Government of Canada
Fisheries and Oceans

Gouvernement du Canada
Pêches et Océans

Your file Votre référence

Our file Notre référence

May 29, 1981

Dr. R. Behnke
Department of Fisheries and Wildlife
Biology
Colorado State University
Fort Collins, Colorado
United States of America
80523

Dear Dr. Behnke:

I am sending you some information on some of our stocking work on pothole lakes.

Bert Vanderveen passed on your monograph and I will give it to the library when I've gone through it.

As you suggested, I found the section on origins of stocks interesting. I believe I mentioned that we have attempted to obtain stocks from a variety of sources, Norway to British Columbia, but most of them have been hatchery stocks. We do, however, find a fair degree of variability and a certain amount of "pre-adaption" to pothole environments.

Sincerely,

G. Burton Ayles
Project Leader
Aquaculture

Encl.

Freshwater Institute
501 University Crescent
Winnipeg, Manitoba
R3T 2N6
(204) 269-7379

Institut des eaux douces
501 University Crescent
Winnipeg (Manitoba)
R3T 2N6
(204) 269-7379

Growth and Food Habits of Strains of Rainbow Trout (*Salmo gairdneri* Richardson) in Winterkill Lakes of Western Manitoba

D. Bernard and C. Holmstrom

Western Region
Fisheries and Marine Service
Department of Fisheries and the Environment
Winnipeg, Manitoba R3T 2N6

December 1978

Fisheries & Marine Service Manuscript Report No. 1477

Fisheries and Marine Service

Manuscript Reports

These reports contain scientific and technical information that represents an important contribution to existing knowledge but which for some reason may not be appropriate for primary scientific (i.e. *Journal*) publication. They differ from Technical Reports in terms of subject scope and potential audience: Manuscript Reports deal primarily with national or regional problems and distribution is generally restricted to institutions or individuals located in particular regions of Canada. No restriction is placed on subject matter and the series reflects the broad interests and policies of the Fisheries and Marine Service, namely, fisheries management, technology and development, ocean sciences and aquatic environments relevant to Canada.

Manuscript Reports may be cited as full publications. The correct citation appears above the abstract of each report. Each report will be abstracted by *Aquatic Sciences and Fisheries Abstracts* and will be indexed annually in the Service's index to scientific and technical publications.

Numbers 1-900 in this series were issued as Manuscript Reports (Biological Series) of the Biological Board of Canada, and subsequent to 1937 when the name of the Board was changed by Act of Parliament, as Manuscript Reports (Biological Series) of the Fisheries Research Board of Canada. Numbers 901-1425 were issued as Manuscript Reports of the Fisheries Research Board of Canada. The series name was changed with report number 1426.

Details on the availability of Manuscript Reports in hard copy may be obtained from the issuing establishment indicated on the front cover.

Service des pêches et des sciences de la mer

Manuscrits

Ces rapports contiennent des renseignements scientifiques et techniques qui constituent une contribution importante aux connaissances actuelles mais qui, pour une raison ou pour une autre, ne semblent pas appropriés pour la publication dans un journal scientifique. Ils se distinguent des Rapports techniques par la portée du sujet et le lecteur visé; en effet, ils s'attachent principalement à des problèmes d'ordre national ou régional et la distribution en est généralement limitée aux organismes et aux personnes de régions particulières du Canada. Il n'y a aucune restriction quant au sujet; de fait, la série reflète la vaste gamme des intérêts et des politiques du Service des pêches et de la mer, notamment gestion des pêches; techniques et développement, sciences océaniques et environnements aquatiques, au Canada.

Les Manuscrits peuvent être considérés comme des publications complètes. Le titre exact paraît au haut du résumé de chaque rapport, qui sera publié dans la revue *Aquatic Sciences and Fisheries Abstracts* et qui figuera dans l'index annuel des publications scientifiques et techniques du Service.

Les numéros de 1 à 900 de cette série ont été publiés à titre de manuscrits (Série biologique) de l'Office de biologie du Canada, et après le changement de la désignation de cet organisme par décret du Parlement, en 1937, ont été classés en tant que manuscrits (Série biologique) de l'Office des recherches sur les pêcheries du Canada. Les numéros allant de 901 à 1425 ont été publiés à titre de manuscrits de l'Office des recherches sur les pêcheries du Canada. Le nom de la série a été changé à partir du rapport numéro 1426.

La page couverture porte le nom de l'établissement auteur où l'on peut se procurer les rapports sous couverture cartonnée.

•Cover design by Christine Rusk

Fisheries and Marine Service

Manuscript Report 1477

December 1978

GROWTH AND FOOD HABITS OF STRAINS OF RAINBOW TROUT (*Salmo gairdneri* Richardson) IN WINTERKILL LAKES OF WESTERN MANITOBA

by

D. Bernard[1] and C. Holmstrom

Western Region

Fisheries and Marine Service

Department of Fisheries and the Environment

Winnipeg, Manitoba R3T 2N6

This is the eighth Manuscript Report

from the Western Region, Winnipeg

[1] Present address: CIDA - El Salvador Fisheries Project
Canton el Matasano, Soyapango, San Salvador
Republic de el Salvador, C.A.

FOREWORD

Claude Holmstrom did his undergraduate work at Guelph University and during those summers worked for the Ontario Ministry of Natural Resources in the Kenora area - his home. It was here he met and married Lynne-Anne White. Following this he did graduate work through the University of Manitoba and the Freshwater Institute, under the supervision of Dr. G.H. Lawler, studying the feeding behavior of rainbow trout in the prairie pothole lakes south of Riding Mountain National Park. Upon completion of his Master's degree in 1972, Claude became a regional biologist with the Manitoba Department of Mines, Resources and Environmental Management. A short time later, on July 25, 1973, Claude was killed in a helicopter crash while carrying out a waterfowl survey in the marshes at the south end of Lake Winnipeg.

Claude's untimely death left a permanent void in the lives of those who knew him well. He is remembered for a fairness and open-mindedness that we could all emulate.

Cat. no. Fs 97-4/1477 ISSN 0701-7618

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES (cont'd)

LIST OF APPENDICES

ABSTRACT

Bernard, D. and C. Holmstrom. 1978. Growth and food habits of rainbow trout (*Salmo gairdneri* Richardson) in winterkill lakes of western Manitoba. Can. Fish. Mar. Serv. MS Rep. 1477: iv + 20 p.

Fingerlings of different strains of rainbow trout, stocked in winterkill lakes, gained an average of 200 g in approximately 160 days (May to October). Seasonal growth was best described by the Gompertz growth curve. Within a lake the domestic strains, Idaho and Nisqually, had the same growth rates, though there was some variability in growth between lakes at harvest time. The wild strain, Tunkwa, was smaller at harvest time than the Idaho domestic strain. The three strains of trout showed the same general pattern of seasonal change in specific growth rate and this pattern was influenced by water temperature.

Amphipods were the major food organism consumed by trout in one lake in 1970 and 1971, but studies in 1973 and 1974 showed marked seasonal differences in food organisms consumed between lakes and harvest years. Amphipods were important to the trout diet but other organisms such as corixids, Odonata nymphs, *Chaoborus* and other fish were also of importance. The changes in food habits are discussed in relation to changes in growth.

Key words: trout,rainbow; growth; feeding; genetic strains.

RESUME

Bernard, D. and C. Holmstrom. 1978. Growth and food habits of rainbow trout (*Salmo gairdneri* Richardson) in winterkill lakes of western Manitoba. Can. Fish. Mar. Serv. MS Rep. 1477: iv + 20 p.

Des alevins de différentes souches de truite arc-en-ciel, qui ont servi à ensemencer des lacs où le taux de mortalité due aux rigueurs de l'hiver est très élevé, ont pris 200 g en moyenne, pendant environ 160 jours (de mai à octobre). La courbe de croissance Gompertz a fourni la meilleure description de la croissance saisonnière. Dans un même lac, les souches domestiques, Idaho et Nisqually, ont eu le même taux de croissance, bien que la taille des poissons ait varié quelque peu d'un lac à l'autre, au moment de la pêche. A cette même époque, la souche sauvage, Tunkwa, était plus petite que la souche domestique Idaho. Le taux de croissance spécifique des trois souches de truite a suivi le même modèle général de variation saisonnière, influencé par la température de l'eau.

Les amphipodes ont été le principal organisme consommé par la truite dans un lac, en 1970 et en 1971, mais des études effectuées en 1972 et 1974 ont montré que le genre d'organismes consommés variait de façon prononcée selon les lacs et les années de pêche. Les amphipodes ont constitué une part importante du régime de la truite, mais d'autres organismes, comme les corises, les nymphes d'odonates, les *Chaoborus* et d'autres poissons ont également compté pour beaucoup. Les changements d'habitudes alimentaires sont étudiés en rapport avec les variations de la croissance.

Mots-clés: truite,arc-en-ciel; croissance; alimentation; souches génétiques.

INTRODUCTION

In 1968 the Freshwater Institute began studying the feasibility of stocking rainbow trout, *Salmo gairdneri*, in prairie winterkill lakes. Trout fingerlings (3-4 g) stocked May grew to marketable size (>200 g) by the fall, feeding only on natural food organisms (Johnson et al. 1970; Sunde et al. 1970; Lawler et al. 1974). This resulted in the development of a small cottage industry across the Canadian prairies: but while annual production has expanded to over 267,000 kg, large-scale industrial development is hampered by a number of biological and non-biological factors (Ayles and Brett 1978).

The productivity of these lakes is very high but quite variable. It is possible that differences in food available in the lakes could be the cause of this variability. The objective of this study was twofold:

- firstly, to determine what the trout were feeding on; and
- secondly, to determine when differences in growth rates occurred and whether they could be associated with differences in feeding.

In 1970-71 the food habits, feeding periodicity, feeding selectivity, rates of gastric digestion in relation to several factors and the estimation of daily ration during the growing season were determined. In 1973-74, in conjunction with a genetics program directed toward the production of a strain of trout better suited to these lakes, comparison was made between seasonal growth rates and food habits of matched plantings of one wild and two domestic strains of rainbow trout in three different lakes.

METHODS

The geography of the study area is described by Sunde and Barica (1975) and the morphometry and water chemistry of the lakes in this study are given by Barica (1975).

STOCKING OF FISH

In the 1970-71 study rainbow trout fingerlings were stocked in Lake 103 on 15 May in 1970 and 5 May 1971 (Table 1). In 1970 eyed eggs were obtained from Pennask Lake, British Columbia, and the trout were reared at the Freshwater Institute in Winnipeg to fingerling size. In 1971 fingerlings were purchased from Livingston Hatchery, Montana.

In 1973 and 1974 plantings of 3 strains (one wild and two domestic) were made in 3 lakes (Table 1). The wild strain was obtained from Tunkwa Lake, British Columbia, in 1973. The two domestic strains were obtained from commercial hatcheries in the United States. One strain was obtained from a private hatchery in Idaho and the other from Nisqually Hatchery in the State of Washington. All 3 strains were received as eyed eggs and were reared under identical conditions at the Freshwater Institute's Rockwood Experimental Hatchery. In 1973 Tunkwa and Idaho fish were planted in each of the 3 lakes and in 1974 the Nisqually and Idaho fish were planted in each lake. Before stocking the strains were marked for identification. In 1973 they were marked by a hot-wire brand (Bernard and van der Veen 1974), while in 1974 a coded wire nose tag was used (Jefferts et al. 1963). Trout size was controlled so that for each lake the strains were approximately the same weight at the time of planting. The stocking time was between 4-11 May in 1973 and between 16-23 May in 1974. Both strains were planted on the same date in each lake except for Lake 318 in 1973. A severe storm at Lake 318 on the day when the Idaho fish were planted in 1973 resulted in nearly complete mortality of this strain.

COLLECTION OF SAMPLES

During 1970-71, 24-hour gillnetting experiments were conducted on Lake 103. All fish were taken with nylon gillnets. For each diel sampling two joined nets (50 m) were set perpendicular to shore at 3-hour intervals and left for not more than 15 minutes. This usually was sufficient to catch the preselected quota of 10 trout. In May and June nets were left in for the entire 24-hour sampling period and checked every 3 hours. Fish from the May and June experiments were combined to provide a sufficiently large sample. If less than 7 fish were caught at any given interval the set was repeated the following day. When more than 10 fish were taken, a random selection of 10 was used for stomach analysis.

In 1973-74, trap nets, which were assumed to be less selective than gillnets, were used to catch trout. Usually, two trap nets were fished per lake per sampling period and these nets were checked daily until a satisfactory sample of trout was obtained (at least 10 fish per strain per lake). If more than 15 fish per strain per lake were caught a random sample of 10 fish per strain in 1973 and 15 fish per strain in 1974 were taken for stomach analysis. Fork length and weight were taken for all fish caught (Appendices 2 and 3). Stomach samples were collected approximately once a month from July to September in 1973 and June till September in 1974 from each lake. Growth data in 1974 were obtained from a separate population dynamics study (Ayles et al. 1976). Gillnets were used in the summers of 1973 and 1974 when no fish could be caught by the trap nets. Gillnets and trap nets were used for the final harvest in the fall.

ANALYSIS OF GROWTH RATES

Differences in final harvest size between fish of different strains and fish from different lakes in 1973 and 1974 were examined by means of an unweighted analysis of variance (Snedecor and Cochran 1967).

Seasonal growth of trout in 1974 was analyzed by means of an asymptotic regression analysis computer program BMOOGR (Dixon 1974) on mean weights (log transformed) of trap-netted fish. Gompertz curves, which are S-shaped curves with a lower and upper asymptotic, gave the best fit to the data and were used to compare seasonal differences between strains and between lakes.

The seasonal changes in specific growth rate (% wet body weight/day, after Brown 1957 and Ricker 1975) were compared between each strain of 1973-74 trout in each lake except for Lake 318 in 1973 where partial summerkill (Barica 1975) developed.

Changes in specific growth rates were compared to the mean daily water temperature. Water temperature (surface and bottom) was recorded continuously with a Weksler recording thermometer. Mean daily temperature was calculated by summing the max and min values for each depth for each day and dividing by four. Due to daily fluctuations the data were analyzed in terms of five-point moving averages to provide smoother graphical presentation. In 1973 the water temperature of Lake 154, which is comparable to the lakes studied, was monitored and in 1974 Lake 318 was used.

ANALYSIS OF FOOD HABITS

In 1973 and 1974 captured trout were identified as to strain, measured and weighed, and individual stomachs were preserved in 10% formalin.

Food analysis initially involved the determination of number and weight of various food organisms present in individual stomachs. Absolute counts in some cases were difficult. Consequently it was often necessary to count head capsules or eyes rather than whole food items. In 1970-71 when cladocerans were the predominant food organism, the contents were subsampled because of the large number involved. Food items in 1970-71 were dried in an oven for 48 hours, at a temperature of 100 C. A freeze-drier was used in 1973-74 and the samples were dried for 24 hours. The dried samples were then weighed on an analytical balance.

Percent frequency of occurrence, total number and total dry weight were determined for each type of food organism. To compare the food habits of the two strains of trout and to compare food habits in different lakes a coefficient of similarity (Whittaker and Fairbanks 1958) was determined. This coefficient is based on the percent contribution of a consumption index (percent C.I.) for each food item, or simply the sum of the minimum values (percent C.I.) for a particular food organism eaten by both strains. Data were grouped according to the sampling interval, date and year. The consumption index (C.I.) was calculated using numerical and gravimetric values of food habit results, similar to that proposed by Godfrey (1955). The square root of the product of the number of fish in the sample that had consumed the organism and the average weight of that organism in the stomachs of all the fish in the sample were determined. This value was converted to a percentage of the total stomach content for the intervals under consideration. The total diet of each strain was also compared for each lake in 1973 and 1974 using Spearman rank correlation coefficient (Fritz 1974; Snedecor and Cochran 1967).

RESULTS AND DISCUSSION

GROWTH OF RAINBOW TROUT

The winterkill lakes in the Erickson area are highly productive lakes (Barica 1975). Rainbow trout fingerlings stocked in these lakes grew to the following size by fall with no supplemental feeding.

		Mean Weight (grams)	
Year	Days in Lake	at Stocking	at Harvest
1970	180	4.5	212
1971	183	1.7	217
1973*	184	8.7	372
1974	143	1.9	219

* Excluding Lake 318

Harvest weight was similar among years except in 1973 where larger fingerlings produced larger trout. An analysis of variance of the final size at harvest for both strains, in lakes 587 and 721 (Appendix 1), showed that Idaho were significantly heavier than Tunkwa trout but the trout were not significantly different between the two lakes. However, there was a significant interaction etween lakes and strains. Ayles (1975) found that the domestic strain, Idaho, grew better than the wild strain, Tunkwa, and that there were significant effects of the environment (lakes) and the genotype-environment interactions. He concluded that the environmental differences were mostly responsible for the variation in growth and survival but these have not yet been identified. The present results are in disagreement with Smith (1957) and Cordone and Nicole (1970) who suggested that wild trout do better in a vigorous environment than domestic trout. An analysis of variance comparing the final harvest size of the Idaho and Nisqually strains in each lake (Appendix 1) showed no significant difference in weight between strains in each lake but a significant difference was found in the size of trout between lakes.

The weights the fish reached in this study are within the range reported by Lawler et al. (1974) for rainbow trout stocked in the Erickson area from 1969 to 1972. Other studies have shown this great potential for trout production in underutilized lakes, such as Myers (MS. 1973) who obtained reasonable growth for rainbow trout fingerlings stocked in similar environments in south central North Dakota with mean weight gains of 270.6 and 128.6 g for 1.4 g fingerlings in 1971 and 208.7 for 6.9 g trout in 1972. Brynildson and Kempinger (1973) working in a soft-water lake in Wisconsin produced rainbow trout of mean weight of 242 g from 8 g fingerlings in 152 days. However, Johnson and Hasler (1954) obtained relatively poor growth ($\bar{x}$ = 104, 128, 154 g) for trout of 5.5 g stocked in three dystrophic lakes near the Wisconsin-Michigan border.

Trout growth in these natural water bodies with no supplemental feeding compares favorably with growth of trout reared in intensive culture situations where fish are grown under "optimum" conditions. For instance Murai and Andrews (1973) in a cage culture experiment obtained 256 g rainbow trout from 60 g fish in 112 days in fresh water of 21.3 C, but in brackish water of 30 o/oo trout grew to only 217 g at 13.5 C. This is only a mean weight gain of 196 and 157 g respectively, while at Erickson the mean gain in weight was 210 g. However, Tatum (1973) was able to provide trout of mean weight gain of 261 g from 93.8 g fish in 120 days when they were reared in cages at low density and high food ration in water of 20 o/oo salinity. Brett (1974) produced pan-size sockeye and pink salmon of 230 g from 4 g fish from tank culture; however, it took 280 days to grow such fish.

SEASONAL CHANGES IN GROWTH AND IN SPECIFIC GROWTH RATES

The seasonal changes in growth of different strains of rainbow trout are given in Appendices 2, 3 and 4. As discussed above, there were ignificant differences in seasonal growth between the Idaho and Tunkwa fish but not between the Idaho and Nisqually fish. For 1974 the growth curves of trout (strains combined) were:

Lake 318 $\ln Y = 6.157 - (5.360)(.988)^x$
Lake 587 $\ln Y = 6.185 - (5.494)(.988)^x$
Lake 721 $\ln Y = 7.535 - (6.927)(.992)^x$
Common curve $\ln Y = 6.696 - (5.945)(.989)^x$ (Fig. 1)

where Y = mean weight and x = growing days. Superimposing the growth curve of trout of each lake yielded very similar curves for the first 100 growing days; thereafter the trout of Lake 721 appeared to grow faster, followed by trout of Lake 318 and then Lake 587 trout.

Variability of growth of trout between lakes encountered in this study is a recognized problem and some of the factors responsible are discussed by Lawler et al. (1974), Ayles et al. (1976), Johnson and Hasler (1954) and Larkin et al. (1957). A possible explanation for the lower growth in Lake 587 is the occurrence of a partial summerkill in July, which has been described by Ayles et al. (1976). This condition killed an estimated 60% of the trout. This probably stressed the surviving fish which may have produced a growth depression, resulting in the lower growth by fall. However, removing this lake from the analysis of variance previously discussed still showed a significant difference in harvest size between trout of Lake 318 and 721. Ayles (1975) suggested that interspecific competition between trout and other fish (stickleback or minnows) may be an important factor. But in 1974 neither Lake 318 or 721 had other fish than trout. There are probably many factors such as "characteristic availability of food organisms" discussed by Larkin et al. (1957), and other physical factors and/or the interaction of several factors which are responsible for variability in growth.

An important factor in variable growth is the growth potential of different strains of trout. Vincent (1960), Flick and Webster (1964), Cordone and Nicole (1970) and Rawstron (1973) have observed differences in growth between strains of trout grown in natural environments. The variable growth observed in the 1974 study was not entirely due to genetic differences since the growth rate between the two domestic strains was not significantly different. There was a significant difference in size between lakes and also a significant strain-lake interaction, particularly when Lake 587 was included in the analysis. This shows that environmental differences were most likely the important factor in 1974.

The specific growth rate (% wet wt/day) of the 1973 and 1974 trout showed a marked seasonal change in both years and the pattern was similar (Fig. 2A) between strains within a lake and also between lakes for both years. There was a general decrease in specific growth rate with growing days (or aging), a low by the beginning of August, a sharp increase thereafter, then a drop to below 1% g/day by October. In 1973 the specific growth rate was lower than in 1974 during most of the season, and the second peak in growth rate was shifted to a much later time in the season. Similar observations of peaks and depressions of growth rates have been reported before for rainbow trout in a natural environment, notably by Johnson and Hasler (1954), Coche (1967) and Brynildson and Kempinger (1973). They related this variation to changes in water temperature since water temperature is one of the most important external environmental factors influencing the growth rate (Swift 1961).

As Johnson and Hasler (1954) and Brynildson and Kempinger (1973) showed, high water temperatures in July-August appear to severely affect the growth rate of trout (Fig. 2). In 1974 a low specific growth of 1.6% g/day was reached between day 200 and day 225 when the average mean daily water temperature was 20.7 C. In 1973 the specific growth rate was lower and the water temperature was 19.9 C. The trout seemed to grow best in June when the lake waters were warming up, averaging 15.2 C, and again in late summer when the water temperature was dropping. This second pulse of growth occurred at different times in 1973 and 1974 and it can be explained by the following table on the average mean daily water temperature.

Day	1973	1974
230-255	19.0(16.5 to 21.6)	14.2(10.8 to 17.8)
255-273	13.0(11.4 to 16.5)	10.7(8.8 to 12.2)

The growth pulses appear at approximately the same water temperature. Both the spring and late summer temperature of 15 C and 13-14 C are within the range of 11-16 C of preferred temperature of rainbow trout calculated by Garside and Tait (1958). However, Schaeperclaus (in Johnson and Hasler 1954) stated that rainbow trout grew most rapidly at 10 C and its optimum for rapid growth is within 15 to 20 C in fish ponds in Germany. Rainbow trout at Erickson tolerated very high water temperatures (24 C) and even grew well at high temperatures of 19 C, but it appears that the optimum temperature for growth for 1973-74 trout is within 12-16 C.

The lake waters of 1973 appeared to be warm for a longer period than in 1974 which may account for the differences in specific growth rate between years (Fig. 2B). However, the 1973 fingerlings were much larger at stocking than the 1974 fingerlings (Table 1). Brown (1946), Brett and Shelbourn (1975) and Elliott (1975) found that specific growth rate decreases with increasing size. This probably accounts for the lower seasonal specific growth rates in 1973 and also for differences between the spring and late summer pulses of growth observed in both years. The small trout in the spring would have a higher specific growth rate than large trout in late summer when grown at approximately the same temperature.

Brett and Shelbourn (1975) described the growth rate-weight relation of three salmonids, fed on full ration and grown at optimum temperatures, by the equation $\ln G = \ln a + b \ln W$ where G = specific growth rate and W = weight. The mean slope of the line for this relationship was $b = -.41 \pm 0.04$. This relationship was calculated for rainbow trout, assuming that is applicable for this species raised in a natural uncontrollable environment, and compared to the observed specific growth rate-weight relation of 1974 trout (Fig. 3). It showed that the 1974 trout at Erickson generally followed the expected decrease in growth rate with increase in size, and also that growth of trout in these lakes is as good if not better than trout reared under optimum conditions. However, the general pattern of seasonal variation in specific growth rate was maintained which strongly suggests the important influence of temperature on growth.

The growth curves of trout in the three lakes studied in 1974 were found to diverge after 100 days of introduction into the lake. This occurs at the same time as the appearance of the second pulse of growth. The model on changes of specific growth rate probably masks these differences in the growth curves. There is no direct evidence to explain this divergence, however Elliott (1975a,b) found that in brown trout food ration size, temperature and fish size are all very important in influencing growth rates. It is likely that food availability played an important role during the second pulse of growth since water temperature in all three lakes was likely in the optimum range and fish were approximately equal in size.

FOOD HABITS OF TROUT IN PRAIRIE WINTERKILL LAKES

Rainbow trout caught in the first four diel gillnetting periods of 1971 showed very little difference in food consumed within a 24-hour period (Fig. 4A). Therefore the stomach contents were pooled for each period (Appendices 5 & 6).

There was a marked, though regular, variation in food habits during the period of July to September 1970 and May through October in 1971 (Fig. 4B). Amphipods were the most important food organism consumed by trout except for May 25-26 and June 2-3 when young fish (4-6 g) fed heavily on chironomid larvae and cladocerans. However, both declined in the diet during the season, rarely occurring after August in 1971, but gained in importance through August and September in 1970.

A comparison of consumption indices, using the coefficient of similarity to express similarity of trout caught in similar periods in different years is shown in Fig. 4B. The diet is at least 66% similar, being most similar in July. The difference in August and September is due to the consumption of cladocerans and the increased evidence of corixids and *Chaoborus* larvae in 1970.

The seasonal variations in consumption are probably entirely related to changes in the relative abundance of the food organisms and/or to changes in size of the stocked trout. During May to September there was a marked reduction in the abundance of cladocerans and a corresponding increase in amphipods in samples taken from the limnetic zone (Holmstrom 1972). This zone was the region in which trout fed previously (Holmstrom 1972). Also the density of chironomid larvae was found to decrease steadily from a high of 9,970/m^2 on June 22 to 2,870/m^2 on August 30. This may account for the extent to which these organisms were utilized by trout. However there may be a size-dependent response ty rainbow trout as has been observed by Hartman (1958) and Galbraith (1967), where smaller trout consume smaller foods. Whatever the mechanism this lower consumption of amphipods in the spring is significant because it corresponds to the reproductive period of *Gammarus* (Biette 1969). This would allow for the perpetuation of *Gammarus* and also provide trout with a large prey population after spring.

The food organisms consumed in 1973 and 1974 by the different strains in any of the lakes studied was at least 66% similar (Appendices 7 & 8). Therefore, data from the different strains were combined for each lake. Mention of the food organisms eaten by some of the strains is made for dates when significant differences were apparent.

The food habits of 1973 trout showed marked differences between the 3 lakes studied as well as seasonal changes in diet (Fig. 5). The diet of the trout in each of these lakes can be described as follows:

1) In Lake 318 corixids were the dominant food organism, comprising from 44 to 92% C.I. by August. By September sticklebacks, *Culaea inconstans*, were also important but they were fed upon only by Idaho trout. Amphipods were fed upon in variable amounts in the season but never formed more than 24% C.I. for any period.

2) The trout of Lake 587 showed a progressive decrease in the consumption of amphipods in the season, from 80% to 5% C.I. by September. Sticklebacks, *Culaea inconstans*, and corixids became more important with the advancing season. Idaho trout consumed relatively more fish and at an earlier time in the season than Tunkwa trout.

3) In Lake 721, which had no fish other than trout, the trout fed mainly on amphipods and odonate naiads. This food comprised between 75 and 90% C.I. of the seasonal diet except for July (small sample size) when corixids formed 51% C.I. of the food eaten.

4) Zooplankton appeared in small amounts in the diet of trout and only in the early sample of July.

The differences between lakes were quantified by calculating and comparing the percentage similarity of each sampling period of each lake (Table 2). Almost all of the comparisons between time and lakes had a percentage similarity of less than 50%. Only Lake 318 showed some similarity to other lakes. In particular the September sample was similar to Lake 587 August and September samples where fish, corixids and amphipods formed about 84% C.I. of the diet. Also the July fish of Lake 318 had a diet similar to most of the Lake 721 fish. This was due to the importance of corixids, amphipods and partly to chironomids in their diet. Surprisingly fish from lakes 587 and 721 had little similarity in diet (Table 2) though in both lakes fish fed on amphipods they ate them at different times in the season.

Similarly in 1974 the trout showed marked seasonal differences in diet in the lakes studied (Fig. 5). Their diets are described as follows:

1) For all lakes in June cladocerans were an important food for the young fish, comprising at least 30% C.I.. They were also consumed thereafter

but to a much smaller extent.

2) In Lake 318 chironomids were also eaten by young fish in June and early July. However, *Chaoborus* became the dominant food in July, at least 60% C.I. By August and September *Chaoborus* Odonata naiads and amphipods became of equal importance to the trout.

3) Similarly in Lake 587 chironomids were highly fed upon by young fish. In July, the only other month that the lake was sampled, the trout had shifted to amphipods and corixids. Trout also fed on stickleback during this month. Only this lake had fish other than trout in 1974.

4) Odonata naiads and amphipods were the most important foods of Lake 721 fish. They amounted to at least 60% C.I. except for July when *Chaoborus* comprised 80% C.I.

Differences in diet in time and between lakes were quantified and it was found that 75% of the comparisons had less than 50% similarity (Table 3). In particular lakes 587 and 721 were different with not more than 38% similarity. Lakes 587 and 318 were also different except for June when fish in both lakes were feeding on cladocerans, *Chaoborus* and chironomids. The most similarity occurred between lakes 318 and 721. For example the June sample of Lake 721 was 57% similar to the August and September samples of Lake 318 because amphipods and Odonata naiads were eaten in both lakes. And in July fish from both lakes were feeding largely on *Chaoborus*. In August and September fish of both lakes were feeding primarily on these organisms, *Chaoborus*, amphipods and Odonata naiads.

The food habits of rainbow trout in the three lakes studied in 1973 and 1974 show clear differences between lakes within and between years. These differences clearly demonstrate that rainbow trout are versatile, opportunistic feeders, capable of exploiting a variety of food sources such as McAfee (1966) described them. This response is most likely dependent on prey availability and/or a size-dependent response as discussed for the 1971 trout. The diet in 1973-74 appeared to be more varied than in 1971, though the studies are not directly comparable since different sampling techniques were used.

There appeared to be a size-dependent response for food habits as the trout grew which was most notable in lakes which had other fish with trout. Generally the diet of the young trou- was composed of a mixture of plankton and insects, then as it grew it shifted to insects and crustaceans. This pattern is similar to that described by Scott and Crossman (1973) for rainbow trout.

RELATIONSHIP BETWEEN FOOD HABITS AND GROWTH PATTERNS

The changes in food habits relative to the changes in -rowth pattern of 1973-74 trout seems not to be related as the literature would suggest. For instance Scott anc Crossman (1973) stated that "the availability of other fish as food is often considered necessary for the attainment of large size by rainbow trout". In this study larger trout were obtained in 1973 and in Lake 587 trout fed partly on fish, with Idaho trout eating relatively more fish and at an earlier time than Tunkwa trout. The Idaho and Tunkwa trout, though significantly different in weight at harvest, were at the same size as those of Lake 721. Yet in Lake 721 only crustaceans and insects were available. This evidence is also striking because Lake 587 had a large population of sticklebacks, a highly probable competitor for the same food resource, yet it produced the same size trout as in Lake 721. Therefore food does not appear to be limiting, at least not for the density of trout stocked in these lakes, and this abundance of food appears able to support strains of rainbow trout with behavioral differences in feeding habits, such as lakes 587 and 721 suggest, with no detrimental effect on growth.

Also Larkin et al. (1957) found that when other fish besides rainbow trout were present in lakes, instantaneous growth rates were not linearly related to size. For example, they found in Paul Lake that trout grew slowly at small size because of competition with shiners for food, but when trout a-tained a larger size, preying on shiners, they embarked on a new growth relationship. But the seasonal change in specific growth rate observed in 1973-74 (Fig. 2) cannot be explained by change in feeding habits since this pattern occurred in trout living in lakes which had no other fish. However, the differences in the diets of trout in the lakes observed in this study may be as Larkin et al. (1957) suggested that "in each lake, a characteristic availability of food organisms determines the ratio of energy gained from food intake to energy expended in living processes". And the availability of food organisms can change within a season like Lake 103 in 1971 but remain the same between years, 1970-71, or change between years, 1973-74, and also vary between lakes in a year as lakes 318 and 721, 1974.

ACKNOWLEDGMENTS

Acknowledgments are extended to Dr. G.H. Lawler who supervised the 1970-71 aspects of the study and to Dr. G.B. Ayles who patiently and critically reviewed the manuscript. Thanks also go to members of the Aquaculture Project who assisted in the field work, and to the staff of the Freshwater Institute Graphic Services Department.

REFERENCES

AYLES, G.B. 1975. Influence of the genotype and the environment on growth and survival of rainbow trout (*Salmo gairdneri*) in central Canada aquaculture lakes. Aquaculture 6: 181-189.

AYLES, G.B., J.G.I. LARK, and H. KLING. 1976. Seasonal mortality of rainbow trout (*Salmo gairdneri*) planted in small eutrophic lakes of central Canada. J. Fish. Res. Board Can. 33: 647-655.

AYLES, G.B., and J.R. BRETT. 1978. Workshop on aquaculture research and development in Canada. Can. Fish. Mar. Serv. Tech. Rep. 750: iv + 20 p. + 191 p. microfiche appendices.

BARICA, J. 1975. Geochemistry and nutrient regime of saline eutrophic lakes in the Erickson-Elphinstone district of southwestern Manitoba.

Can. Fish. Mar. Serv. Res. Dev. Tech. Rep. 511: 82 p.

BERNARD, D.J., and B. VAN DER VEEN. 1974. A portable hot wire fish marking tool for field and laboratory use. Unpub. manuscript, Freshwater Institute Rockwood Hatchery, Activity Reports, No. 5: 8 p.

BIETTE, R.M. 1969. Life history and habitat differences between *Gammarus lacustris* and *Hyalella azteca* (Saussure) in West Blue Lake, Manitoba. M.Sc. Thesis, Univ. Manitoba, Winnipeg, Man. 98 p.

BRETT, J.R. 1974. Tank experiments of the culture of pan-size sockeye (*Oncorhynchus nerka*) and pink salmon (*O. gorbuscha*) using environmental control. Aquaculture 4: 341-352.

BRETT, J.R., and J.E. SHELBOURN. 1975. Growth rate of young sockeye salmon, *Oncorhynchus nerka*, in relation to fish size and ration level. J. Fish. Res. Board Can. 32: 2103-2110.

BROWN, M.E. 1946. The growth of brown trout (*Salmo trutta* Linn.) I. Factors influencing the growth of trout fry. J. Exp. Biol. 22: 118-129.

_____ 1957. Experimental studies of growth, p. 361-400. *In* M.E. Brown (ed.) Physiology of fishes. Vol. 1. Academic Press, Inc., New York, N.Y. 447 p.

BRYNILDSON, O.M., and J.J. KEMPINGER. 1973. Production, food and harvest of trout in Nebish Lake, Wisconsin. Wis. Dep. Nat. Resour. Res. Rep. 65: 20 p.

COCHE, A.G. 1967 Production of juvenile steelhead trout in a fresh-water impoundment. Ecol. Monogr. 37: 200-228.

CORDONE, A.J., and S.I. NICOLA. 1970. Harvest of four strains of rainbow trout, *Salmo gairdneri*, from Beardsley reservoir, California. Calif. Fish Game 56: 271-187.

DIXON, W.J. (ed.). 1974. BMD biomedical computer programs. University of California Press, Berkeley and Los Angeles, Calif. 773 p.

ELLIOTT, J.M. 1975a. The growth rate of brown trout (*Salmo trutta* L.) fed on maximum rations. J. Anim. Ecol. 44: 805-821.

_____ 1975b. The growth of brown trout (*Salmo trutta* L.) fed on reduced rations. J. Anim. Ecol. 44: 823-842.

FLICK, W.A., and D.A. WEBSTER. 1964. Comparative first year survival and production of wild and domestic strains of brook trout, *Salvelinus fontinalis*. Trans. Am. Fish. Soc. 93: 59-69.

FRITZ, E.S. 1974. Total diet comparison in fishes by Spearman rank correlation coefficients. Copeia 1974: 210-214.

GALBRAITH, M.G. 1967. Size-selective predation on *Daphnia* by rainbow trout and yellow perch. Trans. Am. Fish. Soc. 96: 1-10.

GARSIDE, E.T., and J.S. TAIT. 1958. Preferred temperature of rainbow trout (*Salmo gairdneri* Richardson) and its unusual relationship to acclimation temperature. Can. J. Zool. 36: 563-567.

GODFREY, H. 1955. On the ecology of Skeena River whitefish, *Coregonus* and *Prosopium*. J. Fish. Res. Board Can. 12: 599-531.

HARTMAN, G.F. 1958. Mouth size and food size in young rainbow trout, *Salmo gairdneri* L. Copeia 1958: 233-234.

HOLMSTROM, C.C. 1972. Food habits, feeding selectivity, gastric digestion rates, and daily ration of rainbow trout, *Salmo gairdneri* Richardson, in western Manitoba winterkill lakes. M.Sc. Thesis. Univ. Manitoba, Winnipeg, Man. 109 p.

JEFFERTS, K.B., P.K. BERGMAN, and H.F. FISCUS. 1963. A coded wire identification system for macro-organisms. Nature (London) 198: 460-462.

JOHNSON, L., G.H. LAWLER, and L.A. Sunde. 1970. Rainbow trout farming in central Canada. Fish. Res. Board Can. Tech. Rep. 165: 17 p.

JOHNSON, W.E., and A.D. HASLER. 1954. Rainbow trout production in dystrophic lakes. J. Wildl. Manage. 18: 113-134.

LARKIN, P.A., J.G. TERPENNING, and R.R. PARKER. 1957. Size as a determinant of growth rate in rainbow trout, *Salmo gairdneri*. Trans. Am. Fish. Soc. 86: 84-96.

LAWLER, G.H., L.A. SUNDE, and J. WHITAKER. 1974. Trout production in prairie ponds. J. Fish. Res. Board Can. 31: 929-936.

Mc AFEE, W.R. 1966. Rainbow trout, p. 192-215. *In* A. Calhoun (ed.). Inland fisheries management. State of California, The Resources Agency, Department Fish and Game.

MURAI, T., and J.W. ANDREWS. 1972. Growth and food conversion of rainbow trout reared in brackish and freshwater. U.S. Natl. Mar. Fish. Serv. Fish. Bull. 70: 1293-1295.

MYERS, G.L. 1973. Paririe pothole ecology and the feasibility of growing rainbow trout (*Salmo gairdneri* Richardson) in prairie potholes. M.Sc. Thesis. North Dakota State Univ., Fargo, N.D. 91 p.

RAWSTRON, R.R. 1973. Harvest, mortality and cost of three domestic strains of tagged rainbow trout stocked in large California impoundments. Calif. Fish Game 59: 245-265.

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

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

SMITH, S.B. 1957. Survival and growth of wild and hatchery rainbow trout (*Salmo gairdneri*) in Corbett Lake, British Columbia. Can. Fish Cult. 20: 7-12.

SNEDECOR, G.W., and W.G. COCHRAN. 1967. Statistical methods. 6th ed. Iowa State University Press, Ames, Iowa. 465 p.

SUNDE, L.A., J. WHITAKER, and G.H. LAWLER. 1970. Rainbow trout production in winterkill lakes, p. 57-65. *In* E. Schneberger (ed.) A Symposium on the Management of Midwestern Winterkill Lakes. Am. Fish. Soc. North Central Div. Spec. Publ. 1: 75 p.

SUNDE, L.A., and J. BARICA. 1975. Geography and lake morphometry of the aquaculture study area in the Erickson-Elphinstone district of southwestern Manitoba. Can. Fish. Mar. Serv. Res. Dev. Tech. Rep. 510: 32 p.

SWIFT, D.R. 1961. The annual growth-rate cycle in brown trout (*Salmo trutta* Linn.) and its cause. J. Exp. Biol. 38: 595-604

TATUM, W.M. 1973. Brackish water cage culture of rainbow trout (*Salmo gairdneri*) in south Alabama. Trans. Am. Fish. Soc. 102: 826-828.

VINCENT, R.F. 1960. Some influences of domestication upon three stocks of brook trout (*Salvelinus fontinalis* Mitchill). Trans. Am. Fish. Soc. 89: 35-52.

WHITTAKER, R.H., and C.W. FAIRBANKS. 1958. A study of plankton copepod communities in the Columbia basin, southeastern Washington. Ecology 39: 46-55.

Table 1. Lake morphometry, planting rates and sizes of trout, of lakes stocked with different strains of rainbow trout in 1970, 1971, 1973 and 1974.

Lake	Year	Area (ha)	Depth (m) Max.	Depth (m) Mean	Strains	Trout planting: Date planted	Trout planting: No/ha	Trout planting: Mean Size (g)
103	1970	10.1	1.5	0.6	Pennask	May 15	750	4.50
.	1971	.	.	.	Livingstone	May 5	.	1.70
318	1973	21.9	2.4	1.2	Idaho	May 4	238	4.40
.	.	.	.	.	Tunkwa	.	.	4.88
.	1974	.	.	.	Idaho	May 23	.	1.93
.	.	.	.	.	Nisqually	.	.	2.15
587	1973	6.9	4.0	2.5	Idaho	May 11	247	10.80
.	.	.	.	.	Tunkwa	.	.	9.45
.	1974	.	.	.	Idaho	May 18	.	1.87
.	.	.	.	.	Nisqually	.	.	1.93
721	1973	6.5	3.0	1.6	Idaho	May 11	216	6.67
.	.	.	.	.	Tunkwa	.	.	7.96
.	1974	.	.	.	Idaho	May 16	.	1.87
.	.	.	.	.	Nisqually	.	.	1.93

Table 2. The percentage similarity in food habits of the combined Idaho and Tunkwa rainbow trout strains stocked in 1973 in lakes 318, 587 and 721.

	L. 318				L. 587				L. 721			
	July 5	July 26	Aug. 14	Sept. 19	July 5	July 26	Aug. 14	Sept. 19	July 5	July 26	Aug. 14	Sept. 19
L. 318												
July 5	100.0	49.9	49.0	47.6	36.5	30.7	42.6	39.6	26.6	77.1	27.9	27.5
July 26		100.0	89.9	36.3	6.1	14.6	39.2	42.6	5.8	56.8	5.8	4.0
Aug. 14			100.0	31.1	8.1	11.8	34.0	37.5	5.0	56.0	5.0	5.0
Sept.19				100.0	26.5	40.1	82.1	74.8	14.8	46.3	20.1	21.5
L. 587												
July 5					100.0	67.3	16.6	9.4	21.6	31.6	48.2	32.7
July 26						100.0	34.2	23.6	23.9	33.0	44.6	29.3
Aug. 14							100.0	82.4	16.1	42.6	13.5	13.5
Sept.19								100.0	5.1	37.6	5.1	5.1
L. 721												
July 5									100.0	19.8	70.2	75.8
July 26										100.0	31.6	29.0
Aug. 14											100.0	81.4
Sept.19												100.0

Table 3. The percentage similarity in food habits of the combined Idaho and Nisqually rainbow trout strains stocked in 1974 in lakes 318, 587 and 721.

	L. 318					L. 587			L. 721			
	June 26	July 9	July 23	Aug. 22	Sept. 19	June 20	July 9	July 18	June 14	July 12	Aug. 8	Sept. 13
L. 318												
June 26	100.0	23.2	16.6	24.3	22.0	73.9	12.8	4.0	32.0	9.7	18.5	13.6
July 9		100.0	60.7	14.6	13.0	32.7	12.9	4.0	2.1	69.8	19.0	12.4
July 23			100.0	15.2	15.2	6.2	7.6	4.4	7.6	77.0	15.2	14.9
Aug. 22				100.0	79.2	21.2	32.7	24.8	57.7	27.4	57.2	79.5
Sept.19					100.0	18.8	24.8	29.3	57.1	27.4	64.0	74.6
L. 587												
June 20						100.0	21.5	4.0	38.1	11.8	18.5	10.4
July 9							100.0	56.6	25.4	10.7	28.0	19.9
July 18								100.0	33.6	2.0	35.5	23.5
L. 721												
June 14									100.0	14.1	60.3	59.2
July 12										100.0	30.5	27.4
Aug. 8											100.0	60.7
Sept.13												100.0

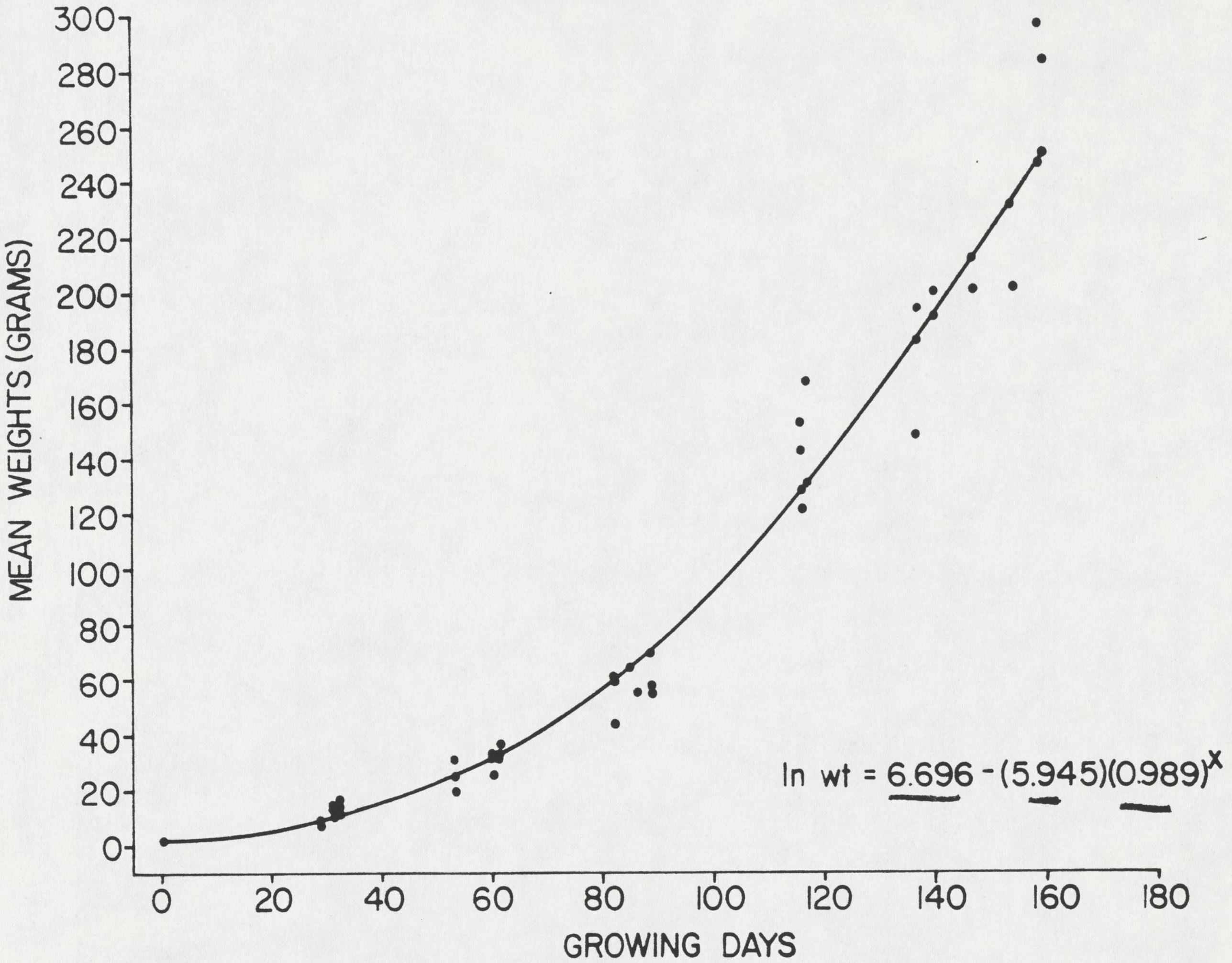

Fig. 1. The growth curve of the 1974 trout expressed by the Gompertz growth curve.

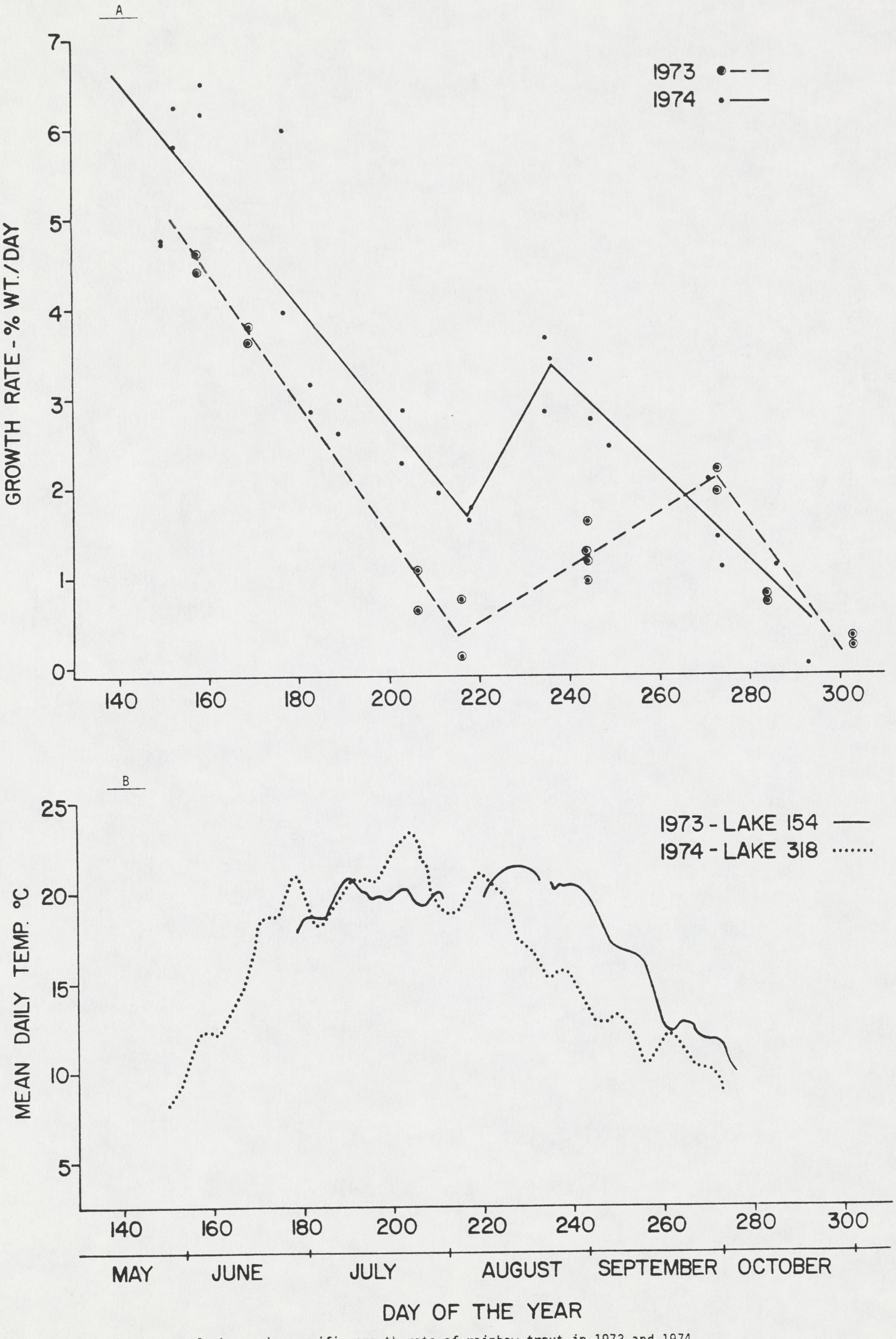

Fig. 2 A. The seasonal change in specific growth rate of rainbow trout in 1973 and 1974.

B. The mean daily water temperature of Lake 154 in 1973 and Lake 318 in 1974.

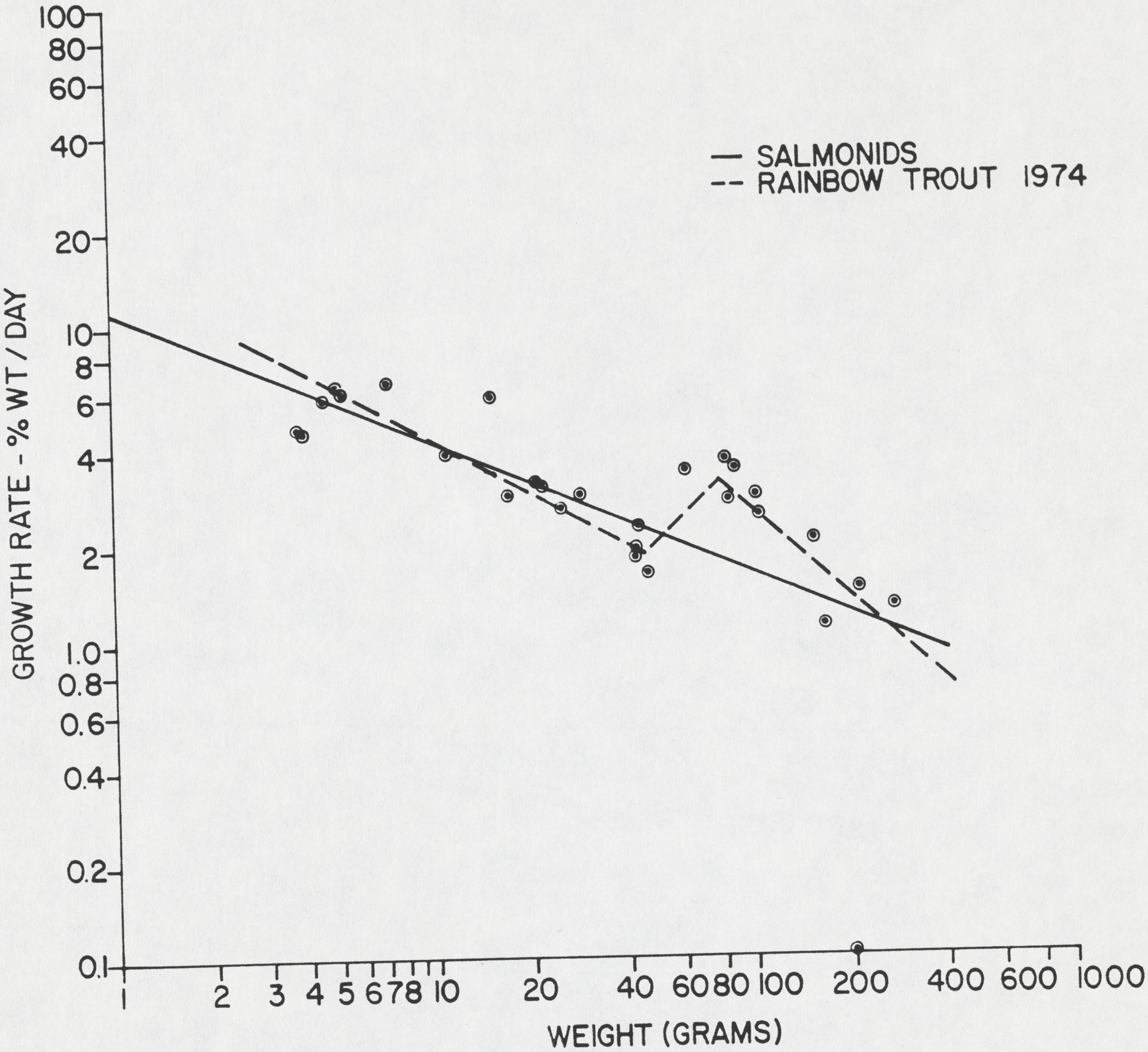

Fig. 3. The growth rate-weight relation of rainbow trout, 1974, grown in a natural environment and compared to the relationship calculated for salmonids grown under optimum temperature from Brett and Shelbourn (1975).

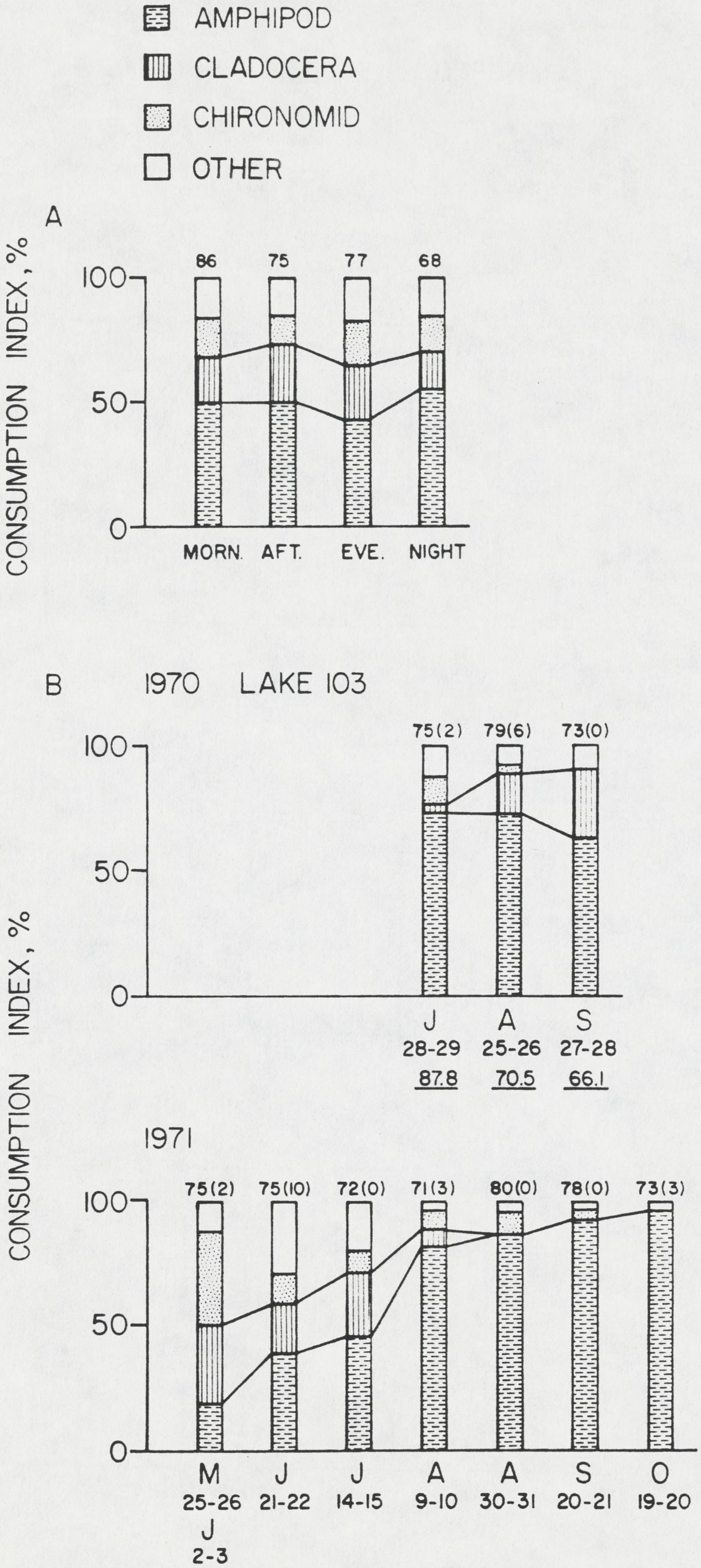

Fig. 4. Relative importance of major food organisms in Lake 103 trout stomachs.

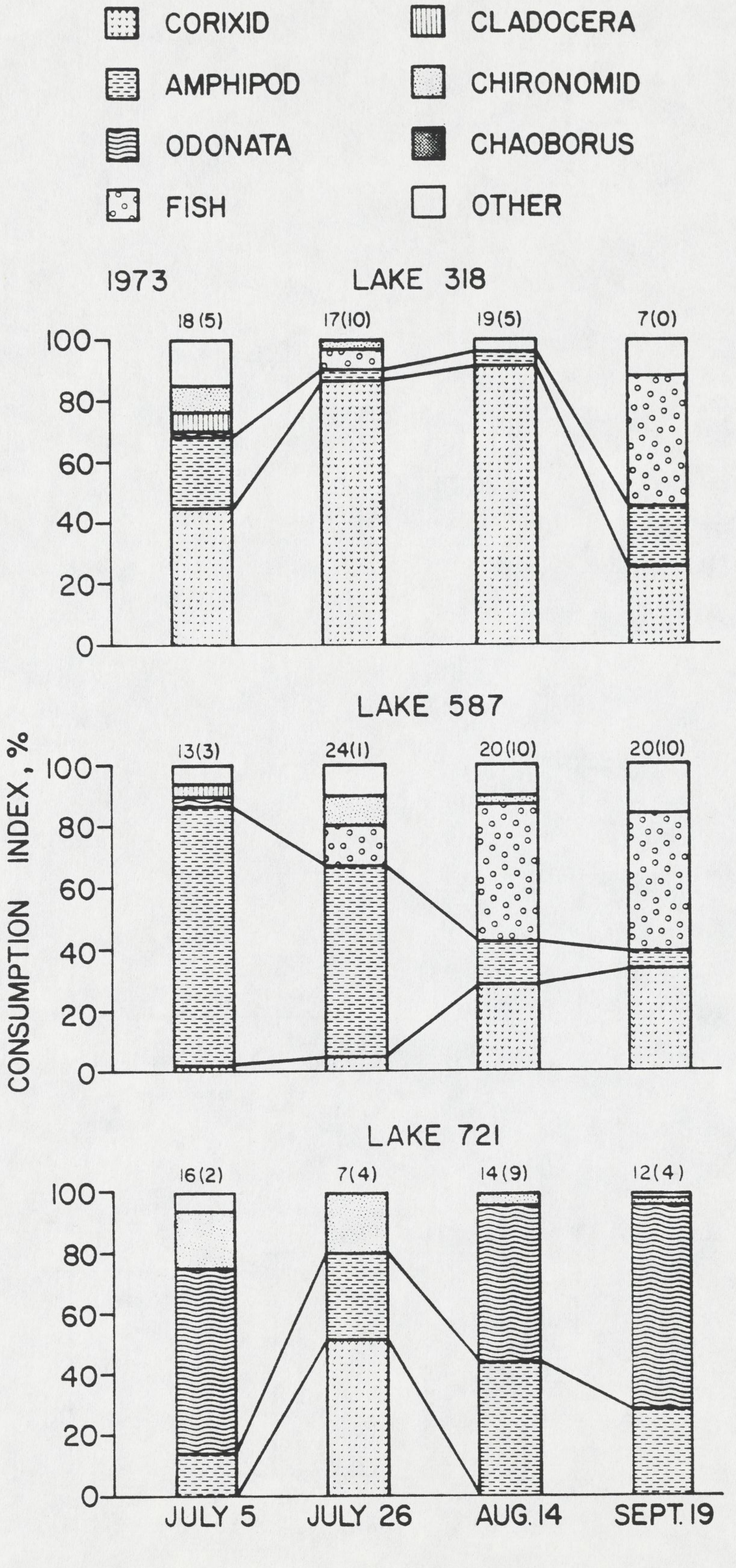

Fig. 5. Relative importance of major food organisms in stomachs of trout of 1973 in lakes 318, 587 and 721, based on consumption index and expressed as a percentage.

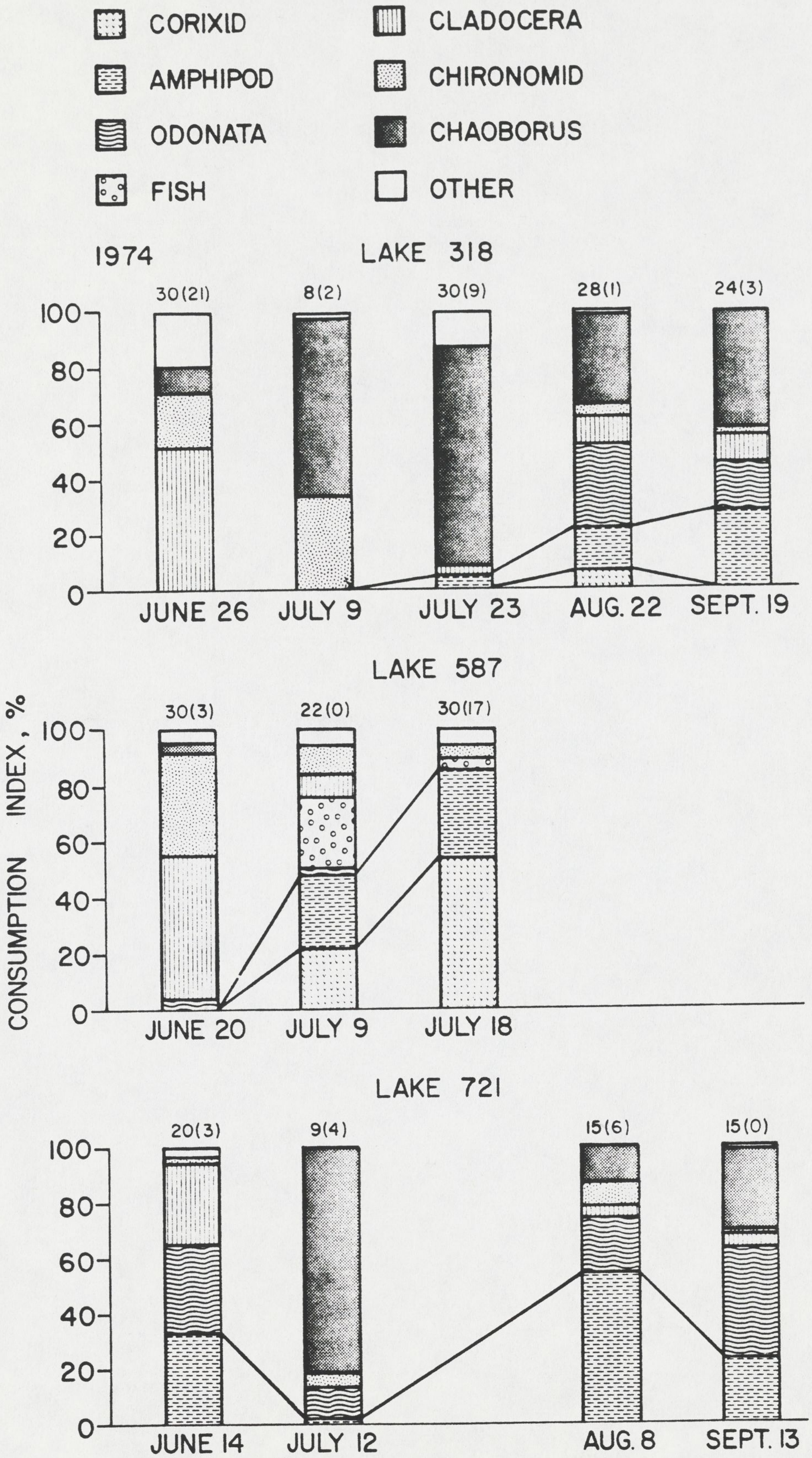

Fig. 6. Relative importance of major food organisms in stomachs of trout in 1974 in lakes 318, 587 and 721, based on consumption index and expressed as a percentage.

Appendix 1.

Analysis of variance of the weight (log transformed) of rainbow trout at the time of harvest in 1974 for lakes 318, 587 and 721.

Source	df	SS	MS	F
Lakes	2	1.676	.838	35.609**
Strains	1	0.026	.026	1.120
L x S interaction	2	0.181	.091	3.850*
Within	373		.023	

Analysis of variance of the weight (log transformed) of rainbow trout at the time of harvest in 1974 for lakes 318 and 721 only.

Source	df	SS	MS	F
Lakes	1	0.840	.840	72.431**
Strains	1	0.002	0.002	.215
L x S interaction	1	0.009	0.009	.774
Within	145		0.012	

Analysis of variance of weight (log transformed) of rainbow trout at the time of harvest in 1973 for lakes 587 and 721 only.

Source	df	SS	MS	F
Lakes	1	0.077	0.077	0.462
Strains	1	2.178	2.178	130.044**
L x S interaction	1	0.730	0.730	43.723II
Within	372		0.017	

* indicates P <.10
** indicates P <.01

Appendix 2. Comparison of growth rate data for Lake 103 rainbow trout in 1970 and 1971.

1970			1971		
Sampling date	Sample size	Mean wet wt.(g)	Sampling date	Sample size	Mean wet wt.(g)
[1] May 15		4.5	[1] May 5		1.7
			May 25	46	5.8
			June 2	36	6.6
			June 22	167	42.4
July 8	25	73.9	July 14	91	61.3
July 28	224	84.8	July 29	17	103.1
			Aug. 9	190	107.7
Aug. 25	193	115.7	Aug. 30	123	133.5
Sept. 27	105	209.6	Sept. 10	108	184.8
			Oct. 20	87	210.1
[2] Oct. 6 - Dec. 17	2207	216.4	[2] Oct. 14 - Nov. 25	1758	219.1

[1] Date of stocking

[2] Range of harvest dates

Appendix 3. Summary of the growth of two strains of rainbow trout in 1973.

Strain	Lake	Gear*	Day sampled	Days of growth	Number of fish	Weight (grams) Mean	S D	Range	Fork length (mm) Mean	S D	Range
Idaho	318		May 4	0	5200	4.40					
		1	July 5-6	62	4	38.25	20.22	19- 65	135.5	24.28	109-162
		1	July 26-27	83	5	89.80	38.64	36-132	181.60	28.17	138-211
		1	Aug 14-15	102	7	114.43	22.02	83-150	196.57	15.93	173-221
		1	Sept 19	138	2	153.50	34.65	129-178	221.50	6.36	217-226
Tunkwa	318		May 4	0	5200	4.88					
		1	July 5-6	62	12	47.00	16.99	23- 70	159.67	15.21	126-190
		1	July 26-27	83	16	72.75	25.55	14-110	181.13	22.74	115-207
		1	Aug 14-15	102	28	69.07	29.96	32-162	181.18	25.01	115-224
		1	Sept 19	138	5	46.20	17.18	25- 60	169.60	19.17	144-185
		2	Nov 2	182	5	77.60	37.15	43-128	194.80	30.97	163-233
Idaho	587		May 11	0	1700	10.80					
		1	July 5-6	55	9	132.89	40.77	70-205	196.89	18.82	174-228
		2	July 27	77	11	180.73	40.14	110-234	219-36	14.83	195-240
		1	Aug 14	95	10	212.50	66.11	136-349	235.70	22.81	200-275
		1	Sept 19	131	10	377.80	108.04	207-470	286.20	24.78	238-316
		1	**Nov 4	177	50	521.12	149.61	135-871	310.76	29.88	207-369
Tunkwa	587		May 11	0	1700	9.45					
		1	July 5-6	55	4	87.00	39.68	30-122	187.50	31.51	141-211
		2	July 27	77	12	160.17	35.28	105-230	228.58	17.21	201-260
		1	Aug 14	95	10	137.60	31.23	94-190	222.40	16.10	197-243
		1	Sept 19	131	10	192.70	58.14	101-326	250.80	19.66	213-290
		1	**Nov 4	177	50	269.98	90.03	113-567	279.66	23.16	221-339
Idaho	721		May 11	0	1400	6.67					
		2	July 5-6	55	9	106.44	21.62	74-135	186.33	14.64	168-204
		1	July 26-27	77	4	119.00	14.28	104-138	198.25	1.71	196-200
		1	Aug 14-15	95	5	137.00	30.43	106-172	209.60	13.28	196-223
		1	Sept 19	131	3	218.33	27.06	195-248	236.67	10.41	225-245
		2	Oct 11	153	38	355.32	93.38	142-522	273.55	22.22	222-312
		2	***Nov 19	192	30	397.83	80.93	243-632	286.97	18.04	248-327
Tunkwa	721		May 11	0	1400	7.96					
		2	July 5-6	55	7	107.71	14.55	94-134	197.71	8.58	188-213
		1	July 26-27	77	4	126.00	22.38	110-159	218.00	10.10	215-233
		1	Aug 14-15	95	9	128.89	54.08	62-214	219.67	26.87	177-266
		1	Sept 19	131	9	196.78	80.21	106-330	250.00	32.27	211-298
		2	Oct 11	153	100	296.73	85.16	113-551	275.12	24.93	196-329
		2	***Nov 19	192	101	334.55	84.07	122-532	290.30	23.47	216-343

* Gear 1-Trap nets 2-Gillnets

** pooled Nov 2 and 6 samples

*** pooled Nov 17, 19 and 21 samples

Appendix 4. Summary of the growth of two strains of rainbow trout in 1974.

Strain	Lake	Gear*	Day sampled	Days of growth	Number of fish	Weight (grams) Mean	Weight (grams) S D	Weight (grams) Range	Fork length (mm) Mean	Fork length (mm) S D	Fork length (mm) Range
Idaho	318		May 23	0	5400	1.93					
		1	June 24	32	40	13.98	3.18	8- 20	9.78	0.75	7.6-11.2
		2	July 9	47	2	11.00	1.41	10- 12	9.55	0.64	9.1-10.0
		1	July 23	61	72	33.19	7.26	10- 48	12.79	0.99	9.7-14.6
		1	Aug 19	88	26	58.62	20.87	15- 88	15.21	1.71	10.5-17.4
		1	Aug 21	90	17	51.06	24.09	12- 85	14.50	2.42	10.5-17.1
		1	Sept 16	116	36	142.47	42.59	70-208	17.34	3.86	8.0-22.5
		1	Oct 17	148	19	200.11	43.37	141-306	22.68	1.76	19.7-26.3
		2	Oct 19	149	17	197.24	30.67	145-253	23.26	1.05	21.2-24.6
		2	Oct 30	160	13	204.15	59.13	95-304	23.22	2.34	18.2-26.0
Nisqually	318		May 23	0	5400	2.15					
		1	June 24	32	107	17.26	11.47	7- 26	10.30	1.05	6.4-14.3
		2	July 9	47	6	15.17	4.75	10- 22	10.88	0.92	10.1-12.3
		1	July 23	61	78	36.72	9.11	14- 61	13.41	1.11	10.3-16.0
		1	Aug 19	88	108	61.19	24.95	15-112	15.37	2.29	10.0-18.9
		1	Aug 21	90	15	54.73	32.08	30-116	14.91	2.23	12.2-19.0
		1	Sept 16	116	80	121.37	36.06	40-187	19.40	2.83	5.5-23.7
		1	Oct 10	140	50	199.94	48.18	85-328	23.47	1.83	17.5-28.5
Idaho	587		May 18	0	1700	1.87					
		1	June 18	31	12	11.33	2.10	4- 16	8.81	0.56	8.1- 9.7
		2	July 9	52	5	15.60	5.55	10- 24	10.78	0.85	9.8-12.0
		1	July 17	60	14	26.00	4.74	15- 32	12.19	1.02	9.4-13.6
		2	Oct 2	137	24	148.08	52.28	84-250	20.99	2.19	16.6-24.8
Nisqually	587		May 18	0	1700	1.93					
		1	June 18	31	91	13.40	3.82	7- 25	9.53	0.93	6.7-11.7
		2	July 9	52	17	31.53	15.82	10- 64	12.81	1.66	10.2-15.7
		1	July 17	60	96	33.74	9.93	9- 63	13.17	1.40	7.0-16.9
		1	Aug 12	86	7	55.57	26.48	30-100	15.39	1.86	13.0-18.2
		2	Oct 2	137	208	193.73	74.01	48-408	20.69	2.54	15.3-27.8
Idaho	721		May 16	0	1600	1.87					
		1	June 14	29	10	7.40	2.63	4- 10	8.57	0.74	7.3- 9.5
		1	July 8	53	8	19.13	8.37	9- 34	11.05	1.39	9.1-13.3
		2	July 12	57	1	49.0	-	-	14.10	-	-
		1	Aug 6	82	8	43.87	9.31	25- 55	14.46	1.07	12.2-15.4
		1	Sept 9	116	4	152.00	22.04	125-170	20.70	0.95	19.3-21.4
		2	Oct 22	159	33	297.12	57.76	150-402	24.63	2.79	14.7-28.1
Nisqually	721		May 16	0	1600	1.93					
		1	June 14	29	7	7.57	4.08	3- 14	9.01	1.28	6.7-10.2
		1	July 8	53	49	31.84	9.28	10- 54	13.00	1.13	10.2-15.0
		2	July 12	57	8	45.00	9.44	32- 56	13.81	0.89	12.8-15.1
		1	Aug 6	82	49	61.32	15.81	31-107	16.13	1.32	13.2-19.5
		1	Sept 9	116	25	151.92	49.07	25-240	20.93	2.82	12.0-24.2
		1	Sept 12	119	32	181.81	39.36	83-240	21.94	1.56	17.3-24.5
		1	Oct 23	160	15	284.27	87.04	119-440	25.15	2.59	19.9-28.5

* Gear 1-Trap nets, 2-Gillnets

Appendix 5. Number and dry weight of major food organisms in the stomachs of 1973 rainbow trout (strains combined).

Lake	Date	No. of fish	Chironomids No.	Chironomids Wt(g)	Chaoborus No.	Chaoborus Wt(g)	Corixidae No.	Corixidae Wt(g)	Odonata No.	Odonata Wt(g)	Amphipods No.	Amphipods Wt(g)	Cladocerans No.	Cladocerans Wt(g)	Fish No.	Fish Wt(g)	Other No.	Other Wt(g)
318	0507	13	21	0.012			52	0.168	1	.001	45	.071	69	.028			8	.066
	2607	7	1	.002			72	.302			1	.002			2	.012		
	1408	14					211	1.122			10	.046					3	.013
	1909						21	.130			20	.103			21	.688	5	.026
7	0507	10					1	.007	1	.009	86	.526	27	.003			4	.011
	2607	23	77	.228			19	.042	1	.001	773	3.404	24	.001	14	.767	33	.300
	1408	10	2	.006			26	.127			46	.163			6	.606	2	.044
	1909	10	1	--			76	.596			34	.043			15	1.474	8	.123
721	0607	14	111	.163	3	.001			198	1.549	117	.133	5	.001			23	.071
	2707	3	10	.008			18	.024			10	.005						
	1408	5	1	.001					20	.058	69	.053						
	1909	8	1	.001					100	.442	58	.071					1	.001

Appendix 6. Number and dry weight of major food organisms in the stomachs of 1974 rainbow trout (strains combined).

Lake	Date	No. of fish	Chironomids No.	Chironomids Wt(g)	Chaoborus No.	Chaoborus Wt(g)	Corixidae No.	Corixidae Wt(g)	Odonata No.	Odonata Wt(g)	Amphipods No.	Amphipods Wt(g)	Cladocerans No.	Cladocerans Wt(g)	Fish No.	Fish Wt(g)	Other No.	Other Wt(g)
318	2606	9	10	.001	5	.001							120	.004			4	.004
	0907	6	81	.051	251	.183							4	--			3	.002
	2307	9	79	.069							2	.001	10	.001			7	.008
	2208	27	18	.025	1775	.737	24	.089	273	.581	175	.175	903	.082			16	.006
	1909	21	7	.013	3035	1.536	36	.241	92	.428	229	.708	954	.133			2	.001
587	2006	27	211	.074	16	.002	2	.001	2	.005			2098	.094			28	.010
	0907	22	29	.049			227	.293	1	.006	24	.098	194	.042	15	.434	9	.019
	1807	13	2	.002			33	.068			12	.029			1	.006	2	.004
721	1406	17	5	.001					54	.065	27	.097	610	.054			2	.003
	0907	5	3	.004	201	.141			2	.010	2	.001						
	0808	9	2	.002	13	.006	1	.001	5	.013	78	.029	6	.001				
	1309	15	4	.004	978	.542			201	1.039	271	.359	35	.008			6	.002

Appendix 7. Comparison of the food consumed by each strain of trout in 1973 in each of the three lakes. (% C.I. = percentage of total consumption index, Nr = number of ranks, r = Spearman rank correlation coefficient.)

Food organisms	Lake 318 Idaho % C.I.	Lake 318 Tunkwa % C.I.	Lake 587 Idaho % C.I.	Lake 587 Tunkwa % C.I.	Lake 721 Idaho % C.I.	Lake 721 Tunkwa % C.I.
Diptera (adult)				1.6		
Chironomidae	1.6	2.5	1.2	8.0	13.2	13.4
Chaoborinae						
Hemiptera (adult)			1.5	2.3		
Corixidae	49.0	75.0	11.0	19.4		4.7
Coleoptera			0.9	1.1		
Dytiscidae	5.2	2.9		0.7	7.2	
Haliplidae		2.9	0.01	1.4		0.8
Gyrinidae		3.8	0.4	1.1		
Odonata						
Zygoptera			1.0		62.4	55.3
Maphipoda	10.3	15.4	36.7	49.5	17.2	26.0
Cladocera		2.3	0.9	.01		
Gastropoda				1.6		
Hirudinea	2.4		2.3			
Salamander			3.2			
Fish	31.4		41.0	10.7		
Number of fish	14	27	28	25	16	14
Percentage similarity	60.9		62.4		85.7	
Nr	9		15		6	
r	0.1000		0.3221		0.8114	
t - test	0.2659		1.2267		2.7766	
Probability	>0.1		>0.1		>0.1	

Appendix 8. Comparison of the food consumed by each strain of trout in 1974 in each of the three lakes. (% C.I. = percentage of total consumption index, Nr = number of ranks, r = Spearman rank correlation coefficient.)

Food organisms	Lake 318 Idaho % C.I.	Lake 318 Nisqually % C.I.	Lake 587 Idaho % C.I.	Lake 587 Nisqually % C.I.	Lake 721 Idaho % C.I.	Lake 721 Nisqually % C.I.
Diptera						
Chironomidae	3.1	5.4	27.2	12.1	1.9	1.9
Chaoborinae	42.7	40.9			6.9	29.9
Hemiptera						
Corixidae	7.9	3.0	27.6	28.4		
Coleoptera	0.01	0.01				
Dytiscidae			3.4		2.7	.01
Haliplidae			1.8			
Gyrinidae	1.1	.01				
Odonata						
Zygoptera	11.8	21.7	1.8	1.6	28.8	38.1
Ephemeroptera				4.9		
Amphipoda	17.6	20.6	12.9	12.8	33.9	24.2
Cladocera	15.7	7.8	23.6	16.3	25.8	5.2
Gastropoda						
Hirudinea						
Salamander						
Fish			1.8	23.4		
Number of fish	27	45	27	35	10	36
Percentage similarity	84.2		72.2		67.0	
Nr	8		9		6	
r	0.8857		0.5200		0.6572	
t - test	4.6708		1.6107		1.7439	
Probability	<0.01		>0.1		>0.1	

Comparative growth and survival of matched plantings of wild and domestic rainbow trout in prairie potholes

by

G.B. Ayles

FISHERIES RESEARCH BOARD OF CANADA

TECHNICAL REPORT NO. 382

FRB

1973

FISHERIES RESEARCH BOARD OF CANADA

Technical Reports

FRB Technical Reports are research documents that are of sufficient importance to be preserved, but which for some reason are not appropriate for primary scientific publication. No restriction is placed on subject matter and the series should reflect the broad research interests of FRB.

These Reports can be cited in publications, but care should be taken to indicate their manuscript status. Some of the material in these Reports will eventually appear in the primary scientific literature.

Inquiries concerning any particular Report should be directed to the issuing FRB establishment which is indicated on the title page.

FISHERIES RESEARCH BOARD OF CANADA

TECHNICAL REPORT NO. 382

Comparative growth and survival of matched plantings of wild and domestic rainbow trout in prairie potholes

G. B. Ayles

This is the thirty-second
FRB Technical Report from the
Fisheries Research Board of Canada
Freshwater Institute
Winnipeg, Manitoba

1973

Abstract

Matched plantings were made in May 1972 of a wild strain and of two size groups of a domestic strain of rainbow trout in 10 prairie pothole lakes of Manitoba. The trout were harvested as marketable fish (over 200 g) in the fall of 1972. The growth and survival of fish from the domestic strain was better than that of the fish from the wild strain. There was considerable variability between lakes and there was significant lake X strain interaction.

The results indicate that the cross breeding of different strains would lead to the greatest increase in growth and survival of trout in these lakes.

Introduction

The Canadian prairies contain thousands of small, shallow, highly productive lakes, many of which are devoid of native stocks of fish due to the regular incidence of winterkill (Johnson et al. 1970).

In 1968 a research program was initiated by the Fisheries Research Board of Canada with the objective of establishing the potential for a prairie trout farming industry. Rainbow trout can be planted in the spring as fingerlings and harvested at a commercial size in the fall (Johnson et al. 1970; Sunde et al. 1970).

Associated with this program is a project, the objective of which is to produce a trout more suited to the atypical rainbow trout environment of these prairie pothole lakes than strains currently available.

These lakes provide a unique field laboratory for the evaluation of different stocks of fish. Attempts to evaluate the performance of different strains in the wild (Flick and Webster 1964; Cordone and Nicola 1970) have been hampered by logistics problems which do not permit the implementation of a sound experimental design. Conditions in the study area (Sunde et al. 1970) facilitate a field evaluation of differences between stocks, differences between lakes and interactions between stocks and lakes.

This paper reports the results of initial matched plantings of a wild stock and two size groups of a domestic stock (total of three lots of fish) made in 10 winterkill lakes in April 1972. The fish were harvested in the fall of 1972 and the survival and growth estimated for each lot.

Methods

The wild stock used was from Pennask Lake, British Columbia, while the domestic stock was from a commercial hatchery in Idaho. Fish were received as eyed eggs and were raised in the Fisheries Research Board experimental hatchery north of Winnipeg, Manitoba. Pennask fish were obtained in July 1971 and the domestic fish were received in November 1971 (Idaho #1) and February 1972 (Idaho #2). Their rates of growth were manipulated by regulating the water temperature so that at the time of planting Pennask and Idaho #1 fish were approximately the same size (6.50 and 5.80 g respectively) while the Idaho #2 fish were considerably smaller (1.7 g).

For identification the Pennask and Idaho #1 fish were hot wire branded (left and right sides respectively) while the Idaho #2 were not.

The lakes were planted between May 4, 1972, and May 19, 1972, shortly after spring breakup. A summary of the morphometry of the lakes and of the stocking information is given in Table 1. Equal numbers of the three lots were stocked in each lake.

The fish were harvested in October and November before freeze-up and in December after freeze-up, using seines, traps and gill nets. Gill nets were the most effective means of capture and lakes were fished until catches fell to less than five fish per net night (50 m nets).

All fish caught were identified by their brand, (damaged and unidentifiable fish were assigned to one of the three lots based on the relative proportions in the identifiable catch) and catch per hectare and rate of survival were estimated for each lot. Differences in survival were analyzed by means of a two-way analysis of variance and a chi square goodness of fit test.

Table 1. Morphometry and stocking rates of test lakes in 1972.

Lake	Hectares	Max.Depth (m)	No. of fish of each lot planted/hectare	Total no. of fish planted
122	1.2	1.5	247	900
316	5.3	3.7	412	6500
318	23.5	2.7	247	17400
587	7.7	3.7	412	9500
673	2.0	1.8	247	1500
624	1.6	1.8	247	1200
721	6.5	3.0	412	8000
825	3.21	2.7	247	2400
826	3.2	2.7	247	2400
879	9.7	2.4	412	12000

In each lake fork lengths of a random sample of each lot were measured (±0.5 cm) and the mean length and variance calculated. The "random sample" was not truly random because the type of gear used was not consistent from lake to lake although it was consistent within each lake. Differences in mean fork length between lots of fish were examined by means of an unweighted analysis of variance (Snedecor and Cochran 1967).

Estimates of the coefficient of condition ($K = \text{weight in grams} \times 10^5 / (\text{length in mm})^3$) and of the relationship between log 10 fork length and log 10 weight for each stock were based on catches from standard gangs of gill nets in four of the lakes (six 50 m x 2 m nets, one each of 3.8, 5.1, 6.4, 7.0, 7.6, 8.3 cm stretch measure).

Regression lines for each lot from each lake were calculated from pooled weights of groups of trout sorted by one centimeter intervals of fork length.

Results

The number of fish caught per hectare of each stock and the percent recovery (number caught/number planted) is given in Table 2 and Appendix 1. The results of the analyses of variance are given in Appendices 2 and 3. There were significant differences, in survival, between lakes and between stocks. The survival of fish from the wild strain was lower than that of similarly sized domestic fish. Within the domestic strain, fish planted at a larger size had a higher survival than did the smaller fish.

A chi square test of homogeneity of the catch per hectare showed that the results were heterogeneous. The survival of Pennask fish was much lower than expected in lakes 318, 623 and 721 and when the data from these lakes were removed and the analysis redone the significant heterogeneity had disappeared. Brook stickleback (Culea inconstans) were present in lakes 318 and 623, the lakes which showed the greatest relative disparity between Idaho and Pennask fish, but in none of the other test lakes. The relative size of the variance components emphasizes the importance of this heterogeneity for 13% of the total variance was attributable to lake X strain interaction (this term contains an unidentifiable portion of error variance).

The mean fork length of each stock in each lake is given in Table 3 and the results of the analysis of variance in Appendix 4. There was significant lake X strain interaction and significant differences between lakes and lots of fish. Fish from the Idaho #1 lot were significantly longer than those from the Idaho #2 lot or from the wild strain.

A further analysis of the data with the Idaho #2 results removed provided a direct comparison between the wild and domestic strains. The results were essentially the same as those above and it is of interest that the variance components for lake X strain interactions for growth and survival were of the same magnitude as those for strain differences for growth and survival.

Table 2. The relative number of rainbow trout recovered by lot and by lake in the fall harvest of 1972.

Lake	Number of trout per hectare		
	Idaho #1	Idaho #2	Pennask
122	33.8	9.1	16.5
316	161.8	117.3	93.6
318	62.8	60.7	11.3
587	196.2	147.7	156.0
623	36.2	9.8	3.5
624	45.1	13.2	23.2
721	220.0	189.6	113.7
825	100.6	56.9	71.7
826	55.7	14.9	52.9
879	12.8	4.3	4.8
Mean	92.5	62.3	55.2

Table 3. The mean size of rainbow trout recovered by lot and by lake in the fall harvest of 1972.

Lake	Mean fork length in cm		
	Idaho #1	Idaho #2	Pennask
122	27.3	23.6	24.6
316	25.8	24.4	25.2
318	24.0	21.7	21.5
587	26.2	23.8	26.5
623	25.0	23.0	26.0
624	26.4	22.6	25.5
721	26.1	24.4	24.8
825	27.0	24.4	25.0
826	28.6	27.1	26.8
879	27.5	25.5	27.7
Mean	26.4	23.0	25.4

The coefficient of condition (K) of Idaho #1 fish (mean 1.74, range 1.68 - 1.76) and Idaho #2 fish (mean 1.75, range 1.64 - 1.85) were larger than those for the Pennask stock (mean 1.40, range 1.35 - 1.43) indicating that the domestic fish were plumper than the fish from the wild stock. Idaho #1 fish were also plumper than the Pennask fish (K = 1.31 and 1.06 respectively) at time of planting. An analysis of covariance indicated that within each lake the elevations of the regression lines relating log 10 length and log 10 weight were higher for the domestic strains than for the Pennask strain. The slope of the regression line was generally higher for the Pennask strain but for all strains there was considerable variability in slopes from lake to lake. The differences in slopes may be a reflection of gear selectivity and are not necessarily biologically significant. The elevations of the regression lines indicate, as do the coefficients of condition, that at any one length the fish from the domestic strain are heavier than the fish from the wild strain.

The fish from the Idaho strain were more uniform in length than those from the Pennask strain ($F^{645}_{1043} = 1.842$). This may indicate that there is greater genetic variability in growth in the wild strain.

Discussion and Conclusions

Previous studies (Nielsen et al. 1957; Flick and Webster 1964; Mason et al. 1967; and Cordone and Nicola 1970) suggest that there are important differences in performance between wild and domestic trout as measured by survival and growth in nature. Although the studies were inconclusive, Cordone and Nicola (1970) suggest that domestic trout do more poorly than wild trout in particularly rigorous environments.

In this experiment the rainbow trout from the domestic strain were larger, plumper and had higher survival to harvest than did those from the wild strain. The growth of fish was exceptional but the survival was not. Sunde et al. (1970) felt that food was not a limiting factor in these lakes but low oxygen levels and possibly high temperatures were. The present results from lakes 318 and 623 indicate that competition may also be important. The significant lake X strain interaction in growth and survival suggests that the factors in the lakes affecting these characters vary from one lake to the other.

The observed growth or survival is the product of the genotype, the environment and interaction between the genotype and the environment. Calaprice found genetic differences in growth and survival between various domestic (1969) and various wild (in preparation) strains of salmonids. Hatchery conditions were the same for both strains in this experiment and it is assumed the observed differences in growth and survival between the strains are genetic and that the strain X lake interactions are genotype-environment interactions, although there is a possibility of a long-term maternal environment effect. The importance of interactions between strains of trout and the environment has been recognized (Calaprice 1969) but not studied extensively.

The presence of significant genotype-environment interactions has certain implications for a selective breeding program. Lerner and Donald (1966) state "it seems likely that genotype-environment interections will be found to be numerous, ... influencing mainly those characters which are most subject to inbreeding depression. These are traits such as fertility and mortality and other components of fitness which have very low heritabilities and show very large amounts of apparently non-heritable variation."

Heritabilities of survival within normal trout populations have been shown to be low (Ayles MS 1972; Calaprice MS 1967, in preparation) and inbreeding has resulted in a significant increase in the mortality of eggs and fry of rainbow trout (Aulstad et al. 1972) It is to be expected then that genotype-environment interactions for survival should be high as is apparent for these winterkill lakes. Growth rate was adversely affected by inbreeding (Bridges 1971) and the present study found that genotype-environment interactions were significant even though others (Aulstad et al. 1972; Calaprice 1967) found the heritabilities of growth rate were relatively high.

Falconer (1952) and Robertson (1959) have developed techniques for selection when genotype-environment interactions are present but selection within a line for a character with low heritability is very difficult (Lerner and Donald 1966; Falconer 1960). Methods of exploiting non-additive genetic variation, which is probably very important for traits such as viability, are based on a combination of selection and crosses between lines (Johansson and Rendel 1968).

High survival of fish in all the lakes is the most important character to be selected for. Consideration of the previous paragraphs makes it clear that inbreeding and selection within a single strain will not give the desired results. The presence of genotype-environment interactions means that it would be necessary to breed a separate strain for each type of lake in order to optimize growth and survival. Mather and Jinks (1971) point out that F_1 hybrids are more stable than inbred lines and in general genotype-environment interaction is less in heterozygotes than in homozygotes (see Allard and Bradshaw 1964, for a review). It is expected, then, that a cross between two strains of trout would show greater stability in survival and growth in the lakes and the total survival and growth would be higher for the hybrid than for either of the parent strains.

The crossing of lines plays a major role in increasing plant (Sprague 1967) and animal (Robertson 1967) production and the conclusion is that the use of several different strains of rainbow trout is a prerequisite to the success of the aquaculture selective breeding program.

Acknowledgments

I would like to acknowledge the assistance of J. Whitaker, L. Sunde, G. Pryznyk, G. Berezay, J. Martin and D. Spriggs, who participated in various aspects of this study.

References

ALLARD, R.W. and A.D. BRADSHAW

1964 Implications of genotype-environmental interactions in applied plant breeding. Crop Science 4: 503-508.

AULSTAD, D., T. GJEDREM and H. SKJERVOLD

1972 Genetic and environmental sources of variation in length and weight of rainbow trout (Salmo gairdneri). J. Fish. Res. Bd. Canada 29: 237-241.

AYLES, G.B.

1972 (MS) The inheritance of early survival in Salvelinus namaycush x fontinalis hybrids (splake trout). Ph.D. thesis. University of Toronto, 173 p.

BRIDGES, W.R.

1971 Annual Progress Report. Fish Genetics Laboratory, Beulah, Wyoming.

CALAPRICE, J.R.

1967 (MS) An experimental evaluation of the relative rate of environmental and genetic factors influencing qualitative changes in salmonid populations. Ph.D. thesis. University of California at Santa Barbara, 83 p.

1969 Production and genetic factors in managed salmon populations. The University of British Columbia Institute of Fisheries, H.R. MacMillan Lectures in Fisheries, Symp. on Salmon and Trout in Streams. 1968. p 377-388.

In prep. Heritable variability in five populations of sockeye salmon, Oncorhynchus nerka. I. Early mortality.

CORDONE, A.J. and S.I. NICOLA

1970 Harvest of four strains of rainbow trout, Salmo gairdneri, from Beardsley reservoir, California. Calif. Fish and Game 56: 271-287.

FALCONER, P.S.

1952 The problem of environment and selection. The American Naturalist 86: 293-298.

1960 Introduction to quantitative genetics. Oliver and Boyd, Edinburgh. 365 p.

FLICK, W.A. and D.A. WEBSTER

1964 Comparative first year survival and production in wild and domestic strains of brook trout, Salvelinus fontinalis. Trans. Amer Fish. Soc. 93: 70-76.

JOHANSSON, I. and J. RENDEL

1968 Genetics and animal breeding. W.H. Freeman and Co., San Francisco. 489 p.

JOHNSON, L, G.H. LAWLER and L.A. SUNDE

1970 Rainbow trout farming in central Canada. Fish. Res. Bd. Canada, Tech. Rept. No. 165. 17 p.

LERNER, M.S. and H.P. DONALD

1966 Modern developments in animal breeding. Academic Press, New York. 294 p.

MASON, J.W., O.M. BRYNILDSON and P.E. DEGURSE

1967 Comparative survival of wild and domestic strains of brook trout in streams. Trans. Amer. Fish. Soc. 96: 313-319.

MATHER, K. and J.L. JINKS.

1971 Biometrical genetics. Chapman and Hall Ltd., London. 382 p.

NIELSON, R.S., N. REIMERS and H.D. KENNEDY

1957 A six-year study of the survival and vitality of hatchery-reared trout of catchable size in Convict Creek, California. Trans. Amer. Fish. Soc. 92: 39-46.

ROBERTSON, A.

1959 The sampling variance of the genetic correlation coefficient. Biometrics 15: 468-485.

1967 Animal Breeding. Ann. Rev. Gen. 1: 295-312.

SNEDECOR, G.W. and W.G. COCHRAN.

1967 Statistical Methods. The Iowa State Univ. Press, Ames, Iowa. 593 p.

SPRAGUE, G.F.

1967 Plant breeding. Ann. Rev. Gen. 1: 269-294.

SUNDE, L.A., J. WHITAKER and G.H. LAWLER

1970 Rainbow trout production in winterkill lakes. p 57-65. In Schneberger E. (ed.) A symposium on the management of midwestern winterkill lakes. Publ. of North Central Division Amer. Fish. Soc. 75 p.

Appendix 1. Recovery data of each lot of trout in 1972 fall harvest, percent recovery (number caught/number planted x 100).

Lake	% survival: Idaho #1	Idaho #2	Pennask
122	13.7%	3.7%	6.7%
316	39.3%	28.5%	22.7%
318	25.4%	24.6%	4.6%
587	47.7%	35.9%	37.3%
623	14.7%	4.0%	1.4%
624	18.3%	5.3%	11.4%
721	53.3%	46.1%	27.6%
825	40.8%	23.1%	29.1%
826	22.6%	6.0%	21.4%
879	3.1%	1.0%	1.2%

Appendix 2. Analysis of variance of number of rainbow trout caught per hectare in 1972 fall harvest.

Source	df	SS	MS	F
Lakes	9	107095.2	11899.5	30.13**
Stocks	2			9.91**
L x S interaction	18	7109.1	335.0	

** Indicates P < .01.

Appendix 3. Analysis of variance of percent survival of rainbow trout in 1972.

Source	df	SS	MS	F
Lakes	9	5633.0	625.9	17.59**
Stocks	2	787.7	393.8	11.07**
L x S interaction	18	640.5	35.6	

Appendix 4. Analysis of variance of fork length of rainbow trout at the time of harvest in 1972.

Source	df	SS	MS	F
Lakes	9	50.914	5.657	9.23**
Stocks	2	30.673	15.336	25.02**
L x S interaction	18	11.025	.613	3.06**
Within	2320		.2004	

n_h = 23.13 = harmonic mean of number of observations in each cell.

** Indicates $P < .01$.

Printed in Canada by the
Department of Supply and Services, Printing
Operations, for exclusive distribution by
the Fisheries Research Board of Canada
Freshwater Institute
Winnipeg, Manitoba
Canada

Government of Canada Gouvernement du Canada
Fisheries and Oceans Pêches et Océans

501 UNIVERSITY CRESCENT
WINNIPEG, MAN.
R3T 2N6

WINNIPEG -1 VI '81 MAN

22

Canada Pot Hole stocking
strain evaluation

Dr. R. Behnke
Department of Fisheries and Wilflife Biology
Fort Collins, Colorado
United Stations of America
80523

- England
30 lb. RA
?

↑ $

: Salmon
coho – red sockeye

– At. salmon

* Largest size
– slow growth – long life
– delay maturity –

– re. extension hatchery raceway
– [illegible] in hatch – [illegible] – [illegible] cond. – general well being

— Niche – Condition – compatib.
– [illegible] predation.
U. Idaho – [illegible] re – [illegible] competition
[illegible] gluttony deep body — body shape
– U. W. thesis
– Utah St. Thesis
– growth – hatch. domest. best
Nut L. –