GILL RAKER VARIATION AND DIET IN LAKE WHITEFISH *COREGONUS CLUPEAFORMIS* IN NORTHERN MANITOBA

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by
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ABSTRACT

Gill raker length, gill raker number, space between gill rakers and stomach contents were recorded for fish from seven lakes. Stomach contents were divided into two categories: 1) those organisms that are almost exclusively benthic, 2) those organisms that are partially or totally pelagic. Variation among lakes was much more striking for gill raker length than for number or spacing. There was a significant negative correlation between gill raker length and the proportion of benthic food eaten. Unexpectedly, gill raker number was positively correlated with the proportion of benthic food eaten. No such relationships occurred within lakes.

In lakes where fish had longer and fewer rakers, they generally displayed poorer growth, and had larger pupils and longer pectoral fins.

Only in Big Athapapuskow Lake was there a relationship between gill rakers and spatial distribution. Here a higher proportion of fish with long rakers were caught in waters with a maximum depth under 15.2 metres.

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INTRODUCTION

The role that gill rakers play in the feeding of fishes has been the subject of much speculation and discussion. This study examines to what extent gill raker number, length and space are interrelated in the lake whitefish, and also whether these variables are correlated with the feeding in this species. The possibility is also examined that gill rakers may, by controlling the diet of the fish, indirectly effect their morphology and spatial distribution.

The Cranberry Portage area in northern Manitoba offers an excellent opportunity to investigate this problem because of the close proximity of lakes containing fish with differing gill raker characteristics.

LAKE DESCRIPTIONS

The lakes studied are situated in northern Manitoba at approximately 54°N latitude and 101°W longitude (Fig. 1). This is an area of transition between Precambrian and Palaeozoic rocks. Roughly speaking, the entire south shore of Big Athapapuskow is Ordovician (dolomite, limestone), while the north shore and the area including the other lakes is Precambrian (granite, gneiss) (Davis et al., 1962).

All the lakes drain from north to south through Big Athapapuskow and eventually into the Saskatchewan River system. In previous times fish could have moved relatively easily between lakes, however due to low water at the time of the study movement was not possible between Payuk and Neso nor between Payuk and Little Twin. The extent to which fish move between lakes is not known.

Some characteristics of each lake are given in Table I. For a summary of physical, chemical and biological data see Appendix 1 and 2.

Figure 1. Map of Study Area.

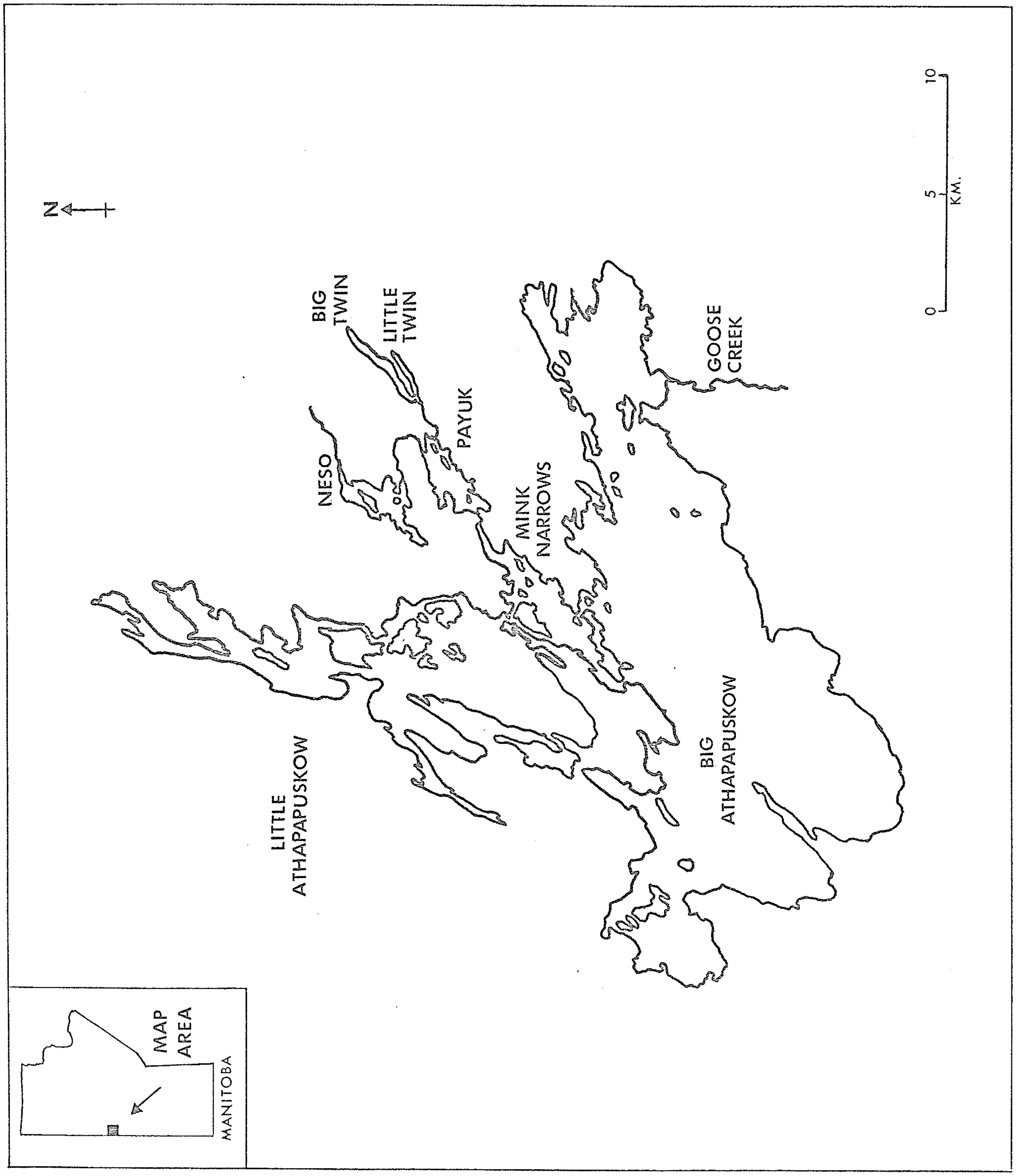
N
BIG TWIN
LITTLE TWIN
PAYUK
NESO
MINK NARROWS
GOOSE CREEK
LITTLE ATHAPAPUSKOW
BIG ATHAPAPUSKOW
0
5
10
KM.
MAP AREA
MANITOBA

Table I. Physical, chemical and biological data for lakes studied[a]

Lake	Max. Depth(m)	Area (Hectares)	Thermal Stratification	Oxygen (Hypolimnion)	Plankton	Benthos
Neso	11.6	386	Yes[b]	Low	Rich	Poor
Payuk	9.1	420	No	High	Rich	Poor
Mink Narrows	30.2	951	Yes	High	Rich	Poor
Big Athapapuskow	62.2	19,916	Yes	High	Poor	Moderate
Little Athapapuskow	38.7	6,680	Yes	High	Poor	Moderate
Big Twin	25.6	135	Yes	High	Poor	Moderate
Little Twin	9.1	40	No	High	Rich	Moderate

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[a] All compiled from summer 1968 data except for benthos which came from the following sources: McLeod (MS, 1943); McTavish (MS, 1950); Stewart-Hay (MS, 1953); Schlick (MS, 1967).

[b] No stratification in late summer 1968.

METHODS

Seven different gangs of monofilament nylon gill nets were used to sample fish. All nets were 15.2 metres long, but varied in depth; five gangs were composed of nets 2.4 m. deep, and two nets 7.6 m. deep. Stretched mesh size ranged from 1.91-5.08 cm. Appendix 3 gives the composition of each gang. The 2.4 m. nets were divided into top, middle and bottom bands, and the 7.6 m. nets, by painted stripes, into 1.5 m. deep bands, thus making it possible to record the approximate depth at which each fish was caught. The nets were set at various locations and depths, sometimes on the bottom, sometimes in midwater, and sometimes suspended along the surface by auxillary floats. Extensive netting was done in the lakes from May 10 to Aug. 26, 1968. From Oct. 5 to Nov. 3, 1968 most of the netting was conducted in spawning areas, including inlet and outlet streams. Three of the lakes were also fished in the winter from Feb. 28 to March 3, 1969. Appendix 4 gives a detailed account of the net sets.

Measurements and counts were taken on the left side of the specimen when appropriate. Except for gill raker number and fork length which were taken mostly on fresh fish, all measurements were from specimens preserved in 10% formalin (4% formaldehyde). Caliper measurements were made with dial calipers reading 0.1 mm. Relative rather than absolute size of body parts has been used. To compensate for non-isometric growth between two related characters, only fish of approximately the same size range (35-45 cm.) were used (except for gill raker variables).

The following measurements were made according to Lindsey (1962):

head length, head depth, inter-orbited width, caudal peduncle depth, gill raker number, suprapelvic scale count, caudal peduncle scale count and dorsal fin ray count. The measurements for fork length, pectoral origin, pectoral length and pelvic origin were made following Lindsey (1963). Also measured were:

Scale Counts Above Lateral Line: taken from the origin of the dorsal fin including the small scales, and counting downward and backward following the natural scale row to and including the lateral line scale.

Pupil Diameter: measured with calipers as the length across the center of the pupil of the eye.

Gill Raker Length: measured under magnification, using pointed calipers, as the distance from the tip to the ventral margin of the base of the longest gill raker on the first gill arch.

Gill Raker Space: measured under magnification, using pointed calipers, as the space between the bases of the longest gill raker and the one dorsal to it.

Scales were taken from the left side of the fish just anterior and ventral to the dorsal fin. Aging was done by professional scale readers of the Fisheries Branch of the Manitoba Provincial Government.

By severing the oesophagus and pyloric sphincter the stomachs were removed, and the contents were scraped into 10 dram vials and preserved in 40% isopropyl alcohol. In order to obtain the volume of food eaten the samples were poured into graded volumetric tubes and allowed to settle for several hours. Also, by washing with water, the contents were strained through seven different mesh sizes (0.3-2.0 mm. squares approximately equal to the gill raker space size range) of nitex mono nylon cloth, thus giving estimates of the size of food eaten. (This method does not allow for such errors as when an organism is partly digested and thus passes through the screens more easily.) The percentage volume of each type of food organism caught by each screen was estimated by eye. For each lake, the percentage of food in the fish's stomach larger than 1.7 mm. was totalled, and then the average for all fish from that lake was calculated. After identification the stomach contents were divided into two general categories, using Pennak (1953) and Ward and Whipple (1966): 1) those organisms that are almost exclusively benthic. This category is so termed since some of the organisms in it such as chironomid larvae are not necessarily confined to the benthic zone (Mundie, 1959). 2) those organisms that are partially or totally pelagic. Table II gives the present categorization of the organisms in the stomachs. (It is very difficult to classify aquatic organisms into two such categories. In this study the term pelagic is probably too restrictive since the category also includes littoral organisms. However, all the organisms in this category have one thing in common, in that at some time they actively swim about in the water.) For each lake, the percentage of benthic food from the stomach of each fish was totalled and the average percentage in all stomachs was calculated.

All weighing was done on preserved fish. Before the body weight was taken, the contents of the body cavity were removed in order to

Table II Classification of whitefish stomach contents.

Benthic Organisms	Pelagic Organisms
Pelecypoda	Hirudinea
Gastropoda	Cladocera
Amphipoda	Copepoda
Diptera (Tendipedidae Larvae)	Mysidacea
Ephemeroptera	Diptera (Culicidae Larvae)
Trichoptera	(Ceratopogonidae Larvae)
Megaloptera	(Tendipedidae Pupae)
Plant	Hemiptera (Corixidae)
Eggs	Coleoptera
	Hymenoptera
	Fish

eliminate variability due to differences in gonad size and also differences in the amount of stomach contents present.

At various times throughout the study period oxygen content, pH and hardness (using a Hach Kit), temperature, turbidity, vertical plankton hauls with #10 mesh and water samples were taken. The water samples were analyzed by the Freshwater Institute of the Fisheries Research Board of Canada.

RESULTS

Gill Raker Number, Length and Space

The average gill raker number and the average relative gill raker length and space for each lake are given in Table III. It was possible to use relative rather than absolute values for gill raker length and space since a fairly good straight line relationship existed between these two factors and fork length over the size range of fish examined. Gill raker counts were stable over this size range and no differences existed between sexes in any of these gill raker variables.

Analyses of variance were calculated for each of the three variables from the seven different lakes (Table V). There were highly significant differences ($P < 0.01$) in gill raker number and in gill raker length, and a significant difference ($P < 0.05$) in gill raker space, among lakes. To quantify the variability (among lakes) in gill raker number, length and space the coefficient of variation was calculated ($cv = {}^{s}/\bar{x} \times 100\%$). For gill raker length it was 10.4%, for gill raker space 3.7% and for gill raker number 3.2%.

The length of every second gill raker on the short part of the gill arch was measured on a few fish from each lake. This showed that the differences in lengths among lakes remained up until the fifth gill raker below the middle, but after that the lengths converged. The measuring technique used was probably not accurate enough to detect differences in the smaller gill rakers at the end of the arch.

Table III Relationship of means of gill raker variables and feeding. (Gill raker length and gill raker space are expressed in percentage of fork length.)

Lake	Gill Raker Number	Gill Raker Length	Gill Raker Space	% Benthic Food	% Food > 1.7 mm.
Neso	26.50	2.209	0.348	41.6	66.7
Payuk	26.75	2.201	0.386	58.1	100.0
Mink Narrows	27.17	2.077	0.391	59.1	92.1
Big Athapapuskow	27.60	1.917	0.385	81.3	87.8
Little Athapapuskow	28.21	1.881	0.364	84.3	81.5
Big Twin	28.24	1.774	0.393	92.9	95.4
Little Twin	28.90	1.684	0.388	74.2	99.7

Table IV Correlation coefficients between gill raker variables and feeding.

	Gill Raker Number	% Benthic Food	% Food > 1.7 mm.	Gill Raker Space
Gill Raker Length	-0.97**	-0.84*	n.s.	n.s.
Gill Raker Number		0.79*	n.s.	n.s.
% Benthic Food			n.s.	n.s.
% Food > 1.7 mm.			n.s.	0.92**

* Significant at 0.05
** Significant at 0.01

Table V Analysis of variance for gill raker variables among lakes.

A. Gill Raker Number

B. Gill Raker Length

C. Gill Raker Space

Source	Degrees of Freedom	Sum of Squares	Mean Square	F
Treatment	6	226.82	37.80	30.10**
Error	901	1131.65	1.26	
Total	907	1358.47		

Source	Degrees of Freedom	Sum of Squares	Mean Square	F
Treatment	6	890.76	148.46	36.43**
Error	511	2082.65	4.08	
Total	517	2973.41		

Source	Degrees of Freedom	Sum of Squares	Mean Square	F
Treatment	6	4.82	0.80	2.68*
Error	451	135.26	0.30	
Total	457	140.08		

* Significant at 0.05
** Significant at 0.01

A highly significant ($P < 0.01$) negative correlation exists between gill raker number and gill raker length (Table IV). In those lakes in which the fish have more gill rakers they also have shorter ones (Fig. 2). Within any one lake, however, there is not a significant relationship between the two factors.

The expected negative correlation between gill raker number and gill raker space was not found, and also no significant correlation existed between gill raker length and space.

Gill Rakers and Food Type

The average percentage of benthic food found in the stomachs of whitefish of each lake is presented in Table III. A significant ($P < 0.05$) correlation (Table IV) exists between gill raker length and the percentage of benthic food eaten. Thus, in those lakes in which the fish have short gill rakers, a higher proportion of benthic food is being eaten (Fig. 3). No such relationship was found within one lake.

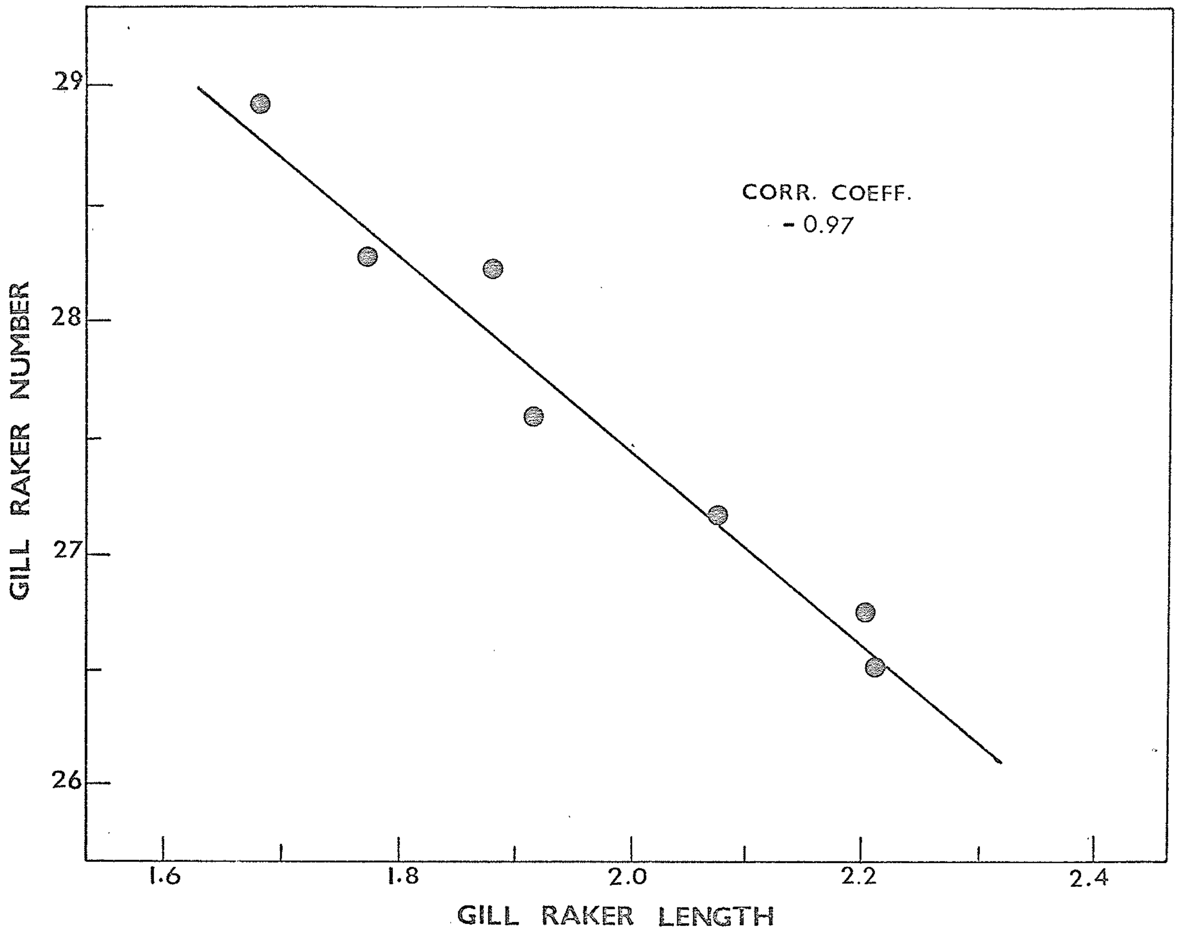
The type of food eaten by the whitefish is positively correlated with gill raker number (Table IV). Where the fish have more gill rakers, a significantly ($P < 0.05$) higher proportion of benthic food has been eaten than where they have fewer gill rakers (Fig. 4). This relationship was not found within any one lake.

In the three lakes with the most plankton and least benthic organisms, Payuk, Neso and Mink Narrows, the whitefish have longer and fewer rakers. Little Twin is exceptional in that it contains a heavy

Figure 2. Relationship between gill raker length and gill raker number.

Figure 3. Relationship between gill raker length and the percentage of benthic food eaten.

18a


29
28
27
26
GILL RAKER NUMBER
1.6
1.8
2.0
2.2
2.4
GILL RAKER LENGTH
CORR. COEFF.
- 0.97

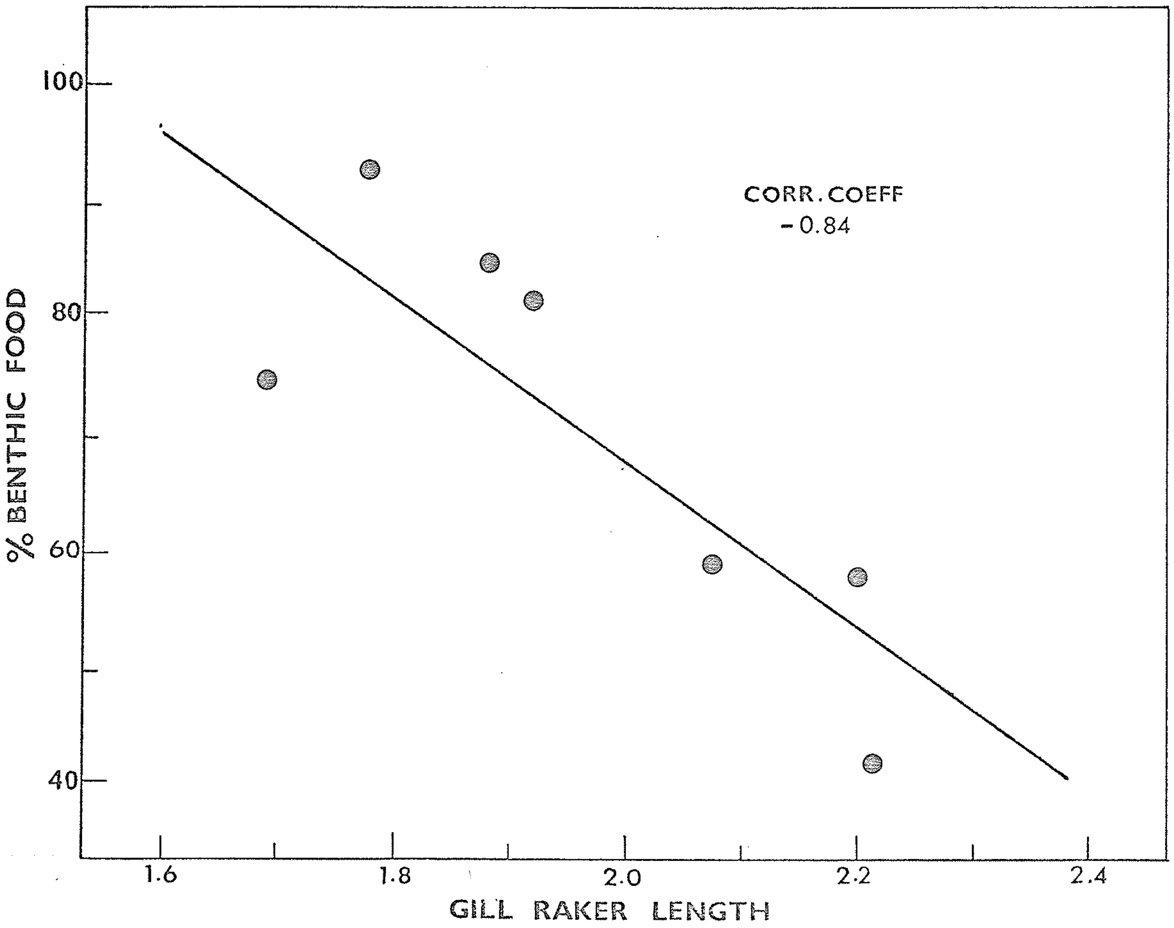
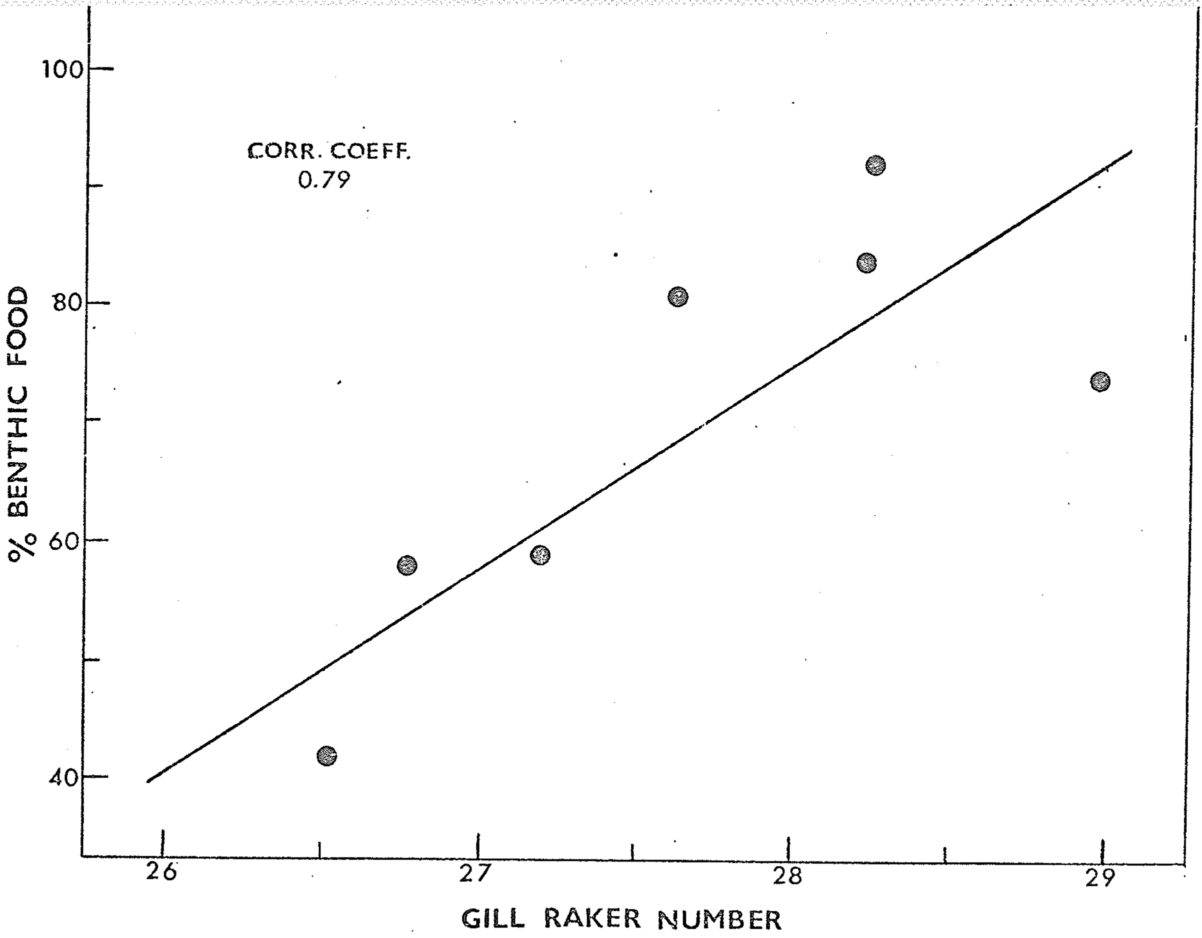
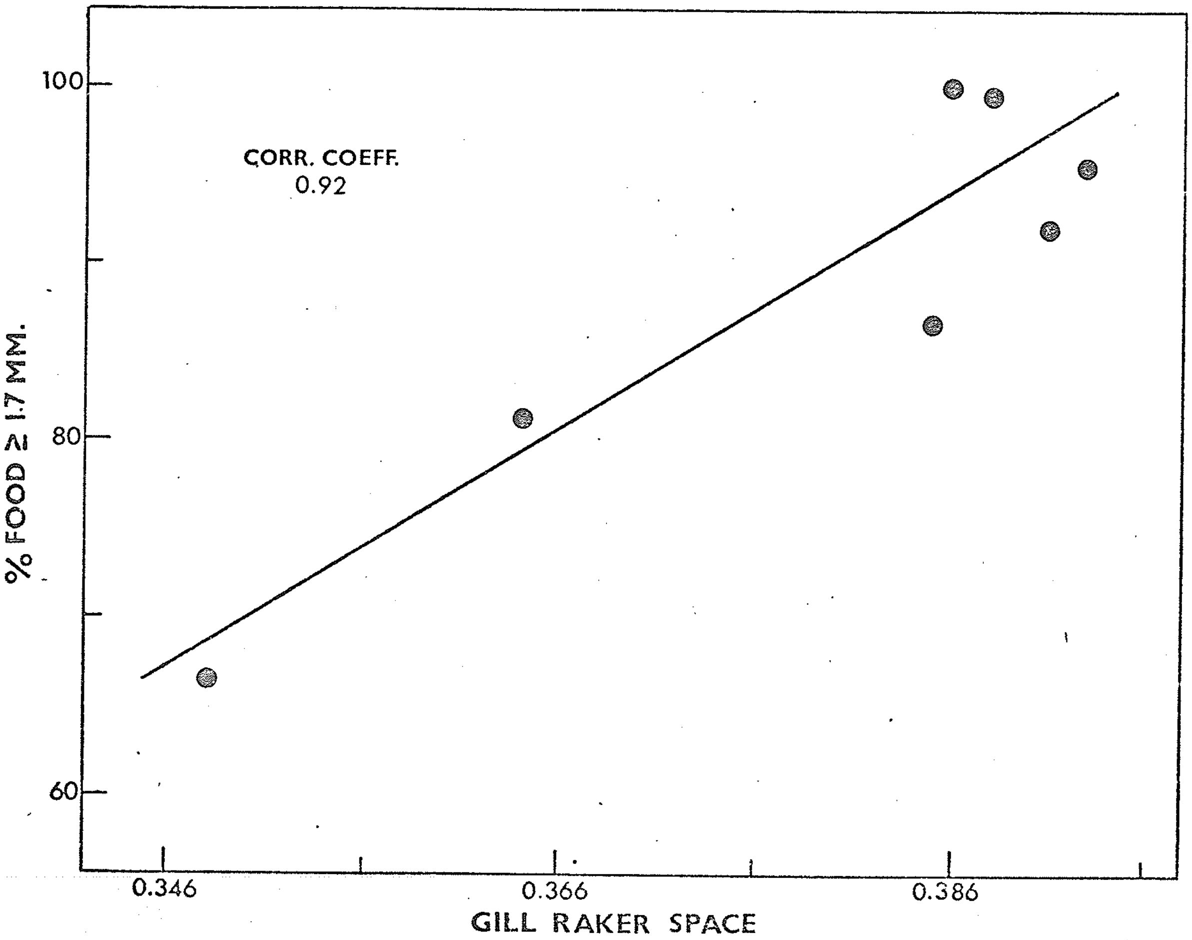

100
80
60
40
% BENTHIC FOOD
1.6
1.8
2.0
2.2
2.4
GILL RAKER LENGTH
CORR. COEFF
- 0.84

Figure 4. Relationship between gill raker number and percentage of benthic food eaten.

Figure 5. Relationship between gill raker space and size of food eaten.


CORR. COEFF.
0.79
% BENTHIC FOOD
100
80
60
40
26
27
28
29
GILL RAKER NUMBER


CORR. COEFF.
0.92
% FOOD ≥ 1.7 MM.
100
80
60
0.346
0.366
0.386
GILL RAKER SPACE

plankton population but the fish have shorter and more numerous rakers. There is reason to believe that this lake does not support a permanent population of whitefish, since despite numerous net sets, fish were not caught there when the water temperatures were high. The fish probably moved through the creek from Big Twin and either moved out when the temperature became high, or if they stayed were almost all caught. Big Twin fish are predominantly benthic feeders; however when they move into Little Twin with its heavy plankton, more pelagic organisms are eaten. Had Little Twin not been used in calculating the correlation coefficients between gill rakers and feeding, they undoubtedly would have been higher.

Gill raker space was not significantly related to the type of food eaten.

Gill Rakers and Food Size

Table III also gives the percentage of food larger than 1.7 mm. found in stomach samples from each lake. A highly significant ($P< 0.01$) positive correlation exists between the relative gill raker space and the food size (Table IV). In those lakes in which the fish have small relative gill raker spaces they have eaten a higher percentage of smaller food than in those lakes in which the fish have larger spaces (Fig. 5). However in each lake the fish have eaten some food from each size category. This relationship is found only among lakes and not within lakes. If one uses the absolute gill raker measurement there is no significant correlation to food size neither among nor within lakes.

Gill raker number and gill raker length were not significantly related to food size. Also no significant correlation existed between food size and the proportion which was benthic or pelagic.

Gill Rakers and Growth in Body Length

Differences in growth exist among lakes, and these differences are apparently correlated with gill rakers. Generally, in those lakes where the fish have more and shorter gill rakers, they tend to be larger in size (Table VI). This is best seen in older fish since the small sample size tends to obscure the differences in the younger age classes.

Growth differences were also looked for within lakes. There was no significant difference in growth between fish with more numerous gill rakers and fish with fewer gill rakers. Also, no significant differences in growth existed between fish with the mean number of gill rakers and fish with extreme counts. The extreme counts were further subdivided into low and high extreme and then the growth of these fish were compared to growth of fish with the mean count; again no significant differences were observed.

Gill Rakers and Length Weight Relationship

Although differences existed in the "condition" of the fish from lake to lake, these differences were apparently not correlated with gill raker characteristics.

Table VI Average length (cm.) of each age group of fish in the lakes studied. (Sample size in parenthesis).

Lake	0	I	II	III	IV	V	VI	VII
Fewer and Longer Gill Rakers								
Neso	9.67 (3)	17.20 (3)	18.60 (1)	29.87 (3)	36.71 (3)	40.77 (22)	43.97 (10)	
Payuk		16.10 (1)		27.30 (1)	34.69 (25)	38.77 (9)	43.50 (3)	48.80 (1)
Mink Narrows	10.60 (2)	17.80 (11)	21.20 (5)	27.43 (26)	33.00 (21)	38.73 (15)	44.48 (4)	47.15 (2)
More and Shorter Gill Rakers								
Big Athapapuskow	11.54 (25)	17.39 (23)	24.35 (32)	32.32 (41)	38.04 (73)	42.15 (97)	45.74 (25)	49.45 (2)
Little Athapapuskow	9.30 (1)	18.90 (1)	23.09 (7)	27.53 (14)	34.82 (17)	40.19 (24)	45.70 (9)	49.18 (3)
Big Twin			18.72 (5)	30.47 (3)	33.87 (11)	41.35 (11)	45.98 (13)	48.96 (5)
Little Twin					36.90 (1)	40.00 (6)	44.69 (8)	49.10 (1)

Gill Rakers and Spatial Distribution

Only in one lake, Big Athapapuskow, was there apparently a correlation between gill rakers and the spatial distribution of fish. There a higher proportion of fish with long gill rakers were caught in waters where the maximum depth was less than 15.2 m. A chi-square test showed the difference to be highly significant ($P < 0.01$). In no lake was there a significant relationship between the gill raker variables and the actual depth at which the fish was caught, for example, fish with longer rakers were not necessarily caught closer to the surface.

Analysis of variance showed a highly significant ($P < 0.01$) difference in the gill raker length between one area of Big Athapapuskow and another (Table VII). Areas I and III had more fish with shorter gill rakers while areas II and IV had more fish with longer gill rakers (Fig. 6). Depth of the area could not fully account for the distribution.

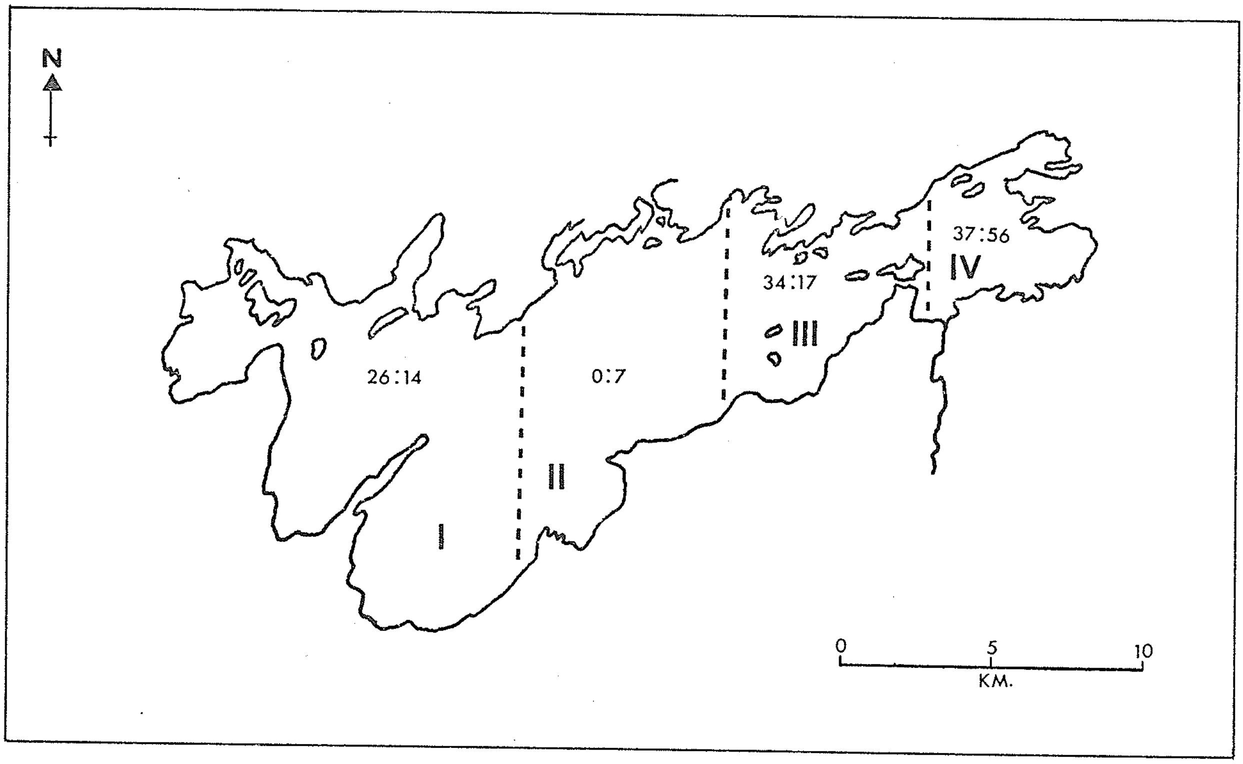
Gill raker number and gill raker space were not related to spatial distribution in any of the lakes.

Gill Rakers and Body Measurements

Only two body measurements seemed to show a relationship to gill rakers (Table VIII, IX). The pupil diameter and pectoral length were greater in those lakes where the fish had fewer and longer rakers. It was possible to use relative values since only a small size range of fish was examined (35-45 cm.) and over this range both measurements showed a fairly good straight line relationship with fork length.

Figure 6. Gill raker length distribution in Big Athapapuskow (number of fish with short gill rakers: number of fish with long gill rakers).

Table VII Analysis of variance of gill raker length distribution in Big Athapapuskow.



Source	Degrees of Freedom	Sum of Squares	Mean Square	F
Treatment	3	93.29	31.10	9.26**
Error	188	624.62	3.36	
Total	191	717.91		

** Significant at 0.01

Table VIII Pupil diameter (as % of fork length).

Lake	Pupil Diameter 1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.4	2.5	2.6
Neso				2		2	2	1	1	1	1				
Payuk							1	1	2				1		1
Mink Narrows	1	1		1	5	1	1								
Big Athapapuskow		1	1	1	3	1									
Little Athapapuskow			1	3	3	3									
Big Twin				2	2	1	1								
Little Twin		1		1		1	1								

Table IX Pectoral Length (as % of fork length).

Lake	Pectoral Length 14	15	16	17	18	19	20	21
Neso					2	4	5	
Payuk				1	4	3	3	1
Mink Narrows				2	3	3		
Big Athapapaskow		1	3	2	1	3		
Little Athapapuskow	1	1	2	4	3	2		
Big Twin			2	3	1			
Little Twin			1	3		1		

In these two measurements there were no consistant differences between sexes.

Gill Rakers and Place of Spawning

In no lake did spawning fish show any significant segregation according to gill rakers. For example, fish with fewer gill rakers spawned at the same time and place as fish with more numerous gill rakers.

DISCUSSION

Svardson (1957, 1965) has summarized the arguments for the stability of gill raker number. He finds that by the time the whitefish reaches a length of 10-12 cm. it has attained the full complement of gill rakers, and this number remains fixed. Jarvi (1940) and Lindroth (1957) came to the same conclusion. However, Peczalska (1958) reported that in the Baltic whitefish the difference between the mean number of gill rakers in young (up to 30 cm. in length) and in sexually mature fish amounts to 3.77 (23.44-27.21). Thus the size at which the whitefish attains the final number of gill rakers may vary in some localities. Reshetnikov (1961) and McCart and Andersen (1967), working with char of the genus Salvelinus and sockeye salmon (Oncorhynchus nerka) respectively, obtained an assymptotic increase in gill raker number in the young fish. Nelson (1968) who worked on kokanee and McPhail (1966), working with the Arctic cisco (Coregonus autumnalis), both found that in the adult fish there was no significant relationship between length of specimen and gill raker number. Since most of the fish examined in the present study were larger than 12 cm., it is not surprising to find no increase in gill raker number with the increase in length of fish. Although some of Svardson's (1952) transplanted populations had significantly different gill raker counts from their parents, the difference was never more than two units and could be explained (Svardson, 1965) by the Founder Principle and the age effect. He concludes that through transplantation experiments and artificial selection the genetic basis for gill rakers has been proven and that there is no evidence that they can be modified by the environment. Kozikowska (1961) found that in Coregonus lavaretus lavaretus gill rakers changed within one lake over a period of several years. This is probably due to the fact that the lakes worked on contained, in addition to autochthonous fish, introduced fish of unselected origin.

Koelz (1929) reported that 30 Coregonus clupeaformis raised in aquaria had gill raker counts (mode 25, range 23-28) considerably below their Lake Erie parents; (mode 28, range 25-30) (Koelz, 1931). This would eliminate the Founder Principle as a possible cause for the variation. Frost (1965) obtained similar results with hatchery reared char (Salvelinus willughbi). McCart and Andersen (1967) found that kokanee and sockeye salmon raised in different lakes than their parents had lower counts, but not by more than two, while those raised in aquaria were affected more extremely. It therefore seems possible for the gill raker number to be influenced by the environment, but only when the fish is subjected to extreme environmental changes, such as would be found in aquaria, is the change more than two units.

In this study the maximum difference in gill raker count is 2.4 units. If the original population had gill raker counts intermediate between the present extremes in the area, the maximum change has been only slightly over one unit, which could possibly be caused by direct environmental modification. However, no physical or chemical factors

(Appendix 1) could be consistantly correlated with gill raker number, thus it would appear more likely that differences in count between lakes are the result of natural selection rather than environmentally produced phenotypic modifications.

Lindsey (1962) found a linear relationship between gill raker length and standard length in humpback whitefish, while in Coregonus nasus there was decelerated growth in the gill raker length in specimens larger than 50 cm. McCart and Andersen (1967) obtained a straight line relationship between the two variables in sockeye salmon, but they were dealing with a smaller size range of fish. Martin and Sandercock (1967) found that in lake trout (Salvelinus namaycush) there was an initial increase in relative gill raker length followed by a decrease in larger fish (> 40 cm.). Probably if larger specimens had been used in the present study, a similar decelerated growth in gill raker length would have been obtained. However, because smaller fish were caught, it was possible to use relative gill raker length and thus make comparisons from lake to lake.

The only mention in the literature of gill raker space and fork length was by Andreu (1960) who found that in juvenile sardines (Sardina pilchardus) there was a straight line relationship between the two. The spacing of rakers probably behaves like gill raker length in that in the larger fish the space does not increase as fast as the fork length. There was slight evidence for this in the present study but not enough to make space comparisons unusable.

Since gill raker length and space are so closely related to fork length, whatever affects the length of the fish must also affect the two gill raker variables. Svardson (1949) has demonstrated that growth is a very alterable characteristic and can readily be influenced by the environment, and thus gill raker length and space must also be greatly influenced by the environment. McCart and Andersen (1967) found that fish reared in aquaria had shorter rakers than those raised in lakes. Lindsey (1962) however, reported that the fish raised by Koelz (1931) in aquaria retained the gill raker length characteristics of the parent population.

The relationship between gill raker length and gill raker number has been looked at by many authors in many different species of fish (Lilljeborg, 1891 in Nilsson, 1958; Hile, 1937; Eschmeyer and Bailey, 1955; Svardson, 1957; Nikol'skii, 1961; Lindsey, 1962, 1963; Shpet et al., 1962; Reshetnikov, 1963; Martin and Sandercock, 1967). They found that generally fish with more gill rakers usually also had longer ones; however, Lindsey (1962) did find two localities where Coregonus nasus had more but shorter rakers than humpback whitefish. This is the only case which agrees with the results obtained in this study. However, it should be noted that only Reshetnikov (1963) and Martin and Sandercock (1967) looked for this relationship within one species, and this was not Coregonus.

Few people have actually measured the relationship between gill raker number and gill raker space. Most have just presumed that the more rakers there are on the gill arch, the smaller the spaces between them must be. This may be the case when comparing different species of fish or fish which show a large range in gill raker number, as in Hypophthalmichthys molitrix which has twice as many gill rakers as H. nobilis and accordingly the spaces between the rakers are only half as wide (Fang 1928). Also Shpet et al. (1962) observed that Carassius auratus had 1.6-1.9 times more gill rakers than C. carassius and also the spaces between them were 0.25-0.75 as wide. However, within single species of fish where differences in gill raker number are slight, it is conceivable that an additional one or two rakers may be added at the end of the gill arch, and as a result increased number does not necessarily mean a smaller gill raker space. This may explain why no correlation was found between these two variables.

Many authors have concluded that fish with fewer and shorter rakers and larger space between them feed on larger and mainly benthic organisms, while fish with more and longer rakers and smaller spaces between them feed on smaller and mainly pelagic organisms (Lilljeberg, 1891 in Nilsson 1958; Fang, 1928; Svardson, 1952, 1965; Nikol'skii, 1961; Reshetnikov, 1961, 1963; Shpet et al., 1962; Lindsey, 1963; Martin and Sandercock, 1967). However exceptions are known. Svardson (1950) found that the form with the larger number of gill rakers, the so-called plankton feeder, had eaten bottom organisms only, while the form with the fewer rakers, the bottom feeder, had eaten plankton although in no large quantities. Nilsson (1958) reports that several people have shown that the rule is not without exception; large individual whitefish with numerous gill rakers may consume bigger food objects. In this study only gill raker length and gill raker space and not gill raker number fit into these usual generalizations regarding gill rakers and feeding.

It seems unlikely that only environmental factors are causing the differences in gill raker length in different lakes; the strong correlation between length and food may suggest causality. Since the length of the raker is related to the percentage of benthic or pelagic food eaten, it seems possible that the type of food present in the lake has caused a gradual change, through natural selection, in the raker length. The coefficient of variation among lakes is much higher in gill raker length than gill raker number. This may indicate that natural selection is playing a much greater role in length than in number. Since such a good correlation was found between gill raker number and the type of food eaten, raker number cannot be discounted as being important in feeding even though no suitable explanation can be offered for this relationship. However, gill raker length is evidently more closely related to variation in feeding than is gill raker number.

As far as gill raker space is concerned, one cannot draw many conclusions from its relationship with food size since the correlation is only significant when relative and not absolute gill raker space is compared to the absolute food size. If there were a simple straining of food particles taking place one would have expected a significant correlation between absolute gill raker space and absolute food size. No reasonable explanation can be given as to why the relative gill raker space and absolute food size are so highly correlated. One cannot ignore the fact that significant differences do exist in gill raker space among lakes. Since other authors have found spacing to be related to food size, it may be that in the present study area this situation holds but only in the young fish and not the adults. Thus in those lakes where the food is slightly larger, selection over the years may have produced a gradual increase in gill raker space. This may account for the differences in spacing among lakes and also, since the fish examined were mainly larger fish, explain why no relationship was found between absolute gill raker space and absolute food size. Even if selection is involved, the coefficients of variation indicates that it is apparently not operating as strongly on spacing as on gill raker length.

Galbraith (1967) found that gill raker space is not the only factor regulating the size of food particles eaten, since both rainbow trout and yellow perch were feeding only on large planktonic organisms even though gill raker spacing indicated smaller organisms could have been strained from the water. He concluded that fish, when feeding do not just strain food from the water but also depend on some form of selection.

It may be that the gill raker characteristics of a fish do not necessarily play a significant role in influencing the type of food eaten, but rather the method of feeding. Loeng and O'Connell (1969) showed that the northern anchovy (Engraulis mordax) displayed two very different modes of feeding depending on the size of the food organism being ingested. Perhaps in the same way whitefish can display two different methods of feeding depending on whether they are eating benthic or pelagic organisms. Those forms feeding in midwater may swim with their mouths open constantly gulping food. In this case large amounts of water would be passing in with the food and thus extra raker length may be an advantage in retaining the food. Even if fish are actively selecting individual food organisms, large quantities of water would still be passing in, making extra length useful. On the other hand, these forms feeding on the bottom probably just suck up organisms, with much less water passing in through the gill area, in which case extra length would not be necessary. Whatever the feeding mechanism involved, the benthic feeders probably show gill raker characteristics which are better adapted for separating food from the sediment.

Svardson (1949, 1950), through transplantation experiments involving lakes of varying limnological characteristics has shown that growth rate can vary considerably from lake to lake. From these transplants he concludes that food, and not temperature and other physical characteristics, is the most important factor in determining the growth of whitefish. Generally the more bottom forms that are eaten the better growth the fish will display (Svardson, 1965). Growth rate is also related to gill raker number, so that populations with few gill rakers display on the average better growth than populations with numerous gill rakers (Svardson, 1952; Nilsson,1958). The results obtained in this study agree to some extent, in that in those lakes where the fish ate more bottom organisms they showed slightly better growth. On the other hand, the relationship found by some authors between gill raker number and growth rate did not hold. However this was to be expected since other authors have shown that a correlation exists between fewer rakers and more benthic food, and thus better growth, while this study shows a relationship between more numerous rakers and benthic food, leading to better growth in forms with higher counts. In other words growth is primarily determined by diet rather than by the morphology of the rakers.

No mention has been made in the above discussion of gill raker length, but since such a strong negative correlation exists between length and number whatever holds for one, holds in reverse for the other. That is, fish with more gill rakers and therefore shorter rakers show better growth.

Since presumably gill raker number, length and space may be changed by selection it might be expected that those forms with the values close to the population mean would have a better growth than those forms with extreme values. However in no lake was there a significant difference in growth between fish with mean and extreme gill raker variables. Svardson (1951) also observed no differences in growth between fish with mean and extreme gill raker number. Selection may be occurring in only one direction, so forms with low extreme and high extreme values were compared separately to the mean, but neither showed a significant difference.

From this one may conclude, as did Svardson (1951), that under the present environmental conditions in the lake, there is no selection taking place towards the present average gill rakers. However, only very slight differences need be present for selection to be occurring and it is possible that the sample size was not large enough to demonstrate these differences.

Since fish with more and shorter gill rakers were eating more benthic food, it was assumed that there would be a difference in the vertical distribution of the two forms, the benthic feeders being found closer to the bottom. Lindsey (1963), working with two sibling species, found that in floating net sets plankton feeders were more common, while in bottom sets benthic feeders were more common. No such separation was found here, perhaps because the nets were left in the water for 24 hours at a time.

No suitable explanation can be given for why fish with long rakers were more predominant in areas where the maximum depth was less than 15.2 m. This is probably related to feeding. The segregation of fish into different areas of the lake according to gill raker length cannot be fully explained by depth alone, since area II is the deepest, while area IV is the shallowest, but yet they both have a predominance of long rakered fish. Vernon (1957) found that kokanee in different areas of the lake had different gill raker counts but could offer no explanation.

As already discussed, growth rate is a very variable character, and this growth rate can, according to Martin (1949), determine body proportions by altering the timing of transition from one growth stanza to another. With Svardson (1950), and many others, he has shown that generally fish with a slower growth rate have increased head and fin measurements. Payuk and Neso Lakes have the slower growing fish, which also have the largest eyes and fins. Alternatively, these differences may be adaptive. Kozikowska (1961) states that the size of the eye may be related to the transparency of the water. Payuk and Neso give the lowest secchi disc readings so this may be why the fish in these lakes have larger eyes. These factors may also be directly related to the feeding habits of the fish, for fish feeding pelagically where there is probably some selection of the prey, may require better eyesight. Also, the midwater forms may have to swim more actively to catch their prey than forms feeding on the bottom, and thus benefit from longer fins.

In summary, significant differences in gill raker characteristics occur between fishes in closely adjacent lakes. The most striking difference, in gill raker length, was correlated with food types in what seems to be a causal relationship, which probably has a genetic basis produced by long-term selection. Other lesser differences, in gill raker number and spacing, and in morphology were present but sometimes in unexpected directions, their explanations are largely conjectural.

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Appendix 1. Physical, chemical and biological data[a] for lakes studied.

Lake	Plank. (ml.)	Oxygen Top	Oxygen Bot	pH Top	pH Bot	Secchi (m.)	Hard ppm	Cond umho/cm.	TDS	Ca	Mg	Na	K	Fe	Cl	SO4	N	P	Si	NO_3-N
												mg/l							ug/l	
Neso																				
19/7/50		9.1	7.4	7.3	6.8	2.0														
19/7/50		8.9	7.6	7.3	6.8	2.1														
31/7/68	4.9	6.0	0.0	6.0		2.9	68.4													
10/8/50		9.0	7.5	7.3	6.8	2.1														
10/8/67		9.0	1.0	7.5		2.4	32.0	70	65											
24/8/68	0.9	7.0		7.0		2.4	51.3	69	65	6.4	2.3	1.4	0.9	0.0	0.6	32	380	36	420	7
3/11/68		6.0						69	44	10.6	6.7	1.7	0.7		0.8	1			64	
Payuk																				
22/7/50		9.4	7.3	7.4	7.0															
24/7/43				7.2		1.8														
24/7/43		7.5	7.5	7.3	7.0	2.1														
24/7/50		9.3	7.5	7.4	7.0															
24/7/50		9.5	7.8	7.4	7.0															
24/7/50		9.3	7.5	7.4	7.0															

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[a] Compiled from original observations and the following sources: McLeod (MS, 1943); McTavish (MS, 1950); Stewart-Hay (MS, 1953); Schlick (MS, 1967 May).

(continued)

Appendix 1 (continued)

Lake	Plank. (ml.)	Oxygen Top	Oxygen Bot	pH Top	pH Bot	Secchi (m.)	Hard ppm	Cond umho/cm.	TDS	Ca	Mg	Na	K	Fe	Cl	SO_4	N	P	Si	NO_3-N
									mg/l								ug/l			
Payuk (cont.)																				
31/7/68		6.0	8.0	7.5		2.4	51.3													
9/8/50		8.9	7.4	7.4	7.0															
11/8/67		8.0	6.0	7.0	7.5		38.0	75	70											
24/8/68	3.0	7.0		7.0		1.2	68.4	73	80	7.3	2.4	1.5	0.9	0.0	0.6	33	455	13	805	29
2/11/68		10.0	10.0	7.5		2.4		78	38	4.4	2.3	1.6	0.7		1.0	1			500	
Mink Narrows																				
12/7/53		8.9	6.9	7.7	7.4	4.3														
25/8/68	2.1	8.0		7.5		4.4	136.8	358	265	37.6	7.1	12.9	2.0	0.0	36.0	83	410	8	400	1
24/10/68		9.0	9.0	7.5		4.3														
Big Athapapuskow																				
19/5/68	0.3	6.0	12.0	7.5		5.2	144													
30/5/68	0.3	10.0	11.0	7.5		4.8	154													
7/6/68	0.4	12.0	12.0	7.5		6.1	154													
19/6/53		10.9	10.8	7.4	7.4	5.5														
8/7/53		9.6	10.9			9.1														

(Continued)

Appendix 1 (continued)

Lake	Plank. (ml.)	Oxygen Top	Oxygen Bot	pH Top	pH Bot	Secchi (m.)	Hard ppm	Cond umho/cm.	TDS	Ca	Mg	Na	K	Fe	Cl	SO_4	N	P	Si	NO_3-N
									mg/l								ug/l			
Big Athapapuskow (continued)																				
12/7/53		9.7	10.7	7.8	7.4	8.5														
17/7/68(1200)						4.3														
17/7/68(1500)						4.3														
17/7/68(1800)						4.3														
17/7/68(2030)						4.3														
17/7/68(2300)						3.4														
18/7/68(600)						5.5														
18/7/68(900)						4.9														
18/7/68(1200)						4.9														
19/7/53		9.0	9.2	7.9	7.9															
22/7/53		9.1	9.5	8.0	7.8	8.2														
5/8/53		9.1	9.6	8.0	7.9	9.0														
6/8/67			11.0	7.5				300	350											
25/8/68	0.1	8.0		7.5		7.3	136.8	301	210	33.3	7.2	8.5	1.8	0.0	23.4	48.0	30.5	65	795	1
29/10/68		9.0	9.0	7.5		5.5		300	213	48.9	14.9	12.2	2.0		26.0	30.0			800	

(continued)

Appendix 1 (continued)

Lake	Plank. (ml.)	Oxygen		pH		Secchi (m.)	Hard ppm	Cond umho/cm.	TDS	Ca	Mg	Na	K	Fe	Cl	SO_4	N	P	Si	NO_3-N
		Top	Bot	Top	Bot				mg/l								ug/l			
Little Athapapuskow																				
24/7/53				8.2	7.9	4.3														
24/7/53				8.4	6.9	1.4														
26/7/67		10.0	9.0	7.5		5.8														
27/7/53		8.8	9.4	8.0	7.6	7.3														
1/8/53		8.6	4.2	8.0	7.5	6.4														
24/8/68	0.4	8.0		7.5		4.9	138.8	500	365	51.1	8.1	20.2	2.6	0.0	71.0	105	375	10	450	1
3/11/68		6.0	8.0	7.0		4.3		485	288	78.0	16.2	25.2	3.1		59.6	80			410	
3/11/68								345	204	56.7	12.8	15.6	2.4		35.2	51			540	
Big Twin																				
29/5/67				7.4	7.0	2.1			78											
29/5/67				7.2	7.2	2.3			78											
29/5/67				7.2	7.0	2.3			86											
29/7/68	1.2	8.0		7.5		2.9	85.5													
9/8/67		8.0	4.0	7.5		4.3	45.0	90	90											

(continued)

Appendix 1 (continued)

Lake	Plank. (ml.)	Oxygen		pH		Secchi (m.)	Hard ppm	Cond. umho/cm.	TDS	Ca	Mg	Na	K	Fe	Cl	SO_4	N	P	Si	NO_3-N
		Top	Bot	Top	Bot				mg/l								uh/l			
Big Twin (continued)																				
24/8/68	0.5	8.0		7.0		3.5	68.4	92	80	9.0	2.7	1.3	0.9	0.0	0.2	14	385	84	1980	2
29/10/68		8.0	8.0	7.0		2.7		96	107	12.3	6.3	1.3	0.7		0.8	1			2020	
Little Twin																				
29/5/67				7.4	6.8	2.0			84											
29/7/68	2.2	8.0		7.5		2.9	68.4													
24/8/68	3.2	8.0		7.0		2.4	68.4	105	90	9.7	2.9	1.7	1.0	0.0	1.4	13	515	198	1550	1
29/10/68		9.0	9.0	7.0		3.4		101	107	12.3	6.8	1.7	0.8		1.6	54			1280	

Appendix 2. Temperature (°C)[a] data for lakes studied.

Depth (m.)	Neso							Payuk				
	19/7/50	19/7/50	31/7/68	10/8/50	10/8/67	24/8/68	3/11/68	22/7/50	24/7/43	24/7/43	24/7/50	24/7/50
0	17.5	17.5	18.0	18.9	19.5	14.9	2.0	19.4	21.5	21.5	20.6	20.6
3.1	17.2	17.2	17.9		19.0	14.9			20.8			20.0
6.1			17.1	18.6	16.5	14.9		18.6		19.7	18.9	
9.2			12.2		8.0	12.6						
12.2			9.0		7.0							
15.3												
18.3												
21.4												
24.4												
27.5												
30.5												
33.6												
36.6												
39.7												
42.7												
45.8												

(continued)

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[a] Last temperature in each column is bottom temperature.

Appendix 2 (continued)

Depth (m.)	Payuk						Mink Narrows			Big Athapapuskow		
	24/7/50	31/7/68	9/8/50	11/8/67	24/8/68	2/11/68	12/7/53	25/8/68	24/10/68	19/5/68	30/5/68	7/6/68
0	20.6	17.9	18.3	21.0	14.9	3.2	19.5	14.4	5.0	6.8	6.1	10.0
3.1		17.8		20.0	14.9	3.2		14.3	5.0	6.8	6.0	7.8
6.2	19.4	17.8		18.0	14.9	3.2		14.1	5.0	6.3	5.8	5.9
9.2		17.8	17.5	17.0		3.2		14.0	5.0		5.9	5.3
12.2								9.1	5.0			5.1
15.3								5.0	5.0			4.9
18.3								4.2	5.0			4.9
21.4								3.9	5.0			4.4
24.4							14.5	3.8	5.0			4.1
27.5								2.3				3.8
30.5												3.8
33.6												
36.6												
39.7												
42.7												
45.8												

(continued)

Appendix 2 (continued)

Depth (m.)	Big Athapapuskow											
	19/6/53	8/7/53	12/7/53	17/7/68 (1200)	17/7/68 (1500)	17/7/68 (1800)	17/7/68 (2030)	17/7/68 (2300)	18/7/68 (600)	18/7/68 (900)	18/7/68 (1200)	19/7/53
0	8.0	17.0	16.5	16.2	16.7	17.1	17.3	17.0	16.9	16.9	17.0	18.0
3.1				15.3	15.3	16.0	16.2	16.0	16.9	16.8	16.5	
6.1				15.1	15.0	15.4	15.9	15.8	16.0	15.8	16.0	
9.2	7.0			15.5	15.7	16.0	16.6	16.3	14.9	14.8	15.2	
12.2												
15.3												
18.3												
21.4												
24.4												
27.5												
30.5												14.5
33.6												
36.6		11.5										
39.7												
42.7												
45.8												
			62.2 9.5 (m.)									

(continued)

Appendix 2 (continued)

Depth (m.)	Big Athapapuskow					Little Athapapuskow						
	22/7/53	5/8/53	6/8/67	25/8/68	29/10/68	24/7/53	24/7/53	26/7/67	27/7/53	1/8/53	24/8/68	3/11/68
0	18.0	16.3	18.0	14.0	6.0	19.0	20.5	19.0	18.0	18.0	14.1	5.0
3.1			17.5	14.0	6.0			19.0			14.1	5.0
6.1			17.5	13.9	6.0			18.0			14.0	5.0
9.2			16.5	13.9	6.0	13.0	13.0	15.0			14.0	5.0
12.2			13.5	13.9	6.0			13.0			13.9	5.0
15.3			11.5	13.1	6.0			10.0			13.9	5.0
18.3			9.5		5.8			8.5		14.8	13.9	5.0
21.4			7.5		5.8			8.0			13.8	5.0
24.4			7.5					8.0			13.8	5.0
27.5	14.0		6.5					8.0			12.2	
30.5			6.0						13.5		8.9	
33.6		12.0	6.0								8.2	
36.6			6.0								8.1	
39.7			6.0									
42.7			6.0									
45.8			6.0									

(continued)

Appendix 2 (continued)

Depth (m.)	Big Twin							Little Twin			
	29/5/67	29/5/67	29/5/67	29/7/68	9/8/67	24/8/68	29/10/68	29/5/67	29/7/68	24/8/68	29/10/68
0	14.4	9.0	11.1	18.1	19.0	14.7	6.0	14.4	18.9	14.9	4.5
3.1			5.6	17.8	18.5	14.7			18.0	14.9	4.5
6.1				16.9	18.0	14.7		8.3	14.8	14.9	4.5
9.2				10.4	11.0	14.4					
12.2				5.0	8.0	6.9					
15.3				4.2	6.0	4.9					
18.3	7.2	7.2		4.0	5.5	4.2					
21.4				4.0	5.0	4.0					
24.4						4.0	6.0				
27.5											
30.5											
33.6											
36.6											
39.7											
42.7											
45.8											

Appendix 3. Composition of gangs of nets.

Gang	Size (m.)	Stretched Mesh Size (cm.)
A	2.4 X 15.2	7.6 - 6.4 - 5.1 - 3.8 - 2.5 - 1.9
B	2.4 X 15.2	8.9 - 7.6 - 5.1 - 3.8 - 2.5 - 1.9
C	7.6 X 15.2	6.4 - 5.1 - 3.8
D	2.4 X 15.2	6.4 - 5.1 - 3.8 - 2.5 - 1.9
E	2.4 X 15.2	10.2 - 8.9 - 3.8 - 1.9
F	2.4 X 15.2	10.2 - 5.1 - 3.8 - 2.5
G	7.6 X 15.2	10.2 - 6.4 - 3.8 - 2.5 - 1.9

Appendix 4. Date, gang, depth and catch of net sets. (All sets, unless indicated are for one night and in 1968).

Lake	Date	Gang	Water Depth (m.)	Depth of net (m.)	Number of Whitefish	Number of Ciscoes
Big Athapapaskow	May 18	C	7.6	0-7.6	7	0
	19	B	10.7	8.2-10.7	8	60#
	19	A	10.7	0-2.4	1	9
	21	A	2.4	0- 2.4	11	300-400
	29	B	9.2	6.7- 9.2	5	17
	29	A	9.2	0- 2.4	1	22
	June 5	B	15.3	12.9-15.3	10	4
	5	A	15.3	0- 2.4	0	9
	5	C	15.3	0- 7.6	0	0
	6	B	30.5	28.1-30-5	17	3
	6	A	30.5	0- 2.4	0	9
	8	B	12.2	9.8-12.2	0	1
	8	A	12.2	0-12.2	1	0
	9	A	2.4	0- 2.4	4	2
	10	B	30.5	28.1-30.5	11	1
	10	A	30.5	0- 2.4	0	5
	11	B	12.2	9.8-12.2	6	13
	11	A	12.2	0- 2.4	2	16
	12	B	9.2	6.7- 9.2	4	3
	12	A	9.2	0- 2.4	7	3
	16	B	18.3	15.9-18.3	9	5
	16	A	18.3	0- 2.4	0	3
	17	B	9.2	6.7- 9.2	1	0
	17	A	9.2	0- 2.4	1	50
	25	B	37.1	35.7-37.1	5	3
	25	A	37.1	0- 2.4	0	26
	July 1	B	45.8	43.4-45.8	4	3
	1	D	45.8	0- 2.4	0	6
	2	B	22.9	20.5-22.9	6	3
	2	D	14.6	0 -2.4	0	11
	3	B	9.2	6.7- 9.2	6	12
	3	D	9.2	0- 2.4	0	20
	7*	D	37.1	0- 2.4	0	2
	7*	B	37.1	35.7-37.1	8	11
	7	E	10.7	8.2-10.7	7	13
	7	F	10.7	0- 2.4	0	1
1200-1500[a]	17	G	7.6	0- 7.6	25	70

[a] Time nets left in water.

*Nets left in water for two nights.

(continued)

Appendix 4. (continued)

Lake	Date	Gang	Water Depth (m.)	Depth of net (m.)	Number of Whitefish	Number of Ciscoes
Big Athapapuskow						
1200-1500	July 17	D	8.2	0- 2.4	0	0
1500-1800	17	G	7.6	0- 7.6	15	-
1500-1800	17	D	8.2	0- 2.4	0	0
1800-2030	17	G	7.6	0- 7.6	15	-
1800-2030	17	D	8.2	0- 2.4	0	0
2030-2300	17	G	7.6	0- 7.6	1	0
2030-2300	17	D	8.2	0- 2.4	24	5
2300-600	17	G	7.6	0- 7.6	43	15
2300-600	17	D	8.2	0- 2.4	9	0
600-900	18	G	7.6	0- 7.6	25	4
600-900	18	D	8.2	0- 2.4	0	0
900-1200	18	G	7.6	0- 7.6	2	3
900-1200	18	D	8.2	0- 2.4	0	0
	29**	E	37.1	35.7-37.1	12	2
	29**	G	37.1	12.2-19.8	38	50
	29**	F	36.6	0- 2.4	0	-
	29**	B	12.2	9.8-12.2	9	4
920-950	Aug 23	G	7.6	0- 7.6	3	0
950-1050	23	G	7.6	0- 7.6	3	2
1050-1350	23	G	7.6	0- 7.6	3	6
	24	G	9.2	1.5-9.2	8	3
	24	B	9.2	6.7-9.2	5	-
	25	G	16.2	6.1-13.7	12	120
	25	B	16.2	13.7-16.2	2	0
	26	F	18.3	15.9-18.3	0	0
	26	G	16.2	6.1-13.7	18	-
	26	B	16.2	13.7-18.3	12	0
	Oct 5		2.4	0- 2.4	8	0
	5		4.0	1.5-4.0	2	0
	5		2.4	0- 2.4	10	-
	11	G	9.2	1.5-9.2	9	-
	18		2.4	0- 2.4	10	-
	18		6.1	Bottom	1	-
	20		5.5	Bottom	5	-
	20		2.4	0- 2.4	5	-
	25		4.6	Bottom	8	-
	26		4.6	Bottom	1	-

** Nets left in water for three nights

(continued)

Appendix 4. (continued)

Lake	Date	Gang	Water Depth (m.)	Depth of Net (m.)	Number of Whitefish	Number of Ciscoes
Big Athapapuskow	Oct 26	G	24.4	16.8-24.4	35	2
	29		2.4	0-2.4	12	3
	Nov 1		2.4-6.1	Bottom	6	0
	1		2.4	0-2.4	0	-
	2		7.6	0-7.6	0	-
	2		2.4	0-2.4	1	0
	2		2.4	0-2.4	0	-
	3		2.4	0-2.4	3	12
	3		2.4-5.5	Bottom	0	6
	Feb 28, 1969		28.1	20.4-28.1	23	1
	28		28.1	14.3-16.8	9	5
Mink Narrows	July 9	B	16.8	14.3-16.8	11	7
	9	G	13.7	0-7.6	17	-
	9	E	3.7	1.2-3.7	2	0
	9	D	3.7	0-2.4	3	1
	Aug 8	B	27.5	25.0-27.5	0	0
	9	E	27.5	25.0-27.5	3	3
	9	G	27.5	15.3-22.9	14	26
	9	E	12.2	9.8-12.2	13	4
	9	G	12.2	1.5-9.2	23	50+
	18	G	10.7	0.6-8.2	25	-
	Oct 28	G	10.7	3.1-10.7	2	0
	28		5.2	2.7-15.2	3	0
Little Athapapuskow						
	May 14	A	2.4	0-2.4	4	0
	14	B	2.4	0-2.4	1	4
	Aug 20	G	27.5	12.2-19.8	35	4
	20	B	27.5	25.0-27.5	16	0
	20	D	24.4	0-2.4	0	0
	21	B	18.3	15.9-18.3	12	2
	21	D	15.3	0-2.4	0	35
	21	G	18.3	6.1-13.7	20	50
	Oct 15		1.8-9.2	Bottom	7	-
	15		2.4	0-2.4	13	1
	25		1.2-6.1	Bottom	8	-
	25		2.4	0-2.4	4	-

(continued)

Appendix 4. (continued)

Lake	Date	Gang	Water Depth (m.)	Depth of Net (m.)	Number of Whitefish	Number of Ciscoes
Payuk	May 31	B	7.6	5.2-7.6	7	6
	31	A	7.6	0-2.4	0	4
	June 14	B	5.8	3.4-5.8	2	2
	14	A	4.0	0-2.4	0	1
	July 11	E	4.6	2.1-4.6	0	-
	11	F	4.6	0-2.4	0	7
	11	B	9.2	6.7-9.2	15	4
	11	D	9.2	0-2.4	0	7
	11	G	9.2	1.5-9.2	25	200+
	Aug 23		7.6	0-7.6	2	50+
	Oct 13		2.4	0-2.4	2	-
	13		2.4	0-2.4	4	-
	13		2.7	0.3-2.7	2	-
	27		7.6	0.6-2.4	1	0
	Nov 1		3.1	0.9-8.5	1	-
	Mar 2, 1969		8.6	6.1-8.5	6	45
	2		8.6		2	2
Neso	June 1	B	7.6	5.2-7.6	5	3
	1	A	6.1	0-2.4	1	31
	July 2	E	4.3	2.4-4.9	0	0
	2	F	15.3	0-2.4	0	0
	3	B	9.2	6.7-9.2	3	-
	3	D	9.2	0-2.4	0	-
	4	E	10.7	8.2-10.7	2	0
	4	F	10.7	0-2.4	0	5
	15	G	11.6	1.5-9.2	10	31
	15	B	11.6	9.2-11.6	4	1
	15	D	9.2	0-2.4	0	3
	Aug 13	E	9.2	6.7-9.2	3	3
	13	G	9.2	0-7.6	21	25+
	Oct 5		10.7	0-2.4	0	2
	14		3.1	0.6-2.4	0	4
	14		2.4	0-2.4	9	-
	19		2.4	0-2.4	3	5

(continued)

Appendix 4. (continued)

Lake	Date	Gang	Water Depth (m.)	Depth of Net (m.)	Number of Whitefish	Number of Ciscoes
Big Twin	May 16	B	25.9	20.5-22.9	8	2
	16	A	25.9	0-2.4	0	1
	June 2	B	10.1	7.6-10.1	4	1
	2	A	10.1	0-2.4	2	6
	July 5	B	4.3	1.8-4.3	10	3
	5	D	4.3	0-2.4	0	0
	6	B	18.3	15.9-18.3	7	6
	6	D	18.3	0-2.4	0	0
	27	E	4.9	2.4-4.9	0	0
	27	F	3.1-4.9	0-2.4	0	1
	Aug 2	B	24.4	22.0-24.4	2	10
	2	E	24.4	0-2.4	0	4
	3	G	15.3	0-7.6	9	25
	3	B	24.4	22.0-24.4	3	3
	11	E	21.4	18.9-21.4	1	0
	11	G	9.2	0-7.6	0	8
	12	E	21.4	18.9-21.4	0	5
	12	G	22.9	7.6-15.3	6	27+
	Oct 12	G	15.3	4.6-12.2	1	100
	12		2.4	0-2.4	3	1
	Mar. 3, 1969		4.6	0-4.6	5	12
	3		4.6	2.1-2.4	0	0
Little Twin						
	June 3	B	4.6	2.1-4.6	10	2
	3	A	6.1	0-2.4	2	3
	July 5	E	7.6	5.2-7.6	6	5
	5	F	7.6	0-2.4	0	0
	6	E	7.6	5.2-7.6	1	8
	6	F	7.6	0-2.4	0	2
	27	E	4.9	2.4-4.9	0	0
	27	F	4.9	0-2.4	0	1
	Aug 2	E	6.1	3.7-6.1	0	6
	2	G	7.3	0-7.3	0	26
	3	E	6.1	3.7-6.1	0	1
	11	B	9.2	6.7-9.2	0	4
	11	D	9.2	0-2.4	0	2
	12	B	9.2	6.7-9.2	0	4

(continued)

Appendix 4. (continued)

Lake	Date	Gang	Water Depth (m.)	Depth of Net (m.)	Number of Whitefish	Number of Ciscoes
Little Twin	Aug 12	D	9.2	0-2.4	0	1
	Oct 11		2.4	0-2.4	1	1
	11		9.2	5.2-7.6	2	2+
Goose Creek	May 23		2.4	0-2.4	0	0
	Oct 11		2.4	0-2.4	0	0
	11		1.2	0-1.2	6	0
	18		2.4	0-2.4	1	0
	25		1.8	0-1.8	29	0
	26		1.8	0-1.8	11	-
	Nov 2		1.2	0-1.2	9	0
Payuk Creek	Oct 6	Seine	0.9		19	0
	13	Dip net	0.9		3	0
	20	Seine			15	0
	20		2.4	0-2.4	2	0
	27		2.4	0-2.4	11	0
	Nov 1		2.4	0-2.4	2	-
Mistik Creek	May 10		2.4	0-2.4	6	0
	10		2.4	0-2.4	0	0
	Oct 14		3.1	0.6-2.4	7	0
	19		3.1	0.6-2.4	11	0
	27		2.4	0-2.4	0	0
	28		2.4	0-2.4	7	0