[1985]

NATIONAL SWEDISH BOARD OF FISHERIES

Reprinted from

INSTITUTE OF FRESHWATER RESEARCH

DROTTNINGHOLM

Report No 62

LUND 1985
BLOMS BOKTRYCKERI AB

[1985]

Ecological Testfishing with the Lundgren Gillnets of Multiple Mesh Size: the Drottningholm Technique Modified for Newfoundland Arctic Char Populations

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ABSTRACT

An ecological standardized testfishing programme was carried out in insular Newfoundland and Labrador, in order to collect information on the population ecology and genetics of the Arctic char (*Salvelinus alpinus*) species complex. Two types of the Lundgren experimental gillnets of multiple mesh size, 6.25—75 mm and 10—75 mm, knot to knot, were used in both benthic and pelagic habitats in 20 water bodies. These systems contained Arctic char, brook trout, lake trout, Atlantic salmon, rainbow smelt, white sucker, three-spined stickleback and American eel. The testfishing design, equipment and techniques used are described. The use of gillnets of multiple mesh size is also discussed in terms of size and species selective characters, and the characteristics of the Lundgren experimental gillnets are pointed out. A complete model of a testfishing programme designed for northern freshwaters is recommended for future surveys in eastern Canada.

. INTRODUCTION

)nly minor parts of the "inaccessible" freshwaters ›f interior Labrador and insular Newfoundland ıave been explored in terms of their fish fauna. In act it was not until 1949 that the presence of ›rctic char on the island became known to the ›ublic (SCOTT and CROSSMAN 1964). This relict pecies is still today considered by many to be re- tricted to a few large and deep lakes. As a con- equence of the increasing exploitation and de- 'elopment on lakes and rivers in the province, here is major concern about the loss of informa- on on the original and virgin ecosystems.

A standardized testfishing programme was car- ed out in 20 water bodies in insular Newfound- ınd and Labrador (Fig. 1) during the summer ıd autumn of 1984.This study was conducted in rder to collect information on the ecology and ıe systematics of the Arctic char (*Salvelinus 'pinus* LINNÉ 1758) species complex, and levels f heavy metals in the fish.

A set of the Lundgren survey type gillnets of ultiple mesh size was used in both benthic and pelagic habitats. The equipment and the techniques used are described. The species and the size selectivity of the gillnets are presented and discussed, in the shadow of general criticism of the use of gillnets, as well as in the light of the experience of several years of their use in Swedish lakes.

This paper emphasizes the significance of the testfishing design and describes gear for a biological, qualitative and semi-quantitative sampling programme rather than a solely quantitative approach to testfishing.

The paper addresses administrators, researchers as well as personel in the fields.

It is the authors' hope that the present study can be used as a model for future testfishing programmes performed by the D.F.O. and consultant groups in eastern Canada to evaluate the impact of environmental changes, salmonid enhancement and stocking programmes as well as to gain a basic understanding of freshwater fish biology.

The testfishing programme in Red Indian Lake has been chosen as a representative example of the recommended sampling technique.

II. BACKGROUND

The need for longterm, compa about the structure of differen in natural lakes and lake reserv order to understand the effects and compensatory management produced a series of standard different combinations of mesh which were conducted in large r densities of benthic and pelagi required large-sized gear. A sys gillnets, 270 metres long and rep ent mesh sizes ranging from 16 to knot, where 30 and 33 m was most frequently used. It wa a biological test gang.

These first gillnets were ma at the end of the 1940's nylon ricated (in pink of course, since from a corset factory) and late testfishing. At the beginning multifilament gillnets were rep by transparent monofilament n creasingly common to use two with mesh sizes of 10 and 12 the extra 30 and 33 mm section bination was used permanently fishing programmes. However, this gear was four times large benthic gangs.

The different mesh sizes used 16.5, 22, 25, 30, 33, 38 and 50 r tive to the 12.5 mm mesh 13 r chosen. These were basically sizes available to any commer mercial fisherman in Sweden, pr solution in terms of both econ ment directives.

Typical biological test fishin consist of a few doubled bent sisting of 9 gillnets per night, depths and in different habit would be anchored in the dee the lake and used repeatedly or 24 hours at different depth nets successively from the surf the bottom.

Multiple Mesh Size:

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II. BACKGROUND

The need for longterm, comparable information about the structure of different fish populations in natural lakes and lake reservoirs in Sweden, in order to understand the effects of impoundment and compensatory management during the 1940's, produced a series of standard gillnet gangs with different combinations of mesh sizes. The surveys which were conducted in large reservoirs with low densities of benthic and pelagic fish populations, required large-sized gear. A system of 9 different gillnets, 270 metres long and representing 7 different mesh sizes ranging from 16.5 to 50 mm knot to knot, where 30 and 33 mm occurred twice, was most frequently used. It was commonly called a biological test gang.

These first gillnets were made of cotton, but at the end of the 1940's nylon gillnets were fabricated (in pink of course, since the fibre originated from a corset factory) and later on introduced to testfishing. At the beginning of the 1960's the multifilament gillnets were replaced successively by transparent monofilament nets. It became increasingly common to use two additional sections with mesh sizes of 10 and 12.5 mm, instead of the extra 30 and 33 mm sections. The latter combination was used permanently in the pelagic testfishing programmes. However, the catch area of this gear was four times larger than that of the benthic gangs.

The different mesh sizes used were thus 10, 12.5, 16.5, 22, 25, 30, 33, 38 and 50 mm. As an alternative to the 12.5 mm mesh 13 mm was sometimes chosen. These were basically the standard mesh sizes available to any commercial and non-commercial fisherman in Sweden, providing a practical solution in terms of both economy and management directives.

Typical biological test fishing gear would thus consist of a few doubled benthic sets, each consisting of 9 gillnets per night, used at different depths and in different habitats. A pelagic set would be anchored in the deeper central part of the lake and used repeatedly for periods of 12 or 24 hours at different depths by lowering the nets successively from the surface down towards the bottom.

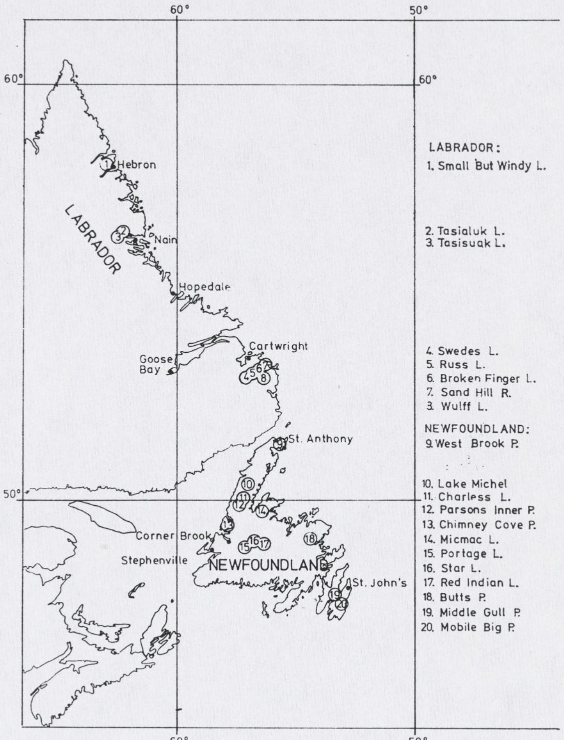

Fig. 1. Map of the Province of Newfoundland showing the location of the lakes where testfishing took place during 1984.

This was the successful technique which lay behind the large ecological programmes concerning the effects of water level regulation, the biology of sibling species complexes, and inter- and intraspecific competition and segregation between fishes conducted by G. Svärdson, T. Lindström and N.A. Nilsson at the Institute of Freshwater Research, Drottningholm in the following decades.

Altough this technique worked well in large lakes the biological standard gang was unpractical in small lakes; too large to use on spawning grounds and for small and valuable fish populations, and too coarse for detailed studies of the depth distribution of species close to the shores. On the other hand, in lakes with dense fish populations the catch was sometimes too large to handle and it was furthermore very difficult to vary the number of efforts gradually.

In cooperation with Lundgren's of Stockholm, the first small bottom net of survey type with multiple mesh sizes was constructed and used in 1968. The traditional mesh sizes previously used were supplemented with some additional larger mesh sizes.

This type of gillnet now dominates in the testfishing programmes performed by the Drottningholm staff, and has been used in scientific studies of fish populations in different parts of the world, from Svalbard, Greenland and Iceland in the North to South Africa and Sri Lanka in the South. The gear and the methods are described by Filipsson (1972).

The idea of catching a substantial amount of fish of different species and sizes at a specific depth in gillnets set parallel to the shore was put forward at the end of the 1960's by the visiting research scientist T. Northcote from the University of British Columbia, Canada (*e.g.* Northcote 1974).

In 1984, a joint research programme arranged by the Institute of Freshwater Research, Drottningholm, Sweden, and the Fisheries Research Branch, Department of Fisheries and Oceans, St. John's, Newfoundland, initiated an intense study of the population ecology and genetics of Arctic char (*Salvelinus alpinus* L.) in Newfoundland and Labrador.

The Arctic char is an important resource in the Northern region and as such heavily exploited by Man (Johnson 1980). The management of this sensitive and mosaic species complex is complicated by an immense variety in ecology, morphology and ethology (Filipsson and Svärdson 1976, Nyman 1984). Studies of population ecology and genetics combined with the knowledge of the group's circumpolar distribution, the preglacial isolation refuges and possible successive postglacial invasions might be one way of coming closer to the unravelling of this taxonomic problem.

The testfishing and the collection of Arctic char and coexisting species were performed using the Lundgren small experimental gillnets of multiple mesh size and the techniques regularly used at Drottningholm today.

A detailed description of two versions of the gillnets of multiple mesh size, its practical use and the sampling procedures are presented in "Material and Methods". Elementary instructions for pelagic gillnetting and a check list of equipment is given in an appendix. The species- and size-selectivity of the gillnets are discussed in "Results and Discussion".

Table 1. *The order, mesh sizes and material of 12 different panels of the Lundgren type S gillnet of multiple mesh size.* (Two bars=one mesh.)

Order	Bar mesh size (mm)	Stretched mesh size (inch)	Twine diameter (mm)
1	10	3/4	0.12
2	60	4 3/4	0.25
3	30	2 3/8	0.15
4	43	3 3/8	0.20
5	22	1 3/4	0.15
6	50	4	0.20
7	33	2 1/2	0.18
8	12.5	1	0.12
9	25	2	0.15
10	38	3	0.18
11	75	6	0.25
12	16.5	1 1/4	0.15

III. MATERIAL AND METHODS

Description of the Lundgren gillnets of multiple mesh size

During the survey of populations of Arctic char in Newfoundland and Labrador two types of benthic gillnets and one type of pelagic gillnet were used exclusively.

The Lundgren benthic survey gillnet of type S is a transparent monofilament nylon gillnet, 1.5 metres (5 ft.) deep, with a 36.6 metres (120 ft.) long headline and a 45.7 metres (150 ft.) long sinkline. It is composed of twelve 3.0 m (10 ft.) panels of different mesh sizes (Table 1). The order of the panels is such that the larger mesh sizes are surrounded by smaller ones.

In the revised type S gillnet another two panels with finer mesh sizes have been included, resulting in a 42.7 metres (140 ft.) long gillnet with 14 panels in the reverse order (Table 2).

The two pelagic types of gillnet consist of the same mesh sizes and material as the benthic nets

Table 2. *The order and the ... panels of the Lundgren re... multiple mesh size.*

Order	Bar mesh size (mm)
1	6.25
2	8
3	16.5
4	75
5	38
6	25
7	12.5
8	33
9	50
10	22
11	43
12	30
13	60
14	10

although the former are 6 m... each panel being 6 metres ... ferent panels are arranged ... mesh size. In order to facili... ling of such large gear, the... two sections.

A gillnet of multiple mes... use in running water clos... is also marketed by Lunc... stream gillnet is mainly a... size with doubled headlir... series of increasing mesh s... following: 6.25, 8, 10, 12.... 38, 43, 50, 60 and 75 mr... graphically in Fig. 2. It mu... that the present range of n... gren experimental gillnet ... used previously in the larg... mentioned earlier, and is ... of an adjustment to a specif...

We do not know the deg... size of a specific mesh ir... changes that occur during a... probably comparable with... standard gillnet.

Description of the lakes

The survey carried out ... water bodies ranging in ... shallow ponds (less than 2....

Table 2. *The order and the mesh sizes of different panels of the Lundgren revised type S gillnet of multiple mesh size.*

Order	Bar mesh size (mm)	Stretched mesh size (inch)	Twine diameter (mm)
1	6.25	1/2	0.10
2	8	5/16	0.10
3	16.5	1 1/4	0.15
4	75	6	0.25
5	38	3	0.18
6	25	2	0.15
7	12.5	1	0.12
8	33	2 1/2	0.18
9	50	4	0.20
10	22	1 3/4	0.15
11	43	3 3/8	0.20
12	30	2 3/8	0.15
13	60	4 3/4	0.25
14	10	3/4	0.12

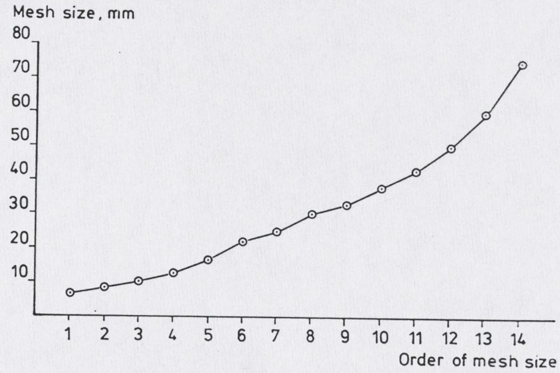

Fig. 2. Graphical illustration of the series of 14 different mesh sizes in the Lundgren experimental gillnet of multiple mesh size. The actual order of mesh sizes in the gillnet is different. For further information see text.

although the former are 6 metres (20 ft.) deep with each panel being 6 metres (20 ft.) long. The different panels are arranged in order of increasing mesh size. In order to facilitate the practical handling of such large gear, the gillnet is divided into two sections.

A gillnet of multiple mesh size for experimental use in running water close to inlets and outlets is also marketed by Lundgren's. This so called stream gillnet is mainly a net of multiple mesh size with doubled headlines and sinklines. The series of increasing mesh size would thus be the following: 6.25, 8, 10, 12.5, 16.5, 22, 25, 30, 33, 38, 43, 50, 60 and 75 mm. The series is shown graphically in Fig. 2. It must be pointed out again that the present range of mesh sizes in the Lundgren experimental gillnet is based on mesh sizes used previously in the larger biological test gang mentioned earlier, and is by no means the result of an adjustment to a specific geometrical series.

We do not know the degree of variation in the size of a specific mesh in a new net, nor the changes that occur during a season's use. These are probably comparable with the variation in any standard gillnet.

Description of the lakes

The survey carried out comprises oligotrophic water bodies ranging in size from small and shallow ponds (less than 25 ha) in alpine regions to deep river canyons and lakes (larger than 18.000 ha) in insular Newfoundland and Labrador (Fig. 1).

Description of the fishing technique

The main aim was to collect samples and ecological information from all of the major habitats and different depth zones, both benthic and pelagic. In order to gain a representative view of the population structure, habitat use and depth distribution of the Arctic char and all coexisting fish species, every mesh size had to be exposed in every habitat and depth zone (Fig. 3).

Benthic gillnetting

In each lake a regular and even shoreline with a gentle depth gradient was chosen for the placing of successive series of gillnets of multiple mesh size at different depths. Since the size of the catch usually decreases with increasing depth, the number of gillnets used in each set was simultaneously increased with depth.

The individual gillnets were attached to each other end-to-end by the existing loops and plastic net handles. By connecting several gillnets together the risk of having the entire equipment tangled by a very large fish is minimized.

With the help of a simple echo-sounder the depth profiles were easily located. The gillnets were set on the bottom parallel to the shore, with a small buoy at each end of the gang. These buoys

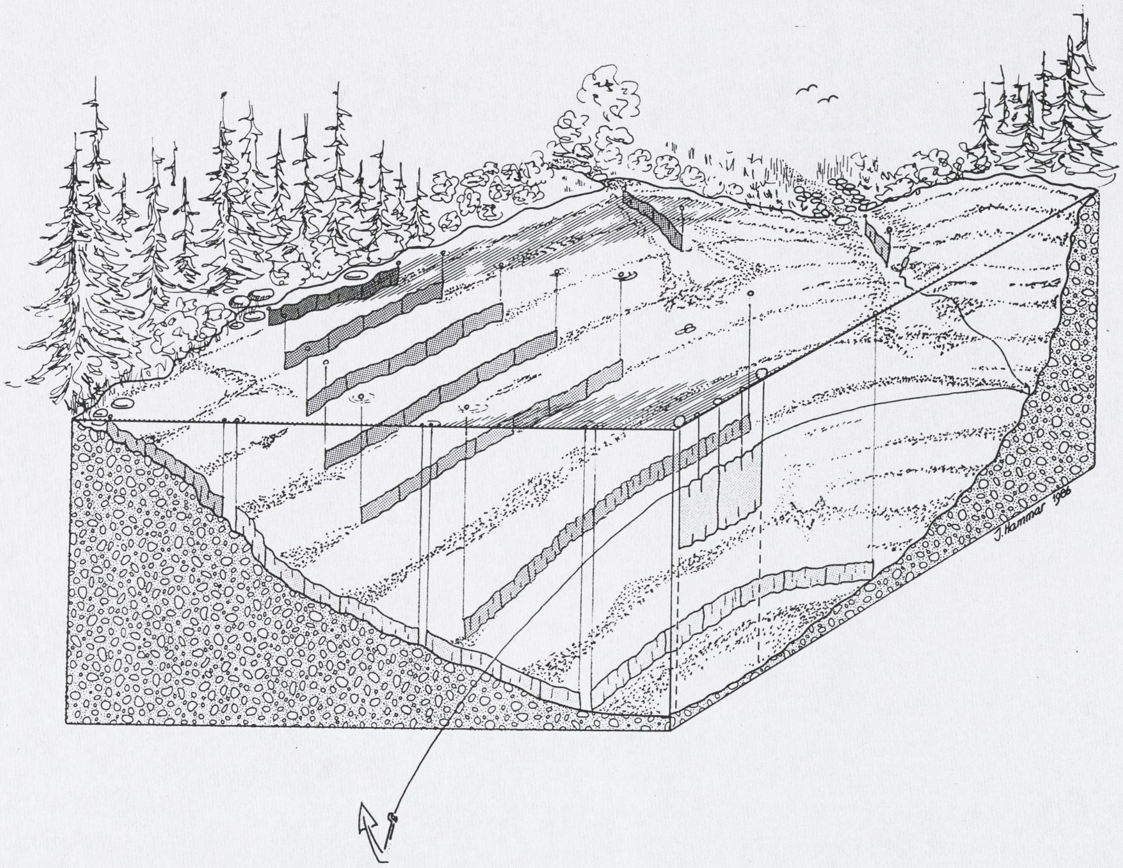

Fig. 3. The Drottningholm technique for ecological sampling of a lake with pelagic and benthic gillnets of multiple mesh size. (Drawing J. Hammar.)

were prepared in advance, with different lengths of line attached and carefully marked. The buoy lines were made of thin cord and with several metres of excess line in order not to disturb the gillnet during rough weather.

The sinkline is heavy enough to keep the small gillnet in place, and there was no need for anchors. The gillnets were hung loose. This is the old fisherman's trick to catch more fish, and according to Riedel (1963) loosely-hung gillnets tangle more fish and also fish of a much wider size range than a straight gillnet.

Depth zones were chosen at 5 or 10 metre intervals from close to shore at 1 to 2 metres depth all the way down to the maximum depth. As a further check of the depth distribution of different fish species a gang of many gillnets of multiple mesh size may be set at a right angle from the shore down to the required depth. Heavier experimental gillnets of stream-type may be used close to the major inlets and the outlet (Fig. 3).

The benthic gillnets were set in late afternoon and examined in the morning.

Pelagic gillnetting

The huge pelagic gillnet requires special handling in order to provide comparable results. The set has to be suspended by buoys and properly straightened with long ropes attached to heavy anchors (Fig. 4).

The buoy lines for the pelagic gillnet were carefully prepared in advance. Since the depth of this gillnet is 6 metres and the gear was lowered 6 metres every 24 hours, the lines were twined around the buoys and tied carefully with two

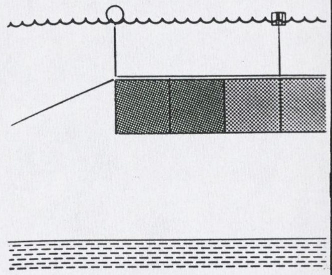

Fig. 4. A model of a correctly fl

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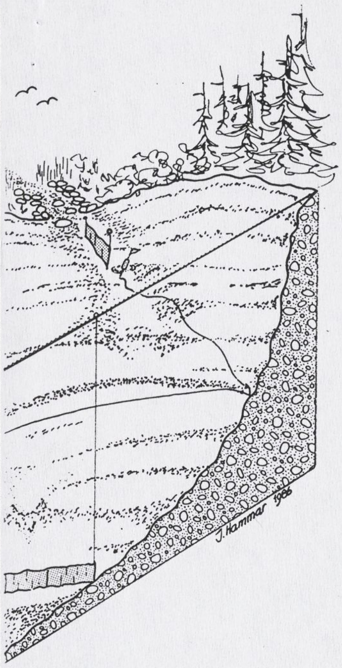

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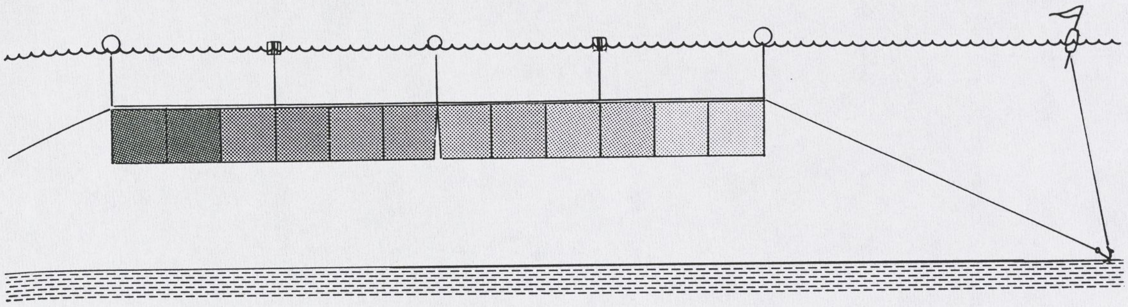

Fig. 4. A model of a correctly floated pelagic gillnet of multiple mesh size.

reversed half hitches at every sixth metre. This knot will lock the line to the buoy at each depth interval and when untied properly it does not form any irritating knots on the cord.

The two sections of the pelagic gillnet were connected to each other end-to-end. Two large and clearly visible red buoys were attached at both headline ends of the whole set. When fishing in the uppermost depth interval these buoys were tied to the gillnet itself. Because of the tension in this part of the gear heavier buoy lines are required, and a number of 6 metre long ropes were tied between the buoys and the headline end of the gillnet in each set.

The rest of the buoys were made of rectangular and protectively painted pieces of plastic foam, around which the line was wrapped symmetrically. Two buoys were attached to each section of the gillnet and one larger buoy was tied inbetween.

Two strong braided ropes of a floating synthetic material were used to anchor the gear from the headline ends. The length of each rope should be three times the water depth. At the other "end" of the heavy anchor, another rope slightly longer than the water depth was connected to a large flag buoy. This was done in order to haul up the anchors from the opposite direction, in the case of a change in wind direction.

The pelagic gear was usually located over the deepest part of the lake, and was set and checked in the morning every 24 hours.

Elementary step by step instructions for setting the pelagic gear are given in an appendix (page 30).

Other procedures connected with testfishing

The survey carried out with gillnets was accompanied by the recording of the following data, in order to broaden the scope of the study.

(1) Exact depth of both ends of each gillnet in metres.
(2) Date and time for setting and checking the nets.
(3) Surface water temperature in centigrade.
(4) Air temperature in centigrade.
(5) Wind strength in metres per second, and the major wind direction.
(6) Cloud cover in per cent and general weather comments.
(7) Comments regarding any factors that could affect the catch statistics such as brown humus slime, sticks and branches in the gillnet, or factors that might be of value for the food analyses, such as mass occurrences of flying ants, sprucebud butterflies and so on.

While the boat was connected to an anchored line it was very convenient to:

(1) Sample zooplankton qualitatively by means of vertical hauls of a plankton net between the bottom and the surface. A standardized mesh is important and in this study 60 µm was used. The plankton sample was preserved in well-buffered 5 % formalin.
(2) Measure the water temperature cline from the surface down to the bottom with a thermistor or a water sampler.
(3) Record the water transparency by using a Secchi-disc. (It is important to standardize the

time of the day for this measurement. Also the side of the boat, *i.e.* shade, and the use of a viewer (to be really correct).)

Sampling techniques

The benthic gillnets were brought back in large baskets to a suitable place, where they were hung up in the shade to be examined and cleaned. The fish from each gillnet were treated as a unit and kept separate in a cold place for further sampling, which was carried out as soon as possible.

The sampling procedure for individual fish depends of course on the objectives of the study. In the present study the Arctic char were of particular interest, although the entire catch was sampled. (It should be a principle in research to measure as many parameters as possible on every fish killed.)

Each fish was given an individual number. This and the number of the gillnet were recorded on a scale envelope. The species, the gillnet number and the date could then be traced to the testfishing form.

The usual standard procedure included:

(1) Measurement of fork length to the nearest mm. (In Sweden the total length is measured as a standard.)

(2) Measurement of the total weight to the nearest gram.

(3) Sampling of otoliths for ageing. The otoliths were cleaned in water before being put into the scale envelope.

(4) Sampling of scales as an additional means of ageing salmon, brown trout, whitefish, rainbow smelt and other large scaled species. (Avoid putting the scales and the otoliths in the same corner of the envelope.)

(5) Recording of sex and degree of sexual maturation.

There are several systems, but generally a description in words of the appearance of gonads is preferable in order to avoid later misinterpretation. In the present study two systems were used parallel:

At the Drottningholm Institute a system combined after Dahl (1917), and Sømme (1941) is generally used. The system was later examined and compared with histological observations (Flumé 1978).

The thickness of the male gonads was described according to six stages of maturity (Lindström 1962) including ripe and spent males. The females were described in terms of the size of the eggs combined with the proportion of the gonads in relation to the body cavity (Lindström 1962). Ripe and spent females were noted as well as the presence of new eggs.

The system modified after Vladykov (1956) generally used by the Freshwater & Anadromous Program, DFO, St. John's, is as follows:

Immature	1
Maturing	2
Mature	3
Ripe	4
Spent	5
Spent last, mature present	6
Spent last, mature next	7

(6) The meat color (white, light pink, pink or red), visible external and internal parasites, and morphological characteristics were also noted on the envelope.

(7) For heavy metal analyses some specimens were sampled with acid-washed glass knives on a clean table covered by plastic sheeting. Samples of muscle, liver and kidney were put in separate acid-washed tubes and frozen. (It is of utmost importance to avoid contamination by metal instruments.)

(8) For electrophoretic studies samples of muscle and liver, and whole eyes were taken with a clean scalpel, and kept in numbered test tubes in a freezer.

(9) The gut was preserved in formalin for further stomach and parasite analyses. (Studies of internal parasites of the stomach region are facilitated by digesting gut tissue in acidic Pepsin. This technique is described by Meyer and Vik (1961). An illustrated key to the metazoan parasites of salmonids of insular Newfoundland is given by Pippy (1970).)

(10) Some specimens were frozen or preserved whole in formalin after sampling, for morphometric measurements and meristic counts.

IV. RESULTS AND DISC

Standardized testfishing

The repeated standardized at certain stations and at c and the year constitutes t used in fish biology to col the status, the relative pc changes in various fish pc Information is sought on di acters such as food habits, and age structures and co

Testfishing may be direc species or restricted to on by using knowledge about selective characters of the g

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IV. RESULTS AND DISCUSSION

Standardized testfishing

The repeated standardized use of defined gear, at certain stations and at certain times of the day and the year constitutes the traditional method used in fish biology to collect information about the status, the relative population size and the changes in various fish populations in a system. Information is sought on different ecological characters such as food habits, growth patterns, length and age structures and competitive rank orders.

Testfishing may be directed to a wide range of species or restricted to only one or few species, by using knowledge about the size and/or species selective characters of the gear.

There are several methods of collecting fish; *i.e.* the passive use of gillnets, fences or fyke traps and the active use of trawls, beach seines, electricity or rotenone. They all show important limitations and/or various degrees of selectivity. Most of them are best suited for studies in streams and smaller bodies of water and provide very limited and narrow information about the ecology of lacustrine fish populations. The common use of fyke traps in Newfoundland freshwater surveys has been shown to be valid for littoral populations of brook trout, whereas the catches of Atlantic salmon showed excessive seasonal differences (Ryan 1984).

The best way to collect samples of and ecological information about fast-swimming salmonids inhabiting lakes and larger bodies of water would at present thus seem to be by gillnetting.

Gillnets are easy to handle and are considered to be very efficient. However, comparative studies based on material sampled by gillnets have been thoroughly criticized by several authors due to the selective nature of the method (Hamley 1975). Various mathematical approaches are exemplified in McCombie and Fry (1960), McCombie and Berst (1969), Hamley (1975) and Hamrin (1979). Different experimental combinations of multiple mesh sizes have been tried in order to reduce the size-selective restrictions of the gear (Moyle 1950, Wilde and Romeo 1951, Berst 1961, Horak and Tanner 1964, Houser and Ghent 1964, Grinstead 1969, Takagi and Ishida 1971). Other models of gillnets of multiple mesh size from Lundgren's have been used by Johnson (1983) in his comprehensive study of Arctic fish populations and by the Greenland Fisheries and Environmental Research Institute (*e.g.* 1985). Due to concern about the different efficiencies of the various mesh sizes these gillnets are still questioned.

Another major reason for concern is insufficiently designed testfishing programmes where even larger errors and lack of information are due to ecologically incomplete sampling in habitats other than the littoral zone. In order to gain information on the fish species of a lake and their depth distributions, as well as an ecological description of the habitat of each of the species, standardized gillnetting with multiple mesh sizes has to cover various depths and biotopes.

In spite of this there are so far no practical alternatives, and the use of gillnets of multiple mesh size is still important in biological research. Providing that the selectivity of the gillnet and its value for different species can be determined, and that it is used in a standardized way, a Lundgren experimental gillnet of multiple mesh size provides a very practical and highly valid testfishing tool in northern lakes.

Significance of the number of efforts

In a practical attempt to facilitate the comparison of catch data from different lakes Moyle (1950), assuming a normal distribution, concluded that catch means at probability levels greater than 80 per cent do not appear to be practically feasible. In order to minimize the variation of the standard error to less than 30 % of the catch at a specific depth at least 4 efforts with Lundgren gillnets of multiple mesh size are recommended in Swedish programmes (P. Nyberg and E. Degerman in prep.). In the present study, repeated efforts in depth zones with dense fish populations gave only minor differences in the numbers of specimens belonging to different taxa. This was exemplified in Red Indian Lake. In order to compare the catch data quantitatively between different depths or different lakes we recommend 4—8 efforts with Lundgren gillnets per depth zone.

Saturation and limits of the Lundgren gillnet of multiple mesh size

The small gillnets of multiple mesh size have been subjected to speculations concerning the saturation

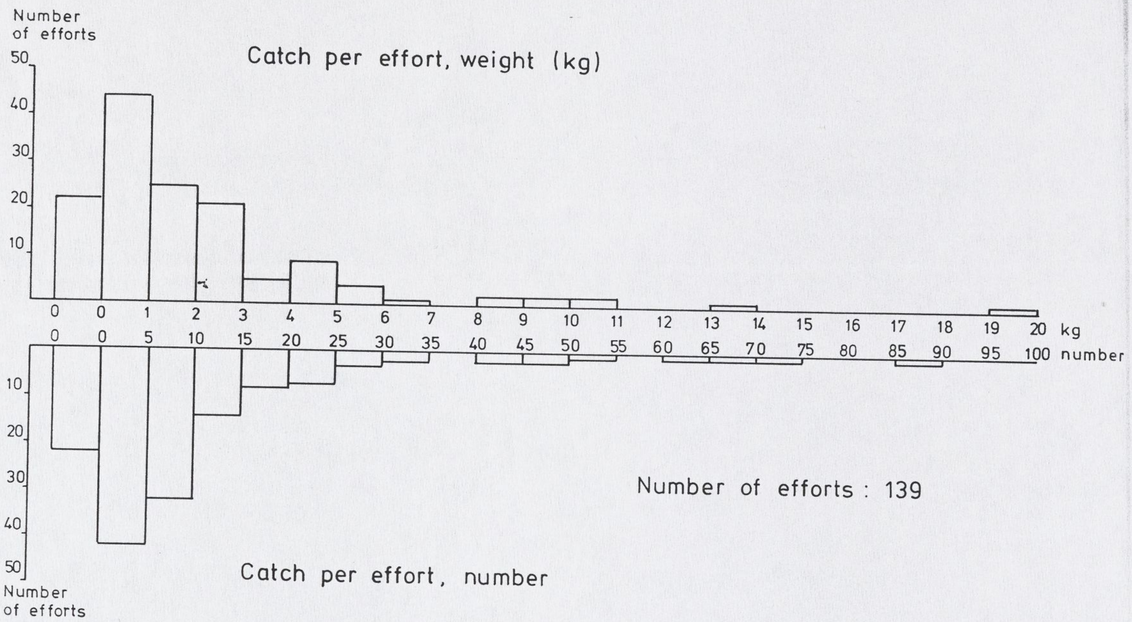

Fig. 5. Saturation of gillnets shown as weight and numbers of fish caught in individual gillnets of multiple mesh size (10—75 mm) for the entire study.

limit and a possible low limit to the number of fish caught, or the total weight of the catch in a single gillnet per night. However, the catches given by the use of this gear in lakes in the High Arctic (less than 5 kg, Hammar unpubl.), in southern Sweden (less than 6 kg, Filipsson unpubl.) and in tropical areas (less than 10 kg in Sri Lanka, Enderlein and Wickström pers. comm.) are far greater than the amounts usually caught in exploited alpine lakes of northern Sweden (less than 0.5 kg, Filipsson unpubl.). In this study testfishing in unexploited alpine lakes of Labrador gave even larger catches (Fig. 5.). In lakes with white suckers and anadromous Arctic char in the Sand Hill River region, the catch varied between 5 and 13 kg per 24 hour effort. The catch of 18 large Arctic char taken in a single deepwater gillnet weighed more than 19 kg.

Species selectivity

Lundgren gillnets of multiple mesh size have been used in 20 lakes with different ecological and physical characteristics in Newfoundland and Labrador. The gillnets have shown to be efficient for catching Arctic char, brook trout, lake trout, Atlantic salmon, rainbow smelt and white sucker. In addition three-spined stickleback was represented, and specimens of brown trout (*Salmo trutta* Linné), mottled sculpin (*Cottus bairdi* Girard) and winter flounder (*Pseudopleuronectes americanus* (Walbaum)) were occasionally caught.

In a large number of lakes the catch and the gillnets showed considerable damage caused by eels, and several smaller specimens of salmonids had been partly eaten by the eels. Only one specimen of the American eel (*Anguilla rostrata* (Le Sueur)) was caught, however, revealing an important restriction of the gear, the problem of quantifying this particular species and coexisting small salmonids.

The gillnet is a passive gear depending to a very large extent on, and perhaps providing a measure of, the activity of the fish. Different species may show different periods of activity in terms of the time of the day as well as the time of the year. The damage caused by the eels might be lessened if the gillnets are checked as early as at dawn. The standardization of the fishing period is consequently selective for certain species.

Since different species have different swimming

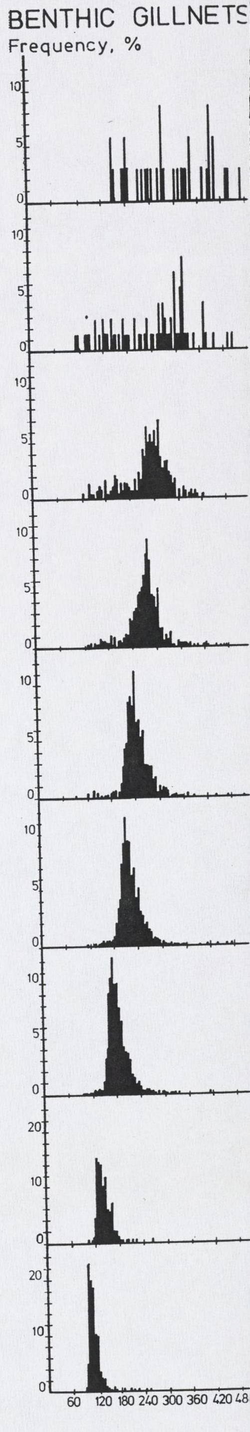

Fig. 6. Length distributions f
in a pooled sample combining

15 16 17 18 19 20 kg
75 80 85 90 95 100 number

efforts : 139

t in individual gillnets of multiple

rainbow smelt and white sucker.
-spined stickleback was represen-
ıs of brown trout (*Salmo trutta*
sculpin (*Cottus bairdi* GIRARD)
ıder (*Pseudopleuronectes ameri-*
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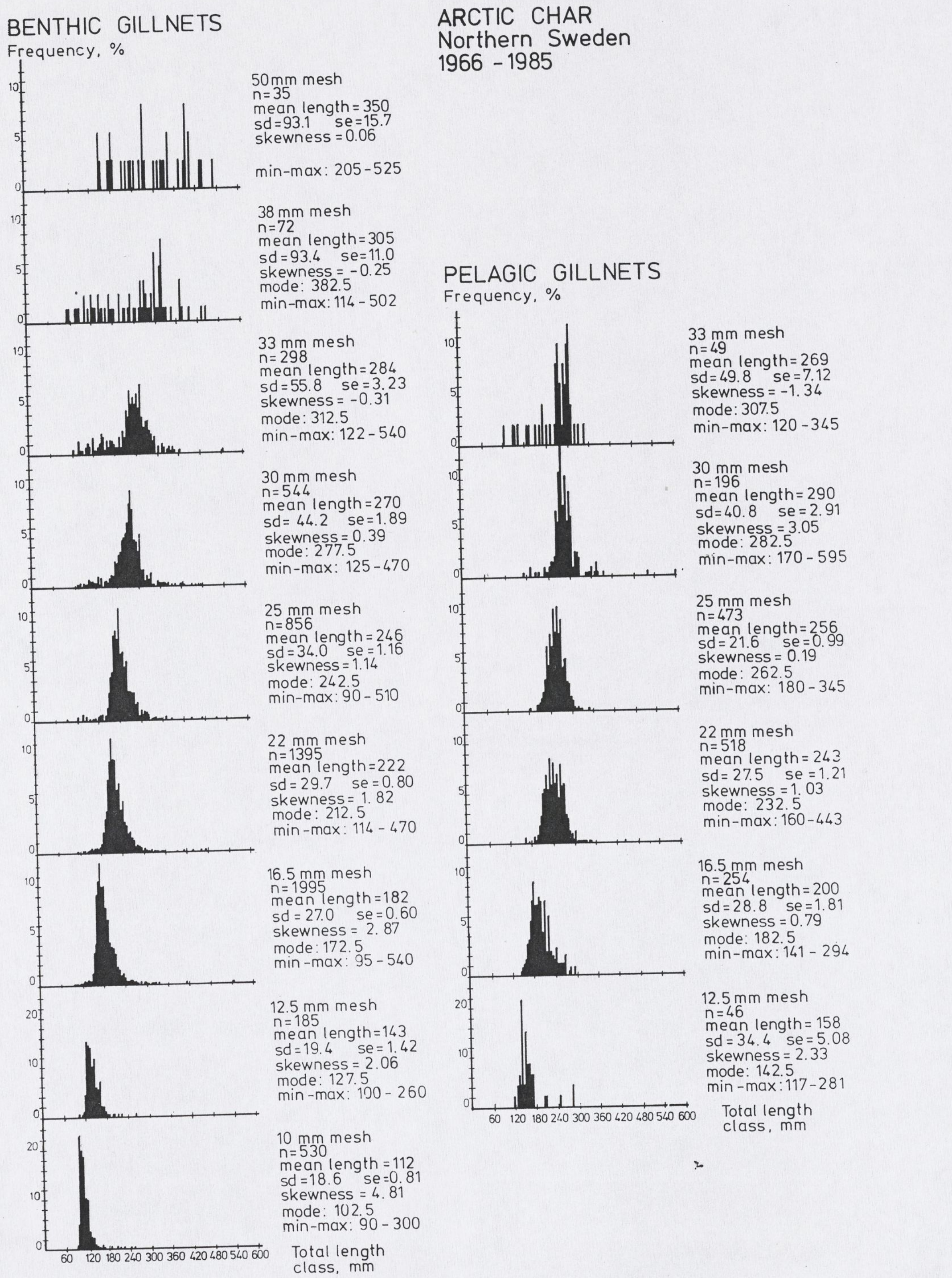
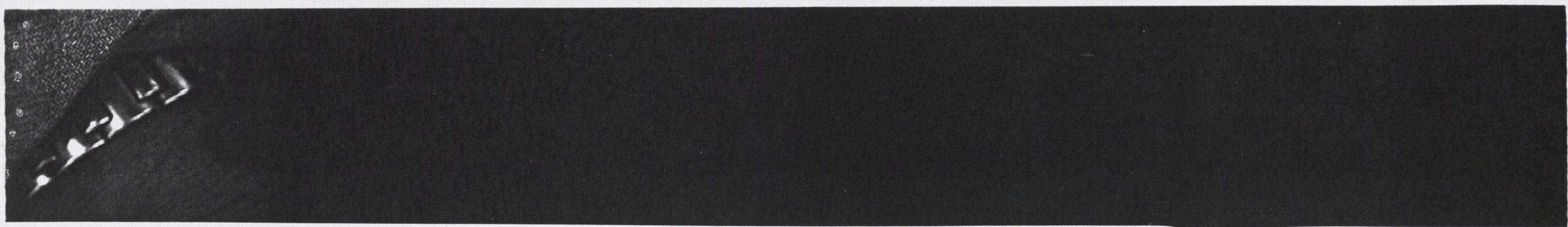


Fig. 6. Length distributions for benthic and pelagic Arctic char caught in gillnets of different single mesh sizes in a pooled sample combining several lakes and years in Sweden.



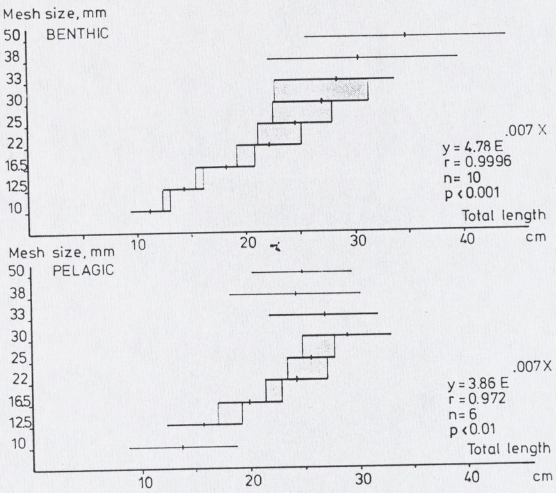


Fig. 7. Graphic relationships of mesh size and mean length with overlapping standard deviations for benthic and pelagic Arctic char as a hypothetical illustration of size selectivity in panels of the Lundgren gillnets of multiple mesh size.

speeds, faster species should encounter a passive gear more frequently than slower species. Rudstam, Magnuson and Tonn (1984) discuss this as a possible explanation for the fact that larger fish are caught more efficiently.

Another major reason for concern is the preference of fish for specific habitats and their movements to and from these habitats. A testfishing programme must therefore consider the division of the different biotopes of the lake between different species. The littoral gillnet is unlikely to catch a pelagic fish or vice versa.

By setting gillnets at an angle to the shoreline there is always a risk of catching unproportionally large numbers of fish species which perform migrations parallel to the shore and unproportionally low numbers of species which migrate between deeper bottoms and the littoral zone. This may be a general fact for migrating anadromous fish and may apply to resident Atlantic salmon and brown trout. In some lakes in this study benthic gillnets were set both parallel to and at a right angle to the shore. Comparisons between single gillnets may show large differences as in Russ' Lake, but when the catches from differently placed gillnets in Butt's Pond were pooled and tested by means of a chi-square test, the species composition showed no significant difference between parallel and perpendicular nets. Neither was there any difference in the CPUE (catch per unit effort) of single species in the differently placed gillnets in Butt's Pond (Mann Whitney U-test).

As will be shown later on, the inclusion of the 6.25 and 8.0 mm mesh expands the length and age structure of the catch considerably, but it also adds a new species to the catch in shallow water — the sticklebacks. In deeper water and in the pelagic habitat the revised types of gillnet seems to have en important effect on yields and length frequencies of smelt.

Size selection and modal lengths

A comprehensive review with a basic statistical description of various analyses of gillnet selectivity is provided by Hamley (1975). Unimodal and accidental bimodal selection curves of different shapes are shown for different species.

However, longterm studies of Arctic populations of the Arctic char have exposed mono-, bi- and trimodal allopatric population structures that are thought to represent a stage of ecological climax (Johnson 1980, 1981, 1983). These structures differ from the normally distributed catches characterized as bell-shaped and monomodal, which have been the object of thorough analyses of gillnet selectivity (Hamley 1975).

The selectivity of nine of the panels used in the Lundgren gillnets of multiple mesh size were studied in Swedish sampling programmes for Arctic char using standard gillnet gangs. Arctic char caught in the pelagic zone have been treated separately because of their monomorphic and planktivorous character (Hammar 1984). The examples (Fig. 6) consist of pooled values from several lakes and years of sampling, and only mesh sizes for which there are a large number of samples are shown. There is a general tendency to obtain a positively skewed sample in the smaller mesh sizes and a negatively skewed sample in the large mesh sizes. This seems to be more pronounced in the benthic samples, probably due to the presence of benthic dwarfs which tangle in the nets by their teeth or fasten due to their rotund form.

Kipling (1957) showed that a good estimate of the structure of a population can be made by

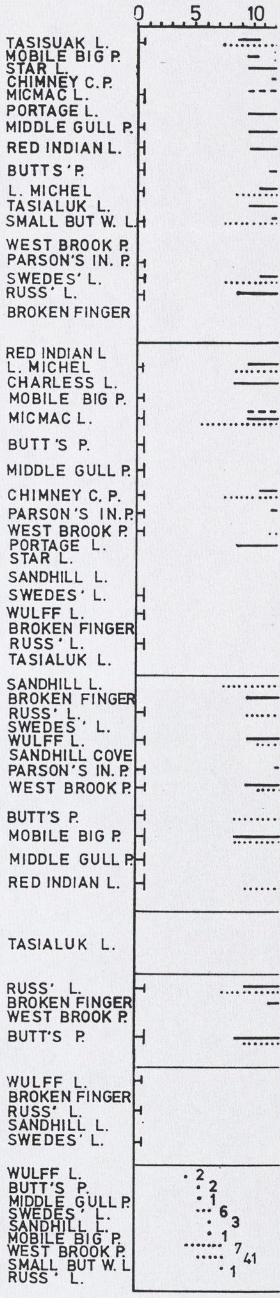


Fig. 8. The size range of differe[n]
size in Newfoundland and Labra[dor]
trout, Atlantic salmon, lake tro[ut]
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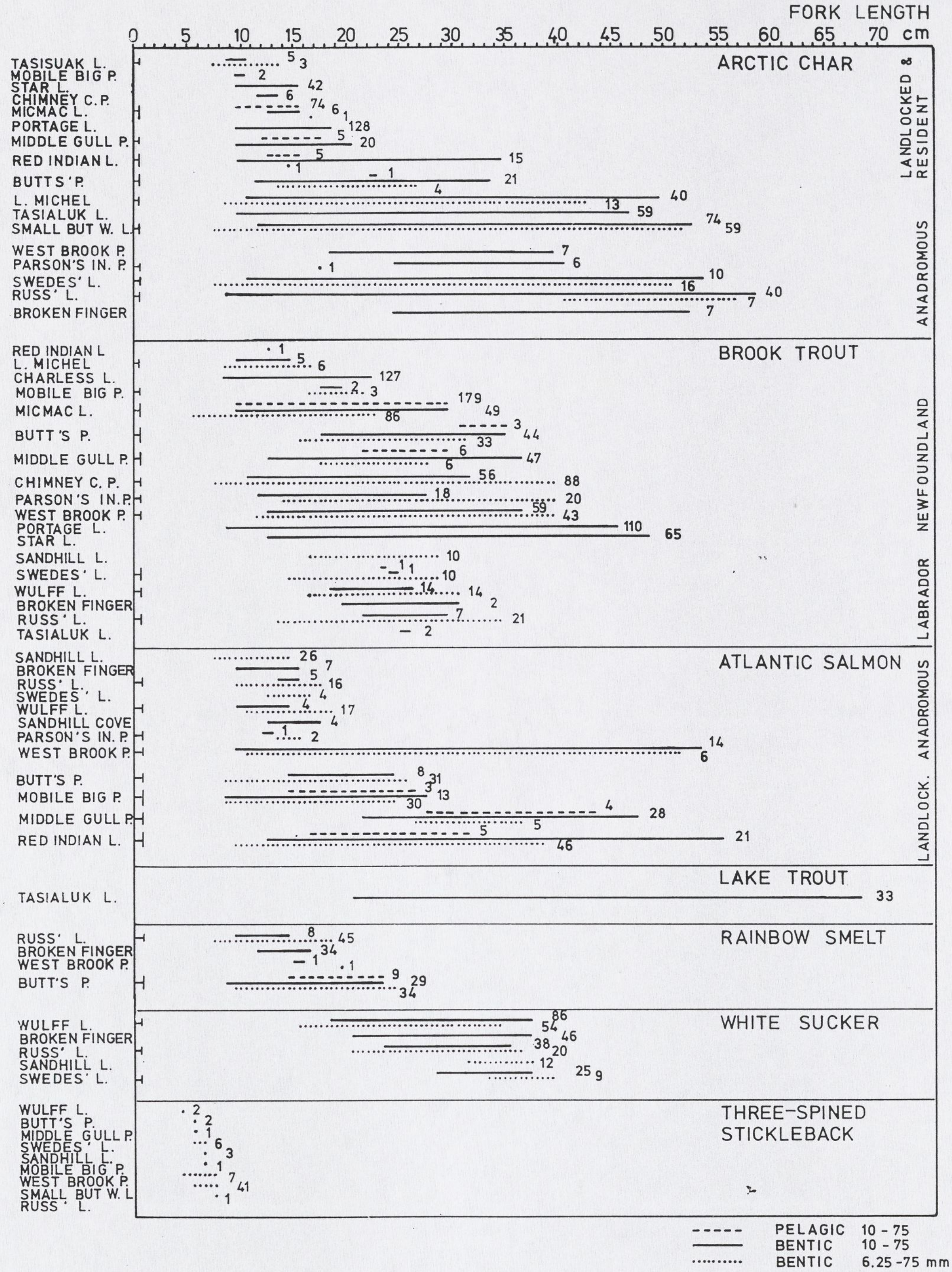

Fig. 8. The size range of different species caught in three different types of Lundgren gillnets of multiple mesh size in Newfoundland and Labrador 1984. Number of specimens in the catch is given for Arctic char, brook trout, Atlantic salmon, lake trout, rainbow smelt, white sucker and three-spined stickleback. Dashed lines= pelagic gillnet, 10—75 mm. Solid lines=benthic gillnet, 10—75 mm. Dotted lines=benthic gillnet, 6.25—75 mm.

using multiple mesh sizes where the length frequency distribution of the catch of each mesh overlaps that of its neighbours.

The mean length and the standard deviation for Arctic char in benthic and pelagic catches in a hypothetical gillnet of multiple mesh size are shown graphically (Fig. 7) in order to illustrate the lack of gaps in efficiency between adjacent meshes. The graphs also clearly demonstrate the general increase in the size distribution of benthic Arctic char with increasing mesh size. This may be specific for diverse benthic populations and to a lesser extent the case for unimodal pelagic populations. However, similar studies based on catches of pelagic cisco (*Coregonus albula* LINNÉ) in the Baltic sea showed the sample distribution in single meshes to be very much affected by the presence of strong year classes (O. ENDERLEIN pers. comm.).

By choosing adjacent mesh sizes so that both ascending and descending arms of the selective curve intersect at 60 per cent, a geometrical series with the constant 1.203 is derived (JENSEN 1984). Upon this basis JENSEN (1984) recommends the following combination of multiple mesh sizes for Arctic char in the size range 160—440 mm: 15.0, 18.0, 21.5, 25.9, 31.3, 37.7, 45.7 and 50.3 mm knot to knot.

Although the Lundgren multiple series of 6.25, 8, 10, 12.5, 16.5, 22, 25, 30, 33, 38, 43, 50, 60 and 75 mm is not strictly geometrical, with a constant of 1.212 ± .074, it greatly resembles the corresponding part of the series recommended by JENSEN (1984).

HAMLEY (1975) also emphasizes the risk of an effect on the size-selection range due to early saturation of the specific mesh that in a specific case becomes the optimal one. This is probably an important source of error for gillnets of multiple mesh size, particularly in dense populations where the testfishing period may be too long.

No doubt the gillnet can be improved to fit the structure of a certain fish population in a certain lake. A statistically-constructed gillnet of multiple mesh size to be used for different species in different lakes is, however, more interesting. It is therefore of the utmost importance for geographical and ecological surveys to develop a gear which can be used in a standardized way in many different lakes, as opposed to a gear that only fits a single, simple population structure. Testfishing in unexploited systems may still reveal unexpected species compositions and size frequencies. The gear used must therefore be as general as possible with regard to size and species selectivity as well as statistically repeatable.

The size selectivity of the 12 or 14 mesh sizes represented in the Lundgren gillnet (Fig. 7) should also be compared with that of the standard gillnet gangs commonly used in Newfoundland. The mesh sizes were 19, 25, 38, 51 and 64 mm in the comprehensive Lower Churchill River Programme (RYAN 1980) and the Red Indian Lake survey (MORRY and COLE 1977). This combination reveals both gaps and very little overlap. A more promising gear with 7 panels ranging from 12.5 to 51 mm was used in Lake Michel (ShawMont Nfld. Ltd. 1982), but in this case all the gangs were set near the surface, with the small mesh sizes near shore.

The size distributions of the catch of different species in different lakes in Newfoundland and Labrador are demonstrated for three different gillnets of multiple mesh size based on the same geometrical series (Fig. 8). The total range includes three-spined sticklebacks as small as 45 mm in the revised gillnet, and lake trout of 685 mm in the ordinary benthic gillnet. The figure exposes the wide size range of the Lundgren gillnets and also reveals biologically different population structures. The latter are not due to the size selectivity of the gillnets, but rather to species interactions and the specific ecological characteristics of the ecosystem.

Arctic char, *Salvelinus alpinus* (LINNÉ)

As pointed out earlier, the Arctic char has a unique ecology due to the existence of allopatric populations with intraspecific complicated structures (JOHNSON 1980, 1983, HINDAR and JONSSON 1982, JONSSON and HINDAR 1982, NORDENG 1983), displaying thermodynamic responses to the environment (JOHNSON 1981, In press). There are even more complex situations in which two or three sympatric populations are known to coexist (ANDERSSON *et al.* 1971, NILSSON and FILIPSSON 1971, NYMAN 1972, 1984, NYMAN and FILIPSSON 1972, KLEMETSEN and GROTNES 1975, 1980, HENRICSON and NYMAN 1976, GYDEMO 1984, HAMMAR

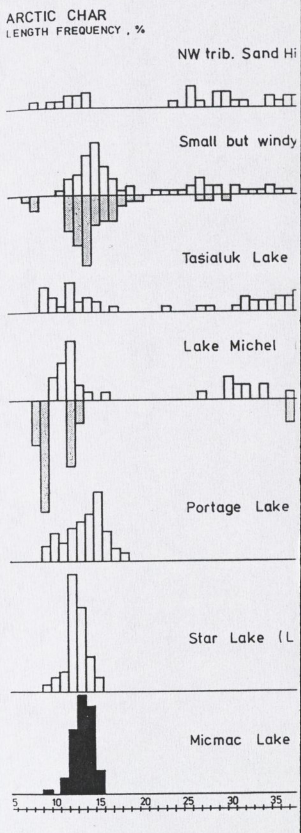

Fig. 9. Size distribution of p
sampled with Lundgren gilln
(gray), 10—75 mm benthic
pelagic (black). (R=Resider
Landlocked.)

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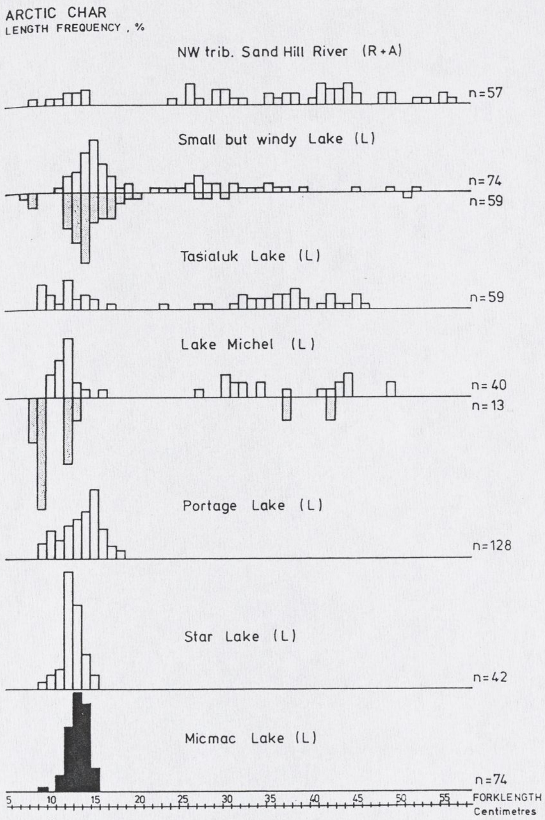

Fig. 9. Size distribution of populations of Arctic char sampled with Lundgren gillnets, 6.25—75 mm benthic (gray), 10—75 mm benthic (white) and 10—75 mm pelagic (black). (R=Resident, A=Anadromous, L=Landlocked.)

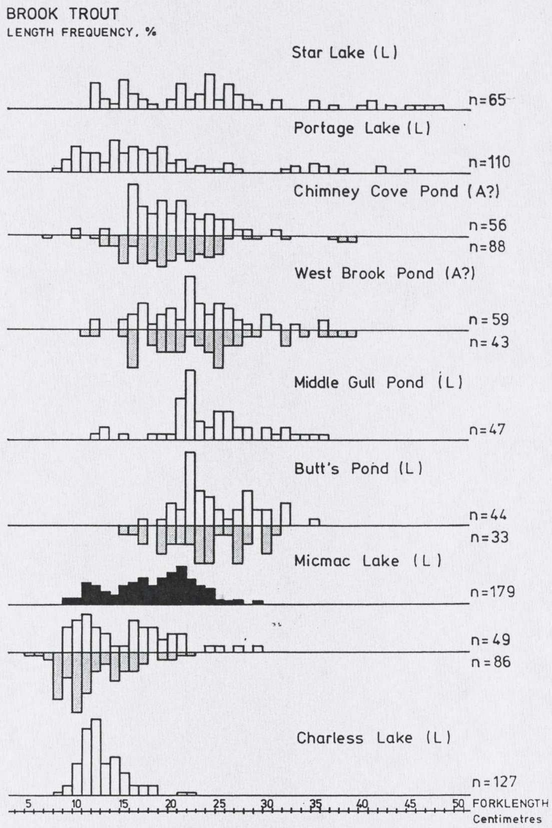

Fig. 10. Size distribution of populations of brook trout sampled with Lundgren gillnets, 6.25—75 mm benthic (gray), 10—75 mm benthic (white) and 10—75 mm pelagic (black). (L=Landlocked, A=Anadromous.)

1984 and KLEMETSEN 1984). Such populations are regarded as sibling species in a number of Scandinavian lakes (SVÄRDSON 1958, 1961, NYMAN *et al.* 1981). The Arctic char is furthermore very sensitive to gillnetting, competition and predation and displays population structures clearly affected by these factors (FILIPSSON and SVÄRDSON 1976).

The wide range of modal lengths and the number of varied population structures is strikingly apparent in some Newfoundland and Labrador lakes (Fig. 8 and 9).

The Arctic char turned out to be more common than expected, and it is probably the dominating species in several lakes in insular Newfoundland. In fact, in this study, the Arctic char was found in all lakes except one, which was of course named Charless Lake.

The Arctic char in "Small but Windy Lake" and Lake Michel may be regarded as allopatric (HAMMAR *et al.* in prep.). In Tasialuk Lake Arctic char coexists with piscivorous lake trout. In Portage and Star Lakes Arctic char is preyed upon by piscivorous brook trout, and in Micmac Lake the Arctic char is considered to be pelagic (HAMMAR in prep.).

The smallest specimen caught in the 6.25—75 mm gillnet was 75 mm and the smallest char in the 10—75 mm gillnet was 81 mm. The largest char caught measured 586 mm. The length range in the pelagic 10—75 mm gillnet was 95—223 mm.

Brook trout, *Salvelinus fontinalis* (MITCHILL)

This species has a broad geographical and ecological distribution in the province (SCOTT and

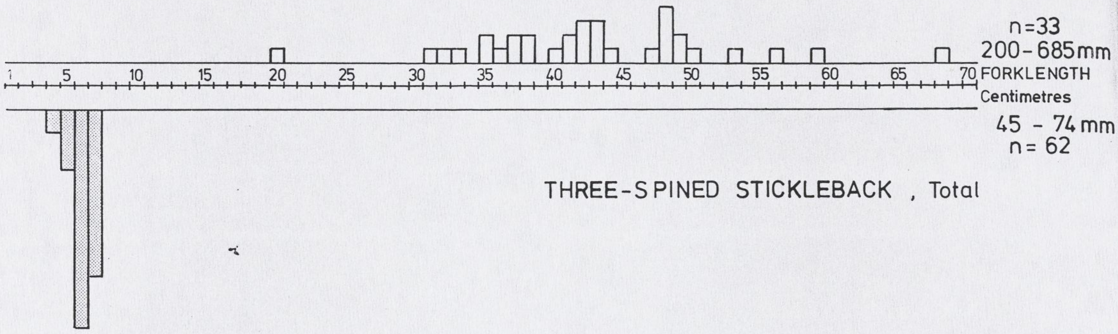

Fig. 11. Size distribution of populations of lake trout and three-spined stickleback sampled with Lundgren gillnets, 6.25—75 mm benthic (gray) and 10—75 mm benthic (white).

CROSSMAN 1964). It resembles the Arctic char in terms of morphology and ecology. The variety in length frequencies is illustrated by anadromous populations, the piscivorous populations of large brook trout in Portage and Star Lakes, and by populations in ecosystems where there are more or less complicated interactions with other species (HAMMAR in prep., Fig. 8 and 10).

The smallest specimens caught were 50 mm in the 6.25 mm mesh, 83 mm in the 10 mm mesh, and the largest specimen was 486 mm. In Micmac Lake which has a dense population (HAMMAR in prep.), the length of brook trout in the large pelagic catch ranged between 97 and 295 mm.

Lake trout, *Salvelinus namaycush* (WALBAUM)

Lake trout were caught only in Tasialuk Lake, Labrador, together with large Arctic char (HAMMAR and SKÖLD in prep.). The total length range in the 10—75 mm gillnet was 200 to 685 mm, and almost all specimens were longer than 300 mm (Fig. 11). The maximum catch in a single gillnet was 5 specimens and 5.6 kg. On one occasion a large lake trout was found to have been almost totally eaten by something, in a gang of three gillnets containing another 16 large specimens of both species. Could this be an example of lake trout cannibalism or did we in fact miss the wonderful sight of a happy otter?

Atlantic salmon, *Salmo salar* LINNÉ

Atlantic salmon were caught in littoral regions as well as in the pelagic zone close to the surface. In Sand Hill River only smolt and parr were caught, and the size range resembles that of the smolt caught by flyfishing (Fig. 12). The figure also displays the structural differences between the anadromous and the landlocked salmon (Ouananiche) in the other bodies of water. The smallest specimens caught were 76 mm in the 6.25 mm mesh and 85 mm in the 10 mm mesh. The largest specimen caught was a 556 mm long ouananiche in Red Indian Lake.

Rainbow smelt, *Osmerus mordax* (MITCHILL)

The use of very small mesh sizes seems to be crucial for the size of the catch and the length frequency of smelt (Fig. 13), due to the inclusion of younger age groups. Large numbers were caught in the Northwest Tributary to Sand Hill River where anadromous migration is documented (ANDERSON 1985). A spectacular difference may be noted between Russ' and Broken Finger Lakes. A pulse of 5+ fish constitutes nearly 80 per cent of the catch in the second lake (HAMMAR unpubl.). Most of these specimens were severely damaged in the nets by eels and are thus underrepresented in the figure.

The 6.25 mm mesh seems to be efficient for 90 mm smelt, *i.e.* 1+ fish, but it caught specimens as small as 74 mm. The 10 mm mesh caught specimens down to 88 mm and seems to be efficient for 100—110 mm smelt. Larger and older specimens are often caught by their conspicuous teeth. The largest smelt caught in Butt's Pond was 245 mm in length.

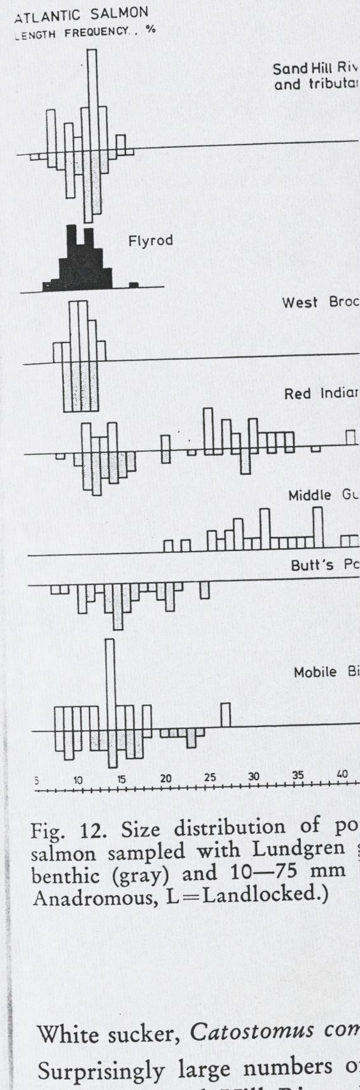

Fig. 12. Size distribution of po
salmon sampled with Lundgren
benthic (gray) and 10—75 mm
Anadromous, L=Landlocked.)

White sucker, *Catostomus com*
Surprisingly large numbers o
caught in Sand Hill River,
length range is 159 to 391 mm
exposes both similarities anc
length structures. The interest
des' Lake is due to the differ
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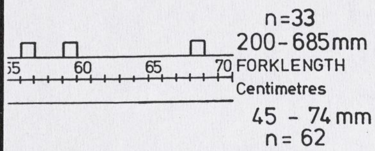

kleback sampled with Lundgren gill-

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Osmerus mordax (Mitchill)

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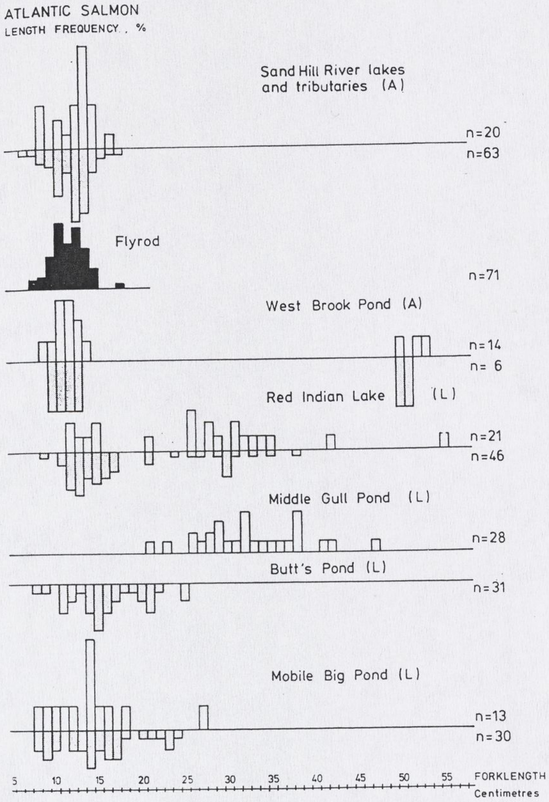

Fig. 12. Size distribution of populations of Atlantic salmon sampled with Lundgren gillnets, 6.25—75 mm benthic (gray) and 10—75 mm benthic (white). (A = Anadromous, L = Landlocked.)

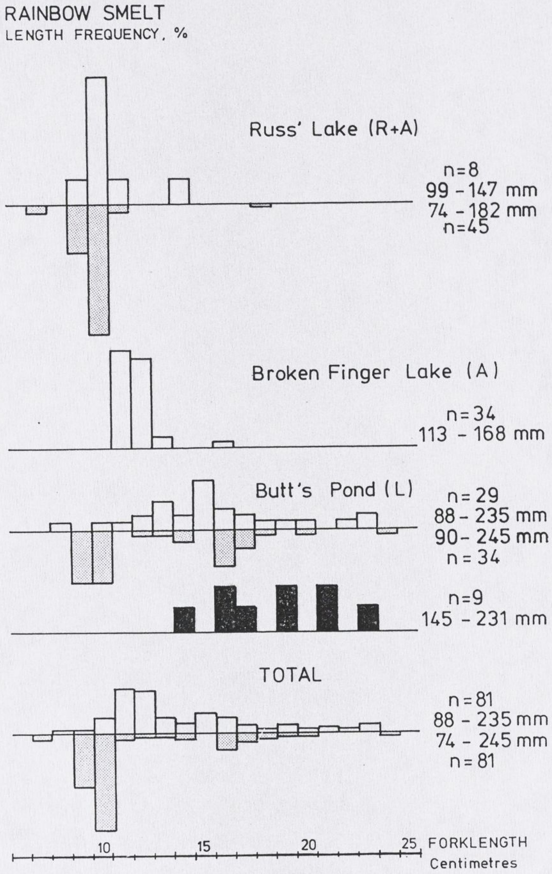

Fig. 13. Size distribution of populations of rainbow smelt sampled with Lundgren gillnets, 6.25—75 mm benthic (gray), 10—75 mm benthic (white) and 10—75 mm pelagic (black). (R = Resident, A = Anadromous, L = Landlocked.)

White sucker, *Catostomus commersoni* (Lacépède)

Surprisingly large numbers of white sucker were caught in Sand Hill River, Labrador. The total length range is 159 to 391 mm (Fig. 14). The figure exposes both similarities and differences in the length structures. The interesting pattern in Swedes' Lake is due to the different depths at which the gillnets were set. The ordinary gillnets were located on deeper bottoms (5—11 m), whereas the revised gillnets were used in the littoral zone (1 m). Since the sucker spawns in running waters and spends parts of its life cycle in different habitats, the differences in modal lengths may be an effect of size or age segregation within the river system (Hammar *et al.* in prep.).

Three-spined stickleback, *Gasterosteus aculeatus* Linné

Armed with both dorsal and ventral spines, the sticklebacks became tangled in the smallest mesh size in the revised gillnets. In "Small but Windy Lake" the catch was considerable after some rough weather. The distribution shows a negatively skewed pattern (Fig. 11) with the fork length ranging from 45 to 74 mm.

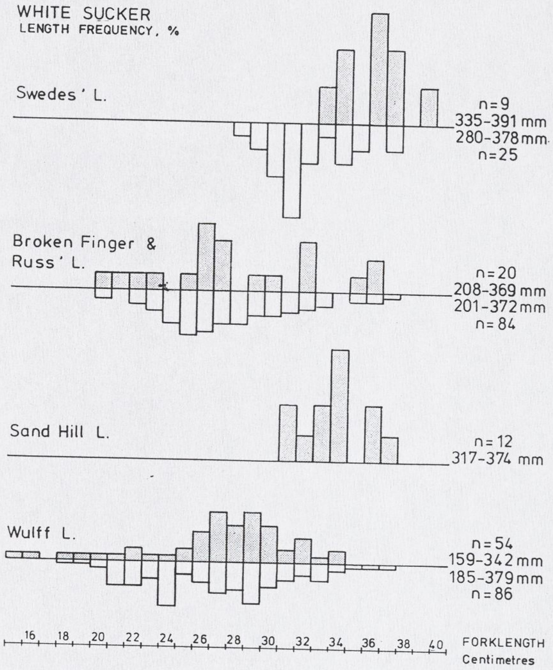

Fig. 14. Size distribution of populations of white sucker sampled with Lundgren gillnets, 6.25—75 mm benthic (gray) and 10—75 mm benthic (white).

V. EXAMPLE OF A TESTFISHING PROGRAMME IN RED INDIAN LAKE

Red Indian Lake

Red Indian Lake is located in the upper part of Exploits River in central Newfoundland. It has by far the largest watershed in insular Newfoundland. It is surrounded by coniferous woods, vast boglands and the Annieopsquotch Mountains. Red Indian Lake is the second largest lake (18.121 ha) on the island, and is impounded for hydroelectric and logging purposes. Major tributaries are Lloyds River, Victoria River and Shanadithit Brook. The lake is very deep (maximum depth 146 m, mean depth 24.7 m) and is inhabited by only four species of fish — landlocked Atlantic salmon (Ouananiche), brook trout, three-spined stickleback and, in deep waters, relict Arctic char (Morry and Cole 1977).

Material and methods

From July 4—11, 1984, gillnets of multiple mesh size were used in the upper part of the lake to investigate the depth distributions of the different

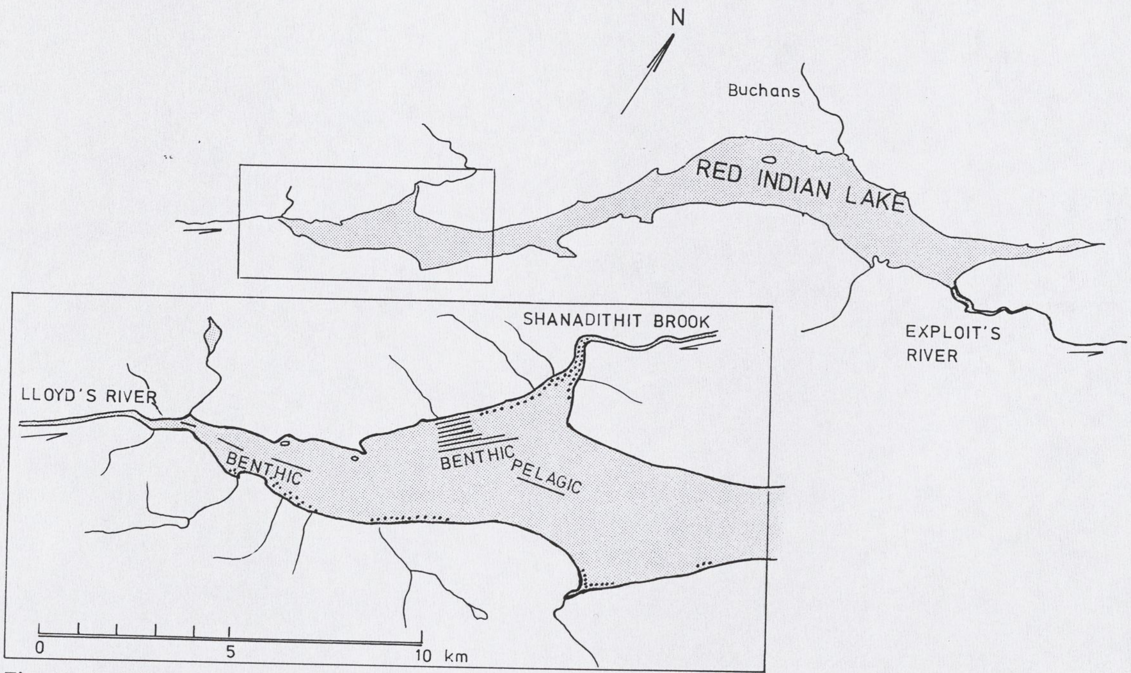

Fig. 15. Red Indian Lake with location of the benthic and pelagic testfishing stations sampled as an example of the technique described in the paper.

Table 3. *Catch* ... *per gillnet and* ...

Depth	A...
Parallel to shor...	
2— 2 m	1(
2— 2 m	1(
5— 5 m	1
5— 5 m	2
10—10 m	2
10—10 m	1
19—19 m	1
19—19 m	C
19—19 m	C
19—19 m	C
19—19 m	C
20—20 m	C
20—20 m	1
30—30 m	C
30—30 m	C
30—30 m	C
30—30 m	C
31—31 m	C
31—31 m	C
31—31 m	C
31—31 m	C
42—45 m	C
45—45 m	C
45—45 m	C
45—48 m	C
47—47 m	C
At an angle to t...	
4— 4 m	3
5— 5 m	C
5— 5 m	5
9—10 m	C
10—10 m	1
10—11 m	C
In the pelagic z...	
0— 6 m	2
0— 6 m	2
12—18 m	0
24—30 m	0
24—30 m	0
54—60 m	0

fish species in the littoral ... zones (Fig. 15).

Benthic gillnets were s... 30—31 and 42—48 metr... northern shore, and at 4... from the inlet of Lloyds ... was anchored over 70 n... 12—18, 24—30 and 54—6...

The surface temperature...

Table 3. *Catch data for Red Indian Lake. CPUE is expressed as numbers and grams per gillnet and 24 hours.*

Depth	Atlantic salmon						Brook trout		Arctic char	
	Adults		Smolt		Parr					
	n	g	n	g	n	g	n	g	n	g
Parallel to shore:										
2— 2 m	10.0	2165	7.2	256	24.4	542	1.4	26	0	
2— 2 m	10.0	2887	2.9	133	11.5	301	0		1.4	30
5— 5 m	1.4	218	0		4.3	79	0		0	
5— 5 m	2.9	777	0		1.4	37	0		0	
10—10 m	2.9	3023	0		0		0		1.4	33
10—10 m	1.4	142	0		0		0		1.4	26
19—19 m	1.3	302	0		1.3	43	0		1.3	24
19—19 m	0		0		0		0		2.6	34
19—19 m	0		0		0		0		2.6	21
19—19 m	0		0		0		0		1.3	24
19—19 m	0		0		0		0		0	
20—20 m	0		0		0		0		0	
20—20 m	1.4	282	0		0		0		1.4	13
30—30 m	0		0		0		0		0	
30—30 m	0		0		0		0		0	
30—30 m	0		0		0		0		0	
30—30 m	0		0		0		0		0	
31—31 m	0		0		0		0		1.3	752
31—31 m	0		0		0		0		0	
31—31 m	0		0		0		0		0	
31—31 m	0		0		0		0		0	
42—45 m	0		0		0		0		1.4	20
45—45 m	0		0		0		0		0	
45—45 m	0		0		0		0		0	
45—48 m	0		0		0		0		0	
47—47 m	0		0		0		0		0	
At an angle to the shore:										
4— 4 m	3.9	1243	0		1.3	45	0		0	
5— 5 m	0		0		0		0		3.3	41
5— 5 m	5.0	1889	0		0		0		1.7	25
9—10 m	0		0		0		0		0	
10—10 m	1.7	642	0		0		0		0	
10—11 m	0		0		0		0		0	
In the pelagic zone:										
0— 6 m	2	424	0		1	32	0		4	104
0— 6 m	2	367	0		0		0		0	
12—18 m	0		0		0		0		1	16
24—30 m	0		0		0		0		0	
24—30 m	0		0		0		0		0	
54—60 m	0		0		0		0		0	

fish species in the littoral, profundal and pelagic zones (Fig. 15).

Benthic gillnets were set at 2, 5, 10, 18—20, 30—31 and 42—48 metres depth parallel to the northern shore, and at 4—11 metres at an angle from the inlet of Lloyds River. The pelagic gang was anchored over 70 metres and set at 0—6, 12—18, 24—30 and 54—60 metres depth.

The surface temperature varied between 7.0 and 11.5°C and a weak thermocline was found at about 50 metres depth. The transparency was between 5.1 and 6.1 metres.

Results

The results of the catch per unit effort (CPUE) is expressed as numbers and weights in grams per gillnet and 24 hours (Table 3).

The testfishing programme was carried out in an exposed part of the lake. No sticklebacks were found, and only one brook trout was caught. Salmon were found down to depths around 20 metres but dominated in the littoral zone. Salmon were also caught in the upper layer of the pelagic zone. Arctic char were caught between 2 and 45 metres and also in the pelagic zone down to 18 metres depth. This is the only species found below 20 metres depth along the bottom.

For further comparative analyses the catch has to be pooled for larger depth zones *e.g.* 0—10, 10—20 m and deeper. There were no apparant differences between gillnets set parallel to or at an angle to the shore.

All specimens were sampled. The results of analyses of the age structure, food habits and genetic variation in the Arctic char caught will be presented elsewhere (HAMMAR in prep.).

Discussion

The catch figures are small compared to the results from other lakes (HAMMAR in prep.), indicating a low density of fish. This rhymes well with earlier conclusions (MORRY and COLE 1977). These authors, who collected their fish in standard gillnets in shallow water, discussed the scarcity of the Arctic char, but speculated that char might be more common in deeper water.

It would now seem that ouananiche and Arctic char are both dominant and segregate in the lake. In fact Arctic char was discovered to be the dominant species in Portage and Star Lakes, two headwaters of Red Indian Lake (HAMMAR unpubl.). Arctic char is furthermore found in Victoria Lake (PIPPY 1966) and Lloyd's Lake (DEMPSON 1985). Electrophoretic studies showed that dwarfed Arctic char were also resident in Lloyd's River, the major tributary (HAMMAR unpubl.).

VI. RECOMMENDATIONS

Large areas of the Province of Newfoundland and Labrador which are covered by numerous lakes and streams are still unexplored in terms of their fish fauna. These areas of grand natural resources are invaluable not just to Man but as an integral part of the nature of Newfoundland.

Insular Newfoundland and Labrador have also been subjected to very large environmental changes in terms of the impoundment and redirection of salmon rivers. Today, large water systems are still being continuously subjected to exploitation and irreversible ecological injury. In addition, the expanding compensatory salmonid enhancement programme includes massive stocking of anadromous salmon in lakes above the salmon region, leading to increased competition with and predation on natural populations of Arctic char and brook trout.

With the above-mentioned facts as a background to the present sombre perspective, we would like to emphasize the importance of continued general biological surveys and monitoring in the freshwaters of interior Newfoundland and Labrador.

We would furthermore like to recommend the Federal and Provincial Fishery authorities in Eastern Canada to consider using the testfishing programme design, the described techniques and the Lundgren modern gillnets of multiple mesh size in future surveys, and to demand that consultant groups commissioned to do biological investigations also use these methods.

VII. APPENDIX — INSTRUCTIONS FOR PELAGIC GILLNETTING

When the buoys, the lines and the two sections of gillnet are prepared and ready to be used, the gear should be set at a time of the day which is convenient for the checking and lowering of the nets during the next few days.

(1) The first heavy anchor is connected to two ropes, one at each "end". The first one slightly longer than the water depth is tied to the "arms" and connected to the flag buoy. The other rope is tied to the "eye". The anchor is thrown overboard while the boat is slowly drifting with the wind and the second rope, which is three times the water depth, is played out. Make sure the anchor has dug into the bottom.

(2) The other end of the second rope is connected to the headline of the first section, preferably the one with coarser meshes, and a larger buoy is tied to the same end.

(3) While setting the fir
two smaller floats are conn
distances 1/3 and 2/3 of the

(4) The headline end of
to the second section and
with a prepared line is
section is set in the same
smaller floats attached.

(5) The end of the headl
is now tied to another lon
waterdepth as well as to
the boat is allowed to d
driven slowly. Connect the
"eye" of the second anchor
rope to the "arms".

(6) The last step requi
strong arms. When the ro
and the second anchor ha
anchor is allowed to hang
the boat and the flag-buoy
the outboard engine is used
gear as much as possible.

(7) When this is done an
straight line the power of
slightly and the anchor is
slowly while releasing th
metre. The anchor has to r
the entire gear is stretche
before the last flag-buoy is
the usual salute of success.

When the gear is set be
6 metres depth it has to b
flags since it is dangerously
boats. These flags are pref
two large anchor buoys fu
gillnets in order to minimize
the fish in the surface layer.

The next day, 24 hours
repeated in reverse. If the
caught is one of the major
the gillnet should of cour
frequently. The gillnets ar
cleaned while being hauled
such a manner that they
backing the boat.

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— INSTRUCTIONS FOR
NETTING

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dline of the first section, prefer-
h coarser meshes, and a larger
same end.

(3) While setting the first section of the gillnet, two smaller floats are connected to the headline at distances 1/3 and 2/3 of the section's length.

(4) The headline end of the first section is tied to the second section and a medium-sized buoy with a prepared line is connected. The second section is set in the same way with another two smaller floats attached.

(5) The end of the headline of the entire gillnet is now tied to another long rope three times the waterdepth as well as to a large red buoy and the boat is allowed to drift with the wind or driven slowly. Connect the end of the rope to the "eye" of the second anchor and the last flag-buoy rope to the "arms".

(6) The last step requires heavy gloves and strong arms. When the rope between the gillnets and the second anchor has been played out, the anchor is allowed to hang just over the side of the boat and the flag-buoy line is kept taut, while the outboard engine is used to straighten the entire gear as much as possible.

(7) When this is done and all the buoys form a straight line the power of the engine is reduced slightly and the anchor is allowed to sink very slowly while releasing the last rope metre by metre. The anchor has to reach the bottom while the entire gear is stretched as much as possible before the last flag-buoy is thrown overboard with the usual salute of success.

When the gear is set between the surface and 6 metres depth it has to be clearly marked with flags since it is dangerously exposed to any passing boats. These flags are preferably attached to the two large anchor buoys furthest away from the gillnets in order to minimize any tendency to affect the fish in the surface layer.

The next day, 24 hours later, the procedure is repeated in reverse. If the food habits of the fish caught is one of the major parameters of interest the gillnet should of course be examined more frequently. The gillnets are simply checked and cleaned while being hauled up into the prow in such a manner that they can be set again by backing the boat.

(1) Hauling in the long ropes against the wind requires gloves. Let the ropes fall into the bottom of the boat. The lee flag-buoy is picked up first and the attached anchor hauled onboard. From now on the ropes have to be kept in perfect order in the bottom of the boat.

(2) The first large buoy attached to the gillnet is untied and kept astern.

(3) The gillnet is hauled up into the prow by two persons, one pulling the headline and the other the sinkline. The net is laid down in perfect order in folds. Meanwhile the fish are removed and put into bags.

(4) The small floats have to be kept in the water until the section of the headline to which the float is connected is brought onboard. The knot on the float is untied and the line is checked so it will roll out another 6 metres when setting the net again. The floats are placed in order along the net in the prow with the lines loosely coiled in the sections of the gillnets where they belong.

(5) The entire gear is laid in folds in the boat, and the line of each float is released another 6 metres until the second large red buoy is reached.

(6) A rope of 6 metres is added to the buoy-line and the boat is allowed to drift backwards while the gillnets are set overboard again.

(7) Each float is thrown overboard on the same side (lee) of the boat, when the section of the headline to which the float is attached to is leaving the boat.

(8) The first large buoy is connected with a 6 metres of rope and tied to the headline end.

(9) From now on the procedure is identical to the previous description of the straightening out of the gear and the placing of the anchor on the bottom.

If everything is in order the headline of the gear will be 6 metres below the surface and the stretched gillnet will catch pelagic fish between 6 and 12 metres depth (Fig. 4).

The gear is lowered in the same way at 6 metre intervals almost all the way down to the bottom. In very deep lakes depth intervals of 12 metres may be chosen instead. This has to be decided in advance, when preparing the float and buoy lines.

VIII. APPENDIX — CHECK LIST OF EQUIPMENT

Boat:

Outboard engine
Repair kit for engine
Extra spark plug
Pressure tank
Gas tank with extra gas
Outboard oil
Oars
Oar-locks
Scoop
Funnel

Rubber boat:

Outboard engine
Repair kit for engine
Extra spark plug
Pressure tank
Gas tank with extra gas
Outboard oil
Oars
Oar-locks
Scoop
Funnel
Aluminum floorboard
Pump
Repair kit for rubber boat
Extra valves

Personal equipment:

Life jacket
Raingear
Rubber boots or waders
Gloves
Sweater
Camera in water-proof bag
First Aid kit

Benthic gillnets:

Gillnets
Baskets (2)
Floats, 2 m (2)
6 m (2)
12 m (2)
18 m (2)
25 m (4)
50 m (4)
Buckets
Numbered tags for identification of the catch in each net

Pelagic gillnets:

Gillnets
Baskets (2)
Large buoys (2)
Small flag buoys (2)
Floats, prepared with lines (1.5 mm) (5)
Anchors (2)
Ropes, 5 mm, braided
2×250 m (for anchors)
2×100 m (for flags)
2×100 m (for buoys)
Buckets

Instruments:

Plastic container
Shoulder bag with testfishing form, pencils, knife (stainless steel), thermometer and maps
Echo sounder
Plumb line
Plankton net
Bottles with buffered formalin
Secchi disc
Thermistor or water-sampler with messenger

Sampling:

Buckets
Plastic bags, many sizes
Measuring board
Scales (battery)
Knives
Scalpel
Tweezers
Scissors
Petri dish for otoliths
Scale envelopes
Pencils
Markers, black and red
Rubber bands
Boxes for envelopes
Gauze cloth for stomachs
Tags with numbers
String
Containers for preservation
Formalin, 37 %
Basin
Dish brush
Paper towels

Camp:

Table with chairs
Boxes with handles for transportation
Tent and poles
Sleeping bag
Foam
Stove
Fuel
Pots
Frying pan
Plate, mug, utensils
Aluminium foil
Cooler
Buckets
Kerosene lamp with extra kerosene
Flashlight
Propane lamp with extra mantels
Backpack
Axe, hammer, saw, pliers and nails
Tape, ruler, calculator
Paper towels
First Aid kit

IX. ACKNOWLEDGMEN

The Newfoundland-Labrado
was initiated and hosted by
at the Fisheries Research Br
Fisheries and Oceans in St.
ways depended on its ent
coming members REX PORT
STEVE DAWSON, GEORGE
LEDREW. Thank's a million

The testfishing programm
JOHAN HAMMAR assisted by
a number of kind and helpfu
of Newfoundland and Lab
wonderful grand help is w

Our warm thanks to ERIK
many valuable contributions
computer analyses and also
on the manuscript.

We would also like to tha
BRIAN DEMPSON and OLLE F
comments on an earlier vers
and CATHERINE HILL for
English.

The research was finan
Research Branch, Departm
Oceans, St. John's, Newfoun
possible through Director M.
interest in the project, a rese
the World University Ser
generous help with field equ
Fjällräven AB.

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Personal equipment:

Life jacket
Raingear
Rubber boots or waders
Gloves
Sweater
Camera in water-proof bag
First Aid kit

Instruments:

Plastic container
Shoulder bag with testfishing form, pencils,
knife (stainless steel),
thermometer and maps
Echo sounder
Plumb line
Plankton net
Bottles with buffered formalin
Secchi disc
Thermistor or water-sampler with messenger

IX. ACKNOWLEDGMENTS

The Newfoundland-Labrador Arctic char project was initiated and hosted by the Arctic char group at the Fisheries Research Branch, Department of Fisheries and Oceans in St. John's and in many ways depended on its enthusiastic and forthcoming members Rex Porter, Brian Dempson, Steve Dawson, George Furey and Larry LeDrew. Thank's a million b'ys, for everything.

The testfishing programme was performed by Johan Hammar assisted by his wife Eva Sköld, a number of kind and helpful colleagues and sons of Newfoundland and Labrador, all of whose wonderful grand help is warmly acknowledged.

Our warm thanks to Erik Degerman who made many valuable contributions to the work with the computer analyses and also critically commented on the manuscript.

We would also like to thank Lennart Nyman, Brian Dempson and Olle Enderlein for helpful comments on an earlier version of the manuscript and Catherine Hill for her correction of the English.

The research was financed by the Fisheries Research Branch, Department of Fisheries and Oceans, St. John's, Newfoundland, and was made possible through Director M. C. Mercer's personal interest in the project, a research scholarship from the World University Service of Canada and generous help with field equipment from Swedish Fjällräven AB.

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[1987]

ZOOGEOGRAPHICAL ZONATION OF FISH COMMUNITIES IN INSULAR NEWF(LAND; A PRELIMINARY ATTEMPT TO USE THE ARCTIC CHAR POPULATIC ECOLOGY TO DESCRIBE EARLY POSTGLACIAL COLONIZATION INTERACTI

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Introduction

In regions of the northern hemisphere where Arctic char, Sal alpinus (L.), inhabit the headwater lakes of most river syst populations of Arctic char are generally considered the firs postglacial colonizers among freshwater fish (e.g. Ekman 192 Johnson 1980, Dumont 1983, Hammar 1984). The earliest fish c ties were then comprised of allopatric or sympatric populati of landlocked, resident and anadromous Arctic char, a systen successions similar to the present situation in the High Arc (Hammar 1987). With the isostatic uplift of land in the marg regions of glaciated areas (such as parts of Scandinavia anc eastern North America), alternations in temperature and sali of coastal water, and new waves of colonizers with other env mental claims, geographical zonations of successively landlc new fish communities were formed. However, due to ecological reasons such as competition from ecologically superior speci and preying from ultimate predators, the sensitive Arctic ch have been exterminated from many original localities. It wei thus successively restricted to cold and less productive hi(altitude lakes, and/or deep, oligotrophic lowland lakes whe: hypolimnion offers a cold and oxygen-rich summer habitat wi' species diversity - a subarctic refuge within the temperate Today numerous marginal populations are lost due to eutroph acidification, introductions of new species, and over-explo (Hammar 1988). The surviving fish fauna in such areas give cient information on postglacial successions. However, in l exploited subarctic regions with low diversity, the Arctic may still survive in coexistence with a series of competiti salmonids.

In insular Newfoundland, where the number of freshwater fis species is very small (Slastenenko 1958, Scott & Crossman 1 and the fish fauna comparably unexploited, the zonation of ferent freshwater fish communities can thus still be catego both geographically, and ecologically by the demographic st and the habitat "choice" of the coexisting Arctic char popu tions. This paper is a speculative attempt to summarize the interspecific relationships demonstrated in a cline of Arct char lakes with increased diversity, based on the results c testfishing program in insular Newfoundland carried out in October 1984 (Hammar & Filipsson 1985).

Postglacial history of insular Newfoundland

Newfoundland was heavily glaciated during the late Cenozoi(

which comprised an unknown number of glaciations and interglaciations. The long and warm interglacial called Sangamon may have persisted for more than 120,000 years. The last glacial period Wisconsin began around 70,000 B.P. In his comprehensive review, Rogerson (1982) described the Late-Wisconsin ice cover of insular Newfoundland as consisting of numerous and complex dispersal centres, instead of a large dome. The major centres for Late-Wisconsin dispersal were the Great Northern Peninsula, two centres of radial outflow north of Red Indian Lake, one west of Meelpaeg Lake in west-central Newfoundland, a similar centre at Middle Ridge in east-central Newfoundland, and the Avalon complex.

Many areas such as the Long Range Mountains of western Newfoundland were not ice-covered during the Wisconsin. Various organisms have thus been suggested to have survived the last glaciation in such biotic refugia. Deglaciation of the coastline commenced soon after the ice maximum, around 13,000 B.P., in the southwest part of the island. The marine limit is highest over the northern tip of the Northern Peninsula (+100 - +125 m) and decreases to the southeast (less than 0 m) indicating the pattern of postglacial coastal emergence. This would suggest the early colonizers of fish to invade from the east. The last ice melted around 8,000 B.P. and a climatic optimum with warm and dry conditions took place between 6,000 and 3,000 B.P.

Geographical distribution of Arctic char in insular Newfoundland.

The Arctic char was officially not documented in insular Newfoundland until 1949 (Scott and Crossman (1963). Still the species is considered rare and restricted to large, deep and cold lakes, and populations of small-sized Arctic char are in some lakes mistaken as odd specimens of mud trout (brook trout) by the anglers. Very little is known about the distribution and the status of the Arctic char in Newfoundland. The fish communities of a few char lakes have although been described due to various other reasons (e.g. Butt's Pond (Seabrook 1961), Victoria Lake (Pippy 1966), Middle Gull Pond (Wiseman & Whelan 1971), Red Indian Lake (Morry & Cole 1977, Hammar & Filipsson 1985), Candlestick Pond (Rombough, Barbour & Kerekes 1978), Lake Michel (Shawmont Nfld Lt 1982), Micmac Lake (Pepper, Oliver & Blundon 1984), Mobile Big Pond (Chaput & Astle 1985). During the testfishing program for Arctic char by the present author in 1984 (Hammar & Filipsson 1985), Arctic char were recorded to be rather common, and in fact the dominating species in some lakes. Four new localities of landlocked / resident Arctic char were recorded (Portage Lake, Lloyd's River and Star Lake on the Exploits River, and Chimney Cove Pond on the Gregory River), and the presence of two previously uncertain populations of anadromous Arctic char were confirmed (West Brook Pond, Parker's River and Inner Pond, Parson's Pond River).

No allopatric populations of Arctic char have yet been recorded, although high altitude lakes in the Great Northern Peninsula, such as Lake Michel, contain populations of char dominating the ecosystem both numerically and ecologically, although coexisting with brook trout, <u>Salvelinus fontinalis</u>.

Further downstream Arctic char is recorded in numerous lakes, and in sympatry with a successively increasing number of other salmonids (brook trout, Atlantic salmon (Salmo salar), introduced brown trout (Salmo trutta), threespine (Gasterosteus aculeatus) and ninespine sticklebacks (Pungitius pungitius), American eel (Anguilla rostrata) and rainbow smelt (Osmerus mordax).

Geographically Arctic char inhabit the Great Northern Peninsula, the headwater regions of most rivers in central Newfoundland, the eastern parts and in the Avalon Peninsula, a distribution pattern resembling the dispersal centres of Late-Wisconsin glaciers listed by Rogerson (1982). A complete description of the geographic distribution of Arctic char in insular Newfoundland is being prepared by Dempson and Hammar.

Table 1. Freshwater fish communities in insular Newfoundland, and examples of case studies from a survey by the author in 1984.

	Arctic char	Brook trout	Threespine stickleback	Atlantic salmon	Brown trout	Rainbow smelt	American eel
CHAR ZONE:							
L. Michel	*	(*)					
TROUT ZONE:							
Portage L.	*	*					
Star L.	*	*					
Micmac Lake	*	*					*
Chimney Cove P.	*	*					*
SALMON ZONE:							
Red Indian L.	*	*	*	*			
Middle Gull P.	*	*	*	*			*
Mobile Big P.	*	*	*	*	*		
SMELT ZONE:							
Butts P.	*	*	*	*		*	*
ANADROMOUS ZONE:							
Parkers R.	*	*	*	*		*	*
Parsons Pond R.	*	*	?	*		?	?

Geographical zonation of freshwater fish communities

All freshwater fish species in Newfoundland are euryhaline, and are suggested to have colonized the island from refugia along the Atlantic coast (Scott & Crossman 1963), a pattern similar to the colonization of southern Labrador (Black, Dempson & Bruce 1986). In Table 1 and Fig. 1 the suggested zonation of five freshwater fish communities is presented. The communities are classified according to the species believed to dominate the ecological interactions of the fish fauna. Thus, the Arctic char zone comprises the high altitude lakes (500-550 m.a.s.l) of the Great Northern Peninsula. The trout zone is much wider and covers most headwaters of the river systems originating in central Newfoundland. The larger and deeper lakes further downstream contain landlocked Atlantic salmon, in Newfoundland commonly called "ouananiche". The presence of American eel in Indian River and Gregory River above the natural distribution of Atlantic salmon indicates that the eel is able to pass waterfalls that are complete obstructions to the salmon. However, since the eel is catadromous, this zonation is of recent age and the colonization thus of the opposite order. The eel zone may thus include both the trout zone, the salmon zone and the smelt zone. In upper Exploits River and Mobile River the absence of "eel rings" and eaten small salmonids in the gillnets indicated that the dams on the two river systems are obstructions to the American eel.

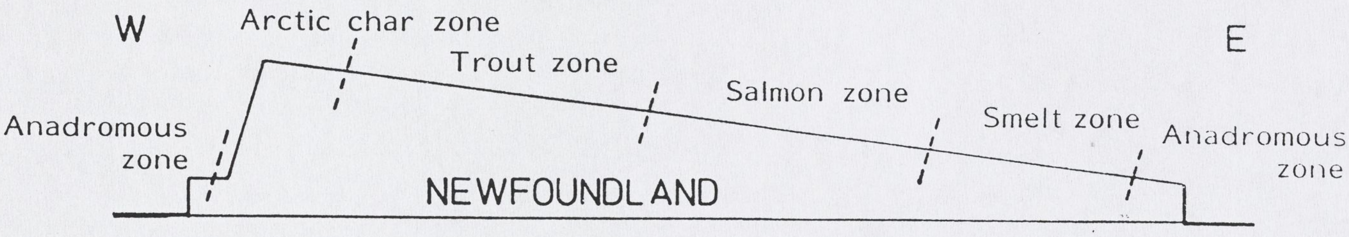

Figure 1. A generalized cross section of insular Newfoundland illustrating the zonation of freshwater fish communities and a suggested order and direction of postglacial colonization.

The ecologically very important rainbow smelt is found landlocked in large lakes close to the coast. In some coastal lakes without outlet obstructions, the Arctic char, the brook trout, the Atlantic salmon and the rainbow smelt may in fact all be anadromous.

Ecological segregation of Arctic char and other species

The Arctic char is known to utilize a wider niche when living allopatrically, causing the population to vary immensely in terms of ecology, morphology and ethology. However, this mosaic species complex may also be considered as very sensitive to competition and predation from other species and the present status of an Arctic char population may thus be used as an indicator of the level of the ecological stress situation (Fig. 2, Table 2). Other salmonids may be considered as more competitive or piscivorous. The rank order between these various species, however, is apparently depending on the present climatic situation, thus giving the Arctic char a more favorable situation at lower temperatures.

The brook trout, which may be considered a more exploratory species than the Arctic char due to its tendency to inhabit small streams and shallow water bodies, has a wide distribution in insular Newfoundland (Scott & Crossman 1963). Allopatric populations are thus sometimes found above lakes containing Arctic char (Hammar & LeDrew in prep.). Similar cases have also been recorded in southern Quebec (Power, Pope & Coad 1973). These cases should, however, not be taken as evidence that the brook trout is an earlier postglacial colonizer. Instead it may reflect a late event of

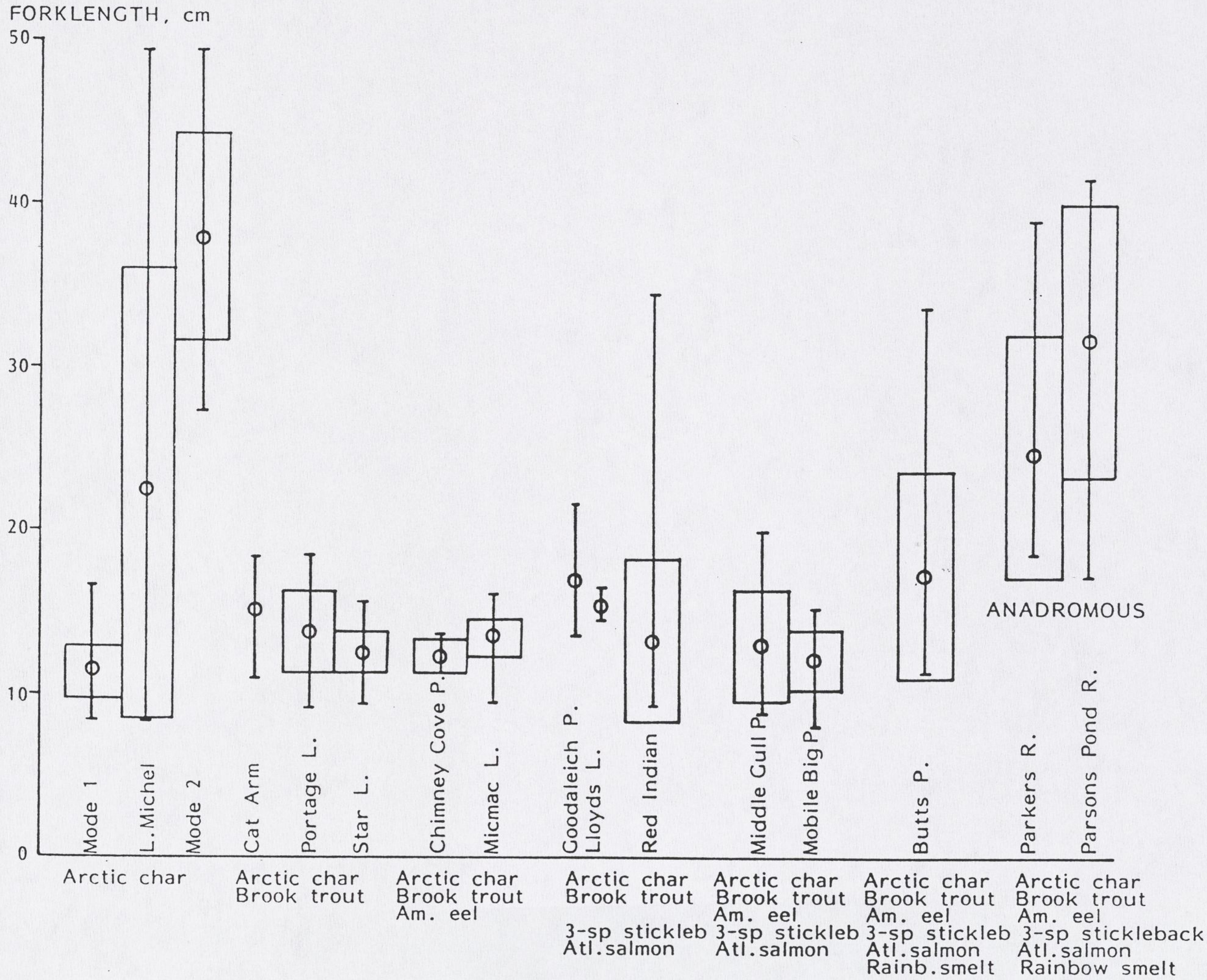

Figure 2. Mean, standard deviation, and maximum range of forklength of Arctic char caught with Lundgren's experimental gillnets in a series of lakes with increasing diversity. Specimens from Mobile Big Pond were collected in a downstream counting fence, and wer mainly spawners. Samples from Cat Arm Reservoir, Goodaleich Pond and Lloyds Lake (from Dempson 1985) were taken with standard gillnets.

colonization by brook trout being more favoured by the present climate than the Arctic char.

In Lake Michel, sympatric populations of very sparse brook trout and numerous Arctic char demonstrate the bimodal length structur characteristic of unexploited arctic populations, where piscivor as well as cannibalistic specimens, forming the second mode according to Johnson (1983) were recorded. The char's growth curve is sigmoid shaped, demonstrating a major increase during the sixth and seventh summer (Hammar in prep.).

In the shallow headwaters of Exploits River, located at lower altitude and thus in a milder climatic region, the dominance and the interactions between Arctic char and brook trout seem to be shifted. Large littoral and piscivorous brook trout were coexisting with small-sized and young Arctic char (Hammar in prep.). In Red Indian Lake, where landlocked Atlantic salmon may be added to the list of competitors and predators, the Arctic char was clearly restricted to profundal zones and deeper pelagic layers (Hammar & Filipsson 1985). Due to the size and depth of the lake and the presence of sticklebacks, odd large specimens of Arctic char may be found. In Micmac Lake, where the small-sized char coexist with dense populations of littoral and highly competitive brook trout, and profundal piscivorous American eel, the catches of Arctic char were restricted to deep pelagic layers. Very few char, however, were caught at deep bottoms (Hammar in prep.)

Table 2. Ecological characteristics of Arctic char populations in different fish communities in insular Newfoundland.

	Length structure:	Habitat:
Char zone:	Large sized, bimodal	Littoral, profundal
Trout zone:	Small-sized, unimodal	Profundal, pelagical
Salmon zone:	Small-sized, unimodal	Profundal, deep pelagical
Smelt zone:	Large-sized, bimodal	Profundal, pelagical
Anadromous zone:	Large-sized, bimodal	Littoral, profundal
[Eel zone:	Small-sized, unimodal	Deep pelagic]

In Butts Pond where the smelt is utilized as the major food resource by most species, including the smelt itself (Hammar in prep.), the Arctic char seems to recover its "former" population structure, with a piscivorous large sized modal group. In the anadromous zone the smelt is replaced by another important prey species, the coastal capelin, Mallotus villosus.

The length structure of the Arctic char population (Fig. 2) thus seems to reflect the present level of competition and predation of the specific fish species combinations, and it also emphasizes the importance of suitable prey species such as sticklebacks and smelt. Further more the Arctic char seem to be favored by the low temperature in deep lowland lakes, such as Red Indian Lake. The zonation of freshwater communities found seems to demonstrate the order of colonization, with Arctic char being the first immigrant, brook trout the second, Atlantic salmon, threespine stickleback and American eel arriving as a third wave. Surprisingly enough, the rainbow smelt seems to be of a more recent invasion, still restricted to coastal areas. However, its northern distribution, anadromous behaviour, combined with poor climbing ability may in fact be taken as evidence of a much earlier colonization period, similar to the conspecific smelt Osmerus eperlanus of northern Europe. Both species demonstrate a unique tolerance to predation.

The very narrow niche of the Arctic char population in lakes where it coexists with brook trout, Atlantic salmon and American eel also emphasizes the danger of introducing further competitive species. If an important prey species such as smelt is absent, the colonization by another salmonid species such as brown trout, rainbow trout or various coregonids may be the ultimate cause extinction of the Arctic char. This may be the explanation fo the natural absence of Arctic char in various areas of Labrad or Quebec. It has also been illustrated in numerous lakes in northern Europe, due to recent introductions of alien species

Acknowledgment

The Newfoundland-Labrador Arctic char project was initiated, hosted and financed by the Science Branch, Department of Fish and Oceans, St. John's, Newfoundland. Colleagues and sons of Newfoundland provided all the help I could ask for during the testfishing programme. Erik Degerman, Drottningholm, gave fru comments on a previous version of the manuscript. Lennart Nyma another swede with a large part of his heart left on the "rock kindly corrected my English. Thank's a million b'ys.

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3/27/00

Hi Bob,

There is finally evidence of anadromy in Alaskan Arctic char. A M.S. student from the Univ. of Alaska at Fairbanks found these fish in Becharof Lake in the Bristol Bay area. Attached are a few pages from Scanlon's M.S. Thesis. This is only a working draft.

If you want to talk to the former Coop Unit leader, Jim Reynolds, his telephone No. is (907) 474-5210.

Scanlon also discovered a benthic form of the Arctic char with big teeth. It's apparently strictly freshwater. This form was only captured in one part of the lake and only in water deeper than 25 meters.

I'm working on what I hope is a final version on the Arctic char distribution in Southcentral Alaska. It should be finished, if we get our computer back on line, by early May.

I'm beginning to know how you probably feel about the taxonomists who have a different species of Arctic char in every watershed or don't believe Dolly Varden are separate from Arctic char.

7

Board Assessment

How well is your board functioning? Check the box that best fits your board.

1. How Well Does Your Board:

A. DETERMINE PROGRAM AND BUDGET

We do this: [ ] well [ ] ok [ ] fair [ ] poorly

B. CARRY OUT THE PROGRAM (DO THE WORK)

We do this: [ ] well [ ] ok [ ] fair [ ] poorly

C. EVALUATE THE ORGANIZATION'S EFFECTIVENESS

We do this: [ ] well [ ] ok [ ] fair [ ] poorly

D. CHOOSE, SUPPORT, AND EVALUATE LEAD STAFF

We do this: [ ] well [ ] ok [ ] fair [ ] poorly

E. GIVE AND GET MONEY FOR THE ORGANIZATION

We do this: [ ] well [ ] ok [ ] fair [ ] poorly

F. CONDUCT PUBLIC RELATIONS → What is the public messages this month

We do this: [ ] well [ ] ok [ ] fair [ ] poorly

G. REPLACE ITSELF

We do this: [ ] well [ ] ok [ ] fair [ ] poorly

2. How Much Change Have You Seen Since You Joined It?

[ ] a lot [ ] some [ ] not much [ ] none

Institute For Conservation Leadership

There must be 10 fishery biologists in the local state office in Soldotna. I haven't encountered a single one that believes Dolly Varden and Arctic char are separate species. The latest comment is that this situation reminds them of the controversy over Grizzly and Brown bears.

Its just as bad down at Kodiak. The state biologists I've talked to act like they've never heard of Arctic char. The federal biologist grudgingly admits that there are Arctic char in Karluk Lake.

I'm putting together a page of color photos to show these folks what Arctic char look like. Most of them have never seen one in spawning colors.

The ice should melt out of the local lakes in 4 or 5 weeks. Can't hardly wait to get out and catch a few Arctic char on hook and line. I've got a canoe stashed at one of the lakes. That's probably the first one I'll fish but there are several other lakes in hope to dip a lure in this coming spring.

Take care, Bob. Your help and encouragement have been appreciated.

Fred

Next page

P.S.

Bob, what criteria does the Russian taxonomist I. A. Chereshnev use to separate Tananetzi from Arctic char? The info you sent on gill rakers, pylorica caeca appeared to be identical with Arctic char.

Do the Russians have a good handle on the distribution of S. tananetzi in Asia?

Brown bear
Stakeholders
1/6/00

FRIENDS OF KENAI NATIONAL WILDLIFE REFUGE
BOARD MEETING AGENDA
December 11, 1999, 2:00 p.m.

1. Call to Order; Announcements and Introductions

2. Approval of Agenda; Approval of Minutes

3. Treasurer's Report; Membership Report

4. Correspondence

5. Refuge Manager's Comments

6. Old Business

   A. IRS 501(c)(3) Charitable Organization Filing -- pending return
   B. Logo and Slogan Report -- pending John Clare's recommendation
   C. Website Report
   D. December 11 Ski Party Report
   E. Adopt-A-Highway Program Report
   F. Adopt-An-Animal Project Report
   G. Friends/NWRA Compatibility Comments
   H. NAS Proposal: Place NWR System Under a New Agency
   I. Proposed Project of Ecological Concern: Wolf Lake Gasline
   J. Chugach National Forest Plan Revision —
   K. Visitor's Center Expansion

7. New Business

   A. NWRA Academy Report -- Bruce/Michelle
   B. Treasurer
   C. Newsletter -- January issue
   D. Annual General Membership Meeting -- January

Next meeting: 2:00 p.m., Saturday January 8, 2000

THE ECOLOGY OF THE ARCTIC CHAR AND THE DOLLY VARDEN IN THE BECHAROF LAKE DRAINAGE, ALASKA

A

THESIS

Presented to the Faculty
of the University of Alaska Fairbanks
in Partial Fulfillment of the Requirements
for the Degree of

MASTER OF SCIENCE

By

Brendan Patrick Scanlon, B. S.

Fairbanks, Alaska

November 1999

Table 2. Meristic variation in Arctic char (AC) and Dolly Varden (DV). Variable acronyms are given on page 12. Standardized and unstandardized coefficients for the discriminant analysis (DA) and coefficients of principal components analysis (PCA) 1, 2, 3, and 4 are given. Significance of the test for difference in character means is designated as NS=non-significant and **=*P*<0.01.

	Mean		Univar.	DA coefficients		PCA coefficients			
Variable	AC	DV	sign.	Std.	Unstd.	1	2	3	4
DRC	10.6	11.1	**	-0.115	-0.169	-0.379	0.524	-0.135	0.281
ARC	9.5	9.5	NS	0.090	0.128	-0.126	0.332	0.740	0.352
PRC	12.5	13.1	**	-0.208	-0.223	-0.204	0.636	-0.442	-0.316
VRC	9.1	9.1	NS	-0.017	0.033	0.700	0.544	0.485	-0.555
BRC	11.4	11.1	**	-0.022	-0.033	0.468	0.311	-0.158	0.251
UGR	8.9	8.3	**	-0.069	-0.067	0.564	0.325	-0.323	0.404
LGR	13.9	12.4	**	0.408	-0.466	0.821	0.096	0.076	0.121
PYL	48.1	26.9	**	0.854	0.147	0.847	-0.089	0.131	0.062
Constant	--	--	--	--	-8.469	--	--	--	--
Eigenvalue	--	--	--	3.339	--	2.135	1.305	1.148	0.901
% of variance	--	--	--	100	--	26.7	16.3	14.4	11.3
Significance	--	--	--	**	--	--	--	--	--

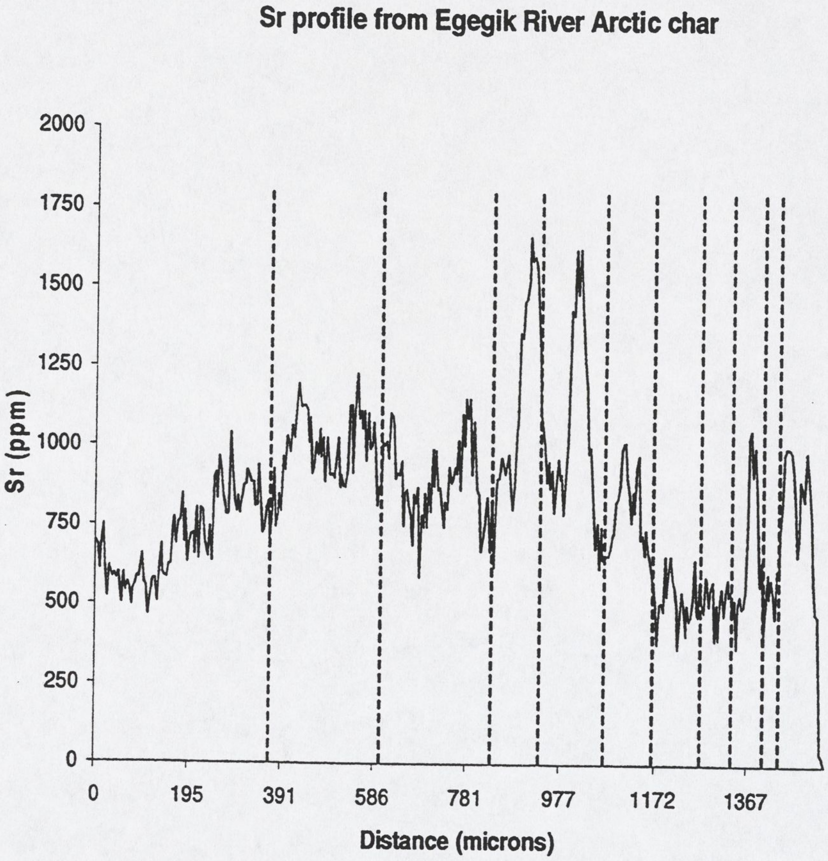


Figure 10. Strontium line scan from an anadromous Arctic char (dashed lines denote annuli).

(Table 9). One fish was observed to have a small mollusk in its stomach, possibly accidentally eaten during ingestion of an invertebrate from the substrate. It is important to note that both the Egegik River and Ruth River fish were sampled 7-8 weeks before the return of the sockeye salmon, therefore salmon eggs could not be a potential food item at this time.

"Benthic form" Arctic char versus "Normal form" Arctic char

Benthic form Arctic char stomach contents contained mostly fish (52.3%) (Table 10). The demersal fishes, pygmy whitefish and nine-spined stickleback, were the most frequently observed (38%). Isopods were only observed in two stomachs (9.5%). Eight stomachs were empty (38.1%).

Normal form Arctic char exhibited a much wider range of food choices, with isopods recorded the most often (21.2% of the time) (Table 10). Diptera larvae and emergents were recorded 11 times, and only one sockeye salmon was recorded.

Discussion

Dolly Varden and Arctic char

Morphometric analysis alone clearly separates Dolly Varden from Arctic char (e.g., bimodality in discriminant scores, excellent classification accuracy, etc.) as a two physically distinct groups. This quantitative separation is further supported by observations of overall body shape and color, preferred habitats, and food types. Sixty-seven out of the seventy Dolly Varden captured were found in running waters (i.e., the inlet streams or the outlet river), and aside from 17 specimens collected from the Egegik River in early summer, all Arctic char were caught in the lake (N=162). It appears that the two species do not directly

Table 10. Stomach contents of "benthic form" and "normal form" Arctic char collected from 6 June 1998 through 13 September 1998. Values are reported as number of observations and frequency of occurrence.

Item	Benthic form (N=21)	Normal form (N=85)
Pygmy whitefish	4 (19.0%)	4 (4.7%)
Nine-spined stickleback	4 (19.0%)	13 (15.3%)
Three-spined stickleback	1 (4.8%)	3 (3.5%)
Unidentified fish	2 (9.5%)	13 (15.3%)
Isopods	2 (9.5%)	18 (21.2%)
Dipterans	0 (0.0%)	11 (12.9%)
Snails	0 (0.0%)	3 (3.5%)
Trichopterans	0 (0.0%)	2 (2.4%)
Sockeye juveniles	0 (0.0%)	1 (1.2%)
Sculpin	0 (0.0%)	1 (1.2%)
Empty stomachs	8 (38.1%)	16 (18.8%)

compete with each other during the summer months, at least in freshwater. I would suspect that this separation in habitat preferences also precludes these two species from hybridizing at any more than a nominal level. Neither species was observed spawning during the field season, and likely do not spawn until at least October. However, observations of body condition (coloration, kype formation, etc.) suggested that the Dolly Varden were much closer to spawning than were the Arctic char when we left the study site (September 12).

Arctic char

The otolith microchemistry results reflect much overlap in movement patterns, and it is believed that this is the first direct evidence of anadromy in Arctic char in the state of Alaska (F. DeCicco, 1998, Alaska Department of Fish and Game, Fairbanks, personal communication). It was previously thought that anadromy in Arctic char generally increases with latitude, with the mechanism for this behavior tied to decreasing productivity in freshwater in northern systems. Becharof Lake is near the southern latitudinal range limit for Arctic char in North America, therefore this observation was unexpected.

The ambiguous signals observed (800-1200 ppm Sr) are more difficult to interpret in terms of movement, but may reflect movement to estuarine environments. Estuaries can often be quite productive in terms of food and shelter for smaller fishes and juveniles (Diana 1995), and therefore may represent an environment for Arctic char with not only plenty of food, but also without the need for a more extensive offshore migration. The eastern section of Bristol Bay receives freshwater inputs from numerous large rivers (including the Kvichak, Naknek, Egegik, Ugashik, and Nushagak Rivers), and may contribute to the intermediate strontium concentrations found in nearshore environments.

two groups were chosen to test because of radical differences in appearance as well as location. The Egegik River fish had a silvery-bright coloration with faint spots (as one would expect from an anadromous fish fresh from the sea), whereas the Ruth River fish were a deep blue with bright pink spots. The Egegik River fish also appeared to be in poor condition, with several fish appearing emaciated. The Ruth River fish appeared much healthier and robust, with a much darker color. It is interesting to note that both the Egegik River and Ruth River serve as outlets for lakes, and perhaps these locations could act as good locations as feeding stations for smolt outmigrations, and may serve as the basis for development of loosely-knit sub-populations.

Otolith microchemistry analysis indicate that Ruth River fish showed what appears to be a mild, possibly estuarine movement signal, similar to the one found in the tagged fish from the King Salmon River. The Egegik River fish exhibited signals of both mild anadromy and true oceanic movements. It seems likely that Dolly Varden throughout the Bristol Bay area congregate in outlet rivers of sockeye salmon nursery lakes in the spring, and these fish may have come from other systems to the Egegik to capitalize on the smolt outmigration. I suspect that while the Ruth River and Egegik River fish are not two discrete sub-populations, the Ruth River Dolly Varden probably exhibit less variability in stock structure, movement, and habits than do the Dolly Varden found in the Egegik River, even in the absence of any barrier between the two groups.

Benthic versus Normal form Arctic char

Meristically, these two groups do not separate well, probably due to the same explanation given above by Power (1997), and any apparent separation based on meristics may be influenced by disparity in sample size (benthic form: N=21; normal form: N=79). It is likely that the two groups would show continuous distributions if the benthic form sample size were larger.

Morphometrically, separation is much more apparent. Much of the separation can be attributed to differences in head morphology, which was the most obvious difference in the field. This may be associated with respect to feeding strategies, for the benthic form showed a much narrower range of food preferences than did the normal form, with particular emphasis on the demersal fishes (nine-spined stickleback and pygmy whitefish). While the benthic form was often caught in the presence of large numbers of isopods, only twice were these fish found to have fed on them.

With the otolith microchemistry analysis, all three benthic form Arctic char tested showed a clear, strictly freshwater signal. The normal form fish showed a mix of freshwater residency, mild anadromy, and true oceanic strontium signals. These results would support the notion of a benthic specialist, for a smaller range of movement would be consistent with a group of fish that focuses on a prey type found in a particular area, whereas as the more generalist group (the normal form fish) might show a wider range of movement patterns. All benthic form fish were caught in the Island Arm basin of the lake, and always in bottom sets in water 25-50m deep. The normal form fish were caught in a wide variety of areas, including shallow and deep water sets, and the outlet river.

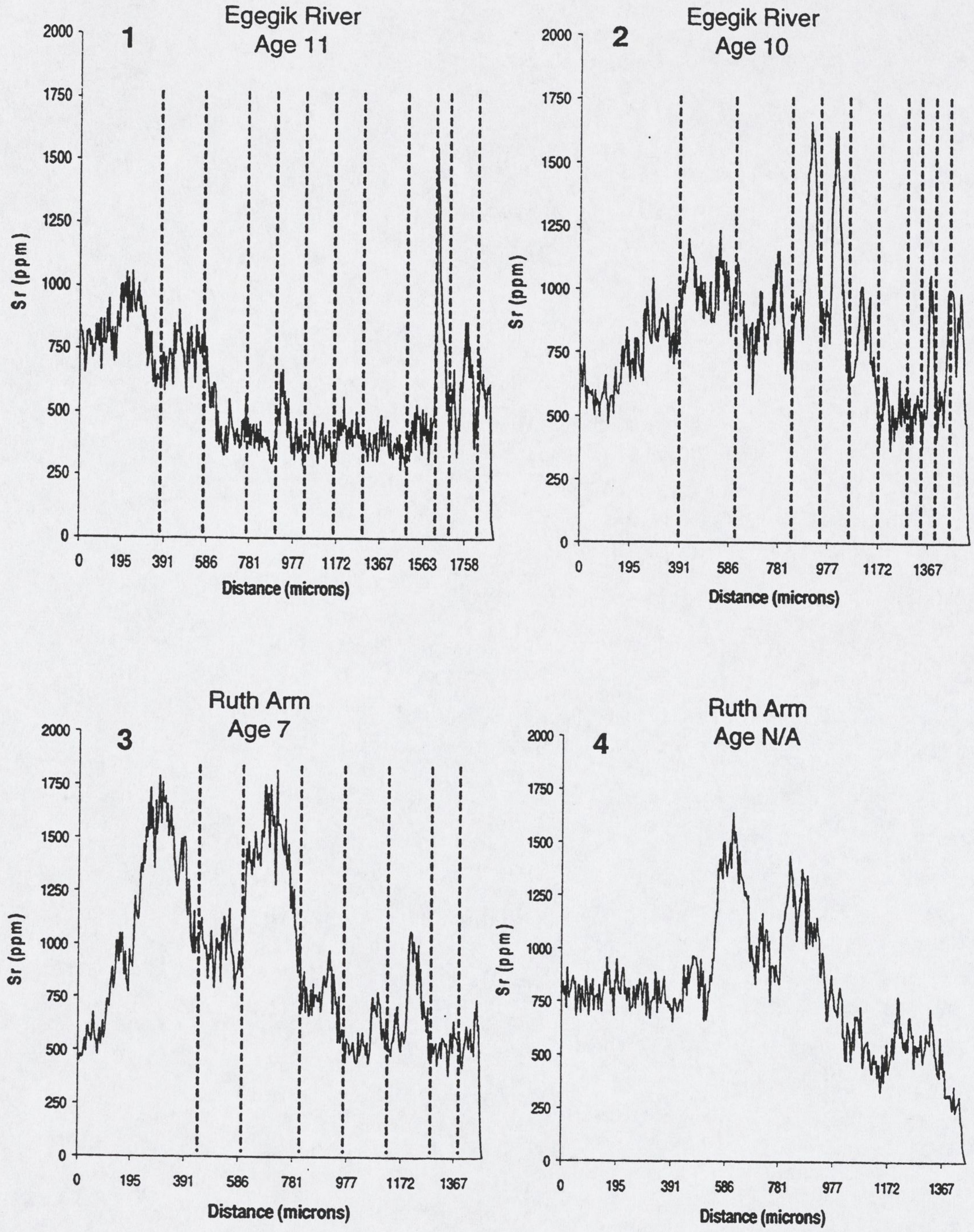
Saavaitova (1989) reports that in nearly all populations of Arctic char, intermediate phenotypes are present and that it is often difficult to determine the status of distinct groups. While it appears that there may be more than one "form" of Arctic char in Becharof Lake, 300-500 ppm for a Becharof Lake signal and 150-650 ppm for stream signals. We did not have a seawater water sample, but Babaluk et al. (1997) report strontium concentrations in otoliths of known anadromous Arctic char from four locations in the Canadian Arctic reported anadromy signals of 1500-2000 ppm. They also collected seawater samples off Victoria and Ellesmere Island and reported concentrations of 3.226 and 4.220 ppm respectively. We will assume a similar relationship exists here in lieu of water data.

Arctic Char Line Scan Data

Twenty-three Arctic char otoliths were run from fish ages 3-13 years. Twelve fish exhibited what we believe to be a strictly freshwater signal (250-500 ppm), such as in Figure 9. Some of these fish show slight rises to 650 ppm, which may be attributed to feeding around a stream outlet of a higher signal or ascending a stream to feed. These fish range in age from 3-11 years, and include at least three spawners and all three "benthic form" fish tested. Line scans from all twelve of these fish are shown in Appendix 1.

Five fish exhibited what appear to be full anadromy signals (1500-2000 ppm) in addition to freshwater signals, such as in Figure 10. Some of these fish show consistent strontium concentrations of 700-900 ppm for over two years, suggesting residence in a water body other than the Becharof drainage. Anadromous movement appears to begin between ages 2-8, and does not always occur in consecutive years. These fish range in age from 6-12 years, and one fish appears to have a healed lamprey scar. Line scans from all five of these fish are shown in Appendix 2.

Six fish exhibited signals that were difficult to interpret as strict freshwater residence or anadromous movement, such as in Figure 11. These fish ranged in age from 7-



Appendix 2. Line scans from five anadromous Arctic char, with locations caught and ages at capture (dashed lines denote annuli).

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[redacted]

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