ECOLOGY OF THE ARCTIC CHARR (*SALVELINUS ALPINUS*) IN NORTHERN LABRADOR WITH REFERENCE TO THEIR PARASITE FAUNAS

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June 1985

A thesis submitted to the Faculty of Graduate Studies and Research of McGill University in partial fulfillment of the requirements for the degree of Master of Science in Oceanography.

SHORT TITLE : *Ecology of the Arctic charr (Salvelinus alpinus) in northern Labrador.*

McGILL UNIVERSITY

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Abstract

Aspects of the ecology and parasite fauna of landlocked and anadromous Arctic charr, *Salvelinus alpinus*, were investigated in northern Labrador during the summer of 1983. Accelerated growth coincided with the first evidence of feeding migrations to the sea for the anadromous charr and with the adoption of a piscivorous diet for the landlocked charr. Early maturation in small landlocked charr may be due to reduced food intake in the first 3 summers of life resulting, ultimately, from high intraspecific competition. Twenty-two species of metazoan parasites were collected from the landlocked and anadromous charr. One species, *Tetraonchus monenteron*, represents a new host record. Based on parasite faunas, stomach content analysis and location of capture it appears that some young (<4+) charr, not yet ready for the annual seaward migration, may make short feeding excursions into saltwater. The eyes of landlocked charr were more heavily infected with *Diplostomum* sp. than has ever been recorded for any species of fish. The high infections observed do not cause mortality or result in significant vision impairment in the charr even though much lower infections may result in blindness in other salmonid species.

Résumé

Certain aspects de l'écologie et de la faune parasitaire d'ombles chevaliers de populations cantonnées et anadromes ont été étudiés pendant l'été de 1983. Une accélération de la croissance des individus est associée à la première migration en mer chez la population anadrome et à l'adoption d'une diète piscivore chez la population cantonnée. Les ombles cantonnées atteignent la maturité sexuelle prématurément, possiblement à cause d'un manque de nourriture relié a une forte compétition intraspécifique durant les trois premiers étés de leur vie. Vingt-deux espèces de parasites métazoaires on été trouvées chez les deux populations. L'epèces *Tetraonchus monenteron* a été trouvées pour la première fois chez l'omble chevalier. D'après les faunes parasitaires, l'analyse des contenus stomacaux et les lieux de captures, il semble que quelques jeunes ombles (<4+) font de courtes excursions en mer pour s'alimenter, même s'ils ne sont pas tout à fait prêts pour la migration annuelle vers la mer. Les ombles cantonnées sont infestés aux yeux par le trématode *Diplostomum* sp à un niveau d'abondance encore jamais rapporté pour aucune espèce de poisson. Les ombles n'en meurent pas, et leur vision ne semble pas significativement affectée, même si chez d'autres salmonidés, des niveaux d'infestation plus faibles peuvent causer la cécité.

TABLE OF CONTENTS

LIST OF TABLES

CHAPTER ONE

CHAPTER TWO

CHAPTER THREE

LIST OF FIGURES

CHAPTER ONE

CHAPTER TWO

CHAPTER THREE

Acknowledgements

Several people contributed to this thesis in a variety of ways. First of all I thank Dr. Max J. Dunbar for graciously accepting me into the program at McGill, providing some funding and suggesting that I should collaborate with the Department of Fisheries and Oceans (Northwest Atlantic Fisheries Centre, St. John's) on a project dealing with Arctic charr. Dr. Mark Curtis provided much direction with the parasitological part of the project. Rex Porter (DFO, St. John's) accepted the project proposal and set up funding through a federal government contract to McGill University in Dr. Dunbar's name. Brian Dempson (DFO, St. John's) is thanked for overseeing my project in the field (Hebron, Labrador) and in the laboratory (DFO, St. John's), for critically reviewing my thesis, and for providing direction and encouragement throughout. Nicholás Jararouse and Elias Harris (Nain, Labrador) and George Furey (St. John's) provided invaluable assistance in the field. Drs. W. Threlfall (Memorial University), R. Khan (Marine Sciences Research Lab.), J. Pippy (DFO, St. John's), and Mr. C. Bourgeois (DFO, St. John's) provided advice in examination and identification of the parasites. I am grateful to all these people for their contribution to this thesis.

PREFACE

The investigations described in this thesis were carried out in conjunction with a long term study of Arctic charr population dynamics in northern Labrador by the Department of Fisheries and Oceans, St. John's, Newfoundland. Funds were made available to me by DFO in the form of a contract to McGill University for a period of one year. Logistic costs north of Goose Bay, Labrador and use of their field station near Hebron, Labrador was also provided by DFO. Fisheries technicians assisted in the capture and measuring (length and weight) of some of the fish. The Department of Fisheries and Oceans also supplied lab space in St. John's but analysis of the collected material was all carried out by myself. As part of the contract with DFO it was necessary that I investigate the parasite faunas of the Arctic charr in this region. This was carried out for landlocked and anadromous Arctic charr of all ages and done in conjunction with a study of the ecology of these fish. Special attention was paid to the less commonly studied juvenile charr (0+ to 4+).

Chapter One investigates the ecology of the Arctic charr in northern Labrador and Chapter Two investigates the parasites of these fish and uses the parasites to make ecological statements about the charr. During the parasite investigation an extraordinarily high number of eye flukes were found in the eyes of the landlocked charr. Chapter Three describes this parasite infection in detail and makes statements about the implications of these infections.

Each chapter has been written so that it can stand on its own as a separate work and it is intended that each chapter will be submitted for publication separately to a refereed journal. For this reason each chapter contains its own abstract, introduction, materials and methods, etc. and, understandably, contains a certain amount of repetition. The chapters of this thesis have been written in a style similar to publications in the Canadian Journal of Fisheries and Aquatic Sciences.

At present, Chapter Three has been submitted to the Journal of Wildlife Diseases and has been accepted pending some revision. My co-author, Dr. Mark A. Curtis, was not involved in any of the data collection, analysis, preparation of figures, or the first original draft. He did, however, contribute significantly to its style and to the emphasis of the chapter's contents.

Historical introduction to the Arctic charr "problem"

Arctic charr (*Salvelinus alpinus*) are infamous for their well known morphological plasticity and ability to occupy a variety of habitats (Behnke 1972, 1980; Johnson 1980). The great variety of forms of Arctic charr has led to the naming of many species and subspecies. Nyman *et al.* (1981) recognize three sibling species in Scandinavia (*S. alpinus*, *S. salvelinus* and *S. stagnalis*) whereas others in the USSR (cf. Savvaitova 1983) still recognize 12 or more subspecies of *S. alpinus*. In North America the *S. alpinus* "complex" has been described as composing of at least two forms: the eastern Arctic charr and the western Arctic charr (McPhail 1961). As well, the west coast of North America is inhabited by the Dolly Varden charr, *Salvelinus malma* (Walbaum). The recent work of Nordeng (1983) and his "solution to the char problem" has shown that, in Norway, coexisting forms of Arctic charr are represented by only one species (*S. alpinus*). Nordeng's rearing and transplantation experiments demonstrated that three morphologically different, coexisting, forms of Arctic charr belonged to the same gene pool and that single individuals could manifest all three forms during their lifetime. Kornfield *et al.* (1981) studied five isolated populations of landlocked charr in eastern North America and compared them electrophoretically to anadromous charr from the Northwest Territories. They concluded that the genetic differences separating these charr were probably of limited evolutionary consequence.

Klemetsen and Grotnes (1980) state that "Two opposing hypotheses relate to the occurrence of sympatric stocks of arctic charr species. One claims that charrs evolved allopatrically during the last glaciation, and that their present distribution and sympatric coexistence is due to immigration from separate glacial refuges (Svärdson 1961, McPhail 1961, Nilsson & Filipsson 1971, Nyman 1972); the other claims that charr are conspecific (Frost 1965, Savvaitova 1961, 1973, Seppovaara 1969, Kolyushev 1971), and that their segregation may have occurred in postglacial times (Behnke 1972, Skreslet 1973b)". Savvaitova (1983) states that "some researchers still prefer to explain the origin of sympatric groupings by multiple invasions, using for the purpose frequently extremely contradictory data from other sciences".

CHAPTER ONE

Ecology of landlocked and anadromous Arctic charr (*Salvelinus alpinus*) in northern Labrador.

Abstract

The ecology of landlocked and anadromous Arctic charr (*Salvelinus alpinus*) was investigated in the Hebron Fiord region of northern Labrador during the summer of 1983. The anadromous charr population (8+ at maturity) exhibited accelerated growth at 3+ coinciding with the first evidence of feeding migrations to the sea. Landlocked charr diverged from the anadromous charr in growth after their third summer of life (2+). The first spawners of landlocked charr were observed at an age of 3+ with more than 50% of the charr mature at 4+. A small proportion of landlocked charr (9 of 221) grew to a large size similar to mature anadromous charr. All large landlocked charr were piscivorous on sticklebacks (*Gasterosteus aculeatus*) or small charr. Accelerated growth (at 8+) in the landlocked population coincided with the adoption of a piscivorous habit. Feeding was on similar food items in young (<4+) anadromous and landlocked charr. Early maturation in the small landlocked charr may be related to reduced food intake in the first 3 summers of life resulting, ultimately, from high intraspecific competition.

Introduction

The ecology of the Arctic charr, *Salvelinus alpinus*, has been studied in Canada by a variety of people including: Grainger 1953; Andrews & Lear 1956; Saunders & Power 1969; McCart & Craig 1973; Moore 1975; Johnson 1976, 1980; Fraser & Power 1984; Dempson & Green 1985, however, the Arctic charr of the Palearctic has had a much greater history of investigation *ie*. Nilsson 1955, 1965; Nordeng 1961, 1983; Savvaitova 1961; Nilsson & Filipsson 1971; Numann 1972; Klemetsen & Grotnes 1975, 1980; Henricson & Nyman 1976; Jonsson & Ostli 1979; Hindar & Jonsson 1982; Jonsson & Hindar 1982.

The variety of morphs that can be exhibited by Arctic charr emphasizes the plasticity of this fish and its opportunistic nature (Johnson 1980, Nordeng 1983). The result is different populations of Arctic charr exhibiting highly variable growth rates within and between populations (cf. Johnson 1980). Nilsson and Filipsson (1971), Hindar and Jonsson (1982), Klemetsen and Grotnes (1975) and others have shown that when more than one morph exists in the same locality there exists a food and habitat segregation between the morphs. Hindar and Jonsson (1982) studied two charr morphs from the same locality in Norway that developed from a uniform young phenotype. The habits of these two morphs indicated that they were adapted to different niches during the growth season. They concluded that habitat segregation was due to intraspecific competition for food and they hypothesized that the number of charr morphs within a locality depends on the number of available niches during the growth season.

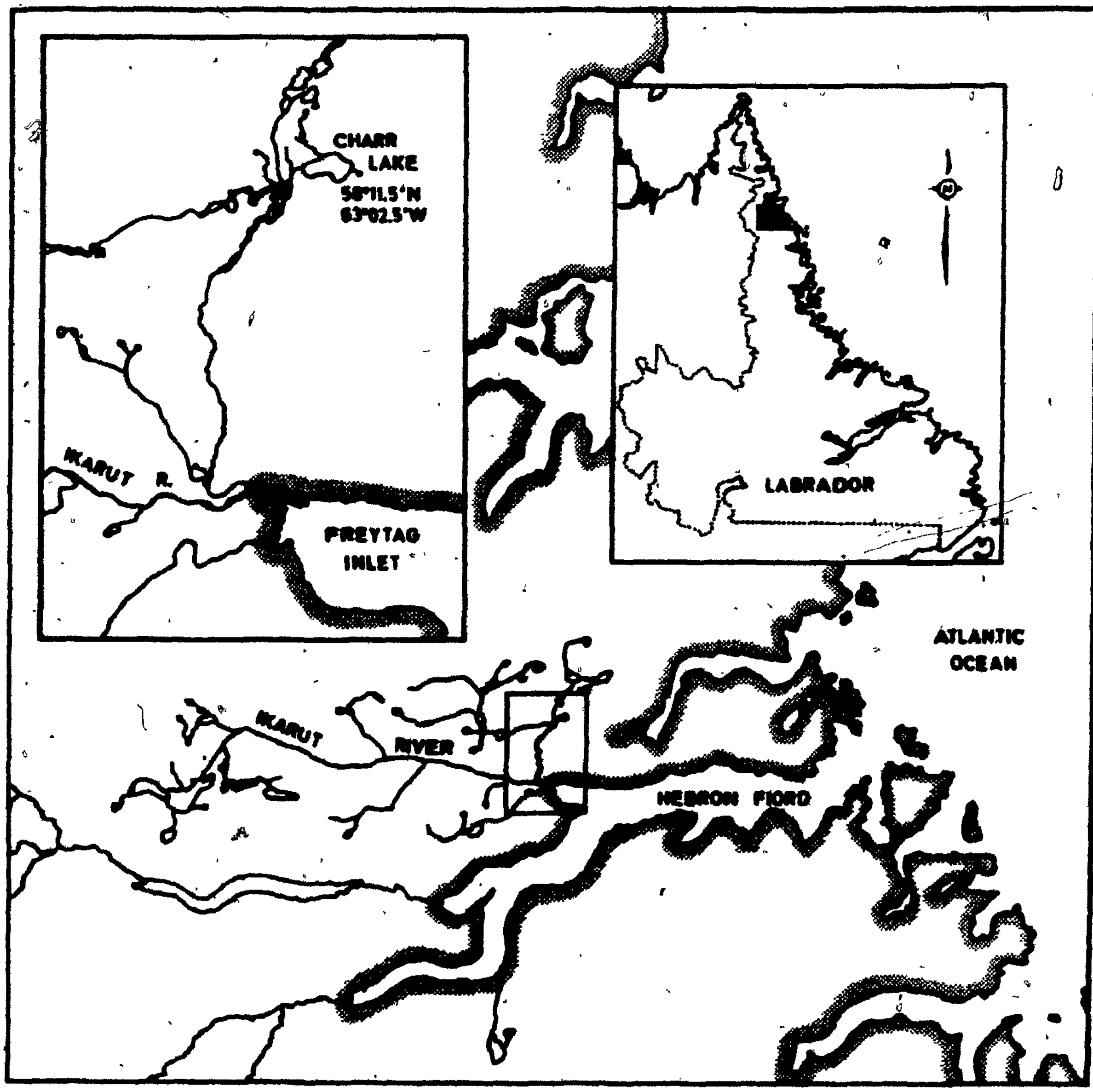
Johnson (1980) believed that the differences in morphological traits and the various forms of segregation result from different phenotypic expressions and the Arctic charr's opportunistic nature to fill empty niches in response to different ecological conditions, not genetic differences. Nordeng (1983) states that segregation during the young stage depends upon both genetic constitution and access to food. Skreslet (1973a,b) and Numann (1972) believe that segregation results from ecological rather than genetic differences whereas Jonsson and Hindar (1982) suggest that it may be due to random events that result in certain individuals experiencing increased growth rates by chance.

The present study on the anadromous charr of the Ikarut River and landlocked charr of Charr Lake, Labrador, was undertaken to obtain biological information on virtually unexploited populations of Arctic charr living in the same river system. Feeding, maturation and growth of the anadromous and landlocked charr were compared and special attention was paid to the young charr of each group where data is often lacking. Since Charr Lake apparently harboured two morphs of Arctic charr the ecology of these fish was studied and compared.

Materials and Methods

The present investigation was carried out in conjunction with a larger study by the Department of Fisheries and Oceans, St. John's. Arctic charr were sampled from northern Labrador between July 13 and August 29, 1983. Sampling sites (Fig. 1) were the Ikarut River, Hebron Fiord and recently named Charr Lake (Newfoundland Geographical Names Board, St. John's, 1984). Charr Lake is approximately 23 hectares in area with a shallow, rocky, littoral fringe and about 13 m depth (J. Hammar, pers. comm.) in the centre. The lake harbours only Arctic charr and threespine sticklebacks (Gasterosteus aculeatus). These fish are landlocked owing to a series of waterfalls along the lake's outlet stream, which drains into the Ikarut River. The river substrate is mainly loose gravel and rubble (Murphy & Porter 1974) and is relatively unstable. The region of study lies about 25 km north of the northern tree limit (Elliott & Short 1979). The Ikarut River contains Arctic charr and brook trout (Salvelinus fontinalis) populations, and empties into Hebron Fiord. All fiord fish were captured in water where salinity ranged from 26.0 to 29.0‰ . River charr were taken within two kilometers of the mouth of the Ikarut River in freshwater, the majority taken in the vicinity of the mouth. Landlocked charr were captured in the littoral zone and some deeper

Figure 1. Location map of Hebron Fiord, northern Labrador, and inset showing Ikarut River and the Charr Lake sampling sites.



CHARR
LAKE
58°11.5'N
63°02.5'W
IKARUT R.
FREYTAG
INLET
LABRADOR
ATLANTIC
OCEAN
IKARUT
RIVER
HEBRON FIORD

areas located close to the shore. Fish collections were made using a dip net, hand seine, fyke net, and gill nets of mesh sizes ranging from 19 mm (3/4") to 114 mm (4 1/2"). Fork length and total weight (whole) was recorded for fresh fish which were then preserved in 4% buffered formalin. Later, the charr were transferred to 70% ethyl alcohol. Only the head and viscera were preserved in larger fish (>20 cm).

Otoliths were removed to age the charr and sex was recorded. Young charr (0+ to 1+ years) were sexed with the aid of a dissecting microscope. Stomach contents were collected and classified only from freshly caught fish (usually caught and preserved within one hour). The majority of stomach samples were taken between July 25 and August 19 (1983) in the lake, river and fiord, with at least three sampling dates per area over this period. Food items were classified according to the major groups to which they belonged (cf. Fig. 4). The proportion of the stomach occupied by each group was then estimated and recorded. Stomach fullness was estimated using the following guide:

STOMACH FULLNESS CODE	DESCRIPTION
0	Empty
1	Nearly Empty
2	Medium Full
3	Full

Gonadal maturity states were determined according to the description given below and is similar to that employed by the Freshwater and Anadromous Fisheries Program, Northwest Atlantic Fisheries Centre, St. John's:

MATURITY STATE	DESCRIPTION
1	Immature, gonads not developed.
2	Maturing, some gonadal development but spawning will not likely occur this year.
3	Mature, fish will spawn this year.
4	Ripe, gonads fill body cavity, sexual product easily expressed from fish.
5	Spent, fish spawned earlier in the year.
6	Spawned previously, maturing this year.
7	Spawned previously, maturing next year or beyond.
9	Questionable.

In this study all fish with a maturity state greater than or equal to 3 are considered to be mature. Fish in maturity states 1 or 2 are considered immature. Fecundity data were collected only from fish in maturity state 3 and average egg size was determined only from fish in maturity state 4 as fish in the latter state may have already lost some eggs and fish in the former state did not contain mature eggs. Fecundity was determined by direct enumeration and egg size was determined by taking the average length of 10 eggs placed in a line. All figures except Fig. 1 were generated using the computer graphics system SAS/GRAPH from the Statistical Analysis System of SAS Institute (Cary NC, USA).

Results

A total of 433 Arctic charr were collected from the Ikarut River and Hebron Fiord (anadromous system). There was no evidence to suggest that these fish were anything other than the anadromous stock ie. no stream resident fish were present in the sample. Two hundred and twenty-one Arctic charr were taken from Charr Lake (landlocked system). The majority of landlocked charr matured at a small size and early age and were caught along the littoral fringe of the lake. Only nine charr were captured that were comparable in size to mature anadromous charr and these were all taken in deep water. Summary statistics for charr from the landlocked and anadromous systems are compared in Table 1. Sex ratios for both the anadromous and landlocked charr were 1:1 at each age and for each population. Mature anadromous charr had a mean length of 54.8 cm (SD = 5.327) and mean age of 9.0 years (SD = 1.512). Mature landlocked charr fell into two groups: small mature charr caught in the littoral zone (mean length = 13.3 cm (SD = 1.659) and mean age = 4.3 years (SD = 0.786)) and large mature charr caught in deeper water (mean length = 58.1 cm (SD = 2.715) and mean age = 14.9 years (SD = 2.545)). Mean fecundity in the small charr was 74 eggs per individual and mean egg size at maturity was 4.4 mm.

Growth rates (mean length-at-age) in the first three

Table 1. Summary statistics comparing the mean, range, standard deviation and sample size with age for the variables fork length and whole weight for Arctic charr from landlocked Charr Lake and the anadromous Ikarut River / Hebron Fiord system, northern Labrador.

AGE GROUP	0+	1+	2+	3+	4+	5+	6+	8+	10+	11+	13+	14+	15+	16+	19+
CHARR LAKE															
MEAN LENGTH (CM)	4.6	6.9	9.5	11.4	12.9	13.9	15.5	19.6	40.4	54.5	57.0	60.0	61.0	58.0	58.0
MINIMUM	3.1	5.9	8.3	9.0	9.5	10.3	12.3	19.6	36.5	54.5	57.0	60.0	61.0	55.0	58.0
MAXIMUM	6.0	7.7	11.6	14.7	18.7	18.1	24.3	19.6	44.2	54.5	57.0	60.0	61.0	61.0	58.0
S.D.	0.739	0.547	0.925	1.508	1.443	1.621	5.843	-	5.445	-	-	-	-	4.243	-
MEAN WEIGHT GM)	1.3	4.0	9.5	17.5	24.7	31.4	58.1	75.7	675	1650	1850	1800	1900	1850	1650
MINIMUM	0.5	2.1	6.0	8.6	9.5	10.2	18.5	75.7	500	1650	1850	1800	1900	1450	1650
MAXIMUM	2.4	5.6	17.0	32.4	68.5	74.8	168.7	75.7	850	1650	1850	1800	1900	2250	1650
S.D.	0.492	0.943	2.845	6.826	8.727	13.18	73.80	-	247.5	-	-	-	-	565.7	-
N	26	18	19	37	71	36	4	1	2	1	1	1	1	2	1

AGE GROUP	0+	1+	2+	3+	4+	5+	6+	7+	8+	9+	10+	11+
IKARUT RIVER HEBRON FIORD												
MEAN LENGTH (CM)	4.1	6.4	9.9	13.6	21.6	26.4	35.4	49.1	51.1	52.4	53.9	60.3
MINIMUM	2.5	4.5	7.1	8.8	12.1	22.3	15.0	45.0	44.5	49.0	43.0	57.0
MAXIMUM	6.1	10.2	13.9	24.5	30.2	32.2	49.5	55.0	55.5	54.0	65.5	63.5
S.D.	0.874	1.184	1.171	3.170	4.364	2.677	12.46	3.564	4.170	2.287	7.052	3.253
MEAN WEIGHT (GM)	0.8	3.0	9.8	27.8	108.3	185.7	600	1300	1379	1625	1607	2133
MINIMUM	0.2	1.1	3.1	5.8	15.3	100.2	25.5	950	1000	1250	850	1750
MAXIMUM	2.0	10.2	19.3	147.5	274.3	350.3	1250	1800	1750	1800	2750	2550
S.D.	0.413	1.640	3.246	25.92	61.43	67.80	504.5	334.2	282.6	259.8	616.1	401.0
N	85	62	93	95	48	14	8	7	7	4	7	3

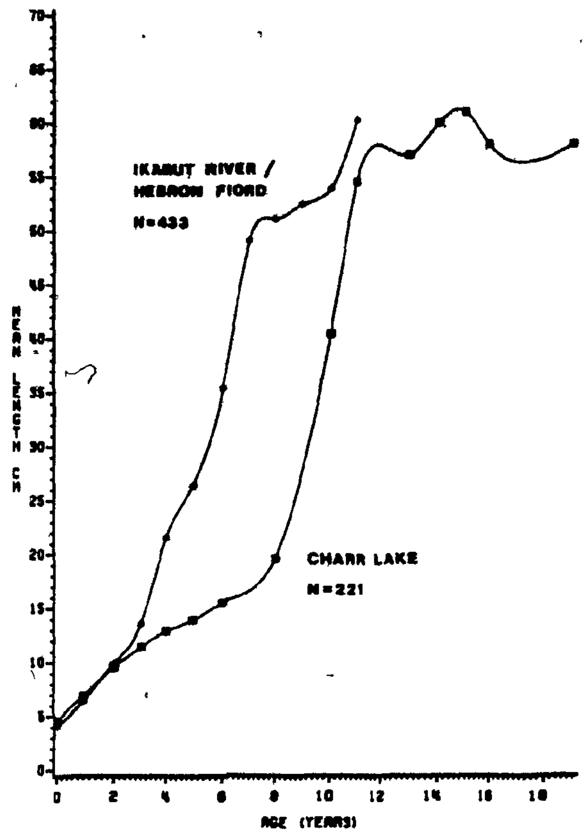
summers of life were similar for the anadromous and landlocked charr (Fig. 2). Afterwards, landlocked charr appeared to have a slow rate of growth compared to the anadromous charr up until an age of 8+. Landlocked Arctic charr older than 8+ exhibit a rapid period of growth and attain a size similar to that found in the anadromous population. The period of accelerated growth in the anadromous population appears to occur between 3+ and 7+ years whereas it occurs between 8+ and 11+ years in the lake. The original length-at-age data in Charr Lake (Fig. 2, bottom) show the separation between the small and large landlocked charr with the latter exhibiting the greatest lengths and ages.

Anadromous charr matured at a larger size and older age than the majority of landlocked charr (Fig. 3). Mature fish do not appear in the anadromous system until 7+. In contrast, mature charr appear in the landlocked system at 3+. The age at which at least 50% of the charr are mature occurs at 8+ in the anadromous system and 4+ in the landlocked system.

Fish in maturity state 7 are often difficult to distinguish from fish in maturity state 2. This may be reflected in the maturity data by a high proportion of the latter in the older fish. It is also not possible, generally, to differentiate between first time spawners and repeat spawners.

Figure 2. Top: Plot showing mean length at age for anadromous (Ikarut River / Hebron Fiord) and landlocked (Charr Lake) populations of Arctic charr in northern Labrador.

Bottom: Plot of raw length data versus age data for small and large forms of Arctic charr from Charr Lake showing one continuous growth curve.


IKARUT RIVER / HEBRON FIORD
N=433
CHARR LAKE
N=221
MEAN LENGTH CM
AGE (YEARS)

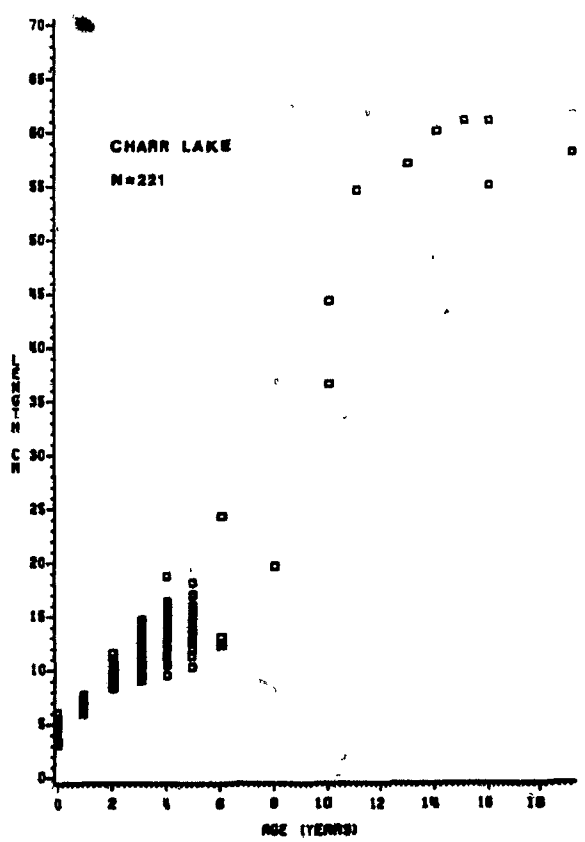
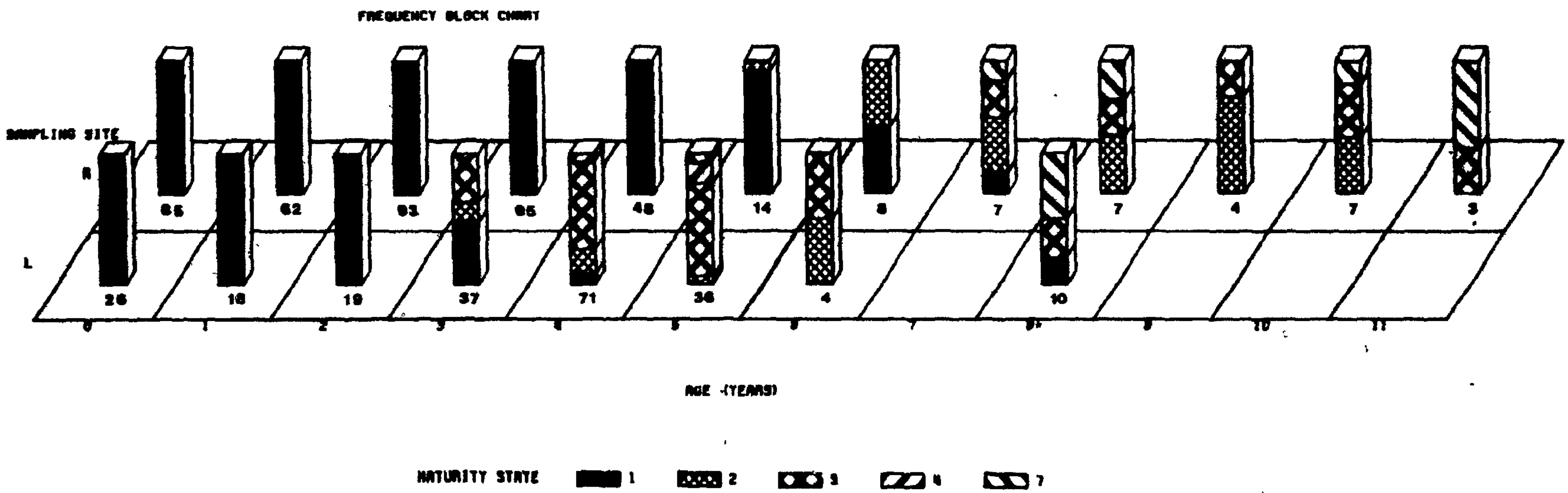

CHARR LAKE
N=221
LENGTH CM
AGE (YEARS)

Figure 3. Frequency block chart showing the state of maturity at each age (adjusted to 100%) of anadromous charr from the Ikarut River / Hebron Fiord system (R) and the landlocked Charr Lake (L). Values immediately under each block are sample sizes.

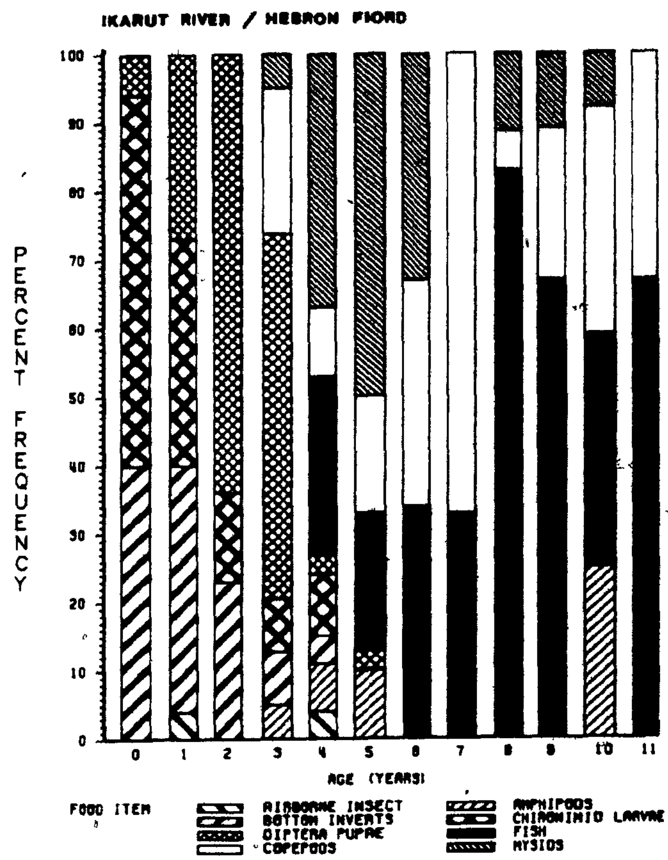


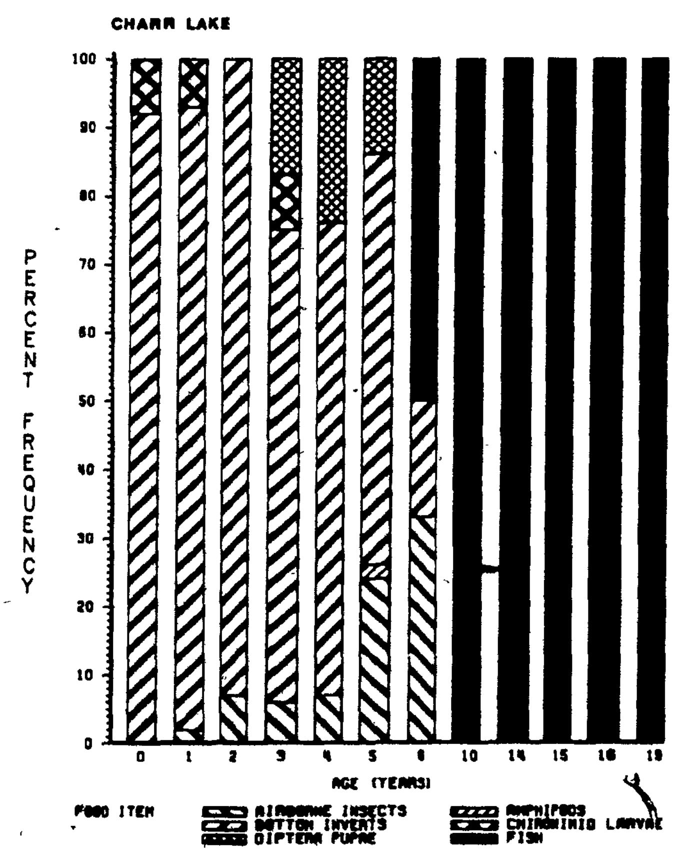
* 8 years and older for lake fish.

The change in the proportion of major food items found in the stomachs of Arctic charr at each age was determined from stomach content analysis. In the anadromous system (Fig. 4, top) chironomid larvae and general bottom invertebrates are important in the first year of life with decreased importance in each successive year until 4+. The proportion of diptera pupae increases until 3+ where the first occurrence of marine food items (copepods, mysids and amphipods) appears in the diet. The percentage of marine food items in the stomach of the anadromous charr increases until 6+ when the charr are feeding exclusively on these items. Fish become part of the diet at 4+ with some indication of increasing consumption with age. All fish recovered from the stomachs of anadromous charr were small (<3 cm) juvenile sculpin (probably *Icelus spatula*). The exceptions were 3 large charr which each contained one of the following: a 6.0 cm sand lance (*Ammodytes* sp.), a 13.0 cm capelin (*Mallotus villosus*) and a 17.5 cm Arctic charr (*Salvelinus alpinus*).

The diversity of major food items is not as great for the landlocked charr, which appear to be feeding more heavily on particular food items (Fig. 4, bottom). Bottom invertebrates remain an important food item at least until the charr are 5+ and the proportion of airborne insects in the diet increases until 6+. At 6+, and a length greater than 24 cm, all landlocked charr have become piscivorous. The

Figure 4. Histograms showing the proportions of food items found in the stomachs of Salvelinus alpinus (adjusted to 100% at each age) for the anadromous charr (Ikarut River / Hebron Fiord) and landlocked charr (Charr Lake). Airborne insects include flying and terrestrial insects. Bottom invertebrates include bivalves, pelecypod mollusks and mainly insect larvae, other than diptera pupae and chironomid larvae, found in the benthos.

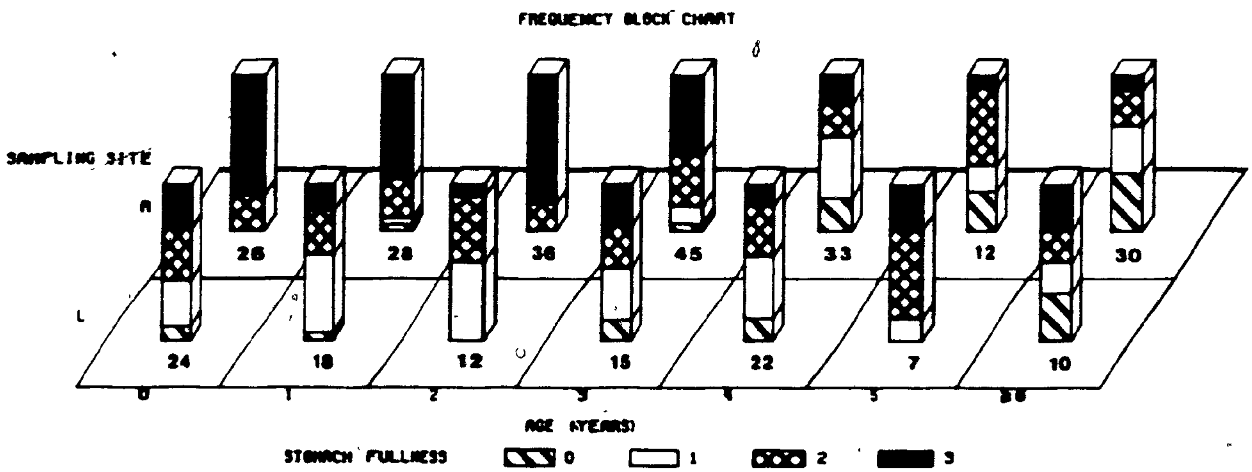

IKARUT RIVER / HEBRON FIORD
PERCENT FREQUENCY
100
90
80
70
60
50
40
30
20
10
0
0 1 2 3 4 5 6 7 8 9 10 11
AGE (YEARS)
FOOD ITEM
AIRBORNE INSECT
BOTTOM INVERTS
DIPTERA PUPAE
COPEPODS
AMPHIPODS
CHIRONIMID LARVAE
FISH
MYSIDS


CHARR LAKE
PERCENT FREQUENCY
100
90
80
70
60
50
40
30
20
10
0
0 1 2 3 4 5 6 10 14 15 16 19
AGE (YEARS)
FOOD ITEM
AIRBORNE INSECTS
BOTTOM INVERTS
DIPTERA PUPAE
AMPHIPODS
CHIRONIMID LARVAE
FISH

smallest piscivorous charr was found to be feeding exclusively on threespine sticklebacks (Gasterosteus aculeatus) whereas all the other piscivorous charr fed exclusively on smaller charr. A total of 19 sticklebacks (mean length = 1.6 cm) were recovered from the stomach of the smallest piscivorous charr. Five large piscivorous charr contained a total of 17 smaller Arctic charr in their stomachs. The mean length of these prey items was 11.8 cm with a range of 9.5 to 14.5 cm. All other large landlocked charr had empty stomachs at the time of capture.

The relative proportion of stomach fullness levels at each age shows differences between the anadromous and landlocked charr (Fig. 5). The anadromous charr tended to have full stomachs in the first four summers of life. Over the same ages, the landlocked charr had only a small proportion of full stomachs and a much higher proportion of nearly empty stomachs. As a general observation, it was also apparent that when anadromous charr had full stomachs they were ,in fact, distended whereas landlocked charr rarely had distended stomachs when they were full. Landlocked charr in maturity state 3 or 4, that were caught in late summer before spawning, were found to have a high proportion of empty stomachs (Fig. 6). These were not included in the data of Fig. 5 since the reason for this is probably behavioural (related to spawning) and not related to food availability.

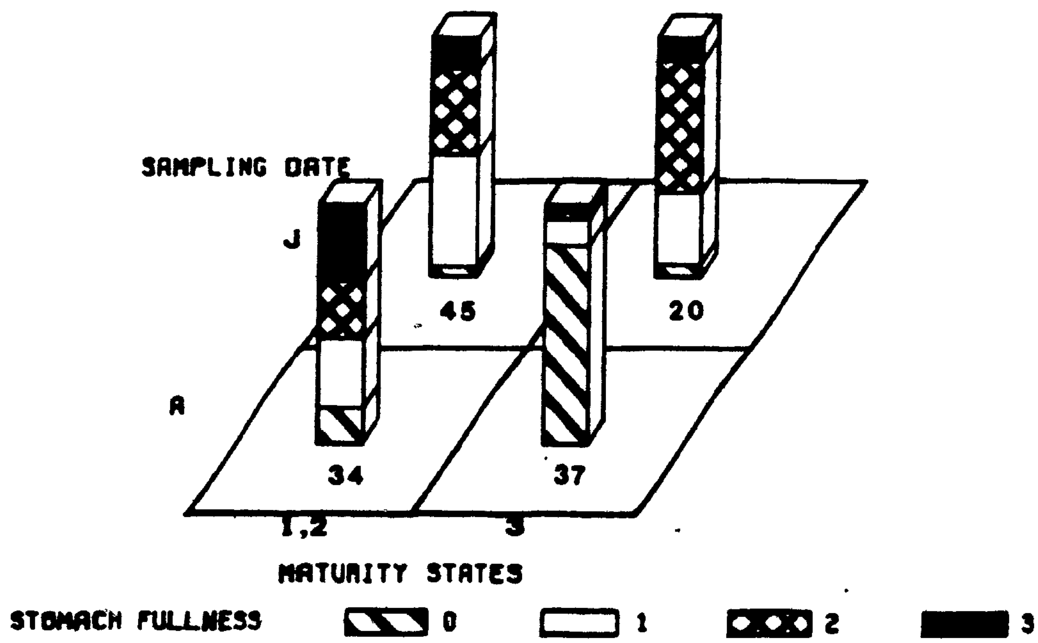
Figure 5. Frequency block chart showing stomach fullness levels at each age (adjusted to 100%) of anadromous charr from the Ikarut River / Hebron Fiord system (R) and the landlocked Charr Lake (L). A stomach fullness value of zero represents an empty stomach and a value of 3 represents a full stomach. Values immediately under each block are sample sizes. Charr in maturity state 4 and those in maturity state 3 caught in mid-to-late August (19 to 29, 1983, spawning September) were not included in the figure (see text).



FREQUENCY BLOCK CHART
SAMPLING SITE
M
L
26
28
36
45
33
12
30
24
18
12
15
22
7
10
0
1
2
3
4
5
≥6
AGE (YEARS)
STOMACH FULLNESS
0
1
2
3

Figure 6. Frequency block chart showing stomach fullness levels for immature fish (maturity states 1 and 2) and maturing fish (maturity state 3) caught between July 25 and August 4, 1983 (J), and those caught from August 28 to 30, 1983 (A), in Charr Lake. Charr spawn in September. Sample of maturity state 3 fish from late August (A) also includes fish in maturity state 4. Values immediately under each block are sample sizes.

FREQUENCY BLOCK CHART



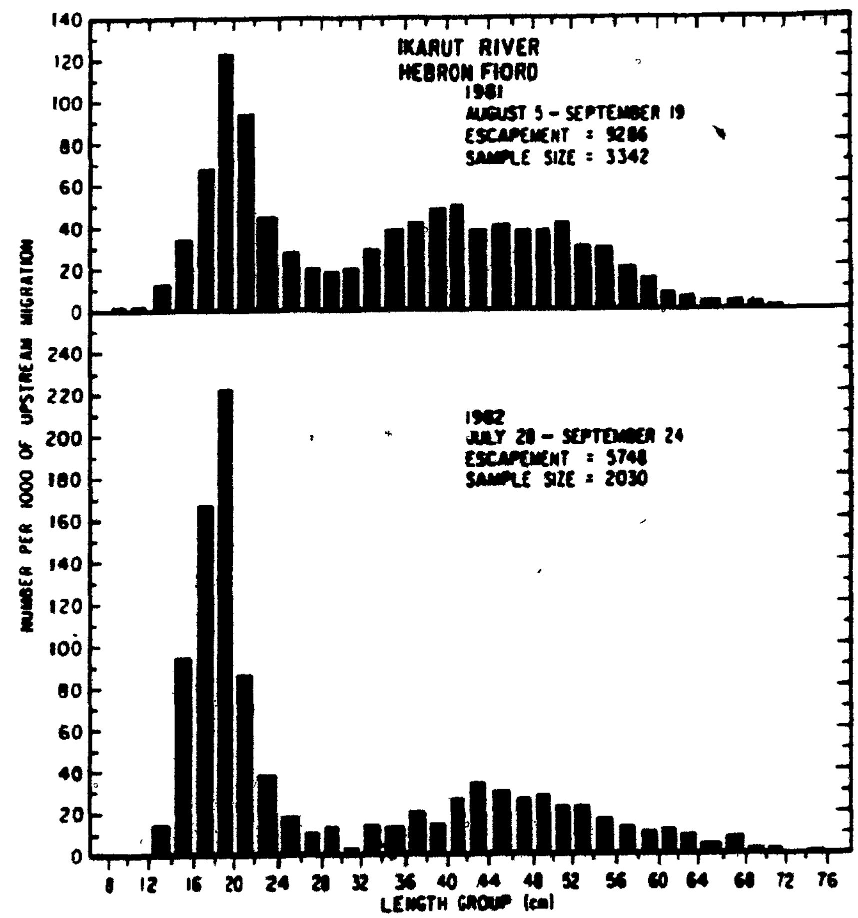
Discussion

It is apparent that the growth patterns of the anadromous and landlocked charr from the study site begin to diverge after their third summer of life. In the fourth summer of life (3+) some anadromous charr will spend their first summer in the sea and some landlocked charr will spawn for the first time. The necessarily large expenditure of energy needed to produce reproductive products in the small landlocked charr and the accelerated growth due to marine feeding of the anadromous charr results in further divergence of their growth curves.

From the feeding studies and growth curves we can conclude that accelerated growth in the anadromous charr occurs when the fish first begin feeding intensively in the sea (at 3+ or 4+). The accelerated growth in the landlocked charr of Charr Lake occurs when the fish develop a piscivorous feeding habit between 6+ and 10+. Numann (1940, from Numann 1972) proposed that some of the charr recruits became piscivorous at a certain size and begin a new stanza of growth, thus accounting for the large difference in size between the two forms. Available data suggest that this is what is occurring in Charr Lake. Individuals may first begin feeding primarily on sticklebacks, eventually switching to charr as they increase in size. Fraser and Power (1984) found a similar situation in Lac Ducreux in northern Quebec.

Arctic fish populations are known to often exhibit bimodal population structures (Johnson 1976). Length frequency distributions of upstream migrating anadromous charr (Fig. 7) caught in a counting fence on the Ikarut River during 1981 and 1982 (from Porter & Dempson 1983) show a characteristic bimodal distribution. In contrast age frequency distributions for these fish were not bimodal. This was also observed in the Ikarut River during 1983 (Dempson, pers. comm.), the year of the present study. A trough in the length frequency distribution occurs between 20 and 40 cm which coincides with the length interval over which accelerated growth takes place in the anadromous charr (Fig. 2). The landlocked population in Charr Lake also exhibits a bimodal length frequency distribution. The central region of the lake was inaccessible to sampling so further sampling may support or refute this finding. The large, piscivorous, landlocked charr were observed to feed exclusively on small, mature or maturing, charr. Few intermediate sized charr were collected during sampling resulting in the bimodal population structure. Johnson (1976) hypothesized that the adult portion of the population suppresses the juvenile mode through some suppressive force and that the suppression is evidenced by the bimodal structure of the population. He suggested that cannibalism plays some part in the suppressive process but that it is unlikely to be the main

Figure 7. Length frequency distributions of upstream migrating anadromous charr caught in a counting fence on the Ikarut River during the summer of 1981 and 1982 (from Porter & Dempson 1983).


IKARUT RIVER
HEBRON FIORD
1981
AUGUST 5 – SEPTEMBER 19
ESCAPEMENT = 9286
SAMPLE SIZE = 3342
1982
JULY 28 – SEPTEMBER 24
ESCAPEMENT = 5748
SAMPLE SIZE = 2030
NUMBER PER 1000 OF UPSTREAM MIGRATION
LENGTH GROUP (cm)

mechanism. Power (1978) stated that it is the combination of the growth and mortality patterns (coupled with the long life spans of the fish) that produces the bimodal population structure often found in Arctic lakes. Power's (1978) explanation is most plausible for Charr Lake although the piscivorous habits of large charr feeding on larger individuals of the small mature charr likely enhances the bimodality of the population.

In alpine and arctic lakes where the zooplankton community is small all charr may be "dwarfs" except for cannibalistic individuals (Hindar & Jonsson 1982). Based on stomach content analysis Charr Lake fits this description. Numann (1972) states that Neresheimer (1941), Schindler (1936, 1950) and Numann himself agree in effect that slow growth is related to food availability, either physiologically or ecologically. Hindar and Jonsson (1982) hypothesize that the occurrence of different charr morphs depends on the number of available niches during the growth season and that habitat segregation of the morphs is due to intraspecific competition for food. Jonsson and Hindar (1982) state that large males are probably the principal spawners throughout the spawning period and appear to fertilize first the eggs of large females, then of the small maturing females.

We have seen that in the first 3 summers of life growth is virtually identical in the anadromous and landlocked populations. Immediately after this period the small landlocked charr begin sexual development whereas the anadromous charr begin to accelerate their growth rate. Nordeng's (1983) transplantation and rearing experiments lead us to believe that the anadromous and landlocked charr have the same potential for growth. The feeding data show us that the landlocked charr have about the same selection of major food items in these early years as the anadromous river charr although the proportion of these food items in the stomach is different and is probably related to availability. The only real difference between these two groups of fish appears to be related to the amount of food in the stomachs. The stomach fullness data indicate that the young river charr have consistently fuller stomachs than the young landlocked charr and suggests that there is a higher abundance of food available in the Ikarut River than there is in Charr Lake. This difference probably results from high intraspecific competition for available food resources in the lake coupled with reduced competition in the river due to the seasonal migration of older, anadromous, charr into the marine environment. The difference in food intake, however, is not apparently sufficient to separate the growth of the anadromous and landlocked charr by the end of the third summer of life (2+). An explanation for this phenomenon may be that the food supply is not limiting to growth in the first three summers of life for the landlocked (and anadromous) charr, but, that the lower food resources available to the landlocked charr triggers some response that commences the maturation process in these fish.

Dutil (1984) stated that the success of Arctic charr throughout the Arctic suggests that they have developed physiological mechanisms to meet the climatic conditions that prevail in northern waters. He concludes that Arctic charr have probably developed mechanisms that permit them to make a balanced decision on whether or not to reproduce in a given year and that this decision may depend upon stored energy reserves. Jonsson and Hindar (1982) state that their data supports the hypothesis that female Arctic charr mature sexually at the age that maximizes their fitness within the constraints imposed by growth and survival. Nordeng (1983) believes that the percentage of offspring reaching sexual maturity at an early age is influenced by feeding intensity. Hindar and Jonsson (1982) suggest that the "decision" of whether or not to mature at a young age / small size may be made in the late parr stage whereas Balon (1980) suggests that events in the early ontogeny determine the adult phenotype.

Data from this study suggest that reduced food intake in the first three summers of life in the landlocked charr (and/or the high density and intraspecific competition usually associated with it) may result in the physiological response of maturing at an early age and small size. The landlocked charr, under high summer density and reduced food intake due to high intraspecific competition, mature at a small size and young age. The anadromous Arctic charr, under low summer densities, a seasonally expanded food base (ocean feeding), and observed greater food intake in the young (<4+) enjoy low intraspecific competition during the "feeding season" and respond by growing and maturing "normally".

The two morphs of charr found in Charr Lake appear to be segregated by food and habitat. The large charr occupy deeper waters and are piscivorous whereas the small charr occupy the littoral zone and mainly feed on the benthos. Hindar and Jonsson (1982) state that only the fast-growing parr transformed to "normal" charr in Vangsvatnet in western Norway. It is possible that this also regulates which charr become large in Charr Lake ie. only fast growing, highly competitive charr, that are able to escape predation by larger charr and reach a size where they themselves become piscivorous.

Acknowledgements

I am grateful to the Department of Fisheries and Oceans, St. John's, Newfoundland for financial support and use of their Hebron, Labrador field station.

I would also like to thank the following people for contributing to the study in various ways: Professors Max Dunbar and Mark Curtis, Mr. Rex Porter and our Inuit helpers Elias Harris and Nicholas Jararouse. Mr. Brian Dempson is especially thanked for the interest he showed in the project throughout its stages and for critically reviewing the manuscript.

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CHAPTER TWO

Infection by metazoan parasites of landlocked and anadromous Arctic charr (*Salvelinus alpinus*) and their use in determining age at first seaward migration.

Abstract

Twenty-two species of metazoan parasites were collected from landlocked and anadromous Arctic charr (*Salvelinus alpinus*) in northern Labrador. One species, *Tetraonchus monenteron*, represents a new host record. Several parasites showed increasing levels of infection with age of the charr but their predominant site of location within the host did not change. The most dominant parasites in the lake fish were *Diplostomum* sp., *Crepidostomum farionis* and *Diphyllobothrium ditremum*. In the anadromous system *Bothrimonus sturionis* and *Brachyphallus crenatus* were most dominant. Landlocked charr had heavier infections of *Diplostomum* sp. than have ever been recorded for any fish. All landlocked charr were infected with parasites by age 1+ whereas all anadromous charr were infected by 3+. At 1+ years of age 43% of anadromous charr were infected with marine or brackish water parasites. Some young charr, not yet ready for the annual seaward migration, may make short feeding excursions into saltwater.

Introduction

Parasites can be used in a variety of ways to study indirectly the behavioral ecology of the host. Parasites as biological tags to separate stocks of fish are probably the best known example (Sindermann 1961; Pippy 1969; Hare & Burt 1976; Platt 1976; Beverley-Burton & Pippy 1978; Kennedy 1978b; Dick & Belosevic 1981). In addition, because parasites can be classified often as freshwater, marine or brackish water, they can be used to indicate at what stage of its life a host is being exposed to these water types. The parasites of Arctic charr (*Salvelinus alpinus*) have been studied in varying degrees of thoroughness in North America (Andrews & Lear 1956; Jamieson 1972; Hicks & Threlfall 1973; Hanek & Molnar 1974; Mudry & McCart 1976; Beverley-Burton 1978; Eddy & Lankester 1978; Curtis 1979, 1983; Dick & Belosevic 1981).

In Labrador, Andrews and Lear (1956) examined commercial sea-run charr and reported only two species of parasites. Hicks and Threlfall (1973) examined a total of 35 charr from four locations in Labrador recovering 16 genera of parasites. No more than 17 charr came from a single location and only 3 charr came from a landlocked lake (a lake with some form of obstruction, *ie*. waterfalls, preventing fish from entering it from the sea).

The present study was designed to describe the parasite faunas of Arctic charr from a landlocked lake, a river and fiord all belonging to the same water system. It was intended to examine the changes in parasite intensities with age with emphasis on the younger charr, and also, to look at increasing prevalence and intensity of marine and brackish water parasites in the anadromous fish to determine when these fish were first entering brackish or marine waters.

Materials and Methods

Arctic charr were sampled from northern Labrador between July 13 and August 29, 1983. Sampling sites (Fig. 1, Chapter One) were the Ikarut River, Hebron Fiord and the recently named Charr Lake (Newfoundland Geographical Names Board, St. John's, 1984). Charr Lake is approximately 23 hectares in area with a shallow, rocky, littoral fringe and about 13 m depth (J. Hammar, pers. comm.) in the centre. The lake harbours only Arctic charr and threespine sticklebacks (Gasterosteus aculeatus). These fish are landlocked owing to a series of waterfalls along the lake's outlet stream, which drains into the Ikarut River. The river substrate is mainly loose gravel and rubble (Murphy & Porter 1974). The region of study lies about 25 km north of the northern tree limit (Elliott & Short 1979). The Ikarut River contains Arctic charr and brook trout (Salvelinus fontinalis) populations, and empties into Hebron Fiord. All fiord fish were captured in water where salinity ranged from 26.0 to 29.0‰. River charr were taken within 2 kilometers of the mouth of the Ikarut River in freshwater, the majority taken in the vicinity of the mouth. Salinity at the river mouth during fish collections was always less than 2‰ . Fish collections were made using a dip net, hand seine, fyke net, and gill nets of mesh sizes ranging from 19 mm (3/4") to 114 mm (4 1/2"). Fork length and total weight (whole) was recorded for fresh fish which were then preserved in 4% buffered formalin. Later, the charr were transferred to 70% ethyl alcohol. Only the head and viscera were preserved in larger fish (>20 cm).

Autopsies were carried out on 80 Arctic charr from Charr Lake and a total of 85 charr from the Ikarut River and Hebron Fiord. Gonadal maturity states were recorded as defined in Chapter One. In this thesis all fish with a maturity state greater than or equal to 3 are considered to be mature. Otoliths were removed and used to age the fish. Stomach contents were collected and identified as to major group. Body surface, body cavity, oral cavity, gills and inner operculum, eyes, esophagus, stomach, pyloric caecae, intestine, ureters and swim bladder were examined for metazoan parasites.

When gill netting fish, it was found that charr caught in the nets would begin to lose parasites from body openings (anus, gills) within minutes of capture. For this reason only freshly caught fish were used for parasite analysis and these fish were immediately placed in individual plastic bags. Despite this effort some parasites still left the fish but were contained by the plastic bag. The body location for these parasites was classified as "indeterminate". Parasites were taken from preserved fish and stored in glycerine alcohol until processed for identification.

Prevalence, mean intensity and dominance values were used to describe the parasite faunas. Prevalence is the percentage of the total sample of fish that is infected with a particular parasite, and mean intensity is the mean number of individuals of a particular parasite species per infected fish in a sample (cf. Margolis _et al._ 1982). Dominance is the total number of individuals of a particular parasite species expressed as a percentage of the total number of all parasites in that sample.

Results

A total of 22 species of parasites were recovered from Arctic charr taken from Charr Lake, Ikarut River and Hebron Fiord in northern Labrador (Table 1). One parasite, Tetraonchus monenteron, was found on the gill filaments of one 10 year old (36.5 cm) charr from Charr Lake and represents a new host record. Identification was based on the examination of the anchors and copulatory organ as described by Bykhovskaya-Pavlovskaya et al. (1962). Sixteen species of parasites were recovered from 80 landlocked charr from Charr Lake and 18 species from 85 Arctic charr from the anadromous population in the Ikarut River and Hebron Fiord (Table 2). Most species of parasites were found in more than one body location but generally there was one body location in which it was most prevalent. Other species were found only in restricted locations ie. Diplostomum sp. in the eyes, Phyllodistomum limnosa in the ureters, Salmincola carpionis in the oral cavity and Salmincola edwardsii only on the gill filaments or attached to the inner operculum.

The data show no trend indicating a change in the predominant location of recovery with increasing age for any of the parasites. As a result data for all ages were grouped to produce the results shown in Table 2. Table 1 summarizes the data and lists the parasite habitat (marine, brackish water or freshwater) according to Margolis and Arthur (1979).

Table 1. Species list of parasites found in Arctic charr (*Salvelinus alpinus*) from the Ikarut River, Hebron Fiord and Charr Lake in northern Labrador. Habitat types are: FW = freshwater, M = marine, and B = brackish water. Parasite location lists locations in order of decreasing importance.

CLASS	SPECIES	HABITAT	LOCATION
Monogenea	*Tetraonchus monenteron** (Wagener, 1857)	FW	Gills
Trematoda	*Brachyphallus crenatus* (Odhner, 1905)	M	Stomach, esophagus, some in caecae, anterior & posterior intestine.
	Bunodera lucioperoae (Müller, 1776)	FW	Posterior intestine, anterior intestine, some in caecae.
	Crepidostomum farionis (Müller, 1784)	FW	Posterior intestine, anterior intestine, caecae
	Derogenes varicus (Müller, 1784)	M	Stomach, esophagus
	Lecithaster gibbosus (Rudolphi, 1802)	M	Posterior intestine, caecae
	Diplostomum sp(p).	FW	Metacercaria in epichorioidal lymph space and lens of eyes.
	Phyllodistomum limnosa (Sandeman & Pippy, 1967)	FW	Ureters.
Cestoda	*Bothrimonus sturionis* (Duvernoy, 1842)	B	Caecae, anterior intestine, posterior intestine.
	Diphyllobothrium dendriticum (Nitzsch, 1824)	FW	Plerocercoids encysted on stomach & caecae, some in body cavity.
	Diphyllobothrium ditremum (Creplin, 1825)	FW	Plerocercoids encysted on stomach & caecae.
	Eubothrium crassum (Bloch, 1779)	FW	Caecae.
	Eubothrium salvelini (Schrank, 1790)	FW	Caecae.
	Proteocephalus tumidocollus (Wagner, 1953)	FW	Caecae, anterior intestine, some in posterior intestine.
	Proteocephalus longicollis (Zeder, 1800)	FW	Caecae, anterior intestine.
Nemotoda	*Capillaria salvelini* (Polyansky, 1952)	FW	Stomach.
	Cystidicoloides tenuissima (Zeder, 1800)	FW	Stomach, some in caecae.
	Philonema agubernaculum (Simon & Simon, 1936)	FW	Stomach, body cavity, caecae, some in intestine.
	Thynnascaris adunca (Rudolphi, 1802)	M	Posterior intestine.
Acanthocephala	*Metechinorhynchus lateralis* (Leidy, 1851)	FW	Anterior intestine, posterior intestine, caecae.
Copepoda	*Salmincola carpionis* (Krøyer, 1837)	FW	Oral Cavity.
	Salmincola edwardsii (Olsson, 1869)	FW	Gills & inner operculum.

*New host record.

Table 2. Frequency of occurrence (%) of each parasite in each body location examined for all ages grouped together. BS = body surface, BC = body cavity, M = oral cavity, GI = gills and inner operculum, EY = eyes, E = esophagus, S = stomach, C = pyloric caecae, AI = anterior intestine, PI = posterior intestine, B = indeterminate, U = ureters, SB = swimbladder. Arctic charr are from Charr Lake (top) and Ikarut River / Hebron Fiord (bottom).

CHARR LAKE

SPECIES	LOCATION												
	BS	BC	M	GI	EY	E	S	C	AI	PI	B	U	SB
Tetraonchus monenteron	-	-		100*	-	-	-	-	-	-	-	-	-
Bunodera luciopercae	-	-	-	-	-	-	-	3	25	72	-	-	-
Crepidostomum farionis	-	-	-	-	-	-	2	27	15	54	2	-	-
Diplostomum sp(p	-	-	-	-	100	-	-	-	-	-	-	-	-
Phyllodistomum limnosae	-	-	-	-	-	-	-	-	-	-	-	100	-
Diphyllobothrium dendriticum	-	5	-				86	5	-	-	4		-
Diphyllobothrium ditremum	-	<	-		-	<	94	5	-		<	-	-
Eubothrium crassum	-	-	)		-		-	100	-	-	-		-
Eubothrium salvelini	-		-	-	-			100					-
Proteocephalus tumidocollis		-					-	76	22	2			
Proteocephalus longicollis							-	75*	25*		-		
Capillaria salvelini					-		100	-			-		
Cystidicoloides tenuissima	-	-	-				90	10		-	-	-	
Philonema agubernaculum		18		-	-	-	82	-	-	-	-		-
Metechinorhynchus lateralis		-	-	-	-	-	2	35	33	22	8	-	-
Salmincola edwardsii	-	-	-	100	-	-	-	-	-	-	-	-	-

* Parasite found in only one fish

IKARUT RIVER / HEBRON FIORD

SPECIES	LOCATION												
	BS	BC	M	GI	EY	E	S	C	AI	PI	B	U	SB
Brachyphallus crenatus	-	-	-	-	-	8	88	2	1	1	-	-	-
Bunodera luciopercae	-	-	-	-	-	-	-	-	48*	52*	-	-	-
Crepidostomum farionis	-	-	-	-	-	-	-	-	31	55	14	-	-
Derogenes varicus	-	-	-	-	-	38	62	-	-	-	-	-	-
Lecithaster gibbosus	-	-	-	-	-	-	-	33	-	34	33	-	-
Bothrimonus sturionis	-	1	-	-	-	-	1	37	17	14	31	-	-
Diphyllobothrium dendriticum	-	-	-	-	-	-	100	-	-	-	-	-	-
Diphyllobothrium ditremum	-	2	-	-	-	-	87	9	-	-	2	-	-
Eubothrium crassum	-	-	-	-	-	-	-	100	-	-	-	-	-
Eubothrium salvelini	-	-	-	-	-	-	-	100*	-	-	-	-	-
Proteocephalus tumidocollus	-	-	-	-	-	-	-	100*	-	-	-	-	-
Capillaria salvelini	-	-	-	-	-	4	96	-	-	-	-	-	-
Cystidicoloides tenuissima	-	-	-	-	-	-	100*	-	-	-	-	-	-
Philonema agubernaculum	-	25	-	-	-	1	18	18	3	2	33	-	-
Thynnascaris adunca	-	-	-	-	-	-	-	-	-	100*	-	-	-
Metechinorhynchus lateralis	-	-	-	-	-	-	-	17	45	27	11	-	-
Salmincola carpionis	-	-	100	-	-	-	-	-	-	-	-	-	-
Salmincola edwardsii	-	-	-	100	-	-	-	-	-	-	-	-	-

* Parasite found in only one fish

Table 3 lists the parasites recovered from mature fish in Charr Lake and the Ikarut River / Hebron Fiord and gives their prevalence, mean intensity, dominance and range. Because of the large difference in size between the mature small charr (mean length = 14.1 cm) and mature large charr (mean length = 58.1 cm) in Charr Lake, it was decided to treat these groups separately for some of the parasite analysis. In the mature small charr from Charr Lake *Diplostomum* sp. and *Crepidostomum farionis* had the highest prevalence, mean intensity and dominance values. These two parasites represent 98.9% (by number) of the total number of parasites recovered from these fish. For the mature large charr in Charr Lake *Diplostomum* sp. and *C. farionis* again showed the highest dominance values respectively with *Diphyllobothrium ditremum* also showing high values. These three parasites account for 95.1% of all parasites recovered from these fish. None of the small charr (immature or mature) were found to be infected with *Diphyllobothrium* spp. In the large landlocked charr *D. ditremum* was found more than 4 times as often as *D. dendriticum*. The only mature charr found in the Ikarut River / Hebron Fiord system were large charr (mean length = 53.9 cm, mean age = 9+ years). *Bothrimonus sturionis* and *Brachyphallus crenatus* showed the highest prevalence, mean intensity and dominance values and these parasites accounted for 98.7% of all the parasites recovered from these anadromous fish.

Table 3. Details of infection of small charr (mean length = 14.1 cm, N = 23) and large charr (mean length = 58.1 cm, N = 8) from Charr Lake (landlocked) and large charr (mean length = 53.9 cm, range 47.5 to 65.5 cm, N = 12) from Hebron Fiord (anadromous). All fish are in maturity state 3 or greater. P = prevalence, I = mean intensity, D = dominance, R = range. Note: Many larval mites (probably of the genus Unionicola) were found free in the stomach and intestine of landlocked charr. It is assumed that these were food items and not parasites of the charr.

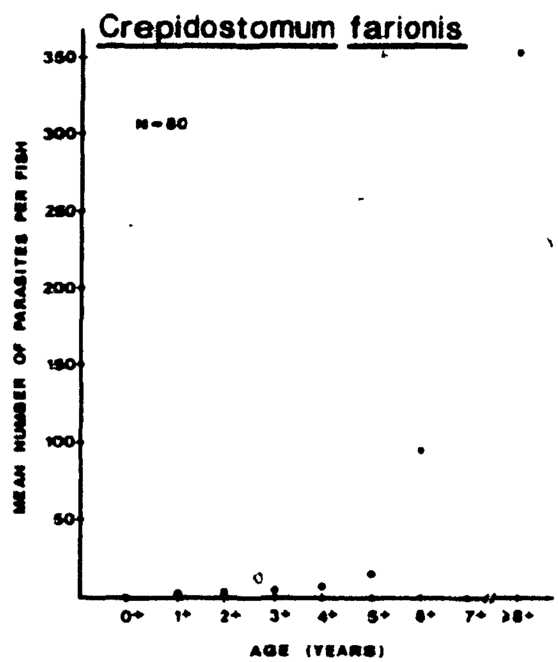
SPECIES	LANDLOCKED								ANADROMOUS			
	SMALL CHARR				LARGE CHARR				LARGE CHARR			
	P	$\bar{I}$	D	R	P	$\bar{I}$	D	R	P	$\bar{I}$	D	R
Brachyphallus crenatus	-	-	-	-	-	-	-	-	100	88.1	18.07	12-360
Bunodera lucioperсae	13.0	3.7	0.04	0-6	71.4	22.8	0.35	0-91	-	-	-	-
Crepidostomum farionis	82.6	11.8	4.48	0-64	100	499	15.22	56-2559	9 1	8.0	0.13	0-8
Derogenes varicus	-	-	-	-	-	-	-	-	18.2	1.5	0.01	0-2
Lecithaster gibbosus	-	-	-	-	-	-	-	-	9.1	2.0	0.04	0-2
Diplostomum sp(p).	100	169	94.39	34-1059	100	2279	69.50	1881-2852	-	-	-	-
Phyllodistomum limnosa	4.3	21.0	0.22	0-21	-	-	-	-	-	-	-	-
Bothrimonus sturionis	-	-	-	-	-	-	-	-	72.7	743	80.60	0-4627
Diphyllobothrium dendriticum	-	-	-	-	100	78.6	2.40	25-156	-	-	-	-
Diphyllobothrium ditremum	-	-	-	-	100	340	10.37	108-654	18.2	18.5	0.13	0-31
Eubothrium crassum	-	-	-	-	71.4	14.2	0.22	0-29	63.6	1.3	0.10	0-2
Eubothrium salvelini	-	-	-	-	42.9	2.7	0.01	0-5	-	-	-	-
Proteocephalus tumidocollus	-	-	-	-	42.9	11.7	0.07	0-32	9.1	1.0	0.02	0-1
Capillaria salvelini	4.3	12.0	0.12	0-12	-	-	-	-	-	-	-	-
Cystidicoloides tenuissima	26.1	4.3	0.16	0-9	-	-	-	-	-	-	-	-
Philonema agubernaculum	8.7	3.0	0.15	0-5	-	-	-	-	27.3	4.7	0.07	0-8
Thynnascaris adunca	-	-	-	-	-	-	-	-	9.1	1.0	0.02	0-1
Metechinorhynchus lateralis	13.0	34.5	0.44	0-72	100	59.3	1.81	4-167	45 5	1.0	0.05	0-1
Salmincola carpionis	-	-	-	-	-	-	-	-	72.7	3.5	0.37	0-8
Salmincola edwardsii	4.3	1.0	0.01	0-1	57.1	4.8	0 05	0-9	63 6	4.7	0.39	0-10

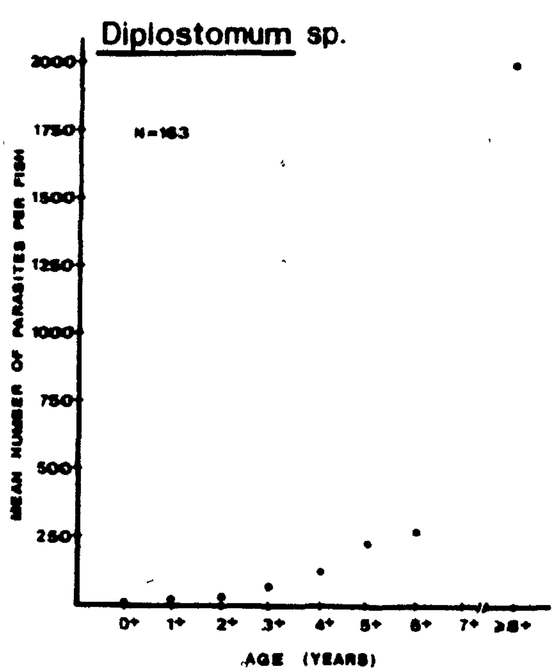
In Charr Lake the following parasites showed some indication of increasing levels of infection with age: C. farionis, Diplostomum sp., E. crassum and S. edwardsii. In the Ikarut River / Hebron Fiord B. crenatus, D. varicus, B. sturionis, M. lateralis, S. carpionis and S. edwardsii exhibited some tendency towards increasing levels of infection with age. Other species did not show increasing levels of infection with age but did exhibit other trends. In the lake D. dendriticum, D. ditremum and M. lateralis were found in the large piscivorous charr, and except for M. lateralis, were not found in the small charr. E. agubernaculum and C. tenuissima on the other hand, were found almost exclusively in the small charr in Charr Lake. D. ditremum and E. crassum were found exclusively in sea-run charr from Hebron Fiord. The remaining species did not have a high enough prevalence of infection to indicate any trends.

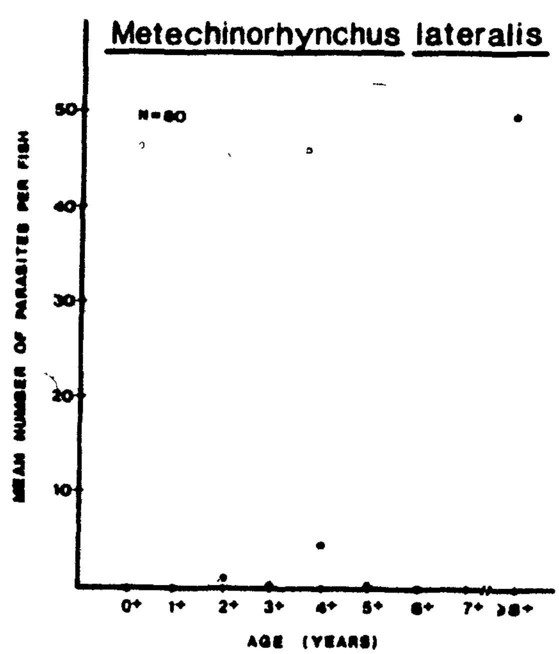
Figure 1 shows changing intensity with age for Crepidostomum farionis, Diplostomum sp. and Metechinorhynchus lateralis in Charr Lake. For C. farionis a very gradual increase occurs with increasing age up to 5+ years and a more steep increase afterwards. A similar trend occurs with Diplostomum sp. except that the level of infection is much higher. The actual values of infection of diplostomula ranged from zero in some 0+ fish to a high of 2852 diplostomula in one 19+ charr. For M. lateralis intensities fluctuate around low values until age 6+ and then increase in the older fish

Figure 1. Mean number of parasites per fish (abundance) versus age in years for *Crepidostomum farionis*, *Diplostomum* sp. and *Metechinorhynchus lateralis* in Charr Lake.

CHARR LAKE


Crepidostomum farionis
N=80
MEAN NUMBER OF PARASITES PER FISH
350
300
250
200
150
100
50
0+ 1+ 2+ 3+ 4+ 5+ 6+ 7+ ≥8+
AGE (YEARS)


Diplostomum sp.
N=163
MEAN NUMBER OF PARASITES PER FISH
2000
1750
1500
1250
1000
750
500
250
0+ 1+ 2+ 3+ 4+ 5+ 6+ 7+ ≥8+
AGE (YEARS)


Metechinorhynchus lateralis
N=80
MEAN NUMBER OF PARASITES PER FISH
50
40
30
20
10
0+ 1+ 2+ 3+ 4+ 5+ 6+ 7+ ≥8+
AGE (YEARS)

with a mean of 49 *M. lateralis* per fish for fish >= 8+ years old. This is in direct contrast to the pattern of infection of *M. lateralis* in the anadromous fish in Fig. 2 (note scale change) where the levels remain below one parasite per fish for all ages. *Brachyphallus crenatus*, a marine parasite, *Bothrimonus sturionis*, a brackish water parasite and *Salmincola carpionis*, a freshwater parasite, all show the general trend of increasing levels of infection with age (Fig. 2).

Table 4 shows the prevalence of infection of parasites at each age in the anadromous and landlocked systems. Anadromous charr enjoy a longer period of parasite free existence in the early years than do the landlocked charr. In the anadromous charr all fish are infected with at least one parasite by age 3+. All landlocked charr are infected by age 1+. Anadromous charr are being infected at a very early age with brackish water and marine parasites (predominantly *B. sturionus* and *B. crenatus* respectively). These young charr were collected in freshwater mostly near the mouth of the river. At age 1+, 43% of the charr are infected with at least one of these parasites. By age 4+ all anadromous charr are infected with marine or brackish water parasites. Table 5 shows the breakdown of infection of these parasites with increasing age in more detail. The marine parasite, *B. crenatus*, maintains an infection level of 100% after age 3+ whereas the levels for *B. sturionis* are more variable but an

Figure 2. Mean number of parasites per fish (abundance) versus age in years for *Brachyphallus crenatus*, *Bothrimonus sturionis*, *Salmincola carpionis* and *Metechinorhynchus lateralis* in the Ikarut River / Hebron Fiord.

IKARUT RIVER / HEBRON FIORD

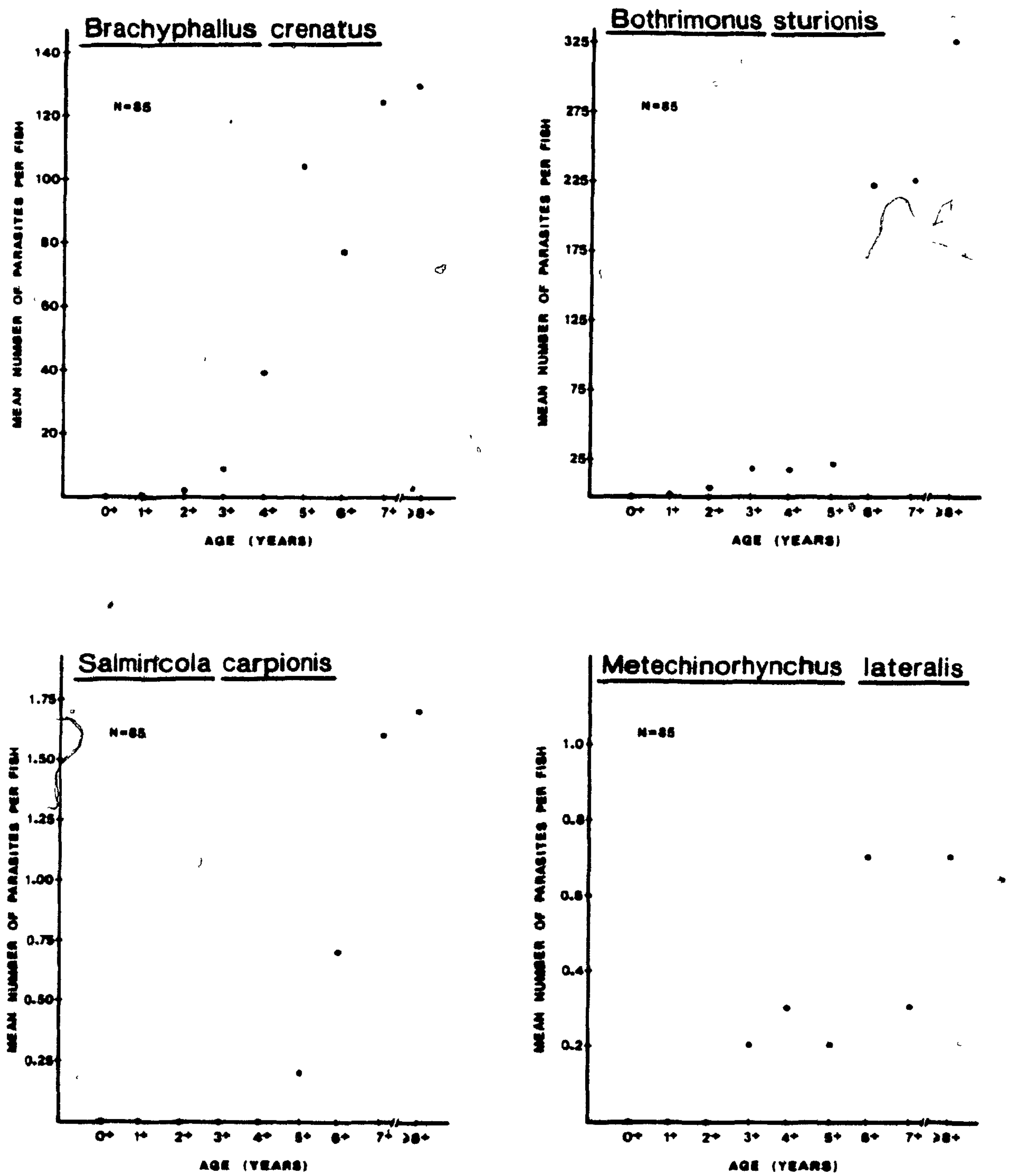


Table 4. Changing prevalence (%) with age for marine / brackish water and freshwater parasites in the anadromous system (Ikarut River / Hebron Fiord) and for freshwater parasites in the landlocked system (Charr Lake). N is sample size.

IKARUT RIVER / HEBRON FIORD	AGE								
	0+	1+	2+	3+	4+	5+	6+	7+	≥8+
MARINE & BRACKISH WATER PARASITES	0	43	73	94	100	100	100	100	100
FRESHWATER PARASITES	0	14	36	41	70	84	100	86	100
ALL PARASITES COMBINED	0	57	73	100	100	100	100	100	100
N	7	7	11	17	10	6	3	7	17
CHARR LAKE									
ALL PARASITES (FRESHWATER)	80	100	100	100	100	100	100	-	100
N	15	12	10	8	15	7	3	0	10

initial increase in infection with age is still observed. The prevalence levels for freshwater parasites in the anadromous fish are lower than that of the marine and brackish water parasites but rise consistently until age 6+ (Table 4). Except for one fish, prevalence of infection levels were 100% for all fish aged 6+ or greater. All freshwater parasites combined are responsible for this pattern since no one freshwater parasite has a particularly high dominance in the anadromous system.

Table 5. Percentage of anadromous charr from the Ikarut River and Hebron Fiord infected with the parasites *Brachyphallus crenatus* (marine) or *Bothrimonus sturionis* (brackish water) at each age.

PERCENTAGE OF FISH INFECTED			
AGE	*Brachyphallus crenatus*	*Bothrimonus sturionis*	N
0+	0	0	7
1+	14	43	7
2+	9	64	11
3+	76	88	17
4+	100	100	9
5+	100	83	6
6+	100	100	3
7+	100	57	7
>=8+	100	82	17

For the landlocked charr prevalence levels are high (90%) starting with the first summer of life (0+) and are 100% for all ages afterward. This high prevalence is due mostly to the infection of *Diplostomum* sp. but also to the infection of *C. farionis*, the two most dominant parasites in these charr.

All charr caught in Hebron Fiord had marine food items in their stomachs and harboured marine parasites (the smallest charr caught in the fiord was 13.8 cm, age 3+). Many small charr were caught at the mouth of the river in freshwater. All of these fish that were examined for parasites and stomach contents (ranging between 6.6 cm (1+ years) and 16.4 cm (3+ years)) harboured marine and/or brackish water parasites. All but one of these fish contained freshwater food items as the major food type in their stomachs. One 16.4 cm charr (3+ years) contained marine copepods as the predominant food type in its stomach. The analysis of stomach contents in this study was such that any food item representing less than 10% of the stomach contents was not recorded. It is therefore possible that some marine food items may have gone undetected in other fish if in low abundance.

Discussion

A total of 22 species of parasites were taken from landlocked and anadromous Arctic charr (Salvelinus alpinus) in northern Labrador. Twenty-one species have previously been reported from charr (Margolis & Arthur 1979; Curtis 1979; Dick & Belosevic 1981) and one parasite, Tetraonchus monenteron, represents a new host record. T. alaskensis has been recorded from Arctic charr in the Yukon (Mudry & McCart 1976) and near Resolute in the Arctic (Beverley-Burton 1978). T. monenteron has been recovered from the gills of northern pike (Esox lucius) in Labrador by Threlfall and Hanek (1970). Eighteen species of parasites were recovered from the anadromous charr whereas only 16 were recovered from the landlocked charr. Mudry and McCart (1976) and Beverley-Burton (1978) have also reported that the number of species of metazoan parasites of S. alpinus is greater in anadromous than freshwater resident fish.

The most dominant lake parasites were Diplostomum sp. Crepidostomum farionis and Diphyllobothrium ditremum respectively. For the anadromous charr Bothrimonus sturionis and Brachyphallus crenatus were most dominant. It is likely that not all of the younger fish (0+ to 3+) had been exposed to the marine environment and this may be the main reason for the low levels of infection of B. sturionis and B. crenatus in these fish. Dick and Belosevic (1981) have shown that B.

sturionis and *B. crenatus* are good indicators of sea-run charr. Black (1981) used the infection of *B. crenatus* to estimate the proportion of sea-run brook trout entering Rivière à la Truite in Quebec.

Arctic charr are infected with parasites starting at a very early age in the lake (80% infected at 0+ years and 100% infected at 1+ years) as compared to the anadromous charr (0% infected at 0+ to 100% infected at 3+ years). The anadromous charr do not carry heavy infections of freshwater parasites at any age. Dick and Belosevic (1981), in referring to *Diphyllobothrium* spp., suggested that the marine sojourn of anadromous charr may be sufficient to cause a reduction in parasite numbers. Infection by marine and brackish water parasites occurs early in the life of anadromous charr with 43% infected at 1+ and 73% at 2+ years of age. All fish 2+ or younger were caught in freshwater, as were many of the 3+ charr. Although freshwater food items were predominant in the stomachs of these fish (Chapter One) many harboured marine and/or brackish water parasites. It appears that young charr living in the region of the river mouth may move with the tide remaining in freshwater, except perhaps for short feeding excursions into saltwater (conversely, it is possible that their marine food items are straying into freshwater). Johnson (1980) stated that relatively little is known about the life history of Arctic charr between the end of the first summer of life and the time when the young fish first goes to sea. Pritchard (1911, from Coady & Best 1976) noted that fish schooling near the mouth of the river in early September were small in size. Moore (1975) found charr of 10 to 19 cm in length in the river mouths but fish less than 10 cm long were never found out of freshwater. Dempson and Green (1985) did not find charr younger than 3+ in the marine environment of Nain Bay, Labrador. Gullestad (1975, from Johnson 1980) showed that charr 4 to 7 years of age had brackish water zones on their scales. Grainger (1953, p. 358) stated that "there seems to be a definite tendency for the char of Frobisher Bay to remain close to the river mouths throughout the summer. This applies to all size groups, but most particularly to the small fish" and that "young char could readily be taken in the river close to its mouth". It appears that young charr may congregate in the region of the river mouth during the summer months. Data from the present study suggests that these young charr may go through a transition phase before spending an entire summer feeding in saltwater. This view is supported by Gyselman's (1984) observation that Arctic charr smolts entering the sea for the first time may stay for only 2 or 3 days. Young charr may stay near the river mouth to feed on stray food organisms near the salt water / freshwater boundary or they make make short feeding excursions into salt water and then return to freshwater (perhaps because they are not yet able to tolerate long periods in salt water). Both scenarios lead to the same observed result of young charr caught in freshwater and harbouring marine and/or brackish water parasites. Johnson (1980) stated that most studies confirm the smallest Arctic charr captured in the sea to be about 15 cm in length with a rather larger mean size. The smallest fish caught in saltwater in the present study was 13.8 cm (3+ years). McCart (1980) stated that Arctic charr in the western Canadian Arctic commonly moved seaward for the first time at ages 3 or 4 but that a few individuals may move seaward as early as ages 1 and 2. Moore (1975) stated that there were instances during the summer in which charr moved into rivers and then back into saltwater.

The best example illustrating increasing levels of infection with age is seen with Diplostomum sp. in Charr Lake. Specific identification of this parasite was not possible because positive verification of Diplostomum species from fish eyes can only be done through experimental infections of final hosts. In charr 8+ or older the observed levels of infection of diplostomula are higher than have ever been recorded in the literature. Despite finding more than 2800 metacercariae in the eyes of a single charr it does not appear that these parasites are interfering with the vision of the host as they may at lower infections in other fish (Palmer 1939; Uspenskaya 1957; Davies et al. 1973; Betterton 1974; Hendrickson 1978). For a more complete presentation on this parasite see Chapter Three.

Salmincola carpionis and *S. edwardsii* are acquired by fish in freshwater (Hoffman 1967) but appear to be able to tolerate marine conditions. Their site of attachment to the fish (oral cavity, gills, operculum) mean that they are in direct contact with salt water as long as the charr are in the fiord. Most fiord charr harbouring these copepoda were caught in late August and had been in the marine environment about 2 months.

Henricson (1977) found most *Diphyllobothrium ditremum* and *D. dendriticum* in the stomach and pyloric caecae respectively, similar to this study. He found 4.8 times as many *D. ditremum* in his charr as he did *D. dendriticum*. In this study 4.7 times as many *D. ditremum* were found in the Arctic charr as were *D. dendriticum*.

The anadromous charr from Hebron Fiord were lightly infected (mean intensity = 18.5) with *D. ditremum* only, whereas charr from Charr Lake had heavy infections of *D. ditremum* (mean intensity = 340) and *D. dendriticum* (mean intensity = 78.6). Curtis (1984) has also found that in eastern arctic Canada lake-resident charr are much more heavily parasitized with *Diphyllobothrium* spp. than are the anadromous charr. Dick and Belosevic (1981) state that "heavy infections of *Diphyllobothrium* spp. in the non-migrating charr ... are related to the feeding of large charr on small charr and sticklebacks ; *Gasterosteus aculeatus* and *Pungitius pungitius*" and that "small charr and sticklebacks were found to have cysts of *D. dendriticum* and *D. ditremum*". In Charr Lake all large charr were found to be feeding on small charr or sticklebacks (*Gasterosteus aculeatus*), however, no small charr (N = 71) or sticklebacks (N = 6) were found to be infected with *Diphyllobothrium* spp.

Large anadromous charr fed on marine copepods, amphipods and mysids and were piscivorous on small (<3 cm) juvenile sculpin (probably *Icelus spatula*) and in one case sand lance (*Ammodytes* sp.) and capelin (*Mallotus villosus*). Infection with *Diphyllobothrium* spp. was low in these charr.

Acknowledgements

I am grateful to the Department of Fisheries and Oceans, St. John's, Newfoundland for financial support and use of their Hebron, Labrador field station.

I would also like to thank the following people for contributing to the study in various ways: Professor Max Dunbar, Messrs. Brian Dempson, Rex Porter and our Inuit helpers Elias Harris and Nicholas Jararouse.

Special thanks go to professors M. Curtis, W. Threlfall, R. Khan, Dr. J. Pippy and Mr. C. Bourgeois for advice in examination and identification of the parasites.

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CHAPTER THREE

The occurrence of Diplostomiasis (Trematoda: Strigeidae) in Arctic charr (*Salvelinus alpinus*) from northern Labrador.

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Abstract

The eyes of 273 Arctic charr (*Salvelinus alpinus*) taken from Charr Lake, the Ikarut River and Hebron Fiord in northern Labrador were examined for the presence of diplostomula. The landlocked fish from Charr Lake were found to be heavily parasitized and intensity of infection increased with age and length. All anadromous charr taken from the Ikarut River and Hebron Fiord were found to be uninfected. Infections of up to 2852 diplostomula in one fish (1478 in one eye) are reported. These are the largest infections ever recorded for *Diplostomum* spp. More than 99% of the diplostomula were found in the epichorioidal lymph space located behind the retina, the remainder being located in the lens. No cataracts or herniations were associated with these high infections and it seems unlikely that the vision of the fish is affected in any direct manner.

Introduction

Metacercariae of the trematode genus *Diplostomum* (Rudolfi 1891) are known to occur as parasites of fish eyes, and have a wide distribution throughout the northern hemisphere (Skrjabin 1960; Hoffman 1967; Kennedy & Burrough 1977; Margolis & Arthur 1979). In several species of host fish vision impairment or blindness has been observed (Uspenskaya 1957; Betterton 1974; Hendrickson 1978), which in severe cases has brought about starvation and death (Palmer 1939; Davies *et al.* 1973). Moreover, intensive episodes of cercarial penetration by these strigeid trematodes have been shown to directly induce fish mortality (Brassard *et al.* 1982a) and to render surviving hosts more susceptible to predation (Brassard *et al.* 1982b).

Diplostomum spp. metacercariae are found in a variety of host fishes representing most freshwater groups (Skrjabin 1960; Bykhovskaya-Pavlovskaya *et al.* 1962). In Canada *D. spathaceum*, the most commonly reported species, occurs in the native salmonids *Salvelinus fontinalis*, *S. namaycush*, *S. alpinus* and *Salmo salar* (Margolis & Arthur 1979). High infections by this parasite have often been noted in fish farms or hatcheries (Rushton 1937; Palmer 1939; Ferguson & Hayford 1941; Uspenskaya 1957; Betterton 1974; Hare & Frantsi 1974; Wood 1979; Sharrif *et al.* 1980), especially for *Salmo gairdneri*, whereas high infections in natural systems appear less common (Davies *et al.* 1973; Wootten 1974). *D. spathaceum* has previously been reported to occur in Arctic charr from Canada in small numbers. Hicks (1971) found only two of 35 anadromous charr from Labrador to be infected and each fish harboured only two metacercariae.

The geographical distribution of diplostomiasis depends upon the availability of suitable hosts for the completion of the parasites' life cycle. The first intermediate hosts in northern Canada are Lymnaeid snails, second intermediate hosts are fish, and definitive hosts are piscivorous birds such as loons or gulls. In northern Quebec a relationship exists between the occurrence of diplostomiasis in fish and the calcium ion concentration of lakes. The parasite is not present in low calcium lakes where Lymnaeid snails are unable to live (Curtis & Rau 1980). Metacercariae of _Diplostomum_ can be found in a variety of locations within the eye. The most common locations are the lens, vitreous humor and/or retinal area depending upon the species of host fish and the specific identity of the parasite. In northern Quebec, brook trout (_S. fontinalis_) harbour the majority of diplostomula on the eye lens, whereas lake whitefish (_Coregonus clupeaformis_) tend to be infected in the retinal region (Rau _et al_. 1979). Dick and Rosen (1980), in a study on metacercariae of lake whitefish from Manitoba, determined that _D. spathaceum indistinctum_ inhabited the lens while _D. baeri bucculentum_ occupied the vitreous humor and retina of its fish host.

As part of a study of Arctic charr biology in northern Labrador during the summer of 1983, samples of metazoan parasites were obtained from an anadromous and landlocked charr stock. While the anadromous charr were found to be entirely free of diplostomiasis, the landlocked charr were heavily infected, a feature not yet reported for other known Arctic charr populations. This paper presents a description of the pattern of ***Diplostomum*** infection in the landlocked stock.

Materials and Methods

Arctic charr were sampled from northern Labrador between July 24 and August 29, 1983. Sampling sites (Fig. 1, Chapter One) were the Ikarut River, Hebron Fiord and the recently named Charr Lake (Newfoundland Geographical Names Board, St. John's, 1984). Charr Lake is approximately 23 hectares in area with a shallow, rocky, littoral fringe and about 13 m depth (J. Hammar, pers. comm.) in the centre. The lake harbours only Arctic charr and threespine sticklebacks (Gasterosteus aculeatus). These fish are landlocked owing to a series of waterfalls along the lake's outlet stream, which drains into the Ikarut River. The river substrate is mainly loose gravel and rubble (Murphy & Porter 1974) and is relatively unstable. The region of study lies about 25 km north of the northern tree limit (Elliott & Short 1979). The Ikarut River contains Arctic charr and brook trout (Salvelinus fontinalis) populations, and empties into Hebron Fiord. Fish collections were made using a dip net, hand seine, fyke net, and gill nets of mesh sizes ranging from 19 mm (3/4") to 114 mm (4 1/2"). Fork length and total weight was recorded for fresh fish which were then preserved in 4% buffered formalin. Later, the charr were transferred to 70% ethyl alcohol. Eyes were removed from the preserved fish and the numbers and locations of diplostomula were recorded separately for the left and right eyes.

Results

The eyes of 273 Arctic charr were examined for the presence of diplostomula. Of these, 110 were taken from the Ikarut River and Hebron Fiord. The range in length was 2.6 to 65.5 cm with an age range of 0+ to 11+ years. None of these anadromous charr harboured any parasites in their eyes. One hundred and sixty-three landlocked charr were taken from Charr Lake. Their range in length was 3.1 to 61.0 cm and ages varied from 0+ to 19+ years. A total of 155 of these fish (95%) were infected with diplostomula. There was no significant difference ($p < 0.05$, t-test) between the number of metacercariae found in male and female charr.

From Table 1 it is evident that the prevalence of eye infections was high, with all lake resident fish two years of age or older harbouring metacercariae. Uninfected fish were found only in the 0+ and 1+ age groups. The abundance of diplostomula per fish ranged from 0 to 2852. As many as 1478 were found in one eye. The percentage of fish with a lens infection was much lower, but the trend again shows an increasing intensity of infection with age (Table 1). Since not all the older fish harboured metacercariae in their lenses it appears that the infection rate for lens diplostomula does not reach 100% at any age. Data on the percentage of metacercariae found in the lens compared to that found in the entire eye for each age group indicates that less than 1% of them

Table 1. Level of infection with increasing age of Arctic charr with metacercariae of the genus *Diplostomum*. Age, mean number of metacercariae per fish at each age, sample size, standard deviation, percentage of fish infected at each age (prevalence), percentage of fish with metacercariae in at least one lens, percentage of metacercariae found in the lens.

AGE	MEAN	N	S.D.	PREVALENCE (% INFECTED)	% WITH LENS INFECTION	% TOTAL NO. IN LENS
0+	5.3	23	5.5	69.6	7.7	1.2
1+	12.7	18	10.5	94.4	10.0	0.6
2+	23.4	19	15.4	100	30.0	2.2
3+	60.9	30	36.5	100	50.0	1.1
4+	118.8	31	88.1	100	36.8	0.6
5+	219.7	28	133.0	100	58.3	0.4
6+	264.0	4	94.9	100	100.0	0.9
8+	1059	1	-	100	0	0
10+	1356	1	-	100	100.0	0.1
11+	1881	1	-	100	100.0	0.2
12+	1621	1	-	100	100.0	0.2
13+	2071	1	-	100	100.0	0.0
14+	2306	1	-	100	0	0
15+	2533	1	-	100	0	0
16+	2153.5	2	-	100	50.0	0.0
19+	2852	1	-	100	0	0

were found in the lens. The highest infection in a single lens was four metacercariae and the highest combined lens infection in a single fish was also four.

Upon detailed examination of the eyes it was found that the remaining 99% of the metacercariae were found behind the retinal areas in the epichorioidal lymph space (Fig. 1). In particular, they were found most often in close association with the ora serrata, the wavy anterior end of the retina. Very few, if any, metacercariae were found elsewhere except in or on the lens. In some samples there appeared to be minute striations immediately adjacent to the metacercariae in the lens. However, no cataracts or herniations that could apparently affect the charr's vision were found in or on the lens.

The mean number of metacercariae per age group increases fairly constantly from 0+ to 5+ years (Table 1). From 6+ to 19+ years, although sample size is small, this trend continues. The data for the mean number of metacercariae per age group was logged to display the results graphically (Fig. 2, top). A nearly exponential increase in number of metacercariae occurs with age up until 8+ years, after which the increase is small and there appears to be a leveling off of the curve. A similar but somewhat weaker relationship is seen with length instead of age (Fig. 2, bottom).

Figure 1. Sectional diagram of the eye of a bony fish showing locations of the metacercariae of *Diplostomum* sp. in the eye of Arctic charr. (Redrawn from Lagler *et al*. 1977).

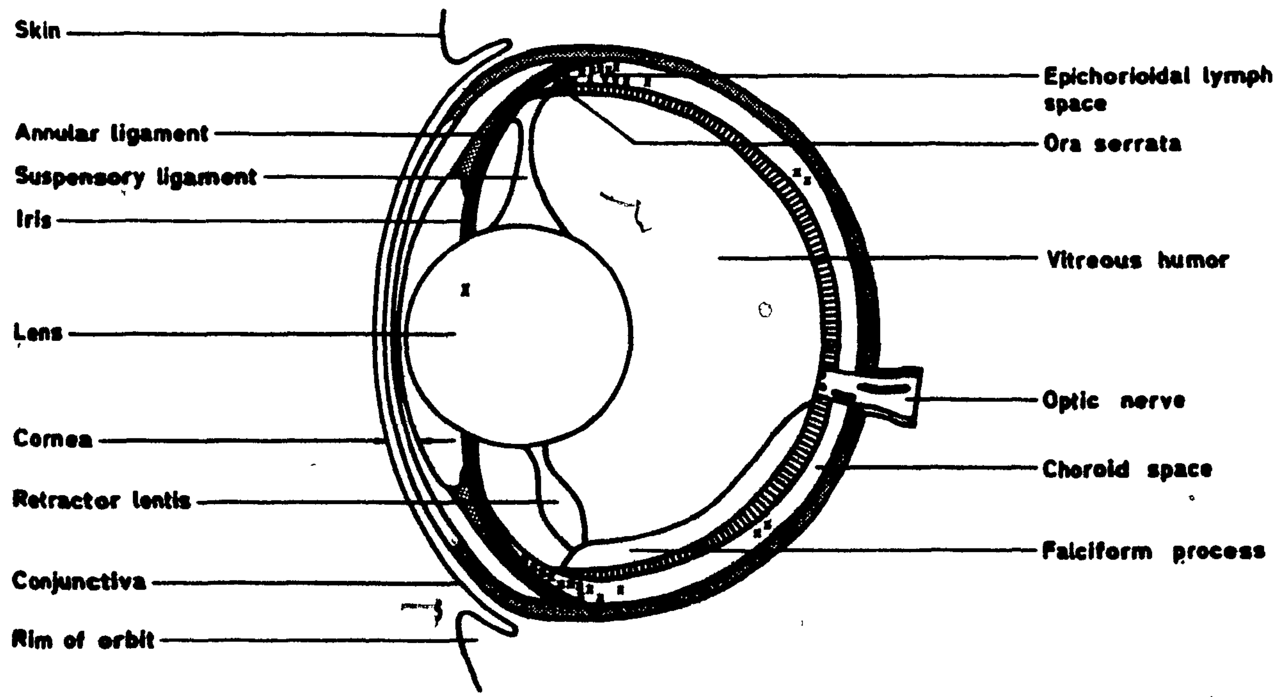
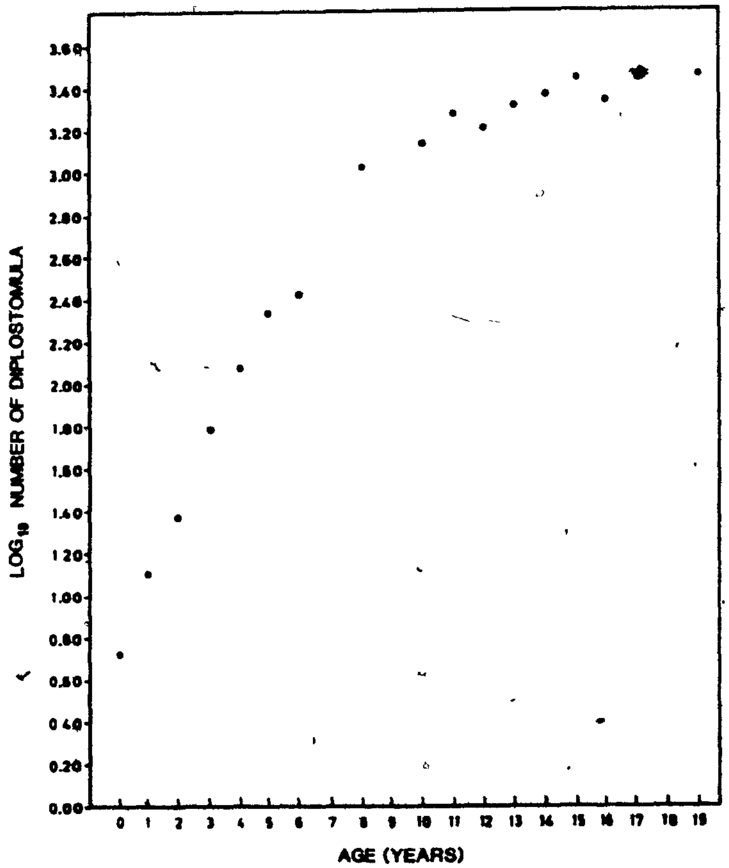
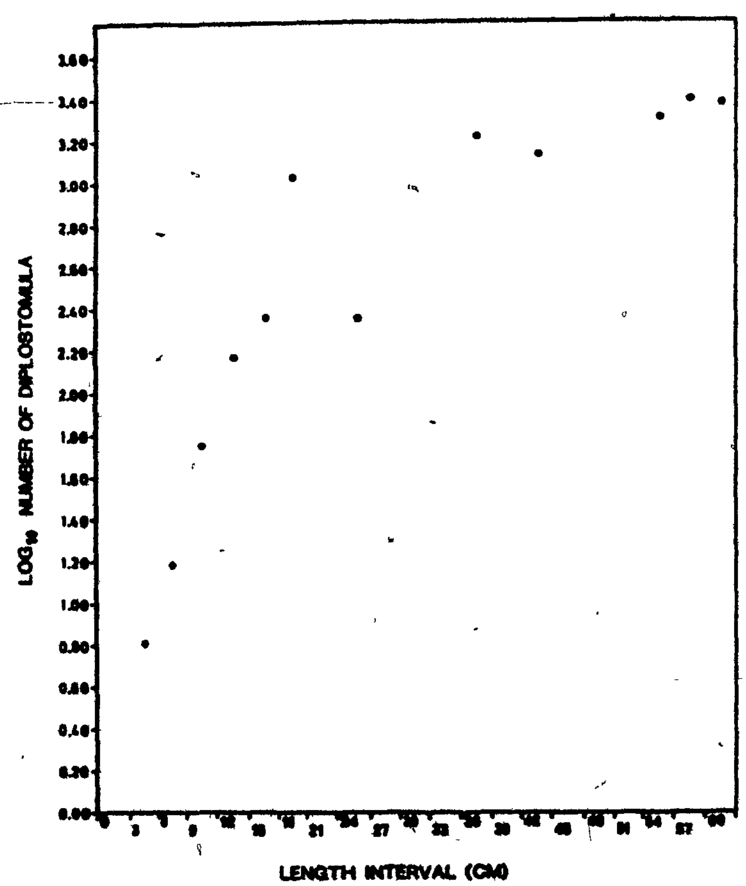

Skin
Annular ligament
Suspensory ligament
Iris
Lens
Cornea
Retractor lentis
Conjunctiva
Rim of orbit
Epichorioidal lymph space
Ora serrata
Vitreous humor
Optic nerve
Choroid space
Falciform process

Figure 2. Top: Relationship between the $\log_{10}$ of the mean number of diplostomula per age versus age in years.

Bottom: Relationship between the $\log_{10}$ of the mean number of diplostomula per length interval versus length interval in centimeters (data generated from class intervals of 3 cm).


LOG10 NUMBER OF DIPLOSTOMULA
AGE (YEARS)


LOG10 NUMBER OF DIPLOSTOMULA
LENGTH INTERVAL (CM)

Discussion

Our general understanding of taxonomic relationships within the genus *Diplostomum* is extremely limited. *D. spathaceum* is normally considered to be a parasite of fish lenses, although Wootten (1974) found metacercariae of this species in the vitreous humor as well as the lens of brown trout (*Salmo trutta*) and rainbow trout (*S. gairdneri*). Brook trout are also reported as having *D. spathaceum* metacercariae in sites other than the lens (Davies *et al*. 1973; Hare & Frantsi 1974; Hendrickson 1978). Dick and Rosen (1980) have shown that metacercariae found in the eyes of lake whitefish (*Coregonus clupeaformis*) can be identified by their location within the eye, with *D. spathaceum indistinctum* found in the lens and *D. baeri bucculentum* in the viteous humor and retina. Positive verification of *Diplostomum* species from fish eyes is only possible through experimental infections of final hosts, and thus the specific identity of the forms infecting Arctic charr in northern Labrador remains unknown.

The absence of Diplostomum from the Ikarut River and Hebron Fiord samples is probably due to the absence of a suitable snail species as intermediate host. Since Charr Lake is close to the Ikarut River, it is likely that infected birds that frequent the lake also visit the river and deposit *Diplostomum eggs* there. However, the river substrate is mainly loose gravel and rubble (Murphy & Porter 1974) and is relatively unstable. In the winter and spring the river bed is subject to ice scouring. This probably explains the absence of snails, which would be unlikely to establish themselves under such habitat conditions.

It has been shown that the intensity of infection in the landlocked population of Arctic charr appears quite high. In fact, the older charr in the sample have higher infections than any previously reported for Diplostomum in any fish species. However, fish from hatcheries and fish farms have been seen to have relatively greater numbers of diplostomula at younger ages, when compared to the charr of this study. The exponential increase in the mean number of metacercariae with age shown in our results is probably a function of the size (surface area) of the fish and the number of years they have been exposed to infection. Hendrickson (1978) states that a continual buildup of metacercariae with increasing fish size may indicate that the longevity of the parasites approaches that of the host fish. In support of this view would be the observation that no obviously degenerating diplostomula were evident in any of the fish examined. Thus the unusually high concentrations of metacercariae in older charr from northern Labrador may be seen as a function of the age of these long-lived fish, rather than a result of more intense seasonal transmission than occurs in temperate lakes.

The primary difference between the infection of Diplostomum in Arctic charr as reported here, and in other fish species appears to be the positioning of the metacercariae within the eye, with most located in the epichorioidal lymph space behind the retina. Only Hendrickson (1978) provides evidence of a similar occurrence of _D. spathaceum_ recovered from the choroids of brook trout and rainbow trout. Davies _et al._ (1973) observed that for infected brown trout 28% of the metacercariae were found on the lens, 62% on the retina, 7% on the iris and 3% in the vitreous humor, while for rainbow trout 20% were on the lens and 80% on the retina. Lester and Huizinga (1977) found a new species of diplostomula (_D. adamsi_) occurring in clusters located within the peripheral regions of the retina of perch (_Perca flavescens_). It remains possible that two species of _Diplostomum_ may be present in the eyes of the charr; one in the lens and another in the epichorioidal lymph space, a situation similar to that reported by Dick and Rosen (1980) for lake whitefish.

In contrast to other locations within the eye, metacercariae in the epichorioidal lymph space of the northern Labrador charr do not interfere with light passing to the retina. As a result, the high infections reported here do not likely affect the vision of the fish in any direct manner. Whether their presence affects eye function in other ways is unknown, but it would appear that charr under these conditions of diplostomiasis would be able to tolerate higher levels of infection than hosts in which the diplostomula occur in other locations within the eye.

Acknowledgements

We are grateful to the Department of Fisheries and Oceans, St. John's, Newfoundland for financial support and use of their Hebron, Labrador field station.

We would also like to thank the following people for contributing to the study in various ways: Dr. Max Dunbar, Messrs. Brian Dempson, Rex Porter and our Inuit helpers Elias Harris and Nicholas Jararouse.

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