FOOD COMPETITION BETWEEN

TROUT AND DACE IN

THE NORTH PINE RIVER,

MANITOBA.

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APPROVAL SHEET

ABSTRACT

Interspecific competition for food between eastern brook trout (*Salvelinus fontinalis*, Mitchill) and two species of dace (*Rhinichthys cataractae*, Valenciennes) and (*Rhinichthys atratulus*, Hermann) was investigated in North Pine River, Manitoba. Yearling and larger brook trout did not compete for food with the dace as their diets differed; however, fingerling brook trout and dace competed because their diets were similar. Fingerling trout, in a section of the stream containing a greater number of dace, grew slower than those fingerling trout that were in the non-competitive section of the stream.

TABLE OF CONTENTS

LIST OF TABLES

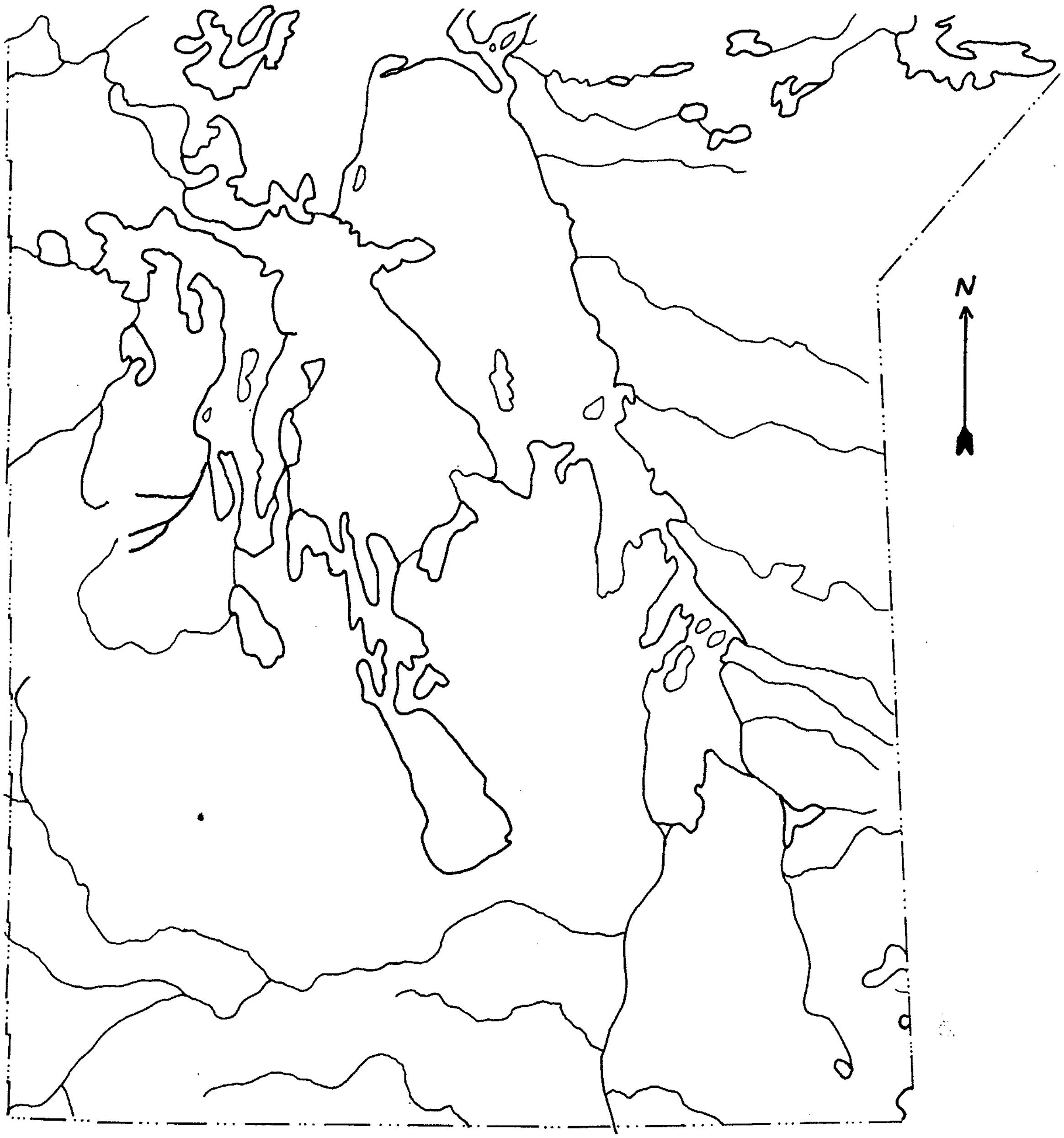
LIST OF FIGURES

INTRODUCTION

In the summer of 1960 Franklin (MS, 1960) surveyed four streams that flow from the Duck and Porcupine Mountains, Manitoba, and eventually empty into Lake Winnipegosis. He suggested that it would be interesting to ascertain whether food competition existed between the trout and dace in these streams which had previously been stocked with eastern brook trout and rainbow trout.

This study was designed to determine if food competition exists between eastern brook trout (*Salvelinus fontinalis*, Mitchill) and two species of dace (*Rhinichthys atratulus*, Hermann and *Rhinichthys cataractae*, Valenciennes). The hypothesis examined in this study was that if significant interspecific competition for food existed between trout and dace, then it should be reflected in a reduced rate of growth of the trout. To test this hypothesis, a relatively uniform stretch of the North Pine River was selected and divided into four sections. The growth rates of fish in two control sections, one containing only brook trout fry and the other containing only yearling trout, were compared to the growth rates of fish in two other sections, one containing brook trout fry and dace, and the other containing yearling brook trout and dace.

The author started this study in the summer of 1961. North Pine River was selected because its flow of water was relatively uniform throughout the season in contrast to that of other streams in the area. Dace and trout were also numerous in this stream.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LITERATURE REVIEW

Competition

Andrewartha and Birch (1954) defined competition as occurring when a "valuable or necessary resource is sought together by a number of animals (of the same kind or of different kinds) when that resource is in short supply, or if the resource is not in short supply, competition occurs when the animals seeking that resource nevertheless harm one another in the process". Andrewartha and Birch (ibid) rejected competition as embracing predation.

Nicholson (1933) concluded that "any factor having the necessary property for the control of populations must be some form of competition". It is strange that he reached this conclusion, as in a preceding sentence he stated that, "Clearly no variation in the density of a population of animals can modify the intensity of the sun, or the severity of frost, or any other climatic factor ---". It is true that animal populations do not influence climate in nature but it is also true that climatic factors influence animal populations. One cannot regard climatic influences, which fit into Nicholson's definition of competition, as competition; therefore, Nicholson's definition of competition is not accepted in this study.

Gause (1934) demonstrated, both mathematically and experimentally, that when two species compete for the same food in a limited environment, the growth rates of both will be reduced, and in most cases one species will eventually eliminate the other. From his work, Gause concluded that two species cannot co-exist in the same locality if they have identical ecological requirements. This is now known as the Gause's or the competitive exclusion principle.

Gause and Witt (1935) stated that if severe competition exists between two species for food and other resources of the environment, i.e., they occupy the same ecological niche, one species would be expected to replace the other species. Mayr (1963) defined an ecological niche as the "constellation of environmental factors into which a species (or their taxon) fits: the outward projection of the needs of an organism, its specific way of utilizing its environment". Riley (1953) maintained that the niche concept has been used so varyingly, that it often means anything, and usually an undetermined something. Yet he stated that "it has become a truism that no two species can occupy the same niche".

However, in most natural situations the competitive exclusion principle does not operate as pointed out by Elton (1946). He stated, "We do not at present know what maintains the state of equilibrium between the different genera actually found in natural communities analyzed, but must postulate that there is some ecological condition that buffers or cuts down the effectiveness of competition ---". Perhaps, this can be explained to a certain extent, as Mayr (1963) did, in that, "Competition favours the entry into new niches and more generally, adaptive radiation. Thus competition is an element in speciation and is an important cause of evolutionary divergence".

Mayr (1963) defined competition as existing when "two species seek simultaneously an essential resource of the environment that is in limited supply. Two species are in competition when they have a controlling factor in common". The first part of this definition of competition is not complete, for it does not allow for intraspecific competition, i.e., competition among members of the same species. Mayr (ibid) was more interested in the interactions between species than interaction between members of the same species. The second sentence of his definition has the same weakness as was considered in Nicholson's (1933) definition of competition which could by definition include climatic factors as competition factors.

Allee, <u>et al</u>. (1949) stated that "in general, competition occurs when there is a common demand on a limited supply. Competition furnishes a special phase both of co-operation and of disoperation". Most authorities on competition stress the inclusion of organisms and "disoperation" in their definition of competition as witnessed by the preceding definitions of competition. Allee, <u>et al</u>. (<u>ibid</u>) omitted organisms and included co-operation in their interpretation of competition. Thus they were able to demonstrate an example of "competition" where spermatozoa of sea urchins were crowded into a limited space, i.e., competition for space, and remained viable longer and hence there was co-operative "competition" as far as the longevity of the spermatozoa was concerned. This example, as far as the author is concerned, demonstrates the weakness in the competition concept of Allee, <u>et al</u>. Spermatozoa are not organisms and the "competition" for space was not determined by the behaviour of the spermatozoa.

Allee, <u>et al</u>. (1949) contributed to the understanding of competition by stating that predator-prey relationships or parasitism are not included in their concept of competition as was included by Larkin (1956). However, Larkin's general definition of competition is useful and is as follows: "Competition is the demand, typically at the same time, of more than one organism for the same resources of the environment in excess of immediate supply".

Although the above definitions of competition vary somewhat from each other, they fit the type of interaction discussed in this paper with respect to the eastern brook trout and dace as observed at Pine River, Manitoba. The author's selection of what constitutes competition is best described by Crombie's (1947) definition. He stated "competition is a demand at the same time by more than one organism for the same resources of the environment in excess of immediate supply". Crombie's (ibid) definition contains the three essential elements of competition. Firstly, that more than one organism is involved, and secondly that the simultaneous behavior of these organisms is creating the competition, and thirdly that the item competed for is available to a lesser extent than is required or desired by the organisms in question.

Competition Among Fishes

The following studies on competition among fishes will serve as a source from which certain conclusions are drawn. The conclusions will be summarized at the end of this topic. Lagler, et al. (1962) stated that the most common competitions among fishes are for spawning sites, food, space and shelter.

Larkin (1956) stated that "fishes have a wide tolerance of habitat type, a flexibility of feeding habits, and in general share many resources of their environment with several other species of fish". He maintained that as a result of this, food chains have more breadth and less height of pyramidal numbers than one would expect. "Fresh water fish overcome unfavourable periods of competition to a large extent due to their flexible growth rates and high productive potential," (Larkin, 1956). "In these circumstances it is difficult to separate the role of interspecific competition from other phenomena as a factor of population control," (Larkin, ibid).

Nikolsky (1963) claimed that young fishes which have not yet started to eat the same foods as their adults are usually more stenophagic and their diets are more similar to that of other species within a single complex.

Northcote (1954) demonstrated that two species of sculpins living in similar habitats had similar diets, but he did not demonstrate conclusively that competition existed because the qualifying factor (whether the demand of the two species upon the food resources was in excess of the supply) was undetermined.

Fedoruk (1965) found that bass, Micropterus dolomieui Lacépède and walleye, Stizostedion vitreum vitreum (Mitchill) did not compete for food in Falcon Lake, Manitoba. He established that though they ate a number of common food items, the intensity pattern of feeding demonstrated that each fish had peculiar preferences, and that bass and walleye frequently inhabited different local habitats.

Larkin and Smith (1953) studied the interaction between redside shiners, Richardsonius balteatus (Richardson) and Kamloops trout, Salmo gairdneri (Richardson). They found three types of interactions; namely, predation by shiners on trout fry, competition for food between the two species and predation by trout on shiners.

Hunt and Carbine (1950) studied the food of young pike, Esox lucius Linnaeus in ditches associated with Houghton Lake, Michigan. They noted that as the pike increased in size, the diet shifted from crustaceans to insects to vertebrates. Brook stickleback, golden shiner, blacknose minnow, spottail shiner and mimic shiner competed with pike up to 40 millimeters in length for crustaceans. Yellow perch, brook stickleback, mudminnow, Iowa darter, creek chub and eight other species competed with pike 21 to 50 mm. in length for insects. Little competition from other fish species was observed when pike were of the size (26 to 152 mm.) to consume vertebrates. Yellow perch, mudminnows and creek chubs consumed small amounts of vertebrates.

Echo (1954) examined the relationship between yellow perch, Perca flavescens (Mitchill) and cutthroat trout, Salmo clarki (Richardson) in Thompson Lakes, Montana. The food of yellow perch was largely immature aquatic insects and plankton while the diet of cutthroat trout was mainly mature aquatic insects and small perch.

Svardson (1949a) studied the competition between trout and char, Salmo trutta Linnaeus and Salvelinus alpinus (Linnaeus) and found that char survived better than trout. Char averaged a larger size (65.9mm.) than did trout (64.8 mm.). He conducted this particular phase of the experiment in hatchery troughs with fry of both species.

Nilsson (1963) also studied the interaction of Salmo trutta Linnaeus with Salvelinus alpinus (Linnaeus). He found that trout were territorial whereas char wandered. When food was abundant, the two species had similar preferences; when it was sparse, they differed in their feeding habits. Trout continued to feed on larger aquatic organisms while char fed on plankton. Trout were more aggressive than char under experimental conditions. In impoundments the differences in feeding habits were even more pronounced than in lakes. In lakes the trout were located in the inner shallow parts of the littoral zone while the char were in outer deeper areas of the littoral zone.

Ward (1962) investigated the possibility that young sockeye in their lacustrine habitat might compete with sockeye smolts of successive year classes for available food. Sockeye were found to have a quadrennial spawning cycle, i.e., coming back to fresh water to spawn four years after hatching. Ward (ibid) found one year class or cycle was larger than the following cycles or year classes. The hypothesis that the numerous Cycle I (dominant year class) fish would over crop the available food supply and thus reduce the growth of the following cycles was advanced. However, this was not found to be the case. Actually, smolts belonging to Cycles II, III and IV populations were, on the average, larger than those belonging to Cycle I populations. This indicates that competition between Cycle I juveniles was greater than between juveniles of Cycles II, III and IV. Measurements of the abundance of zooplankton did not indicate that less food was available to Cycles II, III and IV than to Cycle I populations.

Laakso (1950) stated that, from his work on the Yellowstone and Gallatin rivers in Montana, whitefish and trout competed strongly for aquatic food organisms. The number of trout sampled was few and they were both brown and rainbow trout. Laakso sampled the benthos to compare the availability of food organisms and those observed in fish stomachs.

Allen (1951) suggested that an eel, Anguilla dieffenbachii, which occurs throughout the length of the Horokiwi Stream in New Zealand, is probably a significant competitor for food with the brown trout. This eel may also be a trout predator. Other fishes which are likely to compete with the brown trout in the Horokiwi Stream (Allen, ibid) are the inanga, Galaxias atternatus, the smelt, Reptropinna osmeroides, and two species of Gobiomorphus. These, however, were not thought to be as significant as the eel and are more or less confined to the lower portion of the Horokiwi Stream.

Miller (1958) studied competition between hatchery reared trout and wild trout. His experiment at Gorge Creek, Alberta, had two control sections containing only hatchery trout, and one section containing a mixture of wild trout and hatchery trout. Miller concluded that survival of hatchery trout is poor in lakes and streams where resident trout populations already exist. In streams containing resident trout, hatchery reared trout die after release. In the early stages of this competition they are continuously exercising and exhaust some metabolite and die either of acidosis or starvation.

Conclusions that can be drawn from the above literature with reference to competition among fish are:

1. Fish may compete for food, space, spawning sites and shelter.
2. Some fish have a wide tolerance of habitat type and flexible feeding habits that can overcome unfavourable periods of competition as stated by Larkin (1956) and as shown by Nilsson (1963).
3. The food habits of fish change as the fish become larger and older. This was stated by Nikolsky (1963) and demonstrated by Hunt and Carbine (1950) and Allen (1951).
4. Young fish are more stenophagic than their adults and have similar diets to other species within a single complex.
5. The observation that two or more fishes feed on a number of common food items does not necessarily mean that they are competing for food. This statement is supported by the investigations of Northcote (1954) and Fedoruk (1965).

6. Two species of fish may compete for food but since they share a common habitat other reactions may take place. These other reactions can be beneficial to one or the other species at a particular phase of life history. This was demonstrated by Larkin and Smith (1953) and suggested by Allen (1951).

7. One of the first steps to be taken in a food competition study, is to determine if the fish are feeding on similar food organisms. The fish involved in Echo's study (1954) did not compete for food.

8. To determine whether food competition is significant, a study must be designed to measure the effects of food competition either in terms of growth, as Ward (1962) did, or survival, as Svardson (1949a) and Miller (1958) did. However, survival may be influenced by other factors than food competition.

9. In a situation where one species of fish, through competition, dominates another species, the dominated species may change its ecological requirements to offset the strain placed on it by the original competition. This phenomenon was demonstrated by Nilsson (1963).

10. A stronger case for food competition is developed if the availability of food organisms is studied in conjunction with the food found in fish stomachs. This was done by Ward (1962) and Laakso (1950).

Methods of Estimating Importance of Food Items

A review of the literature reveals that four methods are commonly used to establish the importance of various food organisms. These are the numerical, frequency of occurrence, volumetric, and gravimetric methods.

The numerical method consists of counting the number of each type of organism per stomach. The results are expressed by totalling the number of organisms found in all fish stomachs for that particular type of fish.

The frequency of occurrence method consists of recording the number of stomachs containing a particular food item. The results are expressed either in the number or percentage of stomachs containing a particular organism.

The volumetric method is the measurement of the volume of a fluid displaced by various food organisms and then relating this to the total food volume per stomach.

TABLE I

Tabulation of various methods of estimating importance of food items

Methods	Frequency of Occurrence	Volumetric	Gravimetric
Numerical			Allen, 1951
Frequency of Occurrence	Fedoruk, 1965 Echo, 1954 Hunt & Carbine, 1950 Ide, 1942	Northcote, 1954 Benson, 1953 White, 1930 Clemens, 1928	LeBrasseur, 1966
Volumetric		Gee & Northcote, 1963 Ward, 1962 Laakso, 1950 Kuehn, 1949 Moore *et al.*, 1934 Ricker, 1930	

The gravimetric method is the weighing of individual food items and comparing these to the total weight of the stomach contents. Usually the stomach contents are dried so as to avoid the weighing of water.

All the above methods of estimating the importance of types of food items have disadvantages. The importance of smaller organisms are magnified in both the numerical and frequency of occurrence methods. Both the volumetric and gravimetric methods can be misleading when a single bulky or weighty specimen, perhaps of rare occurrence, assumes an unwarranted position of dominance over smaller but more common items. The best method is possibly a combination of either the numerical or frequency of occurrence method combined with the volumetric or gravimetric method, time permitting.

Allen (1951) preferred the numerical and gravimetric methods. He stated that the frequency of occurrence method is adequate but is a less informative method. Allen (ibid) did not state why the frequency of occurrence method is less informative. The author chose the frequency of occurrence method, as this method seems to give a more realistic picture when considering the diet of a population as a whole. This opinion was expressed by Benson (1953) in his work on the brook trout of Pigeon River, Michigan. He suggested that "as mayflies and caddisflies occurred in a larger percentage of the stomachs than did crayfish, they possibly benefited more fish than did crayfish". LeBrasseur (1966) used both frequency of occurrence and gravimetric methods to determine the importance of food organisms in four species of Pacific salmon and steelhead trout.

METHODS

General Methods

Data were gathered from two sources. The first source was a series of field observations that were made during the summers of 1960, 1961 and 1962. The second source was a controlled field experiment that was carried out in 1964. Various techniques utilized in both the observational and experimental studies are discussed below, but the design and detail of the experimental studies will be discussed under its own heading.

Description of The Stream

The work on the North Pine River was conducted in Township 33, Ranges 23 and 24, W.P.M. The stream arises from a number of lakes and springs in the Duck Mountains and flows eastward and empties into Lake Winnipegosis. The stream crosses Provincial Highway Number 10 approximately one mile north of the town of Pine River.

The experimental section of the stream lies in a steep valley. The stream's immediate shoreline supports alder, willow, black and white poplar, and a few black and white spruce. Further back from the stream and up the slopes, the dominant trees are spruce with occasional jack pine and young stands of balsam fir growing in localized areas where previous log-cutting operations were undertaken. The average width of the stream is 20 feet. The bottom is stony with varying sizes of stones and boulders. Some boulders were quite large and created pools on their downstream sides in otherwise fast running water. A number of log-jams resulted from the larger boulders catching trees that have floated downstream.

Benthic Sampling

Franklin (MS. 1960) collected benthic organisms from Pine River with a one square foot Surber Sampler. These samples were preserved in a 70% ethyl alcohol solution and later analyzed by the author. Benthic samples were again collected by the same method in the summers of 1961 and 1964. Five benthic samples were taken with a Surber Sampler from each of the four experimental sections, in the summer of 1964, before rotenone was applied to this experimental area. After the rotenone was administered five similar benthic samples were collected from each experimental section at two week intervals until the end of the study in September. The numbers of benthic samples collected from Pine River in the summers of 1960, 1961 and 1964 were 209, 52 and 120 respectively, for a total of 381 samples. The bottom samples were cleaned of debris and the organisms classified to orders in most cases and counted in the laboratory.

Methods of Collecting, Measuring and Stomach Analyzing of Fishes

Mature brook trout were caught by angling, and fingerling brook trout caught by electrofishing in the summer of 1961. Longnose and blacknose dace were collected by means of a seine in the summer of 1962. Both fry and yearling brook trout were obtained from the Whiteshell Trout Hatchery in the summer of 1964 for the controlled experiment. Longnose and blacknose dace were collected by electrofishing and used in the experiment. At the end of this experiment, in mid September, all fish were collected by electrofishing and/or rotenone and measured to the nearest tenth of an inch from the tip of the snout to the fork in the tail.

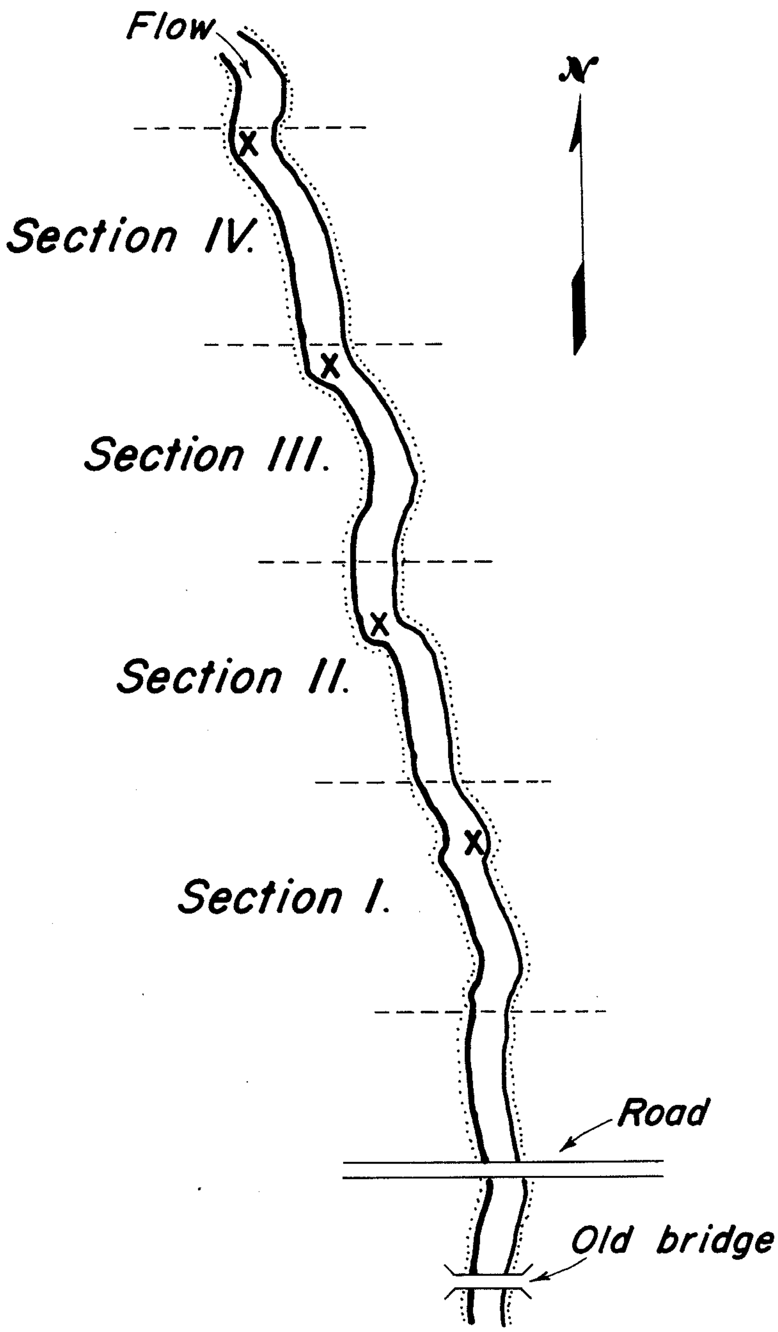
Most workers in the cited literature did not use the metric system. The author has given their measurements and indicated the metric equivalent in brackets.

The stomachs of the fish were held in 10% formaldehyde solution until examined later that winter. The stomachs of trout caught by angling, in the summer of 1961, were examined a day after they were caught. The number of stomachs containing one or more organisms was used to establish the importance of various food organisms. This method is known as the frequency of occurrence method.

The Experiment

In 1964 an experiment was set up to determine if the previously observed similarity in the diet of fingerling brook trout and dace would occur in the controlled conditions of an experiment and if competition for food was severe enough to decrease the rate of growth for the various test lots of fish. This experiment consisted of four test sections; two contained both trout and dace, and two contained only trout. The latter provided control for the former two sections. This experimental design was modified from that of Miller's experiment (see Literature Review).

Four adjacent sections of the stream, each 500 feet long, were screened off by hardware cloth fences. The hardware cloth had 16 meshes to the square inch. The fences were held in position by six-foot angle iron posts driven into the creek bottom. A two and one half foot portion of the hardware cloth extended upstream from the fences and served as an "apron" on which rocks and earth were piled. This was done to ensure that the fish would not escape under the fences. Each of the four sections was a unit by itself, fenced off from the other sections.



----- Section fence

x Log jam

Figure 2.

The stream is relatively uniform within the length of the experimental region. In Sections I and II (Figure 2) the majority of the stream's length contained fast flowing shallow water with numerous large boulders sticking out of the water. There was a major pool at the end of each of these two sections plus another major pool near the middle of the sections in connection with a log-jam. Sections III and IV had a log-jam near the upper end of the section. These sections also contained numerous large boulders and the majority of the water was fast running. The average depth in Sections I, II, III and IV was respectively 2.2, 2.0, 1.7, and 1.3 feet, while the average width of these sections was respectively 21.0, 20.0, 19.5 and 19.0 feet to the nearest half foot.

Prior to the introduction of experimental fish, these four sections were electrofished using a 220 volt alternating generator to remove native fish from the experimental area and to collect dace for the experiment. After the sections were electrofished, rotenone was used to remove all the fish remaining in the screened off sections. Potassium permanganate was used to neutralize the rotenone at the downstream end of the experimental area. This was done to protect the trout populations below the experimental area.

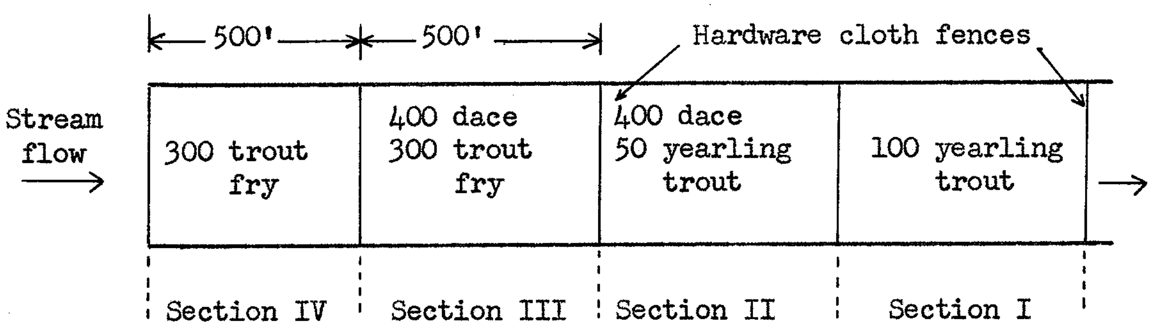

500'
500'
Hardware cloth fences
Stream flow
300 trout fry
400 dace
300 trout fry
400 dace
50 yearling trout
100 yearling trout
Section IV
Section III
Section II
Section I

Figure 3.

Sections I and IV were control sections. Section I contained only yearling trout and Section IV contained only brook trout fry. Section II and III were the experimental sections containing a mixture of trout and dace.

A week after the rotenone was applied, 400 dace were liberated in each of Sections II and III. Before liberation 150 dace were measured. Also 300 brook trout fry were liberated in each of Sections III and IV. One hundred and fifty fry were measured before liberation. Similarly 100 yearling brook trout were introduced into Section I, and 50 yearling brook trout into Section II. A sample of these yearling trout was also measured before being put into the two sections. Both fry and yearling were obtained from the Whiteshell Trout Hatchery. Figure 3 shows the distribution of these fish in the experimental area.

The experiment was terminated in September. The fish were collected by electrofishing and by the use of rotenone. All fish were measured and their stomach contents analyzed. The length of the dace and brook trout from the control sections was compared to their counter parts from the competitive sections. The "t" test was used to establish significant differences in growth between fish from the control and competitive sections.

OBSERVATIONS

Data from the Summers of 1961 and 1962

Contents of 43 stomachs from brook trout were examined in the summer of 1961. The size of these fish ranged from 4.5 to 17.0 inches (11.4 - 41.7 cm.) in length. From this sample, (Figure 4a and c), 71% of the stomachs contained insects, 11% contained snails, 11% contained fish, 3% contained crayfish, one stomach was empty, and another one contained unidentifiable remains. The main insect orders consumed by these fish were Hemiptera, Plecoptera, Coleoptera, and Odonata. Trichoptera and Ephemeroptera constituted only minor portions of the diet of these trout.

Forty fingerling brook trout, averaging 2.4 inches (6.0 cm.) in length, were taken from Pine River for stomach analysis. Trichoptera were found in 33% of the stomachs, Ephemeroptera in 17%, and a combination of Trichoptera-Ephemeroptera in 20% of the stomachs. Coleoptera and Plecoptera constituted minor portions of the fingerling brook trouts' diets. These data are summarized in Figure 5a.

A total of 69 longnose dace averaging 2.3 inches (5.7 cm.) were were taken from Pine River in the summer of 1962. An analysis of the stomach contents of these fish revealed that 41% of the longnose dace contained Trichoptera, 16% contained Ephemeroptera, and 13% contained a combination of Trichoptera and Ephemeroptera. Figure 5c gives this information.

The blacknose dace stomach samples showed that 28% of the stomachs examined contained Trichoptera, 21% contained Ephemeroptera and 4% contained Coleoptera. This information is summarized in Figure 5e.

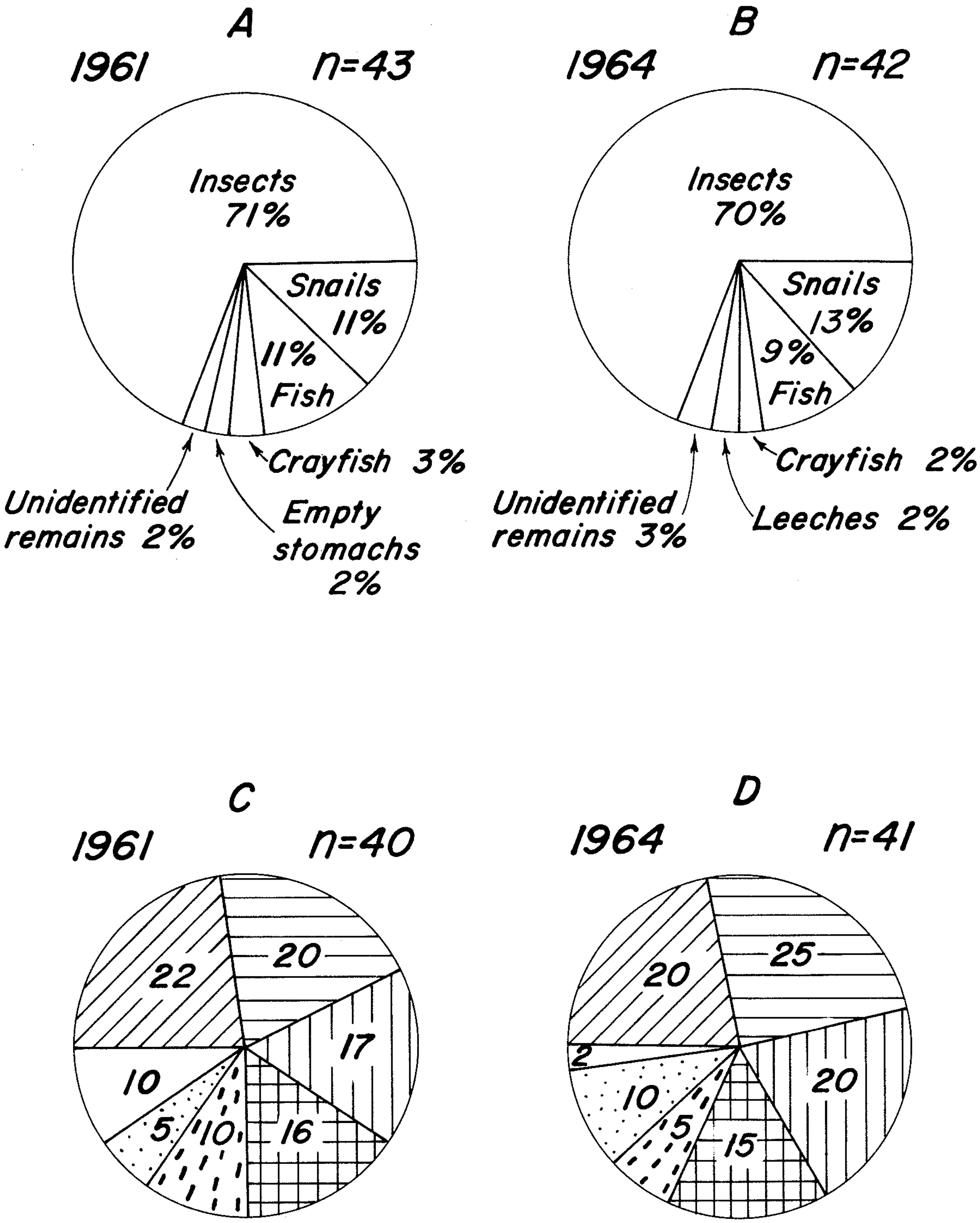

A
1961
n=43
Insects 71%
Snails 11%
11% Fish
Crayfish 3%
Unidentified remains 2%
Empty stomachs 2%
B
1964
n=42
Insects 70%
Snails 13%
9% Fish
Crayfish 2%
Unidentified remains 3%
Leeches 2%
C
1961
n=40
22
20
17
10
5
10
16
D
1964
n=41
20
25
2
10
20
5
15

Figure 4.

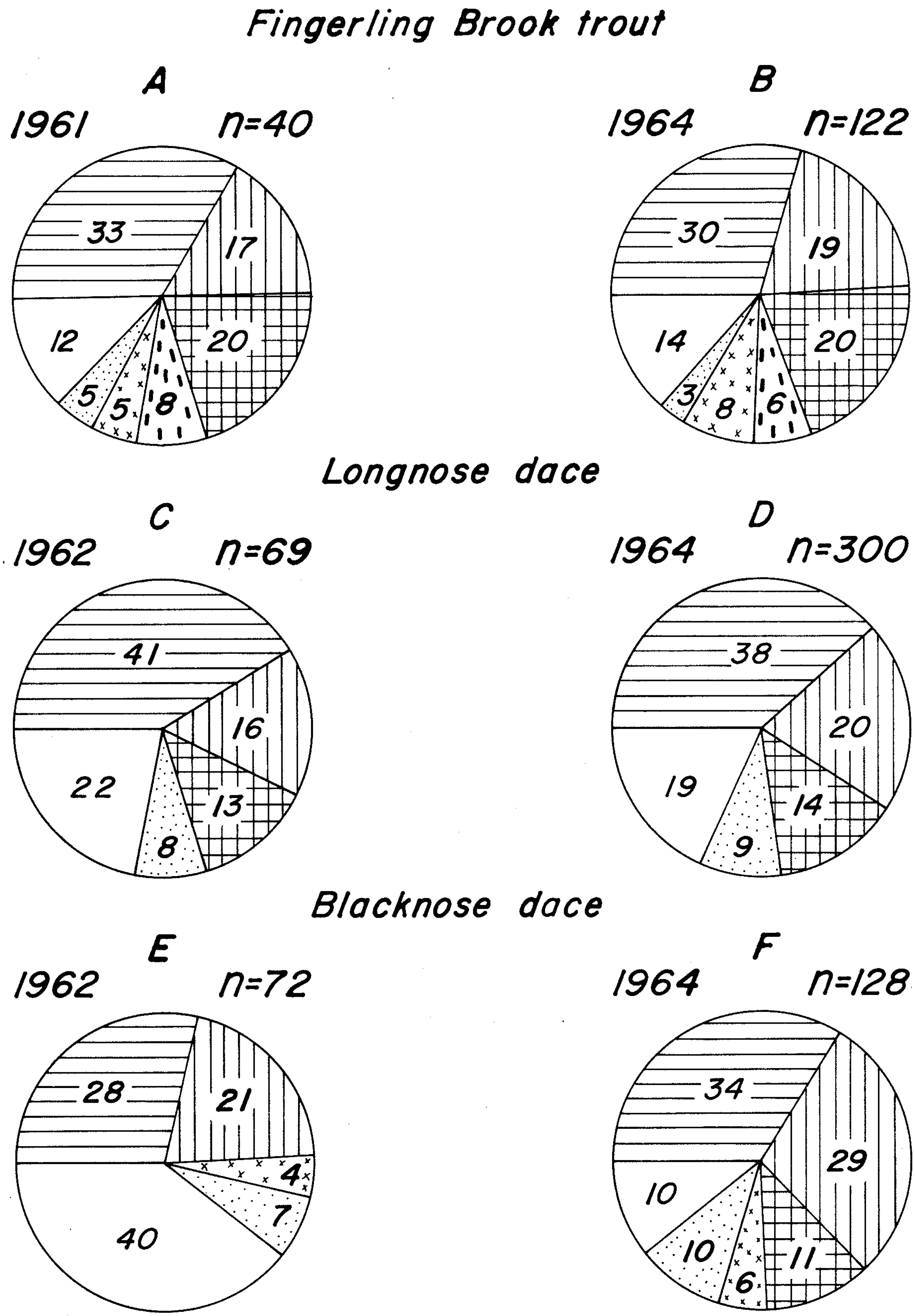

Fingerling Brook trout
A
1961
n=40
33
17
12
20
5
5
8
B
1964
n=122
30
19
14
20
3
8
6
Longnose dace
C
1962
n=69
41
16
22
13
8
D
1964
n=300
38
20
19
14
9
Blacknose dace
E
1962
n=72
28
21
4
7
40
F
1964
n=128
34
29
10
10
6
11

Figure 5.

The 1964 Experiment

Difficulties were encountered in the conduct of this experiment. Unfortunately the hatchery truck did not deliver 200 yearling trout and this was unknown at the time of delivery. As a result the control section and the experimental section did not contain equal numbers of yearling (100 and 50 respectively). Also 86 dace entered Section I, the non-competitive section containing the yearling trout. However, stomach analysis of the dace (Figure 5d and f) showed that these fish feed mainly on Trichoptera and Ephemeroptera. The yearling trout (Figure 4d) fed mainly on Plecoptera, Hemiptera, Coleoptera and Odonata.

The average lengths of the yearling trout in Section I and II were compared and the means were not significantly different ($t = 1.428$, NS.) at the 5% level. This was also true of the average lengths of the dace, in the two sections ($t = 0.8333$, N.S.).

Only 300 brook trout fry, averaging 0.9 inches (2.3 cm.) in length were put into Section IV. At the end of the experiment, 77 fingerling brook trout were collected with 46 dace which had apparently entered this control section. These trout had tripled their original length, a relative growth rate of 2.00. The dace gained 0.3 inches (0.8 cm.) in length, a relative growth rate of 0.013. The low number of fingerling brook trout recaptured in this section may be attributed to predation by mink and kingfisher. Ravens landed along the stream or on boulders that projected out of the water, but were never seen to catch fish.

Low returns of both fingerling brook trout and dace were obtained in Section III. This was possibly due to an extensive formation of a filamentous algae which made recovery of the fish difficult and predation by birds and mink was probably also significant in the low recapture of fish.

TABLE II

Statistics of experimental fish released, Pine River, 1964.

Section	Type of Fish[1]	Number of Fish	Number Measured	Average Length, Inches[2]	Length range, inches
I	Y,B.T.	100	50	5.7 ± 0.4	4.2 - 6.7
II	Y,B.T.	50	50	5.7 ± 0.3	4.2 - 6.6
II	Dace	400	75	2.3 ± 0.3	1.1 - 3.3
III	F,B.T.	300	75	0.9 ± 0.03	0.8 - 1.0
III	Dace	400	75	2.3 ± 0.3	1.1 - 3.3
IV	F,B.T.	300	75	0.9 ± 0.03	0.8 - 1.0

[1] Y,B.T. = yearling brook trout

Dace = blacknose and longnose dace

F,B.T. = brook trout fry

[2] $\bar{x} \pm$ one standard deviation

TABLE III

Statistics of experimental fish recaptured, Pine River, 1964.

Section	Type of Fish[1]	Number of Fish Caught & Measured	Average Length, inches[2]	Length range, inches
I	Y,B.T.	26	7.0 $\pm$ 0.4	5.2 - 8.6
	Dace	88	2.6 $\pm$ 0.3	1.2 - 4.0
II	Y,B.T.	16	6.8 $\pm$ 0.5	5.2 - 8.5
	Dace	183	2.7 $\pm$ 0.3	1.2 - 3.6
III	F,B.T.	45	2.1 $\pm$ 0.1	1.9 - 2.5
	Dace	113	2.4 $\pm$ 0.4	1.1 - 3.6
IV	F,B.T.	77	2.7 $\pm$ 0.2	2.0 - 3.6
	Dace	46	2.6 $\pm$ 0.3	1.1 - 3.7

[1] Y,B.T. = yearling brook trout

Dace = blacknose and longnose dace

F,B.T. = fingerling brook trout

[2] $\bar{x} \pm$ one standard deviation

A total of 113 of the original 400 dace were recaptured, and only 45 fingerling brook trout caught of the original 300. These fingerling trout gained 1.2 inches (3.0 cm.), a relative growth rate of 1.24. The dace in the same section gained 0.1 inches (0.3 cm.) in length, a relative growth rate of 0.004.

The dace in the non-competitive section (IV) showed a larger relative growth rate than the dace in the competitive section (III). This was statistically significant at the 1% level, (t = 3.33*). The fingerling brook trout in section IV were significantly larger, at the 1% level, (t = 15.00*) than the fingerlings in Section III. The relative growth of the fingerling trout in the non-competitive section was considerably greater than that of the fingerlings from Section III, 2.00 and 1.24 respectively.

Stomach analyses showed that fingerling brook trout fed mainly on Trichoptera and Ephemeroptera and that these two orders were contained in 69% of the stomachs sampled (Figure 5b). Also 300 longnose dace stomachs sampled (Figure 5d) showed that 72% of the stomachs contained either Trichoptera or Ephemeroptera or a combination of both. A similar analysis of blacknose dace (Figure 5f) showed that 70% of the stomachs contained Trichoptera and Ephemeroptera or both.

Observations on Benthic Fauna

In 1960, 209 bottom samples were collected from the North Pine River, and again another 52 samples in 1961. In 1964, 120 bottom samples were collected in the experimental area of Pine River. These 381 bottom samples (Table IV) showed that the numbers of caddisfly larvae and mayfly nymphs decreased as the summer progressed. Both orders showed a peak density (organisms per square foot) from the middle of June to the end of June. These two orders of insects were the most numerous organisms encountered.

It was interesting to know if the rotenone affected the caddisfly larvae and mayfly nymphs in the experimental area. Table IV shows a reduction of approximately one-third of their numbers compared to similar periods (June 1 to June 15) in 1960 and 1961. The rotenone was administered near the end of May. However, at the end of June the populations of these insects increased to normal numbers, to judge from benthic fauna collected in the summers of 1960 and 1961.

Table V shows that in May and June all four sections of the stream contained approximately equal numbers of mayflies and caddisflies, but that in July and August their proportions greatly reduced in sections III and IV compared to sections I and II.

TABLE IV

Abundance of Trichoptera and Ephemeroptera during summer months, measured per sq. ft. of riffle bottom

Periods	No. Trichoptera 1960	1961	1964	No. Ephemeroptera 1960	1961	1964
June 1 - 15	34	32	24	46	43	28
June 16 - 30	50	49	48	68	66	59
July 1 - 15	24	21	29	28	23	24
July 16 - 31	19	19	23	20	18	15
August 1 - 15	-	21	18	-	12	13
August 16 - 31	-	14	16	-	13	11

TABLE V

Abundance of Trichoptera and Ephemeroptera in the four experimental sections of Pine River, 1964

	May				June				July				August			
Section	I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV
Trichoptera	28	31	35	29	37	35	38	33	36	30	18	20	23	18	12	16
Ephemeroptera	37	43	44	36	39	43	47	42	25	22	13	16	15	14	9	10

DISCUSSION

Interspecific competition for food can be measured in terms of growth rates of the competitors, as food is closely related to growth. The food habits of fish influence the type of food eaten. Interspecific food competition is not achieved if the species feed on different foods. These relationships suggest a format for the discussion which will consist of three major topics. These topics deal with interspecific competition between brook trout and dace and the relationship of growth, and food habits of trout and dace. A third major heading will deal with Trichoptera and Ephemeroptera. These insects were significant food items in the competition study.

Food Competition Between Trout and Dace

As far as the author could determine there is no literature actually demonstrating food competition between brook trout and dace. Kuehn (1949) concluded from literature the possibility that longnose dace compete for food with young trout and possibly adult trout, because dace feed on similar food items and frequent similar habitats. Moore, et al. (1934) suggested that food competition exists between blacknose dace and brook trout. They found that brook trout in the same stream fed mainly on the same insect orders as did blacknose dace.

The North Pine River experiment showed that yearling trout did not compete for food with the longnose and blacknose dace as the trout and daces' main diets differed. Also there was no statistically significant difference in the growth of the yearling trout and dace in the experimental and control sections. Fingerling brook trout and dace have similar diets. Their main source of food was Trichoptera larvae and

Ephemeroptera nymphs. The growth rates of the fingerling brook trout and dace in the non-competition section were significantly greater than the growth rates of fingerling trout and dace in the competitive section. Both the difference in the growth of the fishes in the control section compared to the growth of fishes in the experiment section, and the similarity of diets suggests that fingerling brook trout compete for food with dace.

Unfortunately there was a limited exchange of fish between the control and experimental sections. However, it is difficult to relate the differences in growth observed, in the case of the fingerling v.s. dace sections, except that in the original experimental section the dace were present in larger numbers and thus competition was greater.

Food Habits of Brook Trout and Dace

Food habits of brook Trout

Ricker (1930) and Clemens (1928) indicated that the diets of brook trout changed with an increase in the size of the trout. Clemens found that as the brook trout increased in size, aquatic insects and miscellaneous invertebrates decreased in importance while fish and other miscellaneous forms increased in importance to the trout's diet. He also observed that surface insects increased and then decreased in importance to the trout's diet.

Allen (1951), working with brown trout in New Zealand, found that chironomids and Ephemeroptera were relatively more numerous in the stomachs of first-year fish than in the older trout. The change in feeding habits of the brown trout, as they increased in size and age, was largely completed by the second winter.

Yearling brook trout in Pine River fed mainly on Plecoptera, Hemiptera, Coleoptera and Odonata. These orders were the chief source of food for brook trout 4.5 to 1.7 inches (11.4 - 43.9 cm.) in length. By contrast, fingerling brook trout, 1.9 to 3.6 inches (2.7 - 9.1 cm.) in length, fed mainly on Trichoptera and Ephemeroptera. Information from the literature cited, and from the author's own observations and experiment shows that trout change their food habits as they become larger and older.

Food of larger brook Trout

Ricker (1930) found that mayfly nymphs and caddisfly larvae were the most significant food items of brook trout 3 to 6 inches (7.6 - 15.2 cm.) in length. In brook trout 4 to 6 inches (10.2 - 15.2cm.) in length, he observed the occurrence of a few small crayfish. Ricker noticed that 6 to 8 inch (15.2 - 20.3 cm.) brook trout fed chiefly on Simulium larvae, but fish also appeared in their diet.

Clemens (1928) noticed that grasshoppers, mayfly nymphs and caddisfly larvae constituted the greater volume of food in brook trout 4 to 6 inches (10.2 - 15 cm.) in length, but that in frequency of occurrence mayflies, beetles, caddisflies, bugs and ants along with miscellaneous flies were encountered in most stomachs. In trout 6 to 8 inches (15.2 - 20.3 cm.) in length, most stomachs contained caddisflies, beetles, miscellaneous flies and ants. Clemens found that brook trout, 8 to 10 inches (20.3 - 25.4 cm.) in length fed chiefly on fish, salamanders, mayflies, and caddisfly larvae.

Needham (1930) observed that the diet of brook trout changed with changes in seasons. Observations on seasonal changes in brook trout diets were not undertaken at Pine River. He noticed also that 90% of the food of brook trout 3 to 9 inches, ave. 5.5 (7.6 - 22.9 cm., 14.0 cm.) was insects. The insects accounted for 94% of the aquatic food and 91% of the terrestrial food. At Pine River insects occurred predominantly in the stomachs of all sizes of brook trout and forage fish constituted a minor role in the diet of brook trout. Allen (1951) reported that fish were not major food items of brown trout in the Horokiwi Stream.

Ide (1942) stated that Trichoptera occurred most frequently in the stomachs of brook trout 5 to 6 inches (12.7 - 15.2 cm.) long. The diets of trout shifted from insects to fish as the trout became larger.

Benson (1953) examined stomachs of 420 brook trout from Pigeon River, Michigan, and noted that mayflies, caddisflies and crayfish were the most common food organisms of brook trout (6.8 to 12.9 inches ((17.3 - 32.8 cm.))) in May and June. He suggested that as mayflies and caddisflies occurred in a larger percentage of the stomachs than crayfish, the former were probably more beneficial to more fish than the latter.

Juday (1907) investigated the stomach contents of 126 brook trout ranging in size from 4 to 13 inches (10.2 - 33.0 cm.) in length. He concluded that Hymenoptera, Coleoptera, Orthoptera, and chironomids were the most important food items of the diet of these fish.

A comparison of the findings of the above authors reveals that insects are the main type of food consumed by brook trout, 3 to 13 inches (7.6 - 33.0 cm.) long. Thus the author's data both from field observations and from the experimental study agree with the cited literature that brook trout 3 to 17 inches (7.6 - 41.7 cm.) in length feed chiefly on insects. The main types of insects eaten by these trout vary considerably from the findings of one investigator to another. From this one may conclude that larger or yearling brook trout feed chiefly on insects but that the main types of insects which are consumed vary from area to area in North America.

Food of fingerling brook Trout

White (1930) examined the stomach contents of brook trout fry, of which some had not yet absorbed their yolk sacs. Chironomids and copepods were the most important food items of these trout, both in the frequency of occurrence and in bulk. Ricker (1930) observed that Entomostraca were the most important food of slightly larger fish (0.8 to 1.0 inches ((2.0 - 2.5 cm.)) in length). Chironomids were the dominant food items in fry 1.0 to 1.5 inches (2.5 - 3.8 cm.) in length. No stomach analysis were made of brook trout fry at Pine River.

Juday (1907) found that trout 1 to 2 inches (2.5 - 5.1 cm.) in length fed mainly on mayflies, Diptera and chironomids. Ricker (1930) noted that fingerling brook trout (1.5 to 3 inches ((3.8 - 7.6 cm.)) in length) fed on a variety of insect life but Plecoptera was absent. Clemens (1928) stated ~~that~~ brook trout up to 2 inches (5.1 cm.) in length fed mainly on mayflies.

Leonard (1941) concluded that brook trout 80.3 mm. (3.1 inches) in length fed mainly on larvae and pupae of midges and blackfly which occurred in 84.7% of the stomachs he examined. Mayfly nymphs occurred in 7.5% of the stomachs. At Pine River trout, 1.9 to 3.6 inches (4.8 - 9.1 cm.) in length, fed mainly on mayfly nymphs and caddisfly larvae, Figure 4a and b.

The above mentioned investigators' findings differed with respect to the main food items of fingerling brook trout. The findings of the author agree partially with those of Clemens (ibid) and Juday (ibid) that mayflies are important food items of fingerling brook trout.

Food of longnose and blacknose Dace

Information gathered from Pine River during the summers of 1962 and 1964 (Figure 4c and d) showed that longnose dace fed predominantly on Trichoptera larvae and Ephemeroptera nymphs. Kuehn (1949) observed that longnose dace fed mainly on Chironomid and Simulidae larvae, and Ephemeroptera nymphs. Data from Kuehn suggests that these dace may grow 14 mm. (0.56 inches) per year depending upon their age. Dace in the non-competitive sections (I and IV) of Pine River grew 0.4 inches (10.2 mm.) during the summer. Gee and Northcote (1963) found that longnose dace fed predominantly upon aquatic insects, chiefly Diptera and Ephemeroptera. The author agrees with Kuehn, (1949) that longnose dace feed substantially on Trichoptera, and with Gee and Northcote (1963) that dace feed on Ephemeroptera, though these investigators used volume for their measurement of food and the author used the frequency of occurrence method.

Moore et al. (1934) noted that blacknose dace, ranging in size from 32 to 97 mm. in length (1.3 to 3.9 inches), fed mainly on Diptera larvae and pupae, mayfly nymphs, and caddisfly larvae. They used volume as a basis to evaluate the food organisms. The blacknose dace in Pine River, both in the summers of 1962 and 1964, fed mainly on Trichoptera and Ephemeroptera, based on the frequency of occurrence in numbers of stomachs. These dace were 1.1 to 3.6 inches (2.7 - 9.1 cm.) in length. The observations of Moore et al. (ibid) verifies the author's findings on Pine River, except that in Pine River, Diptera did not constitute an appreciable portion in the dace's diet.

Trichoptera and Ephemeroptera

Caddisfly larvae and mayfly nymphs were the most abundant macro-organisms found in bottom samples taken from Pine River in the summers of 1960, 1961, and 1964. Table IV shows their numerical strength at two-week intervals. These insects were also the major food items of dace and fingerling trout.

It was interesting to know how the rotenone, administered near the end of May, might affect the populations of caddisfly larvae and mayfly nymphs. If the numbers of these insects were drastically reduced the effect might have induced abnormally severe competition, both interspecifically and intraspecifically. Table IV shows a reduction of about one-third in their numbers in the first half of June, compared to the first part of June in 1960 and 1961. However, at the end of June, the populations of these insects had increased to approximately normal numbers, judging from the 1960, 1961 samples. This indicated that the use of rotenone did not drastically affect the Trichoptera and Ephemeroptera populations. These populations recovered their normal, numerical strengths in approximately three weeks.

The literature on the effects of rotenone on aquatic insects shows that they can withstand rotenone better than fish (Leonard 1938, Smith 1939, and Prevost 1960). Brown and Ball (1942) submerged cages of food organisms into water containing rotenone at 2 p.p.m. or greater and found Trichoptera to be one of the more rotenone resistant groups of fish food. Smith (1939) found Trichoptera to be one of the more rotenone resistant forms. Caddisfly larvae, and mayfly and stonefly nymphs were unaffected by concentrations of derris toxic to brook trout and salmon parr (McGonigle and Smith, 1938).

SUMMARY AND CONCLUSION

Interspecific food competition between eastern brook trout (*Salvelinus fontinalis*, Mitchill) and two species of dace (*Rhinichthys cataractae*, Valenciennes) and (*Rhinichthys atratulus*, Hermann) was investigated in North Pine River, Manitoba. Field observations on the benthos were made in the summers of 1960, and 1961. Information on the food of brook trout and longnose and blacknose dace was gathered in the summers of 1961 and 1962.

A study consisting of two control and two experimental sections was designed, in the summer of 1964, to test for interspecific food competition between trout and dace. Native fishes were removed from the sections by rotenone and by electrofishing. Later appropriate numbers of yearling brook trout, dace, and brook trout fry were introduced into these sections. Benthic samples were collected of each of the four sections at two week intervals. At the end of the experiment all the collected fish from sections were measured and their stomachs analyzed for types of food organisms. The average length of the fish in the non-competitive sections were compared to those in the competitive sections. Conclusions from this study are as follows:

(1) Fingerling brook trout experience food competition from both species of dace.

The major food items of these trout and dace, in the North Pine River, are Trichoptera larvae and Ephemeroptera nymphs. Also the growth rate of the fingerling brook trout in the non-competitive section was greater than the growth rate of the fingerlings in the competitive section. The average size of the dace which entered the non-competitive section were significantly larger than those which were in the competitive section at the end of the experiment.

(2) Yearling brook trout and larger trout do not compete for food with the longnose and blacknose dace in the North Pine River.

This is based on the findings that yearling trout in Pine River fed predominantly on other aquatic insects than did the dace. In streams where larger trout feed mainly on mayfly nymphs and caddisfly larvae, food competition from these species of dace is a possibility.

(3) The food of all sizes of brook trout, from fingerlings to 17 inches (41.7 cm.) in length, is mainly insects.

Fingerling brook trout, in the North Pine River, fed mainly on Trichoptera and Ephemeroptera while yearling and larger trout fed mainly on Hemiptera, Coleoptera, Plecoptera and Odonata.

(4) Forage fish constitute a minor role in the food of larger brook trout.

This conclusion is reached from field observations on the North Pine River and from the cited literature.

(5) The diet of brook trout varies with the size of the trout.

This is evident when the main food items observed in the fingerling brook trout, from the North Pine River, are compared to those of the yearling brook trout. The cited literature also supports this observation.

(6) Observations made on the North Pine River and conclusions drawn from the cited literature indicate that concentrations of rotenone which kill fish do not drastically reduce populations of benthic fauna, i.e., Trichoptera and Ephemeroptera.

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