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THE LIFE HISTORY OF THE ROUND WHITEFISH, PROSOPIUM CYLINDRACEUM (PALLAS) OF NEWFOUND LAKE, NEW HAMPSHIRE

DONALD ARTHUR NORMANDEAU

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THE LIFE HISTORY OF THE ROUND WHITEFISH

PROSOPIUM CYLINDRACEUM (PALLAS) OF NEWFOUND LAKE, N. H.

BY

DONALD A. NORMANDEAU

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Philip J. Sawyer

Albion R. Hodgdon

A. E. Teeri

George M. Moore

Paul A. Wright

May 2, 1963

Date

ABSTRACT

The life history and ecology of the round whitefish, Prosopium cylindraceum (Pallas), of Newfound Lake, Bristol, New Hampshire, has been studied. Field studies began in the summer of 1959 and continued through December, 1962.

The round whitefish of Newfound Lake are morphologically similar to other populations of this species located in the Great Lakes, Canada, and Siberia, but differ in having significantly fewer pyloric caeca.

In Newfound Lake, these fish attain sexual maturity in their fourth or fifth year. Spawning, which occurred during the first three weeks of December, took place on a shallow, rocky reef located between Pike's Point and Mayhew Island. Fecundity studies indicated that female round whitefish averaged approximately 5,000 eggs, but a range of 2,000 to 10,000 was found. The number of eggs produced depended, for the most part, on the age and size of the fish.

The peak of hatching occurred during the last week of April. This was approximately 140 days from the time of fertilization. These eggs were incubated at a temperature of 36°F.

Larval descriptions were made from fry reared at the New Hampshire Fish and Game Department, Powder Mill Rearing Station. Several stages from newly hatched fry to juveniles 59.0 mm total length were described.

The food of the round whitefish consisted mainly of _Dapnia pulex_. These fish did feed heavily on _Chaoborus_ during the month of Agust, 1959, but only at the time these insects were plentiful. In December, at the time of the spawning run, these fish were noted to feed upon their own eggs. Although predominantly a plankton feeder, these fish were often observed feeding off the bottom and in shallow water.

The age and growth of these fish was described. The length-weight relationship, the body-scale relationship, calculated growth in length, and conversion for total length to standard and fork lengths were determined.

The only helminth parasite found in the round whitefish was _Azygia sebago_ Ward. This is a digenetic trematode which occurred in the stomachs of these fish. The incidence of infection was very light.

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It would be impossible to personally mention all of those who have contributed in one way or another to the success of this study. There are many persons who have unselfishly given both time and effort so that certain phases of this investigation could be accomplished. However, special acknowledgment is extended to Professor Philip J. Sawyer, Zoology Department, University of New Hampshire, under whose supervision this entire program was conducted, and without whose advice and recommendations progress would have been most difficult, if not impossible. Special gratitude is also extended to Professor George M. Moore, Chairman, Zoology Department, University of New Hampshire, for his cooperation and for the use of the facilities of that department.

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I am also greatful to Mr. Robert MacWatters for his help in identifying some of the food items found in the stomachs of the round whitefish collected in the summer of 1959.

I am greatly indebted to the staff of the New Hampshire Fish and Game Department for their aid and advice, and especially to Mr. Ralph G. Carpenter, 2nd, Director, and Mr. Bernard W. Corson, Chief, Fisheries Division. Special thanks are also due to Mr. Henry Muise, of the Fisheries Division, for the loan of nets and other equipment that was necessary for this study, and to Mr. Hilaire V. Gagnon, Fish Culturist, Powder Mill Rearing Station, for his assistance in hatching and rearing whitefish fry. I also wish to extend my thanks to Mr. Hilbert R. Siegler, Chief, Management and Research Division and Mr. Arthur E. Newell, Supervisor of Fisheries, Management and Research Division, for their cooperation throughout this entire study.

To Mr. Ronald E. Towne, of Bridgewater, New Hampshire, I am sincerely grateful. His assistance during the early phases of this investigation was especially valuable, and he remained a constant source of inspiration throughout this study.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF ILLUSTRATIONS

Figure | Page

INTRODUCTION

In the fall of 1958, I had an opportunity to assist in a study of the sport fisheries of Newfound Lake, Bristol, New Hampshire. This investigation was being conducted by the New Hampshire Fish and Game Department's Research and Management Division with whom I was employed as a fisheries biologist. In the course of the preliminary survey of this lake, several round whitefish, Prosopium cylindraceum (Pallas), were captured. These are rather unusual fish in New Hampshire for they are reported from only three bodies of water in the State. A brief review of the literature revealed that there was a very obvious lack of knowledge concerning its life-history. In fact, most of the work that had been done with this species dealt primarily with its taxonomic position rather than its life-history. In Newfound Lake, nothing was known concerning its behavior or habits. The preliminary survey of the sport fisheries of the lake disclosed that there was a large population of the round whitefish present.

In the summer of 1959, several round whitefish were captured, and data necessary for the study of their age and growth and their food and feeding habits were obtained. This information was analyzed and unpublished reports were prepared showing the results of these studies. This was accomplished as part of my graduate program in the Zoology Department of the University of New Hampshire. Later, in partial fulfillment of the requirements for the degree of Doctor of Philosophy, more intensive studies were made of many of the phases of the life history and ecology of this species. Field studies began in the fall of 1961 and continued through December, 1962. Included among the various aspects of this life history study were investigations concerned with this whitefish's reproduction, early life history and development, food and feeding habits, age and growth, and many others. The results are presented in the following sections of this paper.

A photograph of a 13.5 inch (342 mm) specimen of the round whitefish is presented in Fig. 1.

FIGURE 1. The round whitefish, Prosopium cylindraceum (Pallas)

MATERIALS AND METHODS

Netting Procedures

Many different nets were used in attempts to capture round whitefish from Newfound Lake. Gill netting was, by far, the most productive method. Fyke nets, pound nets, otter trawls, seines and dip nets were also employed but were not particularly effective. This species does not follow a lead readily and is, therefore, seldom taken in fyke or pound nets. This fact is well known by the commercial fishermen of the Great Lakes. Although P. cylindraceum is seldom captured in their large trap nets, they are often taken in commercial quantities in the gill nets (Koelz, 1929). The only instance in which fyke nets were fairly successful in Newfound Lake was during the height of the spawning season. The nets were set on the spawning reef and the fish were present in such large numbers that they apparently could not avoid them. Even in this situation, however, gill nets were much more effective but had to be removed so as not to injure or kill too many fish.

Many sizes of gill nets were used experimentally. Most of these nets were between six and eight feet in depth and one hundred feet long. The size of the mesh varied from one inch to three and one-half inch stretch. A small, one inch stretch, double-mesh gill net was used in an attempt to capture immature whitefish, but it was not at all effective.

In fact, although most of the gill nets worked well, they were also highly selective. Small mesh nets less than two inch stretch did not capture whitefish readily and it appears that the fish were able avoid these nets. The larger mesh nets of two to three and one-half inch stretch captured many whitefish but each size was noticeably selective. Small whitefish could easily have passed through these nets without becoming entangled. This selectivity of the gill nets in the capture of the round whitefish is further substantiated by Berst (1961) in his paper on the selectivity of experimental gill nets in Lake Huron.

Dip nets were used with limited success in taking whitefish as they attempted to feed on lake trout eggs in the shallow water of the spawning reef. Only a few fish were caught in this manner, and this procedure was carried-out only at night.

In the summer of 1962, a small otter trawl was employed in trying to locate and capture immature whitefish. Despite several attempts, not a single whitefish was captured with this net. It is possible, however, that the juvenile whitefish were able to avoid this device. Attempts at seining were also unproductive.

It is interesting to note that P. cylindraceum, unlike many other whitefishes, is a relatively shallow-water species. Most of these fish were taken in depths of less than 40 feet and nets set in 100 feet or more were not at all productive.

Methods of Physical and Chemical Survey

The procedures used in determining the amount of dissolved oxygen and free carbon dioxide in Newfound Lake are essentially as found in the 11th edition of the Standard Methods for the Examination of Water and Wastewater, American Public Health Association, Inc. The Alsterberg (Azide) modification of the Winkler method was used in determining the amount of dissolved oxygen. A Beckman Pocket pH meter model 180 was utilized in the determination of pH for all of the samples taken from this lake. Conductivity readings were obtained with a model RA-2A conductivity meter manufactured by Industrial Instruments Inc. The Whitney Underwater Daylight Meter was most effective in defining light intensity at various depths. Readings were taken at every meter until the one percent level of incident light penetration was reached. Temperatures were measured with an electronic thermometer manufactured by Applied Research Inc., of Texas. Unfortunately, this instrument contained only one hundred feet of cord and there were instances when more was needed. The total hardness of the lake water was obtained with a Taylor Total Hardness Kit.

Methods Used in Collecting Eggs

A four-foot hand-operated bilge pump was modified and used satisfactorily for collecting whitefish eggs from the spawning reef. This method was described by Hart (1930) in his efforts to collect the eggs of <u>Coregonus clupeaformis</u>

from the Bay of Quinte in Ontario. In Newfound Lake, areas 20 to 30 feet in depth were sampled by the addition of rigid plastic pipe to the end of this pump. However, this proved to be unnecessary for all of the whitefish eggs were collected in shallow water less than 3 feet in depth.

Methods Used in Determining Fecundity

There were essentially two methods used in determining fecundity of the round whitefish captured in Newfound Lake. These techniques were described in Lagler (1956) and involve both volumetric and gravimetric analyses. Ovarian volume was measured by displacement of water in a graduated cylinder. A portion of approximately two milliliters was then taken from each pair of ovaries, and this sample volume was carefully determined. The number of eggs in each sample was counted. From this figure, the total number of eggs per milliliter was obtained and the ova count for the entire ovary was calculated. In essentially the same way, the number of eggs for each fish was determined gravimetrically. However, instead of their volume, the total weight of the ovaries and the weight of the sample were obtained.

Egg diameters varied depending on the size and age of the specimen as well as the season of the year. Because of this, sample counts were taken from the ovaries of each of the 48 specimens examined. That this variation in egg diameters existed, was well substantiated by the following: samples of eggs from five fish captured between October 17 and 21, 1961, average 118 eggs per gram or 127 per milliliter;

eggs of five fish trapped between November 14 and 16, 1961 averaged 92 eggs per gram or 110 eggs per milliliter; those taken from fish netted between the 24th and 26th of November, averaged 88 eggs per gram or 94 per milliliter. This is certainly a good indication of the increasing size and development of the eggs prior to spawning. Errors due to the presence of ovarian tissue in the ovary were accounted for by the sampling procedures. Each sample contained both eggs and ovarian tissue in the same proportion, it is believed, as in the intact ovary. The actual number of eggs for specimen number N-14-80 was counted and compared with both gravimetric and volumetric estimates.

Methods of Food Studies

Essentially, there were two methods employed in studying the food of the round whitefish. These were the frequency of occurrence method, and the volumetric analyses of the stomach contents as described by Lagler (1956). In the frequency of occurrence technique, the number of individual stomachs in which each kind of food occurred was recorded. The results are expressed as percentages of the total number of examined specimens containing food. The volumetric analyses consisted of two parts. The volume of each kind of food found in the whitefish stomachs collected during the summer of 1959 was determined by displacement of water in a graduated cylinder. These were then expressed as percentage by volume of the total contents. The volume of each food item found in the whitefish stomachs collected in 1961 was also determined, but by the "points method" as described by Hynes (1950).

Because of the nature of the food items, actual determination of the volume of planktonic organisms, especially those that are not abundant, is most difficult. The total food volume in the stomachs of larger whitefish was less than 3 milliliters and usually about 2 milliliters. As several food items were found in each stomach, the task of separating these into phylogenetic groups was most difficult and tedious. Also, it was not possible to determine the volume by displacement for each of these groups. For this reason, the stomachs collected in the summer of 1959 were separated into groups according to the date captured. The stomach contents of all the fish captured on the same date were removed and the total volume determined. Each food item was separated as well as possible and the volume for each group determined. These were then expressed as the percentage of the total volume for that date.

The above method was not particularly satisfactory and was certainly time consuming. For this reason, a new approach was used with the samples collected in 1961. This, the points method, was performed in the following manner. The contents of each stomach was placed in a petri dish and examined with a dissecting microscope. Each food item was separated into categories and each category assigned a higher or lower number of points depending on its size and abundance. All the points gained by each food item were summed and the percentage for each item determined.

This method was found to be rapid, sufficiently accurate, and much preferred over other volumetric methods. In his paper, Hynes stated:

> Facts in its favour are that it is rapid and easy, requires no special apparatus for measurement, is not influenced by frequent occurrence of a small organism in small numbers, nor of heavy bodies, like snail shells and caddis cases, and does not involve trying to count large numbers of small and broken organisms. It also does not give the spurious impression of accuracy which is given by some methods.

Methods Used in Age and Growth

All of the fish were measured to the nearest millimeter. The total length, i.e., the length from the tip of the snout to the tip of the tail with lobes compressed, the fork length and the standard length for each fish was taken. The fish were weighed to the nearest gram and scale samples were removed from their left sides midway between the lateral line and the base of the dorsal fin. The fish were then sexed and the state or condition of the gonads was recorded as mature or immature. Those fish that would have spawned in the fall of the year captured, were called mature.

Impressions were made in cellulose acetate of whitefish scales collected in 1959. This was done with a roller type scale press as described by Smith (1954). Scales taken from whitefish captured in 1961 were mounted in a glycerin-gelatin medium (VanOosten, 1929). Several scales from each were used thus permitting a choice in case of mal-formed or non-readable scales. The scale images were magnified 37 times by a Bausch and Lomb Microprojector. The number of formed annuli were counted and the age for each fish was recorded. Fish captured in April and early June of 1959 had not formed their last annulus but each was credited with one more annulus than was actually present. The annulus would have been formed in late June or early July anyway, and so it was felt that this procedure was justified. Fish captured in the fall of 1961 had completed their last annulus and no such problem was encountered.

Measurements of scale dimensions (to the nearest millimeter) were made from the focus, anteriorly to each annulus and from the last annulus to the margin of the scale as described by Van Oosten (1929). Some of the scales were difficult to read and many were replacement scales that could not be used at all. Fortunately, there were enough scales from most specimens so that one or more was usable.

All calculations concerning length-weight relationships, body-scale relationships and back calculations for growth in length, were performed with an IBM 1620 computer available at the University of New Hampshire's Computation Center. The use of this computer was made possible by National Science Foundation Grant G-13606.

HISTORY OF THE ROUND WHITEFISH

Systematic Position of the Species

The round whitefish, Prosopium cylindraceum (Pallas), is perhaps one of the most widely distributed of all the whitefishes (Evermann, 1896). A review of the literature indicates that this species was first described by Pallas in 1784 and given the name Salmo cylindraceus. Richardson (1823) described specimens from small rivers about Fort Enterprise, British America, and in the Arctic Sea. These he referred to as Coregonus quadrilateralis. He indicated also that these may have been the same as the Sea Gwiniad of Thomas Pennant (1792), but he could not confirm this with any degree of certainty. The taxonomy of this species has since undergone many changes. In 1851, Dr. William Prescott of Concord, New Hampshire described what he believed to be a new species from Lake Winnipisseogee (now called Winnipesaukee) in New Hampshire. This fish he named Coregonus Nov-Angliae, the shad waiter or New England whitefish. This later proved to be the same as the round whitefish described by Richardson. Jordan, in 1878, after reviewing a manuscript by Prof. James W. Milner, subdivided the genus Coregonus into three genera or subgenera; Argyrosomus, Coregonus, and Prosopium. He then changed Coregonus quadrilateralis to Prosopium quadrilateralis (Rich.). It is strange that Jordan has not been recognized as the author of the generic name Prosopium for it appeared in print for the first time in his Manual of the Vertebrates in 1878. Although he does give credit to Milner, Jordan is nevertheless the true author of this genus. Evermannn and Smith (1896) and Kendall and Goldsborough (1908), were either unaware of the changes by Jordan or did not recognize these changes for they continued to use Coregonus quadrilateralis Richardson. The name Prosopium quadrilateralis did not appear again in the literature until it was contained in the work published by Dymond (1926). Koelz (1929) raised Prosopium from the subgenus level to that of genus. In 1931, Koelz described what he believed to be a subspecies from Lake Chazy in New York and called this Prosopium quadrilaterale minor. Berg (1932) referred to the Asiatic forms as Coregonus cylindraceus. In 1936, however, he regarded Prosopium as a subgenus of Coregonus and believed that there were two forms; Coregonus (Prosopium) cylindraceus quadrilateralis (Richardson) found in North America and Coregonus (Prosopium) cylindraceus cylindraceus (Pallas) found only in the Old World and Siberia. The only difference between the two is in the number of lateral line scales and gill rakers. Dymond (1943) indicated that clines may exist for gill rakers and scale counts from Siberia southeast across North America, and therefore, any separation of P. cylindraceum into subspecies may be arbitrary. He pointed-out also that Prosopium is subject to considerable variation from one locality to another even in the same region. Russian workers also regard Prosopium as a subgenus of Coregonus. Walters (1955) stated that this is not acceptable since juvenile Prosopium have parr marks which are absent in Coregonus. Also, there is but a single flap between the nostrils in Prosopium. There is a double flap in Coregonus. The current proper taxonomic designation for the round whitefish, therefore, as taken from the American Fisheries Society Special Publication No. 2, 1960, is Prosopium cylindraceum (Pallas). It is a member of the order Clupeiformes and the family Salmonidae.

There are many common names given to P. cylindraceum in the different localities where it is found. In the Great Lakes Region, it has been variously referred to as the pilot, menominee, round whitefish, frost fish, cisco, gray back, cross whitefish, and lake minnow. Jordan (1929) gave its common name as the river whitefish. Evermann (1896) referred to it as the pilot fish, Chateaugay shad, or black back. Backus (1951) indicated that in Labrador, it is called the bottlefish. According to Kendall and Goldsborough (1908), in Maine it is called the chiven and chivy which are corruptions of chevaine the french name for chub. Locally, in New Hampshire, it is called the bill fish in the Connecticut Lakes Region and the shad in Lake Winnipesaukee and Newfound Lake. Only occasionally it is referred to as the round whitefish. This is the most acceptable common name and is used in all scientific literature dealing with this species.

Geographic Distribution

The round whitefish has a nearly circumpolar distribution. It is found in Northern Asia from the Yenesei River east across Siberia, the Bering Straits, and then through northern North America to Labrador, New Brunswick and Maine. In North America, this species has been found as far north as the Arctic Ocean in northern Alaska, in the Hudson's Bay Region, and in Labrador. It has been reported as far south as the Great Lakes in the Midwest and in Connecticut in southern New England. This species has been reported from many lakes in Maine and from East Twin Lake in Connecticut (Conn. State Board of Fisheries and Game Lake and Pond Survey Unit, 1942). In New Hampshire, this whitefish has been reported from Lake Winnipesaukee (Prescott, 1851; Bailey, 1938), from the First Connecticut Lake and from the Connecticut River by Kendall and Goldsborough (1908). Two specimens of the round whitefish were taken by this author from the Connecticut River just below Lake Francis in September of 1961. It is no longer reported in any abundance from that area. Newfound Lake, Bristol, New Hampshire is the only other body of water in this State in which P. cylindraceum is known to occur.

Smith (1957) presented a fine account of the evolution and distribution of the Coregonids. In his paper, he pointed-out that members of the genus Prosopium differentiated in northwest North America and from there became distributed both east and west. He also mentioned that since

P. cylindraceum is quite capable of withstanding increased salinities, its migration across the Bering Strait did not pose a serious problem.

The round whitefish is considered, for the most part, a river fish. The type specimen described by Richardson came from small rivers about Fort Enterprise in British America. Many individuals have been taken from rivers and streams in Siberia. This species has, however, done well in large oligotrophic lakes. It is reported from nearly all of the Great Lakes except Lake Erie (Koelz, 1929). In New England, *P. cylindraceum* is found mostly in lakes although it does occur in the Connecticut River in northern New Hampshire.

Economic Importance

The round whitefish is taken commercially from the Great Lakes and sold on the market. In 1960, the total catch of this species was 91,000 lb valued at 21,840 dollars. This is according to fishery statistics of the United States Department of the Interior, Fish and Wildlife Service, Bureau of Commercial Fisheries. This species, however, has never had the reputation of the lake whitefish, *Coregonus clupeaformis*, as a food fish, but apparently was preferred to lake herring, *Coregonus artedii* (Koelz, 1929). In 1908, Kendall mentioned its excellence as a pan fish and that it was often sold in city markets as smoked whitefish or lake herring. He also stated that when baked or broiled, this fish made a delicious breakfast dish.

This species cannot be truly considered a sport or game fish for it is seldom taken by hook and line and only rarely is it sought after by anglers. Because of its feeding habits and small tender mouth, it does not respond to lures and if hooked, is easily lost. Gill netting was once permitted for the round whitefish in East Twin Lake in Connecticut, but is no longer allowed there.

PHYSICAL AND CHEMICAL CHARACTERISTICS OF NEWFOUND LAKE

Newfound Lake is a large, deep, oligotrophic lake situated in the townships of Bristol, Bridgewater, Hebron and Alexandria, New Hampshire (Fig. 2). It is the State's fourth largest lake with an area of approximately 4,100 acres. Also, it is probably one of the deepest for much of the lake is over one hundred feet in depth. Only a few shallow, sandy areas are found in this lake, and these are located at the mouths of the Fowler and Cockermouth Rivers. Rooted aquatic vegetation is very scarce and occurs in quantities only in a small area at the northern tip of the lake near the mouth of the Cockermouth River. There are also a few scattered rocky reefs the most prominent of which is located between Mayhew Island and Pike's Point. Rocky and rubble bottom types are also found along Whittemore Point, the northern tip of Mayhew Island, and a few other isolated areas along the shoreline.

Newfound Lake is apparently a glacial lake and has been formed, in part at least, by ice-scour. This is quite obvious off the "Ledges" on the western shore of the lake. Many indications of ice-scour are also present on Belle and Cliff Islands. White (1938) explained that "The alignment of the long axis of Newfound Lake parallel to ice motion would indicate that glacial erosion had a large part in shaping this basin."

There are two major and several lesser tributaries

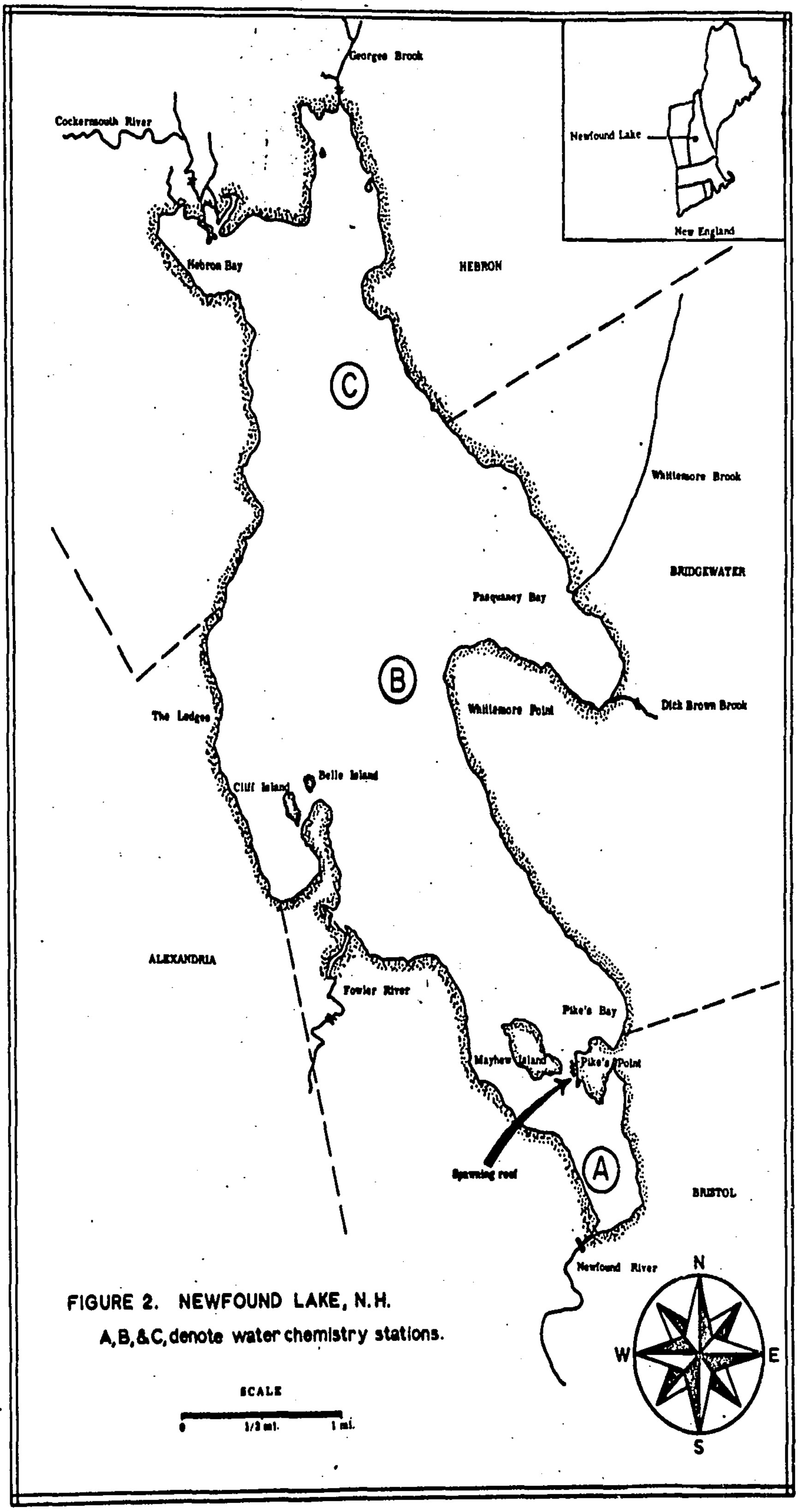

FIGURE 2. NEWFOUND LAKE, N.H.
A,B,&C, denote water chemistry stations.

to Newfound Lake. The Cockermouth River located at the northern tip of the lake and the Fowler River entering on the western shore of the lake are by far the largest tributaries. The outlet, which forms the Newfound River, is located at the southernmost tip of the lake. A dam, owned and operated by the Public Service Co. of New Hampshire, is located on the Newfound River approximately one hundred yards from the lake. This dam is used to control the water level of the lake and the water flow in the river. The level of the lake may fluctuate some three to five feet depending on the season and the amount of precipitation.

Since Newfound Lake is a deep,oligotrophic lake, it is, as would be expected, high in dissolved oxygen, low in free carbon dioxide, and has a relatively cold temperature. Fuller (1938) reported that he had not surveyed a lake that had a comparable volume of cold, well oxygenated water. On August 8, 1938 he found at 142 feet a temperature of 45°F, and dissolved oxygen content at 9.4 ppm. On July 23, 1962 a few samples were taken from this lake and the following information was recorded; at 50 feet, dissolved oxygen 8.0 ppm, free carbon dioxide 3 ppm, water temperature 50°F, methyl orange alkalinity 20 ppm, pH 6.2, and secchi disk reading 28 feet. The one percent level of light penetration as indicated by a Whitney underwater daylight meter was 17 meters. A definite thermocline was evident at this time. A conductivity reading of 25 Mmhos/cm indicated 35 ppm total dissolved solids. Samples were taken from three separate stations in Newfound Lake on the 11th, 16th, and 18th of October, 1962.

The results and a summary of the data collected from these stations (stations A, B, and C Fig. 2) are presented in Table 1. The seasonal fluctuation in temperature is presented in graphic form in Fig. 3. The one per cent light penetration level was found to be 17 meters on the 23d of July, but on the 11th and 16th of October, this level was only 11 and 12 meters respectively. The results of the secchi disk readings also tended to confirm this.

TABLE 1. Results of the chemical and physical survey of Newfound Lake conducted in October, 1962.

	Depth meters	Water temperature °F	Dissolved oxygen ppm	Free CO_2 ppm	Specific conductance Mmhos/cm	Total dissolved solids ppm	Total hardness $CaCO_3$ ppm	pH
Station A Date 10/11/62 Secchi disk 16 ft								
Surface	0	56	9.1	3.0	25	32.3	--	8.2
Middle	14	54	8.7	4.0	23	30.7	--	8.6
Bottom	26	45	8.7	5.5	20	32.0	--	7.9
Station B Date 10/16/62 Secchi disk --								
Surface	0	54	9.5	1.5	21	29.2	4.0	7.2
Middle	17	52	9.1	2.5	25	31.7	11.0	7.2
Bottom	34	45	8.2	5.0	19	30.2	8.0	6.8
Station C Date 10/18/62 Secchi disk 19.5 ft								
Surface	0	53	9.9	2.0	22	30.7	8.0	6.8
Middle	15.5	53	9.8	3.0	19	27.8	8.0	6.6
Bottom	31.0	45	8.6	6.5	19	31.3	10.0	6.6

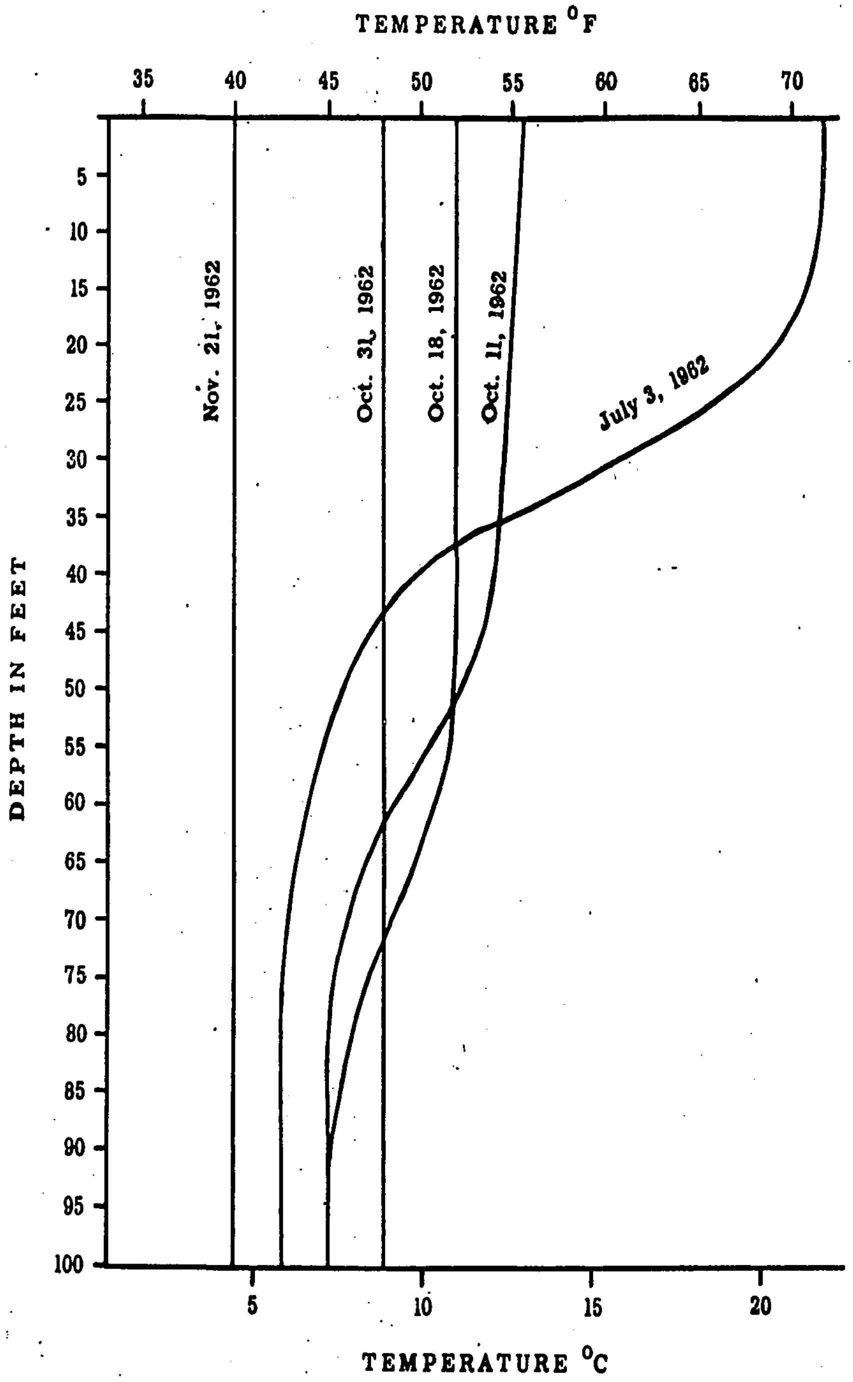

FIGURE 3. Seasonal fluctuations in the water temperature of Newfound Lake.

HISTORY OF THE SPORT FISHERIES OF NEWFOUND LAKE

General

Newfound Lake has long been noted for its fine lake trout, Salvelinus namaycush, and salmon, Salmo salar, fisheries. Musgrove (1904) stated that "As many as 400 pounds have been taken from the lake in one day. It is seldom that a trout is taken by trolling that weighs less than five pounds, while the larger number weigh from eight to fifteen pounds." He mentioned also the stocking of salmon in the late 1800's which resulted in as fine a salmon fishery as was that for the lake trout. He made no mention, however, of the round whitefish but merely indicated the presence of other less desirable fishes. In fact, there is no mention of the round whitefish of Newfound Lake until 1931 when Koelz mentioned examining a specimen from the Museum of Comparative Zoology at Harvard University, Cambridge, Massachusetts. Further inquiry proved that this specimen had been collected by Elverton C. Berry in 1918. Mr. Berry was a conservation officer for the New Hampshire Fish and Game Department at that time. This specimen was obtained from Mrs. Myvanwy M. Dick of the museum and I was able to examine it carefully. It seems strange that there are no published reports of the presence of the round whitefish in this lake prior to 1931, for the species was first described from Lake Winnipesaukee in 1851 by Prescott and in 1908 from the First Connecticut

Lake and the Connecticut River by Kendall. Information concerning the round whitefish of Newfound Lake appeared again in the literature in 1938. At that time, Bailey gave a brief description of it, but again he described the specimen from the Museum of Comparative Zoology. Carpenter and Siegler (1947), in their Fishes of New Hampshire, indicated also that it was present in Newfound Lake.

This whitefish is probably indigenous to Newfound Lake. Since it was reported from Lake Winnipesaukee in 1851 several years prior to any stocking by the New Hampshire Fish and Game Department, and since this body of water is only a few miles from Newfound Lake and is part of the same watershed, it is conceivable that the round whitefish is indigenous to both lakes and was not introduced from other areas. Although the stocking records for Newfound Lake are quite extensive, there is no indication that the round whitefish has ever been introduced in this State. Lake whitefish eggs were stocked in Newfound Lake in 1883, 1898, 1899, 1943, and 1944 (New Hampshire Fish & Game Dept. stocking records). These eggs were sent from the Northville Hatchery in Northville, Michigan. Personal correspondence with Louella E. Cable, Fishery Biologist, United States Department of the Interior, Fish and Wildlife Service, Bureau of Commercial Fisheries, indicated that eggs of the round whitefish were never distributed or hatched at this station. This again substantiates the thinking that these fish were indigenous to this lake. It is interesting to note that there are no authenticated reports of lake whitefish ever being caught from Newfound Lake. A report by conservation officers to the survey crew investigating the fisheries of this lake in 1938, indicated the presence of lake whitefish, Coregonus clupeaformis. However, none of the fisheries personnel conducting this survey actually collected any of this species. It is quite possible that the conservation officers were mistaking the round whitefish for the lake whitefish. Netting operations conducted by the author and the New Hampshire Fish and Game Dept. in 1958, 1959, 1961, and 1962 did not produce a single lake whitefish although several hundred round whitefish were taken.

It is not surprising to find that many of the residents of the Newfound Lake area and ardent anglers who have fished this lake for as many as twenty and thirty years, are not aware of the presence of the round whitefish. The reasons for this are perhaps due in part to the secretive behavior and feeding habits of this fish. This whitefish feeds almost entirely on plankton or other minute aquatic invertebrates and may be nocturnal in its feeding habits. I have observed these fish at night feeding in shallow waters less than one foot deep. They appear to move into deeper water during the day, for only an occasional fish has been observed during daylight hours. The large hooks, bait, or artificial lures used in sport fishing are highly selective and for this reason, it is doubtful if any of these whitefish could be taken by conventional angling methods. In the spring, a few whitefish migrate into some of the tributaries to Newfound Lake. A few are captured at this season by means of a tiny hook and a bit of bait (usually a worm). Occasionally, one or more whitefish are taken through the ice during the winter. It is doubtful, however, if more than fifty individuals are taken in any one year from this lake. A review of the findings of a preliminary survey of the fisheries by the N.H. Fish & Game Dept. in 1958 and 1959, indicated from the creel census data that the number of whitefish taken during a single year was insignificant. The round whitefish, then, did not constitute a fishery but instead, were usually taken incidentally to the pursuit of other species.

The population of the round whitefish in Newfound Lake appears to be quite large as they were captured in far greater numbers than any and all game fish combined. On many occasions, there were as many round whitefish taken as yellow perch or other abundant species. Newfound Lake, therefore, appears to support a large thriving population of round whitefish and one which is relatively unexploited by man.

As far as is known, P. cylindraceum has never been reported from the Newfound River just below the lake. A fish screen has been constructed by the N.H. Fish & Game Dept. and maintained for years in hopes of preventing salmon and other desirable species from leaving the lake. It is doubtful, however, that this screen has had any substantial effect. Quite often the screen is left open to allow debris to pass into the river and the size of the mesh is such that small fish can easily pass through. Furthermore, there is little reason to believe that the fish would attempt to leave the lake.

New Hampshire Fishing Regulations

The regulations concerning the taking of round whitefish in New Hampshire are the same as those applied to the lake whitefish. In fact, these regulations were designed specifically for the lake whitefish without much thought for *P. cylindraceum*. In many of the larger lakes of New Hampshire, lake whitefish constitute an important winter sport fishery. In the Squam Lakes, Towne (1959), stated "However, from the creel census of 1952 and 1953, it appears that this fish [lake whitefish] is fast usurping the position held by the lake trout as the most popular sport among bob-house fishermen." The round whitefish is seldom seen and only an occasional fish is caught through the ice. Because of this, and since the majority of anglers cannot distinguish between the two species of whitefish, the taking of "shad", as they are commonly called, is governed by a single regulation. According to the State of New Hampshire 1962 Rules and Regulations of the Fish and Game Commission, "Shad, whitefish or bluefins, may be taken and possessed from January first to August thirty-first. A person may take a total number of not more than 6 shad, whitefish, or bluefin in one day." The manner of taking these fish is further regulated by the rule concerning the number of fishing devices permitted. In lakes which contain populations of lake trout and salmon, as does Newfound, not more than two fishing devices are permitted. This is also true of Lake Winnipesaukee, the only other lake in New Hampshire that supports a population of the round whitefish. An interesting and rather strange regulation is that which concerns the type of bait that may be used and states "No person shall use shad or whitefish for bait for cusk [Lota lota]."

As will be seen in subsequent sections of this paper, the regulations now governing the taking of round whitefish from Newfound Lake are quite reasonable and adequate. It is possible, however, that even if the regulations were removed entirely, the population of *P. cylindraceum* in this lake would not suffer appreciably. Just a very few of these fish are taken during the entire open season and not many more could be caught during the remainder of the year. If any changes in the regulations are to be made, these should be to extend the season to September 30th to coincide with the closing of the lake trout and salmon fisheries.

DESCRIPTION OF THE ROUND WHITEFISH OF NEWFOUND LAKE

General

The body of the round whitefish found in Newfound Lake is subterete, little compressed, except at the head and tail, and uniformly tapered. It is much more cylindrical in cross section than the more laterally compressed lake whitefish, the only other representative of this group in New Hampshire. Its greatest depth, which is just before the dorsal fin, is contained in its standard length 4.85 (4.30-5.80) times. The head is relatively small and is contained 5.40 (5.08-5.71) in the standard length and has a depth of 1.48 (1.08-1.64) in its own length. The eye is contained 4.72 (4.20-5.15) times in the head length and the interorbital distance is found 4.20 (3.66-4.69) in this same length. The snout is blunt and is contained 4.29 (3.87-5.72) times in the length of the head. The maxillary, the distance from the tip of the snout to the end of the maxillary, is found 5.90 (5.00-6.80) times in the head length. From the side, the head is roughly ovoid in shape and tapers sharply toward its anterior end. The mouth is very small and slightly subterminal. There are no teeth in <u>Prosopium</u> although vestigial teeth have been found in other genera of the whitefishes. The nares are conspicuous and there is but a single flap separating the two openings of each nostril. This is a characteristic which is used to separate <u>Prosopium</u> from other whitefishes. Dorsally, the head is acutely triangular with a slight pinched nose appearance (Fig. 4) at the position of the nares. This is a characteristic which permits quick and reliable identification when looking down upon the fish in the lake. The branchiostegal membranes are roughly trapezoidal in shape with an average of 7.1 (6-8) rays each. The dorsal fin is moderately long, 1.30 (1.20-1.52) in the head length, and its margin is straight. The base of this fin is 1.64 (1.43-2.03) in the head and contains an average of 11.1 (10-12) rays. The pectorals are relatively long 1.23 (1.04-1.55) in the length of the head and are pointed. The margins are somewhat rigid and curve toward the body when extended. The ventral fins are somewhat smaller than the pectorals, 1.49 (1.36-1.69) in the head, and also curve toward the body when extended. The anal fin is found 1.61 (1.38-1.91) times in the length of the head and the base of this fin 2.14 (1.95-2.48) in this same length. There are approximately 10 (9-11) rays in this anal fin and the leading edge is fairly straight and rigid. The adipose fin is small, 2.87 (2.48-3.56) in the head length. The caudal is sharply forked. The caudal peduncle is slender, 6.30 (5.68-6.74) in its standard length and the depth of the peduncle is 14.52 times the standard length.

Lateral line scales for thirty-five round whitefish taken from Newfound Lake averaged 89.5 (83-95). Scales above the lateral line averaged 9.85 (9-10) while scales below the lateral line averaged 9.06 (9-10) in number. The scales of

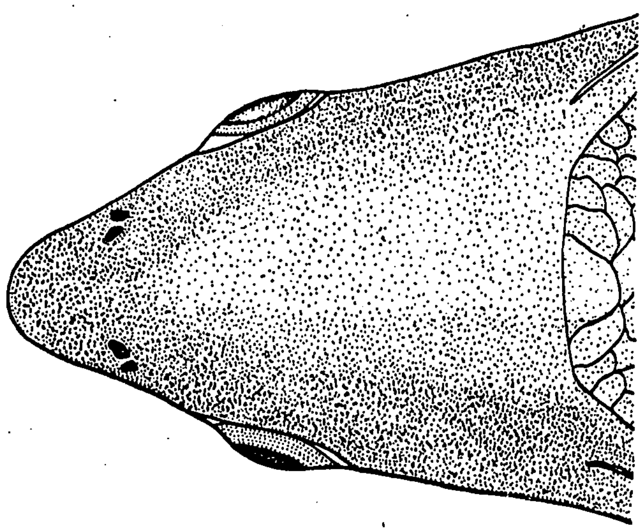

FIGURE 4. Dorsal view of the head of the round whitefish. Note the tapering snout; a characteristic used in identifying these fish in their natural environment. The single flap between the nostrils is also quite obvious in this figure. This is a characteristic used to distinguish Prosopium from other genera of whitefishes.

<u>P. cylindraceum</u> are quite large and deciduous. The gill raker count for these same thirty-five specimens averaged 16.8 (14-19). The pyloric caeca averaged 66.6 (51-80) in number.

There has been considerable discussion about lateral line scale counts and gill raker counts for this species. It seems that the type specimen described by Richardson in 1923 as <u>C. quadrilateralis</u> may have been, in fact, more representative of the Asian species <u>C. cylindraceus</u> (once believed to be a subspecies) than it was of those found in North America or at least of the Great Lakes Region. Specimens from Northwestern Canada examined by Dymond in 1943 were more typical of <u>P. cylindraceus</u> than of <u>P. quadrilaterale</u>. These two forms are no longer considered subspecies but merely variations within the same species. As was previously mentioned, Dymond (1943) considered these differences to represent clines for gill raker counts and lateral line scale counts. This was particularly evident in proceeding southeast across North America. This may be further substantiated with the results of the pyloric caeca count of the round whitefish captured in Newfound Lake. Although <u>Prosopium cylindraceum</u> of Newfound Lake is very similar to the forms found in the Great Lakes, it differs markedly from all previous published data in having significantly fewer pyloric caeca. The references I have been able to find are not numerous. However, the whitefish of Newfound Lake average about 66.6 pyloric caeca as compared to the Lake Huron specimens with a range of 87 to 117 caeca and the Baker and

Great Bear Lakes specimens with an average of 90 and 100 pyloric caeca respectively. These data point to a reduction in the numbers of pyloric caeca from west to east across North America. It would seem, then, that these results tend to substantiate the existence of clines.

The whitefish of Newfound Lake is compared with those of other areas in Table 2. This includes two specimens collected from the Connecticut River in Pittsburg, New Hampshire.

Color and Odor

The head and back are uniformily brown to sepia with some tinge of green. The sides are also tinted with brown, the intensity being greatest above the lateral line and decreasing and disappearing altogether about the fifth or sixth row of scales below the lateral line. A silvery tinge is also quite obvious on the sides and this in combination with the brown gives a pinkish cast to the organism. The ventral surface is mostly white although there is some variation in different specimens. The dorsal fin is bronze with a faint, black leading edge and a black margin. The adipose fin is light to dark brown in color. The caudal fin is also a brownish color with black leading edges and a black margin. The pectorals range in color from a gray to a pale orange to a bright almost red appearance with the intensity of the color greatest near the leading edges and disappearing completely back about two thirds of the fin. The ventral fins are similar but the color is not as intense. The anal fin

TABLE 2. Comparative counts of body parts of Prosopium cylindraceum from Newfound Lake and other localities.

Locality	Number of specimens	Lateral line scale counts	Gill rakers	Pyloric caeca	Branchiostegal rays	Dorsal rays	Anal rays
Newfound Lake *	35	89. 5(83-95)	16. 8(14-19)	66. 6(51-80)	7. 14(6-8)	11(10-12)	10(9-11)
Connecticut River*	2	91(88-94)	18	63(55-71)	7. 5(7-8)	11. 5(11-12)	10. 5(10-11)
Labrador	21	86. 7(79-93)					
New Brunswick	3	87					
Lake Michigan	65	(84)87-95(100)	(15)16-18(19)		7 or 8	11-12(13)	9 to 11
Lake Huron	64	(80)84-91(95)	(15)16-17(19)	87-117			
Lake Superior	69	(84)86-93(98)	(15)16-18(20)				
Lake Nipigon **	-	86(80-92)	17		6 or 8	12 or 11	10 or 11
Great Slave Lake	8	90. 6(85-97)					
Great Bear Lake	4	95(90-100)	18. 8(18-19)	100. 8(82-116)	8	13. 5(13-14)	12. 5(12-13)
Baker Lake	6	92(86-99)	17(16-18)	90. 4(76-105)	6. 6(6-7)	13. 4(13-14)	12. 4(12-13)
Arctic Alaska	24	95(89-101)					
Siberia	-	97(89-106)	18-20				

* Specimens examined by this author
** Description given by Dymond (1926)
All others from a table by Walters (1955)

ranges from a red or orange color to an almost complete lack of color in some individuals.

These fish have a rather peculiar odor when freshly captured. I have noticed a similar odor while examining the smelt (Osmerus mordax).

Size

The longest fish captured during this entire study was 451 mm (17.8 inches) in total length. The heaviest fish weighed 594 grams (1.3 pounds). It appears that this is approximately the maximum size for this species in Newfound Lake. The majority of the specimens captured ranged in size from 300 to 375 mm (12 to 15 inches). In other areas, notably the Great Lakes, P. cylindraceum may attain a maximum weight of four or more pounds.

Sexual Dimorphism

Several male and female specimens were examined prior to and during the spawning period in 1961 and again in 1962. At first, there appeared to be some evidence that the males developed a brighter coloration especially on the pectoral and ventral fins. However, attempts to determine the sexes by color alone soon proved to be impossible. It seems that the males are, for the most part, more brilliantly colored than the females but there are females more brilliantly colored than some of the males. There are also some males that lack this bright coloration altogether and look very much like a female. The larger, older, sexually mature individuals of both sexes are more highly colored than the smaller and younger spawning fishes. These larger fish have a considerable amount of color on the belly as well as other parts of the body. There seems to be some increase in pigmentation on the abdomen which results in a yellowish appearance. It is doubtful, therefore, that any real color differences exist between the sexes during the spawning season.

Perhaps another method of differentiating between the males and females during the spawning season is by the relatively heavier appearance of the females. Their abdomens are somewhat more distended when compared with the more slender males. This, however, is not a very accurate method and certainly leaves much to be desired.

The most reliable characteristic used to distinguish the two sexes is the relative size and development of the pearl organs. The males have prominent pearls while in the females, these are much less developed and in some cases, barely noticeable. By gently rubbing the sides of the fish or by handling several of these fish, it becomes possible to separate the sexes with a fair degree of accuracy. This method, however, is not fool-proof and I have misidentified many specimens.

A combination of all these, i.e., color, shape, and development of the pearl organs, are highly useful in distinguishing between sexes. It is only during the spawning season, however, that this can be done. At other times of the year, the fish must be dissected and the gonads examined in order to be able to make this distinction.

Pearl Organs

Pearl organs are found in all of the whitefishes and may be used as a method of separating various genera (Koelz, 1929). In P. cylindraceum, these nuptial buttons are much more prominent on the males than they are on the females. I observed them first of November 15, 1961, only fifteen or so days prior to spawning, and in 1962, they were first noticed on November 18th. This would indicate that these breeding structures are formed in the first two weeks of November. Each nuptial tubercle consists of a thickening in the center of the exposed area of the scales. Each scale has but a single pearl except for the lateral line scales. In some cases, these have two per scale. The pearl organs are prominent on the first four rows of scales above and below the lateral line on each side of the fish and are somewhat less noticeable on the fifth and sixth rows. There are a few of these structures scattered on the backs of the fish, however, these are much reduced. These projections are more prominent along the posterior half of the fish and especially along the caudal peduncle. The pearls are not very permanent structures, in fact, they slough-off quite easily only a few hours after the fish is dead, even when the specimens are kept under refrigeration.

REPRODUCTION

General

The literature contains little information concerning the reproduction and spawning of the round whitefish. Koelz (1929) indicated that these fish spawn in the fall sometimes between November and December. Most of this information came from commercial fishermen in lakes Huron, Michigan, and Superior. Koelz stated;

> The inshore movement in the fall is for the purpose of spawning. While there are no definite dates available as to when the eggs are deposited, the fishermen say that the run is the heaviest during the last two weeks in November, which may indicate that this is the spawning period.

Kendall (1908) indicated that the round whitefish of the First Connecticut Lake ascend the streams to spawn about the last of October and the first of November. Bailey (1938) stated "In Newfound Lake, they [*P. cylindraceum*] are reported to ascend streams to spawn."

Armed with this limited information and confronted with a 4,000 acre lake, the task of finding the spawning area and doing this at the right time seemed at first to be a formidable undertaking. It was. No one had any idea when or where these fish spawned in Newfound Lake. Indeed, if they spawned in deep water, there was little chance of anyone discovering the spawning grounds. This problem was approached by setting gill and fyke nets at various locations around the lake. Nets were set near the mouths of the major tributaries of the lake, and at depths ranging from four feet to over one hundred feet. In the fall of 1961, netting activities were conducted from the 17th of October through the 11th of December. Although the spawning grounds were not located at that time, the time of spawning was determined. The first ripe female was taken on the first of December 1961 and twenty spent females were captured on the 11th of December.

The spawning area was located January 23, 1962 when whitefish eggs were collected from the rocky reef between Pike's Point and Mayhew Island (see map Fig. 2).

Spawning Habitat

The spawning habitat consists of a large, shallow, rocky reef located near the southern end of the lake. This is the same reef used by the spawning lake trout late in October. It is not known if the whitefish spawn elsewhere in the lake. Other potential spawning grounds were examined, but no indication of spawning activity was noticed.

The reef is quite extensive and is between one and two acres in area. The bottom consists of gravel and rubble with large boulders scattered in various areas. There are some sandy areas both on and adjacent to the reef. Most of the eggs were collected from the gravel-rubble bottom type in relatively shallow water (Fig. 5). It would seem that the fish prefered to spawn on this type of substratum. The reef slopes into deeper water on all sides. A channel, present between the reef and Pike's Point, is 6 to 10 or more feet deep depending on the lake level. The northwest side of the reef descends very rapidly toward deep water. Another channel is located between Mayhew Island and the southern tip of this reef. The spawning area is exposed to the prevailing northwesterly winds and is, therefore, kept relatively free from silt by the action of waves and water currents. The water level fluctuates quite markedly from year to year and season to season and may differ as much as four or five feet. In the fall of 1961, large boulders stood out on the reef as much as three feet above the water. During this same period in 1962, these boulders were entirely submerged. The eggs are deposited in depths of just a few inches to several feet. It is interesting to note that although three feet of ice may form on the main part of the lake, water over part of the reef itself may not freeze at all except for a thin skim of ice during the coldest periods (Fig. 6). This phenomenon may be due to one of two reasons. Either there are springs in the area that keep warmer water flowing upwards preventing ice from forming or there are currents in the lake which also carry warmer water upwards and prevent freezing.

Observations on the Spawning Activity of *P. cylindraceum*

The whitefish begin arriving on the spawning reef about the last week of November. An occasional whitefish was taken prior to this but it was not until the 21st of

FIGURE 5. Collecting round whitefish eggs from the spawning reef in Newfound Lake on February 3, 1962.

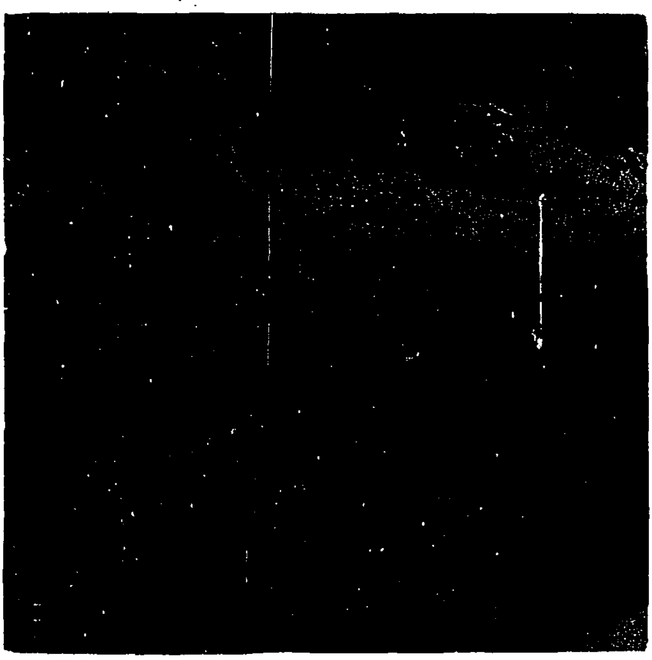

FIGURE 6. Winter conditions on the whitefish spawning grounds, February 3, 1962. Although much of the lake was covered with as much as two feet of ice, the spawning reef was not completely iced-over.

November 1962, that many were caught. In 1962, many of the males arrived at an earlier date than did the females. In contrast, it was not until the females were ripe or nearly so that they approached the spawning grounds in any numbers. The numbers and proportions for each sex as well as the water temperatures for these dates is given in Table 3. Although a partially-ripe female was caught on the 30th of November, it was not until the 3d of December that the spawning females arrived in force. These spawning fish apparently cease to feed before and during the spawning period. Stomachs were examined from over two hundred fish at that time and most of these were empty. Prior to the onset of spawning, stomachs of captured whitefish were usually full.

TABLE 3. Sex ratio of P. cylindraceum captured on or near the spawning reef in Newfound Lake during the 1962 spawning period

Date	Males		Females		Water
	number	percent	number	percent	temperature °F
Nov. 18	3	100.0	0	--	--
Nov. 20	3	60.0	2	40.0	--
Nov. 24	27	87.1	4	12.9	40
Nov. 26	20	80.0	5	20.0	39
Nov. 28	40	80.0	10	20.0	40
Nov. 30	33	84.6	6	15.4	40
Dec. 1	59	93.7	4	6.3	40
Dec. 3	23	63.9	13	36.1	40
Dec. 7*	19	57.6	14	42.4	39
Dec. 11*	21	53.8	18	46.2	38
Dec. 15	44	50.0	44	50.0	37

* Note that the proportion of males and females is nearly the same. This is believed to be the peak of spawning activity.

Several schools of whitefish were observed on the reef at the beginning of the spawning run, but these fish were very wary of the boat and moved off at the slightest provocation. These schools varied in size, but it is certain that there were several hundred fish per school. In fact, there were so many whitefish in the area, gill nets were removed so as to prevent unecessary injuries or mortalities to the spawning population. A fyke net was set on the reef but it was not as effective as the gill nets in capturing whitefish. An advantage of this type of net, however, was that the fish, when caught, were not injured and could be released after their sex was determined. After a two day set, this net had taken only five whitefish. On December 7, after a four day set, 33 whitefish were caught in this net. On the 11th of December, after being re-set for four more days, 39 white-fish were taken. All were ripe as had been the fish of Dec. 7 and eggs poured from the females as soon as they were handled. It would seem that this was the peak of spawning activity. On the 15th of December, 44 male and 44 female round whitefish were captured. Many of these fish were spent indicating that the spawning run was nearly over and that the peak had probably occurred a few days before. The net was removed from the lake on this day as ice had already formed in some of the smaller coves around the margin of this lake, and it would soon be impossible to get onto the reef to tend the nets.

Indications are, then, that the round whitefish of

Newfound Lake spawn during the first three weeks of December and that the peak of this spawning activity occurs during the second week.

Predation at Time of Spawning

There is a general increase in the activity among fishes at the onset of the spawning run. Not only are there more round whitefish taken in the nets, but there is also an increase in the numbers and kinds of other fishes captured. Of these, the two most numerous are the white sucker, Catostomus commersoni, and the yellow perch, Perca flavescens. Other species netted at this time included the burbot, Lota lota, the fallfish, Semotilus coporalis, the chain pickerel, Esox niger, the brown bullhead, Ictalurus nebulosus, and the Atlantic salmon, Salmo salar.

It is difficult to determine which species may be the most serious predator of whitefish eggs, but eggs have been found in the stomachs of most of those mentioned above. The white sucker was certainly an important predator as it occurred in tremendous numbers and the stomachs were often full of eggs. As many as 100 of these large fish have been taken from a single fyke net after a two day set. Also, large numbers of both the white sucker and the yellow perch were observed on or near the spawning reef apparently searching for eggs. They were present both during the day and in the evenings. The burbot and brown bullhead also feed on these eggs, and on many occasions were seen swimming between the smaller rocks and crevices in the search for food. The stomachs of two burbot examined December 3, 1962 contained several whitefish and lake trout eggs. Another possible predator, the crayfish, Oronectes limosus, is known to be abundant on the reef and these may feed on fish eggs. Perhaps the most unexpected source of predation and an interesting one at that, is the round whitefish themselves. Female whitefish were captured shortly after spawning in 1961. These fish were spent and had apparently just left the spawning grounds when they were caught in the gill nets. Examination of their stomachs revealed several whitefish eggs. Apparently, after their spawning fast, they will feed voraciously and their own eggs are as acceptable as any other type of food. It is a wonder that any eggs remain to produce a new generation, especially when one realizes that this initial predation is only one form of destruction and that these eggs must remain on the reef for the duration of the winter. Here, they are exposed to many other dangers before finally hatching. The increase in activity during the spawning period and the concentration of fishes in this area is not entirely for the sole purpose of feeding on whitefish eggs. Some species find other food there. For example, the piscivorous pickerel and large fallfish were catching smaller fishes such as yellow perch, small fallfish, other minnows, and crayfish. The stomach of one large chain pickerel yielded the remains of a 10 inch whitefish.

Fecundity

The only reference I have discovered in the literature concerning the fecundity of *P. cylindraceum* is in Slastenenko (1958). He indicated that females produce about 20,000 eggs. This is approximately twice the number of eggs found in the largest individual taken from Newfound Lake.

The results of fecundity studies of the round whitefish of Newfound Lake indicate that the number of eggs per female range between 2,200 and 9,445 based on the volumetric method of determination. Both the volumetric and gravimetric estimates of the number of eggs plus ages, lengths and weights for each of the 48 specimens examined are presented in Table 4. The ovaries ranged in weight from 23.6 grams to 108 grams and in volume from 22.0 ml to 100.5 ml. The gravimetric estimates of egg number are, for the most part, greater than the volumetric evaluations. In 35 of the 48 cases, the gravimetric assessments were greater than the volumetric. The reverse was true in only 13 cases.

The information presented in Figures 7 and 8 comparing age and fecundity and weight and fecundity are based on volumetric estimates. Actual count of the number of eggs and comparison of this with the volumetric and gravimetric evaluations show that the former is about 3 percent greater than the actual count whereas the gravimetric assessments were 5 percent lower. This small error is well within reason for estimates of this nature. Vladykov (1956) used this method in studying the fecundity of the brook trout, *Salvelinus*

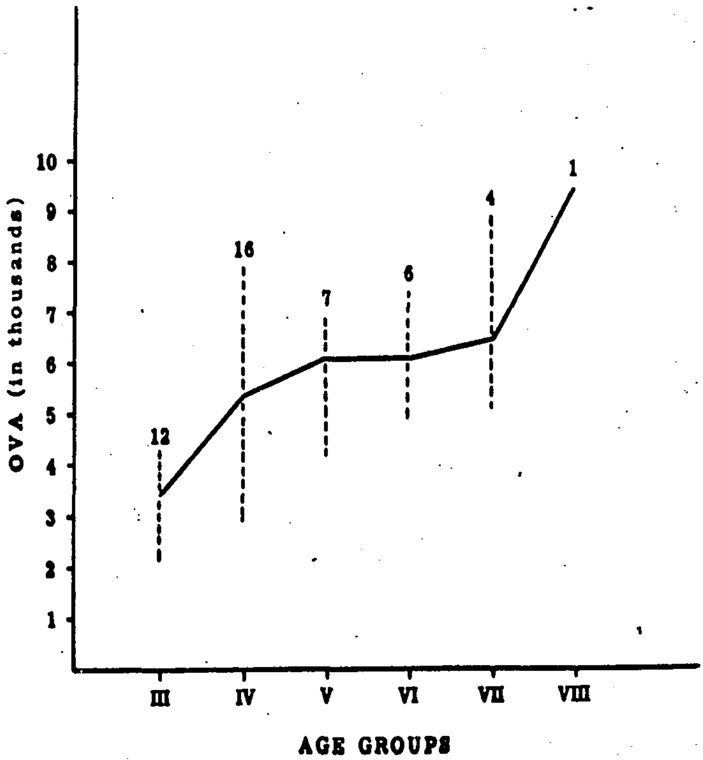

FIGURE 7. Fecundity of the round whitefish of Newfound Lake. Dotted lines indicate range. Solid line indicates mean number of eggs for each age group. Number above dotted line represents the size of the sample for each age group.

fontinalis and in no case did the evaluated number differ from the counted number by more than 10 percent.

There appears to be a definite correlation between age and fecundity and between weight and fecundity. This is to be expected for as the fish increase in age and size, so too there is a corresponding increase in fecundity. There may be some evidence, however, that the older fish are not as productive as some of the younger specimens. Kelley (1962) indicated that this was the case for the largemouth bass, Micropterus salmoides, in Maine.

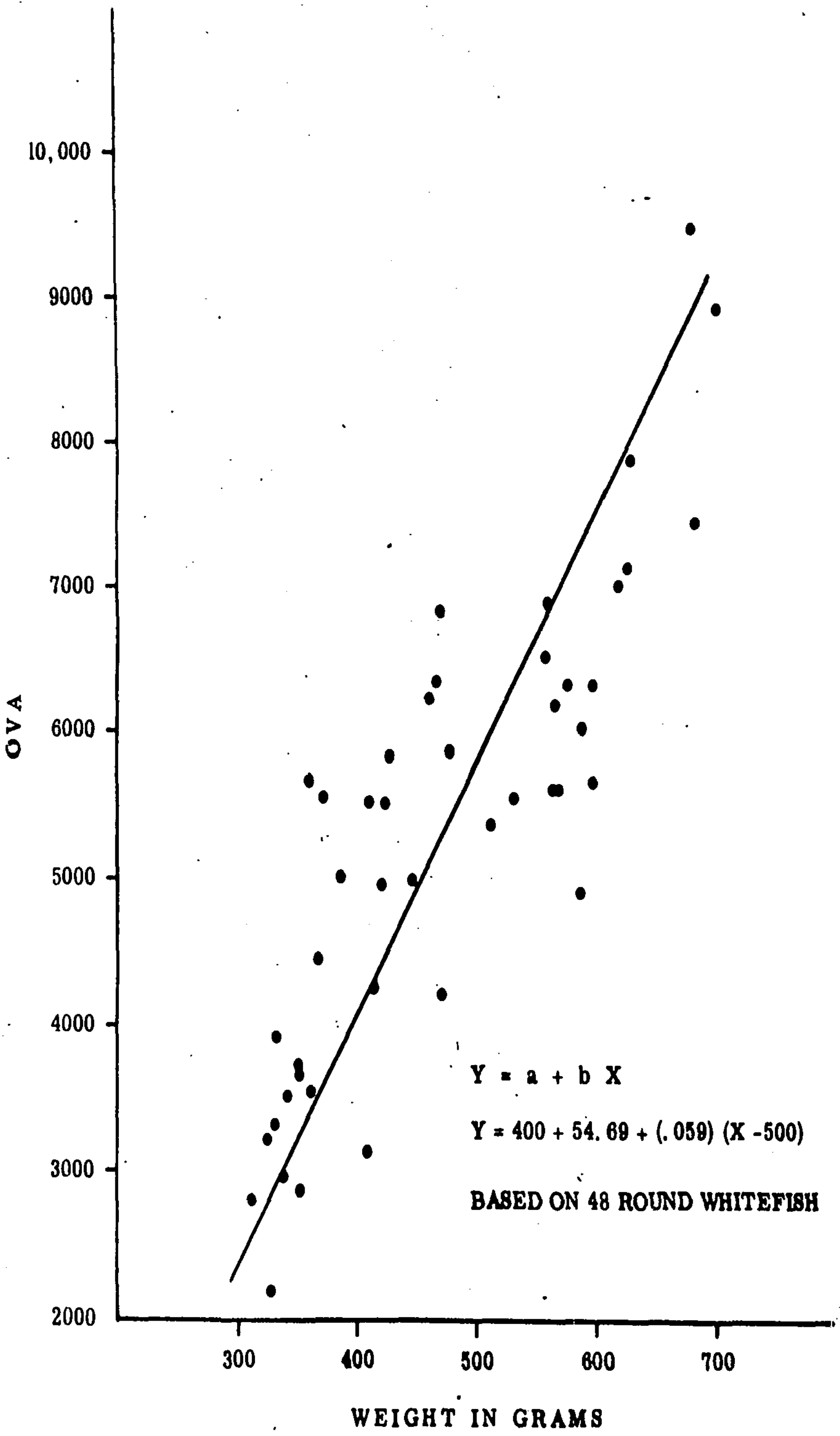

FIGURE 8. Comparison of weight of the fish with the number of eggs produced of 48 round whitefish from Newfound Lake.

TABLE 4. Fecundity of the round whitefish of Newfound Lake, Bristol, New Hampshire.

Collection number	Age	Total length	Weight in grams	Ovary weight in grams	Estimated number of eggs	Ovary volume in ml.	Estimated number of eggs
117	III	331	331	38.7	3,367	36.0	3,312
233	III	353	472	54.6	4,313	51.0	4,233
45	III	328	332	30.8	4,035	28.5	3,933
147	III	328	351	44.2	3,801	41.0	3,731
160	III	343	363	39.4	3,428	37.0	3,552
83	III	329	372	33.8	3,718	31.0	3,596
99	III	336	352	32.4	3,046	29.0	2,871
60	III	328	325	23.6	3,186	22.0	3,212
167	III	318	311	29.1	2,735	27.5	2,806
162	III	331	327	26.8	2,218	25.0	2,200
148	III	331	353	35.3	3,530	33.0	3,663
152	III	349	415	44.8	4,346	42.0	4,284
24	IV	391	553	50.8	6,807	47.0	6,627
30	IV	347	386	38.9	4,940	35.5	5,005
158	IV	345	374	54.9	5,327	51.5	5,562
129	IV	332	369	57.6	4,433	54.5	4,469
139	IV	350	412	63.3	5,507	59.0	5,546
80*	IV	342	361	50.8	5,496	48.0	5,664
11	IV	357	470	67.2	6.384	63.6	6,350
165	IV	404	632	88.0	7,832	82.0	7,872
36	IV	344	423	44.8	5,107	41.5	4,980
49	IV	405	600	46.3	5,741	43.0	5,633
53	IV	405	565	65.6	7,019	61.0	6,893
153	IV	323	341	39.4	3,585	36.5	3,504
101	IV	350	425	59.3	5,337	55.0	5,225
102	IV	324	339	36.9	3,026	34.5	2,967
114	IV	351	409	39.4	3,191	37.0	3,145
118	IV	352	428	63.2	6,004	58.5	5,850
104	V	357	481	75.5	6,040	70.0	5,880
16	V	406	578	80.2	6,496	74.5	6,333
7	V	403	627	68.2	7,366	63.5	7,176
54	V	373	410	30.0	4,290	28.0	4,200
75	V	385	565	57.9	5,732	54.0	5,616
92	V	358	473	68.7	6,939	64.5	6,837
122	V	367	463	70.7	6,363	65.0	6,240
109	VI	373	513	60.7	5,281	55.5	5,383
3	VI	394	589	46.1	5,025	43.0	4,902
106	VI	392	593	70.4	6,054	66.5	6,052
125	VI	394	568	77.9	6,388	72.0	6,192
46	VI	402	686	108.0	7,560	100.5	7,437
111	VI	380	560	82.4	6,674	76.5	6,503
113	VII	410	600	77.5	6,278	72.5	6,308
64	VII	370	448	43.1	5,172	39.7	5,002
19	VII	436	705	86.8	9,027	81.0	8,910
98	VII	390	569	59.3	5,752	55.0	5,610
47	VIII	417	685	81.2	9,181	77.5	9,455
26	?	386	534	59.0	5,422	55.5	5,550
28	?	395	623	67.4	6,740	62.5	7,000

* Actual count of eggs 5,496

These remarks on fecundity, as presented here, do not take into consideration the total reproductive potential of the population, but only that of the individual. It was not possible to determine the size of the spawning population or if there was more than one area in which they spawned. Many schools composed of several hundred individuals were seen on or near the reef, however. Taking this into consideration and realizing that each female can produce about 5,000 eggs, it would seem that the total number of eggs deposited on this reef might number several millions. Thus the reproductive potential is great and must of necessity be so if a portion of these eggs are to be fertilized, survive predation, disease, suffocation and many other hazards, and still hatch in the spring.

Sex Ratio

It is difficult to determine the sex ratio of this species in a population of the size found in this lake. However, in the summer of 1959, the sex was determined for 200 whitefish. Of these, 92 or 46% were males and 108 or 54% were females. As these fish were captured randomly over the entire lake, this may be a reliable indication of the sex ratio of the population. In the fall of 1961, 192 fish were sexed. Of these, 75 or 39% were males and 115 or 61% were females. The figures for 1961 indicate a larger proportion of females, but this may be misleading as several spent females were captured shortly after they spawned and apparently before the males had left the spawning reef. In fact, there were several days during the spawning run when no males were taken at all, for at that time, the spawning reef had not been located. During the fall of 1962, 327 whitefish were netted and of these, 249 or 76.1% were males and 78 or 23.9% were females. Again, this is not indicative of the population ratio for it is the reverse of the 1961 results. This time, netting was conducted on or near the spawning grounds and as has been mentioned before, the males arrive before the females and thus were captured in greater numbers. Perhaps what is more indicative of the actual sex ratio is the numbers and proportion of both sexes taken in fyke nets at the height of the spawning activity between December 3d and 11th. Although only a few fish were taken at this time so as not to interupt the natural spawning activity, the proportion of males to females was more nearly equal.

The only conclusions that can be drawn from this rather sketchy information are that it would appear that both sexes are more or less equally represented. The sex composition for various age groups is presented in Table 5. However, any conclusions drawn from this information must take into consideration that the fish captured in 1961 were netted during their spawning run. Also, where there are only a few individuals involved, as in the older age groups, few conclusions can be made.

TABLE 5. Sex ratios by age groups for the round whitefish captured in 1959 and 1961 from Newfound Lake, N.H.

Age groups	April to August 1959			Oct. to Dec. 1961		
	Number	Males	Females	Number	Males	Females
I	0	-	-	0	-	-
II	41	26	15	10	6	4
III	37	15	22	51	16	35
IV	36	14	22	51	18	33
V	30	14	16	41	23	19
VI	32	14	18	19	6	13
VII	12	4	8	9	4	5
VIII	10	4	6	3	-	3
XI	2	1	1	0	-	-
Total	200	92	108	185*	73	112

* A total of 190 fish were sexed but five could not be aged.

Sexual Maturity

The state of development of the gonads was determined for 194 whitefish taken during the summer of 1959. Those fish that would have spawned in the fall of that year were recorded as mature fish. This included those that would probably spawn for the first time, those that had well developed gonads, and those cases in which a few atretic eggs could still be found in the body cavity. The individuals whose gonads did not appear to be developed enough so that they could spawn in the fall, were noted as immature. From this information, indications are that the female round whitefish attain sexual maturity in their fourth or fifth year. This was based on 104 females Table 6. Results based on the information taken from 90 males also indicate that they attain sexual maturity in their fourth or fifth year, i.e., fish that are three or four years old. Note that none of the males or females in age group II were sexually mature. This was also the case for the 1961 captures. Since these were captured shortly before spawning, the state of gonad development was more easily determined than for those taken in the summer of 1959. All of the fish 3 years of age or older were sexually mature and would have spawned that year. These fish attained sexual maturity between 300 and 350 mm (12 to 13 inches) in total length.

TABLE 6. State of gonad development for the round whitefish captured between April and August 1959 in Newfound Lake, N.H.

Age groups	Males		Females	
	Immature	Mature	Immature	Mature
I	--	--	--	--
II	25	0	15	0
III	10	8	13	17
IV	1	12	--	21
V	--	12	--	15
VI	--	13	--	18
VII	--	4	--	8
VIII	--	4	--	6
IX	--	1	--	1
Total	36	54	18	86

Description of the Whitefish Ova

The unfertilized, ovarian round whitefish eggs, are small, yellow to orange spheres ranging in size from 2.40 mm to 2.95 mm with a mean diameter of about 2.70mm (based on 30 measurements from 3 different fish taken during the spawning period). Once in the water, the ova settle to the bottom rather quickly. They then begin to absorb moisture and increase in diameter. After being exposed to the water for a few hours, they reach maximum diameters of about 3.94 mm with a standard deviation of 0.34 mm. The range varies from 3.30 mm to 4.60 mm based on the measurements of 100 ova collected randomly over the spawning reef. These water-hardened eggs have an orange appearance and upon closer examination, the colored oil globules can be seen inside the yolk. The chorion is colorless and provides the space and protection for the developing embryo.

The eggs are apparently fertilized soon after their release into the water. Although it is not known what percent of the total are fertilized, it is believed to be quite high. In fact, most of the eggs collected with the previously described pump were in excellent condition. However, there were several dead eggs and empty shells which were evidence that not all had developed normally.

Many of the eggs collected throughout the winter were incubated in a refrigerator at a temperature of 36°F, the same temperature as on the spawning reef. Periodically, these eggs were dipped for 20 to 30 seconds in a 1:15,000 solution of malachite green. This was in order to prevent infection by the fungi. Several hundred whitefish eggs were incubated at the New Hampshire Fish and Game Department's Powder Mill Rearing Station in New Durham, N.H. These eggs were placed on trays made of a wooden frame covered by nylon mesh small enough to support the eggs but large enough to permit the fry to pass through upon hatching. The entire tray was submerged about two inches below the surface of the water in a wooden trough. A continuous supply of fresh lake water was permitted to pass through this trough. Fortunately, there was little mortality among these advanced eggs as they developed. Samples of eggs were taken periodically from the spawning reef and examined. The temperature of the water was taken at each collection. As the temperatures were the same on the reef, in the refrigerator, and at Powder Mill in the hatching troughs, the embryos developed at approximately the same rate at each place. Table 7 presents the water temperatures at the 3 localities in which whitefish eggs were incubated.

Many eggs on the spawning reef succumbed during the winter. Fungi, suffocation due to siltation, and possible predation by some invertebrates were some of the major causes of this loss. Crayfish and leeches were collected along with the eggs, but it is not known what effect these may have on the survival of the developing whitefish embryos. It is reasonable to assume, however, that mortality during the winter months is quite heavy.

Hatching

On March 31, 1962, the first sac-fry were collected from the reef. This was the beginning of the hatching period. The peak of hatching activity occurred during the last week of April, and apparently all the whitefish had hatched by May 11, 1962. At the Powder Mill Rearing Station, the eggs began to hatch on the 11th of April, 1962. The peak of hatching activity occurred between the 23d and the 30th of April with a few hatching as late as May 6. In the refrigerator, all hatched between the 16th and the 25th of April. However, only a few dozen eggs were involved. The exact duration of the embryonic development could not be ascertained, since it was impossible to determine when the eggs had been deposited. However, assuming that the peak of the spawning period occurred at the end of the first week of December and the peak of hatching activity occurred during the last week of April, the total number of days required for development at 36 °F is approximately 140. This is almost identical to that for C. clupeaformis developing under similar conditions as described by Hart (1930).

TABLE 7. Water temperatures at the three localities in which round whitefish eggs were incubated.

Spawning reef		Powder Mill Rearing Station		Refrigerator	
Jan.	36°F	Jan.	36°F	Jan.	36°F
Feb.	36°F	Feb.	36°F	Feb.	36°F
Mar.	36°F	Mar.	36°F	Mar.	36°F
Apr. 14	36°F	Apr. 3	37°F	Apr.	36°F
Apr. 28	41°F	Apr. 9	38°F	May	36°F
		Apr. 11	39°F		
		Apr. 25	40°F		
		Apr. 30	41°F		
		May 2	42°F		
		May 9	43°F		

EARLY LIFE HISTORY OF THE ROUND WHITEFISH

General

The first newly hatched fry were taken from the spawning reef on March 31, 1962 from just a few inches of water. The water temperature at this time was 36°F. The fry, upon hatching, remained on the bottom and when disturbed, they could be seen swimming vigorously attempting to seek shelter in the tiny crevices amd beneath larger rocks. Many lake trout sac-fry were also collected at this time and as none of their eggs could be found, it appeared that the peak in hatching activity for this species had occurred. The ice conditions on the reef had changed somewhat from earlier observations for there was considerably more open water at this time than there had been earlier in the month. On the 14th of April, a marked change had occurred. The water level had risen some 4 or 5 feet and where whitefish fry had been collected in only a few inches of water the week before, the area was now under several feet of water. The water temperature had risen to 37°F and a large area of the reef was now exposed. Shifting ice, however, made it difficult to collect eggs and fry. Of the few fry collected, several stages of early development were observed. Some had prominent yolk sacs while others had absorbed much of this embryonic structure. None of the fry examined had started to feed. On the 28th of April, several fry and eggs were collected. The lake was completely free of ice and the water temperature had risen to 41°F. Hart (1930) and Pritchard (1930) showed that the fry of the cisco and the lake whitefish upon hatching and absorption of the yolk sac, moved to the surface and began to school near the shore in shallow water. Observations in the shallow water along the shore of Newfound Lake on the 28th of April did not reveal a single round whitefish fry. On the 4th and 5th of May, several round whitefish fry were collected from the spawning reef. Some of these were well developed and it may have been that some of the more advanced fry were able to avoid the pump and thus were not captured. The hatching process was nearly over for only a few eggs were collected. Observations along the shoreline did not reveal any of these organisms. On the 11th of May, only a single whitefish fry was collected from the spawning reef itself. Again, no whitefish were observed along the shallow waters and it seemed obvious that these fry, if they schooled, did not frequent the shallow waters as was the case for the cisco and the lake whitefish. A tow net, approximately one meter square, was used in an attempt to collect fry on this date. This procedure was partially successful when three specimens were collected just below the surface several hundred yards from the spawning reef and over deep water (50 feet or more). The water on this date was highly turbid and a strong wind had blown for several days prior to these observations. It is possible that the fry had attempted to rise to the surface and leave the spawning reef but had been scattered by the rough water conditions at that time. This could explain why these three specimens had been found near the surface and over deep water. Observations along the shallow water on the 17th of May were again without success and no whitefish were seen or collected. However, many schools of yellow perch were seen in the area. On the 28th and 29th of May, many small schools of fry were observed in the shallows near the spawning reef, but these later proved to be fry of the white sucker.

Although several attempts were made to collect the fry and later the juveniles of the round whitefish, none were collected after the 11th of May. Periodically throughout the summer, attempts were made to capture juvenile and immature specimens with the use of an otter trawl. Although there were no whitefish collected with this net, several sculpins, Cottus sp., smelt, Osmerus mordax, and an occasional lake trout were captured.

Few conclusions can be made, therefore, regarding the early life history of P. cylindraceum of Newfound Lake, particularly once it has left the spawning reef and has started to feed. In fact, nothing is known concerning its distribution in the lake, its food or any of its habits until it is nearly mature. Although over one thousand round whitefish have been captured between 1959 and 1962, there were none of age group 0 (except for a few sac-fry taken on the spawning reef) and only two of age group I taken during this entire study.

Predation Upon the Round Whitefish Fry

On the 4th and 5th of May, 1962, gill nets set on and near the spawning reef yielded 4 large salmon and many yellow perch. Two of the salmon were released and the stomach contents of the other two were examined. The stomach of one 16 inch salmon contained over 200 whitefish sac-fry and the other contained 25. The stomachs of the yellow perch were, for the most part, empty and did not contain a single whitefish fry. These perch were all males and were nearly ready to spawn. Stomachs of thirty yellow perch collected on the 11th of May were also void of any fry of the round whitefish. In the Bay of Quinte, Ontario, Hart (1930) found that the stomachs of 15 yellow perch contained 3,500 lake whitefish fry and the stomachs of 12 ciscoes about 10 inches long contained 3,300 whitefish fry. He also indicated, however, that in 1928 the stomachs of 100 yellow perch did not contain a single whitefish fry although the fry were very abundant in the area. It would seem, then, that the yellow perch can and may be an important predator of the fry of the round whitefish and although about 40 yellow perch stomachs were examined and no fry were observed, this does not preclude the possibility that they would feed on these fry under the proper conditions. Many schools of yellow perch, each containing hundreds of individuals, were seen on or near the spawning reef during the month of May, 1962. Although this is only speculation, it would seem that when the whitefish have absorbed their yolk sacs and are in the process of leaving the spawning reef, they are probably entering one of the most critical phases of their life history. Not only must they search for food, but they are at the same time vulnerable to many dangers, particularly predation. Unfortunately, conditions were such that it was not possible to investigate this aspect more thoroughly.

Observations of the Fry at the Powder Mill Rearing Station

As was mentioned before, over one hundred whitefish eggs collected from the spawning reef during the winter of 1962, were brought to the New Hampshire Fish and Game Department's Powder Mill Rearing Station. Many of these hatched successfully and observations were made on the developing fry. Although environmental conditions were somewhat artificial, certain aspects in the behavior of these fry probably resemble those of fry developing under normal conditions. Since many of these observations could not be carried-out in the field, the following account is presented.

Upon hatching, the fry settled to the bottom of the trough where they remained until the yolk sac was completely absorbed. Although these sac-fry were able to swim about by a violent jerking motion of the tail, they usually remained still unless otherwise disturbed. Approximately two to three weeks after hatching, the yolk sac was completely absorbed and the fry left the bottom of the trough and began to swim against the current. The water supply, coming from Merrymeeting Lake located only a few hundred yards from the hatchery building, contained considerable quantities of planktonic organisms. Both copepods and cladocerans were observed in large quantities in the hatching trough and the fry were seen feeding on these organisms. To compensate for the reduction in the quantity of plankton available by the feeding of these fry, strained liver was fed two to three times per day until the last fingerling was removed. Once the fry had started to feed, they were very agile and were able to swim quite rapidly. In fact, they seemed to prefer the faster currents in the troughs. Heavy unexplained mortality accounted for the majority of these fry early in the summer. By August, only four surviving fingerlings remained, and the last was removed on the 30th of November. Individuals showing various stages of development were removed periodically, and a description of each stage was made.

DEVELOPMENT OF THE ROUND WHITEFISH FRY

General

The following paragraphs contain descriptions of the early stages of the round whitefish hatched at the Powder Mill Rearing Station. Although there may be some variation in morphology due to the artificial environment of this station, it is believed that development of the young whitefish at this hatchery was not unlike the development of the young whitefish in Newfound Lake. The rate of growth may differ significantly between these two situations but anatomical differences at any given size are probably slight. All measurements are presented in millimeters.

May 1, 1962 - Newly Hatched Fry

The body of the newly hatched fry is somewhat elongate and transparent. The large, prominent yolk sac is very obvious and the fry has a yellowish appearance in reflected light. A drawing of a newly hatched fry is presented in Fig. 10.

Total length	13.9	Length of yolk sac	3.7
Head length	2.6	Depth of yolk sac	1.5
Head depth	1.7	Pectoral fin length	1.9
Length of snout	.5	Pectoral fin width	1.2
Diameter of eye	1.1	Length to vent	9.7
Length of maxilla	.26	Number of myomeres	60

Yolk sac. The yolk sac is prominent and contains two large, yellow oil globules at its antero-dorsal end. Also, there is a single large oil globule at the anterior and ventral end of this embryonic structure. Several small colorless droplets are observable throughout this sac. Approximately 52 large, stellate melanophores are present on the ventral and sub-lateral surfaces. Approximately 56 smaller melanophores are found on the antero-lateral surface of this yolk sac and these extend into the region of the throat.

Head. The head is quite large and contains approximately 44 small, dendritic melanophores in the region of the occiput. No melanophores are found on the lateral and ventral surfaces. Raptorial teeth are present on both the upper and lower jaws but the exact number is not known. The eyes are heavily pigmented, very prominent and oval in shape. The choroid fissures are also distinct at this stage.

Body. The dorsal surface of the body contains two rows of melanophores each of which is made-up of approximately 30 of these pigmented structures. These extend almost to the caudal fin. Another double row of about 35 melanophores each is found to lie just dorsal and lateral to either side of the vertebral axis. Many larger stellate melanophores are also present on the lateral and ventral surfaces and extend from the yolk sac to the caudal peduncle. Xanthophores are very small and numerous and are scattered throughout the body. These give the fry a yellowish over-all appearance. These are particularly concentrated in the region of the head.

Fins. The embryonic dorsal fin originates 3.5 mm posterior to the snout and undulates caudally. It rises to form a peak at 7.0 mm from the anterior end of the fry and then, it decreases forming a notch at 8.0 mm. It forms another peak at 10.0 mm, and a notch at 12.5 mm (over the region of the caudal peduncle). From this point, it rises to form the tail. Ventrally, the marginal fin fold originates at the posterior end of the yolk sac at 5.0 mm from the snout. This fin extends continuously, except for a slight dip, and breaks in the region of the vent, 9.8 mm posterior to the snout. The fin rises from the vent, runs posteriorly, dips at 12.5 mm to form the caudal peduncle, and rises again to complete the caudal fin.

The pectoral fins are broadly rounded, quite large, and originate at 2.25 mm from the snout. None of the other fins, except the caudal, are formed at this stage.

May 3, 1962 - Three-Day Old Fry

These fry differ from newly hatched fry in being somewhat longer. The yolk sac is still very prominent and this stage is not much advanced from the newly hatched specimens.

Total length	15.0	Length of yolk sac	3.8
Head length	2.5	Depth of yolk sac	1.5
Head depth	1.9	Pectoral fin length	2.0
Length of snout	0.4	Pectoral fin width	1.4
Diameter of eye	1.1	Length to vent	9.5
Length of maxilla	0.5	Number of myomeres	60

Yolk sac. The yolk sac contains a single large oil globule at its anterior end and several smaller ones dispersed throughout. The distribution of melanophores is similar to that of the newly hatched fry and extends posteriorly to blend with those of the body. This forms a

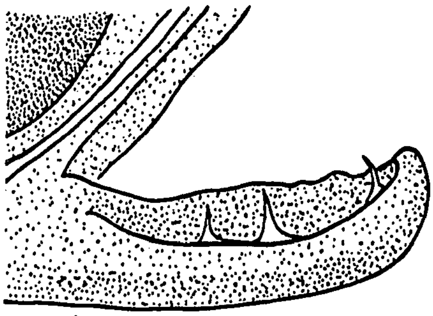

FIGURE 9. Lower jaw of three-day old round whitefish fry showing some of its larval teeth.

continuous band of melanophores to the vent.

Head. The head is quite large and there is a heavy concentration of melanophores in the region of the occiput. Several smaller melanophores are situated deeply within the head. There is also a rather dense concentration of xanthophores in this region. The jaws are well armed with tiny needle-sharp teeth (Fig. 9).

Body. The body is similar to the previously described specimen. The myotomes are easily visible through the almost transparent body. Approximately 32 large, stellate melanophores are found on either side of the dorsal surface of the body. A double row containing approximately 20 melanophores each is located just dorsal and lateral to the vertebral axis. A large number of these pigment cells is found, also, extending from the yolk sac to the caudal fin. The concentration, however, decreases rapidly posterior to the vent.

<u>Fins</u>. Dorsally, the embryonic marginal fin originates at 3.5 mm and rises gradually to form a peak at 7.0 mm. From this point, it decreases rapidly and forms a notch at 8.0 mm, rises to peak at 10.0 mm and decreases to form the caudal peduncle at 12.0 mm. Rising again, it then forms part of the caudal fin. Ventrally, the fin fold originates on the yolk sac at 5.3 mm and runs unbroken to the vent at 9.5 mm. Here, it forms a complete break and then, rising again, proceeds posteriorly where it notches to form the ventral portion of the caudal peduncle at 12.0 mm. It then rises again and completes the formation of the tail.

The insertion of the pectoral fin is anterior and dorsal to the yolk sac at approximately 2.8 mm from the snout. There are no signs of any other fins at this stage and neither the caudal or pectorals are rayed.

May 3, 1962 - 11 to 13 Day Old Fry

There is a considerable change between this and the previously described stage. The yolk sac is much reduced, the fry has elongated and appears somewhat thinner. The fry are also more active than in the earlier stages. The most striking difference, however, is that the fins are in the early stages of differentiation (Fig. 11).

Total length	16.0	Length of yolk sac	2.0
Head length	3.0	Depth of yolk sac	0.8
Head depth	1.9	Pectoral fin length	2.3
Length of snout	0.6	Pectoral fin width	1.5
Diameter of eye	1.3		
Length of maxilla	1.2		

<u>Yolk sac</u>. The yolk sac is much reduced and contains a single large oil globule at its anterior end. The posterior regions of this structure are poorly defined in this stage. There are several large, stellate melanophores (ca. 14) on either side and many punctate forms scattered throughout.

<u>Head</u>. The head is quite similar to the previous stage. Four or more recurved teeth are present on the lower jaw and about the same number were observed on the upper jaw. The eyes are very large and the choroid fissures are still prominent. Approximately 28 large melanophores are present on the head in the region of the occiput. Several smaller forms are scattered throughout this same region.

<u>Body</u>. There is a general increase in the number of melanophores from the previous stage. A double row of about 35 of these pigment cells located on either side of the dorsal surface, extend from the head to the region of the caudal fin. A double row of approximately 50 each located internally and dorso-lateral to the vertebral axis, extend along the entire length of the body. A considerable number of large melanophores are present on the ventral surface and extend all the way to the vent.

<u>Fins</u>. At this stage, areas of differentiation within the embryonic marginal fin are observable for the first time. Although no distinct rays are visible as yet, the beginning of the formation of the ventral, dorsal, and anal fins is quite obvious. The caudal fin is unchanged from the previous

stage. The insertions of the pectoral fins are at 3.1 mm, the ventral fins, 7.3 mm; the anal fin, 11.3 mm; and the dorsal fin, 7.0 mm.

May 7, 1962 - Fry Two to Three Weeks Old

This stage differs from the previously described in that the yolk sac is completely absorbed and the fry have begun to feed. The fry are actively swimming and no longer resting at the bottom of the trough.

Total length	16.0	Pectoral fin length	2.5
Head length	3.0	Ventral fin length	0.5
Head depth	1.9	Greatest depth of the body	3.3
Length of snout	0.5		
Diameter of eye	1.3		

Chromatophores. A heavy concentration of xanthophores is present in the region of the head and on the dorsal surface of the body. Otherwise, these are scattered throughout the body. The number and distribution of melanophores is unchanged from the previous description.

Fins. Elements of the dorsal and caudal fins are observable for the first time. Approximately 8 or 9 can be seen on the differentiating dorsal fin and 8 in the caudal fin. The caudal fin is not, as yet, completely symmetrical.

May 25, 1962 - Fry Three Weeks Old

This fry differs from the previous stage in that the area of the coelom is becoming silvery in appearance. A deposition of guanin is occurring in this region and extends only to the vent. All of the fins, except the adipose, are in various stages of development and a few rays are visible in the caudal fin.

Total length	16.3	Length of maxilla	1.4
Head length	3.1	Pectoral fin length	2.3
Head depth	1.9	Ventral fin length	0.5
Length of snout	0.7	Dorsal fin length	1.5
Diameter of eye	1.4	Anal fin length	1.0

June 12, 1962 - Total Length 23.0 mm

Marked changes have occurred between this and the previously described stages. The most obvious changes are in the reduction of certain parts of the marginal fin, the formation of rays in the dorsal and anal fins, the differentiation of the adipose fin, and the upturning of the posterior tip of the vertebral axis. These changes are illustrated in Fig. 12.

Total length	23.0	Greatest body depth	2.3
Head length	4.8	Length to vent	15.5
Depth of head	3.0	Pectoral fin length	3.0
Length of snout	1.0	Ventral fin length	1.0
Diameter of eye	1.8	Dorsal length	1.8
Length of maxilla	1.5	Anal length	1.0

Head. Melanophores are densely aggregated on top of the head and extend onto the snout. Xanthophores are also very numerous. Silvery patches can be seen on the opercula and they extend to below the eyes. The jaws are still well armed with teeth. The nares are in the process of developing and each contains two buds. These are enlarging and will eventually meet and fuse to form the single flap, a characteristic of taxonomic importance. The choroid fissures are less well defined than in the previous stages.

Body. A double row of melanophores found on the dorsal surface of the body extends from the head to the region of the caudal fin. A double row of these pigment cells are found lying along each side of the body. Just beneath this and dorso-lateral to the gut, another row can be seen which extends to the tail. The ventral and sub-lateral surfaces of the body just below the area of the lateral line, possess a definite silvery appearance. The folds of the gut are quite obvious in this stage.

Fins. The marginal fin originates 5.0 mm posterior to the snout and rises gradually to form the base of the dorsal fin at 10.0 mm. It then continues around the dorsal fin and breaks entirely just posterior to it. The dorsal marginal fin rises again at 14.5 mm and attains a peak at 17.0 mm. It then declines rapidly and disappears entirely at 18.5 mm. This is the region of the developing adipose fin. Ventrally, the marginal fin originates 8.5 mm caudad to the snout, rises gradually to form a continuous medial fin, dips slightly in the region of the developing ventral fins, and is interrupted at the vent. A slight indication of the presence of this embryonic fin is observable around the margins of the anal and caudal fins. The pectorals have their insertion at 5.0 mm, the ventral fins along each side of the marginal fin fold at 10.5 mm, the dorsal fin at 10.0 mm and the anal fin at 15.6 mm. All of these fins contain numerous rays. The caudal fin is still somewhat asymmetrical.

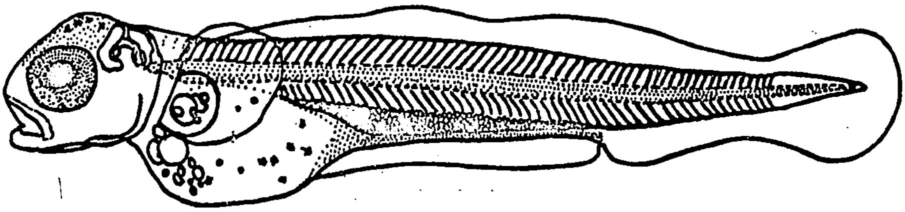

FIGURE 10. Newly hatched round whitefish fry 13.9 mm total length

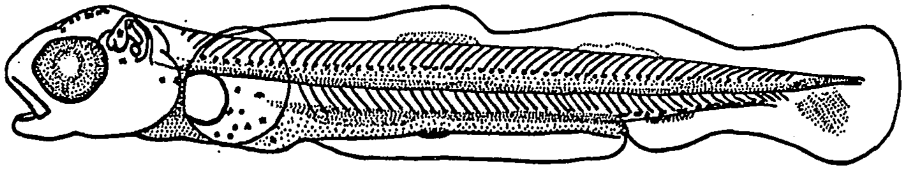

FIGURE 11. Twelve day old round whitefish. The yolk-sac is much reduced and the fins are in the process of developing. Total length, 16.0 mm.

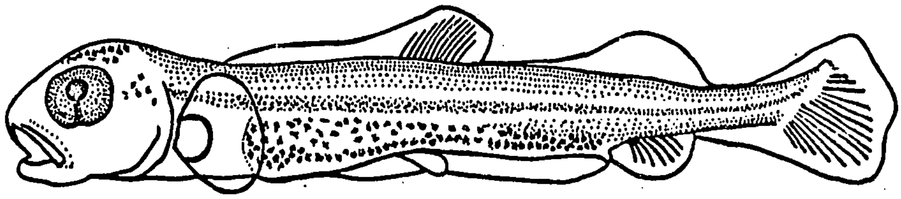

FIGURE 12. Round whitefish fry 23.0 mm total length.

July 3, 1962 - Total Length 29.0 mm

In this stage, all but a small portion of the marginal fin fold has been lost. The fry is rapidly taking on adult characteristics and the single flap in the nares is formed. An illustration of this specimen is presented in Fig. 13.

Total length	29.0	Pectoral fin length	2.3
Head length	5.8	Ventral fin length	2.5
Head depth	3.3	Dorsal fin length	4.0
Snout length	0.9	Anal fin length	2.0
Diameter of eye	2.3	Adipose fin length	2.5
Length of maxilla	2.0		

Head. The head is somewhat blunt in appearance, particularly when compared with previous stages. The snout protrudes beyond the tip of the mandible and the mouth is definitely sub-terminal. Patches of melanophores are distributed along the dorsal surface of the head and extend to the snout. Scattered melanophores are also observable on the opercula. The eyes are still very large but the choroid fissures are no longer visible.

Body. A double row of melanophores with intermittent areas of greater and lesser densities is present on the dorsal surface of the body and extends from the head to the caudal fin. There are approximately 14 dark areas on the dorsal surface of the body of these fingerlings. These are more or less evenly distributed with 7 patches on either side. This is the first indication of juvenile markings. Melanophores are also scattered along both sides with a concentrated band distributed along the region of the lateral line. The ventral surfaces are relatively free of these dark pigment cells except for a thin double row running from the vent posteriorly to the tail and along either side of the anal fin.

Fins. All of the fins, except for the adipose of course, are rayed. The caudal fin is symmetrical and homocercal in shape. A small portion of the dorsal marginal fin is still evident anterior to the dorsal fin. All other fins are typical of those found in the adults.

July 20, 1962 - Total Length 37.0 mm

The most significant difference between this and the previous stage is that in the 37.0 mm fingerlings, the scales have begun to form. Lateral line scales are very prominent and the fingerlings have taken-on many of the adult characteristics. Unfortunately, the descriptions for this and the following stages are made from preserved specimens and it is, therefore, impossible to describe natural pigmentation and color.

Total length	37.0	Length to vent	24.0
Head length	8.0	Pectoral fin length	3.1
Head depth	5.1	Ventral fin length	3.8
Length of snout	1.8	Dorsal fin height	5.0
Diameter of eye	2.9	Anal fin length	5.0
Length of maxilla	2.2		

Head. The head is heavily pigmented especially on the dorsal surface in the region of the occiput. This pigmentation extends to the snout and the opercula.

Body. The pigmentation is heavily concentrated on the dorsal and dorso-lateral surfaces of the body. The melanophore concentration decreases rapidly and disappears altogether just ventral to the lateral line. The only pigmentation visible on the ventral surface is a double row of melanophores running from the vent to the caudal fin.

Fins. The fins are well developed and rayed. The pectoral fins have their insertion at 7.0 mm, the ventrals at 15.5 mm, and the anal at 25.0 mm. The dorsal fin originates 14.0 mm from the snout. The caudal fin is completely homocercal. The ventral fin has about 10 rays, the dorsal has 14 rays, the anal has 11 rays. Melanophores were found on the dorsal and caudal fins.

August 15, 1962 - Total Length 40.0 mm

This stage is similar to the previous stage except that the fingerlings are completely scaled and the juvenile markings on the dorsal surface are more pronounced. An illustration of the dorsal view of this stage showing the juvenile markings is presented in Fig. 14.

Total length	40.0	Length to vent	24.5
Head length	9.0	Pectoral fin length	4.5
Head depth	5.0	Ventral fin length	4.5
Length of snout	2.3	Dorsal fin length	6.0
Diameter of eye	3.1	Anal fin length	4.3
Length of maxilla	2.3		

Head. The head is not much changed from the previous description.

Body. The only significant difference between this and the previous specimen is that in this stage, the fingerlings are fully scaled.

October 19, 1962 - Total Length 56 mm

This stage differs for there is an increase in the size of body parts and the juvenile or parr markings are well defined. This is illustrated in Fig. 15.

Total length	56.0	Pectoral fin length	6.0
Head length	12.0	Ventral fin length	6.1
Head depth	8.5	Dorsal fin height	8.6
Snout length	2.0	Anal fin length	5.6
Diameter of eye	4.0		
Length of maxilla	3.0		

Body. Parr markings are observable along the dorsal and lateral surfaces of the body. Approximately seven to eight of these spots are found along each side of the dorsal surface and about the same number can be distinguished along the sides in the region of the lateral line.

November 30, 1962 - Total Length 59.0 mm

This specimen differs from the previous stage only in the size of body parts. Juvenile markings and distribution of chromatophores are the same. Unfortunately, this was the last specimen available from the hatchery. As it was impossible to obtain any others from the lake itself, descriptions cannot be given beyond the 59.0 mm stage. It is believed, however, that by this stage the fingerlings do not differ much in appearance from the adult. In fact, excepting for size and proportion, the parr markings of the juveniles seem to be the only visible difference between the two life stages.

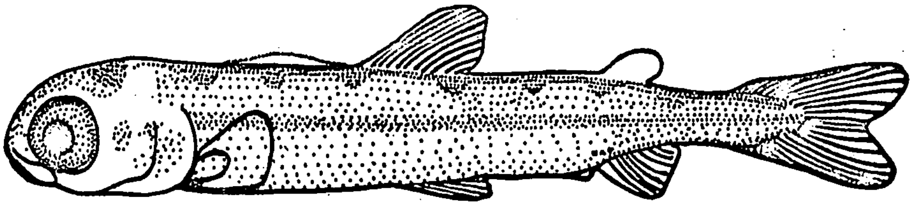

FIGURE 13. Round whitefish fry 29.0 mm total length

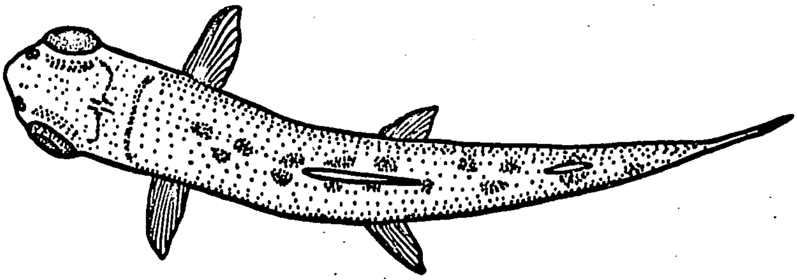

FIGURE 14. Round whitefish fingerling 40.0 mm total length. Dorsal view showing the juvenile markings

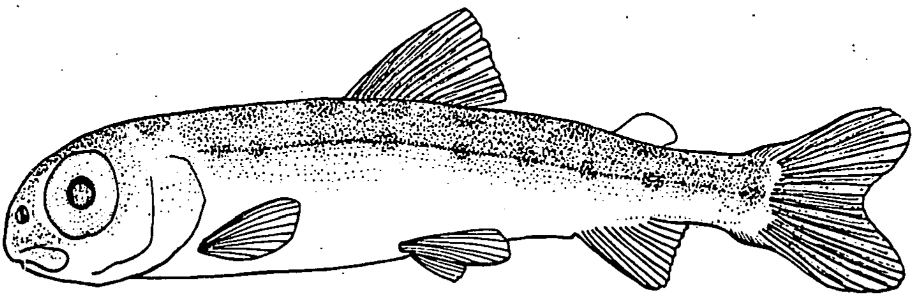

FIGURE 15. Round whitefish 56.0 mm total length. Note the parr markings along the dorsal and lateral surfaces of the body.

Differences Between the Fry of *P. cylindraceum* and *C. clupeaformis*

The only other fry or fingerling which could be confused with the larval round whitefish in New Hampshire is that of the lake whitefish. Fortunately for this particular study, lake whitefish apparently do not occur in Newfound Lake despite attempts at its introduction several years ago. Both species, however, are found in Lake Winnipesaukee in New Hampshire, and it may be of great advantage to disguish between the two during the early stages of their development and growth. Since there were no lake whitefish available during this study, all of the information concerning its description comes from Hart (1930). In reading Hart's detailed account of the lake whitefish fry, it becomes quite obvious that the fry of *C. clupeaformis* and *P. cylindraceum* are very similar. Both are approximately the same length at hatching. Both hatch at approximately the same time and the distribution of melanophores and xanthophores are very much alike in both species. Also, they are morphologically similar in their early stages. The only significant difference that can be used in distinguishing between the two is the formation of the single flap in the nares of the round whitefish. The Lake whitefish has a double flap. However, this occurs when the fry attain a length of approximately 25 mm. Also of probable significance, is the formation of juvenile or parr markings in the round whitefish.

These are apparently lacking altogether in the lake whitefish. In any case, both of these characteristics may be used only after the fry have attained a length of at least 25 mm. It is not possible, at this time, to describe differences in the younger stages.

FOOD AND FEEDING HABITS OF THE ROUND WHITEFISH OF NEWFOUND LAKE

General

It is important to know the food and feeding habits of an organism in order to describe its life history more completely. The role an animal plays in its ecosystem is somewhat determined by the kind of food it eats and how this effects other organisms. Competition for food is usually very keen, and could be a limiting factor in the success or failure of a species to survive in a given environment.

The coregonids are noted for being primarily plankton feeders and P. cylindraceum is certainly no exception. However, its food does vary considerably and perhaps more so than other whitefishes. Depending on its environment, the food of the round whitefish occurring in streams may consist almost entirely of aquatic insect larvae whereas its food in a lake, consists of plankton as well as aquatic insects. In the Great Lakes, Koelz (1929) indicated that its food consisted mainly of Gastropoda, aquatic insect larvae, and the spawn of other fishes. The round whitefish is limited to feeding on minute planktonic organisms or small benthic animals because of its small mouth. Therefore, it is not considered a predator of other fishes. However, little is known concerning its effect as a competitor with the young life stages of other species or whether it feeds on the larval stages of other fishes.

The contents of 71 stomachs collected during the months of June and August 1959, and 107 stomachs collected during the months of October, November, and December 1961 were examined. The frequency of occurrence for each food item was determined as was the percent volume of each. From this, seasonal fluctuations in the relative abundance of certain organisms and the food preferences of the whitefish were defined.

A complete study of the food of the whitefish would have necessitated sampling throughout an entire year. However, it was not possible to conduct such an intensive operation in the course of this particular study. In fact, although the summer and fall months are reasonably well represented, the June and August samples were collected in 1959 and the October, November and December samples were collected in 1961. There were no samples collected during the winter and spring months. There is reason to believe, however, that for the most part, the relative abundance of each organism for any given period is more or less constant, and would remain so from year to year. Therefore, although samples were collected in two different years, it is believed that they did not differ anymore significantly than if they had been collected in a single year.

Food of the Summer Sample 1959

Nine of the 71 stomachs examined from the June and

August samples were empty. Forty-one of the stomachs containing food were collected in June and 21 were collected in August of 1959. The number of stomachs (frequency of occurrence) in which each food item was found for this period is presented in Table 8. The cladoceran, Daphnia pulex, was found in 68% of the stomachs examined. Bosmina was found in 45% of the stomachs, but it was not present in any great numbers. The copepod, Diaptomus and the trichopteran, Limnephilus, was found to occur only in June. None were found in the August sample. However, Chaoborus was very abundant in the August sample and completely absent from the June sample. Many other organisms were found in the June and August samples but these did not constitute major portions of the diet.

Quantitative estimates by percent volume for each important organism found in the stomachs of the whitefish captured in June and August are presented in Fig. 16, Crustaceans, mostly Daphnia pulex, made over 50.5% of the total diet (by volume) of the round whitefish for the month of June. Diptera larva, mostly as Chironomus, and Culicinae made up 11.1% and the Trichopteran, Limnephilus, constituted 8.3% of the diet of these fish. In August, Diptera, in the form of Chaoborus, constituted the most important item in the diet (51.6%). These organisms were not found in the June sample. The cladoceran, Daphnia pulex, was the second most important item in the diet and made up 16.3% of the total volume of food.

Food of the Fall Sample 1961

The contents of 105 stomachs from fish captured between October and December 1961 were examined. Thirty-seven of these were empty. Of the 68 that contained food, 16 were captured in October, 36 were taken in November, and 16 were netted in December. The number of stomachs in which each food item was found for this period is presented in Table 8. Daphnia pulex was discovered in 96% of all the stomachs examined during this period. In fact, it was found in all of the stomachs of the whitefish collected between October 18 and December 4, 1961. Chaoborus, the next most important in terms of number of stomachs in which it was observed, represented only 8.8% of the total number of stomachs and did not occur at all in the November and December samples. The gastropod, Amnicola, occurred in November only and was seen in only four stomachs. Chironomus larva were detected intermittently throughout the sampling period but in only 7.4% of all the stomachs which contained food. In December, at the peak of the spawning period, P. cylindraceum was noted to feed on its own eggs and 56% of the stomachs collected in December contained whitefish eggs.

Quantitative estimates by percent volume disclosed that Daphnia pulex made up 89.5% of the total volume of food organisms in the stomachs of the round whitefish for this period in 1961. Actually, Daphnia represented 98.8% and 99.2% of the volume of food eaten in October and November respectively. Except for the rather interesting situation

TABLE 8. Frequency of occurrence of food organisms in the stomachs of the round whitefish of Newfound Lake

Food organisms and stomach contents	Percent of stomachs in which each food item was found																					
	June 1959				August 1959			October 1961						November 1961					December 1961			
	17	20	25	29	4	5	6	18	19	20	21	23	28	11	14	16	18	24	1	4	7	11
Class Crustacea																						
Order Cladocera																						
Leptodora kindti					100	50																
Diaphanosoma sp.			29																			
Daphnia pulex	57	89	64	64	100	50	64	100	100	100	100	100	100	100	100	100	100	100	100	100	78	75
Bosmina sp.		67	64	36			64															
Subclass Copepoda																						
Diaptomus sp.		89	14	18																		
Class Insecta																						
Order Diptera																						
Chironomus		33							100	50						25		20				25
Culicinae	43		57																			
Chaoborus					100	75	86	40		50		33	100									
Limnephilus	29		21	27																		
Order Ephemeroptera																						
Baetidae	29																					
Unidentifiable insect remains								20				17						20				
Class Arachnoidea																						
Hydracarina	29																					
Class Gastropoda																						
Amnicola sp.																25	22	20				
Round whitefish eggs																				50	56	75
Stones & sand													100		14				50	44		
Fish scales																				22		
Total no. of stomachs	7	9	14	11	3	4	14	5	1	2	1	6	1	4	14	4	9	5	1	2	9	4

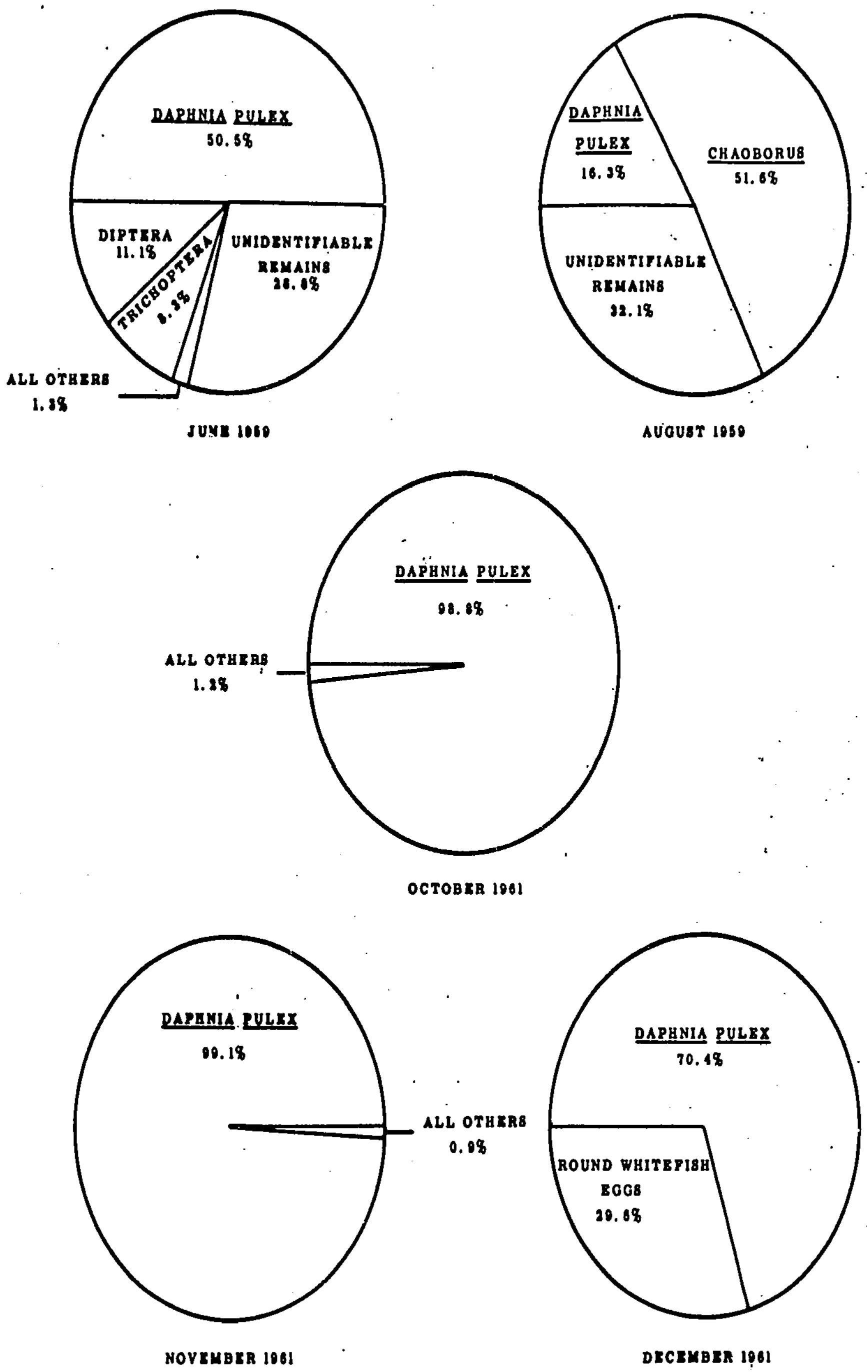

FIGURE 16. Volumetric analysis of the food of the round whitefish of Newfound Lake. Each item is presented as the percent of the total volume.

in December when they were feeding on their own eggs, Daphnia would probably have made up well over 90% of its diet during that month also. As it was, Daphnia constituted 70.4% of the total diet for December.

Discussion of the Food of P. cylindraceum

There is little doubt that cladocera, mainly Daphnia pulex, make up the largest part of the diet of the round whitefish of Newfound Lake. Although there are seasonal variations in the types of organisms available, Daphnia constituted a substantial part of the diet for every month in which samples were available. The only other substantial organism in the diet of the whitefish is the phantom midge, Chaoborus. During the month of August when these were plentiful, some of the full whitefish stomachs examined contained nothing else. It would be difficult to determine the food preferences of the round whitefish although it is obvious that Daphnia tops the list. Its choice of other organisms apparently depends, for the most part, on their availability.

The round whitefish has often been accused of eating the spawn of other fishes. In the Great Lakes, the commercial fishermen have often accused P. cylindraceum of being an important predator on the eggs of the lake trout (Koelz, 1929). It has already been shown in this study that it will feed upon its own eggs and observations in the field have revealed that it does feed on lake trout eggs in Newfound Lake. The stomachs of round whitefish captured on the spawning reef at the time the lake trout were spawning contained several lake trout eggs. Many whitefish were seen on or near the spawning reef at this time and there certainly was no doubt of their intent. However, these fish are not believed to be as serious a predator of these eggs as the white sucker. In fact, the round whitefish were not present in any great numbers at this time for my notes show that there were no more than 20 or so at any given observation. However, hundreds of white suckers were present on the spawning reef both night and day.

Feeding Habits

It is very difficult to determine the feeding habits of an organism as secretive as the round whitefish. However, after examining the contents of their stomachs, observing their movements in the evening with the aid of a powerful light, and noting certain characteristics in the way they were captured, a few conclusions can be reached concerning the feeding habits of these fish.

There appears to be little doubt that *P. cylindraceum* is predominantly a plankton feeder. The stomach contents of over 130 round whitefish were carefully examined and except for some aquatic insect larva, occasional gastropods, and fish eggs, the diet consisted almost entirely of planktonic organisms. Most of the coregonids are plankton feeders but there is one striking anatomical difference between the round whitefish and other members of this group. The gill rakers of *P. cylindraceum* are unusually short and stubby

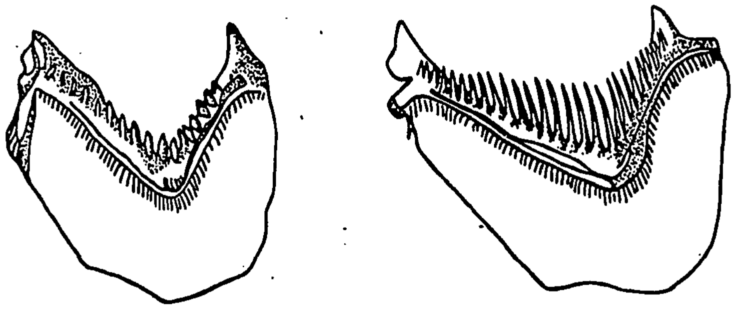

FIGURE 17. Anterior gill-arches showing gill-rakers of A, Prosopium cylindraceum and B, Coregonus clupeaformis. This figure has been modified and redrawn from Hubbs and Lagler (1949).

when compared with other whitefishes. This is well illustrated in Fig. 17 in which the gill rakers of the round whitefish are compared with those of the lake whitefish. It would appear that the gill-rakers of the round whitefish are much less efficient organs for the filtering of plankton from the water than are those of other members of this group of fishes. However, P. cylindraceum does have a wider distribution than most of the other whitefishes and occurs in a variety of habitats. It is often considered a stream fish rather than a lake's fish and it is obvious that efficient gill rakers, such as is found in Coregonus clupeaformis, would not be neccessary in such a habitat. Fish found in streams feed primarily upon bottom organisms such as aquatic insect larvae.

The round whitefish of Newfound Lake also appears, at times, to feed on or near the bottom. The contents of several stomachs which were examined included small grains of sand, a few snails, and fish eggs. Many aquatic insect larvae, most of which were probably picked-up off the bottom, were also found in these stomachs. Field observations have shown that many individuals move into shallow water in the evening and at this time, many were seen feeding on or near the bottom. Also, when my nets were set in shallow water, many of the whitefish captured were entangled near the lead line at the bottom of the net. This certainly indicates that these fish were moving near the bottom at the time of their capture.

One of the most interesting phases of the life history of the round whitefish of Newfound Lake is its annual movement into some of the major tributaries of the lake. It was once believed, by the local inhabitants, that this was for the purpose of spawning. This run is of short duration and only lasts approximately two weeks about the time of ice-out in April. Enough round whitefish are present, however, to attract many anglers to these streams each year. In fact, this is the only time of the year when any significant numbers are taken from the lake. Actual observations by this author have revealed that this is probably a feeding movement of adults. Many swarms of aquatic insect larvae have been seen in these streams at the time of this migration and the stomachs of these fish have been reported by the fishermen to have contained numerous aquatic insect larvae. I have never seen any great numbers of round whitefish at any one time in these streams. The Cockermouth River, the Fowler River, Dick Brown Brook, and Georges Brook are the tributaries which these fish are known to frequent in the spring.

AGE AND GROWTH

General

The age and growth of Prosopium cylindraceum of Newfound Lake was determined from two samples. The first, consisted of 211 round whitefish taken between April and August of 1959. The second, consisted of 186 round whitefish captured from October through December of 1961. A sample collected in December, 1962 was not utilized to determine age and growth but instead, was used to illustrate certain discrepancies in body-scale relationships.

The age and growth of the round whitefish is of particular interest for there is little information available concerning this aspect of its life history. In Newfound Lake, the round whitefish are not subjected to intense pressures due to sport or commercial fisheries. For this reason, a study of the age and growth of this relatively unexploited population may be of special significance. Results of such a study could conceivably be important in future investigations concerned with this same species. This is particularly true in areas, such as the Great Lakes, where it is taken in commercial quantities. Also, unlike most of the other species of fish in Newfound Lake, the round whitefish, even in the adult stages, is a plankton feeder. It converts plankton directly into fish flesh and is, therefore, more efficient than its piscivorous neighbors in the utilization of food in this lake.

Unfortunately, the younger age groups were inadequately represented in the samples and a complete description of the age and growth cannot be presented. Only two fish of age group I could be found and none of age group 0 were collected. Because of this, it was impossible to describe the early growth history of this whitefish. Also, the lack of young fish caused certain errors in describing the growth of the older stages.

Length Distribution of Age Groups

The numbers, mean total lengths, and ranges for each age group of the round whitefish captured in 1959 and 1961 are presented in Table 9. There is a considerable range in length within each age group and a wide overlap between age groups. Because of these large variations, an attempt to show year classes by the length-frequency method was abandoned. Comparison of the mean length for each age group of the 1959 sample with those taken in 1961 cannot justifiably be made, since the fish were taken during different seasons of the year. Those individuals captured in 1959 had, for the most part, just begun their growing season. The specimens captured in 1961 had nearly completed their growing season. Although the older age groups were well represented, the younger age groups were not well represented in either sample.

TABLE 9. Mean total length for each age group of the Newfound Lake round whitefish captured in 1959 and 1961.

Apr. through Aug. 1959 No.	Mean tot. length mm	inches	Range mm	Age group	Oct. through Dec. 1961 No.	Mean tot. length mm	inches	Range mm
2	188.5	7.4	187-190	I	--	--	--	--
47	256.7	10.1	220-281	II	10	278.6	11.0	266-307
37	306.8	12.1	276-355	III	51	333.7	13.1	295-377
36	353.9	12.9	284-390	IV	51	358.8	14.1	323-405
30	367.2	14.4	322-390	V	43	383.0	15.1	352-421
32	389.2	15.3	357-411	VI	19	399.8	15.7	373-419
13	407.4	16.0	373-439	VII	9	399.7	15.7	370-436
10	414.5	16.3	401-501	VIII	3	416.7	16.4	405-428
2	412.0	16.2	411-413	IX	--	--	--	--

Length-Weight Relationship

The length-weight relationships for 107 female and 92 male round whitefish captured in 1959 and for 77 female and 73 male specimens trapped in 1961 were determined. The general parabola $W = aL^n$, where W equals weight, L equals length, and "a" and "n" are empirically determined constants has been used satifactorily in determining the length-weight relationship for numerous species of fishes. The length-weight relationship was calculated for each year (1959 and 1961) and for each sex separately. There appears to be little difference between the males and females from the 1959 collection and practically none for those taken in 1961. However, there are great variations between the 1959 sample and that of 1961 when compared. The differences in length-weight relationships between these two samples reflects deviations due to the state of the developing gonads.

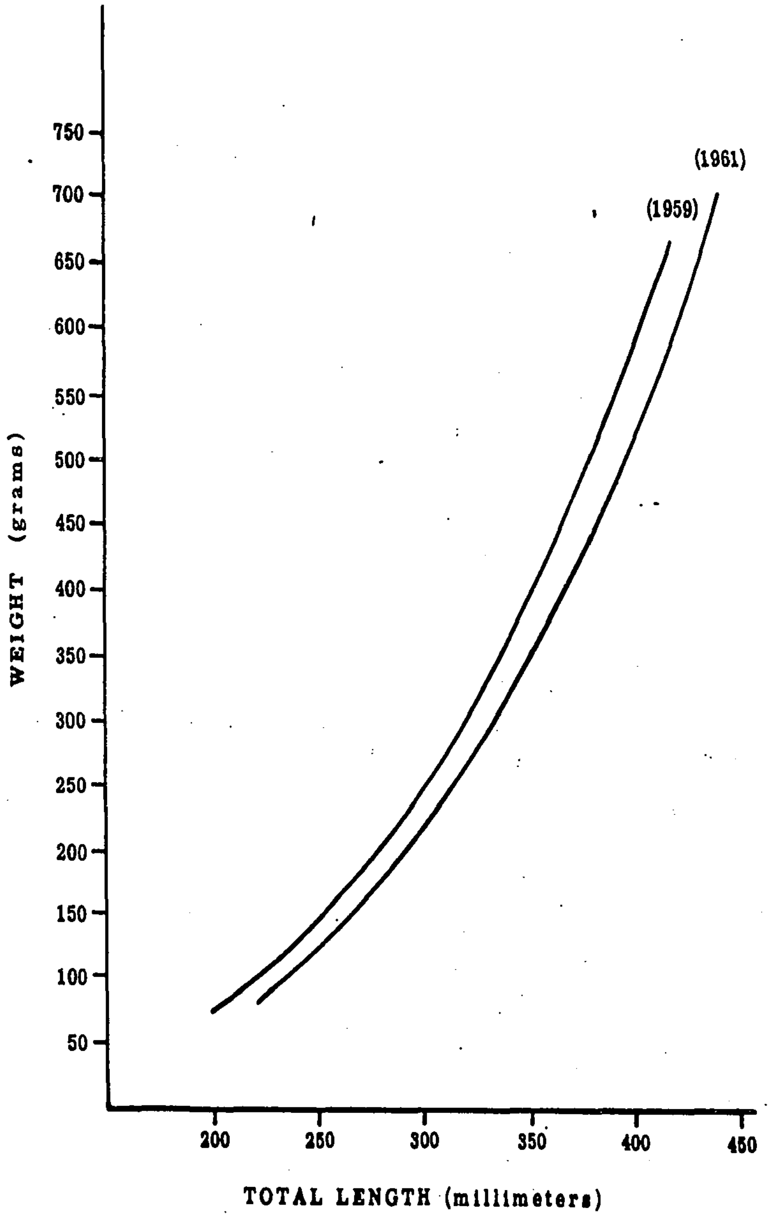

FIGURE 18. Length-weight relationship of P. cylindraceum captured in 1959 and 1961.

These differences are illustrated in Fig. 18. All of the 1959 captures were made at least three or as many as six months before the spawning season. The 1961 captures were made not more than two months prior to spawning and most were taken only a few weeks before the actual spawning time. The values for each equation describing the length-weight relationships where the log W = log a + n log L (natural or Naperian logarithms) are as follows:

1959 males	Log W = -12.11807 + 3.1 log L
1959 females	Log W = -11.34987 + 2.9 log L
1961 males	Log W = -12.30394 + 3.1 log L
1961 females	Log W = -11.59867 + 3.0 log L
1959 males & females	Log W = -12.21757 + 3.1 log L
1961 males & females	Log W = -11.60930 + 3.0 log L

The correlation coefficient of the length-weight relationship for the 1959 groups is .98 and for the 1961 group, r = .96.

Body-scale Relationship

The body-scale relationship was determined for 209 round whitefish captured from Newfound Lake in 1959, for 186 whitefish collected in 1961, and for 100 whitefish taken in 1962. This relationship was determined by the Lee method as described by Lagler (1956). This method assumes that the mathematical relationship between body length and scale length is expressed by the equation L = a + b S where L = total fish length, S = length of the scale from the focus to its anterior margin, and a and b are empirically determined constants. Lines were fitted to these data by means of the least squares method (Fig. 19). The equations determined

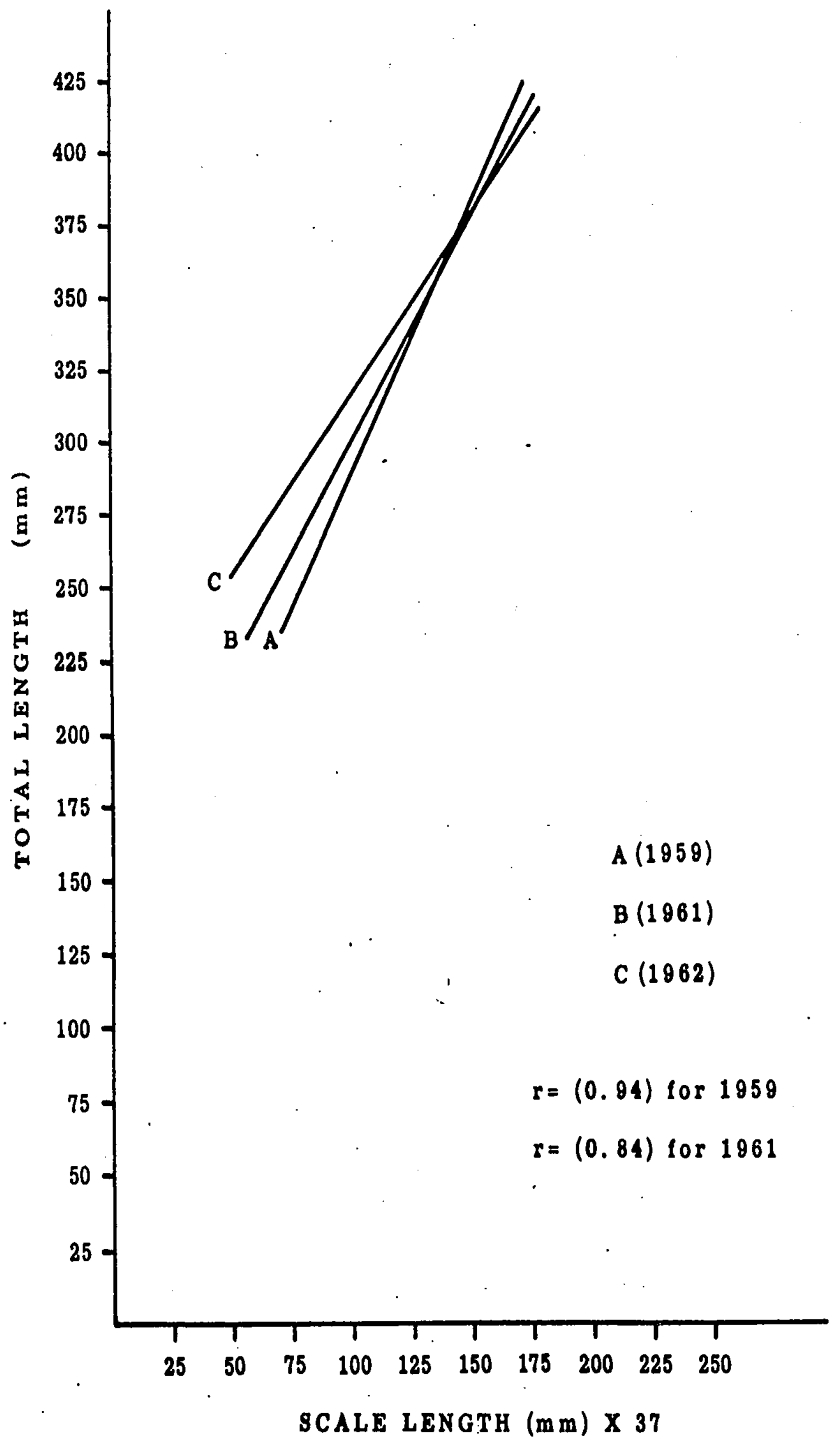

FIGURE 19. Body-scale relationships for the round whitefish captured in Newfound Lake.

for the round whitefish of Newfound Lake are as follows:

For the sample captured in 1959, $L = 105.9 + 1.82\ S$

For the sample captured in 1961, $L = 148.5 + 1.50\ S$

For the sample captured in 1962, $L = 191.6 + 1.20\ S$

The body-scale relationship for the 100 round whitefish taken during the 1962 spawning season was determined for the purpose of explaining dicrepancies due to samples which were not adequately representative of all age groups.

Although straight lines fitted by the least squares method appear to conform to the data, the intercepts in all cases are higher than they should be. The intercept determined from the 1959 data, that which is most likely nearest the proper fit, is approximately 105.0 mm. This cannot be correct for the intercept is thought to show size of the species at scale formation. In lake herring, Coregonus artedii, and the lake whitefish, Coregonus clupeaformis, scale formation begins when the fish are approximately 35 to 40 mm in length (Van Oosten, 1929; Hart, 1930; Edsall, 1960). Actual observations by this author of the round whitefish reared at the New Hampshire Fish and Game Department's Powder Mill Rearing Station showed that scales of three specimens were formed when the fish attained a length of 35 to 40 mm. Reasons for this discrepancy are not clear. However, according to Van Oosten (1929), in the coregonids, there is a great difference between the rate of increase in length of the scales and of the body in early years of life. The scales grow at a much more rapid rate than does the body. In the case of the samples taken from Newfound Lake, the early age groups were poorly represented or not at all. Because of this, the body-scale relationships determined from the present data, do not take into consideration the younger age groups. This is further substantiated by comparing all three samples (1959, 1961, and 1962) and noting that the slope as calculated from the 1959 data is perhaps nearer the actual slope (if it were known) than are the slopes calculated from the 1961 and 1962 data. The slope determined from the 1962 data is even less representative than those determined from the 1959 and 1961 samples. The reason for this becomes quite obvious when each sample is carefully analyzed. The actual numbers of fish captured, their ages, and mean lengths for 1959 and 1961 are presented in Table 9. The 1959 sample is by far the better sample since it contains many more fish of the younger age groups. The 1961 group consists, for the most part, of mature individuals but has a greater coverage of sizes and age groups than the 1962 sample. This latter sample consisted of 100 adult, spawning fish. All of these were taken within two days at the time of spawning and they represented only a very small portion of the total population. It may be concluded then, that the differences in the slopes for the body-scale relationships of the round whitefish of Newfound Lake are due, for the most part, to sample bias. Had there been a better representation of the population (particularly the younger age groups) in the sample, the body-scale relationship could have been more accurately described.

The correlation coefficients for body length and scale length were determined for the 1959 and 1961 samples. The coefficient of correlation (r) for 1959 was .94 and for 1961, was .84.

Calculated Growth in Length

The growth in length for P. cylindraceum of Newfound Lake was calculated by the Dahl-Lea method (Lagler, 1956) using the formula $Ln = 105.9 + \frac{Lt - 105.9}{St} Sn$ where Ln equals the length of the fish at the end of the nth year of life, Sn equals length of the scales from the focus to the nth annulus, Lt equals total length of the fish at the time of capture, St equals length from the focus to the edge of the scale, and 105.9 is the intercept determined for the 1959 sample of whitefish. Since this intercept is believed to be higher than the true intercept, the following results may be slightly in error. The calculated growth in length was not determined from the 1961 data, since this intercept was in much greater error than that of the 1959 sample. Table 10 presents the calculated total length at the end of each year of life and average growth for the combined age groups of the Newfound Lake round whitefish. As was expected, the mean length increment for the first year was quite large and the increments for each successive year were smaller than the previous year until the growth gain for the ninth year was only 16.1 mm. The rate of growth is depicted as a curve in Fig. 20.

TABLE 10. Calculated total length at the end of each year of life and average growth for the combined ages of the Newfound Lake round whitefish.

No. of formed annuli	No. of fish	Length (millimeters) at end of year							
		1	2	3	4	5	6	7	8
1	2	150.3							
2	49	147.7	227.3						
3	42	141.6	216.7	285.4					
4	44	148.9	228.1	299.8	338.2				
5	31	147.9	228.3	301.8	336.3	362.2			
6	26	147.9	223.0	293.6	331.0	360.6	383.8		
7	12	146.8	213.3	277.9	315.5	348.4	374.8	397.1	
8	3	144.3	205.4	265.0	301.8	331.8	359.1	382.4	398.5
Grand average		146.7	223.8	293.0	332.8	358.1	379.4	394.2	398.5
Increment of average		146.7	77.1	69.2	39.8	25.3	21.3	14.8	4.3
Grand average increment of length		146.7	73.8	68.1	37.0	29.6	25.6	22.8	16.1
Sum of average increment		146.7	220.3	288.6	325.6	355.2	380.8	403.6	419.7

This curve could have been based on the grand average calculated lengths but was instead, based on the sum of the average increments. Edsall (1960) believed that this results in a smoother curve, particularly in the later years of life which are represented by few fish.

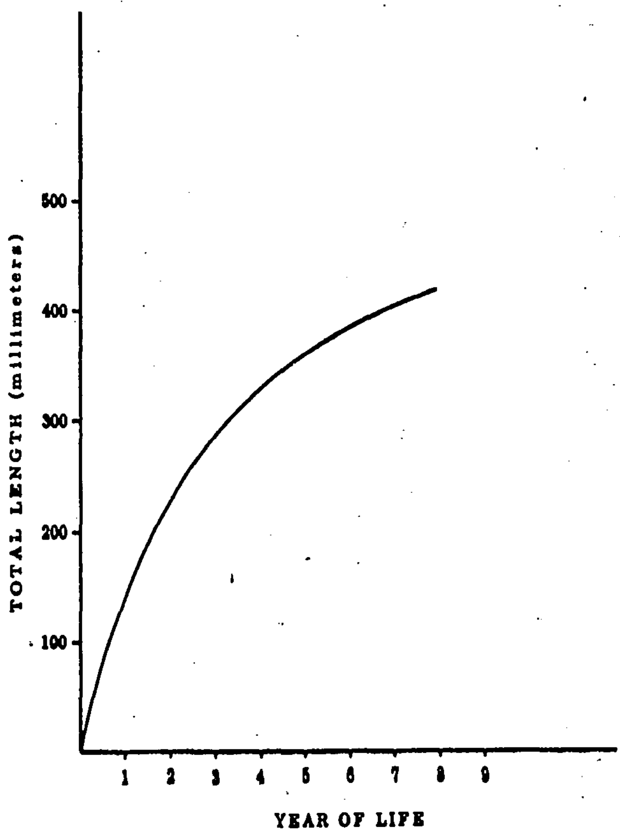

FIGURE 20. Growth rate of the round whitefish.

Conversion of Total Length to Standard and Fork Lengths

Conversion of total lengths to fork lengths and total lengths to standard lengths for 190 round whitefish from Newfound Lake is presented in Fig. 21. Straight lines were fitted to these data by the least squares method. The equation $Y = a + b X$ was used to determine the slopes of these lines where Y = length to be determined (either fork or standard), a and b are empirically determined constants, and X is equal to the total length. The formula for converting total length to fork length for the whitefish is

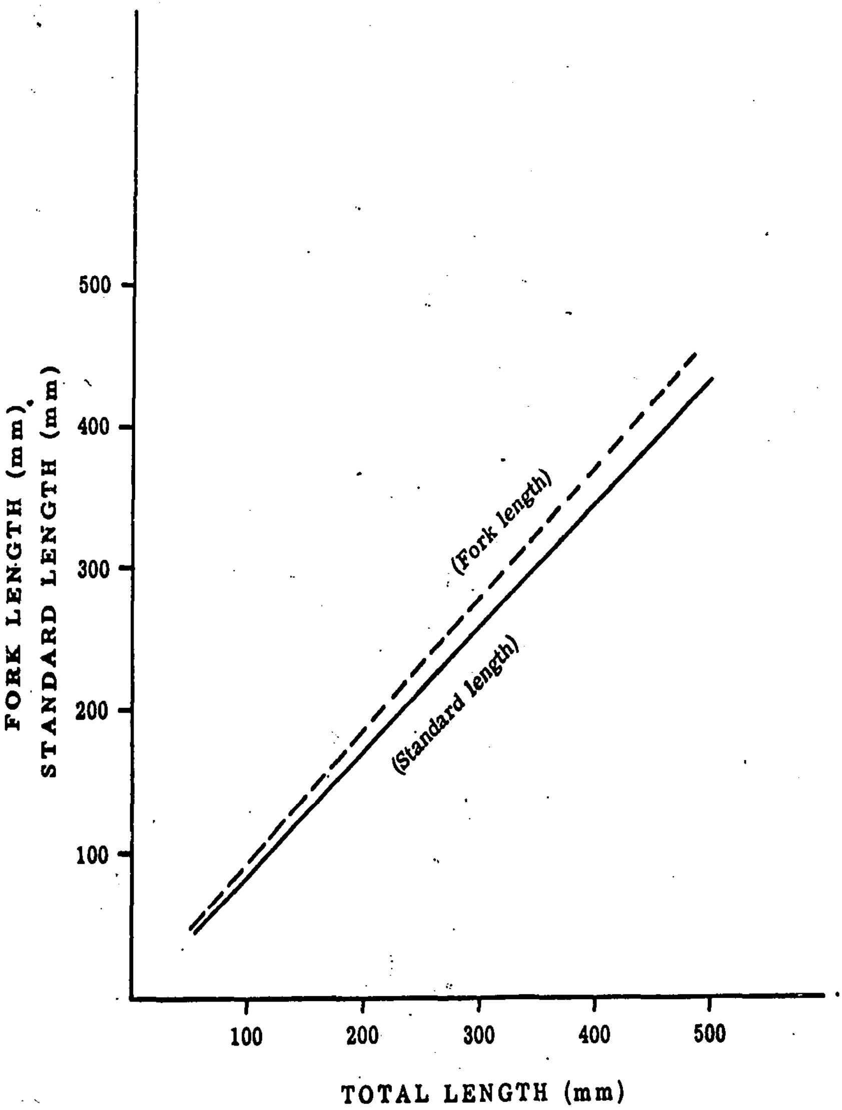

FIGURE 21. Conversion of total lengths to fork and standard lengths for the round whitefish of Newfound Lake.

Y = -1.19 + .92 X. The equation for converting total length to standard length is Y = -1.19 + .86 X. The correlation coefficients for total length/fork length is .99 and that for total length/ standard length is .97.

Comparison of the Round Whitefish of Newfound Lake with Those of Other Areas

There is little information concerning the age and growth of *P. cylindraceum* other than that found in Carlander (1950, 1953). Table 11 compares whitefish from Newfound Lake with those of Moosehead Lake in Maine and Great Bear Lake in N.W.T. in Canada. Since all measurements for the round whitefish of Moosehead Lake and Great Bear Lake are presented in inches, those of Newfound Lake have been converted to inches so that comparisons can be made. Both total and fork lengths are presented for the Newfound Lake specimens, since fork length only was used for the Great Bear Lake specimens and total length was used for the specimens from Moosehead Lake. It would appear from this rather sketchy information that the round whitefish of Newfound Lake grow more rapidly than those of either Moosehead Lake or Great Bear Lake. However, since these are only average measurements for each age group, and some age groups are poorly represented, it is impossible to draw any substantial conclusions from these data.

TABLE 11. Comparisons of round whitefish from Newfound Lake with those of Moosehead Lake in Maine and Great Bear Lake in N.W.T., Canada.

Age group	Newfound Lake (1959) No.	T.L. inches	F.L. inches	Moosehead Lake No.	T.L. inches	Great Bear Lake No.	F.L. inches
0	-	-	-	-	-	-	-
I	2	7.4	6.9	-	-	-	-
II	47	10.1	9.4	-	-	-	-
III	37	12.1	11.1	20	10.2	-	-
IV	36	12.9	12.0	9	10.8	-	-
V	30	14.4	13.2	12	11.5	6	12.9
VI	32	15.3	14.0	9	12.3	11	13.3
VII	13	16.0	14.8	3	12.3	22	13.9
VIII	10	16.3	15.0	6	14.3	24	14.5
IX	2	16.2	15.0	3	14.8	6	16.6

PARASITES OF THE ROUND WHITEFISH OF NEWFOUND LAKE

Between June, 1959 and December, 1962, 75 to 100 round whitefish were examined for the presence of helminth parasites. It is interesting to note that *Azygia sebago* Ward, a digenetic trematode, was the only parasite discovered in the course of this entire study. Only a dozen of these organisms were found, which indicates a very light infection. These are parasites of the esophagus and stomach and were described by Ward (1910) from the stomachs of *Salmo salar* from Sebago Lake in Maine. To the best of this author's knowledge, *Azygia sebago* have never been reported from the round whitefish prior to this study.

The identity of these parasites was based primarily upon Stunkard (1956), Wooten (1957), and Sillman (1962) and confirmed by Professor Marvin C. Meyer of the University of Maine. The genus *Azygia* contains many species some of which are morphologically very similar. In fact, Sillman (1962) questions the validity of *A. sebago* and indicates that it may be synonymous with *A. longa*. The snail *Amnicola limnosa* is the intermediate host for *A. longa.* It is interesting to note that *Amnicola sp.* have been found in the stomachs of the round whitefish from Newfound Lake.

SUMMARY

An investigation of the life history and ecology of Prosopium cylindraceum has been carried-out in Newfound Lake, Bristol, New Hampshire. Preliminary studies began in the summer of 1959 as part of a survey of the sport fisheries of this lake. This particular survey was conducted by this author for the New Hampshire Fish and Game Department. More comprehensive studies, concerned with the life history of this species, were renewed in September, 1959 and continued through December, 1962. Since there is little information available concerning the round whitefish, it is hoped that these results will be of value to those who wish a better understanding of this species.

In summary, the round whitefish, Prosopium cylindraceum, is perhaps the most widely distributed of all whitefishes. It is found from the Yenesei River in Siberia east across the Bering Straits, through northern North America to the Atlantic Coast. In New England, it is found in Maine, New Hampshire, and Connecticut. In New Hampshire, it occurs in Lake Winnipesaukee, the Connecticut River, and in Newfound Lake.

Newfound Lake is a typical oligotrophic lake. It is a deep lake (much of it is over 100 feet in depth) and is high in dissolved oxygen, low in free carbon dioxide, and has relatively cold temperatures.

Although Newfound Lake is well known for its lake

trout and Atlantic salmon sport fisheries, the round whitefish is seldom taken by sport fishermen. For this reason, it cannot be considered a sport or game fish. This is unfortunate, for there is a large and thriving population of these fish in this lake.

The round whitefish of Newfound Lake is subterete, little compressed except at the head and tail and is more cylindrical in cross-section than the lake whitefish (the only other member of this group that occurs in N.H.). These fish are morphologically similar to other individuals of the species located in other bodies of water in New England and in the Great Lakes, but differs from northwestern (N.W.T., Canada and Siberia) specimens in having fewer gill rakers and lateral line scales. Those of Newfound Lake also have fewer pyloric caeca.

It is most difficult to distinguish males and females of this species. There is no true sexual dimorphism, and except for the reduced nature of the pearl organs in the females at the time of spawning, both sexes are indistinguishable.

In Newfound Lake, these fish spawn during the first three weeks of December. They attain sexual maturity in their fourth or fifth year. Spawning takes place on a shallow rocky reef located between Pike's Point and Mayhew Island. The water over this reef did not freeze completely in the winter and therefore, there was little danger of serious winter-kill of eggs in normal winters even though these eggs were deposited in shallow water. A fecundity study showed that females averaged about 5,000 eggs, but a range of 2,000 to 10,000 eggs was found. The size and age of the females determined the egg count. Whitefish eggs that have been fertilized and deposited in the water, have an average diameter of 3.94 mm.

The peak of hatching activity occurred about the last week of April, approximately 140 days from the time of fertilization (at a temperature of 36°F). Upon hatching, the fry remained on the bottom and did not leave the reef until the yolk sac had been absorbed. Once the fry left the spawning reef, they were not found again.

Some of the fertilized eggs were reared in a hatchery, and it was from these specimens that the larval descriptions were made. Upon hatching, the fry had prominent yolk sacs, they were yellow in appearance, their jaws contained several larval teeth, and only the pectoral fins were formed. The 12 day old fry was marked by a reduction in the size of the yolk sac, the beginnings of dorsal, anal, and ventral fins, and an increase in length. Within two to three weeks, the fry rose to the surface and began to feed. By July, the fingerlings were well developed. All of the fins had formed and all but the adipose were rayed at this time. Parr markings were also present. Except for a change in size and proportion, the fingerlings had taken-on most of the adult characteristics by November.

The food of the round whitefish consisted almost entirely of Daphnia pulex. These fish did feed heavily upon

Chaoborus during the month of August, 1959 at the time these insects were plentiful. In December, they fed extensively on their own eggs. The round whitefish is predominantly a plankton feeder, but it was observed moving in shallow water during the evenings where it fed upon tiny bottom invertebrates.

Since young, immature whitefish were not captured, the age and growth of these animals could not be studied completely. Analysis of 209 specimens ranging in length from about seven to sixteen inches showed that the whitefish of Newfound Lake grow more rapidly than those of Moosehead Lake in Maine and Great Bear Lake in Canada. At the end of their first year of life, they attain a length of 146.7 mm. At the end of their second year, they are 220 mm long. The maximum size captured was approximately 450 mm and the maximum age was about 8 years old.

The only helminth parasite found in the round whitefish was *Azygia Sebago* Ward. This is a digenetic trematode which occurred in the stomachs of these fish. The incidence of infection was very light.

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