.3	1.33	0.10-5.20	$Log_{10}W = 2.62Log_{10}L - 4.23$	0.88
Okak Bay	303	47.0	32.9-60.8	1.49	0.47-3.00	$Log_{10}W = 2.74Log_{10}L - 4.42$	0.93
Napartok Bay	335	47.5	27.6-66.4	1.50	0.20-3.50	$Log_{10}W = 3.20Log_{10}L - 5.21$	0.96
Hebron Fiord	489	44.6	21.7-75.5	1.29	0.10-5.00	$Log_{10}W = 3.22Log_{10}L - 5.27$	0.98
Saglek Fiord	546	45.0	16.5-67.0	1.31	0.10-4.30	$Log_{10}W = 3.04Log_{10}L - 4.95$	0.98
Ramah Bay	221	48.6	21.0-71.9	1.58	0.10-4.28	$Log_{10}W = 2.94Log_{10}L - 3.79$	0.98

4.2.2. Migration

4.2.2.1. Size and age at first seaward migration

Seaward migration of adult Arctic charr in the Nain area of Labrador occurs during the latter part of May and early June. It is assumed that charr smolts migrate concurrent with, or on the basis of Johnson's (1980) findings, shortly after the downstream movement of adults which generally coincides with the period of spring runoff and ice breakup along the rivers. Although adults have been captured at this time, usually in the transition zone between the still ice covered marine areas and the opening river mouths, no direct samples of smolts have been obtained. Consequently determination of age and size at first seaward migration were derived in an indirect manner by examining the size and age structure of the Fraser River population, and by sampling for juvenile charr at sea later in the summer.

As mentioned in Section 4.2.1.2. the largest annual length increment occurred between 5 and 6 year old charr and was 10.3 cm. Annual increases of 6.8 cm and 7.1 cm occurred between 4-5 and 6-7 year old fish respectively. Another method of examining these size increases is in terms of instantaneous growth (G) which is the natural logarithm of the ratio of final size to initial size of a fish in a unit of time (Ricker 1975). Except for age 0-1 charr, instantaneous growth was highest between ages 5-6 and 4-5 with values of 0.37 and 0.35 respectively. Instantaneous growth, however, is more commonly expressed in terms of weight. The corresponding values for the above ages were 1.27 and 1.25 which were the highest values calculated except for 1-2 year old charr where G was also 1.25. If this increased growth is construed as reflecting migration to the sea and feeding in the more productive marine environment, then charr migrate to the sea for the first time when they are 4 and 5 years old. The establishment of a large length range in individuals is first apparent at age 3 although it is most pronounced at 4 and 5 years (Fig. 8). Nielsen (1961a) and Johnson (pers. comm.) indicate that some charr in their first migration often remain in the vicinity of the river mouth migrating back and forth between freshwater and the sea. Unlike the case in Atlantic and Pacific salmon, a large increase in growth will not likely occur during the charr's first migration to the ocean.

Juvenile charr of a typical smolt appearance were captured in Nain Bay during 1979 and 1980. All fish were silver in colour with no visible parr marks. The former samples were caught in 25.4, 38.1 and 50.8 mm mesh gillnets set on the north side of the bay approximately 8 km out from the headwaters. Salinity, water temperature and corresponding depths taken at this time were:

Depth	Temperature °C	Salinity ‰
Surface	7	23
1 m	6	23
2 m	5	24

Samples obtained in 1980 were caught using a beach seine in a small cove on the south side of the bay 15 km from the head of Nain Bay. No salinity measurements were taken in 1980.

The youngest charr caught in both years was age 3 and the smallest 8.7 cm (Table 13). Larger size of the 1979 samples were likely due to selectivity of larger meshed gillnets. The 1980 samples ranged in age from 3-7 years, however, mean size differed by only 0.7 cm with overall length ranging from 8.7-13.1 cm (Table 13). Owing to the consistent size of fish in the samples, it is possible that these were all first time migrants. Mean size for the 49 charr was 11.1 cm with a coefficient of variation of 7.2%. Although no age 2 juveniles were caught at sea the size distribution of the 1980 smolts would suggest that a small proportion of 2 year old charr would likely migrate for the first time at this age. Only 4% of the 1980 smolt sample were less than 10.0 cm, however, of the 2 year old juvenile charr captured in the Fraser River 8% were larger than 11.0 cm but 29% were greater than 10.0 cm in length. Age at first seaward migration, therefore, generally ranges in charr from 3-7 years but some 2 year olds may smoltify.

4.2.2.2. Annual and seasonal movements

Results presented in Section 4.1.2. indicated that northern Labrador Arctic charr have a tendency to remain within localized areas rather than undergo extensive coastal migrations. Any extensive movements were generally directed into outer offshore areas. Recaptures of Fraser River charr over a five year period showed their annual movements were relatively consistent. Many charr returned back to the Fraser River and were consistently recaptured

Table 13. Length at age relationship for Arctic charr juveniles captured in Nain Bay during 1979 and 1980.

	1979[1]					1980[2]			
Age	N	Mean Length (cm)	S.D.	Range		N	Mean Length (cm)	S.D.	Range
3	6	12.9	0.8	11.9-14.0		6	10.9	1.1	8.7-11.7
4	17	13.9	2.5	11.3-18.5		13	11.0	0.8	10.0-12.2
5	3	13.1	0.2	12.9-13.3		20	11.1	0.8	9.5-13.1
6	2	16.6	3.6	14.0-19.1		8	11.2	0.8	10.2-12.3
7						2	11.6	0.1	11.5-11.6
Total	28	13.8	2.3	11.3-19.1		49	11.1	0.8	8.7-13.1
Mean age		4.0	0.8	3-6	Mean age		5.1	0.9	3-7

[1]Samples captured in 25.4, 38.1 and 50.8 mm gill nets. Salinity measurements were $23^{0}/oo$ at the surface and 1 m, and $24^{0}/oo$ at 2 m. Corresponding temperatures were $7^{0}C$, $6^{0}C$ and $5^{0}C$.

[2]Samples captured in a beach seine net. No salinity measurements available.

in Nain and Tikkoatokak Bay. Information was available for the specific recapture location in Tikkoatokak Bay of 87 charr tagged at the Fraser River and in Nain and Tikkoatokak bays. Tikkoatokak Bay was a major feeding area for these charr and they were distributed along coastal margins of all sections of the bay throughout the fishing season. Charr were not concentrated in any one specific location.

Of the seaward migrants tagged in Tikkoatokak Bay during spring of 1979 and 1980, the average duration at sea before recapture was 40 days. For 1980 Nain Bay seaward migrants, the period was 54 days, the longest of which was 98 days. This latter charr was recaptured in adjacent Anaktalik Bay. Most rapid movement was observed in a charr tagged in Nain Bay in 1979 and recovered 5 days later at the Fraser River counting fence, a distance of 82 km at an average daily speed of 16.4 km day^{-1}.

4.2.2.3. Time and duration of upstream migration

The upstream migration of Arctic charr into the Fraser River began during the middle of July with the first charr captured on July 18 in 1976 and in 1979. Since the counting fence was located approximately 65 km from the sea it was likely that charr began entering freshwater during the second week of July. Numbers of fish fluctuated daily with as many as 700 charr counted and released on certain days (Fig. 9). Numbers also fluctuated annually (Table 14).

Figure 9. Daily counts of upstream migrant Arctic charr in Fraser River, 1975-1979.

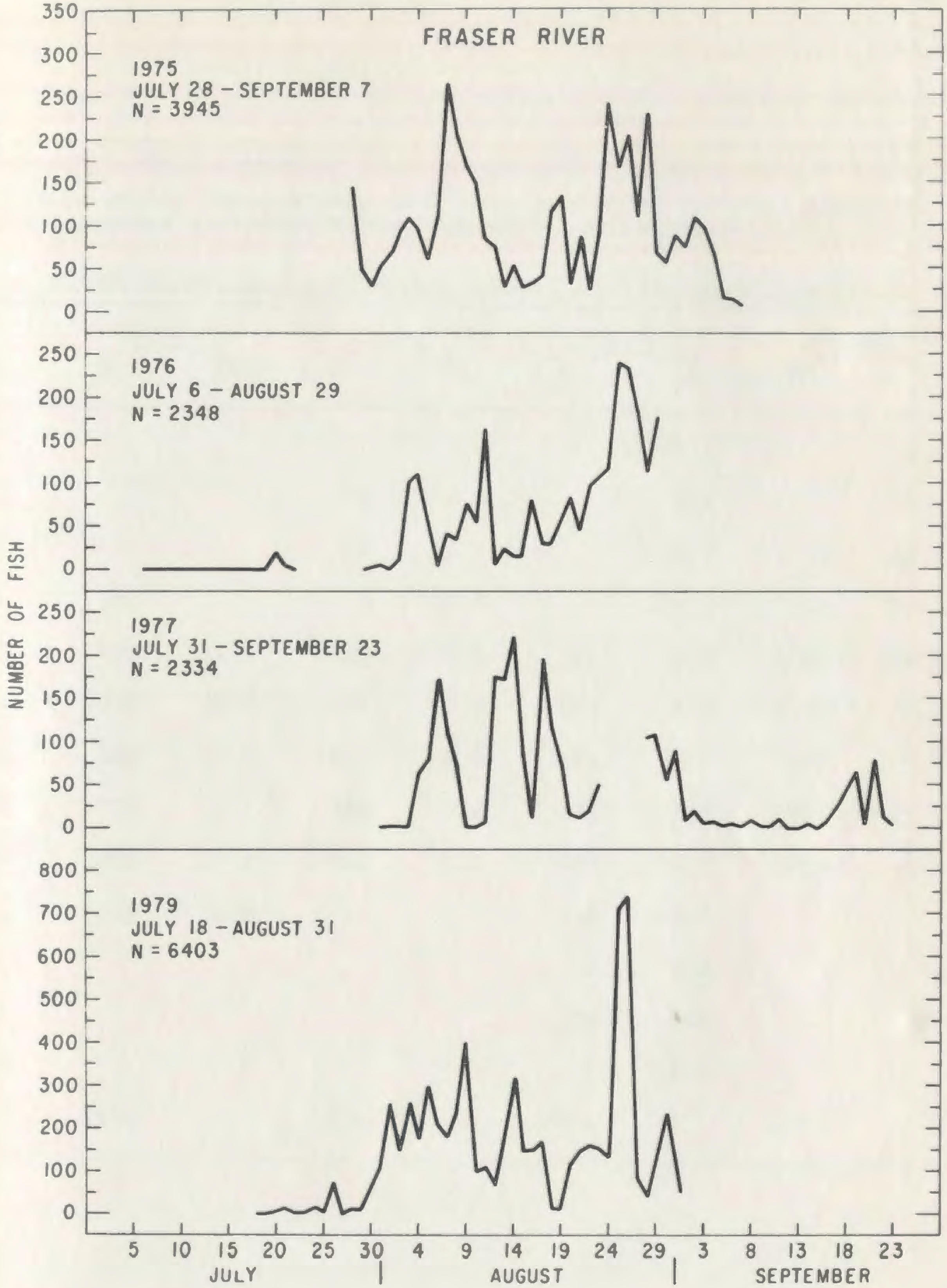

FRASER RIVER
1975
JULY 28 – SEPTEMBER 7
N = 3945
1976
JULY 6 – AUGUST 29
N = 2348
1977
JULY 31 – SEPTEMBER 23
N = 2334
1979
JULY 18 – AUGUST 31
N = 6403
NUMBER OF FISH
350
300
250
200
150
100
50
0
800
700
600
500
400
300
200
100
5 10 15 20 25 30 4 9 14 19 24 29 3 8 13 18 23
JULY
AUGUST
SEPTEMBER

Table 14. Mean weekly temperatures and total number of upstream migrating Arctic charr recorded at Fraser River, Labrador, 1975-1979.

	1975		1976		1977		1979	
	N	°C	N	°C	N	°C	N	°C
July 1-7						7.9		8.5
8-14			0	9.5		8.9		8.4
15-21			25	11.2		10.7	15	10.4
22-28	144		0	10.5		10.7	121	10.4
29-4	486	12.9	229	9.0	67	11.1	1025	10.4
Aug. 5-11	1035	12.9	436	8.9	451	9.3	1530	9.7
12-18	383	10.5	203	8.8	978	8.7	982	9.1
19-25	768	10.6	740	9.6	173	9.3	1446	8.7
26-1	828	11.3	715	9.8	364	8.9	1284	7.9
Sept. 2-8	308	11.0			41	8.3		
9-15					20	6.9		
16-22					239	5.4		
23-29					1	5.0		
Total	3952		2348		2334		6403	

Although complete counts of fish were not available during the month of July in any of the study years (Fig. 9), it was apparent that the peak migration took place in August. During the period of time when the counting fence was operable in 1975, 1976, 1977 and 1979, an average of 60% of the run occurred between August 5-25. High water levels at the end of August in 1976 and 1979 necessitated the premature removal of the counting fence. In 1977, however, the fence was operated until September 23. Counts of fish in September represented 13% of the total run for that year. From this it was assumed that charr migrations extend on toward the end of September but daily numbers of fish decline rapidly after the first week of the month.

Water temperatures in the river also fluctuated daily. Mean weekly temperatures during the month of August ranged from 8.7-12.9°C. By mid-September weekly temperatures averaged 5.0°C (Table 14). No correlations were found between numbers of migrating fish and water temperatures. On several occasions large numbers of charr passed through the fence on or shortly after spring tide conditions at the mouth of the river.

4.2.2.4. Age and size composition of upstream migration

Mean age of upstream migrating Fraser River charr ranged from 8.1 years in 1977 to 8.6 years in 1976. The youngest charr caught passing through the fence was 3 years old while the oldest was 18 years. Sixty-nine percent of the run over the years 1975-1979 were 7-9 years old, however, the contribution of these age classes varied annually from 60-77%. Only 10% were less than age 7 and 21% greater than age 10. Although 12 year old charr were relatively abundant in 1975 and 1976 (Fig. 10) in general the migratory population had few fish beyond this age.

Mean length of upstream migrants was relatively consistent varying from 44.5 cm in 1977 to 45.8 cm in 1975. Approximately 70% of the fish were between 40.0 and 53.9 cm (Fig. 11). Charr larger than 60.0 cm represented only 2.5% of the run. There was a tendency for mean size of fish to decrease progressively throughout the duration of the upstream migration (Table 15). Upstream migrants during the week of July 22-28 in 1975 and in 1979 averaged 51.1 cm in length while mean size of charr migrating during the week of August 26-September 1, for all years combined, was 42.5 cm. Late runs in September of 1977 had mean lengths less than 42.0 cm.

4.2.3. Reproduction

4.2.3.1. Sex ratio

The sex ratio of upstream migrant charr varied annually with females representing 48-69% of the run between 1975 and 1979 (mean = 60%). Females were more abundant than males during the initial part of the migration with sexes generally equal later in the summer. Table 16 provides a summary of age specific sex ratios for all years combined. Most age groups from 7-18 years had

Figure 10. Age distributions of upstream migrating charr in Fraser River as derived from annual age-length keys and length-frequency distributions, 1975-1979. Number (N) refers to total fence counts.

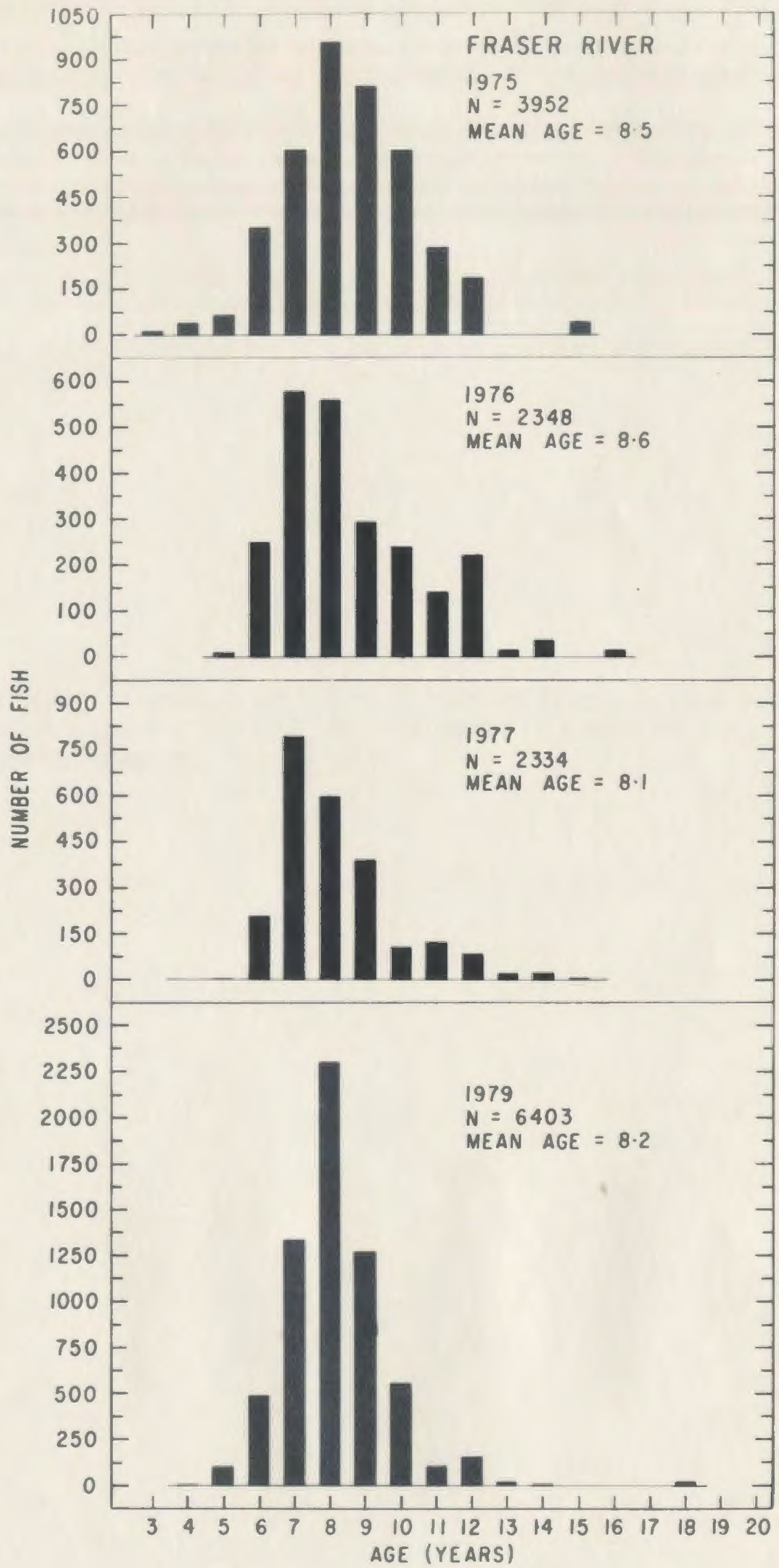

FRASER RIVER
1975
N = 3952
MEAN AGE = 8·5
1976
N = 2348
MEAN AGE = 8·6
1977
N = 2334
MEAN AGE = 8·1
1979
N = 6403
MEAN AGE = 8·2
NUMBER OF FISH
AGE (YEARS)
1050
900
750
600
450
300
150
0
600
500
400
300
200
100
0
900
750
600
450
300
150
0
2500
2250
2000
1750
1500
1250
1000
750
500
250
0
3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20

Figure 11. Length distribution of upstream migrant Fraser River Arctic charr, 1975-1979. Number (N) refers to number sampled for length.

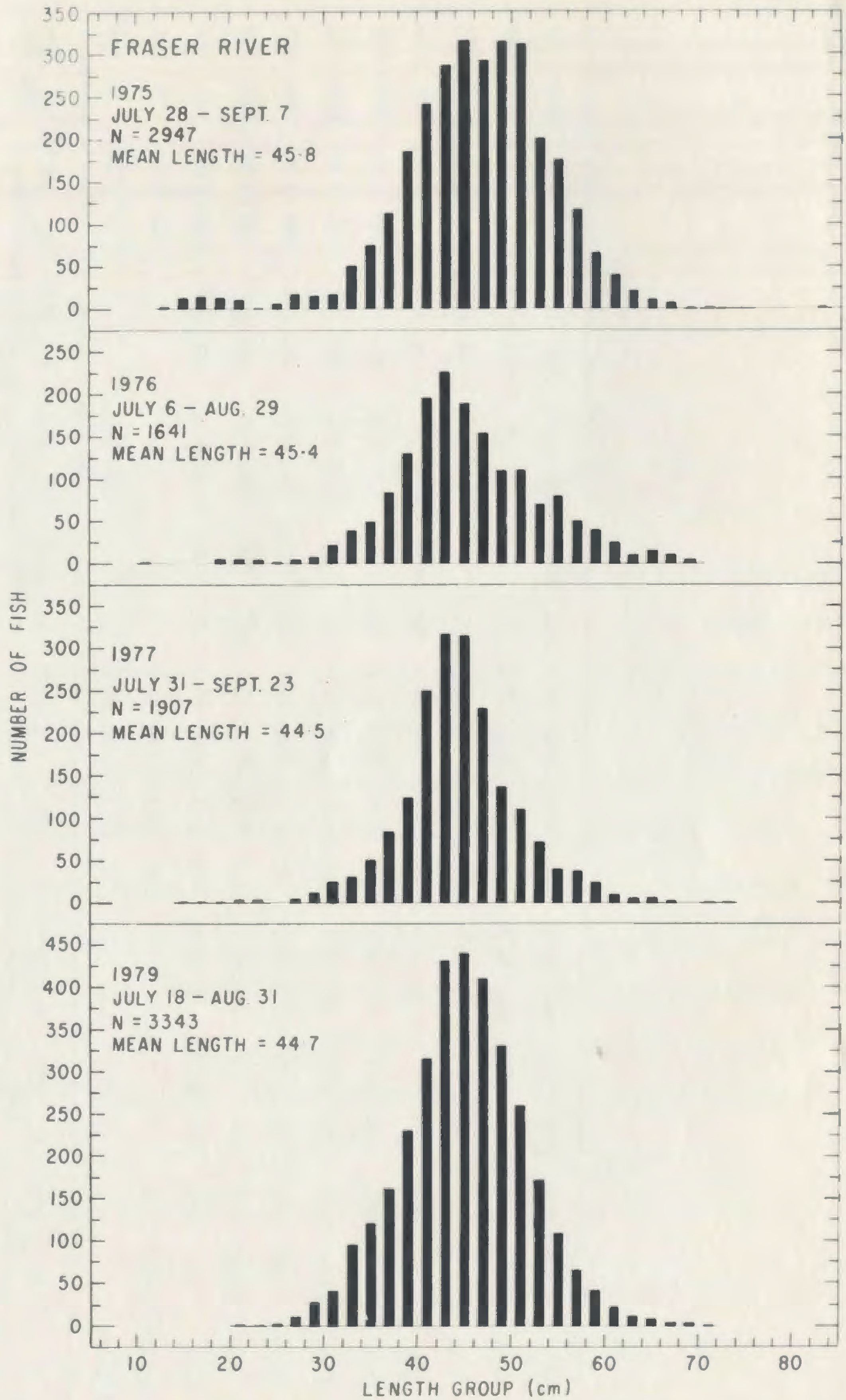

FRASER RIVER
1975
JULY 28 – SEPT. 7
N = 2947
MEAN LENGTH = 45·8
1976
JULY 6 – AUG. 29
N = 1641
MEAN LENGTH = 45·4
1977
JULY 31 – SEPT. 23
N = 1907
MEAN LENGTH = 44·5
1979
JULY 18 – AUG. 31
N = 3343
MEAN LENGTH = 44·7
NUMBER OF FISH
LENGTH GROUP (cm)

Table 15. Mean length (cm) and weight (kg) by week of upstream migrant Arctic charr in the Fraser River, Labrador, 1975-1979.

Date	Fork Length										Whole Weight									
	1975		1976		1977		1979		1975-1979		1975		1976		1977		1979		1975-1979	
	N	Mean	N	Mean	N	Mean	N	Mean	N	Mean	N	Mean	N	Mean	N	Mean	N	Mean	N	Mean
July 15-21			24	52.9			15	49.4	39	51.6			24	2.41			15	1.30	39	1.98
22-28	143	51.8					121	50.3	264	51.1							121	1.45	121	1.45
29-4	361	49.7	226	48.9	66	46.3	429	47.1	1082	48.3	420	1.95	226	2.01	64	1.65	157	1.38	867	1.84
Aug. 5-11	1030	47.9	426	47.1	444	46.5	773	46.7	2673	47.2	1029	1.58	426	1.80	444	1.41	502	1.29	2401	1.53
12-18	318	44.9	199	43.2	587	44.9	712	45.4	1816	44.9	314	1.36	198	1.40	489	1.29	603	1.30	1604	1.32
19-25	541	45.1	513	44.2	165	42.1	756	42.1	1975	43.5	537	1.31	513	1.56	165	1.06	733	1.08	1948	1.27
26-1	290	42.7	253	42.9	357	44.2	537	41.2	1437	42.5	289	1.07	253	1.44	357	1.26	520	1.06	1419	1.18
Sept. 2-8	264	34.5			39	41.0			303	35.3	206	0.78			39	0.84			245	0.79
9-15					18	40.9			18	40.9					18	0.84			18	0.84
16-22					231	41.9			231	41.9					231	0.87			231	0.87
Total	2947	45.8	1641	45.4	1907	44.5	3343	44.7	9838	45.1	2795	1.45	1640	1.66	1807	1.24	2651	1.20	8893	1.37

significantly more females than males. Males were virtually absent from samples beyond age 13, however, males were slightly more abundant in younger age classes.

The sex ratio of juvenile Arctic charr (8.7-13.1 cm) captured in Nain Bay during 1980 (Section 4.2.2.1.) was 1.6:1 in favour of females. The difference, however, was not significant ($\chi^2 = 2.47$, df = 1).

4.2.3.2. Age and size at maturity

Male Fraser River Arctic charr had a mean age of 5.2 years at 50% maturity. The youngest sexually mature males were 3 years old (14.0-15.9 cm) and the inclusion of these precocious males resulted in a lower age at maturation in contrast to including only adults. Females tend to mature at an older age than males with 50% mature at 6.9 years. Seventy-five percent of the females were mature at a mean age of 7.9 years and by age 12, females were 100% mature (Table 16).

Corresponding mean sizes at 50% maturity were 24.5 cm and 38.1 cm for males and females respectively. These charr were obtained from counting fence and seine net samples and, therefore, are not directly comparable with other areas where samples were obtained entirely from gillnets.

Table 16. Age specific sex ratios and age at maturity for Fraser River Arctic charr, 1975-1979. Sex ratios compared by chi-squared analyses (Elliott 1977). Significance levels are $P<0.05$ (*) and $P<0.01$(**) for deviations from a 1:1 sex ratio.

Age	Female		Male		Sex Ratio	
	Number	% Mature	Number	% Mature	% Female	X^2
1	29	0	31	0	48	0.1
2	18	0	22	0	45	0.4
3	7	0	22	13	24	7.8**
4	11	0	27	22	29	6.7**
5	32	12	31	36	51	0.0
6	49	14	50	65	49	0.0
7	106	61	54	92	66	16.9**
8	95	78	66	100	59	5.2*
9	67	93	53	100	56	1.6
10	38	97	22	100	63	4.3*
11	26	96	14	100	65	3.6
12	21	100	8	100	72	5.8*
13	6	100	2	100	75	
14	8	100			100	
15	3	100			100	12.6**
16			1	100	0	
17	1	100			100	
18	2	100			100	
Total	519	61	403	67	56	14.6**

4.2.3.3. Time and location of spawning

The Fraser River counting fence was located 5 km upstream from where the river empties into Tessisoak Lake (Fig. 2). Approximately 27 km upriver from the fence is a small lake 27 hectares in size. From repeated aerial surveys of the entire river by helicopter in October of 1976, 1977 and 1978, concentrations of spawning Arctic charr were located in the 8 km section of the river immediately downstream from the small lake. Redds were situated in concentrated groups throughout the network of channels which branched off from the main river and were assumed to be fed by springs. Redds were observed in water 0.5-1.5 m in depth. Bottom composition in the side channels varied from fine and coarse sand to walnut sized gravel approximately 4-5 cm in diameter. Charr were also observed over areas where substrates were composed of larger stones estimated to be 10-20 cm in diameter. It appeared that redds were not constructed in these areas. However, as evidenced by the agonistic behaviour of the fish, eggs could have been expelled and deposited between the larger stones. This has been observed by Kircheis (1976) in landlocked Arctic charr from Floods Pond, Maine. Charr were also abundant in the main river channel but due to the fast flow no redds were discernible. During the three years of observations in October, charr were never seen in the lower 24 km of the river although charr were observed congregating in the lake adjacent to the mouth of the river. The absence of any redds or associated spawning activity by these fish suggested that they had either spawned upstream and subsequently moved downstream or that they represented a nonspawning component of the run which overwinters in Tessisoak Lake. The spawning period appeared to extend over a three week period in October with peak activity around the middle of the month.

Water temperatures recorded during spawning surveys ranged from 1 to 3°C. In all three years, however, ice had begun to form in the shallow pools along the upper sections of the river and in several smaller channels branching off from the main stem.

Brook charr (Salvelinus fontinalis) spawned at the same time and in the same general area as Arctic charr. Brook charr were considerably smaller than Arctic charr having lengths ranging from 12.0-32.0 cm. Spawning was segregated spatially to some extent with brook charr common on sandy and fine gravel areas and Arctic charr dominant on larger gravel and rocky substrates. Overlap of spawning area, nevertheless, did occur.

In addition to spawning in the upper section of Fraser River, Arctic charr also spawned in the small lake upriver from this area. At the west end of the lake, adjacent to the inlet, numerous redds and several spawning charr were observed in water approximately 1.5-2.0 m in depth. Although Arctic charr were not observed spawning in the small lakes separating Nain Bay and Tessisoak Lake, nor in Tessisoak Lake, some spawning likely occurs in these areas if suitable substrates are available.

4.2.3.4. Maturity index, egg size and fecundity

The maturation process was examined in 96 female charr over a five week period of the 1979 Fraser River upstream migration. Egg size in these maturing charr increased from an average 2.3 mm in diameter at the end of July to 3.3 mm by the last week in August (Table 17). Gonad weight similarly increased over the first several weeks but declined in average size by the end of the month. The decrease in gonad size appeared related to the decline in mean size of fish over the duration of the run (Table 15).

The maturity index (gonad weight/body weight x 100; Hunter 1970) increased from 3.1 to 7.1 over the 5 week period. In 1979 it was estimated from the degree of gonadal development that 60% of the upstream migrating females would spawn.

Fecundity data were obtained from nine charr captured on the spawning grounds in October 1976. Data from complete egg counts of these fish are as follows:

Mean fish length (cm)	=	55.3
range (cm)	=	45.0-60.7
Mean fish weight (kg)	=	2.14
range (kg)	=	1.05-3.00
Mean fecundity	=	5242
range	=	2863-9245
Mean egg diameter (mm)	=	4.4
range	=	4.1-4.6
Mean age	=	10.1
range	=	7-13

Table 17. Relationship between maturity index, gonad weight and egg diameter in mature Fraser River Arctic charr, 1979.

Week	N	Maturity index	Gonad weight (g)	Egg diameter
July 29 - August 4	30	3.1	40.0	2.3
August 5-11	24	4.1	63.6	2.8
August 12-18	25	5.1	76.1	2.6
August 19-25	10	4.8	54.5	2.6
August 26 - September 4	7	7.1	59.2	3.3

Fraser River charr were estimated to produce an average of 2450 eggs per kg of body weight. Although sample size was small, a statistically significant regression ($P < 0.05$) was fitted to the relationship of fecundity (number of eggs produced) (f) on fork length (cm) (l):

$$\log f = 2.543 \log l - 0.728$$

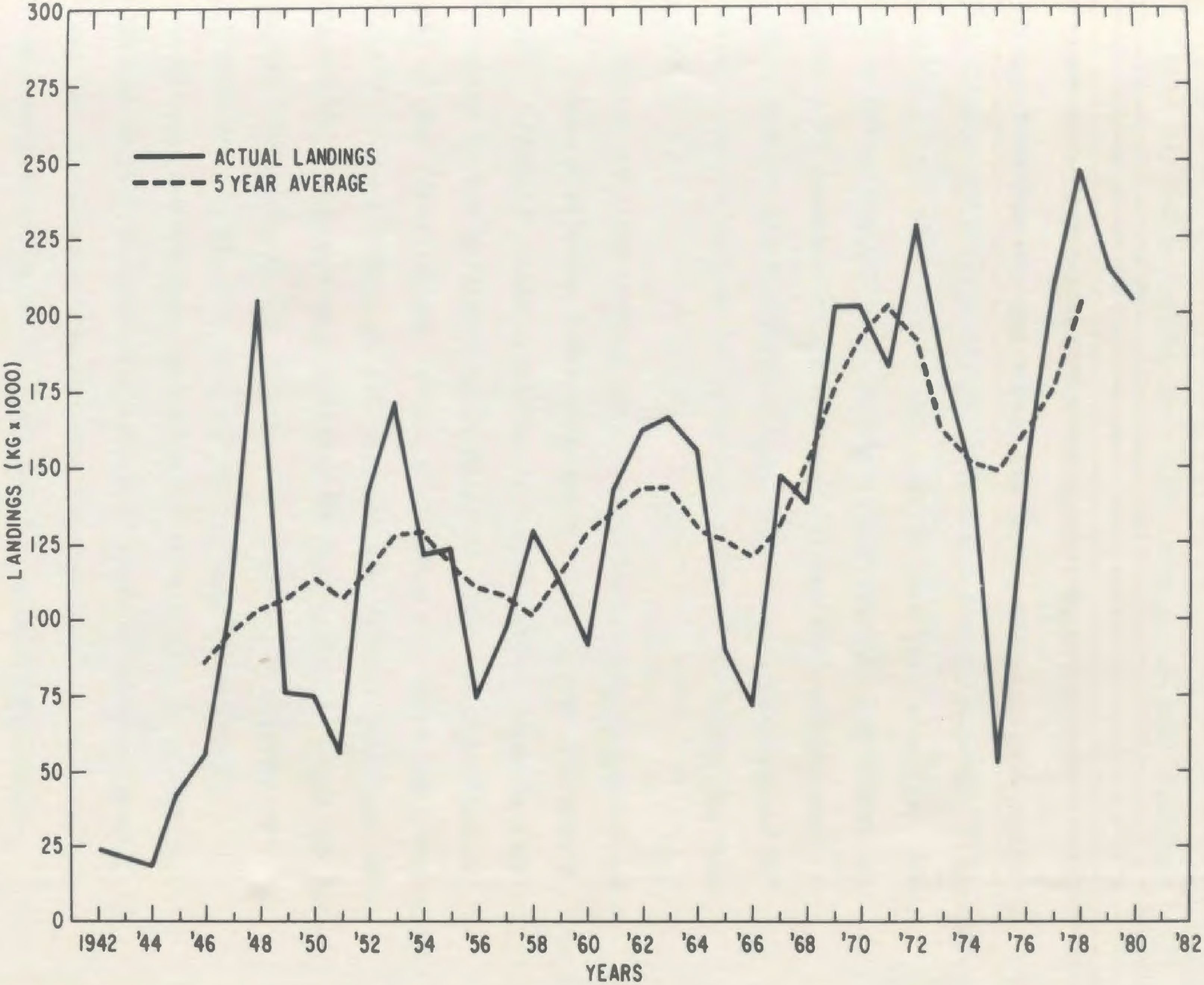
$$(r = 0.79, F = 12.02, df\ 1,7).$$

4.3. COMPARATIVE POPULATION DYNAMICS

4.3.1. Catch and effort data

Records of Arctic charr production from the northern Labrador coast have been available since 1942 (Fig. 12). Information from 1949-1966 represented charr exports as opposed to landings since charr with red flesh colour only, and not white or pink charr were marketed (Coady 1974). Production, however, varied annually with exports for the first ten years, averaging 82 t y^{-1}. During the next twenty years (1953-1972) charr production rose to an annual average of 141 t. The general trend for increased production has continued and during the past four years (1977-1980) in excess of 200 t y^{-1} have been landed in northern Labrador with 86% caught within the Nain fishing region (Fig. 1). Highest recorded landings were in 1978 when approximately 250 t of anadromous charr were caught.

Figure 12. Summary of Labrador Arctic charr production, 1942-1980.


ACTUAL LANDINGS
5 YEAR AVERAGE
LANDINGS (KG x 1000)
300
275
250
225
200
175
150
125
100
75
50
25
0
1942 '44 '46 '48 '50 '52 '54 '56 '58 '60 '62 '64 '66 '68 '70 '72 '74 '76 '78 '80 '82
YEARS

Detailed catch and effort information from individual areas has been available since 1974 and is summarized in Table 18. Tikkoatokak Bay, Okak Bay and Voisey Bay have been three of the most important charr fishing areas during the past five years. In excess of 200 t of charr have been removed from Tikkoatokak Bay since 1976. Total landings from Okak Bay and Voisey Bay during the past five years were 125 and 102 t respectively. Catch and effort, however, fluctuated annually in all areas (Table 18). Quotas have been in effect since 1979 on Voisey Bay (22.5 t), Anaktalik Bay (21.5 t) and Tikkoatokak Bay (39.5 t) (Dempson 1981), although catches were effectively reduced only in the Tikkoatokak area. Quotas were not reached in Anaktalik Bay in 1979 or 1980 and were achieved in Voisey Bay only in 1979.

Effort data are derived weekly and subsequently are useful only in providing a relative index of fishing intensity for the entire season. Effort directed specifically toward Arctic charr is highly influenced by the availability of Atlantic salmon in the offshore areas of Dog Island, Black Island, Kiglapaits and Cutthroat. Abundance of charr in these areas, as indicated by the average catch per unit effort (C/E), has been comparatively low and variable. Mean C/E for the past five years in Dog Island, Black Island, Kiglapaits and Cutthroat was 27, 83, 127, and 123 kg/man-week respectively. Corresponding coefficients of variation (C.V.) were 41.7%, 59.7%, 25.8% and 28.3%. In contrast, principal charr fishing areas of Voisey Bay, Tikkoatokak Bay and Okak Bay had five year average catch per unit effort values of 327, 381 and 285 kg/man-week. Charr abundance was less variable in these latter areas with coefficients

Table 18. Summary of catch (kg round), effort (man-weeks fished) and size composition statistics for various areas in northern Labrador. Size composition expressed as proportion of landings greater than 2.3 kg (gutted head-on).

Year	1974	1975	1976	1977	1978	1979	1980
Anton's Point							
Catch	9,135	3,489	3,172	2,111	4,006	19,371	8,457
Effort	34	20	6	20	17	63	32
C/E	269	174	529	106	236	307	264
% > 2.3 kg			21.0	24.3	27.9	21.9	13.5
Voisey Bay							
Catch	20,045	238	12,232	22,485	33,585	21,877	11,553
Effort	64	2	45	56	91	59	52
C/E	313	119	272	402	369	371	222
% > 2.3 kg			42.1	34.6	33.9	32.0	16.8
Anaktalik							
Catch	7,821	2,548	14,670	21,598	13,067	14,907	8,038
Effort	28	10	45	63	55	76	53
C/E	279	255	326	343	238	196	152
% > 2.3 kg			35.6	37.7	27.1	20.5	11.9
Dog Island							
Catch	2,659	653	212	2,036	385	1,436	3,045
Effort	38	40	11	49	25	61	86
C/E	70	16	19	42	15	24	35
% > 2.3 kg			11.0	8.6	7.9	14.7	11.3
Nain Bay							
Catch	12,461	-	3,119	8,460	-	-	-
Effort	37	-	10	28	-	-	-
C/E	337	-	312	302	-	-	-
% > 2.3 kg			16.4	15.5			
Tikkoatokak							
Catch	9,960	27,695	31,568	39,477	55,047	37,912	42,127
Effort	28	76	81	85	145	110	130
C/E	356	364	390	464	380	345	324
% > 2.3 kg			18.7	20.0	18.5	14.3	10.3
Webb Bay							
Catch	580	833	4,550	2,514	3,473	3,035	3,007
Effort	1	5	15	21	16	9	8
C/E	580	167	303	120	217	337	376
% > 2.3 kg			21.4	19.0	20.1	38.6	38.7
Black Island							
Catch	4,264	2,101	2,725	3,387	2,961	10,630	20,047
Effort	60	62	48	65	81	92	130
C/E	71	34	57	52	37	116	154
% > 2.3 kg			8.4	10.3	14.4	6.7	6.1

Table 18. (Cont'd)

Year	1974	1975	1976	1977	1978	1979	1980
Kiglapaits							
Catch	5,131	1,504	6,089	5,435	12,097	17,607	16,536
Effort	26	32	59	57	103	120	95
C/E	197	47	103	95	117	147	174
% > 2.3 kg			25.2	24.7	34.1	14.5	17.9
Tasiuyak							
Catch	1,467	-	281	-	2,279	1,838	1,138
Effort	15	-	2	-	9	11	8
C/E	98	-	141	-	253	167	142
% > 2.3 kg			21.3	-	71.2	34.5	14.3
Okak							
Catch	34,250	2,354	17,812	27,592	36,125	26,168	17,430
Effort	105	15	52	110	104	121	65
C/E	326	157	343	251	347	216	268
% > 2.3 kg			28.6	25.9	17.8	10.8	8.2
Cutthroat							
Catch	12,641	2,703	7,526	15,488	41,146	17,793	32,390
Effort	95	47	103	130	267	161	205
C/E	133	58	73	119	154	111	158
% > 2.3 kg			16.9	24.2	24.6	12.1	11.9
Mugford							
Catch	-	-	1,970	1,375	1,147	170	513
Effort	-	-	15	9	7	2	5
C/E	-	-	131	153	164	85	103
% > 2.3 kg	-	-	30.1	35.8	31.5	15.6	15.3
Napartok							
Catch	-	-	28,972	28,039	8,551	2,484	752
Effort	-	-	124	126	50	33	11
C/E	-	-	234	223	171	75	68
% > 2.3 kg			13.8	22.1	19.9	15.6	13.0
Hebron							
Catch	-	-	-	5,952	-	-	2,915
Effort	-	-	-	37	-	-	6
C/E	-	-	-	161	-	-	486
% > 2.3 kg	-	-	-	16.4	-	-	19.5
Total							
Catch	120,414	44,118	134,898	186,135	213,869	175,228	167,948
Effort	531	309	616	856	970	918	886
C/E	227	143	219	217	220	191	190
% > 2.3 kg	20.5	21.7	23.5	25.3	24.4	17.4	12.3

of variation of 23.4%, 14.1% and 20.3% respectively. With respect to the entire Nain fishing region charr abundance has been relatively constant for the past five years. Average C/E for the period 1976-1980 was 207 kg/man-week with a C.V. of 7.5%. Catch and effort data for 1980 suggest a possible change in distribution with Arctic charr utilizing offshore areas for feeding more than in previous years (Table 18). Charr abundance (C/E) in the Dog Island, Black Island, Kiglapaits and Cutthroat areas combined was 43% greater than the previous four year average abundance. Tag recaptures in 1980 of Fraser River, Nain Bay, Tikkoatokak Bay, Anaktalik Bay and Voisey Bay charr also substantiated the distribution change (Section 4.1.2.) and indicated that the fishery in offshore areas exploits a composite of stocks from inner bay regions.

Coady and Best (1976) provided limited production estimates for a number of areas between 1961 and 1969. Average production for six years in Hebron Fiord was 19 t y^{-1} while Saglek Fiord produced an average of 62 t y^{-1}. Saglek has been unexploited since 1969 but a limited commercial fishery occurred in Hebron during 1977 when 6 t were caught and on an experimental basis in 1980 when 3 t were removed. Catch per unit effort in Hebron for 1977 was 161 kg/man-week. Information provided by the local Fishery Officer in Nain, Labrador, indicated that fishing occurred only in outer coastal areas of the Hebron region by Napartok Bay fishermen fishing for Atlantic salmon. In 1980 when fishing was carried out within the fiord specifically for charr, C/E was 486 kg/man-week (Table 18).

4.3.2. Age and size composition of the catch

Commercial samples of age and size distribution have been obtained from Voisey Bay, Tikkoatokak Bay and Okak Bay annually since 1977 (Table 19). Only limited data were obtained from the Hebron fishery in 1977, however, the 1980 experimental fishery was adequately sampled.

A noticeable trend was for mean age of commercially caught charr to increase with latitude, however, no similar trends were found with respect to mean length and weight. Average age of Arctic charr caught in Voisey Bay and Tikkoatokak Bay was 8.6 and 8.7 years respectively (Table 20, 21). Okak Bay charr had a mean age of 10.0 years (Table 22) while charr from the Hebron area averaged 11.2 years (Table 23). Substantial differences were observed between areas in the age compositions of landings. Dominant age classes in Voisey Bay and Tikkoatokak Bay were 7-9 year olds which represented 77% and 75% of the catch in the two areas respectively. These age classes represented only 43% and 40% of the commercial catch in the Okak and Hebron regions. As expected from the concentration of fishing on younger age classes in the immediate Nain areas, few charr age 12 or older were represented in the fishery with only 5.0% in Voisey Bay and 4.5% in Tikkoatokak Bay over the period 1977-1980. Charr age 12 and older did, however, contribute 28% of the Okak Bay catches and 35% of the catch from Hebron Fiord. Variation in numbers at age occurred annually within individual areas. Estimated numbers at age for the commercial catches from Voisey Bay, Tikkoatokak Bay and Okak Bay for 1977-1980 are summarized in Tables 24, 25 and 26.

Table 19. Summary of age samples available from the commercial northern Labrador Arctic charr fishery, 1977-1980.

Area	1977	1978	1979	1980	Total
Anton's				55	55
Voisey	322	340	364	404	1430
Anaktalik	213	330		210	753
Tikkoatokak	458	416	308	430	1612
Okak	128	351	423	390	1292
Cutthroat	34			384	418
Napartok	306	206	170	22	704
Hebron	92			384	476
Total	1553	1643	1265	2279	6740

Table 20. Summary of age, length and weight data for commercially caught Arctic charr from Voisey Bay, 1977-1980.

Age	N	Fork Length (cm) Mean	Fork Length (cm) S.D.	Fork Length (cm) Range	Weight (kg)* Mean	Weight (kg)* S.D.	Weight (kg)* Range
5	1	48.0			1.34		
6	46	45.6	4.8	38.1-56.5	1.07	0.40	0.52-2.07
7	283	49.7	4.1	38.6-60.5	1.37	0.40	0.62-2.56
8	491	52.7	4.8	40.4-68.8	1.59	0.49	0.60-4.17
9	290	56.6	5.2	41.6-72.0	1.98	0.63	0.59-4.65
10	134	59.2	5.2	44.9-70.3	2.20	0.68	0.93-5.06
11	72	61.1	6.2	42.0-71.3	2.32	0.68	0.55-3.83
12	36	63.2	4.6	51.5-71.5	2.55	0.61	1.19-3.88
13	27	62.8	5.6	52.1-70.6	2.60	0.76	1.30-4.01
14	12	66.3	4.9	55.5-74.6	3.10	0.75	1.58-4.04
15	6	64.9	10.9	43.1-71.8	2.79	1.11	0.68-3.92
16	1	60.5			1.92		
19	1	68.0			2.67		
Summary	1400	54.4	6.6	38.1-74.6	1.77	0.67	0.52-5.06
Mean age	8.6						

*Gutted head-on weight

Table 21. Summary of age, length and weight data for commercially caught Arctic charr from Tikkoatokak Bay, 1977-1980.

Age	N	Fork Length (cm)			Weight (kg)*		
		Mean	S.D.	Range	Mean	S.D.	Range
6	36	42.2	4.0	32.1-49.0	0.75	0.26	0.32-1.29
7	248	46.9	4.1	34.5-62.8	1.07	0.33	0.30-2.35
8	524	50.2	4.5	38.5-64.2	1.31	0.43	0.48-3.03
9	389	53.7	5.1	40.8-73.8	1.59	0.49	0.55-3.20
10	206	56.7	5.3	44.2-67.0	1.84	0.58	0.69-3.20
11	90	57.2	5.6	41.7-70.3	1.88	0.63	0.63-3.77
12	51	59.4	6.1	44.2-71.4	2.06	0.57	0.70-3.58
13	11	62.0	6.1	52.9-73.8	2.19	0.78	1.12-3.90
14	8	59.2	3.5	55.1-64.7	2.08	0.53	1.54-2.82
15	1	61.6			2.08		
16	1	67.4			2.00		
17	1	70.7			3.01		
Summary	1566	52.1	6.3	32.1-73.8	1.47	0.57	0.30-3.90
Mean age	8.7						

*Gutted head-on weight

Table 22. Summary of age, length and weight data for commercially caught Arctic charr from Okak Bay, 1977-1980.

Age	N	Fork Length (cm)			Weight (kg)*		
		Mean	S.D.	Range	Mean	S.D.	Range
6	5	44.0	4.8	38.8-50.5	0.95	0.33	0.62-1.42
7	76	46.8	3.9	29.8-54.6	1.15	0.28	0.21-1.72
8	286	49.7	3.7	40.4-59.5	1.34	0.31	0.50-2.39
9	265	51.6	4.6	39.5-66.0	1.47	0.40	0.66-2.88
10	221	52.9	5.5	34.0-68.6	1.59	0.51	0.29-3.25
11	126	54.1	5.6	32.0-69.9	1.66	0.54	0.26-3.65
12	104	56.8	6.4	38.2-74.6	1.87	0.56	0.34-3.75
13	62	56.9	4.8	45.5-70.8	1.90	0.50	0.66-3.42
14	33	56.7	5.7	45.2-69.0	1.88	0.51	1.04-2.96
15	36	56.8	7.0	40.0-69.5	1.94	0.73	0.83-3.72
16	15	56.5	6.2	49.4-71.0	1.83	0.79	0.91-3.12
17	9	56.3	6.0	44.3-64.4	1.47	0.82	0.53-3.00
18	3	57.7	10.4	47.6-68.4	1.71	1.16	0.65-2.95
19	3	58.8	13.2	44.7-70.8	2.20	1.82	0.47-4.10
20	2	60.3	0.0	60.3-60.3	1.80		1.80-1.80
Summary	1246	52.5	5.8	29.8-74.6	1.55	0.51	0.21-4.10
Mean age	10.0						

*Gutted head-on weight

Table 23. Summary of age, length and weight data for commercially caught Arctic charr from Hebron Fiord, 1977 and 1980.

		Fork Length (cm)			Weight (kg)*		
Age	N	Mean	S.D.	Range	Mean	S.D.	Range
7	9	45.0	4.1	38.9-50.5	1.05	0.31	0.56-1.50
8	47	49.3	3.5	39.7-56.1	1.36	0.29	0.66-1.92
9	99	51.5	4.5	38.9-64.5	1.51	0.39	0.66-2.76
10	75	54.1	5.0	41.1-67.6	1.71	0.49	0.76-3.26
11	50	54.5	3.9	46.3-69.2	1.71	0.45	1.02-3.25
12	64	57.3	5.9	47.3-71.1	1.91	0.62	1.02-3.63
13	38	59.4	5.5	46.2-67.7	2.07	0.55	0.94-3.27
14	28	60.7	6.2	50.6-73.0	2.20	0.76	1.10-4.42
15	26	59.4	5.6	49.4-68.6	2.10	0.55	1.08-3.07
16	11	59.2	3.8	53.5-65.1	1.95	0.30	1.52-2.42
17	10	59.6	3.8	54.4-67.2	1.90	0.43	1.36-2.66
18	3	60.6	8.3	51.5-66.6	2.05	0.80	1.16-2.70
19	3	60.4	9.0	51.0-69.0	1.95	0.71	1.28-2.70
20	2	55.3	6.2	50.9-59.6	1.40	0.40	1.11-1.68
21	2	56.9	1.3	56.0-57.8	1.57	0.02	1.55-1.58
22	1	58.5			1.58		
Summary	468	54.8	6.2	38.9-73.0	1.74	0.56	0.56-4.42
Mean age	11.2						

*Gutted head-on weight

Table 24. Estimated numbers at age for Arctic charr caught in Voisey Bay, 1977-1980 (A) with catch per unit effort by age (B) and Paloheimo total mortality rates (C).

	A				B					C		
Age	1977	1978	1979	1980	1977	1978	1979	1980	Age	1977	1978	1979
5	0	42	0	0		0.5						
6	290	506	242	74	5.2	5.6	4.1	1.4				
7	1902	3876	2506	374	34.0	42.6	42.5	7.2				
8	3675	4761	4042	1880	65.6	52.3	68.5	36.3				
9	1902	2065	1724	2294	34.0	22.7	29.2	44.1	9	1.04	0.81	0.70
10	1128	1096	593	753	20.1	12.0	10.1	14.5	10	0.59	0.78	0.59
11	548	1011	323	292	9.8	11.1	5.5	5.6	11	0.97	1.82	0.68
12	354	337	108	146	6.3	3.7	1.8	2.8	12	0.53	0.97	0.00
13	193	337	81	93	3.4	3.7	1.4	1.8				
14	97	169	27	18	1.7	1.9	0.5	0.3				
15		84		14		0.9		0.3				
16		42				0.5						
17												
18												
19				4				0.1				
Total	10089	14326	9646	5942					Average $\bar{Z}$ 9-13	0.78	1.10	0.49
Effort	56	91	59	52					Average $\bar{Z}$ 1977-79		0.79	

Table 25. Estimated numbers at age for Arctic charr caught in Tikkoatokak Bay, 1977-1980 (A) with catch per unit effort by age (B) and Paloheimo total mortality rates (C).

	A				B					C		
Age	1977	1978	1979	1980	1977	1978	1979	1980	Age	1977	1978	1979
6	1365	209	257	0	16.1	1.4	2.3	0				
7	6197	3973	2508	489	72.9	27.4	22.8	4.2				
8	6670	10037	7395	7260	78.5	69.2	67.2	62.6				
9	3887	6273	5402	9143	45.7	43.3	49.1	78.8	9	0.62	0.93	0.20
10	1996	3555	1865	4663	23.5	24.5	17.0	40.2	10	0.55	1.25	0.07
11	735	1951	772	1837	8.6	13.5	7.0	15.8	11	-0.11	0.66	0.85
12	368	1394	772	349	4.3	9.6	7.0	3.0	12	1.12	2.08	1.16
13	105	209	129	253	1.2	1.4	1.2	2.2				
14	53	209	129	84	0.6	1.4	1.2	0.7				
15		70				0.5						
16		70				0.5						
17				11				0.1				
Total	21376	27950	19229	24089					Average $\bar{Z}$ 9-13	0.55	1.23	0.57
Effort	85	145	110	116					Average $\bar{Z}$ 1977-79		0.78	

Table 26. Estimated numbers at age for Arctic charr caught in Okak Bay, 1977-1980 (A) with catch per unit effort by age (B) and Paloheimo total mortality rates (C).

	A				B					C		
Age	1977	1978	1979	1980	1977	1978	1979	1980	Age	1977	1978	1979
6	84	102	0	26	0.8	1.0		0.4				
7	84	1228	1227	353	0.8	11.8	10.1	6.0				
8	251	4040	4546	2126	2.3	38.8	37.6	36.0				
9	752	2762	3067	3305	6.8	26.6	25.3	56.0				
10	1839	2813	2020	2517	16.7	27.0	16.7	42.7	10	-0.09	1.01	0.13
11	2173	1892	1191	867	19.8	18.2	9.8	14.7	11	0.06	1.40	0.40
12	3595	1944	541	391	32.7	18.7	4.5	6.6	12	0.90	1.57	0.72
13	1505	1381	469	129	13.7	13.3	3.9	2.2	13	1.70	1.59	0.37
14	1087	256	325	162	9.9	2.5	2.7	2.7	14	0.70	0.17	-0.32
15	920	511	253	219	8.4	4.9	2.1	3.7				
16	501	153	216	0	4.6	1.5	1.8					
17	84	205	144	0	0.8	2.0	1.2					
18	84	51	72	0	0.8	0.5	0.6					
19	84	51	36		0.8	0.5	0.3					
20			36				0.3					
Total	13043	17389	14143	10095				Average $\bar{Z}$ 10-14		0.65	1.15	0.26
Effort	110	104	121	59				Average $\bar{Z}$ 1977-79			0.69	

Some variation has also occurred in the size distribution of landings. The percentage of charr greater than 60 cm (fork length) in Voisey Bay declined from 20% in 1977 to 11% in 1980 (Fig. 13). Over the combined four year period these larger charr represented 17% of the catch. Similar changes were noted in Okak Bay landings where the proportion has changed from 27% in 1977, to 10% in 1978 and finally to 3% in 1980 (Fig. 15). The combined four year contribution was 11%. Landings from Tikkoatokak Bay were characterized by having 39% of the catch represented by 40-50 cm charr (Fig. 14) in contrast to 26%, 29% and 21% for Voisey Bay, Okak Bay and Hebron Fiord (Fig. 16) landings. However, mean length of catches in Voisey Bay and Tikkoatokak Bay has remained relatively constant during the past three years.

Additional information regarding the size composition of landings was available from commercial landings data for individual areas since 1976 and for the total Nain fishery since 1974. Arctic charr were graded in the fish plant according to those over or under 2.3 kg (gutted head-on weight). Figure 17 summarizes the landings by week and illustrates the change in size composition throughout the duration of the summer fishery from 1976-1980 for all areas combined. Table 18 summarizes changes in size proportions for individual areas. Of the major charr fishing areas, substantial decreases in fish size have occurred in Voisey Bay, Anaktalik Bay, Tikkoatokak Bay, Okak Bay and the Cutthroat area (Table 18). During 1976 and 1977 approximately 27% of the total landings from these areas were composed of charr over 2.3 kg (gutted head-on weight). In 1980 this figure had decreased to 11%.

Figure 13. Frequency distribution of Arctic charr landings from the Voisey Bay commercial fishery, 1977-1980. Number (N) refers to number sampled for length.

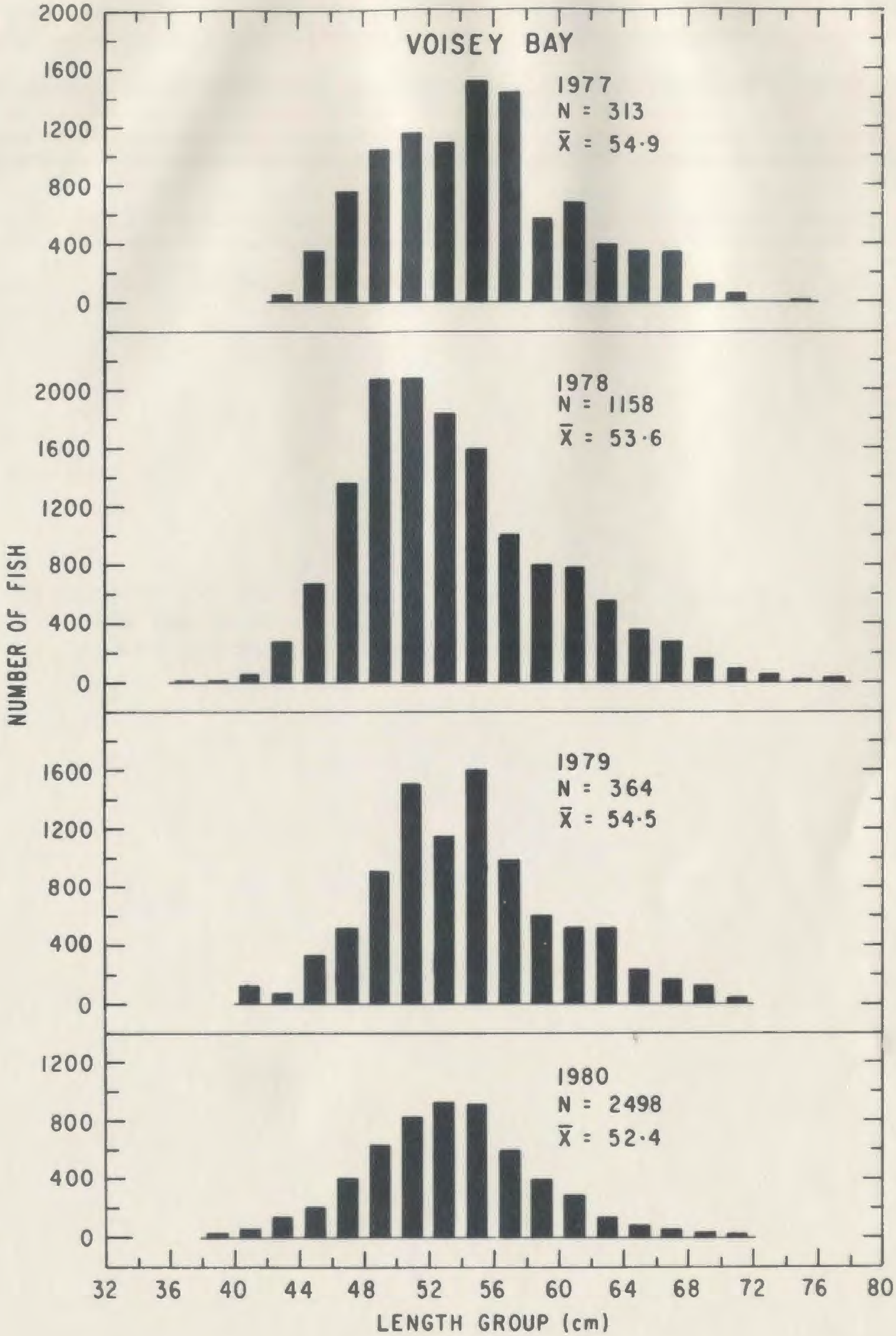

VOISEY BAY
1977
N = 313
X̄ = 54·9
1978
N = 1158
X̄ = 53·6
1979
N = 364
X̄ = 54·5
1980
N = 2498
X̄ = 52·4
NUMBER OF FISH
LENGTH GROUP (cm)
0
400
800
1200
1600
2000
32
36
40
44
48
52
56
60
64
68
72
76
80

Figure 14. Length-frequency distribution of Arctic charr landings from the Tikkoatokak Bay commercial fishery, 1977-1980. Number (N) refers to number sampled for length.

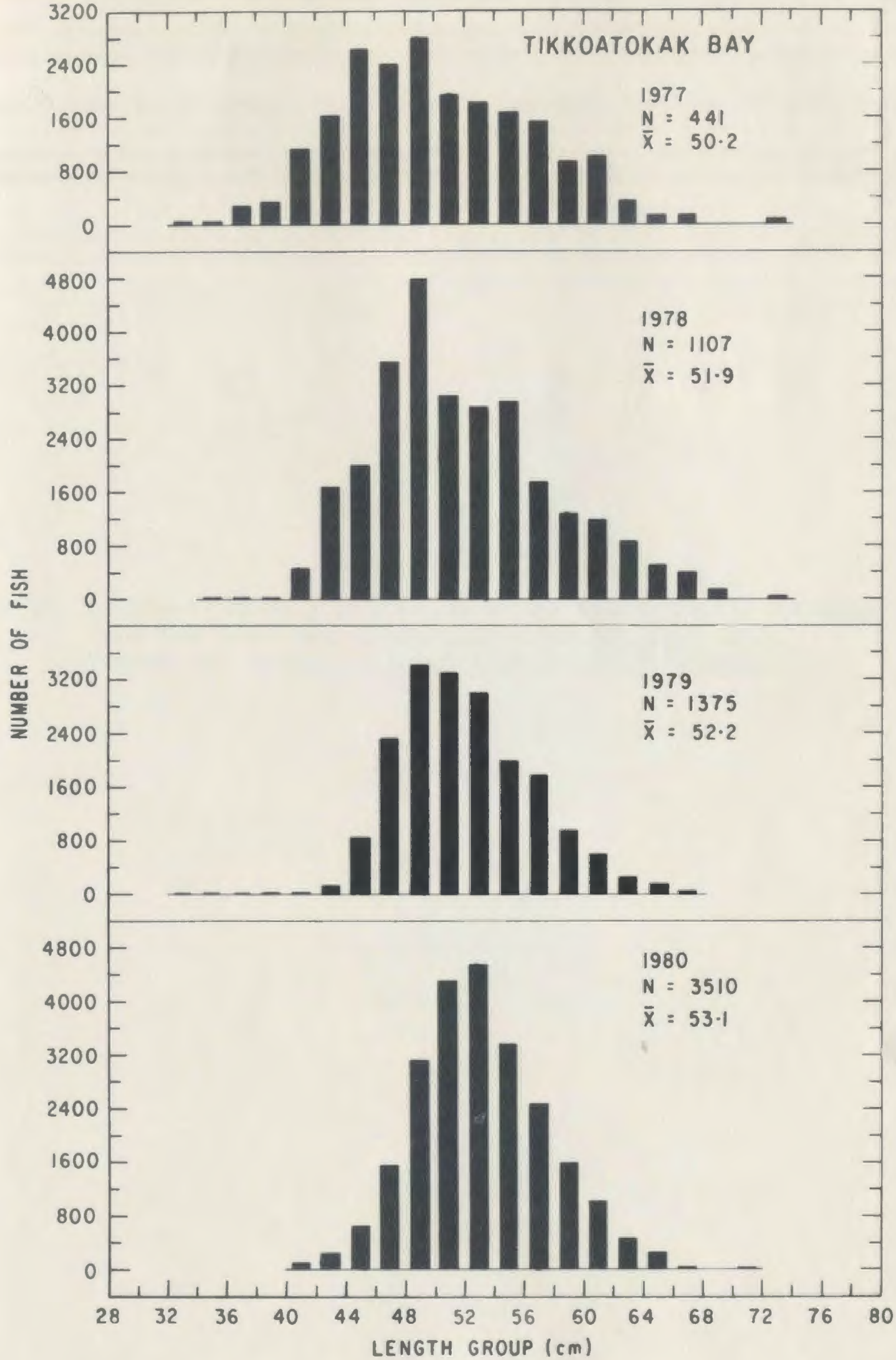

TIKKOATOKAK BAY
1977
N = 441
X̄ = 50·2
1978
N = 1107
X̄ = 51·9
1979
N = 1375
X̄ = 52·2
1980
N = 3510
X̄ = 53·1
NUMBER OF FISH
LENGTH GROUP (cm)
0
800
1600
2400
3200
4000
4800
28
32
36
40
44
48
52
56
60
64
68
72
76
80

Figure 15. Length-frequency distribution of Arctic charr landings from the Okak Bay commercial fishery, 1977-1980. Number (N) refers to number sampled for length.

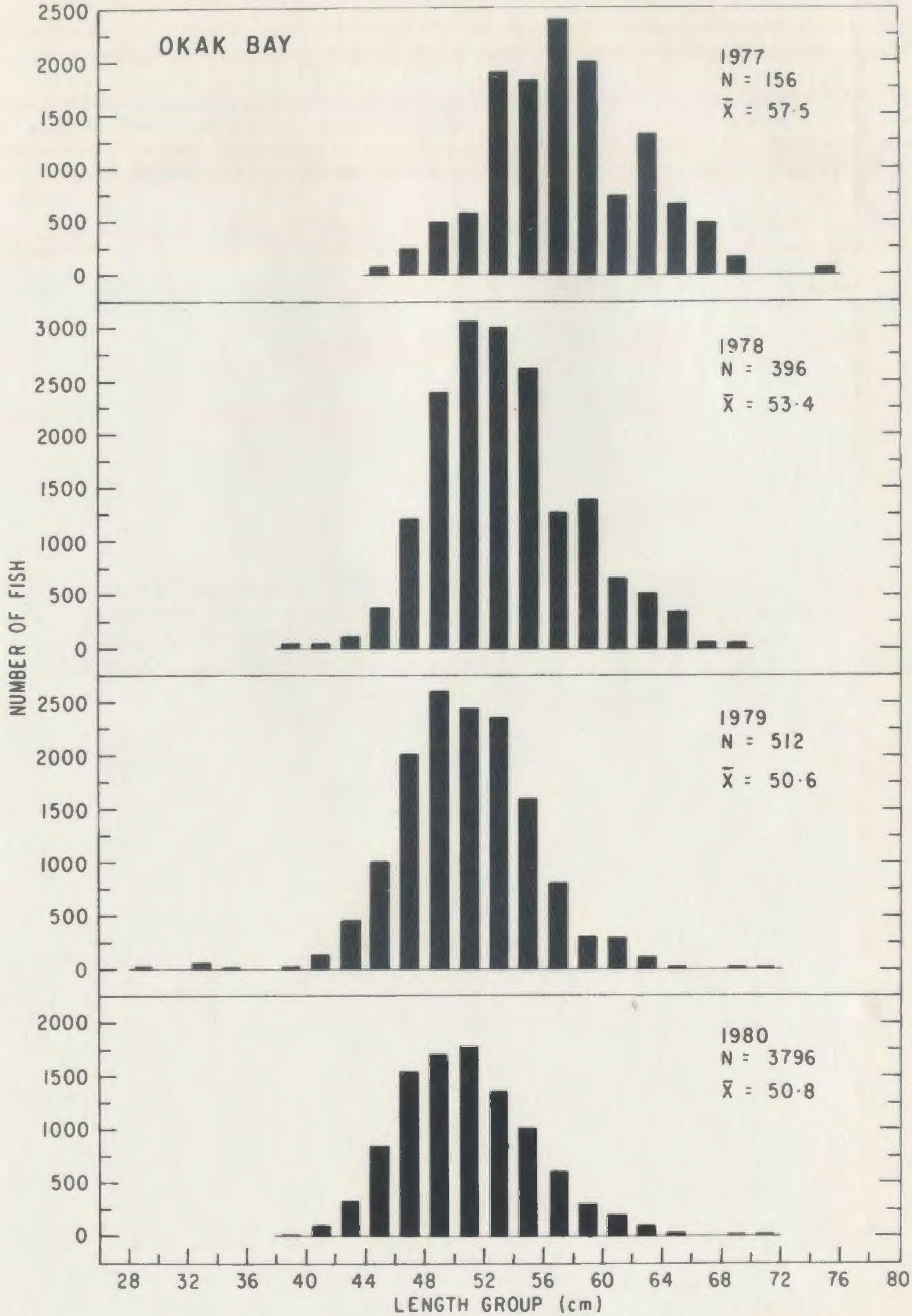

OKAK BAY
1977
N = 156
X̄ = 57·5
1978
N = 396
X̄ = 53·4
1979
N = 512
X̄ = 50·6
1980
N = 3796
X̄ = 50·8
NUMBER OF FISH
LENGTH GROUP (cm)
2500
2000
1500
1000
500
0
3000
28
32
36
40
44
48
52
56
60
64
68
72
76
80

Figure 16. Length-frequency distribution of Arctic charr landings from the 1977 commercial fishery and 1980 experimental fishery in Hebron Fiord. Number (N) refers to number sampled for length.

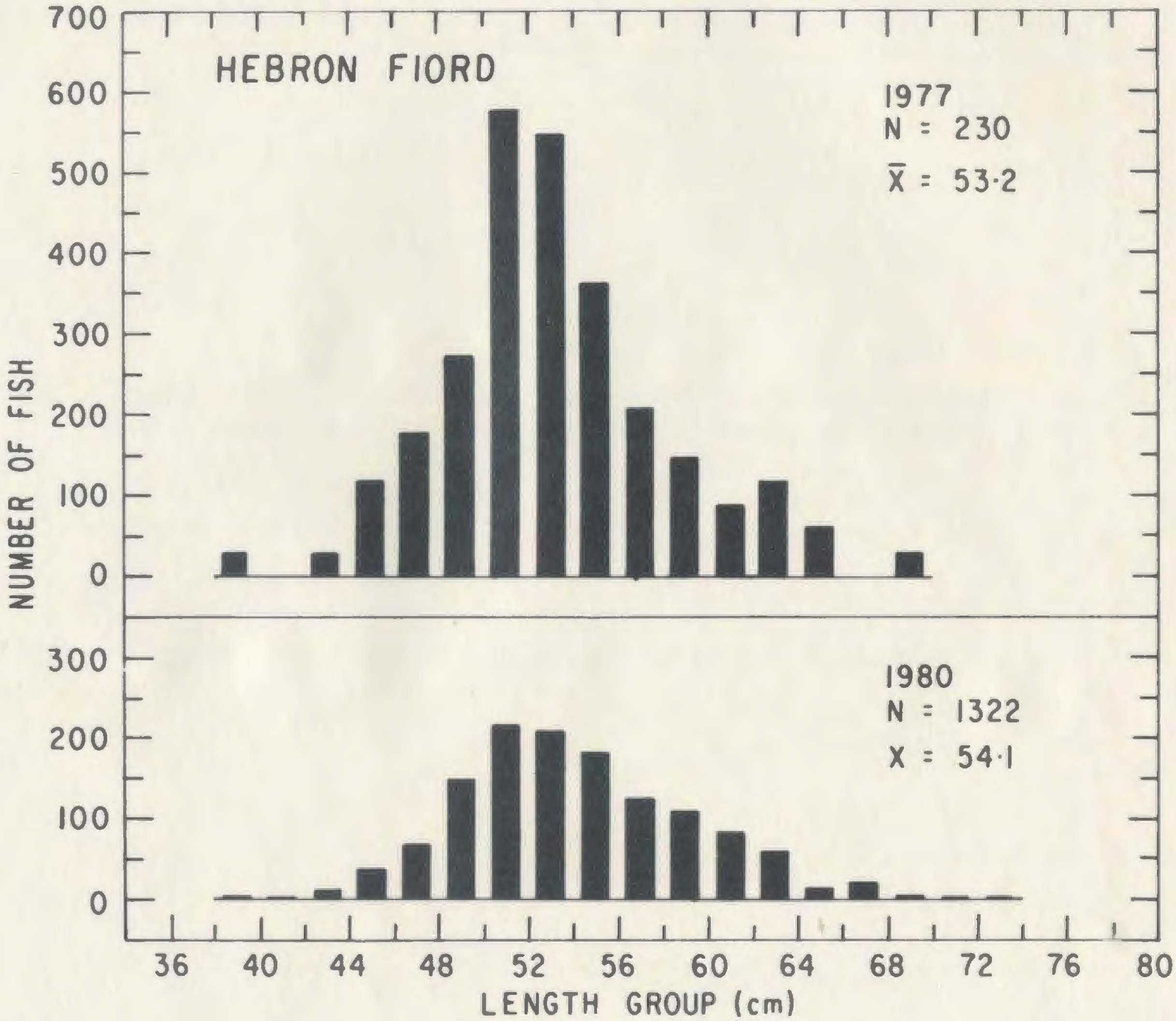
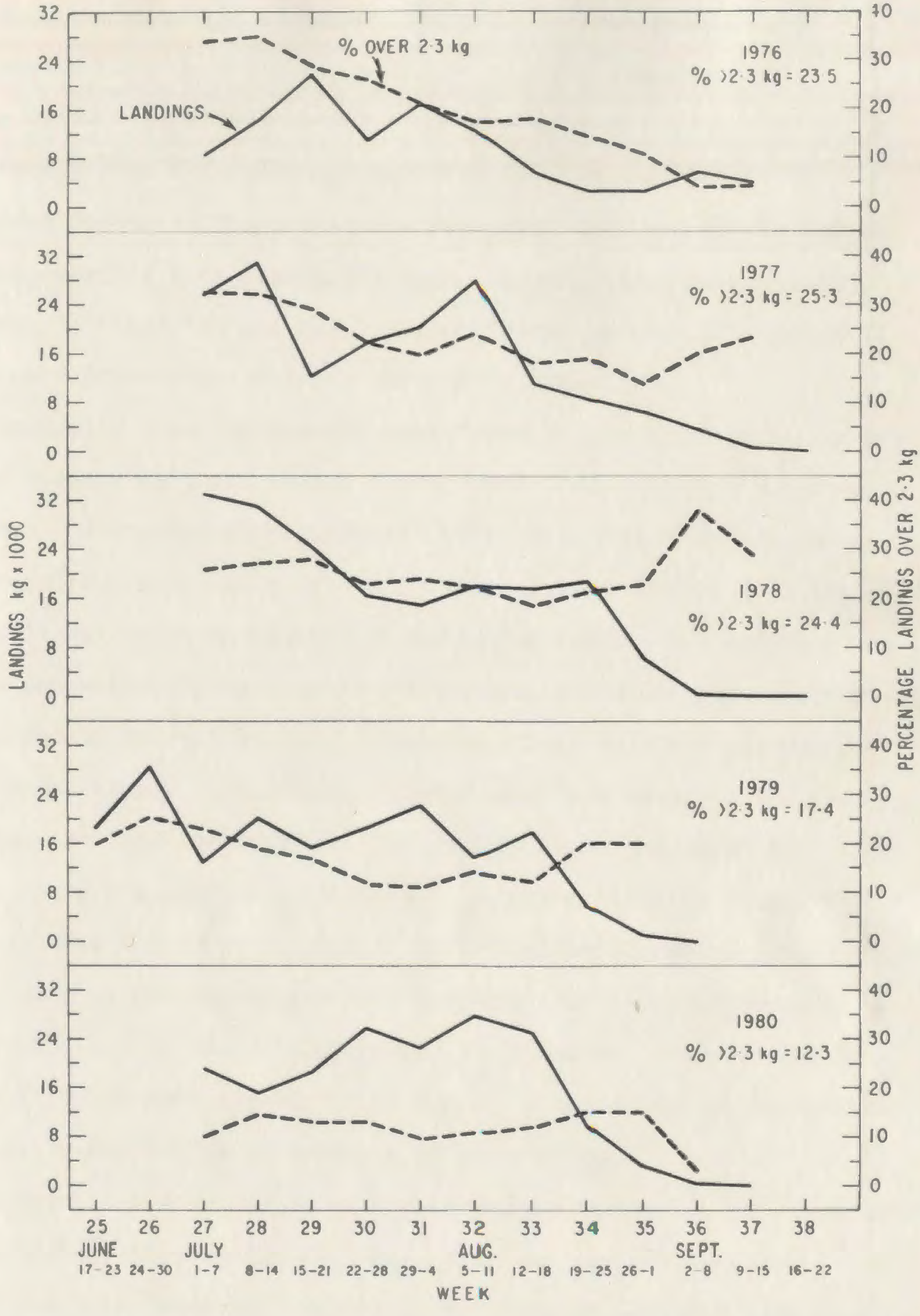

HEBRON FIORD
1977
N = 230
$\bar{X}$ = 53·2
1980
N = 1322
X = 54·1
NUMBER OF FISH
700
600
500
400
300
200
100
0
300
200
100
0
36
40
44
48
52
56
60
64
68
72
76
80
LENGTH GROUP (cm)

Figure 17. Summary of northern Labrador Arctic charr landings and change in size composition by week, 1976-1980.


% OVER 2·3 kg
LANDINGS
1976
% >2·3 kg = 23·5
1977
% >2·3 kg = 25·3
1978
% >2·3 kg = 24·4
1979
% >2·3 kg = 17·4
1980
% >2·3 kg = 12·3
LANDINGS kg x 1000
PERCENTAGE LANDINGS OVER 2·3 kg
25 26 27 28 29 30 31 32 33 34 35 36 37 38
JUNE
JULY
AUG.
SEPT.
17-23 24-30 1-7 8-14 15-21 22-28 29-4 5-11 12-18 19-25 26-1 2-8 9-15 16-22
WEEK

4.3.3. Age and growth comparison

Size and age data of commercial catches from Voisey Bay, Tikkoàtokak Bay, Okak Bay and Hebron Fiord are summarized in Tables 20-23. Appendices 2 and 3 contain commercial age and growth information from Anaktalik and Napartok bays respectively. Since charr are landed in the gutted head-on condition, separation by sex was not possible from commercial data. Growth comparisons by sex, however, were carried out from research sampling data to examine if there were differences between sexes from other areas.

Generally, few differences were found in comparisons of length at age between male and female Arctic charr from the various areas examined. A similar situation was observed in Fraser River charr (Section 4.2.1.2.). As a result, it was assumed that growth comparisons between areas based on commercial data were valid. Research data on length and weight by age for separate sexes are presented in Tables 27, 28, 29 and 30 for Voisey Bay, Tikkoatokak Bay, Okak Bay and Hebron Fiord respectively. Additional comparisons from research samples are also provided for Napartok Bay, Saglek Fiord and Ramah Bay Arctic charr (Appendices 4, 5 and 6). A characteristic common to all areas was the large overlap in distribution of age at length as illustrated in the age-length keys prepared for all research data (Tables 31, 32, 33 and 34; Appendices 7, 8 and 9). Differences in age at first seaward migration and degree of maturity are undoubtedly responsible for the large variaton in size at age.

Significant differences were observed in length at age comparisons between Voisey Bay, Tikkoatokak Bay, Okak Bay and Hebron Fiord Arctic charr for most ages tested by analysis of variance (Table 35).

Table 27. Comparison of mean length at age between male and female Arctic charr, with age-weight relationship and sex ratio from Voisey Bay, 1978. Significance levels are P<0.05 (*) and P<0.01 (**).

	Fork Length (cm)								Round Weight (kg)						
	Male			Female					Male			Female			
Age	N	Mean	S.D.	N	Mean	S.D.	Range	t	N	Mean	S.D.	N	Mean	S.D.	Range
6	2	42.5	8.8	1	47.8		36.3-48.7		2	1.18	0.79	1	1.55		0.62-1.74
7	22	51.2	4.8	27	47.4	2.6	43.2-62.0	3.38**	22	2.14	0.79	27	1.63	0.24	1.12-4.23
8	22	53.7	3.8	28	50.1	3.0	44.1-61.4	3.85**	22	2.41	0.62	28	1.86	0.29	1.34-3.87
9	6	52.8	5.7	8	52.8	2.6	45.0-62.3	0.01	6	2.32	0.75	8	2.19	0.45	1.48-3.65
10	4	49.8	9.0	3	52.3	6.8	37.6-60.1	0.41	4	1.96	1.03	3	2.39	1.06	0.67-3.60
Total	56	52.0	5.3	67	49.4	3.5	36.3-62.3	3.13**	56	2.22	0.75	67	1.83	0.40	0.62-4.23
Mean age		7.8			7.8										
% Male		45.5													
X^2		0.98													

Table 28. Comparison of mean length at age between male and female Arctic charr, with age-weight relationship and sex ratio from Tikkoatokak Bay, 1978. Significance levels are $P<0.05$ (*) and $P<0.01$ (**).

	Fork Length (cm)								Round Weight (kg)						
	Male			Female					Male			Female			
Age	N	Mean	S.D.	N	Mean	S.D.	Range	t	N	Mean	S.D.	N	Mean	S.D.	Range
6	1	44.2		2	44.2	0.1	44.1-44.3		1	1.09		2	1.23	0.11	1.09-1.30
7	7	48.2	5.8	8	44.6	4.1	39.4-59.8	1.37	7	1.59	0.80	8	1.25	0.39	0.80-3.33
8	23	51.1	4.6	23	48.0	3.5	40.7-61.3	2.64*	23	1.87	0.63	23	1.52	0.38	0.76-3.49
9	11	53.8	4.3	13	51.9	4.1	45.3-60.2	1.11	11	2.08	0.53	13	1.73	0.35	1.26-3.24
10	6	56.7	5.9	8	52.2	5.3	44.8-63.1	1.46	6	2.59	1.06	8	1.89	0.57	1.16-3.84
11	3	56.8	8.3	6	56.4	3.0	50.4-66.2	0.09	3	2.62	1.83	6	2.44	0.58	1.54-4.73
12				5	59.2	4.5	54.5-66.1					5	2.78	0.75	2.13-4.06
13	1	64.4		2	62.3	0.1	62.2-64.4		1	3.36		2	3.32	0.31	3.10-3.54
14															
15				3	62.3	8.2	54.8-71.0					3	3.40	1.34	2.30-4.89
Total	52	52.4	5.8	70	51.2	6.4	39.4-71.0	1.27	52	2.01	0.83	70	1.86	0.76	0.76-4.89
Mean age		8.5			9.2										
% Male		42.6													
X^2		2.66													

Table 29. Comparison of mean length at age between male and female Arctic charr, with age-weight relationship and sex ratio from Okak Bay, 1978-1980. Significance levels are P<0.05 (*) and P<0.01 (**).

	Fork Length (cm)								Round Weight (kg)						
	Male			Female					Male			Female			
Age	N	Mean	S.D.	N	Mean	S.D.	Range	t	N	Mean	S.D.	N	Mean	S.D.	Range
6	4	44.2	1.8	5	40.0	6.1	32.9-48.9	1.74	4	1.28	0.27	5	1.00	0.42	0.52-1.56
7	28	44.0	3.5	21	43.3	4.5	33.1-49.7	0.69	28	1.21	0.30	21	1.20	0.33	0.47-1.90
8	31	46.4	4.5	29	45.3	3.5	38.0-58.3	1.03	31	1.51	0.49	29	1.40	0.32	0.59-3.00
9	28	47.4	3.8	36	46.2	3.3	37.7-59.5	1.32	28	1.52	0.37	36	1.46	0.33	0.72-2.50
10	19	49.0	5.5	25	48.0	4.2	39.3-60.7	0.68	19	1.59	0.48	25	1.54	0.37	0.79-2.40
11	3	51.1	1.0	13	49.3	3.1	44.3-53.8	1.02	3	1.80	0.30	13	1.69	0.34	1.23-2.23
12	9	48.4	5.2	17	48.6	5.1	38.2-60.8	0.10	9	1.50	0.48	17	1.59	0.46	0.63-2.50
13	5	47.0	2.8	6	52.9	1.7	44.4-55.1	4.24**	5	1.29	0.16	6	1.98	0.31	1.12-2.32
14	1	42.5		5	54.8	3.1	51.8-59.3		1	1.90		5	2.00	0.54	1.40-2.69
15				2	55.3	6.9	50.4-60.2					2	2.11	0.76	1.57-2.65
16				4	52.2	5.0	47.4-57.5					4	2.05	0.68	1.34-2.75
17	1	50.8		1	49.6		49.6-50.8		1	1.55		1	1.43		1.43-1.54
18	1	48.1		1	55.1		48.1-55.1		1	1.25		1	2.17		1.25-2.17
Total	130	46.8	4.5	165	47.0	4.9	32.9-60.8	0.53	130	1.48	0.43	165	1.51	0.43	0.47-3.00
Mean age		9.0			9.7										
% Male		44.1													
X^2		4.15*													

Table 30. Comparison of mean length at age between male and female Arctic charr, with age-weight relationship and sex ratio from Hebron Fiord, 1978-1980. Significance levels are $P<0.05$ (*) and $P<0.01$ (**).

	Fork Length (cm)								Round Weight (kg)						
	Male			Female					Male			Female			
Age	N	Mean	S.D.	N	Mean	S.D.	Range	t	N	Mean	S.D.	N	Mean	S.D.	Range
4	6	24.1	1.7	3	24.2	0.4	21.7-26.4	0.05	6	0.16	0.04	3	0.14	0.01	0.10-0.20
5	6	28.2	4.0	9	28.7	3.6	22.1-33.0	0.28	6	0.27	0.11	9	0.26	0.10	0.10-0.40
6	23	31.9	4.1	36	33.0	5.0	23.5-48.3	0.83	23	0.36	0.20	36	0.43	0.18	0.10-1.06
7	47	39.5	5.4	47	39.2	5.3	25.6-49.8	0.28	47	0.78	0.33	47	0.76	0.34	0.20-1.53
8	48	43.7	4.8	30	44.3	3.3	32.1-52.5	0.65	48	1.11	0.44	30	1.14	0.32	0.40-2.21
9	22	49.5	7.9	26	46.6	3.7	37.0-65.0	1.62	22	1.76	0.90	26	1.31	0.32	0.50-3.50
10	20	52.7	8.5	20	47.2	5.2	31.4-65.5	2.48*	20	2.02	1.06	20	1.42	0.50	0.50-4.10
11	22	56.3	7.1	16	49.1	3.3	34.1-69.0	4.15**	22	2.49	0.93	16	1.47	0.39	0.40-4.20
12	16	55.6	9.6	16	51.9	5.4	36.8-68.5	1.35	16	2.33	1.05	16	1.86	0.62	0.50-3.50
13	4	50.9	13.6	15	53.8	5.9	36.5-69.4	0.42	4	1.83	1.32	15	2.17	0.85	0.60-3.90
14	8	59.0	11.4	5	56.9	4.2	42.6-75.5	0.39	8	2.55	1.38	5	2.58	0.67	0.70-5.00
15	3	62.5	9.7	6	51.9	2.3	48.9-70.3	1.87	3	3.02	1.29	6	1.69	0.29	1.30-4.00
16	2	55.4	14.0	3	56.3	9.6	45.5-66.7	0.09	2	2.65	2.19	3	2.35	1.24	1.10-4.20
17	5	50.4	10.4	3	51.1	2.4	39.5-67.6	0.11	5	1.47	0.80	3	1.59	0.34	0.67-2.80
18	1	56.5		3	54.6	2.8	53.0-57.9		1	1.70		3	1.91	0.34	1.64-2.29
19	1	54.2		4	60.1	10.1	52.0-74.8		1	1.80		4	2.81	1.47	1.80-5.00
20				2	55.3	8.1	49.5-61.0					2	2.25	1.06	1.50-3.00
21	1	56.8		1	50.4		50.4-56.8		1	2.30		1	1.80		1.80-2.30
Total	235	45.4	11.3	245	43.9	9.2	21.7-75.5	1.62	235	1.39	1.04	245	1.20	0.77	0.10-5.00
Mean age		9.0			9.3										
% Male		49.0													
X^2		0.21													

Table 31. Distribution of age at length with mean length, weight and condition factor for Arctic charr research samples (sexes combined) from Voisey Bay, Labrador, 1978.

Length interval (cm)	6	7	8	9	10	Total
36.0-37.9	1				1	2
38.0-39.9						
40.0-41.9						
42.0-43.9		2				2
44.0-45.9		11	1	1		13
46.0-47.9	1	8	8			17
48.0-49.9	1	10	10	1	3	25
50.0-51.9		9	8	4		21
52.0-53.9		4	11	3	1	19
54.0-55.9		1	4	3		8
56.0-57.9		2	6	1		9
58.0-59.9					1	1
60.0-61.9		1	2		1	4
62.0-63.9		1		1		2
Total	3	49	50	14	7	123
Mean length (cm)	44.3	49.1	51.7	52.8	50.8	50.5
S.D.	6.9	4.2	3.8	4.0	7.6	4.6
Round weight (kg)						
Mean	1.30	1.86	2.10	2.25	2.14	2.00
S.D.	0.60	0.61	0.53	0.57	0.98	0.62
Condition Factor	1.41	1.53	1.50	1.50	1.51	1.51

Table 32. Distribution of age at length with mean length, weight and condition factor for Arctic charr research samples (sexes combined) from Tikkoatokak Bay, Labrador, 1978.

Length interval (cm)	6	7	8	9	10	11	12	13	14	15	Total
38.0-39.9		1									1
40.0-41.9		1	1								2
42.0-43.9		4	3								7
44.0-45.9	3	1	5	2	1						12
46.0-47.9		4	11	1	3						19
48.0-49.9		2	6	4							12
50.0-51.9			7	2	1	1					11
52.0-53.9		1	6	6		3					16
54.0-55.9			4	4	3	1	1			1	14
56.0-57.9			2	1	2	1	2				8
58.0-59.9		1		2	2	1					6
60.0-61.9			1	2	1	1	1			1	7
62.0-63.9					1			2			3
64.0-65.9								1			1
66.0-67.9							1	1			2
68.0-69.9											
70.0-71.9										1	1
Total	3	15	46	24	14	9	5	3		3	122
Mean length (cm)	44.2	46.3	49.5	52.8	54.2	56.5	59.2	63.0		62.3	51.7
S.D.	0.1	5.1	4.3	4.3	5.8	4.8	4.5	1.2		8.2	6.2
Round weight (kg)											
Mean	1.18	1.41	1.69	1.89	2.19	2.50	2.78	3.33		3.40	1.93
S.D.	0.11	0.62	0.54	0.47	0.86	1.03	0.75	0.22		1.34	0.79
Condition Factor	1.37	1.35	1.35	1.27	1.32	1.32	1.32	1.33		1.36	1.33

Table 33. Distribution of age at length with mean length, weight and condition factor for Arctic charr research samples (sexes combined) from Okak Bay, Labrador, 1978-1980.

Length interval (cm)	Age 6	7	8	9	10	11	12	13	14	15	16	17	18	Total
30.0-31.9														
32.0-33.9	1	2												3
34.0-35.9		2												2
36.0-37.9	1			1										2
38.0-39.9		3	4		1		1							9
40.0-41.9	2	4	4	2	2		1							15
42.0-43.9	2	8	12	10	4		2							38
44.0-45.9	1	15	12	13	8	2	4	2						57
46.0-47.9	1	10	10	18	8	3	4	2			1			57
48.0-49.9	1	5	10	10	5	2	6				1	1	1	42
50.0-51.9			4	6	4	5	1	3	1	1		1		26
52.0-53.9			1	2	6	4	3	2	3					21
54.0-55.9			2	1	4		2	2			1		1	13
56.0-57.9							1		1		1			3
58.0-59.9			1	1	1				1					4
60.0-61.9					1		1			1				3
62.0-63.9														
N	9	49	60	64	44	16	26	11	6	2	4	2	2	295
Mean length (cm)	41.9	43.7	45.9	46.8	48.4	49.6	48.5	50.2	54.6	55.3	52.2	50.2	51.6	47.0
S.D.	5.0	4.0	4.0	3.5	4.7	2.9	5.0	3.7	2.8	6.9	5.0	0.8	4.9	4.8
Rouhd weight (kg)														
Mean	1.11	1.21	1.46	1.49	1.56	1.71	1.56	1.67	1.98	2.12	2.05	1.49	1.71	1.48
S.D.	0.37	0.31	0.41	0.35	0.42	0.32	0.46	0.43	0.49	0.76	0.68	0.08	0.65	0.43
Condition Factor	1.46	1.42	1.48	1.44	1.35	1.39	1.34	1.29	1.20	1.22	1.39	1.18	1.20	1.40

Table 34. Distribution of age at length with mean length, weight and condition factor for Arctic charr research samples (sexes combined) from Hebron Fiord, Labrador, 1978-1980.

Length interval (cm)	Age 4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	Total
20.0-21.9	1																		1
22.0-23.9	3	2	2																7
24.0-25.9	4	3	3	1															11
26.0-27.9	1	1	5																7
28.0-29.9		2	6	5															13
30.0-31.9		5	11	6			1												23
32.0-33.9		2	9	6	1														18
34.0-35.9			12	4	2			1											19
36.0-37.9			4	11	2	1	1		2	1									22
38.0-39.9			4	11	10	2			1					1					29
40.0-41.9				19	12	2	2			1									36
42.0-43.9			2	10	8	7	3				1								31
44.0-45.9				12	15	9	5	3	2	1			1						48
46.0-47.9				6	15	6	5	3	2	1	1		1	2					42
48.0-49.9			1	3	9	7	2	7	2	2		2		1			1		37
50.0-51.9					2	6	5	3	2	1	2	1		1				1	24
52.0-53.9					2	1	7	3	5	3		3		2	2	1			29
54.0-55.9						1	1	2	3	1	1	1	1			1			12
56.0-57.9						2	2	4	3	4	1				2	2		1	21
58.0-59.9						2	1	7	2	1	2								15
60.0-61.9							2	1	3	1	1						1		9
62.0-63.9							1	2	3	1	2								9
64.0-65.9						2	2	1	1			1	1						8
66.0-67.9													1	1					2
68.0-69.9								1	1	1									3
70.0-71.9											1	1							2
72.0-73.9																			
74.0-75.9											1					1			2
Total	9	15	59	94	78	48	40	38	32	19	13	9	5	8	4	5	2	2	480
Mean length (cm)	24.1	28.5	32.6	39.3	43.9	47.9	49.9	53.3	53.7	53.2	58.2	55.3	55.9	50.7	55.1	58.9	55.2	53.6	44.6
S.D.	1.4	3.7	4.7	5.3	4.2	6.1	7.5	6.8	7.9	7.8	13	7.4	9.8	8.0	2.5	9.1	8.1	4.5	10.3
Round weight (kg)																			
Mean	0.16	0.27	0.41	0.77	1.12	1.52	1.72	2.06	2.10	2.10	2.56	2.14	2.47	1.52	1.86	2.61	2.25	2.05	1.30
S.D.	0.03	0.11	0.19	0.33	0.39	0.68	0.87	0.90	0.88	0.93	1.13	0.95	1.41	0.64	0.30	1.36	1.06	0.35	0.92
Condition Factor	1.12	1.09	1.11	1.19	1.27	1.30	1.29	1.27	1.26	1.30	1.23	1.20	1.28	1.12	1.11	1.21	1.27	1.33	1.09

Table 35. Analysis of variance of length (cm) at age comparisons between commercial samples of Arctic charr from four areas in northern Labrador. Significance levels are P<0.05(*) and P<0.01(**).

Age	Voisey Bay			Tikkoatokak Bay			Okak Bay			Hebron Fiord			df	F*	
	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.			
6	46	45.6	4.8	36	42.2	4.0	5	44.0	4.8				2, 14	5.6	*
7	283	49.7	4.1	248	46.9	4.1	76	46.8	3.9	9	45.0	4.1	3, 64	26.0	**
8	491	52.7	4.8	524	50.2	4.5	286	49.7	3.7	47	49.3	3.5	3, 598	46.4	**
9	290	56.6	5.2	389	53.7	5.1	265	51.6	4.6	99	51.5	4.5	3, 756	57.8	**
10	134	59.2	5.2	206	56.7	5.3	221	52.9	5.5	75	54.1	5.0	3, 494	46.0	**
11	72	61.1	6.2	90	57.2	5.6	126	54.1	5.6	50	54.7	3.9	3, 291	29.3	**
12	36	63.2	4.6	51	59.4	6.1	104	56.8	6.4	64	57.3	5.9	3, 221	12.6	**
13	27	62.8	5.6	11	62.0	6.1	62	56.9	4.8	38	59.4	5.5	3, 56	8.1	**
14	12	66.3	4.9	8	59.2	3.5	33	56.7	5.7	28	60.7	6.2	3, 64	11.1	**
15	6	64.9	10.9	1	61.6		36	56.8	7.0	26	59.4	5.6	2, 10	2.5	NS
16							15	56.5	6.2	11	59.2	3.8	1, 23	1.9	NS
17							9	56.3	6.0	10	59.6	3.8	1, 13	2.1	NS
18							3	57.7	10.4	3	60.6	8.3	1, 4	0.1	NS

Voisey Bay charr had the fastest growth rate (Fig. 18) averaging 63.2 cm at age 12 while Tikkoatokak Bay, Hebron Fiord and Okak Bay charr averaged 59.4, 57.3 and 56.8 cm respectively at age 12. Multiple comparison tests indicated that Voisey Bay Arctic charr were significantly larger than charr from the other three areas between ages 7-12.

Growth of Okak Bay and Hebron Fiord charr parallelled each other for ages 7-12 after which a larger size was achieved by Hebron fish. No significant differences, however, occurred in any length at age comparison between these two areas. Okak Bay charr were significantly smaller than charr from Tikkoatokak Bay at ages 9-11. Similarly, Tikkoatokak and Hebron charr differed only at ages 9-11. In general, Okak Bay charr had the slowest rate of growth.

4.3.4. Weight-length relationship

Weight-length regressions were derived from commercial sampling data (Table 36) and relationships for Voisey Bay, Tikkoatokak Bay, Okak Bay and Hebron Fiord charr were compared by analysis of covariance. Regression coefficients varied from 2.60 for Hebron Fiord charr to 3.07 for Tikkoatokak Bay and Anaktalik Bay Arctic charr. These relationships were derived from gutted head-on samples and thus comparisons were not biased by differential gonadal development or variation in stomach contents.

Analysis of covariance indicated differences in weight-length relationships existed between all areas compared except Okak Bay and

Figure 18. Comparison of mean length at age in four northern Labrador Arctic charr populations.

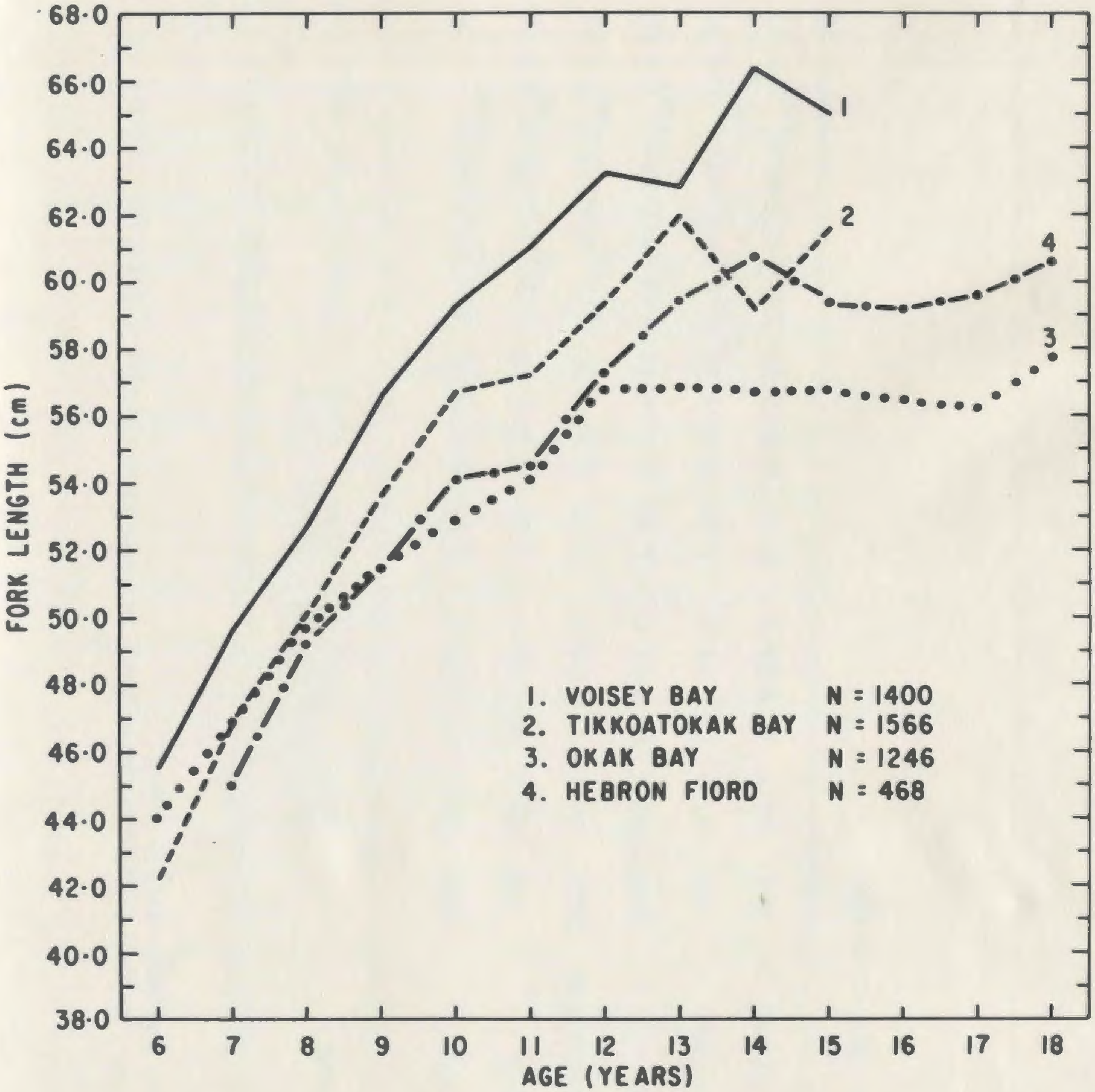

68·0
66·0
64·0
62·0
60·0
58·0
56·0
54·0
52·0
50·0
48·0
46·0
44·0
42·0
40·0
38·0
FORK LENGTH (cm)
6
7
8
9
10
11
12
13
14
15
16
17
18
AGE (YEARS)
1
2
3
4
1. VOISEY BAY N = 1400
2. TIKKOATOKAK BAY N = 1566
3. OKAK BAY N = 1246
4. HEBRON FIORD N = 468

Table 36. Weight-length relationships derived from various commercial samples of northern Labrador Arctic charr.

Area	N	Fork Length (cm)		Weight (kg)*		Weight-length regression	r
		Mean	Range	Mean	Range		
Voisey Bay	1429	54.4	38.1-74.6	1.77	0.52-5.06	$Log_{10}W=3.00Log_{10}L-4.98$	0.94
Anaktalik	751	54.1	40.0-81.5	1.81	0.11-6.90	$Log_{10}W=3.07Log_{10}L-5.08$	0.91
Tikkoatokak Bay	1612	52.1	32.1-73.8	1.47	0.30-3.90	$Log_{10}W=3.07Log_{10}L-5.13$	0.94
Okak Bay	1292	52.4	29.8-74.6	1.54	0.21-4.10	$Log_{10}W=2.78Log_{10}L-4.60$	0.92
Napartok Bay	703	57.0	23.0-75.1	1.80	0.11-4.51	$Log_{10}W=2.74Log_{10}L-4.58$	0.95
Hebron Fiord	474	54.9	38.9-73.0	1.74	0.56-4.42	$Log_{10}W=2.60Log_{10}L-4.29$	0.93

*Gutted head-on weight

Table 37. Comparison of weight-length relationships, derived from commercial data for Arctic charr from Voisey, Tikkoatokak, Okak and Hebron areas using analysis of covariance. Pairwise comparisons analysed by t-test, values below diagonal represent the t-statistic, above diagonal the significance levels: P<0.05 (*), P<0.01 (**).

Analysis of covariance		Mean Squares			
	df	adj. mean	error	F	
Equality of adjusted means	3,4802	0.2049	0.0032	64.0	**
	df	slopes	error	F	
Equality of slopes	3,4799	0.1015	0.0031	32.7	**

Comparison of areas

	Voisey	Tikkoatokak	Okak	Hebron
Voisey		**	**	**
Tikkoatokak	13.3		**	**
Okak	3.5	9.5		NS
Hebron	3.9	5.4	1.3	

Hebron Fiord (Table 37). Within the length interval 35.0-50.0 cm Hebron fish were the heaviest while Voisey Bay charr were the heaviest in the 55.0-65.0 cm length category. In general, charr from Tikkoatokak Bay weighed less at a specific length than those from the other three areas. Voisey Bay charr also were heavier at age than those from Tikkoatokak Bay, Okak Bay and Hebron Fiord (Tables 20-23).

Weight-length relationships were also calculated from research data and are listed in Table 12. Comparisons between areas of growth, or weight-length relationships derived from research samples were not made due to differences in the numbers of fish caught in gillnets of various mesh sizes. Appendices 10-14, however, summarize the size distribution of research data derived from experimental gillnetting.

4.3.5. Sex ratio and spawning stock composition

Analysis of research data indicated that the relative proportions of male and female charr caught at sea during the summer varied annually in all areas (Table 38). In general, females were more abundant than males although significant deviations from a 1:1 sex ratio occurred only in Okak and Napartok bays when the three years of data were combined (Table 29, Appendix 4). Research data from Voisey, Tikkoatokak and Ramah bays were available only for 1978 and female to male sex ratios were 1.2:1, 1.2:1 and 1.0:1 respectively. In excess of 1900 commercial samples of Arctic charr were examined from Tikkoatokak Bay during July of 1979. The corresponding number of male and female charr were as follows:

Date	Number Male	Female
July 7	95	91
July 10	178	243
July 12	213	196
July 14	232	245
July 20	111	74
July 25	101	130
Total	930	979

The overall sex ratio for this sample was 1.1:1 in favour of the females. Arctic charr populations in Okak Bay, Napartok Bay, Hebron Fiord and Saglek Fiord had female to male sex ratios of 1.3:1, 1.4:1, 1.0:1 and 1.2:1 respectively from marine sampling carried out over the three year period 1978-1980.

Annual variations also occurred in the relative contribution of potential spawners at sea during the summer (Table 38). Based upon samples collected from 1978-1980 it was estimated from the degree of gonadal development that on average 43% of the females in Okak Bay during the summer would spawn that season. Similar values for Napartok Bay, Hebron Fiord and Saglek Fiord were 46%, 30% and 34% respectively. Corresponding values for the estimated proportion of males contributing to the spawning stock ranged from 51% in Okak Bay to 21% in Hebron Fiord (Table 38). Individual values as high at 79% potential female spawners were recorded from Napartok Bay in 1978, however, values as low as 7% were obtained from Okak Bay and Saglek Fiord in 1980. These estimates were highly influenced by the relatively short period of time over which samples were obtained (Table 2). Marine sampling carried out over the entire summer would undoubtedly yield different results particularly if potential spawners have a tendency to enter rivers earlier than nonspawning fish, and since it

Table 38. Variation in sex ratio and spawning stock composition for Arctic charr from various areas in northern Labrador, 1978-1980.

Area	1978						1979						1980						Total			
	Male			Female			Male			Female			Male			Female			Male		Female	
	N	%Sp	%Ps*	N	%Sp	%Ps	N	%Sp	%Ps	N	%Sp	%Ps	N	%Sp	%Ps	N	%Sp	%Ps	N	%Sp	N	%Sp
Voisey Bay	56	23	61	67	66	5													56	23	67	66
Tikkoatokak Bay	52	62	23	70	36	46	930			979									52	61	70	36
Okak Bay	73	58	14	110	45	24	34	59	15	41	49	44	23	13	74	14	7	64	130	51	165	43
Napartok Bay	37	81	11	52	79	48	30	60	33	52	65	40	69	13	74	87	15	46	136	42	191	46
Hebron Fiord	34	26	18	51	41	22	68	41	18	83	53	18	133	9	53	111	8	21	235	21	245	30
Saglek Fiord	51	43	22	87	46	10	77	47	26	101	50	13	108	6	51	92	7	10	236	28	280	34
Ramah	108	34	45	110	25	21													108	34	110	25

*%Sp = percentage of sample spawning in current year
%Ps = percentage of sample having evidence of previous spawning

is known from Fraser River data that charr do enter rivers as early as the middle of July (Section 4.2.2.3.). The information, however, does indicate that a high proportion of charr are alternate year spawners while some charr spawn in consecutive seasons.

4.3.6. Age and size at maturity

Mean age at maturity in male Arctic charr varied from 6.3 years at Napartok Bay to 8.0 years at Hebron Fiord (Table 39). Corresponding mean size at maturity similarly varied from 33.0 cm to 40.8 cm. No pattern was evident in males for higher age at maturity in more northerly areas.

There was a definite trend in females for older mean age at sexual maturity with increase in latitude ranging from 7.9 years at Tikkoatokak Bay to 10.2 years at Ramah Bay (Table 39). Mean age at maturity in female charr from Okak Bay was 8.5 years and at Hebron Fiord 9.6 years. In general size at maturity in females increased with latitude, ranging from 42.0 cm at Okak Bay and Napartok Bay to 49.9 cm at Ramah Bay. However, in Tikkoatokak Bay which is located south of Okak Bay, female charr had a mean size at maturity of 46.3 cm.

Table 39. Age and length (cm) at 50% maturity of Arctic charr from different areas in northern Labrador.

	Male							Female						
		Age			Length				Age			Length		
	N	Range	Age_{50}	S.E.	Range	Lth_{50}	S.E.	N	Range	Age_{50}	S.E.	Range	Lth_{50}	S.E.
Fraser River	403	1-13	5.2	0.1	4.4-72.8	24.5	0.1	519	1-18	6.9	0.1	4.1-66.5	38.1	0.0
Tikkoatokak Bay	52	6-13	7.2	0.4	40.8-66.2	44.4	0.3	70	6-15	7.9	0.2	39.4-71.0	46.3	0.2
Okak Bay	130	6-18	6.6	0.2	34.3-60.7	39.6	0.2	165	6-18	8.5	0.1	32.9-60.8	42.0	0.1
Napartok Bay	136	5-20	6.3	0.3	15.7-66.4	33.0	0.3	191	6-19	8.5	0.1	30.3-62.5	42.0	0.1
Hebron Fiord	235	4-21	8.0	0.1	21.7-75.5	40.8	0.1	245	4-21	9.6	0.1	22.1-74.8	45.9	0.1
Saglek Fiord	236	3-17	7.3	0.1	16.5-67.0	40.1	0.1	280	3-21	10.0	0.1	18.2-59.7	47.3	0.1
Ramah Bay	108	5-17	7.4	0.2	21.0-71.9	39.3	0.2	110	6-16	10.2	0.2	33.6-58.9	49.9	0.1

4.3.7. Mortality rate

Estimates of total instantaneous mortality rate (Z), as derived from catch curves, represent mortality rates in effect during the period of time fish were recruited into the fishery and not those rates occurring during the year the population was sampled (Ricker 1975). Ricker (1975) suggests using catch curves when variability in data is mainly a result of unequal year-class strength. By combining several years of information the effects of variable recruitment can be reduced (Ricker 1975).

Total instantaneous mortality for age 9-14 year old Voisey Bay charr was 0.68 (Fig. 19). This was the average mortality in effect during the period 1972-73 to 1976-77. Similarly, for Tikkoatokak Bay charr total mortality was 0.83. In comparison, age 10-19 year old Okak Bay Arctic charr had a total mortality of 0.48. The virtual absence of a commercial fishery in Hebron Fiord since 1969 resulted in a total mortality of only 0.35 for ages 10-19, and 0.26 if ages 10-17 are used. These Hebron rates were derived from the 1980 experimental fishery age structure data. Mortality rates with 95% confidence limits are summarized in Table 40.

Corresponding total annual mortalities (A) were calculated from the relationship:

$$A = 1-e^{-Z} \qquad \text{(Ricker 1975).}$$

Annual mortalities expressed as a percentage were: Voisey Bay 49.4%; Tikkoatokak Bay 56.2%; Okak Bay 38.0%; Hebron Fiord 29.7%.

Figure 19. Catch curves of Arctic charr age-frequency distribution from various areas taken by commercial gillnets, 1977-1980. Hebron data 1980 only.

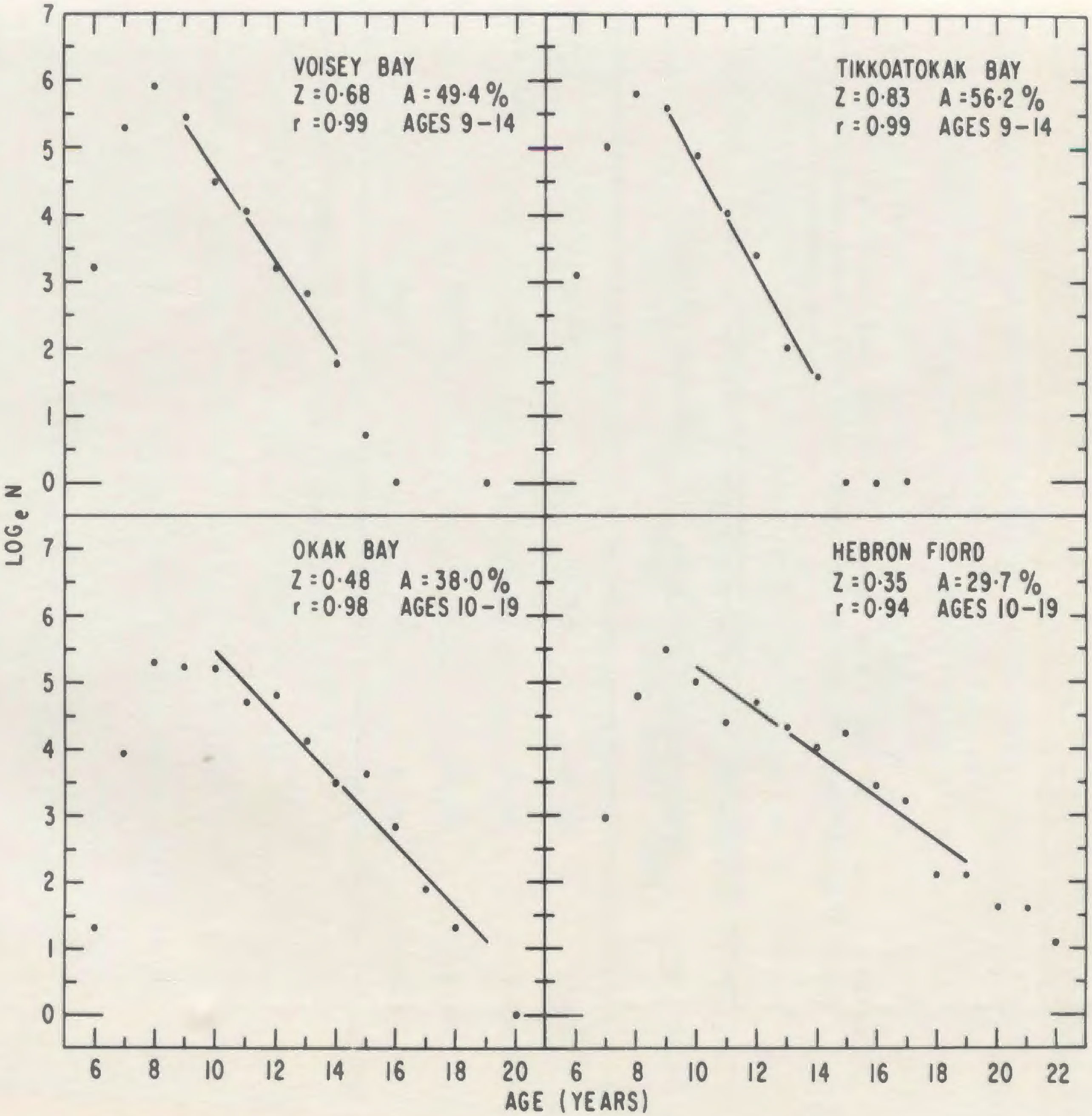

VOISEY BAY
Z = 0·68 A = 49·4 %
r = 0·99 AGES 9 – 14
TIKKOATOKAK BAY
Z = 0·83 A = 56·2 %
r = 0·99 AGES 9 – 14
OKAK BAY
Z = 0·48 A = 38·0 %
r = 0·98 AGES 10 – 19
HEBRON FIORD
Z = 0·35 A = 29·7 %
r = 0·94 AGES 10 – 19
LOGe N
AGE (YEARS)

Table 40. Total instantaneous mortality rates with 95% confidence limits and age range derived from 1977-1980 commercial age frequency data from various northern Labrador areas.

Area	Total mortality Z	95% Confidence Limit lower limit	95% Confidence Limit upper limit	Age range
Voisey Bay	0.68	0.58	0.78	9-14
Tikkoatokak Bay	0.83	0.69	0.96	9-14
Okak Bay	0.48	0.40	0.55	10-19
Hebron Fiord[1]	0.35	0.25	0.46	10-19

[1]1980 experimental commercial fishery data only.

Estimates of current total mortality rate were calculated for Arctic charr from Voisey Bay, Tikkoatokak Bay and Okak Bay using the method of Paloheimo (Ricker 1975) where catch per unit effort at age for at least two consecutive years are utilized. Total mortality rates calculated in this manner for Voisey Bay, Tikkoatokak Bay and Okak Bay Arctic charr were 0.79, 0.78 and 0.69 respectively (Tables 24, 25 and 26).

Additional total mortality rates were calculated for Hebron Fiord and Saglek Fiord Arctic charr using research data combined for years 1978-1980. Saglek Fiord has not been fished commercially since 1969 while a limited fishery occurred in the Hebron Fiord during 1977 and 1980 (Section 4.3.1.). Gillnets of varying mesh size were used in research sampling theoretically allowing for the sample to be more representative of the marine population. Mortality estimates derived from catch curves (Fig. 20) were 0.28 and 0.29 for 8-18 year old Hebron Fiord and Saglek Fiord charr respectively (Table 41). Owing to the lack of commercial fishing in both areas, these estimates, therefore, approximate values expected in virgin populations where mortality results from a variety of natural causes.

Tag recapture information for Fraser River Arctic charr was used to derive estimates of survival and exploitation rates on this stock. Table 42 lists tag recaptures of Fraser River charr from the first (R_1) to sixth (R_6) year after tagging. Tag returns to the Fraser River counting fence have been omitted from this table. An estimate of exploitation on Fraser River Arctic charr in the first year following upstream migration was calculated from recaptures in the first year after tagging by:

Figure 20. Catch curves of Arctic charr age-frequency distribution from Hebron and Saglek research data, 1978-1980.

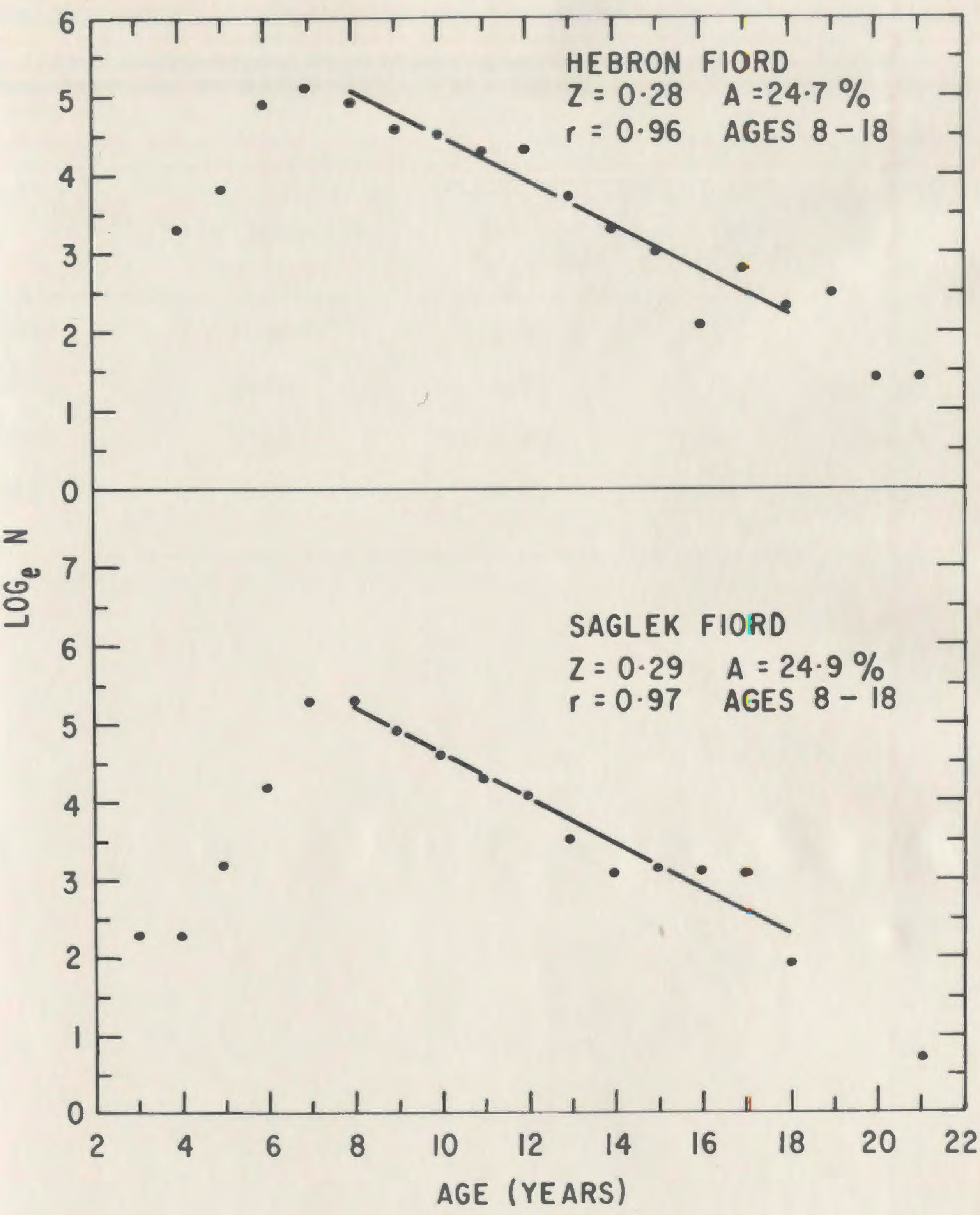

HEBRON FIORD
Z = 0·28 A = 24·7 %
r = 0·96 AGES 8 – 18
SAGLEK FIORD
Z = 0·29 A = 24·9 %
r = 0·97 AGES 8 – 18
LOGe N
AGE (YEARS)
0 1 2 3 4 5 6 7
2 4 6 8 10 12 14 16 18 20 22

Table 41. Total instantaneous mortality rates with 95% confidence limits and age range derived from Hebron Fiord and Saglek Fiord, 1978-1980 research age frequency data.

Area	Total mortality Z	95% Confidence Limit lower limit	95% Confidence Limit upper limit	Age range
Hebron Fiord	0.26	0.19	0.33	8-15
Hebron Fiord	0.28	0.22	0.35	8-18
Saglek Fiord	0.33	0.29	0.37	8-15
Saglek Fiord	0.29	0.23	0.34	8-18

Table 42. Tag recaptures of Fraser River Arctic charr from 1976-1981.

Year	No. Tagged	Recaptures						Total
		R_1	R_2	R_3	R_4	R_5	R_6	
1975	287	27	10	13	8	3	1	62
1976	100	8	3	2	1	0		14
1977	200	15	12	7	2			36
1978	31	6	1	3				10
1979	190	37	18					55
Total	808	93	44	25	11	3	1	177

$$\mu = R/M \qquad \text{(Ricker 1975).}$$

where R is the number of recaptures and M is the number of tags applied. The estimate weighted by number of tags applied was 0.12 which varied from 0.08 to 0.19. Exploitation rates in the second and third year after tagging were 0.06 and 0.04 respectively.

Survival was calculated from R_2/R_1 (Ricker 1975) and found to be S = 44/93 = 0.47 (Z = 0.75).

Estimates were also made for survival and exploitation on Nain Bay and Tikkoatokak Bay charr. Here only those charr tagged in the spring prior to the commercial fishing season were used. Within season exploitation on Nain Bay charr during 1980 was μ = 21/98 = 0.21. Exploitation of these charr during the second year (1981) was μ = 12/77 = 0.16, although no adjustment was made for losses due to natural mortality. In 1981, within season exploitation was μ = 30/130 = 0.23. Survival was estimated from:

$$S_1 = \frac{R_{12} \cdot M_2}{M_1 \cdot (R_{22}+1)} \qquad \text{(Ricker 1975)}$$

where R_{12} is the number of recaptures of first year tags during the second year; R_{22} is the number of recaptures of second year tags during the second year; M_1 and M_2 are the number of fish marked at the beginning of the first and second year respectively (Ricker 1975). Estimated annual survival of Nain Bay charr was 0.51 (Z = 0.67) where R_{12} = 12; R_{22} = 30; M_1 = 98 and M_2 = 130. Variance of this estimate was calculated by:

$$Var(S_1) = S_1^2 \left(\frac{1}{R_{12}} + \frac{1}{R_{22}} - \frac{1}{M_1} - \frac{1}{M_2}\right) \qquad \text{(Ricker 1975)}$$

and found to equal 0.026. Estimation of annual survival based on two successive years of recaptures in marine areas may be inaccurate owing to variability in magnitude of the sea-going component of the total stock.

Three estimates were available for within season exploitation on Tikkoatokak Bay Arctic charr. During 1979 $\mu = 24/72 = 0.33$. Second and third year exploitation on these fish was 0.21 and 0.08. After three years, therefore, in excess of 50% of the Tikkoatokak Bay charr were captured. In 1980 only nine charr were tagged during the spring, however, six were recaptured later that season giving $\mu = 0.67$. Finally during 1981 $\mu = 11/25 = 0.44$. The weighted mean within season exploitation for the three years was 0.39 (95% C.L. = 0.28-0.52).

It is interesting to note that the within season exploitation on Nain Bay charr was virtually identical over two years ($\mu = 0.21$ and $\mu = 0.23$). In addition, the second year exploitation calculated on Nain Bay fish of 0.16 was relatively similar to the exploitation on Fraser River charr in the first year following their upstream migration ($\mu = 0.12$).

5. DISCUSSION

Analyses of morphological and biological characteristics and movement patterns of tagged fish indicated that separate populations of Arctic charr exist along a limited section of the northern Labrador coast. Results suggested that Fraser River (Nain Bay) and Tikkoatokak Bay charr represent one stock complex distinctly different from Voisey Bay, Okak Bay and Hebron Fiord charr each of which similarly are separate stocks.

Numerous studies have examined variation in meristic characteristics in order to clarify systematic relationships within the Salvelinus genus (McPhail 1961; Frohne 1973; Qadri 1974; McCart and Craig 1971; Behnke 1972, 1980; Cavender 1980; McCart 1980; Morrow 1980; Savvaitova 1980). Literature pertaining to the use of morphological and biological data for the purpose of stock discrimination required for proper management is generally lacking although Dick and Belosevic (1981), have recently used parasites and morphological characteristics to separate anadromous and nonmigratory components in the commercial Arctic charr fishery from the Nettilling Lake-Koukdjuak River system on Baffin Island. In their study anadromous and resident charr, initially separated on the basis of their parasite faunas, differed significantly in meristic and morphometric characteristics when analyzed by discriminant analysis. However, they suggested that the distinction should be viewed with caution as Blouw (1976), in an earlier study of morphic variation in charr, was unable to clearly differentiate sea-run and nonmigratory charr from Nettilling Lake.

Analyses of meristic characters, which are known to be influenced by genetic and environmental parameters (Taning 1952; Barlow 1961; Garside 1966), indicated that there were significant differences between charr from separate areas along the northern Labrador coast with the exception of those from Voisey Bay and Tikkoatokak Bay. Andrews and Lear (1956) concluded on the basis of vertebrae and fin ray counts that intermingling of populations between Adlatok and Nain, Okak and Hebron, and Nain and Hebron is doubtful. However, they found no significant differences in meristic characters between Nain and Okak charr while in this study Tikkoatokak (Nain) and Okak charr differed significantly in the number of pectoral fin rays.

Meristic characters have been used extensively in trying to clarify the Arctic charr systematic problem. Although this study is not concerned with the problem of systematics, it is important to recognize the morphological variability of this polymorphic group of fish particularly when variations in meristic characters are utilized in differentiating populations to aid in the local management of the species.

According to Behnke (1980) Labrador charr represent an introgression of two ancestral forms of charr which came in contact postglacially in Labrador. This hypothesis was based on comparisons of gill raker and vertebrae counts. Relict populations from eastern North America had total gill raker and vertebrae counts of 21.1 and 64.1 respectively (weighted mean of three groups from Qadri 1974). Labrador charr had a total gill raker count of 24.3 and 65.0 vertebrae (weighted means of Voisey-Hebron charr) while the eastern Arctic ancestral charr was characterized by an average of 27-28 gill rakers and 67 vertebrae

(Behnke 1980). A mean vertebrae count of 63.2 was reported for Arctic charr from Northwest Tributary of Sand Hill River, southern Labrador (Peet 1971). Both the present study and Andrews and Lear (1956) found a general trend for mean value of meristic characters to increase with latitude. The intermediate values for gill rakers and vertebrae in Labrador charr support Behnke's hypothesis. However, an alternative explanation for the latitudinal variation in meristic characters is that populations have responded to differences in temperature. Several studies have shown that low temperatures during the embryological development stage often result in higher numbers of certain meristic characters (Taning 1952; Garside 1966).

The previously reported upper limit of the range for vertebrae number in Arctic charr was 71 (McPhail 1961; Scott and Crossman 1975; McCart 1980). This study found one charr from the Hebron area with a total vertebrae count of 72.

Multivariate analysis of morphometric data revealed significant differences ($P < 0.01$, Table 6) between the four major study areas. After selecting charr samples from within a specific length interval, analyses were then performed on raw untransformed data since several studies have indicated that corrections to remove effects of size and particularly size-related shape often produce meaningless results (Marr 1955; Atchley et al. 1976; Oxnard 1978). However, morphometric data were also analyzed after adjusting for size by a) logarithmic transformation of data and b) using body proportions. Results were virtually identical to those obtained from analyses of untransformed data. The fact that covariance matrices differed significantly between several groups is acceptable if Klecka (1975), Lachenbruch (1975) and Pimental (1979) are correct in stating that the discriminant analysis technique is robust enough to disregard the assumption of homogeneity of within-group covariance matrices as long as departures are not "too" severe.

Differences in growth rate, age at maturity and distribution pattern corroborated the morphological analyses and support the view that there are discrete charr stocks within this limited section of the Labrador coast. While significant differences in meristic characters were not found in Voisey Bay and Tikkoatokak Bay charr, growth differences and tag recapture patterns clearly illustrated the separation of these two populations. Growth comparisons between Voisey Bay and Anaktalik Bay charr yielded no significant differences, however, tag recaptures during the next several years will clarify the position of these two areas as well as indicate the relative contributions of charr from the inner bays to the offshore regions of Dog Island and Black Island. Presently tag recapture data indicate that the fishery in the latter two areas exploits a composite of stocks from the inner bays of the Nain area but not of stocks originating from the Okak and Hebron regions. Several small rivers on these offshore islands produce Arctic charr (Brice-Bennett 1977) and likely contribute to the commercial charr fishery in the immediate areas.

Grainger (1953) reported that charr from Sylvia Grinnell River, Frobisher Bay, have a tendency to remain close to their home river. Moore (1975b), on the basis of length-frequency data, suggested that there was little intermingling of charr from different rivers in

Cumberland Sound, Baffin Island. Glova and McCart (1978) stated that Arctic charr in the Nachvak Fiord, Labrador, were most abundant within 25-30 km of Nachvak and Palmer Rivers while few charr were captured at the fiord mouth. Tagging studies in Greenland (Nielsen 1961a) and western Hudson Bay (Sprules 1952) similarly suggested Arctic charr migrations were localized, however, Jensen and Berg (1977), Johnson (1980) and McCart (1980) have found that in some areas Arctic charr marine migrations may be extensive. The present study suggests that minimal interchange occurs between inner bays and that although environmental conditions can influence annual distribution patterns, the movements are primarily directed into offshore feeding areas. Migration patterns are likely related to resource availability. Yessipov (1935) reported that charr in Novaya Zemlya, USSR, generally remain in the bays and gulfs along the coast and suggested that this was largely due to the abundance of small benthic and pelagic fish in these areas. Considering the intensity and distribution of the commercial Arctic charr and Atlantic salmon (*Salmo salar*) fishery along the Labrador coast north of the Hamilton Inlet (Dempson 1978), it is likely that if charr were undertaking extensive coastal migrations then during the past four years some tag recaptures from distant areas would have occurred.

Recaptures of tagged Fraser River charr in the same system over several years (Table 4) indicated that some adult charr return to their previous overwintering stream. Evidence of homing has been observed in several Arctic charr populations (Alm 1951; Nielsen 1961a; Johnson 1980; McBride 1980; McCart 1980) and additional experiments have shown that charr displaced from their breeding areas will return to the same spawning sites (Frost 1963; McCleave et al. 1977). Nordeng (1971, 1977) suggested population specific pheromones released by resident freshwater and downstream migrating smolts are responsible for allowing returning adults to orientate to their home rivers.

While northern Labrador charr have a tendency to remain in bays and fiords during their marine existance, interchange between rivers within areas does occur. Evidence for this came in 1979 when a charr tagged in a river of Tikkoatokak Bay, was recaptured later that summer at the Fraser River counting fence. Occasionally juvenile charr and nonspawning adults will overwinter in nonnatal streams but subsequently return to the home river for spawning (Johnson 1980; McCart 1980). This behaviour also has been observed in Dolly Varden charr (Armstrong 1974; Armstrong and Morrow 1980). Johnson (1980) found that Arctic charr in Nauyuk Lake, Kent Peninsula, Northwest Territories, do not migrate to sea during the year in which they spawn. In Stanwell-Fletcher Lake, Somerset Island, N.W.T., maturing migratory fish generally remain in the lake during the summer prior to spawning instead of going to sea (Eddy and Lankester 1978). A similar situation apparently occurs in Labrador charr but to a lesser degree since some maturing adult charr have been captured in the small pond located 27 km upriver from the Fraser River counting fence (Section 4.2.3.3.) in early July prior to any upstream migration. The migratory patterns of Arctic charr are, therefore, rather complex and a thorough understanding is essential for the proper management of the species.

Growth rate of adult Fraser River Arctic charr was relatively slow in comparison with other North American anadromous charr populations (Table 43). Of the areas listed in Table 43 only charr from Nachvak Fiord, Labrador, Sylvia Grinnell River and Nettlling Lake, Baffin Island grew slower. However, the population of the latter area was likely composed of both resident and anadromous charr (Thompson 1957). Within Labrador there was a noticeable trend for increased mean age of charr but decreased growth rate with increase in latitude (Tables 20-23 and 43). The trend continued into Baffin Island although charr from Leaf River (Lee 1969) and George River (Le Jeune 1967), Ungava Bay, and charr from western Hudson Bay (Sprules 1952) deviated from this pattern (Table 43). Charr from the latter area, however, were aged by scales and since several authors have shown scales to be unreliable for determining the age of charr (Slastnikov 1935; Nordeng 1961; Dalene 1973; Gullestad 1974) these growth data may be questionable.

Juvenile Fraser River charr, age 0-4, also grew comparatively slower than both resident and anadromous juveniles from various populations in the western Arctic (Bain 1975; McCart 1980), Leaf River, Ungava (Lee 1969), and Tree River, Northwest Territories (Falk and Dahlke 1979). Only juvenile charr from Sylvia Grinnell River, Frobisher Bay (Grainger 1953) and Kigdlut-iluat River, West Greenland (Nielsen 1961b) grew slower than Fraser River charr. This slow rate of growth during the freshwater phase of the life cycle may reflect a lower productivity in the Fraser River system which results in juveniles migrating to sea at smaller sizes but comparable ages with other populations (Table 44).

Table 43. Summary of age and length (mm) data for various anadromous populations of Arctic charr in North Amercia.

Age	a	b	c	d	e	f	g	h	i	j	k	l	m	n
0				39										
1				65			91					85	117	
2		195	182	90	80		108		61			125	192	
3		238	232	125	97		196	90	78	225	218	150	220	
4	320	248	327	160	120		270	130	90	239	244	171	283	318
5	352	316	369	228	171		310	139	90	234	273		355	381
6	394	466	454	331	235		427	172	190	278	310		398	408
7	484	502	511	402	319	473	453	302	231	416	349	605	447	445
8	533	514	540	435	365	499	541	337	244	510	359	584	484	467
9	660	515	545	491	414	512	608	363	258	601	448	638	512	494
10		480	597	502	439	541	630	414	335	605	481	655	545	522
11				543	464	579	670	425	333	653	474	708	558	565
12				540	470	613	672	484	345	676	499	748	560	602
13				580	545	652	695	510	382	694	545	752	581	637
14				559	565	650	699	553	386	725	554	790	584	635
15				608		738	700	557	433	721	590	783	625	-
16				528	545		678	559	474	742	633	822		679
17				501	533			600	448	736	635			787
18				532				613	475	724	793			749
19								649	483		737			
20					699			642	546		671			
21								658	445		754			
22								678			538			819
23								678						
N	139	80	182	1130	400	287	504	794	295	264	223	197	1784	96

a. St. Charles R., southern Labrador (Peet 1968)
b. Northwest Tributary, Sand Hill R. Labrador (Peet 1971)
c. Middle Brook, Double Brook, Labrador (Peet 1971)
d. Fraser R., Labrador
e. Nachvak Fiord, Labrador (Glova and McCart 1978)
f. George R., Quebec (Le Jeune 1967)
g. Leaf R., Quebec (Lee 1969)
h. Sylvia Grinnell R. Baffin I. (Grainger 1953)
i. Nettling L., Baffin I. (Thomson 1957)
j. Nauyuk L., Northwest Territories (Johnson 1980)
k. Jacko R., Victoria I., Northwest Territories (Dahlke and Falk 1979)
l. Tree R., Northwest Territories (Falk and Dahlke 1979)
m. Western Arctic. Summary of several areas in Alaska and Yukon (McCart 1980)
n. Wilson R., Term Point, Western Hudson Bay (Sprules 1952)

Table 44. Summary of migratory and reproductive information on various anadromous Arctic charr populations. Bracketed figures represent mean values.

	Downstream migrants		Upstream migrants				Maturation and Fecundity			
	Age at first sea migration	Size at migration (mm)	Mean length (mm)	Range	Mean age	Range	Age at first maturity	Size at maturity (mm)	Mean fecundity	No. eggs 100 g^{-1}
1. St. Charles R. Labrador	2-5		450	251-708	6.2	4-9				
2. Northwest Tributary Sand Hill R. Labrador			400	187-641	5.2	2-10				
3. Middle Brook - Double Brook, Labrador			419	196-767	5.3	2-10				
4. Fraser R. Labrador	3-7	87-191	451	107-820	8.3	3-18	5(6.9)	262(381)	5242	245
5. Nachvak Fiord Labrador	2-6	78-115					7(10.0)	358	2876	281
6. Leaf R. Ungava Bay	3-7	220-					6(8.0)	(500)	4397	167
7. Sylvia Grinnell R. Frobisher Bay	4-7	130-170	476	130-825		4-21+	11	450	3465	179
8. Cumberland Sound Baffin Island	5-7	114-210	562	250-750	17.2	7-20	11	392	5400	284
9. Sandy Point R. Hudson Bay			613	248-928	7.7	3-17				
10 Diana R. Hudson Bay			567	176-882	8.4	3-20				
11 Jackyo R. Victoria I. N.W.T.			424	209-822	9.5	3-22				
12. Nauyuk L. Kent Penninsula, N.W.T.	4-7	180-250	598	~120-~900		5-21	10	620	4781	140
13 Sagavanirktok R. Alaska	2-5	145-195	482	210-710			6-7	481	4153	335
14. Novaya Zemlya USSR	4-5		480	275-660	7-8	3-12	6-7		3507	148

1. Peet (1968)
2. Peet (1971)
3. Peet (1971)
5. Glova and McCart (1978)
6. Lee (1969)
7. Grainger (1953)
8. Moore (1975a, 1975b)
9. Johnson (1980)
10. Johnson (1980
11. Dahlke and Falk (1979)
12. Johnson (1980
13. Yoshihara (1973)
14. Yessipov (1935)

Consistent differences in growth rate between male and female charr were not found in this study nor in any previous investigations on charr in Labrador (Peet 1971; Coady and Best 1976; Glova and McCart 1978). Although male charr were larger than females in the catch at Tree River, N.W.T., (Falk and Dahlke 1979), no consistent differences were observed in the size at age between sexes. Similarly, Bain (1975) found no consistent differences in size at age between sexes in anadromous charr from Fish Hole Creek, Yukon Territory, nor Sekerak et al. (1976) at Creswell Bay, Somerset Island, N.W.T. However, in other areas there is a strong tendency for anadromous male charr to be larger at age than females (Grainger 1953; Thomson 1957; Le Jeune 1967; Lee 1969; Craig 1977; Jensen and Berg 1977; Dahlke and Falk 1979).

Variation in length at age, a phenomenon common to anadromous Arctic charr in all areas, is highly influenced by age at first seaward migration and age at maturation. The youngest mature females caught at the Fraser River were age five but the mean age at maturation was 6.9 years. Mean age at maturity in other Labrador populations increased with latitude to 10.2 years at Ramah Bay. Eastern Arctic populations mature at older ages (Table 44) and Sekerak et al. (1976) reported that the youngest mature female charr at Creswell Bay, Somerset Island, N.W.T., were age 13, with 50% mature by age 17. In the western Arctic and Alaska where the maximum age of the western form was 10-15 years (McCart 1980), age at maturity was comparable to Fraser River charr.

Fecundity of northern Labrador Arctic charr appeared intermediate between charr from eastern and central Arctic regions and those from the western Arctic. Fraser River charr produced 245 eggs 100 g^{-1} while charr from Ungava Bay, Frobisher Bay and Nauyuk Lake, Kent Peninsula produced 27-43% fewer eggs (Table 44). In contrast the western forms of Arctic charr had the highest values with 335 eggs 100 g^{-1} produced in charr from Sagavanirktok River, Alaska (Table 44) and 368 egg 100 g^{-1} in charr from the Firth River, Yukon Territory (Glova and McCart 1974). Webb Bay and Saglek Fiord charr were virtually identical to Fraser River charr producing 252 and 256 eggs 100 g^{-1} respectively (Appendix 15).

Although egg production per unit body weight in Labrador charr was consistent between areas sampled in 1976, annual variations can occur in population fecundity. Yearly differences in sex ratios and spawning stock composition as well as nutritional state and condition of the fish are known to affect population fecundity (Bagenal 1973). In anadromous charr populations, adult females are generally more abundant than males (Johnson 1980; McCart 1980) and this was observed in Labrador populations although few significant differences from a 1:1 in sex ratio occurred.

Certain characteristics of upstream migrant charr were similar throughout other regions. The tendency for larger fish to enter the river first, occasionally with females predominating, has been observed in eastern and western Arctic areas (Grainger 1953; Lee 1969; Peet 1971; Sekerak et al. 1976; McCart 1980). Peak upstream movement coinciding with spring tide conditions was observed in the Fraser River population during 1975 (Coady and Best 1976) and in the other years of investigations. This phenomemon has also been noticed in the eastern Arctic (Grainger 1953), Ungava (Lee 1969), and southern

Labrador (Peet 1971). Fraser River charr were older and larger than upstream migrants in southern Labrador, but were of comparable age and smaller size than Hudson Bay charr (Table 44). Maximum ages were greater in Arctic populations.

Growth comparisons between commercially exploited northern Labrador stocks indicated that Okak Bay charr had the slowest rate of growth. These data were derived from commercial samples and may be influenced to some degree by the gear in use (Hamley 1975). The information, therefore, pertained to the exploitable part of the stock and does not necessarily relate to the true age and size characteristics of the population.

Commercially exploited Labrador Arctic charr populations were characterized by having catches with mean ages ranging from 8.6 and 8.7 years in Voisey Bay and Tikkoatokak Bay to 10.0 and 11.2 years for charr in the Okak and Hebron districts. While age compositions of stocks have not changed appreciably since the early 1950's, there has been an apparent increase in the size of fish being caught (Table 45). Mean lengths of charr sampled in 1953 (Andrews and Lear 1956) were somewhat shorter than recent measurements, however, weight of charr was considerably less than those observed at present.

In comparison with Coady and Best's (1976) data from 1974, little change has occurred in mean length of catches in Voisey Bay and Tikkoatokak Bay (Table 45). With respect to the Okak Bay fishery, mean length, weight and age have decreased. Mean length in 1974 was similar to that in 1977 (Figure 15) but a decline occurred in 1978 and again in 1979 with the 1980 catch consistent with 1979.

Table 45. Comparative length, weight, age and mortality statistics on exploited anadromous Arctic charr populations. Mortality rates from regression analysis of age frequency data (Ricker 1975).

Location	Year	Fork Length (mm) Mean	Fork Length (mm) Range	Round weight (kg) Mean	Round weight (kg) Range	Age Mean	Age Range	Mortality Z	Mortality A%	Mortality Ages
1. Sand Hill Bay	1971	458	312-622	1.15	0.34-3.02					
2. S. Labrador	1973	492	382-585	1.65	0.79-2.42					
3. Adlatok	1953	553	400-699	2.00	0.91-4.08	8.5	5-13	0.44	35.3	7-13
3. Nain	1953	488	350-649	1.13	0.45-2.72	8.9	6-13	0.79	54.8	9-13
(Tikkoatokak)	1974	526	413-641	2.06	1.09-4.29	9.4	7-14	0.70	50.3	9-14
(Tikkoatokak	1977-1980	521	371-738	1.82	0.37-4.84	8.7	6-17	0.83	56.2	9-14
4. Voisey Bay	1974	537	430-671	2.33	1.09-4.98	9.3	7-13	0.75	52.6	9-13
	1977-1980	544	381-746	2.19	0.64-6.27	8.6	5-19	0.68	49.4	9-14
3. Okak Bay	1953	455	300-649	0.95	0.45-2.27	10.2	7-16	0.32	27.7	9-13
	1974	566	467-762	2.62	1.34-5.96	11.7	7-19	0.54	41.7	11-19
	1977-1980	525	298-746	1.92	0.26-5.08	10.0	6-20	0.48	38.0	10-19
3. Hebron Fiord	1953	495	350-649	1.32	0.45-3.63	10.5	7-14	0.30	26.2	9-14
	1980	548	389-730	2.16	0.69-5.48	11.2	7-22	0.32	27.6	10-19
5. George R. Ungava Bay	1960	580	440-760	2.33	1.15-5.53	10.8	7-15	1.01	63.6	11-15
6. Sylvia Grinnel R. Frobisher Bay	1948	636	350-845	2.83		16.0	12-24	0.40	33.6	14-20
7. Sandy Point Hudson Bay	1972	614	432-774	2.99	0.87-6.03	8.9	6-14	0.54	42.0	8-14
8. Ekalluk R. Victoria I. N.W.T.	1976-1978	666	400-899	3.64		14.7	10-21	0.71	50.8	16-21
8. Halovik R.	1976-1978	665	400-799	3.42		14.4	8-20	0.87	57.9	15-20
8. Lauchlan R.	1977-1978	678	450-849	3.53		14.1	9-21	0.78	54.2	15-19
8. Jayco R.	1976-1978	689	450-849	3.83		17.2	10-32	0.37	30.7	17-26
8. Ellice R.	1976-1978	601	300-849	2.96		11.1	7-21	0.60	45.0	11-19

1. Murphy (1972)
2. Murphy (1974)
3. Andrews and Lear (1956)
4. Coady and Best (1976)
5. Le Jeune (1967)
6. Grainger (1953), Hunter (1976). Mortality rate extrapolated from Hunter's data for 1951.
7. Bond (1974)
8. Kristofferson and Carder (1980). Size, age and mortality information derived from a combination of several years data.

Catch statistics (Table 18) have shown that exploitation is effectively removing larger charr (those over 2.3 kg gutted head-on weight) from the population in Voisey Bay, Tikkoatokak Bay and Okak Bay. Stock size of the adult populations have undoubtedly decreased considering that in excess of 92,000 charr were caught in Tikkoatokak Bay from 1977-1980, and more than 40,000 and 54,000 were caught during the same period in Voisey Bay and Okak Bay respectively. In general the average catch of charr from Voisey Bay and Tikkoatokak Bay has increased by 63% and 66% respectively in the period 1978-1980 compared to 1974-1977. In Okak Bay landings averaged 30% more during the former period. Although exploitation has been high in the Nain-Tikkoatokak area, both Voisey Bay and Tikkoatokak Bay stocks have maintained approximately the same mean lengths since 1974. Similarly the Fraser River population which was monitored by a nonselective counting fence, has had the same general length distribution with mean length varying by less than 1.5 cm from 1975 to 1979. Johnson (1980; pers. comm. 1981) has observed the same phenomenon in Nauyuk Lake Arctic charr where stock size and numbers of larger fish have decreased yet the adult migratory population has maintained virtually the same mean length.

Johnson (1976) hypothesized that a feedback mechanism is responsible for controlling recruitment of juvenile charr into the adult population. According to this hypothesis adults in unexploited systems suppress the juvenile population allowing only enough recruitment into the adult phase to compensate for losses due to mortality. Exploitation of the adult stock creates increased opportunities for juveniles to enter the adult phase through a period of rapid growth, consequently maintaining a stable size distribution. When exploitation is severe, recruitment is eventually reduced resulting in a decline in size and age structure of the stock as observed in the population of Sylvia Grinnell River, Frobisher Bay (Sopuck 1977; McCart and Den Beste 1979). Given the opportunity charr populations are resilient enough to recover to their original size as did the charr stock in Keyhole Lake, Victoria Island (Johnson 1976) after intense fishing during the 1960's (Hunter 1970).

Although speculative, evidence for Johnson's hypothesis may be found in Voisey Bay and Tikkoatokak Bay charr stocks. Mortality has certainly been high enough (Table 45) to reduce the adult population size, particularly if tag return information is any indication. Over a three year period an average of approximately 40% of the marine stock in Tikkoatokak Bay was caught within the same fishing season. Either the adult stock size is large enough to maintain relatively similar length and age distributions in the commercial catches or alternatively, recruitment into the adult exploitable phase is continuing at a high enough rate to maintain the adult population length distribution. Comparison of current length at age data in Voisey Bay and Tikkoatokak Bay Arctic charr with 1974 data indicated that growth rate has increased. It is possible that juvenile charr have responded by increasing their rate of growth to enter into the adult phase and thus compensate for losses from the commercial fishery.

The decline in the proportion of larger charr in the fishery (those over 2.3 kg gutted head-on weight) can be partially explained from changes in weight-length relationships. A 50 cm Tikkoatokak Bay charr weighed 1.44 kg in 1974 (gutted head-on weight). In 1979 a 50 cm fish was 1.29 kg and in 1980 only 1.17 kg. Similarly the mean weight of a 60 cm fish was 2.44 kg in 1974 but only 2.21 kg and 2.13 kg in 1979 and 1980 respectively. Similar changes have also occurred in Voisey Bay Arctic charr. It appears that an increased rate of growth in length is occurring at the expense of an increase in body weight resulting in a general decrease in the condition of fish. This could also result from earlier maturity whereby after obtaining a minimal size, energy is diverted into reproductive products as opposed to increasing body weight.

At least eight different year-classes annually contribute to the spawning stock of charr in the Nain area although with varying magnitude. In addition, variations in growth rate and age at migration result in recruitment occurring over a number of different ages. Juvenile stock levels have been built up over previous years, when exploitation was low (mid 1960's - early 1970's), to maintain the fishery at its current high level of exploitation. However, it remains to be seen how long 15,000-25,000 Arctic charr can be removed annually from the adult stock in one area before the surplus of pre-recruitment juveniles is depleted and recruitment overfishing occurs. It is doubtful that variations in catch per unit effort will adequately reflect changes in stock abundance due to the frequent spatial concentration of adult charr at sea. Fish will continue to encounter gear and be captured until stock size is drastically reduced. It is imperative, therefore, in areas such as northern Labrador where a concentration of fishing is occurring on individual Arctic charr stocks that populations are continually monitored, and if necessary, measures taken, using the best available information, to try and maintain commercially viable populations.

With respect to Okak Bay and Hebron Fiord Arctic charr stocks mortality rates are considerably lower than those occurring in the Nain area (Table 45). Okak charr, however, have shown a decrease in growth rate since 1974. This was the slowest growing population of the four areas concentrated on in this study and even in 1953 Andrews and Lear (1956) observed this stock to have the slowest rate of growth.

Exploited charr stocks in other regions are generally larger and older than northern Labrador fish (Table 45). The Sandy Point, Hudson Bay fishery (Bond 1974) took charr of similar ages but of larger sizes. In comparison, Cambridge Bay fisheries exploited both older and larger charr while in the Ungava Bay fishery ages were comparable to Okak-Hebron fish, but again Ungava Bay charr were larger. The George River Ungava stock had the highest rate of mortality (Table 45). Cambridge Bay stocks had mortality rates comparable to several Labrador populations although the former rates were generally derived on older individuals in the fishery since recruitment appears to occur over a greater number of ages. In several cases, however, after ages 16-17 these charr were not major contributors to the fishery.

Healey (1975), in a study on the dynamics of exploited whitefish populations in the Northwest Territories, discussed problems in deriving mortality estimates from catch curves. Overestimates of mortality can arise from selectivity of the fishing gear in use, and from incorrect aging when older fish are inadvertently underaged.

In both instances the available older fish in the population are not correctly represented resulting in higher mortality estimates. The issue of net selectivity has been questioned by Johnson (1976, 1980) who believes that the relative abundance of the stock is accurately represented over the lengths sampled. Nevertheless, the problem is less serious in heavily exploited stocks where, as Healey (1975) pointed out, many of the older larger fish have likely been removed from the population.

Variability in year-class strength can also create problems when estimating survival from catch curves. These estimates are historic in that they refer to the period when these fish were recruited into the fishery (Ricker 1975). As Healey (1975) explained when only one or two years data are available, the presence of a strong or weak year-class tends to overestimate or underestimate the mortality rate respectively. Carder's (1981) and Kristofferson and Carder's (1980) data on anadromous charr from Cambridge Bay, N.W.T., particularly on the Halovik, Lauchlan and Ellice Rivers, illustrate how variable annual survival rates can be. These estimates could be influenced by sampling errors, variable recruitment or annual variations in the migratory stock component from which these estimates were derived. To remove effects of variable recruitment and reduce errors resulting from annual differences in the exploitable marine stock component, several years data were combined in estimating mortality rates in this study. In summarizing data for the Cambridge Bay Arctic charr fishery (Table 45) Kristofferson and Carder's (1980) data were also combined over several years.

Few estimates have been made of natural mortality in Arctic charr populations (Johnson 1980). Moore (1975b) estimated natural mortality in anadromous charr from Cumberland Sound, Baffin Island to be 16%. Hunter (1976) reported a value of 14% for charr in Sylvia Grinnell River, Frobisher Bay, and Nordeng (1961) estimated natural mortality in anadromous charr in Norway also to equal 14%. In comparison of upstream and downstream migrants in Nauyuk Lake between 1975 and 1977, Johnson (1980) reported a loss of 12.5%. On the basis of 84% tag recapture in seaward migrant mid-sized charr (30.0-50.0 cm) he concluded mortality was minimal. Total annual mortality (A) calculated from research sampling of charr from Hebron and Saglek fiords yielded values of 24% and 25% respectively (ages 8-18). Although these stocks have been virtually unexploited since 1969, mortality estimates would still be influenced by earlier exploitation.

Many questions remain to be answered concerning the dynamics of Arctic charr populations. Short term studies while useful for certain aspects can only provide limited information regarding the dynamics of individual stocks. The relative consistency in age and size structure in heavily exploited populations creates management problems when trying to identify definite signs of stress in these populations. Arctic charr are a relatively long lived species although in exploited Labrador stocks the commercial fishery is concentrated heavily on three or four age groups. Changes in sex ratio, maturation frequency, fecundity and additional characteristics by which other species are known to respond to exploitation are currently unknown or speculative. In several Arctic areas adults generally remain in freshwater during the year in which they will spawn. While there is some evidence to suggest this occurs in Labrador stocks, the degree to which this happens is unknown and likely varies between areas and years. As Johnson (1980) has pointed out recruitment is one of the most difficult factors to estimate in anadromous charr populations. It is known that recruitment into the fishery takes place over a number of years. Similarly recruitment of new individuals into the population occurs as a result of a large number of year-classes contributing to the annual spawning stock. Therefore, populations are buffered to some extent from disturbances that will severely impair any one year-class (McCart 1980). However, as McCart (1980) stated, disturbances that affect a wide range of year-classes, such as heavy fishing, are more detrimental. Geographically isolated charr stocks cannot withstand long periods of intense exploitation (Bigelow 1963). Just how long populations subjected to heavy exploitation can maintain stable length distributions is unknown. Northern Labrador is one area where both heavily exploited and unexploited populations can be studied. Only by continued monitoring and assessment will a full understanding develop on the biological characteristics of these populations and their responses to exploitation.

6. SUMMARY

1. Biological and morphological studies on northern Labrador Arctic charr (Salvelinus alpinus) indicated that a number of discrete stocks exist along a limited section of the northern Labrador coast. Movement patterns as derived from tag recaptures, suggested that charr remain within the same general area with only a minimal interchange between inner bays and fiords.

2. Biological investigations on Fraser River Arctic charr concentrated on age, growth, migration and reproductive characteristics. Growth rate was relatively slow and adult charr were comparatively smaller at age than other North American anadromous charr populations. Age at first seaward migration ranged from 3 to 7 years. Adult upstream migration began in mid-July with peak runs occurring in August. Larger charr enter the river first with a progressive decline in mean length throughout the duration of the run. Spawning occurred in October and fecundity was estimated to be 245 eggs 100 g^{-1}.

3. Commercial production of Labrador Arctic charr has exceeded 200 t y^{-1} since 1977. Catch statistics and biological characteristics have been available from individual commercial fishing areas since 1974 and 1977 respectively.

4. Mean age of charr caught in the commercial fishery increased with latitude from 8.6 years in Voisey Bay to 10.0 years at

Okak Bay and 11.2 years in the relatively unexploited Hebron Fiord. Voisey Bay charr had the fastest rate of growth while Okak Bay charr had the slowest.

5. Exploitation has reduced the proportion of larger charr (charr greater than 2.3 kg gutted head-on weight) in the commercial catches. However, mean length of catches has remained relatively constant in several areas despite large removals by the commercial fishery.

6. Estimates of total mortality varied from 0.48 for Okak Bay Arctic charr to 0.83 in the heavily exploited Tikkoatokak Bay stock. The latter area has had in excess of 200 t of charr removed by the commercial fishery since 1976. Total mortality in the unexploited Hebron and Saglek populations was 0.28 and 0.29 respectively.

REFERENCES

Alm, G. 1951. The tagging of char (Salmo alpinus, Linné) in Lake Vattern. Inst. Freshwater Res. Drottningholm Rep. 32: 15-31.

Anderson, T.C. The rivers of Labrador. In preparation.

Anderson, T.C., and B.P. McDonald. 1978. A portable weir for counting migrating fishes in rivers. Fish. Mar. Serv. Tech. Rep. 733: 13 p.

Andrews, C.W., and E. Lear. 1956. The biology of Arctic char (Salvelinus alpinus L.) in northern Labrador. J. Fish. Res. Board Can. 13(6): 843-860.

Armstrong, R.H. 1974. Migration of anadromous dolly varden (Salvelinus malma) in southeastern Alaska. J. Fish. Res. Board Can. 31: 435-444.

Armstrong, R.H., and J.E. Morrow. 1980. The dolly varden charr, Salvelinus malma, p. 99-140. In E.K. Balon (ed.) Charrs, salmonid fishes of the genus Salvelinus. Dr. W. Junk, Publisher, The Hague, Netherlands.

Atchley, W.R., C.T. Gaskins, and D. Anderson. 1976. Statistical properties of ratios. I. Empirical results. Syst. Zool. 25: 137-148.

Backus, R.H. 1957. The fishes of Labrador. Bull. Am. Museum Nat. History. 113(4): 277-337.

Bagenal, T.B. 1973. Fish fecundity and its relations with stock and recruitment. Rapp. P.V. Reun. Cons. Int. Explor. Mer 164: 186-198.

Bain, L.H. 1975. The life-history and systematics of Arctic char, Salvelinus alpinus (Linnaeus), in the Babbage River system, Yukon territory. M. Sc. Thesis, University of Calgary. 162 pp.

Barlow, G.W. 1961. Causes and significance of morphological variation in fishes. Syst. Zool. 25: 105-117.

Behnke, R.J. 1972. The systematics of salmonid fishes of recently glaciated lakes. J. Fish. Res. Board Can. 29: 639-671.

Behnke, R.J. 1980. A systematic review of the genus Salvelinus, p. 441-481. In E.K. Balon (ed.) Charrs, salmonid fishes of the genus Salvelinus. Dr. W. Junk, Publisher, The Hague, Netherlands.

Beverton, R.J.H., and S.J. Holt. 1956. A review of methods for estimating mortality rates in fish populations, with special reference to sources of bias in catch sampling. Rapp. P.-V. Reun. Cons. Perm. Int. Explor. Mer. 140: 67-83.

Bigelow, H.B. 1963. Fishes of the western North Atlantic. Arctic Charr. Memoir Sears Foundation for Marine Research, New Haven, Conn. p. 507-524.

Blackith, R.E., and R.A. Reyment. 1971. Multivariate morphometrics. Academic Press, London. 391 p.

Bliss, C.I. 1952. The statistics of bioassy with special reference to the vitamins. Academic Press, New York. 184 p.

Blouw, D.M. 1976. On the analysis of morphic variation; a critical examination of methodology, and application to a taxonomically difficult group. M. Sc. Thesis, University of Manitoba, Winnipeg. 137 p.

Bond, W.A. 1974. The commercial Fishery at Sandy Point, District of Keewatin, Northwest Territories in 1972. Fish. Mar. Serv. Data Report Series No. CEN/D-74-2: 1-16.

Brice-Bennett, C. 1977. Land use in the Nain and Hopedale regions, p. 97-203. In C. Brice-Bennett (ed.) Our footprints are everywhere. Labrador Inuit Association, Nain, Labrador.

Brown, M.B., and A.B. Forsythe. 1974a. The small sample behaviour of some statistics which test the equality of several means. Technometrics 16(1): 129-132.

Brown, M.B., and A.B. Forsythe. 1974b. The ANOVA and multiple comparisons for data with heterogenous variances. Biometrics 30: 719-724.

Carder, G.W. 1981. Data from the commercial fishery for Arctic charr, Salvelinus alpinus (Linnaeus), in the Cambridge Bay area, Northwest Territories, 1979-1980. Can. Data Rep. Fish. Aquat. Sci. 264: 22 p.

Carscadden, J.E., and R.K. Misra. 1980. Multivariate analysis of meristic characters of capelin (Mallotus villosus) in the Northwest Atlantic. Can. J. Fish. Aquat. Sci. 37: 725-729.

Catt, J. 1980. Salvelinus alpinus in Walton Lake, New Brunswick The Canadian Field-Naturalist. 64: 189.

Cavender, T. M. 1980. Systematics of Salvelinus from the North Pacific Basin, p. 295-322. In E. K. Balon (ed.) Charrs, salmonid fishes of the genus Salvelinus. Dr. W. Junk, Publisher, The Hague, Netherlands.

Coady, L. 1974. The Arctic char fishery of northern Labrador. Progress Rept. No. 104. Resource Development Branch, Newfoundland Region. 31 p.

Coady, L., and C. W. Best. 1976. Biological and management investigations of the Arctic char fishery at Nain, Labrador. Fish. Mar. Serv. Tech. Rep. 624: 103 p.

Cooley, W. W. and P. R. Lohnes. 1962. Multivariate procedures for the behavioural sciences. John Wiley and Sons. New York. 211 p.

Craig, P.C. 1977. Ecological studies of anadromous and resident populations of Arctic char in the Canning River drainage and adjacent coastal waters of the Beaufort Sea, Alaska, p. 1-116. In P. McCart (ed.) Fisheries investigations along the North slope and Beaufort Sea coast in Alaska with emphasis on Arctic char. Arctic Gas Biological Rept. Series 41.

Craig, P.C., and V.A. Poulin. 1975. Movements and growth of Arctic Grayling (Thymallus arcticus) and juvenile Arctic char (Salvelinus alpinus) in a small Arctic stream, Alaska. J. Fish. Res. Board Can. 32: 689-697.

Dahlke, L.W., and M.R. Falk. 1979. Data on Arctic char from the Jayco River, Northwest Territories, 1975. Can. Fish. Mar. Serv. Data Rep. 156: 1-11.

Dalene, M. 1973. Roya (Salvelinus alpinus (L)) i Katnosa, Alder, vekst, bestandstorrelse, dodlighet og beskatning. Thesis, University of Oslo, Norway. The char (Salvelinus alpinus (L.)) in Katnosa Lake. Age, growth, population, mortality, and exploitation. Can. Transl. Fish. and Aquat. Sci. No. 4613, 1979.

Dempson, J.B. 1978. Biological assessment of Arctic char (Salvelinus alpinus L.) stocks and summary of the Atlantic salmon (Salmo salar L.) fishery in northern Labrador. Fish. Mar. Serv. Tech. Rep. 817: 54 p.

Dempson, J.B. 1981. Assessment of several northern Labrador Arctic charr stocks. CAFSAC Res. Doc. 81/14. 15 p.

Dempson, J.B., L. LeDrew, and T. Nicholls. 1979. Review of biological information on Arctic char (Salvelinus alpinus) in Labrador and present status of the commercial fishery, p. 60-74. In symposium on research in the Labrador coastal and offshore region. Memorial University of Newfoundland Printing Services.

Dick, T.A., and M. Belosevic. 1981. Parasites of Arctic charr Salvelinus alpinus (Linnaeus) and their use in separating sea-run and non-migrating charr. J. Fish. Biol. 18: 339-347.

Dixon, W.J., and M.B. Brown. 1979. Biomedical computer programs P-series. University of California Press, Berkeley. 880 pp.

Dyke, A.P. 1967. The Arctic char Fishery in northern Labrador, p. 1-10. In field research in Labrador-Ungava. McGill Sub-Arctic Research Laboratory Annual Report 1965-66. Paper No. 23.

Eddy, S.B., and M.W. Lankester. 1978. Feeding and migratory habits of Arctic char, Salvelinus alpinus, indicated by the presence of the swimbladder nematode Cystidicola cristivomeri White. J. Fish. Res. Board Can. 35: 1488-1491.

Elliott, D.L., and S.K. Short. 1979. The northern limit of trees in Labrador: a discussion. Arctic 32(3): 201-206.

Elliott, J.M. 1977. Some methods for the statistical analysis of samples of benthic invertebrates. Freshwater Biological Association Scientific Publication No. 25. 156 p.

Everhart, W.H., and C.A. Waters. 1965. Life history of the blueback trout (Arctic char, Salvelinus alpinus (Linnaeus)) in Maine. Trans. Am. Fish. Soc. 94: 393-397.

Falk, M.R., and L.W. Dahlke. 1979. Data on the Arctic char sport fishery at Tree River, Northwest Territories, 1978. Can. Fish. Mar. Serv. Data Rep. 153: 32 p.

Fleming, A.M. 1960. Age, growth and sexual maturity of cod (Gadus morhua L.) in the Newfoundland area, 1947-1950. J. Fish. Res. Board Can. 17(6): 775-809.

Frohne, I.V. 1973. Statistical analyses of discrete morphology in northern populations of the fish genus Salvelinus. University of Alaska Biol. Pap. 13: 10-20.

Frost, W.E. 1963. The homing of charr Salvelinus willughbii (Gunther) in Windermere. Anim. Behav. 11: 74-82.

Garside, E.T. 1966. Developmental rate and vertebral number in salmonids. J. Fish. Res. Board Can. 23(10): 1537-1551.

Glova, G., and P. McCart. 1974. Life history of Arctic char (Salvelinus alpinus) in the Firth River, Yukon Territory p. 1-50. In P. McCart (ed.) Life histories of anadromous and freshwater fish in the western Arctic. Can. Arctic Gas Study Ltd., Biol. Rept. Series 20(3).

Glova, G., and P. McCart. 1978. Studies of Arctic char populations in Nachvak Fiord, Labrador. Report to Esso Resources Canada Limited, Aquitaine Co. of Canada Ltd., and Canada-Cities Services Limited, Calgary, 116 p.

Grainger, E.H. 1953. On the age, growth, migration, reproductive potential and feeding habits of the Arctic char (Salvelinus alpinus) of Frobisher Bay, Baffin Island. J. Fish. Res. Board Can. 10: 326-370.

Gulland, J.A. 1969. Manual of methods for fish stock assessment. Part I. Fish population analyses. FAO Man. Fish. Sci., 4, FRS/M4, Rome, 154 p.

Gullestad, N. 1974. On the lack of winter zones in the centre of scales from Arctic char (Salmo alpinus L.). Norw. J. Zool. 22: 141-143.

Hamley, J.M. 1975. Review of gillnet selectivity. J. Fish. Res. Board Can. 32: 1943-1949.

Healey, M.C. 1975. Dynamics of exploited whitefish populations and their management with special reference to the Northwest Territories. J. Fish. Res. Board Can. 32(3): 427-448.

Hubbs, C., and K.F. Lagler. 1970. Fishes of the Great Lakes region. University of Michigan Press, Ann Arbor, Mich. 213 p.

Hunter, J.G. 1964. Arctic char fishery of the Labrador coast. Arctic Biological Station Annual Rept. 1964-1965: 1-9.

Hunter, J.G. 1970. Production of Arctic char (Salvelinus alpinus Linnaeus) in a small arctic lake. Fish. Res. Board Can. Tech. Rep. 321: 1-190.

Hunter, J.G. 1976. Arctic char and hydroelectric power in the Sylvia Grinnell River. Fish. Res. Board Can. Man. Rep. No. 1376: 21 p.

Jennrich, R., and P. Sampson. 1979. Stepwise discriminant analysis, p. 711-733. In W.J. Dixon and M.B. Brown (ed.) Biomedical computer programs P-series. University of California Press, Berkeley.

Jensen, K.W., and M. Berg. 1977. Growth, mortality, and migrations of the anadromous char, Salvelinus alpinus L., in the Vardnes River, Troms, Northern Norway. Inst. Freshw. Res. Drottningholm Rep. 56: 70-80.

Johnson, L. 1976. Ecology of arctic populations of lake trout (Salvelinus namaycush), lake whitefish (Coregonus clupeaformis) and arctic char (Salvelinus alpinus) and associated species in unexploited lakes of the Canadian Northwest Territories. J. Fish. Res. Board Can. 33: 2459-2488.

Johnson, L. 1980. The arctic charr, Salvelinus alpinus, p. 15-98. In E. K. Balon (ed.) Charrs, salmonid fishes of the genus Salvelinus. Dr. W. Junk, Publisher, The Hague, Netherlands.

Kipling, C. 1972. The commercial fisheries of Windermere. Trans. Cumberland and Westmorland Antiquarian and Archaeological Society. LXXII(XI): 156-204.

Kircheis, F. W. 1976. Reproductive biology and early life history of the sunapee trout of Floods Pond, Maine. Trans. Amer. Fish. Soc. 105(5): 615-619.

Klecka, W. R. 1975. Discriminant analysis, p. 434-467. In N. H Nie et al. (ed.) Statistical Package for the Social Sciences. McGraw-Hill, New York.

Kornfield, I., K.F. Beland, J.R. Moring, and F.W. Kircheis. 1981. Genetic similarity among endemic Arctic char (Salvelinus alpinus) and implications for their management. Can. J. Fish. Aquat. Sci. 38: 32-39.

Kristofferson, A. H., and G. W. Carder. 1980. Data from the commercial fishery for Arctic charr, Salvelinus alpinus (Linnaeus), in the Cambridge Bay area, Northwest Territories, 1971-78. Can. Data Rep. Fish. Aquat. Sci. No. 184. 25 p.

Lachenbruch, P. A. 1975. Discriminant analysis. Hafner Press, London. 128 p.

Lachenbruch, P. A., and Mickey. 1968. Estimation of error rates in discriminant analysis. Technometrics. 10: 1-11.

Le Cren, E. D. 1951. The length-weight relationship and seasonal cycle in gonad weight and condition in the perch (Perca fluviatilis). J. Animal Ecol. 20: 201-219.

Lee, R. L. G. 1969. The ecology of the Arctic char, Salvelinus alpinus L., the brook trout, Salvelinus fontinalis Mitchill, and the Atlantic salmon, Salmo salar L., in the Leaf River, Ungava. M. Sc. Thesis. University of Waterloo. 147 p.

Le Jeune, R. 1967. L'Omble chevalier anadrome du Kagnersoualoudjouark. Service de la Faune, Quebec, Bull. 10: 1-45. The sea-run Arctic char of George River. Fish. Mar. Serv. Transl. No. 4360, 1978.

Lidicker, W. Z. 1952. Biological field report, p. 1-2. In D. C. Nutt, Blue Dolphin Labrador Expedition 1952. Annex C.

Lopoukhine, N., N.A. Prout, and E.H. Hirvonen. 1978. Ecological land classification of Labrador; a reconnaissance. Ecological Land Classification Series No. 4. Environmental Management Service, Fisheries and Environment Canada, Halifax, N.S. 85 p.

Marr, J.C. 1955. The use of morphometric data in systematic, racial and relative growth studies. Copeia 1: 23-31.

Mattox, W.G. 1973. Fishing in west Greenland 1910-1966 the development of a new native industry. Medd. om Grønland. Bd. 197 Nr. 1.

McAllister, D.E., and B.W. Coad. 1974. Fishes of Canada's national capital region. Fish. Res. Board Misc. Spec. Pub. 24. 203 p.

McBride, D.N. 1980. Homing of Arctic char, Salvelinus alpinus (Linnaeus) to feeding and spawning sites in the Wood River Lake system, Alaska. Alaska Dept. Fish and Game, Info. Leaflet No. 184.

McCart, P.J. 1980. A review of the systematics and ecology of Arctic char, Salvelinus alpinus, in the western Arctic Can. Tech. Rep. Fish. Aquat. Sci. No. 935. 89 p.

McCart, P., and H. Bain. 1974. An isolated population of Arctic char (Salvelinus alpinus) inhabiting a warm mineral spring above a waterfall at Cache Creek, Northwest Territories. J. Fish. Res. Board Can. 31: 1408-1414.

McCart, P., and P. Craig. 1971. Meristic differences between anadromous and freshwater resident Arctic char (Salvelinus alpinus) in the Sagavanirktok River drainage, Alaska. J. Fish. Res. Board Can. 28: 115-118.

McCart, P., and Craig. 1973. Life history of two isolated populations of Arctic char (Salvelinus alpinus) in spring-fed tributaries of Canning River, Alaska. J. Fish. Res. Board Can. 30: 1215-1230.

McCart, P.J., and J. Den Beste. 1979. Aquatic resources of the Northwest Territories. Science Advisory Board of the Northwest Territories. 56 p.

McCleave, J.D., G.W. LaBar, and F.W. Kircheis. 1977. Within-season homing movements of displaced mature sunapee trout (Salvelinus alpinus) in Floods Pond, Maine. Trans. Am. Fish. Soc. 106(2): 156-162.

McPhail, J.D. 1961. A systematic study of the Salvelinus alpinus complex in North America. J. Fish. Res. Board Can. 18(5): 793-816.

Moore, J.W. 1975a. Reproductive biology of anadromous Arctic char, Salvelinus alpinus (L.), in the Cumberland Sound area of Baffin Island. J. Fish Biol. 7: 143-151.

Moore, J.W. 1975b. Distribution, movements, and mortality of anadromous Arctic char, Salvelinus alpinus L., in the Cumberland Sound area of Baffin Island. J. Fish. Biol. 7: 339-348.

Moore, J.W. and I.A. Moore. 1974. Food and growth of Arctic char, Salvelinus alpinus (L.), in the Cumberland Sound area of Baffin Island. J. Fish Biol. 6: 79-92.

Morrison, D.F. 1967. Multivariate statistical methods. McGraw-Hill, New York. 338 p.

Morrow, J.E. 1980. Analysis of the dolly varden charr, Salvelinus malma, of northwestern North America and northeastern Siberia, p. 323-338. In E.K. Balon (ed.) Charrs, salmonid fishes of the genus Salvelinus. Dr. W. Junk, Publisher, The Hague, Netherlands.

Murphy, H.P. 1972. A report of biological operations Sand Hill River, Labrador, 1971. Prog. Rep. No. 89. Res. Dev. Branch, Nfld. Region. 107 p.

Murphy, H.P. 1974. Biological operations Sand Hill River, Labrador, 1972 and 1973. Int. Rep. Ser. No. New/I-74-6. Res. Dev. Branch. Nfld. Region.

Nielsen, J. 1961a. Contributions to the biology of the Salmonidae in Greenland. III. Preliminary results of tagging experiments with char, Salvelinus alpinus (L.), in Greenland. Medd. om Grønl. 159: 24-48.

Nielsen, J. 1961b. Contributions to the biology of the Salmonidae in Greenland. IV. Age and growth of the freshwater stage of anadromous char, Salvelinus alpinus (L.). Medd. om Grønl. 159: 49-75.

Nordeng, H. 1961. On the biology of char (Salmo alpinus L.) in Salangen, North Norway. I. Age and spawning frequency determined from scales and otoliths. Nytt. Mag. Zool. 10: 67-123.

Nordeng, H. 1971. Is the local orientation of anadromous fishes determined by pheromones? Nature 233: 411-413.

Nordeng, H. 1977. A pheromone hypothesis for homeward migration in anadromous salmonids. Oikos 28: 155-159.

Nutt, D.C. 1953. Certain aspects of oceanography in the coastal waters of Labrador. J. Fish. Res. Board Can. 10(4): 177-186.

Nutt, D.C. 1963. Fjords and marine basins of Labrador. Polar Notes V. Reprinted in Symposium on research in the Labrador coastal and offshore region. 1979: 258-280. Memorial University of Newfoundland Printing Services.

Nutt, D.C., and L.K. Coachman. 1956. The oceanography of Hebron Fiord, Labrador. J. Fish. Res. Board Can. 13(5): 709-758.

Oxnard, C.E. 1978. One biologist's view of morphometrics. Ann Rev. Ecol. Syst. 9: 219-241.

Peach, J.A. 1975. The tourism and outdoor recreation climate of Newfoundland and Labrador. Env. Can. Atmospheric Env. Serv. Toronto. Project Rept. No. 20.

Peet, R.F. 1968. A report on a reconnaissance survey and counting fence operation conducted in south-east Labrador during 1966. Prog. Rep. No. 48. Res. Dev. Branch. Newfoundland Region. 153 p.

Peet, R.F. 1971. A report on the counting trap and reconnaissance surveys conducted in central coastal Labrador during 1967. Prog. Rep. No. 68. Res. Dev. Branch, Newfoundland Region. 286 p.

Pimental, R.A. 1979. Morphometrics: the multivariate analysis of biological data. Kendall/Hunt Publishing Co., Iowa. 276 p.

Power, G., and R. Le Jeune. 1976. Le potentiel de pêche du Nouveau-Québec. Cah. Geogr. Que. 20(50): 409-428. The fishery potential of New Quebec. Fish. Mar. Serv. Trans. No. 4197, 1978.

Qadri, S.U. 1974. Taxonomic status of the Salvelinus alpinus complex. J. Fish. Res. Board Can. 31: 1355-1361.

Rao, C.R. 1952. Advanced statistical methods in biometric research. John Wiley and Sons, New York. 390 p.

Ricker, W.E. 1975. Computation and interpretation of biological statistics of fish populations. Bull. Fish. Res. Board Can. 191: 382 p.

Robertson, M.R., and D.H. Dowler. 1973. The history of exploitation of the Arctic char of Tree River, Northwest Territories. Paper presented at the Can. Con. Fish. Res. Halifax. 10 p. Manuscript.

Rombough, P.J., S.E. Barbour, and J.J. Kerekes. 1978. Life history and taxonomic status of an isolated population of Arctic char, Salvelinus alpinus, from Gros Morne National Park, Newfoundland. J. Fish. Res. Board Can. 35: 1537-1541.

Ruhlé, Ch. 1977. Biologie and Bewirtschaftung des Seesaiblings (Salvelinus alpinus L.) in Zugersee. Schweiz. Z. Hydrol. 39: 12-45. Biology and management of the European lake char (Salvelinus alpinus L.) in Lake Zug. Fish. Mar. Serv. Transl. No. 4374, 1978.

Saunders, L.H., and J.A. McKenzie. 1971. Comparative electrophoresis of Arctic char. Comp. Biochem. Physiol. 38B: 487-492.

Saunders, L.H., and G. Power. 1969. The Arctic char, Salvelinus alpinus (Linnaeus), of Matamek Lake, Quebec. Nat. Can. 96: 919-934.

Savvaitova, K.A. 1980. Taxonomy and biogeography of charrs in the Palearctic, p. 281-294. In E.K. Balon (ed.). Charrs, salmonid fishes of the genus Salvelinus. Dr. W. Junk, Publisher, The Hague, Netherlands.

Scott, W.B., and E.J. Crossman. 1964. Fishes occurring in the fresh waters of insular Newfoundland. Dep. Fish. Ottawa. 124 p.

Scott, W.B., and E.J. Crossman. 1973. Freshwater fishes of Canada. Bull. Fish. Res. Board Can. 184. 966 p.

Sekerak, A.D., D. Thompson, H. Bain, and J. Acreman. 1976. Summer surveys of the marine ecology of Creswell Bay, Somerset Island and Assistance Bay, Cornwallis Island, N.W.T. 1975. LGL Ltd. Env. Res. Associates, Toronto. 215 p.

Slastnikov, G. 1935. O vozraste i tempe rosta Novozenmil'skogo gol'tsa (Salvelinus alpinus L.). Tr. Arkt. Inst. XVII: 71-89. On the age and growth rate of Novaya Zemlya char (Salvelinus alpinus L.). Fish. Mar. Serv. Trans. No. 4423, 1978.

Sokal, R.R., and F.J. Rohlf. 1969. Biometry. W.H. Freeman and Co., San Francisco. 776 p.

Sopuck, R.D. 1977. The Arctic char fishery of the Sylvia Grinnell River, Northwest Territories in 1976. File Report, Freshwater Institute, Fish Mar. Serv. Winnipeg. 21 p.

Snedecor, G.W., and W.G. Cochran. 1967. Statistical methods. Iowa State University Press, Ames, Iowa. 593 p.

Sprules, W.M. 1952. The Arctic char of the west coast of Hudson Bay. J. Fish. Res. Board Can. 9(1): 1-15.

Tåning, A.V. 1952. Experimental study of meristic characters in fishes. Biological Reviews 27: 169-193.

Thomson, J.A. 1957. On the biology of the Arctic char, Salvelinus alpinus (L.) of Nettilling Lake, Baffin Island N.W.T. M. Sc. Thesis. McGill University, Montreal. 95 p.

Vladykov, V.D. 1954. Taxonomic characters of the eastern North American chars (Salvelinus and Cristivomer). J. Fish. Res. Board Can. 11: 904-932.

Vladykov, V.D. 1956. Fecundity of wild speckled trout (Salvelinus fontinalis) in Quebec lakes. J. Fish. Res. Board Can. 13: 799-841.

Walters, V. 1955. Fishes of western Arctic America and eastern Arctic Siberia: taxonomy and zoogeography. Bull. Am. Mus. Nat. Hist. 106(5): 255-368.

Waters, C.A. 1960. A study of the life history and taxonomic position of the blueback trout, Salvelinus oquassa (Girard). M. Sc. Thesis. University of Maine. 90 p.

Westrheim, S.J., and W.E. Ricker. 1978. Bias in using an age-length key to estimate age frequency distributions. J. Fish. Res. Board Can. 35: 184-189.

Wheeler, E.P. 1935. The Nain-Okak section of Labrador. The Geographical Rev. 25: 240-254.

Yessipov, V.K. 1935. Materialy po biologii i promyslu novozemil'sogo gol'tsa (Salvelinus alpinus L.). Tr. Arkt. Inst. XVII: 5-71. Materials on the biology and fishery of the Arctic char (Salvelinus alpinus L.) on Novaya Zemlya. Fish. Mar. Serv. Transl. No. 4436. 1978.

Yoshihara, H.T. 1973. Some life history aspects of Arctic char. Federal aid in fish restoration Project F9-5. Sport Fish Investigation of Alaska 14: 1-63.

Appendix 1. Univariate statistics for meristic and morphometric characters from Napartok Bay, Saglek Fiord and Ramah Bay Arctic charr. Morphometric data from charr captured in 114 and 127 mm mesh gillnets and within fork length interval 44.0-59.9 cm.

	Napartok Bay				Saglek Fiord				Ramah Bay			
Meristic characters	N	Mean	S.D.	Range	N	Mean	S.D.	Range	N	Mean	S.D.	Range
Fork L.	87	49.19	3.19	44.0-57.8	50	51.75	3.55	44.5-59.6	98	49.44	3.75	44.0-58.5
Standard L.	87	44.35	2.81	39.6-51.8	50	47.11	3.54	40.5-58.7	84	45.29	3.51	39.5-54.2
Girth-oper.	87	24.73	1.69	22.0-28.7	50	25.05	2.20	19.3-29.6	80	24.74	2.30	18.5-31.8
Girth-max.	87	29.63	1.95	21.0-33.9	50	29.46	2.30	25.4-33.7	80	29.34	2.64	23.0-36.4
Predorsal	87	20.61	1.70	17.4-28.6	50	21.32	1.49	17.8-24.4	85	20.45	1.65	17.2-25.1
Dorsal to adip.	87	11.41	1.01	9.5-14.3	50	11.78	1.11	9.2-14.6	86	11.28	1.05	8.9-14.4
Head	87	9.76	0.77	8.2-11.8	50	10.35	0.93	7.9-12.9	86	9.75	0.95	8.3-13.2
Postorbital	87	5.42	0.45	4.4-6.6	50	5.75	0.50	4.6-6.8	86	5.52	0.57	4.5-7.3
Pectoral L.	87	6.96	0.69	5.5-8.7	50	7.29	0.89	5.3-4.7	86	6.74	1.07	2.3-9.7
Snout L.	87	2.71	0.36	1.9-3.6	50	2.91	0.42	2.1-4.1	86	2.83	0.43	2.0-4.2
Orbit dia.	87	1.41	0.14	1.0-1.8	50	1.42	0.16	1.1-1.8	79	1.31	0.12	1.1-1.6
Upper jaw L.	87	5.16	0.67	3.7-6.7	50	5.44	0.71	3.8-7.7	86	5.13	0.73	4.0-7.9
Morphometric characters												
Dorsal	76	14.71	0.81	12-16	107	14.82	0.71	13-16	89	14.99	0.68	13-16
Anal	76	13.71	0.61	12-15	107	13.38	0.65	12-15	88	13.57	0.77	12-15
L. Pectoral	76	14.07	0.96	11-16	106	13.89	0.80	11-15	89	13.83	0.77	12-15
L. Pelvic	76	9.20	0.46	8-10	108	9.10	0.39	8-10	89	8.23	0.45	8-10
Vertebrae	93	64.93	0.82	63-67	144	65.51	1.04	63-69	180	65.38	1.06	63-69
Gill raker - upper	91	9.88	0.71	9-12	139	9.96	0.79	8-12	187	9.54	0.92	8-13
Gill raker - lower	91	15.51	0.96	14-18	139	15.19	1.05	13-18	187	14.85	0.92	12-17
Gill raker - total	91	25.39	1.38	23-29	142	25.13	1.55	22-29	187	24.39	1.45	21-28
Branchiostegal	93	10.62	0.82	9-13	148	10.94	0.78	9-13	191	10.80	0.75	9-13

Appendix 2. Summary of age, length and weight data for commercially caught Arctic charr from Anaktalik Bay, 1977-1980.

Age	N	Fork Length (cm)			Weight (kg)*		
		Mean	S.D.	Range	Mean	S.D.	Range
6	13	45.5	3.4	41.2-52.2	1.01	0.30	0.71-1.59
7	137	49.6	4.7	40.0-60.5	1.48	0.50	0.11-2.99
8	189	53.0	4.7	42.0-69.0	1.71	0.50	0.68-3.87
9	164	55.1	6.0	41.3-69.5	1.85	0.68	0.61-3.76
10	101	57.0	7.5	42.5-76.0	2.08	0.98	0.70-5.32
11	59	57.1	7.8	41.2-76.2	2.04	1.02	0.62-5.18
12	28	57.2	7.8	45.2-69.9	2.01	0.99	0.71-4.19
13	14	58.3	7.4	44.1-71.0	2.21	1.08	0.79-4.50
14	9	56.5	7.1	49.3-69.5	2.03	1.01	1.14-3.75
15	3	65.3	14.4	54.0-81.5	3.38	3.05	1.57-6.90
16	1	50.0			1.14		
Summary	718	54.0	6.7	40.0-81.5	1.80	0.77	0.11-6.90
Mean age	8.9						

*Gutted head-on weight

Appendix 3. Summary of age, length and weight data for commercially caught Arctic charr from Napartok Bay, 1977-1980.

Age	N	Fork Length (cm)			Weight (kg)*		
		Mean	S.D.	Range	Mean	S.D.	Range
7	6	48.3	5.0	44.5-58.3	1.26	0.52	0.89-2.28
8	21	50.0	3.8	42.5-57.5	1.31	0.34	0.79-1.81
9	51	53.3	5.7	44.0-66.0	1.55	0.52	0.81-2.96
10	92	54.6	5.2	42.5-67.5	1.60	0.42	0.69-2.80
11	106	57.2	5.3	47.1-73.6	1.83	0.54	0.96-4.18
12	155	58.6	5.2	46.0-73.2	1.90	0.53	0.90-4.17
13	82	59.3	4.8	50.0-72.0	1.96	0.51	1.17-3.22
14	63	60.1	6.1	49.5-75.1	2.01	0.63	0.97-4.51
15	33	59.5	5.9	50.0-70.2	2.00	0.60	1.16-3.71
16	12	58.6	4.7	52.5-67.5	1.80	0.42	1.26-2.39
17	8	56.9	3.2	51.5-60.4	1.69	0.36	1.16-2.17
18	8	60.0	6.5	50.5-70.0	1.93	0.59	1.10-2.80
19	3	54.7	3.9	52.0-59.2	1.43	0.27	1.26-1.74
20							
21	1	52.9			1.38		
Summary	641	57.3	5.9	42.5-75.1	1.81	0.55	0.69-4.51
Mean age	11.9						

*Gutted head-on weight

Appendix 4. Comparison of mean length at age between male and female Arctic charr, with age-weight relationship and sex ratio from Napartok Bay, 1978-1980. Significance levels are P<0.05 (*) and P<0.01 (**).

	Fork Length (cm)								Round Weight (kg)						
	Male			Female					Male			Female			
Age	N	Mean	S.D.	N	Mean	S.D.	Range	t	N	Mean	S.D.	N	Mean	S.D.	Range
5	2	29.6	2.8				27.6-31.6		2	0.25	0.07				0.20-0.30
6	5	36.4	2.7	7	37.7	3.8	30.3-40.9	0.62	5	0.62	0.19	7	0.60	0.17	0.30-0.90
7	21	41.7	4.6	16	39.1	3.5	32.6-51.3	1.87	21	0.99	0.42	16	0.71	0.21	0.40-2.01
8	19	46.5	4.2	26	45.9	2.6	37.4-56.2	0.59	19	1.36	0.33	26	1.34	0.24	0.60-1.90
9	22	49.4	6.7	26	45.6	4.8	30.8-62.2	2.24*	22	1.76	0.74	26	1.36	0.42	0.30-3.40
10	23	48.6	4.4	23	49.1	5.1	36.9-61.4	0.34	23	1.65	0.41	23	1.65	0.49	0.60-2.80
11	17	51.1	7.6	21	49.8	4.2	37.8-65.5	0.63	17	1.93	0.82	21	1.70	0.41	0.58-3.50
12	8	50.1	7.4	22	51.4	2.9	42.0-66.4	0.48	8	1.73	0.69	22	1.76	0.36	1.10-3.30
13	8	48.2	3.6	23	51.9	4.5	42.4-62.5	2.09*	8	1.47	0.34	23	1.94	0.49	1.02-3.10
14	3	47.4	1.6	14	50.0	5.3	39.1-57.8	0.81	3	1.40	0.27	14	1.66	0.53	0.70-2.60
15	2	46.5	0.8	9	50.8	3.1	45.9-56.0	1.96	2	1.46	0.20	9	1.75	0.21	1.31-2.23
16	2	47.5	0.6	1	47.9		47.0-47.9		2	1.38	0.02	1	1.42		1.36-1.42
17	2	48.5	4.9				45.0-52.0		2	1.60	0.43				1.30-1.90
18	1	52.4		2	55.6	0.4	52.4-55.8		1	1.77		2	2.00	0.06	1.77-2.04
19				1	45.5							1	1.29		
20	1	48.5							1	1.50					
Total	136	47.0	6.6	191	47.8	5.7	27.6-66.4	1.21	136	1.48	0.64	191	1.41	0.53	0.20-3.50
Men age		9.8			10.6										
% Male		41.6													
X^2		9.25**													

Appendix 5. Comparison of mean length at age between male and female Arctic charr, with age-weight relationship and sex ratio from Saglek Fiord, 1978-1980. Significance levels are P<0.05 (*) and P<0.01 (**).

	Fork Length (cm)								Round Weight (kg)						
	Male			Female					Male			Female			
Age	N	Mean	S.D.	N	Mean	S.D.	Range	t	N	Mean	S.D.	N	Mean	S.D.	Range
3	5	19.1	1.3	1	18.2		17.3-20.6		5	0.10	0.00	1	0.00	0.00	0.10-0.10
4	3	18.2	1.5	3	24.6	10.0	16.5-36.1	1.10	3	0.10	0.00	3	0.27	0.29	0.10-0.60
5	7	27.8	5.1	7	26.2	6.1	19.7-37.0	0.53	7	0.27	0.11	7	0.23	0.19	0.10-0.60
6	20	34.4	5.0	16	33.7	4.9	25.6-48.0	0.34	20	0.56	0.33	16	0.48	0.21	0.20-1.62
7	50	42.3	4.4	51	40.7	4.2	31.7-51.2	1.92	50	1.00	0.34	51	0.91	0.29	0.30-2.00
8	57	44.9	5.1	48	43.6	3.9	31.5-55.0	1.47	57	1.28	0.47	48	1.16	0.34	0.30-2.30
9	35	48.4	5.6	35	46.6	4.1	35.8-58.6	1.54	35	1.62	0.56	35	1.42	0.41	0.60-2.80
10	23	50.5	5.0	27	48.0	5.7	35.4-59.1	1.59	23	1.78	0.58	27	1.64	0.48	0.56-2.90
11	12	50.4	4.7	22	49.7	4.6	39.5-62.7	0.40	12	1.82	0.65	22	1.70	0.51	0.61-3.50
12	7	53.2	6.7	21	50.5	4.3	42.5-67.0	1.25	7	2.08	1.01	21	1.70	0.49	1.00-4.30
13	8	53.0	5.3	9	50.0	5.1	42.5-62.9	1.20	8	1.69	0.29	9	1.66	0.50	1.00-2.41
14	1	50.0		11	53.0	2.8	48.5-57.0		1	1.40		11	1.87	0.34	1.40-2.40
15	2	50.4	3.5	9	54.8	2.3	47.9-58.6		2	1.41	0.16	9	1.90	0.21	1.40-2.22
16	1	57.5		10	53.8	3.2	49.0-59.7		1	2.25		10	1.95	0.43	1.20-2.62
17	1	51.5		6	54.7	2.4	46.4-58.8		1	1.67		6	2.03	0.23	1.20-2.37
18				3	48.9	2.1	46.8-51.0					3	1.38	0.21	1.20-1.61
19															
20															
21				1	47.0							1	1.30		
Total	236	44.2	8.9	280	45.2	7.9	16.5-67.0	1.33	236	1.27	0.66	280	1.31	0.59	0.10-4.30
Mean age		8.2			9.7										
% Male		45.7													
X^2		3.75													

Appendix 6. Comparison of mean length at age between male and female Arctic charr, with age-weight relationship and sex ratio from Ramah Bay, 1978. Significance levels are P<0.05 (*) and P<0.01 (**).

	Fork Length (cm)								Round Weight (kg)						
	Male			Female					Male			Female			
Age	N	Mean	S.D.	N	Mean	S.D.	Range	t	N	Mean	S.D.	N	Mean	S.D.	Range
5	1	21.0							1	0.10					
6	3	39.6	2.8	2	40.8	0.8	37.2-42.7	0.58	3	0.83	0.22	2	0.99	0.05	0.70-1.08
7	22	40.8	5.1	14	40.5	3.2	28.8-48.3	0.24	22	0.95	0.34	14	0.88	0.23	0.24-1.50
8	10	46.2	4.4	16	43.9	4.9	33.6-52.1	1.20	10	1.30	0.33	16	1.15	0.38	0.45-1.97
9	12	49.2	5.1	23	47.5	4.4	35.2-55.5	1.03	12	1.64	0.48	23	1.41	0.39	0.63-2.31
10	23	50.5	6.9	25	50.1	2.7	35.6-61.3	0.28	23	1.74	0.68	25	1.62	0.27	0.59-3.16
11	17	54.4	4.9	12	49.8	4.9	37.8-63.1	2.47*	17	2.20	0.71	12	1.68	0.47	0.68-3.86
12	9	54.2	7.7	5	50.4	3.4	45.8-69.8	1.04	9	1.96	0.63	5	1.57	0.26	1.21-2.84
13	2	61.7	14.4	4	54.4	2.4	51.5-71.9	0.72	2	2.96	1.86	4	1.95	0.26	1.65-4.28
14	3	62.1	4.6	4	53.6	2.5	51.8-67.2	3.12*	3	2.94	0.39	4	1.92	0.32	1.64-3.39
15	4	59.1	2.4	2	55.4	2.6	53.5-61.3	1.74	4	2.52	0.20	2	2.24	0.16	2.13-2.75
16	1	67.2		3	56.4	0.4	56.0-67.2		1	4.18		3	2.11	0.18	1.99-4.18
17	1	61.5							1	2.34					
Total	108	49.4	8.8	110	47.8	5.6	21.0-71.9	1.64	108	1.69	0.82	110	1.45	0.46	0.10-4.28
Mean age	9.7				9.8										
% Male	49.5														
X^2	0.02														

Appendix 7. Distribution of age at length with mean length, weight and condition factor for Arctic charr research samples (sexes combined) from Napartok Bay, Labrador, 1978-1980.

Length Interval (cm)	Age																
	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
26.0-27.9	1																1
28.0-29.9																	
30.0-31.9	1	1			1												3
32.0-33.9		1	2														3
34.0-35.9		2	5														7
36.0-37.9		3	4	1	2	1	1										12
38.0-39.9		3	6	1	2		1			1							14
40.0-41.9		2	3	3	2	1											11
42.0-43.9			10	3	3	4	1	1	2								24
44.0-45.9			4	13	10	4	6	1	2	2	1		1		1		45
46.0-47.9			2	13	5	9	3	6	5	4	3	3					53
48.0-49.9				6	12	11	6	3	2	4	3					1	48
50.0-51.9			1	4	5	9	7	6	7	1	2						42
52.0-53.9						2	5	8	6	1			1	1			24
54.0-55.9					1		4	3	3	1	1			2			15
56.0-57.9				1	3	3		1	3	3	1						15
58.0-59.9						1	1										2
60.0-61.9						1	2										3
62.0-63.9					2				1								3
64.0-65.9							1										1
66.0-67.9								1									1
Total	2	12	37	45	48	46	38	30	31	17	11	3	2	3	1	1	327
Mean length (cm)	29.6	37.2	40.6	46.2	47.3	48.9	50.3	51.1	50.9	49.6	50.0	47.6	48.5	54.5	45.5	48.5	47.4
S.D.	2.8	3.3	4.3	3.4	6.0	4.7	5.9	4.5	4.5	4.9	3.3	0.5	4.9	1.8			6.1
Round weight (kg)																	
Mean	0.25	0.61	0.87	1.35	1.55	1.65	1.80	1.75	1.82	1.62	1.70	1.39	1.60	1.92	1.29	1.50	1.50
S.D.	0.07	0.17	0.37	0.28	0.62	0.45	0.63	0.41	0.49	0.60	0.23	0.03	0.43	0.14			0.57
Condition Factor	0.95	1.16	1.24	1.36	1.38	1.39	1.35	1.30	1.35	1.29	1.36	1.29	1.39	1.19	1.36	1.31	1.34

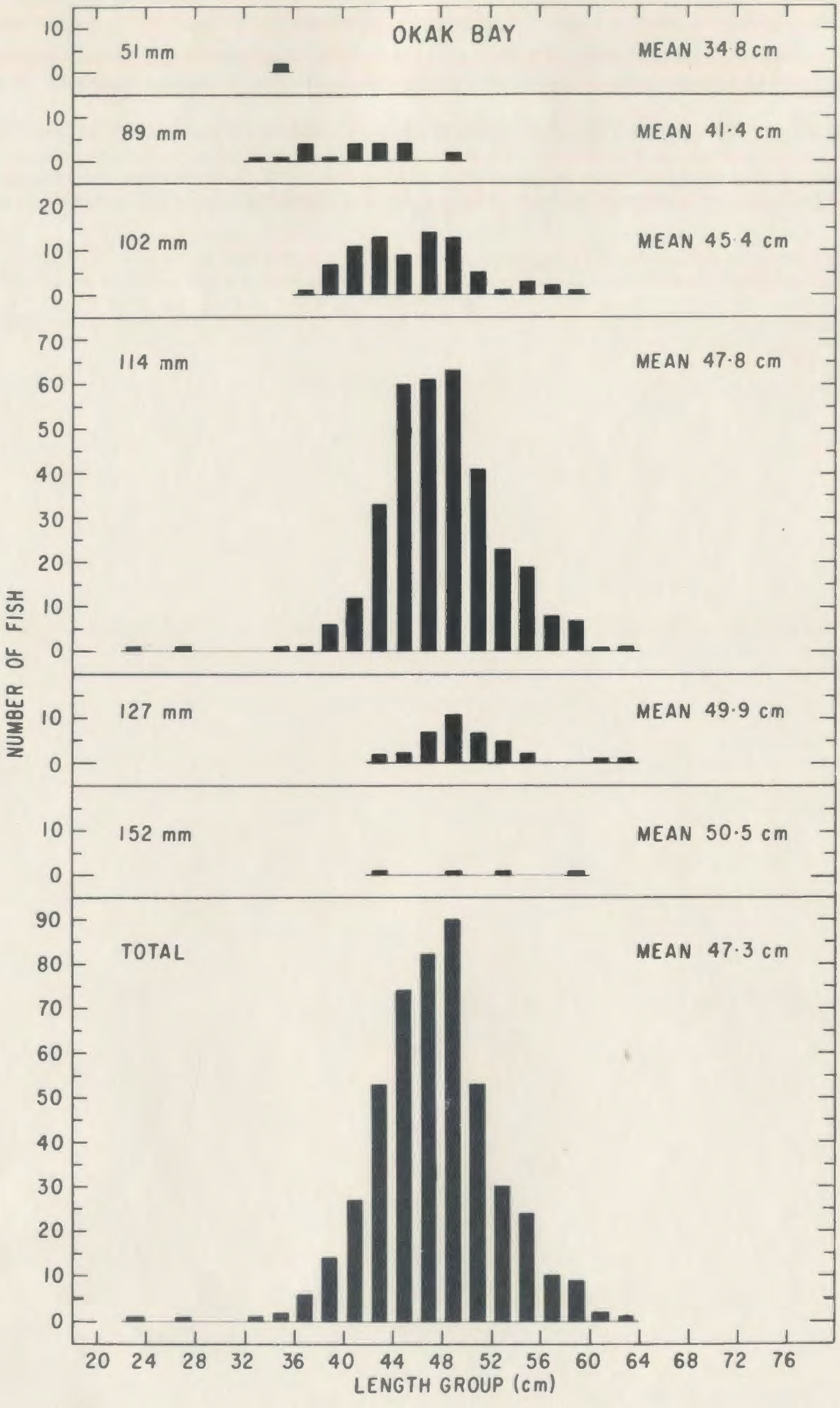
Appendix 8. Distribution of age at length with mean length, weight and condition factor for Arctic charr research samples (sexes combined) from Saglek Fiord, Labrador, 1978-1980.

Length interval	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	Total
16.0-17.9	1	1																		2
18.0-19.9	3	4	2																	9
20.0-21.9	2		1																	3
22.0-23.9			2																	2
24.0-25.9			1	1																2
26.0-27.9			1	3																4
28.0-29.9			3	4																7
30.0-31.9			1	5	2	1														9
32.0-34.9			2	5	4	1														12
34.0-35.9				1	5	2	1	1												10
36.0-37.9		1	1	9	7	5	1	1												25
38.0-39.9				5	17	6	2	1	1											32
40.0-41.9				2	17	14	5	1												39
42.0-43.9					19	19	9	4	1	2	1									55
44.0-45.9					14	20	8	3	3	3	2									53
46.0-47.9					7	16	8	7	6	2	1		1		2	1			1	52
48.0-49.9				1	8	10	14	8	6	2	2	2		2		1				56
50.0-51.9					1	5	12	7	7	6	1	3		1		1				44
52.0-53.9						3	3	8	5	5	5	2	5	2	4					42
54.0-56.9						3	3	3	2	6	2	3	2	2	4					30
56.0-57.9							2	5	1	1	2	2	2	3						18
58.0-59.9							2	1	1				1	1	1					7
60.0-61.9																				
62.0-63.9									1		1									2
64.0-65.9																				
66.0-67.9										1										1
Total	6	6	14	36	101	105	70	50	34	28	17	12	11	11	11	3			1	516
Mean length (cm)	19.0	21.4	27.0	34.1	41.5	44.3	47.5	49.2	49.9	51.2	51.5	52.8	54.0	54.1	53.2	48.9			47.0	44.8
S.D.	1.3	7.3	5.4	4.9	4.4	4.6	4.9	5.5	4.6	5.0	5.3	2.8	3.0	3.3	3.5	2.1				8.3
Round weight (kg)																				
Mean	0.10	0.18	0.25	0.52	0.95	1.22	1.52	1.70	1.74	1.80	1.67	1.83	1.83	1.98	1.87	1.38			1.30	1.30
S.D.		0.20	0.15	0.28	0.32	0.42	0.50	0.52	0.55	0.65	0.40	0.35	0.25	0.41	0.35	0.21				0.62
Condition Factor	1.50	1.57	1.14	1.22	1.29	1.35	1.37	1.40	1.37	1.30	1.22	1.24	1.16	1.24	1.23	1.18			1.25	1.32

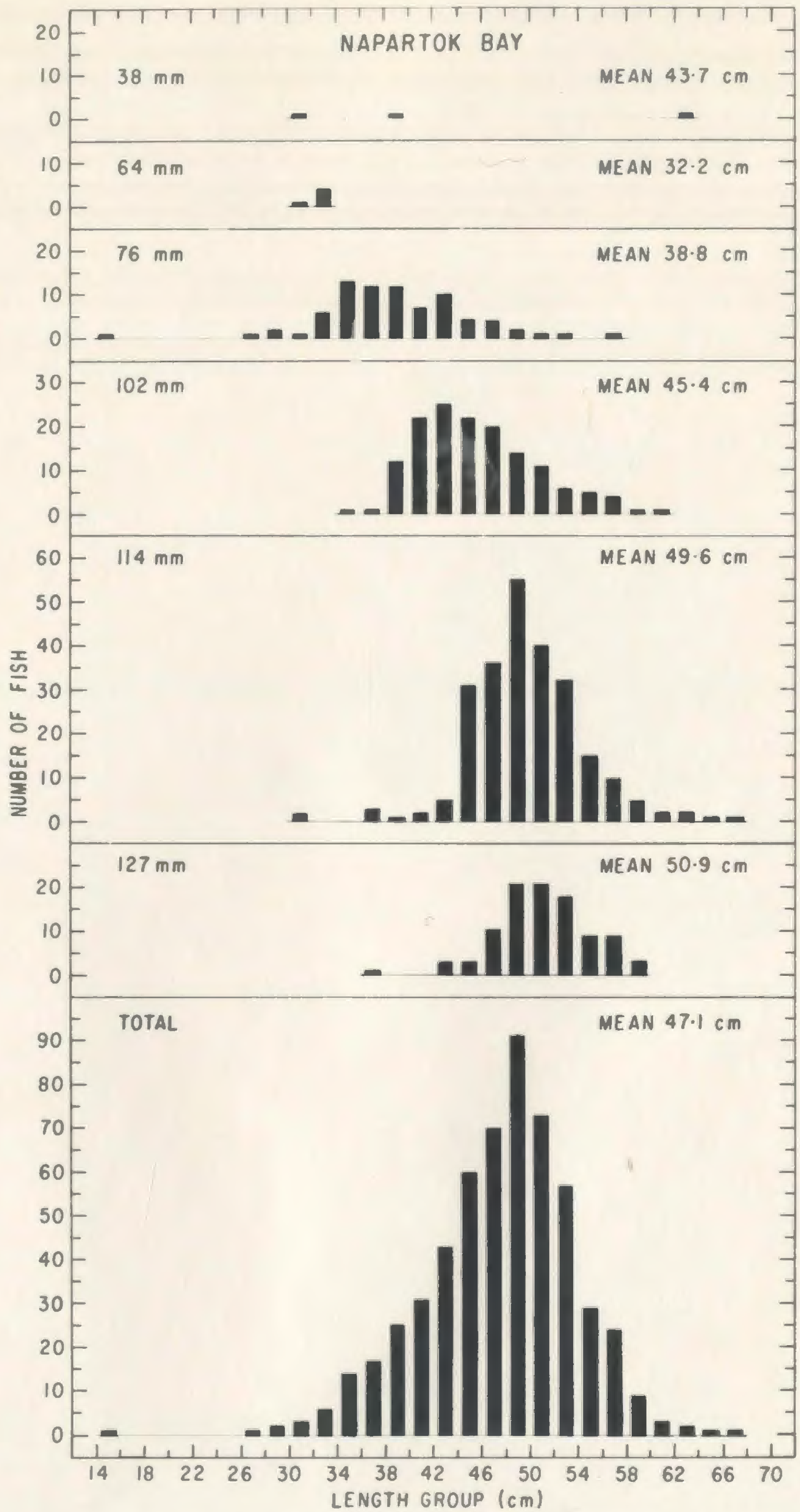
Appendix 9. Distribution of age at length with mean length, weight and condition factor for Arctic charr research samples (sexes combined) from Ramah Bay, Labrador, 1978.

Length interval (cm)	5	6	7	8	9	10	11	12	13	14	15	16	17	Total
20.0-21.9	1													1
22.0-23.9														
24.0-25.9														
26.0-27.9														
28.0-29.9			1											1
30.0-31.9														
32.0-33.9			2	1										3
34.0-35.9			3		1	1								5
36.0-37.9		1	3	1	1		1							7
38.0-39.9		1	5	3										9
40.0-41.9		2	5	3	1									11
42.0-43.9		1	7	1	2	2	1							14
44.0-45.9			7	6	5	8		1						27
46.0-47.9			2	2	4	4	4	1						17
48.0-49.9			1	6	8	5	1	4						25
50.0-51.9				2	6	12	6	2	1	1				30
52.0-53.9				1	4	6	5	1	2	2	1			22
54.0-55.9					3	4	3	2	1		1			14
56.0-57.9						3	2		1	1	1	3		11
58.0-59.9						1	5	1		1	2			10
60.0-61.9						2		1		1	1		1	6
62.0-63.9							1							1
64.0-65.9														
66.0-67.9											1		1	2
68.0-69.9								1						1
70.0-71.9									1					1
Total	1	5	36	26	35	48	29	14	6	7	6	4	1	218
Mean length (cm)	21.0	40.0	40.7	44.8	48.1	50.3	52.5	52.8	56.8	57.2	57.8	59.1	61.5	48.6
S.D.		2.1	4.4	4.8	4.6	5.1	5.3	6.6	7.7	5.5	2.9	5.4		7.4
Round weight (kg)														
Mean	0.10	0.89	0.93	1.21	1.49	1.68	1.98	1.82	2.29	2.36	2.42	2.63	2.34	1.57
S.D.		0.18	0.30	0.36	0.43	0.50	0.67	0.55	1.00	0.63	0.22	1.04		0.67
Condition Factor	1.06	1.37	1.33	1.31	1.31	1.29	1.32	1.22	1.20	1.24	1.26	1.23	1.01	1.29

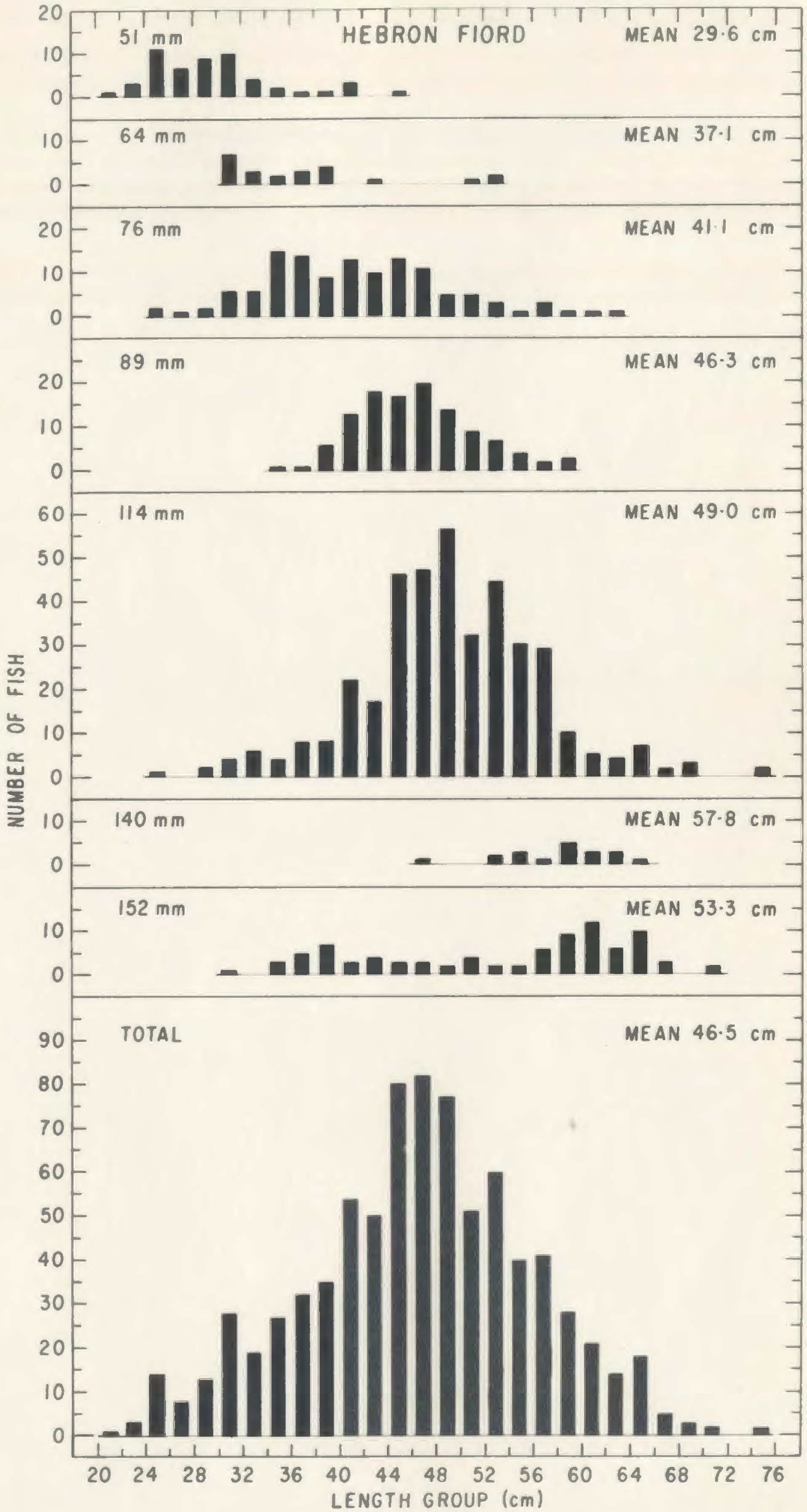
Appendix 10. Length-frequency distribution by mesh size of Okak Bay Arctic charr, 1978-1980.


OKAK BAY
51 mm
MEAN 34·8 cm
89 mm
MEAN 41·4 cm
102 mm
MEAN 45·4 cm
114 mm
MEAN 47·8 cm
127 mm
MEAN 49·9 cm
152 mm
MEAN 50·5 cm
TOTAL
MEAN 47·3 cm
NUMBER OF FISH
0
10
20
30
40
50
60
70
80
90
20
24
28
32
36
40
44
48
52
56
60
64
68
72
76
LENGTH GROUP (cm)

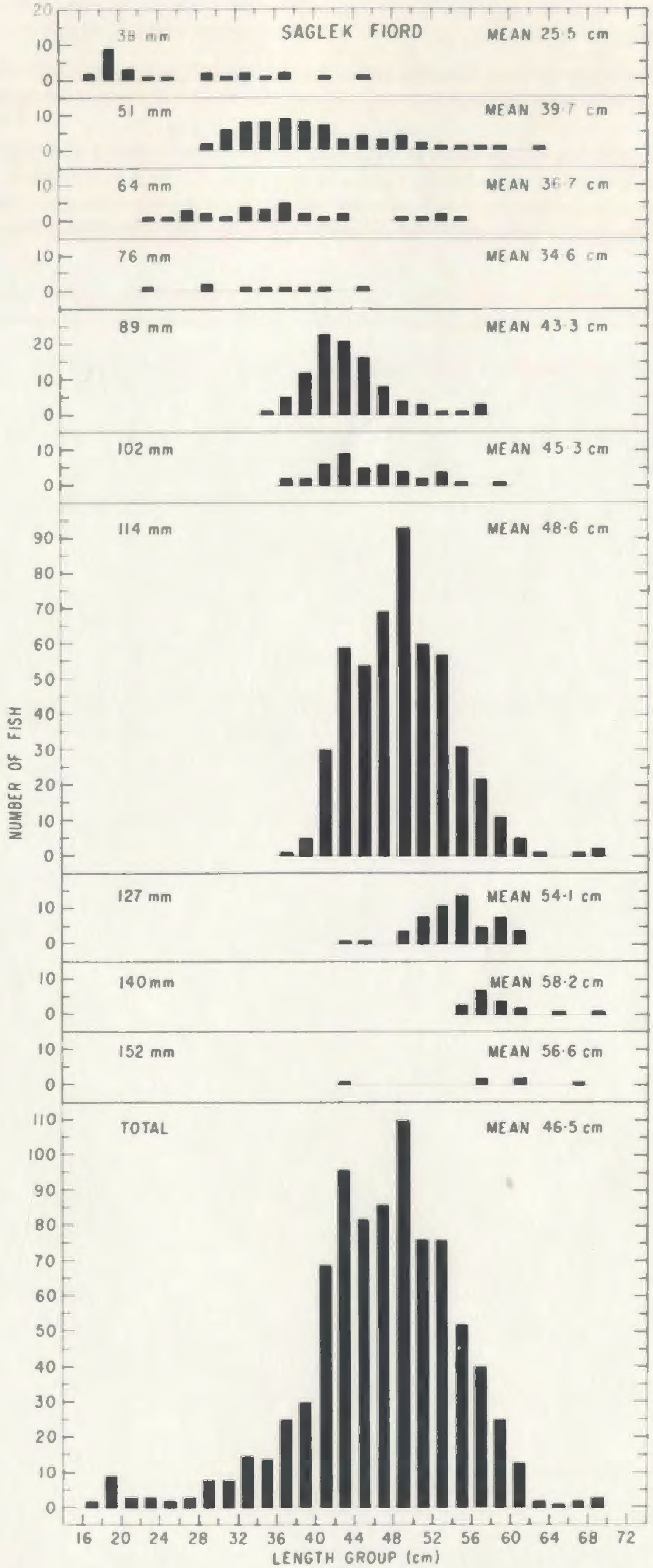
Appendix 11. Length-frequency distribution by mesh size of Napartok Bay Arctic charr, 1978-1980.


NAPARTOK BAY
38 mm
MEAN 43·7 cm
64 mm
MEAN 32·2 cm
76 mm
MEAN 38·8 cm
102 mm
MEAN 45·4 cm
114 mm
MEAN 49·6 cm
127 mm
MEAN 50·9 cm
TOTAL
MEAN 47·1 cm
NUMBER OF FISH
LENGTH GROUP (cm)
14 18 22 26 30 34 38 42 46 50 54 58 62 66 70

Appendix 12. Length-frequency distribution by mesh size of Hebron

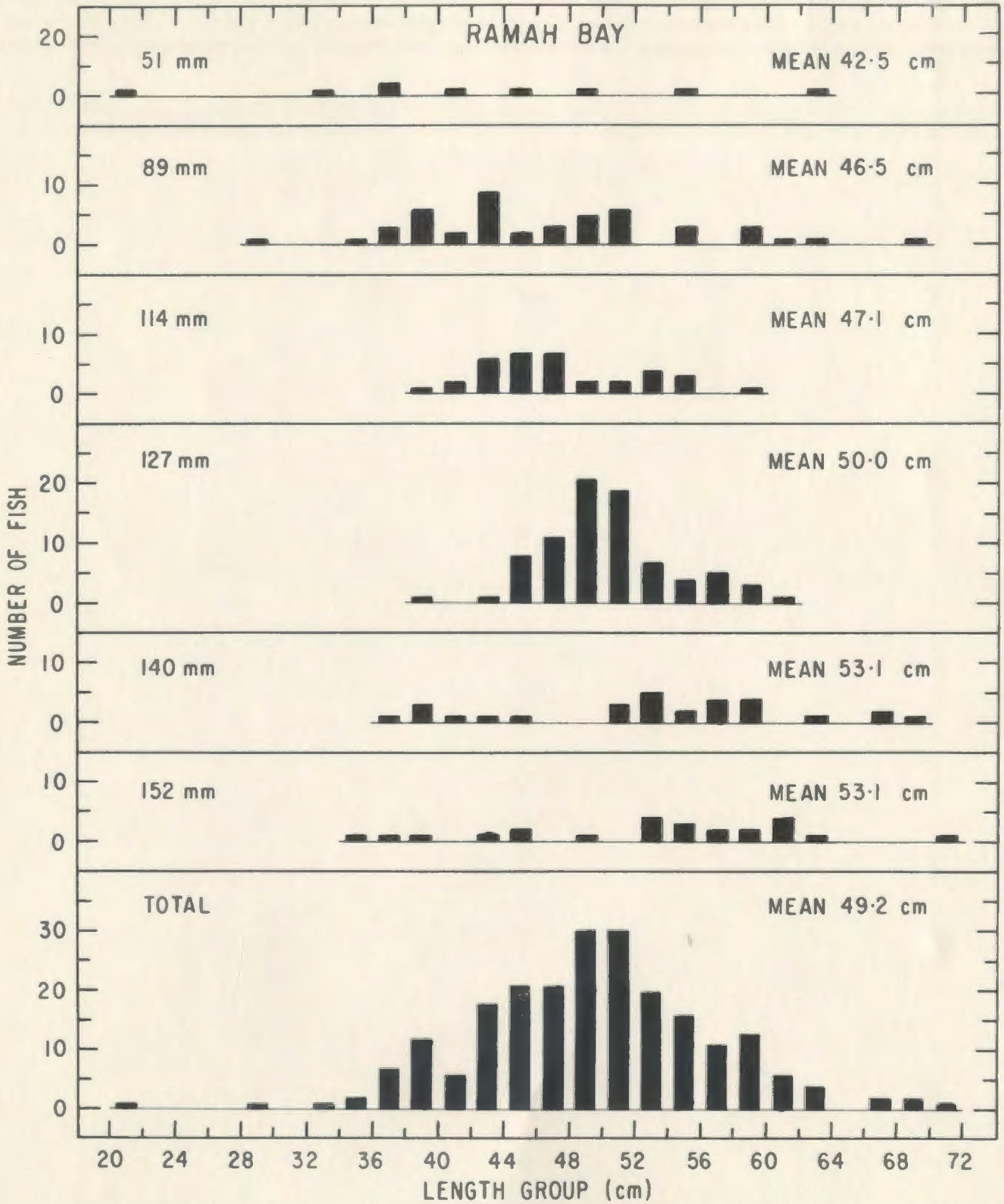

HEBRON FIORD
51 mm
MEAN 29·6 cm
64 mm
MEAN 37·1 cm
76 mm
MEAN 41·1 cm
89 mm
MEAN 46·3 cm
114 mm
MEAN 49·0 cm
140 mm
MEAN 57·8 cm
152 mm
MEAN 53·3 cm
TOTAL
MEAN 46·5 cm
NUMBER OF FISH
LENGTH GROUP (cm)
20 24 28 32 36 40 44 48 52 56 60 64 68 72 76

Appenidx 13. Length-frequency distribution by mesh size of Saglek Fiord Arctic charr, 1978-1980.



SAGLEK FIORD
38 mm
MEAN 25·5 cm
51 mm
MEAN 39·7 cm
64 mm
MEAN 36·7 cm
76 mm
MEAN 34·6 cm
89 mm
MEAN 43·3 cm
102 mm
MEAN 45·3 cm
114 mm
MEAN 48·6 cm
127 mm
MEAN 54·1 cm
140 mm
MEAN 58·2 cm
152 mm
MEAN 56·6 cm
TOTAL
MEAN 46·5 cm
NUMBER OF FISH
LENGTH GROUP (cm)
16 20 24 28 32 36 40 44 48 52 56 60 64 68 72

Appendix 14. Length-frequency distribution by mesh size of Ramah Bay Arctic charr, 1978.


RAMAH BAY
51 mm
MEAN 42·5 cm
89 mm
MEAN 46·5 cm
114 mm
MEAN 47·1 cm
127 mm
MEAN 50·0 cm
140 mm
MEAN 53·1 cm
152 mm
MEAN 53·1 cm
TOTAL
MEAN 49·2 cm
NUMBER OF FISH
LENGTH GROUP (cm)
20 24 28 32 36 40 44 48 52 56 60 64 68 72
0 10 20 30

Appendix 15. Fecundity of anadromous Arctic charr from Webb Bay and Saglek Fiord, September 1976.

Area	N	Age		Fork Length (mm)		Round weight (kg)		Fecundity			
		Mean	Range	Mean	Range	Mean	Range	Mean	Range	No. eggs $100g^{-1}$	Egg diameter (mm)
Webb Bay	14	10.3	6-13	549	455-609	2.06	1.42-2.56	5190	2744-7804	252	3.9
Saglek Fiord	9	12.6	11-16	546	480-586	1.93	1.07-2.97	4953	2549-8320	256	3.7