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A COMPARATIVE STUDY OF LAKE TROUT FISHERIES IN ALGONQUIN PARK ONTARIO

By

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STUDIES ON ALGONQUIN PARK

No. 1. Report on the 1936 Lake Trout Investigation, Lake Opeongo, Ontario, by F. E. J. Fry and W. A. Kennedy. University of Toronto Studies, Biol., 42. Pub. Ont. Fish. Res. Lab., 54, 1937.

No. 2. Birds of Algonquin Provincial Park, Ontario, by D. A. MacLulich. Contributions of the Royal Ontario Museum of Zoology, No. 13, 1938.

No. 3. A Comparative Study of Lake Trout Fisheries in Algonquin Park, Ontario, by F. E. J. Fry. University of Toronto Studies, Biol., 46. Pub. Ont. Fish. Res. Lab., 58, 1939.

CONTENTS

A COMPARATIVE STUDY OF LAKE TROUT FISHERIES IN ALGONQUIN PARK, ONTARIO

Abstract

Algonquin Park, Ontario, contains many lakes in which there are distinct populations of lake trout, *Cristivomer namaycush* Walbaum. The lake trout in different populations grow at different rates, mature at different sizes, and are present in different densities. They are also subjected to different fishing intensities. The fishing offered by these populations has been studied by the method of the creel census, and some populations have also been made the object of a biological investigation. The lake trout fishing in a given lake has been found to depend on the migratory and feeding habits of the lake trout and on the density of the population. A relation has been found between the average size of the lake trout captured and the number taken per unit effort. This relation is independent of the size of the lake but is dependent on the rate of growth of the lake trout and the size which they attain before reaching maturity. The application of catch statistics to the management of lake trout fisheries is discussed, and a management programme for those of Algonquin Park is outlined.

Introduction

Great strides have been made in the artificial propagation of game fish and in devising methods for the improvement of spawning facilities and the food supply in lakes and streams. The successful application of these methods to the conservation of sporting fisheries requires a knowledge of game fish populations. Then too, anglers still depend in large measure on wild populations of game fish to furnish their angling. The management of wild populations also requires an understanding of the relations which exist between the angler and the object of his sport.

In 1936 the Ontario Fisheries Research Laboratory began a study of the populations of the lake trout, *Cristivomer namaycush* Walbaum, in Algonquin Park lakes. The object of this investigation was to build up a picture of lake trout fishing based on information that may be obtained from anglers, and to seek an interpretation of this picture through a biological study of these lake trout and of the waters which produced them. The Laboratory sought this knowledge to determine whether such a study would yield information on which a programme of management of the lake trout fisheries in Algonquin Park could be based.

Algonquin Provincial Park has an area of approximately 2,700 square miles. It lies on the Precambrian shield to the south and west of the Ottawa river. The parallels 45° 45′ N. and 78° 30′ W. intersect near its centre. The land rises to an altitude of over 1,400 feet. Four river systems rise in the area, the water all finally reaching the sea by way of the St. Lawrence although travelling quite diverse paths to arrive there. There are innumerable lakes of which a great many contain populations of lake trout. Most of the country is covered with the forest typical of the transition zone. Two railroad lines and one motor highway pass through the Park; travel off these beaten routes is by water and also to an increasingly greater extent by air.

The large number of separate populations of lake trout and the great diversity of conditions under which they exist in the lakes of Algonquin Park present a most favourable opportunity for a comparative study. The Park lakes in which lake trout are found vary in area from a few acres to over twenty square miles. The lake trout in them differ considerably in the maximum size which they attain and in the size at which they reach maturity. Fishing intensities to which these waters are subjected are equally diverse. Many lakes bordering the railroads and the newly constructed highway have been fished heavily. In one instance for which we have records, Cache lake, it has been estimated (Doan, 1938) that in the neighbourhood of 90 per cent of the lake trout of catchable size were taken in one season. Other lakes, particularly small ones at the ends of hard portages, may be visited by only a single party of anglers in a year.

ACKNOWLEDGEMENTS

Financial support for this investigation has been provided by four organizations. The work was carried out in the Ontario Fisheries Research Laboratory, of the Department of Biology, the University of Toronto, which maintains a field station in Algonquin Park. The Department of Game and Fisheries of the Province of Ontario has contributed to the support of the laboratory by grants.

The Department of Lands and Forests has co-operated with the Laboratory by extending free use of its facilities in Algonquin Park, and by providing labour and loaning equipment. Also in 1938 certain material used in this report was gathered through the aid of a grant from the National Committee on Fish Culture made through the agency of the National Research Council of Canada.

Mr. F. A. MacDougall, Superintendent of Algonquin Park, and Professor W. J. K. Harkness, Director of the Ontario Fisheries Research Laboratory, have encouraged and supported this work. Much assistance has been received from the following junior members of the staff: Messrs. W. A. Kennedy, J. S. Hart, and J. R. Brett. Finally it is a pleasure to acknowledge the whole-hearted co-operation of the anglers visiting Algonquin Park who have made it possible for us to apply the method of the creel census to the analysis of the lake trout populations there.

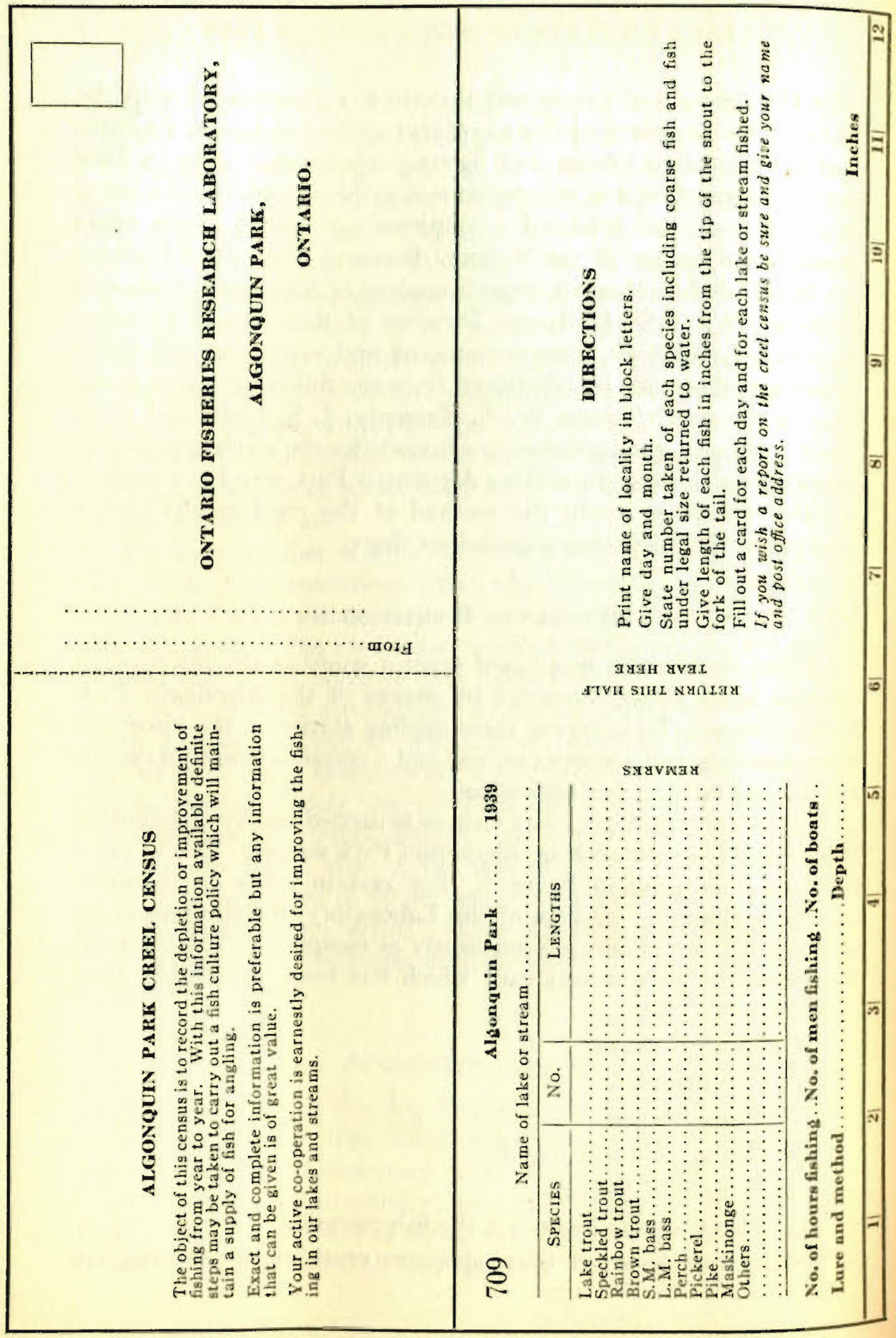
METHODS OF INVESTIGATION

This investigation was based upon a study of the information on lake trout fishing recorded by means of the Algonquin Park Creel Census. To interpret these angling statistics, the viscera of numerous lake trout were examined and a certain amount of experimental gill netting was undertaken.

The Algonquin Park Creel Census is carried out by distributing form cards to anglers fishing Algonquin Park waters. One of these cards is illustrated in figure 1. For certain lakes an intensive census is taken by workers of the Laboratory, for the remainder of the Park the returns are not nearly as complete. The information recorded on a census card which has been completely filled in gives:

(*a*) Locality fished
(*b*) Calendar date
(*c*) Species taken
(*d*) Size of each fish taken
(*e*) Method of fishing
(*f*) Effort required to catch the fish recorded.

While it is believed that adequate creel census returns are


ALGONQUIN PARK CREEL CENSUS

The object of this census is to record the depletion or improvement of fishing from year to year. With this information available definite steps may be taken to carry out a fish culture policy which will maintain a supply of fish for angling.

Exact and complete information is preferable but any information that can be given is of great value.

Your active co-operation is earnestly desired for improving the fishing in our lakes and streams.

709 Algonquin Park 1939

Name of lake or stream ....

Species	No.	Lengths
Lake trout........		
Speckled trout........		
Rainbow trout........		
Brown trout........		
S.M. bass........		
L.M. bass........		
Perch........		
Pickerel........		
Pike........		
Maskinonge........		
Others........		

No. of hours fishing .. No. of men fishing .. No. of boats..

Lure and method .... Depth .....

1 2 3 4 5 6 7 8 9 10 11 12 Inches

REMARKS

TEAR HERE
RETURN THIS HALF

From..............................

ONTARIO FISHERIES RESEARCH LABORATORY,
ALGONQUIN PARK,
ONTARIO.

DIRECTIONS

Print name of locality in block letters.
Give day and month.
State number taken of each species including coarse fish and fish under legal size returned to water.
Give length of each fish in inches from the tip of the snout to the fork of the tail.
Fill out a card for each day and for each lake or stream fished.
If you wish a report on the creel census be sure and give your name and post office address.

Figure 1.—Form card used in the Algonquin Park Creel Census.

sufficient in themselves to determine the status of a fishery, biological information concerning the fish captured is a valuable supplement. It is extremely desirable to know, for instance, how many of the fish taken are immature, what is the rate of growth, and what are the feeding habits of the species under consideration in the waters fished. Such information has been gathered by workers stationed at lake Opeongo, and at Cache lake, who examine fish taken by anglers. Many of these findings are not discussed directly in this report, but nevertheless form a background of knowledge necessary for interpreting the results of the creel census.

The Yield of Lake Trout Fisheries

The poundage per year which can be removed from the water below an acre of lake surface depends on a complex system of variables, and the subject cannot be discussed at length in this report. However, some estimates of the annual removal of lake trout from certain Algonquin Park lakes are given in table 1. The estimates in table 1 are not given with the suggestion that they represent the average annual production of the four lakes that are listed, but rather to indicate the extent of the drain which angling may exert upon a population of lake trout. In all probability the poundage removed from Opeongo, Merchant, and Redrock lakes in the years listed, was considerably higher than the poundage which could be taken from them consistently year after year.

In themselves the figures in table 1 mean little; therefore table 2 was prepared for the purpose of comparing the drain resulting from angling with that which has resulted from commercial fishing in certain waters. Many people are under the impression that commercial fishing removes far more fish than the most intensive of angling activity is ever likely to do. When the potentialities of a particular lake are under discussion, it is not uncommon to hear the expression, "Why it was fished commercially." A comparison of the magnitudes of the removals per acre listed in table 1 with those in table 2 shows that such a statement means almost nothing. Angling activity can remove practically as high a poundage per acre per year as is taken by commercial netting.

The statistics on which table 2 is based are taken from the annual reports of the Ontario Game and Fish Commissioners, 1899, the Department of Fisheries of the Province of Ontario, 1900 to 1906, and the Game and Fisheries Department, Ontario, from 1907 to the present. The records which are listed are the highest given for any one year that is recorded from 1899 to 1936 and thus represent the maximum commercial yield which has been taken from any of these waters during that time.

TABLE 1.—Maximum annual removal of lake trout from certain Algonquin Park lakes by angling, recorded in the records of the Algonquin Park Creel Census.

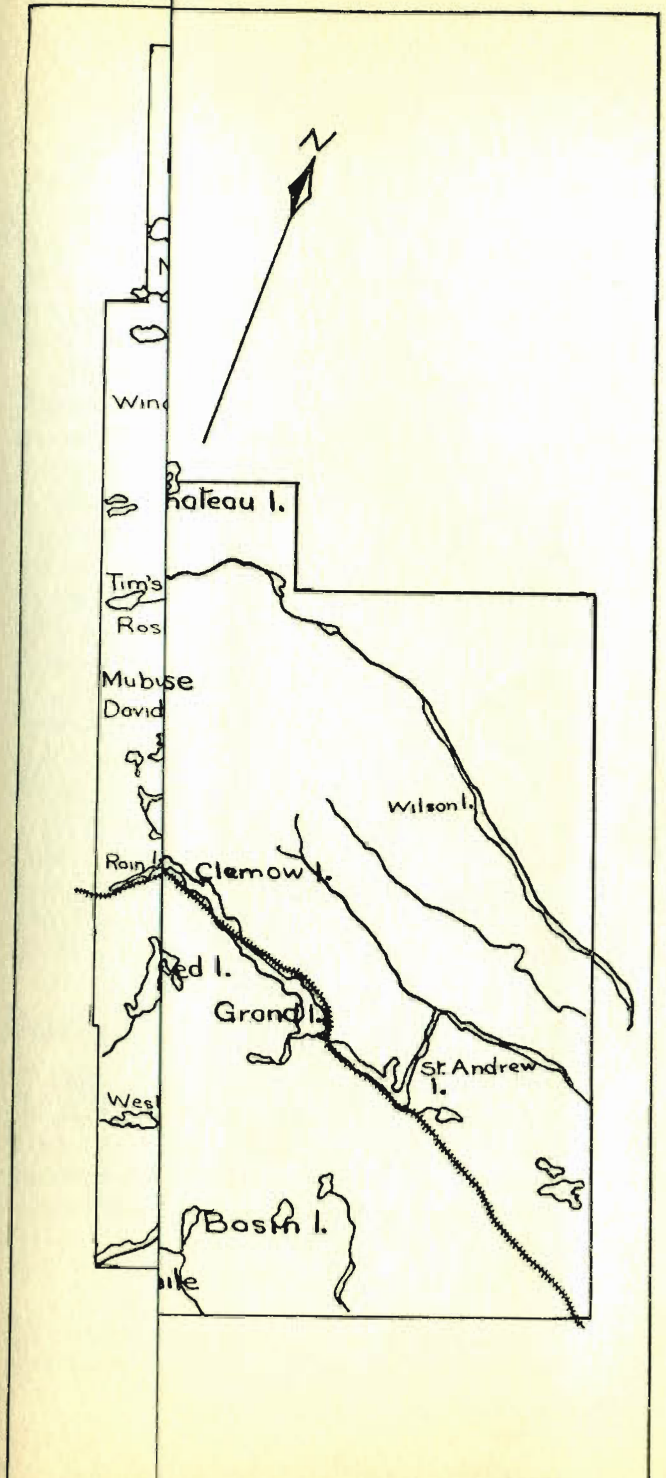
Water	Approx. area, sq. mi.	Max. annual removal, lbs.	Lbs. per sq. mi.	Lbs. per acre	Year
Lake Opeongo	20.1	9,400	470	0.7	1936
Merchant lake	1.5	2,730	1,800	2.8	1938
Redrock lake	1.4	1,130	820	1.3	1937
Whitegull lake	0.2	188	940	1.9	1936

TABLE 2.—Maximum annual removal of lake trout by commercial fishing, recorded from certain Ontario waters.

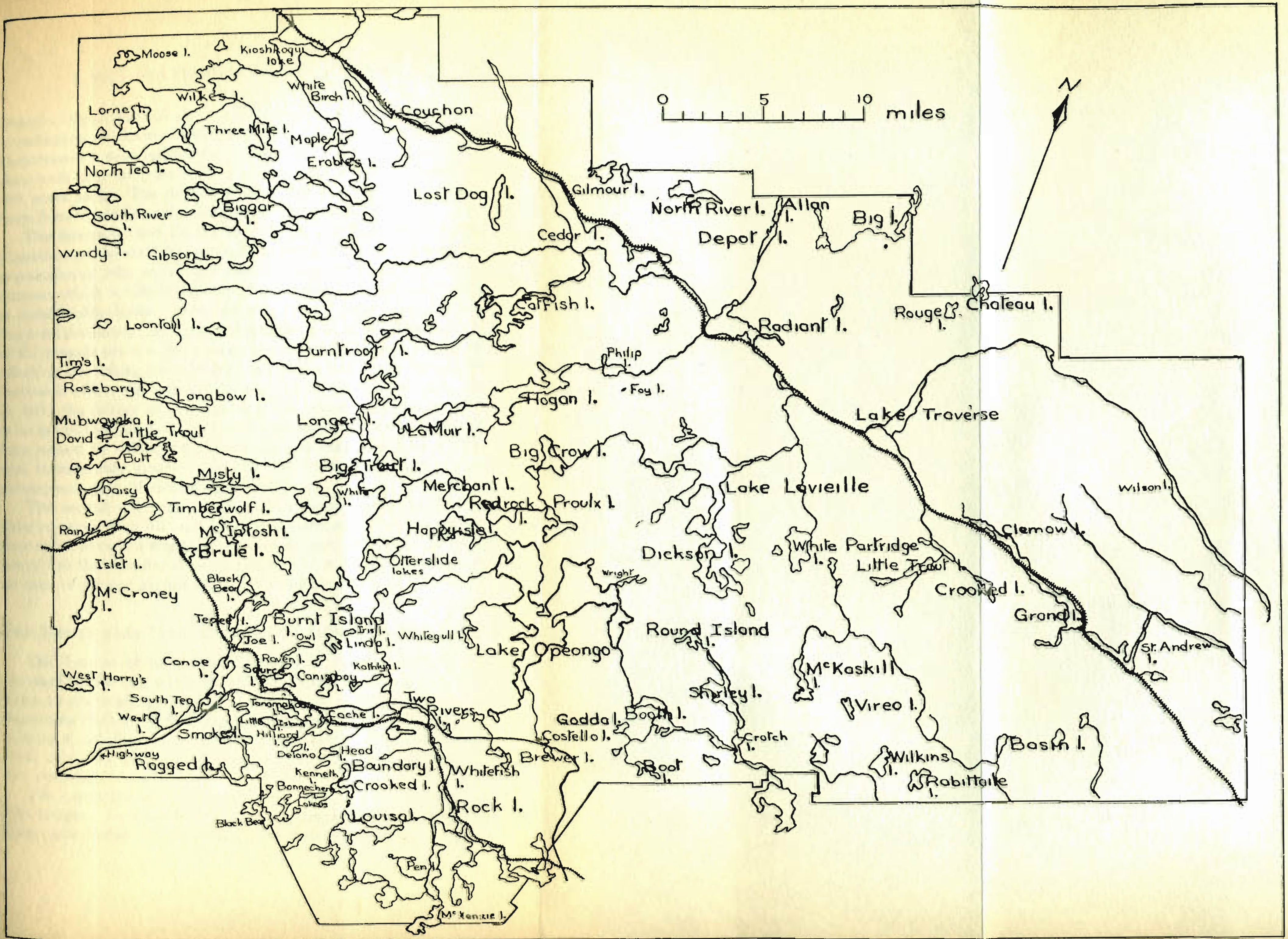
Water	Approx. area, sq. mi.	Max. annual removal, lbs.	Lbs. per sq. mi.	Lbs. per acre	Year
Georgian bay	5,250	1,622,400	310	0.5	1929
Lake Nipigon	1,730	617,900	350	0.5	1919
Lake Simcoe	300	48,800	160	0.2 (5)	1918
Lake Wabigoon (Kenora)	14.2	10,000	700	1.1	1907
Butler lake (Kenora)	0.7	1,900	2,700	4.2	1899

Two conclusions may be taken from the data in tables 1 and 2. It is certain that the productivity of lake trout waters is quite low. The highest removal for any water in a single year that is shown in these tables is 4.2 pounds per acre which was taken from Butler lake in 1899. To remove this amount from this lake of 0.7 square miles required the efforts of three men fishing 1,000 yards of gillnet, enough net to stretch almost two-thirds of the way around the lake in a single setting.

There are also records of removal of lake trout from two Algonquin Park lakes (Brewer and Costello) that were fished by the



0 5 10 miles
N
Moose l.
Kioshkoqui lake
White Birch l.
Wilkes l.
Lornet l.
Couchon
Three Mile l.
Maple
Erables l.
North Tea l.
Lost Dog l.
Gilmour l.
Biggar l.
South River l.
North River l.
Allan l.
Big l.
Cedar l.
Depot l.
Windy l.
Gibson l.
Catfish l.
Rouge l.
Chateau l.
Radiant l.
Loontail l.
Burntroot l.
Philip l.
Tim's l.
Rosebary l.
Longbow l.
Foy l.
Hogan l.
Mubwayaka l.
David l.
Little Trout
Longer l.
LaMuir l.
Lake Traverse
Butt
Big Crow l.
Misty l.
Big Trout l.
Merchant l.
Lake Lavieille
Daisy l.
White l.
Timberwolf l.
Redrock l.
Proulx l.
Wilson l.
Rain l.
McIntosh l.
Happy Isle l.
Clemow l.
Brulé l.
Dickson l.
White Partridge l.
Otterslide lakes
Little Trout l.
Islet l.
Black Bear l.
Wright l.
Crooked l.
McCraney l.
Grand l.
Tepee l.
Burnt Island
Round Island l.
Joe l.
Owl
Iris l.
Linda l.
Whitegull l.
Lake Opeongo
St. Andrew l.
Canoe l.
Raven l.
Kathlyn l.
West Harry's l.
Source l.
Canisbay
McKaskill l.
Shirley l.
South Tea l.
Tanamakoon
Two Rivers l.
Vireo l.
West l.
Little Island
Cache l.
Godda l.
Booth l.
Smoke l.
Hilliard
Costello l.
Crotch l.
Bosin l.
Highway
Delano l.
Head l.
Brewer l.
Wilkins l.
Ragged l.
Boundary l.
Whitefish l.
Root l.
Kenneth l.
Robitaille
Bonnechere Lakes
Crooked l.
Rock l.
Black Bear
Louisa l.
Pen l.
McKenzie l.



0 5 10 miles
N
Moose l.
Kioshkoqui lake
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South River l.
Biggar l.
Cedar l.
Windy l.
Gibson l.
Catfish l.
Rouge l.
Chateau l.
Radiant l.
Loontail l.
Burntroot l.
Philip l.
Tim's l.
Rosebary l.
Longbow l.
Hogan l.
Foy l.
Mubwayaka l.
David l.
Little Trout
Longer l.
LaMuir l.
Lake Traverse
Butt l.
Big Crow l.
Misty l.
Big Trout l.
Merchant l.
Daisy l.
White l.
Redrock l.
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Lake Lavieille
Wilson l.
Timberwolf l.
McIntosh l.
Happyisle l.
Clemow l.
Rain l.
Brulé l.
Dickson l.
White Partridge l.
Islet l.
Otterslide lakes
Little Trout l.
Black Bear l.
Wright
Crooked l.
McCroney l.
Grand l.
Teepee l.
Burnt Island
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Raven l.
Kathlyn l.
McKaskill l.
West Harry's l.
Source l.
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Shirley l.
South Tea l.
Tanamakoon
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Little Island
Cache l.
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Costello l.
Smoke l.
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Head
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Wilkins l.
Bosin l.
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Boundary l.
Whitefish l.
Ragged l.
Kenneth l.
Boot l.
Bonnechere Lakes
Crooked l.
Robittaile l.
Rock l.
Black Bear
Louisa l.
Pen l.
McKenzie l.

Ontario Department of Game and Fisheries in 1934 prior to the introduction of brown trout and rainbow trout. Although the Department's men netted until they could catch no more fish, they took only 0.9 lake trout per acre from these two lakes of 100 acres each. The weight of the lake trout per acre taken from Brewer and Costello lakes was not recorded.

The figures quoted for the removal of lake trout from Butler, Costello, and Brewer lakes probably approximate the total standing population of lake trout that was contained in these waters; the amount which a lake is capable of producing as a sustained yield is considerably lower. Over the past twenty years Georgian bay has been producing just under 0.5 pounds to the acre. The removal of 0.7 pounds per acre from lake Opeongo in 1936 had a noticeable effect on the fishing there in 1937, for in the latter year, in spite of increased effort, the removal dropped to 0.5 pounds per acre, and in 1938 the fishing in Opeongo was still poorer. Moreover there is no doubt that the drain on the lake trout population of Merchant lake caused by taking 2.8 pounds per acre from that lake in 1938 was considerably greater than the lake could withstand in each subsequent year of fishing (page 42).

The second conclusion is that while the individual angler may take no more than his legal limit, it is quite possible for the aggregate catch of even a moderate number of anglers to equal the number of fish that can be taken by commercial methods in lakes with an area of twenty square miles and smaller.

THE SIZE OF LAKE TROUT CAPTURED IN ALGONQUIN PARK LAKES

The lengths of lake trout captured in Algonquin Park and recorded by the Algonquin Park Creel Census have extended from eight to thirty-six inches. The size of the lake trout taken in Algonquin Park in 1938 for which the lengths were recorded is given in table 3 and illustrated in the frequency polygon figure 3. Lake trout thirty-six inches long weigh on the average about twenty-five pounds.

The maximum size which lake trout attain varies greatly from lake to lake. In general, as is so common in the case of many other fishes, small lakes contain populations of small lake trout while the larger lakes contain lake trout which attain a maximum length of thirty inches or more and a weight of over twenty pounds. As a rule, lakes with an area of over one square mile contain trout which commonly reach a large size, unless they are prevented from doing so by over-fishing. On the other hand, lakes of about one-half a square mile or less, contain lake trout which rarely reach a weight of more than five pounds. Like all good rules this one has some

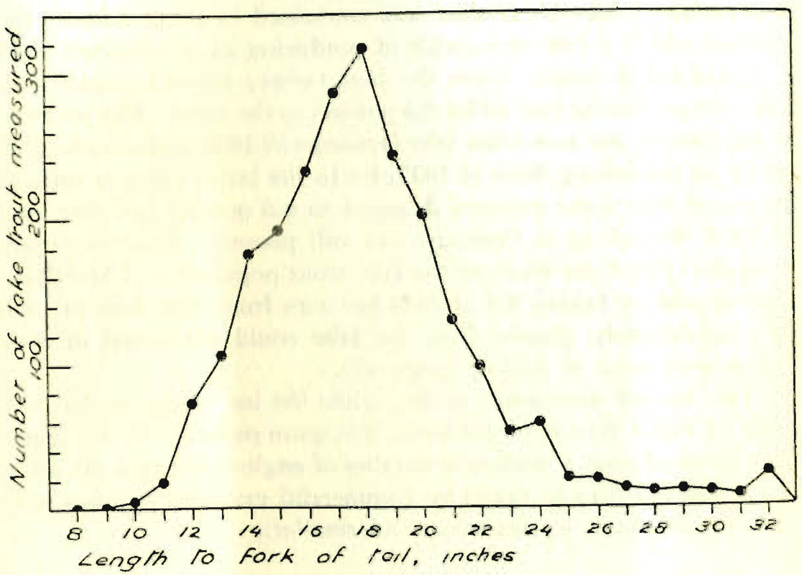

FIGURE 3.—Frequency diagram showing the length composition of lake trout catches taken in Algonquin Park in 1938 by anglers. Data from table 3.

notable exceptions. For example, lake Louisa, which has an area of nearly two square miles, is well known for its small and numerous lake trout, while Kathlyn lake with an area of no more than fifty acres has produced some eight pound trout during the last two fishing seasons.

In 1938, one per cent of the lake trout measured had a length of over thirty-one inches and weighed in the neighbourhood of twenty pounds. Most of these large fish were taken in the more

TABLE 3.—Lengths of certain lake trout taken by angling in Algonquin Park in 1938.

Lake	Lengths of lake trout measured, inches																								
	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	over 31
Annie											1															
Booth								1			1	3	2		4		1	1	1	1						
Big Crow										3	1	8	6	8	10	5	4	2	1	2	1		1	1		
Big Trout										1		2		1												
Boundary								9	1	7	1	1														
Burnt Island																	1									
Butt										1	1	9	20	5	1											
Cache				2	5	9	19	20	20	12	6	5	2		1											
Canisbay					1	3	8	5	8	7	7	3	2													
Canoe														1												
Chicadee										1	1				1	3										
Cradle					2	2	1	4	2	4	1		1													
Crooked (w.)						1				4	3	7	3	3												
Delano					1	6	4		2																	
Dickson										2	1	1		3	2	1		3	1							
Happyisle						2	1	13	41	56	21	18	16	16	9	2	1	3	1	1	2	1	1	1	2	5
Head	1				2	6	4	12	12	7	8	13	4	4		4	1									
Hilliard													1													
Kathlyn																				1						
Kenneth							3	3	2	1	1															
La Vieille								1		2		1	1	2												
Little Crow											1															
Little Island					2	7	4	3	2	7	25															
Louisa						6	20	39	20	9	6	4				1										
Merchant						1	9	8	11	22	51	52	39	27	23	16	7	17	9	6	6	6	6	6	5	15
Opeongo			1	2	3	20	21	52	63	77	138	182	147	125	69	53	19	23	7	8	2	3	4	1	1	3
Proulx														3	9	10	11	7	1							
Smoke									3	2	2	2		2	2	2	2	2						1		
Source				2	1	6	2		1	3	1	2														
Tanamakoon					2	2	8	4	2	4		1														
Threemile						1	1				2		1					1		1						
Two Rivers						1		3	2	2	2															
Whitefish							1			1																
Wright											1	3	1	1												
Total	1	0	1	6	19	73	106	177	192	235	283	317	246	201	131	97	47	59	21	20	11	10	12	10	8	23

inaccessible lakes which have not been subject to heavy fishing in the past. About twenty-five lake trout of this size were taken from Merchant lake. On the average 1.4 per cent of the lake trout which have been landed from lake Opeongo during the last three years have weighed over ten pounds but the number of these large fish taken has become steadily less.

Opeongo has produced some very satisfactory catches of lake trout in recent years. In 1928 or 1929 Mr. Dan Goodwin of Maynooth, Ontario, with three companions captured twenty lake trout in one afternoon which weighed together 111 pounds. In 1935 he and three others caught another twenty lake trout in four hours on the morning of July 1 which weighed in the neighbourhood of one hundred pounds. Again in 1936 Mr. Goodwin and three friends took twenty lake trout in one day weighing a total of ninety pounds.

There is a record of much larger lake trout being taken from Algonquin Park waters in the sixties of the last century. In an article published in the *Ottawa Citizen*, Nov. 29, 1865, entitled "Fishes of the Ottawa"—a digest of an essay on the fishes of the Ottawa river with its tributaries and some of the contiguous lakes, read before the Ottawa Natural History Society on Friday, Nov. 24, 1865 by Edward Van Cortlandt, M.D., curator of the society—it is stated: "I have seen specimens [of lake trout] from the Opeongo between fifty and sixty pounds." No fish approaching such a weight have been reported within recent years, but between fifteen and twenty years ago, John Stringer, a Park ranger who was recently retired, captured a lake trout in Big McCraney lake which weighed thirty-five pounds. A photograph of this fish hung in the Algonquin Park railway station for a number of years.

While there is much interest in the size of the largest fish captured, the smallest size at which fish are taken by angling is also of importance from the point of view of the effect of angling on the population. There is a definite limit to the smallest size at which lake trout take the baits in use. Only two lake trout out of 2,306 measured in 1938 were less than ten inches long, and only twenty-seven, or just over one per cent, were less than twelve inches long.

Although trout of less than twelve inches do not readily take

the bait, this factor does not always govern the size of the smallest fish that are regularly taken in a given body of water. Peculiar as it may seem, small lake trout are extremely rare in some lakes. In Proulx lake for instance, no lake trout of less than nineteen inches in length has been taken in the last three years. However, lake trout down to about twelve inches are taken commonly in other lakes which have been fished consistently over a period of years.

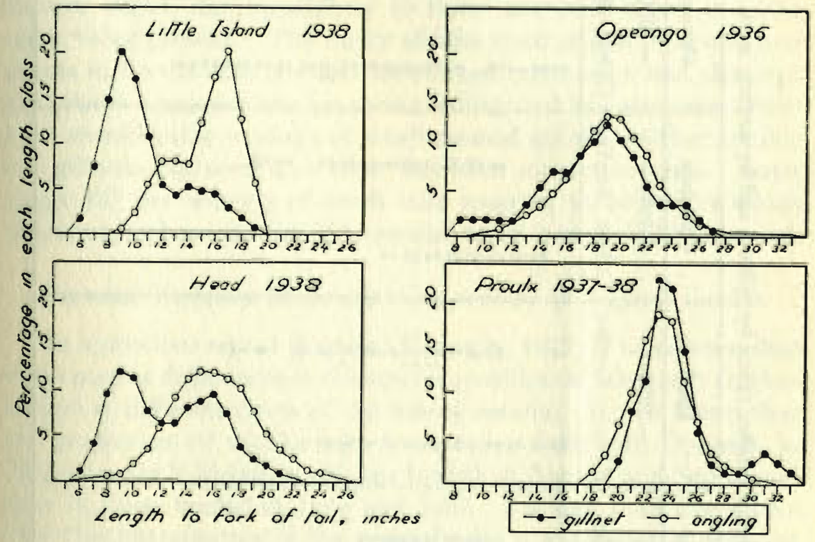

FIGURE 4.—Differences in the size composition of lake trout catches taken by gillnets and by angling in four Algonquin Park lakes. Values reduced to percentages and points smoothed twice by threes. Original data in table 4.

A comparison of the size of lake trout captured in a graded series of gillnets varying from 1¼ to 5 inches stretched mesh, with the size of lake trout captured by angling in the same waters, illustrates the relative efficiency of angling as a method of taking lake trout of different lengths, and also the difference in the proportion of small lake trout which may be present in different lakes. The length compositions of lake trout catches taken by gillnets and by angling in six Algonquin Park lakes are given in table 4, and are

TABLE 4.—Comparison of the size composition of catches taken by gillnets and by angling in six Algonquin Park lakes.

Length of fish captured, inches	Boundary		Little Island		Head		Canisbay		Opeongo		Proulx	
	—1938—		—1938—		—1938—		—1938—		—1936—		1937-38	
	Gillnet	Angling	Gillnet	Angling	Gillnet	Angling	Gillnet	Angling	Gillnet	Angling	Gillnet	Angling
8	1		3		2	1			1			
9			8		5		2		2			
10			3		3		1		1			
11				2	1	2	6	1	2	3		
12	3		2	7	1	6	4	3		10		
13	7			4	2	4	2	8	1	14		
14	5	8	3	3	2	12	2	5	2	26		
15	3	1		2	1	12	2	8	5	28		
16	1	6	1	7	5	7	1	7	6	35		
17		1	1	25	1	8		7	2	62		
18	1	1			1	13		3	3	91		
19					1	4		2	14	111		1
20						4			3	103		7
21								1	6	83		5
22						4		3	2	45	2	15
23						1			2	37	2	17
24									3	27	3	22
25									2	8		9
26									1	7	1	2
27										3		2
28										1		2
29										3		1
30										5		
31										1	1	
over 31										6		

shown for four of these in figure 4. The four examples illustrated in figure 4 represent lakes in which the average lengths of the lake trout taken by angling vary from 15.3 inches in Little Island to 23.2 inches in Proulx lake. In figure 4 it may be seen that gillnets set in Little Island and Head lakes captured a considerably higher proportion of lake trout less than twelve inches long than were taken by angling. In Opeongo and Proulx lakes the difference between the size composition of the gillnet and the angling catches is very slight, due apparently to fewer numbers of smaller lake trout being present. The rarity of lake trout of less than nineteen inches in Proulx lake has been mentioned previously, and although the lake is a popular one for spring fishing and has also been fished by a considerable yardage of small-meshed gillnet, neither angling nor gillnets captured lake trout less than nineteen inches. Later (page 43) the scarcity of small lake trout in those waters which contain a high proportion of large lake trout is more fully discussed.

Seasonal Variation in the Size Composition of Anglers' Catches

In a previous report (Fry and Kennedy, 1937) it was shown that there may be differences in the size composition of lake trout catches landed at different times of the fishing season. It was found that the proportion of smaller lake trout taken from lake Opeongo in 1936 was much higher in catches landed in August and September than in those landed in June and July. Further work has shown that this phenomenon is the general rule in a number of different lakes.

The great difference that may sometimes be found in the average size of the lake trout captured in a given lake at different times of the year is illustrated in figure 5, in which the length compositions of the lake trout catches taken from Merchant lake over the period June 16-30, 1938, are compared with catches taken there over the period September 1-20 of the same year. In the latter half of June more than 50 per cent of the lake trout landed were longer than twenty inches while in September less than 20 per cent of the lake trout captured were as long as this. It might be possible that this difference in size composition resulted from an absence of large fish in September because of their capture earlier in the season. This is partially true, but as will be seen later, the difference in size composition was to a far greater extent the result of the increased ease with which small trout were captured in September, rather than because of the decrease in the numbers of large fish present in the lake.

The typical changes found in the size composition of lake trout catches are as follows. In early May, lake trout are taken in shallow water and the average size of those captured lies close to the average for the season as a whole. In late May and early June the lake trout are still sought in the shallow water but during that period the fish taken average smaller than those taken in early May. In late June the shallow water fishing is over in most years, and for the rest of the summer lake trout are generally taken in water between twenty-five and fifty feet deep. During the early weeks of this deep water fishing most of the lake trout captured are large. As the summer passes, smaller trout become somewhat commoner in the catches but it is not until some time in September that they

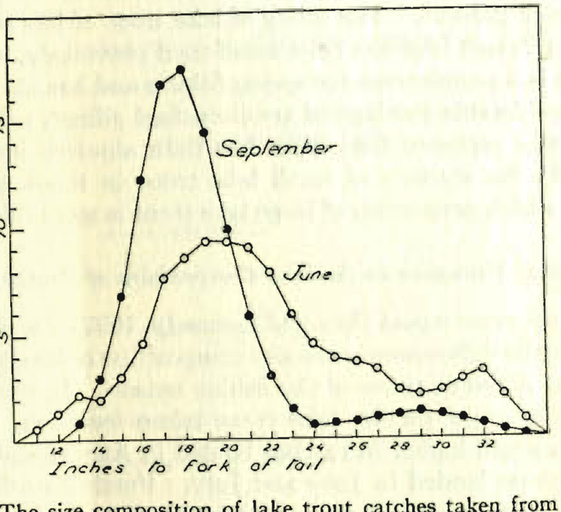

FIGURE 5.—The size composition of lake trout catches taken from Merchant lake in June and in September, 1938. Numbers reduced to percentages and points smoothed twice by threes. Original data in table 5.

TABLE 5.—Number and size of lake trout captured in Merchant lake in 1938, recorded in the Algonquin Park Creel Census.

Date	Length in inches: under 14	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	over 31	Not measured	Total
May 1–31		1		1		2		3				2	2					2		1	27	41
June 16–30	5	1	1	1	13	6	8	7	9	9	3	4	4	2	4	3	1	1	2	7	2	93
July 1–15	2	2		6	18	17	13	10	6	4	3	5	2	2	2	2	1	3	1	3	52	144
" 16–31	1	3	4	4	5	5	2	2	2			5		1			2		1	1	20	58
Aug. 1–15	2			1		2				1	1											7
" 16–31		1	2			4	4	1	1			1								2		16
Sept. 1–20			4	9	15	16	12	4	5	2			1	1		1	2		1	1	8	82
Total	10	8	11	22	51	52	39	27	23	16	7	17	9	6	6	6	6	6	5	15	109	441

are taken as commonly as they were in June. When the small trout appear predominantly in the catches in September they do so somewhat suddenly.

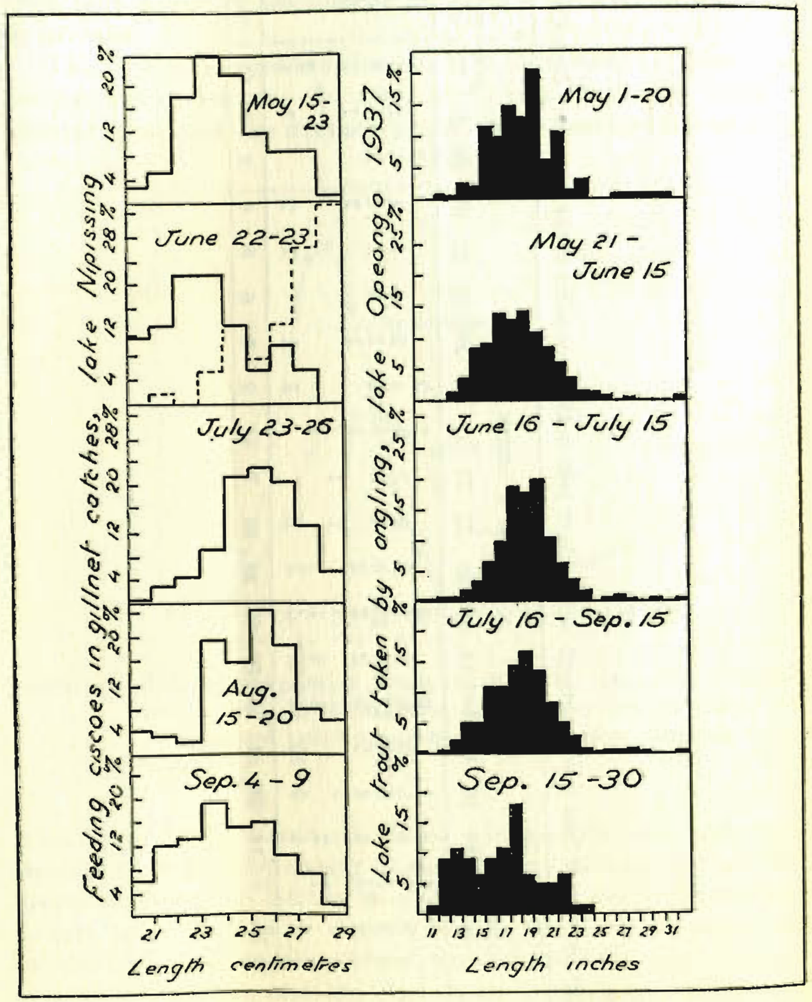

FIGURE 6.—Changes in the size composition of lake trout catches taken by angling from lake Opeongo during the fishing season of 1937, compared with the feeding activity of ciscoes in lake Nipissing. Data from tables 6 and 7. For explanation see text page 23.

Changes in the length composition of lake trout catches taken from the beginning of May until the end of September from lake Opeongo in 1937 are shown in the right-hand panel of figure 6. Following down these diagrams illustrating the length composition of the lake trout catches from lake Opeongo the following facts can be noted.

From May 1 to May 20 more lake trout were taken which fell into the twenty inch length group than fell into any other single group: 20.7 per cent of the lake trout taken were of this group. On the whole, more of the fish taken were shorter than twenty inches than were twenty inches and longer, the actual percentages being 55.5 and 44.5 respectively. But still a goodly proportion of the catch consisted of lake trout longer than nineteen inches.

Fishing during the period May 21 to June 15 yielded quite a different type of lake trout catch from that taken earlier in the month of May. The percentage of lake trout taken which were twenty inches and longer dropped from 44.5 to 35.8, while conversely the percentage of lake trout in the catches shorter than twenty inches rose from 55.5 to 65.2. The twenty inch length group was no longer the most numerous; this distinction was shared almost equally between the seventeen, eighteen, and nineteen inch groups which contained 14.4, 13.2, and 14.8 per cent of the total catch respectively. From this it may be seen that our national holiday, May 24, unfortunately does not coincide with the best spring lake trout fishing in lake Opeongo.

Coincident with the change to deep water fishing in the latter half of June, the length composition of the catches again showed a marked change. The twenty inch length group was again the most numerous group landed. Again the relative numbers of large fish rose in the catches, 42.6 per cent of the lake trout landed being twenty inches and over, and the proportion of small fish dropped correspondingly.

During the two months from July 16 to September 15 there was no significant change in the relative numbers of trout of different sizes taken in Opeongo in 1937. The catches taken in this period as a whole were characterized by fewer large and more small lake trout than were landed in the previous month, June 16 to July 15.

The length group that was most common over this period was nineteen inches and the percentage of the total catch which consisted of fish less than twenty inches in length was 65.7. The percentage of lake trout captured which were twenty inches and longer dropped from 42.6 to 34.3.

The size composition of the catch of lake trout taken in the last two weeks of September was strikingly different from that for the preceding two months. During the latter half of September small lake trout were biting freely while large trout were hardly taken at all. The length group most commonly occurring in the catch was eighteen inches, and practically all the fish taken were twenty inches or less. Only 18.4 per cent of the lake trout taken between September 16 and September 30 were twenty inches or over in length.

Although it is legal to take lake trout in Algonquin Park until October 15, fishing for them in lake Opeongo after October 1 is extremely barren of results. In three years a total of not more than twenty-five lake trout have been captured by angling in Opeongo after October 1. It is plain then that practically no lake trout of catchable size are biting in Opeongo at that time, although it is possible to catch them readily during this period in smaller lakes in the neighbourhood.

Causes of Seasonal Variation in the Size Composition of Anglers' Catches

The parallel that exists between the feeding activities of the cisco, *Leucichthys artedi* (Le Sueur), and the lake trout, as interpreted from angling statistics, has already been pointed out by Fry and Kennedy (1937) in discussing the results of the first season's creel census of lake Opeongo. They state (page 16):

The lake trout in Opeongo participate in a summer migration from shallow to deep water similar to that found in the case of the cisco, *Leucichthys artedi* (Le Sueur), in lake Nipissing (Fry 1937), and in other lakes. If the details of the events in the lake trout migration parallel those of the cisco migration, then the observations concerning the capture of lake trout by angling are quite understandable.

As the upper waters of a lake become warmer the ciscoes, like the lake trout, swim deeper and deeper. Large ciscoes are more sensitive to high temperatures

TABLE 6.—Percentage size composition of lake trout catches taken in lake Opeongo, May to September inclusive, 1937.

Date	Length in inches																							Number measured	χ^2	P.
	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	over 31			
May 1–20......			0.6	0.6	2.5	1.9	11.3	10.1	15.1	13.2	20.7	5.7	10.6	1.3	3.2			0.6	0.6	0.6	0.6	0.6		159		
May 21–June 15.				1.2	4.0	8.0	9.6	14.4	13.2	14.8	11.2	8.8	6.0	4.0	1.6	1.2	0.8		0.4				0.8	250	35.66	<0.05
June 16–July 15.	0.3	0.3	0.3	0.7	1.7	3.5	6.4	9.9	17.3	17.0	20.3	9.9	5.9	3.6	1.7	0.2	0.3	0.2			0.2		0.3	579	39.81	<0.05
July 16–Sept. 15.	0.3		0.8	1.9	4.7	5.7	9.7	11.2	14.2	17.5	13.9	9.5	4.4	2.2	0.9	0.4	0.6	0.5	0.5	0.5	0.1	0.1	0.4	847	49.53	<0.01
Sept. 16–30......		1.5	9.2	10.8	9.2	6.2	9.2	10.8	18.5	6.2	4.6	4.6	6.2	1.5	1.5									65	82.58	<0.01

TABLE 7.—Percentage size composition of the fraction of the lake Nipissing cisco population feeding on various dates.

Date	Length group, centimetres									Number measured
	20.0 –20.9	21.0 –21.9	22.0 –22.9	23.0 –23.9	24.0 –24.9	25.0 –25.9	26.0 –26.9	27.0 –27.9	28.0 and over	
May 15-23, 1935, shallow and deep	2.7	5.3	17.3	26.8	21.4	11.3	7.3	7.3	0.6	150
June 22-23, 1934, shallow........	11.9	13.1	21.4	21.4	13.1	4.8	9.5	4.8		84
June 22-23, 1935, oblique........		1.8		5.5	13.0	7.4	13.0	25.9	33.4	54
July 23-26, 1935, oblique........	0.7	2.7	4.7	9.1	21.4	22.6	20.6	13.0	5.2	299
August 15-20, 1935, oblique......	4.0	3.2	2.4	19.3	15.3	24.3	18.6	7.3	5.6	124
September 4-9, 1935, oblique.....	6.1	12.6	13.0	19.0	15.2	15.5	10.3	6.8	1.5	263

and go deep earlier. Just before the ciscoes leave the warm water, they stop feeding and they do not resume feeding immediately on entering the colder deeper water. The later the ciscoes leave the warm water the longer they fast in the cold water. This leads to a condition wherein most of the ciscoes that are feeding in July are large. In late summer practically all the ciscoes have begun to feed again. In October the ciscoes leave the deep water, which is still cold, and return to shallow water, which, while it has cooled considerably, is still warmer than the deep water. At this time they again stop feeding.

The description of the extent to which ciscoes of different size classes feed in lake Nipissing which is summarized in the preceding quotation is illustrated more specifically in the left-hand panel of figure 6. This part of figure 6 was constructed from data gathered through the examination of the alimentary tracts of ciscoes captured in lake Nipissing in gillnets. The gillnet samples were taken from all depths in the lake; often this was done by setting the nets on a long slant from surface to bottom. Thus it was possible, by knowing the relative abundance of ciscoes of different sizes at different depths and the extent to which they were feeding, to plot a series of frequency graphs showing the lengths of the members of the cisco population which were feeding at any time of the season of open water. These frequency graphs make up the left-hand panel of figure 6. The measurements of the ciscoes have been given in centimetres instead of in inches because the smaller unit enables these smaller fish to be plotted in diagrams having similar proportions to those given for the lake trout on the right-hand side. Ciscoes of less than twenty centimetres have not been shown since the nets which capture such small specimens were not always used. If the trend in the size composition of the cisco groups in the left-hand panel is compared with the trend in the lake trout groups to the right it will be seen that the changes are parallel throughout the season.

In May almost all the ciscoes are in shallow water and all are feeding. The most frequent length group in the 1935 samples consisted of ciscoes between 23.0 and 23.9 centimetres. These fish made up 26.8 per cent of the catch. About 48 per cent of the fish taken were longer than 24.0 centimetres and about 52 per cent below that length.

The ciscoes which are feeding in lake Nipissing in June fall into two distinct groups. During the fourth week of June most of the ciscoes there are to be found near bottom where the water is thirty to forty-five feet deep. Usually only the larger ones are caught at greater depths or in strata of the same depth over deeper water. A catch taken in water forty-five feet deep on June 22-23, 1934, is shown by the solid line in the June panel of figure 6. This diagram shows the size composition of the section of the population containing the majority of the feeding ciscoes. All the ciscoes present in shallow water were feeding. In this section of the population the two size groups between 22.0 and 23.9 centimetres together contained 42.8 per cent of the total sample. The percentage of feeding ciscoes longer than 24.0 centimetres dropped from 48 to 32 per cent; this drop was due to the migration of the larger fish to deep water which had already taken place.

However, by the latter half of June, the largest ciscoes of the group which has already migrated have usually resumed feeding in deep water. The size of the feeding ciscoes in a catch taken in a series of gillnets set obliquely from surface to 150 feet of water on June 22-23, 1935, is shown by broken lines in the same panel. These fish were nearly all large ones. The size group 28.0 centimetres and longer contained 33.4 per cent of the sample, and 91 per cent were over 24.0 centimetres. The actual number of these large fish that are feeding in lake Nipissing is small but they are concentrated in an area which is less than two per cent of the area of the whole lake. Ciscoes had not been taken commercially in lake Nipissing for at least ten years previous to 1935, and these large fish represent a section of the population which has disappeared from the trout population of Opeongo as a result of angling activity.

This behaviour of the ciscoes is exactly similar to that shown by the lake trout in lake Opeongo in late May and early June, if we interpret the readiness with which trout of different sizes take the bait as evidence of their willingness to feed. There is a quantitative difference between the behaviour of the ciscoes and the lake trout in the time at which they cease to feed and start to migrate. In Opeongo the migration is well under way in late May and practically over by the third week in June. In lake Nipissing there is little migration in early June and migration is not usually complete until after the middle of July.

By July 20 in 1935 (the date varies from year to year with climatic conditions), the migration of the ciscoes over twenty centimetres in length to deep water was virtually complete. Since the ciscoes stop feeding just before they migrate and do not feed again until some time after reaching deep water, those which were feeding on July 20 were predominantly the ones which had migrated in early June. These ciscoes which migrated early were nearly all large ones. Again the size composition of the group of ciscoes which are feeding immediately after the completion of the migration to deep water corresponds to the size composition of the group of lake trout which are biting when the lake trout population has reached a corresponding stage in its summer migration.

By the middle of August, 1935, a certain number of the smaller ciscoes had started to feed again. The most numerous length group still consisted of ciscoes measuring from 25.0 to 25.9 centimetres as it had in the July catches, but the percentages of ciscoes below 24.0 centimetres had increased to 29 from the value of 17 per cent that had been found in July. The lake trout catches from July 16 to September 15 show a greater decrease in the proportion of larger fish than do the cisco catches, but that is easy to understand. Only samples large enough to determine the extent to which the members of the population were feeding were withdrawn from the cisco population. These samples were taken by gillnets which caught alike feeding and non-feeding individuals. In the capture of the lake trout, the anglers removed a special part of the population which consisted of those trout which were biting. Moreover, instead of taking only samples at intervals, angling was pursued steadily day after day, with the result that the numbers of feeding fish were noticeably reduced. This will be seen more clearly when the changes in fishing effort are discussed (page 33). Hence the removal of 900 lake trout over the period June 16 to July 15 had an appreciable effect on the size composition of the catch taken later in the summer.

In early September many smaller ciscoes began to feed almost simultaneously and a marked change in the size composition of the feeding group of ciscoes was found. The most numerous size class changed from 25.0-25.9 centimetres to 23.0-23.9 centimetres, and the percentage of fish less than 24.0 centimetres long rose still further to 50.7. As well as an increase in the number of smaller fish that were feeding, there had been an actual loss of larger fish from the feeding population by upward migration. The upward migration, which is correlated with advancing stagnation of the deeper waters cut off from the circulating upper layers by the sharp temperature gradient of the thermocline, is also associated with a cessation of feeding activity. The similarity between the size composition of the group of ciscoes feeding in late September and of the group of lake trout which were biting at this date is so obvious as to need no comment.

The extremely close similarity that can be seen between the changes found in the size composition of groups of ciscoes which are feeding throughout the months from May to September, and those seen in the size composition of catches of lake trout taken by angling offers almost indisputable proof in favour of the belief that lake trout and ciscoes behave similarly in their migratory and feeding habits. Although there is general agreement in their behaviour, the lake trout population in lake Opeongo and the cisco population in lake Nipissing may not be in precisely the same phase of migration on the same calendar date. The lake trout in Opeongo migrate earlier in the spring and the small ones do not resume feeding quite as early in the fall. These differences in degree, however, are to be expected on two grounds. In the first place the lake trout, although quite closely related to the cisco, is nevertheless a different fish and can be expected to behave differently. Secondly, physical and chemical conditions in lakes Nipissing and Opeongo differ considerably, and a migration which is correlated with physical and chemical factors can be expected to differ in the two lakes for that reason also.

In angling for lake trout, the fish that are captured are not always actively feeding, although such fish are in the majority. When lake trout are taken by trolling they may be snagged by the moving bait although they may not have actually seized it in their mouths. Moreover, it has been shown in feeding experiments (Blair, 1938) that when fish are not feeding they will nevertheless pick up food in their mouths and snap at moving objects. These exceptions do not influence the size composition of the catch to a great degree. Among the viscera of 1,200 Opeongo lake trout taken

Table 8.—Number and size of lake trout captured by angling in lake Opeongo in 1936, 1937, and 1938, recorded in the Algonquin Park Creel Census.

Date	Length in inches 1936																								
	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	over 31	Not measured	Total
May							2	4	7	4	7	1	1		1							1	1	49	78
June		1		2		3	1	4	11	7	10	4	3	1	3		1						2	104	157
July			1	1	9	8	8	18	28	43	40	36	22	24	16	6	2	1		1	4		2	98	368
August	2	2	7	6	10	11	11	21	27	36	29	26	12	9	6	1	2	1	1	2	1		1	102	326
September			2	5	6	6	13	15	18	20	17	15	7	3	1	1	2	1						28	160
October					1					1		1													3
Total	2	3	10	14	26	28	35	62	91	111	103	83	45	37	27	8	7	3	1	3	5	1	6	381	1,092
											1937														
May 1–20			1	1	4	3	18	16	24	21	33	9	17	2	5			1	1	1	1	1		45	204
" 21–31				1	7	6	16	23	19	21	17	11	5	9	4	1	1		1				2	29	173
June 1–15				2	3	14	8	13	14	16	11	11	10	1		2	1							17	123
" 16–30			1		4	4	13	18	40	41	36	23	11	7	2			2					1	10	213
July 1–15	2	2	1	4	6	16	24	39	60	57	81	35	23	14	8		1		1		1		1	22	398
" 16–31			4	3	14	14	31	26	30	48	32	23	7	7	3	1	2	1	1	2			1	62	312
Aug. 1–15			3	6	10	20	28	37	47	64	52	33	15	5	3	2	3	2				1	1	31	363
" 16–31	3			5	13	11	13	27	34	26	26	21	10	3	1			1	2	2	1			27	226
Sept. 1–15				2	4	3	10	5	9	10	8	3	5	4	1				1				1	49	115
" 16–30		1	6	7	6	4	6	7	12	4	3	3	4	1	1									12	77
Oct. 1–15								1	1	1		1		1											5
Total	5	3	16	31	71	95	167	212	290	309	299	173	107	54	28	6	8	7	7	5	3	2	7	304	2,209

Table 8—*Continued*

Date	Length in inches 1938																								
	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	over 31	Not measured	Total
May 1–20				1	3	2	3	9	16	11	9	7	3	3	2	1	1							57	128
" 21–31					2	10	18	39	38	21	14	16	7	2	3	3	1							19	193
June 1–15			1	3	1	6	6	18	25	29	18	17	2		1									11	138
" 16–30		1	2	2	6	3	4	7	16	10	6	2	1	6	1					1				0	68
July 1–15			2		9	8	15	12	20	21	17	9	11	1	4	1	3		1					91	225
" 16–31		1	3	7	3	17	17	22	36	27	34	7	17	4	6		3	1	1	2	1	1		51	261
Aug. 1–15			5	2	11	4	4	13	16	14	13	7	3	2	3	1		1	1				1	42	143
" 16–31	1		4	1	7	4	3	10	4	4	9	4	6	1	2	1				1			1	9	72
Sept. 1–15	1	1	1		2	3	4	6	8	7													1	0	34
" 16–30	1		2	5	8	6	3	2	3	3	5		3		1									0	42
Oct. 1–15																									
Total	3	3	20	21	52	63	77	138	182	147	125	69	53	19	23	7	8	2	3	4	1	1	3	280	1,304

by angling that were examined in 1937, only eight per cent showed evidence that the fish had not been feeding just prior to capture.

ANGLING SUCCESS IN FISHING FOR LAKE TROUT IN ALGONQUIN PARK

Angling success can be recorded by measuring the length of time required to capture a given number of fish in a certain way. Lake trout fishing in Algonquin Park is done largely by trolling from a skiff or a canoe, with usually two fishermen in a boat, although certain anglers prefer to anchor and catch their trout by still fishing. The unit of gear chosen to express the Algonquin Park records is two men in one boat, and the unit of effort taken has been two men in one boat fishing for one hour. This unit of effort will be referred to subsequently as a "boat hour."

The result of fishing effort can be expressed in a number of ways each suitable for a particular purpose. Here it will be discussed in two of them. The first of these ways of expressing the result of fishing effort has been designated "availability." Availability is a measure of abundance of fish from the angler's point of view, although it does not necessarily give a measure of the precise number of fish present. Availability has been defined as the number of fish taken per 100 boat hours of fishing. A fishing time of 100 hours is rather an artificial unit since no fisherman is likely to devote so many consecutive hours to angling, but using such a length of time avoids large decimals. It is particularly convenient to use a fishing period of this magnitude when it is desired to consider the relative availability of fish of different sizes in the total catch.

A second measure of the quality of the fishing afforded by a given fishery is the "poundage per 100 boat hours of fishing." This figure expresses the size of the fish taken as well as the ease with which they are captured, and is calculated by multiplying the availability by the average weight of fish captured. Poundage has been used in an effort to express the relative desirability of large fish compared to small ones. It is of course impossible to assess mathematically the relative value that a fisherman places on the capture of a large fish compared to the capture of a small one.

However, it would seem safe to say that an angler values one ten pound fish at least as highly as he does ten one pound individuals of the same species.

Seasonal Variation in Angling Success

Concomitant with the cycle of changes in size composition of catches of lake trout taken by angling, there is a fluctuation in the length of time required to catch the fish by a standard method of angling. This fluctuation varies from lake to lake, and also depends upon the past history of each fishery and upon the amount of fishing activity during the current season. It can be explained by assessing the effects of the migratory and feeding habits of the lake trout on fishing which are summarized in the quotation given on page 24.

Consideration of the availability of lake trout to the angler as well as of the size composition of his catch, emphasizes still further the difference in fishing at different times of the year.

On page 19 where the marked difference in the size composition of the catches of lake trout taken from Merchant lake in June compared with that of catches taken there in September is mentioned, the catches are discussed on the basis of percentage size composition. It was pointed out that the proportion of small fish in the September catches was considerably greater than in those taken in June, but this might have been due to the relative scarcity of large fish in September rather than to a particular abundance of small ones. However, since the fishing effort is also known, it is possible to plot the availability of each size group, and to determine what actually were the differences in the two groups of catches in this respect. The catches have been plotted in this way in the right-hand panel of figure 7.

The left-hand panel compares the percentages and is a reproduction of figure 5, page 20. During the two week period, June 16-30, the total availability was 134 lake trout per 100 boat hours. In September the total availability was 178 lake trout per 100 boat hours. The availability of fish in each length group can be calculated by multiplying the fraction of the catch occurring in that length group by the total availability. When this procedure is carried out it can be seen that small lake trout were not only relatively more abundant in the catches but they were also much more easily taken. Not only were over 80 per cent of the fish captured in September twenty inches or smaller as compared with less than 50 per cent of the same size range in late June (page 19), but also in September the availability of lake trout twenty inches and less was 142 as compared with 64, the value for the latter half of June. Thus small fish were not only 1.6 times more numerous in September catches than they were in those taken in June but also

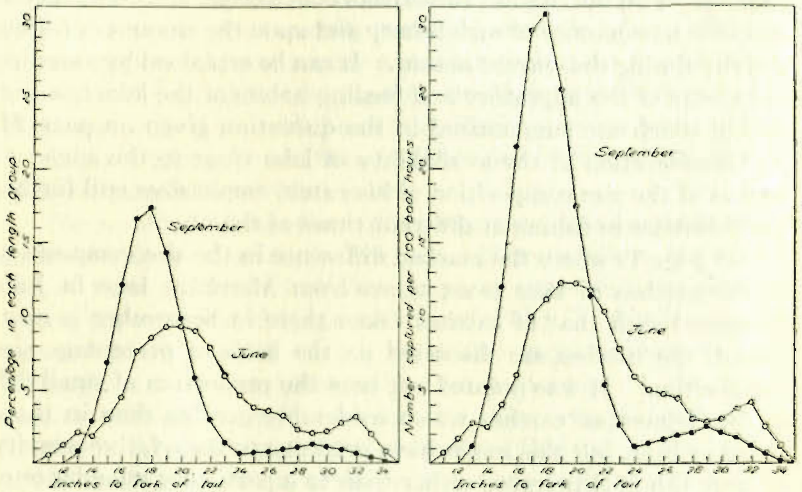

FIGURE 7.—Availability of lake trout of various sizes in Merchant lake in June and in September, 1938, compared with the size composition of catches of lake trout taken by angling in the same intervals. Data from tables 5 and 9.

they were caught over twice as easily. In contrast, large fish were relatively scarcer in September catches and they were also much harder to catch than they had been in June. In June 100 boat hours of fishing yielded seventy lake trout over twenty inches in length. In September only thirty-six lake trout longer than twenty inches were captured per 100 boat hours of fishing. Thus a consideration of the availability as well as the size composition of the catch emphasizes further the magnitude of variations in angling success that may occur in one lake during a single year.

The seasonal variation in availability of lake trout in lake Opeongo in 1937 is given in figure 8 and table 9. During the first three weeks in May the average availability of lake trout in Opeongo was 111 fish per 100 boat hours. From May 21 to May 31 the availability dropped to an average of 86. In the first two weeks of June the availability rose again and surpassed that recorded for early May. The average number of lake trout captured per 100 hours over the period June 1-15 was 122. The availability of lake trout in lake Opeongo continued to rise in the latter half of June and

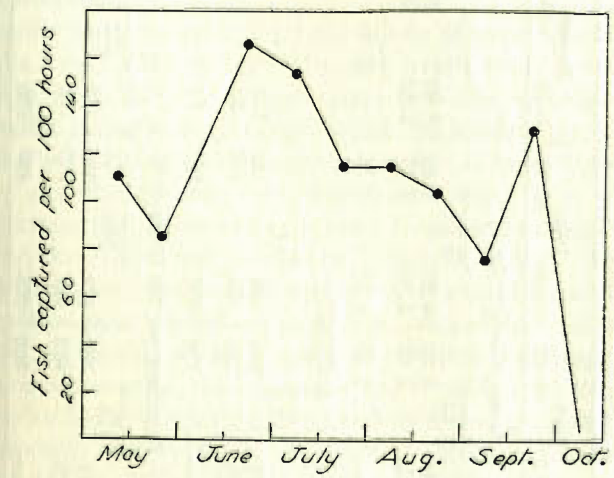

FIGURE 8.—Seasonal changes in the availability of lake trout to anglers fishing in lake Opeongo in 1937. Data from table 9.

was highest for the year in this two week period, the average being 167. Following the peak in the latter half of June the availability dropped slightly to 159 for the first two weeks of July. In the last two weeks of July the availability dropped precipitously and after a check in August declined to a low for the year of 76 during the period September 1-15. Finally in the half-month September 16-30, the availability rose again to a value of 130 lake trout per 100 hours. The rise in availability in late September does not continue into October, for in the first two weeks of that month it is extremely difficult to catch lake trout in Opeongo by angling.

TABLE 9.—Average weight, availability, and poundage of lake trout captured per 100 boat hours, in lake Opeongo and Merchant lake.

Lake	Year	May 1–20	May 21–31	June 1–15	June 16–30	July 1–15	July 16–31	August 1–15	August 16–31	September 1–15	September 16–30	October 1–15
		Average weight lbs.										
Opeongo......	1936	3.89		3.64		3.71		3.01		2.76		
"	1937	3.14	3.10	2.71	3.01	2.97	2.87	2.82	2.80	3.12	2.13	
"	1938	2.94	2.65	2.62	2.66	2.85	3.17	2.86	3.01	2.25	1.94	
Merchant.....	1938	6.55		—	5.75	4.38	4.12	3.94		2.63*		
		Availability										
Opeongo......	1936	—		115		141		117		159		
"	1937	111	86	122	167	159	115	115	104	76	130	5
"	1938	85	137	90	131	129	113	69	80	67	86	
Merchant.....	1938	96		—	134	127	102	74	83	178*		
		Poundage per 100 hours										
Opeongo......	1936	—		418		524		353		429		
"	1937	349	267	341	503	472	324	324	291	236	277	
"	1938	251	363	238	394	357	356	198	241	151	167	
Merchant.....	1938	627		—	766	555	427	290	327	593*		

*September 1-20.

Seasonal variation in availability such as is shown in figure 8 can be explained as follows. In early May lake trout of all sizes are feeding in shallow water and are scattered over the shallow areas of the lake. At this time also the water is cold and the lake trout may not be feeding as actively as they do later when the temperature is somewhat higher. During the last week or ten days of May, the older members of the lake trout population cease feeding and migrate to deeper water. A considerable proportion of the lake trout population is then not available to the angler and fishing drops off.

In early June, in spite of a further loss of large trout by migration, the availability is higher because small trout are more concentrated since they no longer range into the extreme shallows. Further the water in the strata in which the feeding trout are living is probably reaching the temperature which is most favourable to activity and the fish may be biting more freely.

Following the last of the migration from shallow water, anglers find that the large trout are biting in deeper water. These large fish although not the most numerous group in the population are concentrated over a relatively restricted area of lake bottom where the water is approximately twenty-five to fifty feet deep. Because of this concentration, and because the localities where they are likely to be found are known, anglers find it easy to take their limit and the availability is high. If a lake is fished to the extent that Opeongo was in 1937, a heavy toll is taken from the concentration of feeding lake trout during the first month of deep water angling. There is no great resumption of feeding activity on the part of the fish which migrate later until about the middle of September, and fishing becomes progressively poorer after the earlier feeders in deep water have been captured and carried off.

In mid-September, with the sudden increase in feeding activity on the part of the smaller length classes, fishing from the point of view of numbers captured per unit effort becomes better again but the average size of the fish taken is small.

In October, lake trout return to shallow water and do not bite readily again before the closing date of the fishing season, October 15.

If the availability is multiplied by the average weight of the fish landed, a rather more satisfactory picture of fishing conditions can be obtained than results from a discussion of numbers taken per unit time alone. Seasonal variation in the poundage of lake trout taken per 100 boat hours is shown for Merchant lake 1938, and lake Opeongo 1937, in figure 9. The average weight of the lake trout captured has been calculated from the length composition of the catches by using a length weight conversion graph (Fry and Kennedy, 1937).

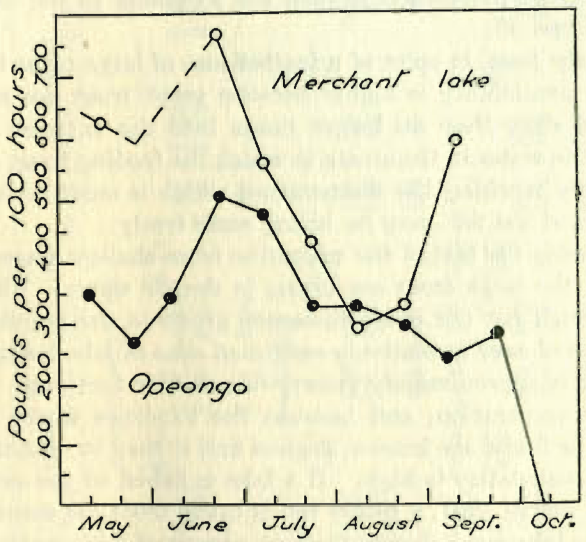

FIGURE 9.—Seasonal changes in the poundage of lake trout removed per 100 boat hours from lake Opeongo in 1937 and Merchant lake in 1938. Data from table 9.

The upper curve in figure 9 shows the seasonal variation in the poundage of lake trout taken per 100 hours in Merchant lake. Previously Merchant lake had been no more than moderately fished in any year, but in 1938 about 600 lake trout were removed from this lake of one thousand acres.

Because of blackflies and mosquitoes, Merchant lake was not fished from about May 20 until June 15 so that the course of the early changes in fishing cannot be traced. An interrupted line is drawn to suggest that probably the poundage per 100 hours drops slightly in late May as the large fish cease feeding and migrate. From June 15 until September 20 a great deal of fishing was done in Merchant lake and there are records available for every two week interval.

The maximum poundage per 100 boat hours for any half month was 766 pounds, the average for June 16-30. From the June maximum there was a rapid and continuous decline to a low value of 290 pounds per 100 hours in the first half of August. In September fishing again improved and the poundage captured per 100 hours rose again to 593 pounds.

Merchant lake showed a very pronounced cycle of variation in angling success in 1938. The records for the month of August contain only a few fish but there is no doubt that fishing in Merchant lake was very poor at that time. It has not been the custom to record effort expended when no fish were taken, and this was the luck of a number of anglers visiting Merchant lake in August. After failing to catch lake trout in Merchant lake they usually returned to the next lake, Happyisle, a lake ordinarily ignored when fishing was good in Merchant lake.

In previous discussion on page 19 and on page 34 it has been shown that the good fishing offered by Merchant lake in June was quite different from that offered in September. June fishing yielded fair numbers of large fish while September fishing yielded large numbers of small ones. There seems to be every reason to believe that the depression in fishing in August was due to the removal of a high percentage of the feeding population by angling activity in late June and early July.

The graph for Opeongo showing the variation in poundage per 100 hours throughout the season of 1937 should be compared with the graph of seasonal variation in availability for the same year given in figure 8. The trend shown in both figures is the same except that the importance of September fishing is minimized in the poundage diagram since although the trout were taken more readily at that time this ease in capture was offset by the smaller size of the fish landed. On comparison it will be noted that the seasonal variation in Opeongo was not so marked as in Merchant lake. This comparison will be discussed in a following section (page 42).

Changes in the Seasonal Variation in Angling Success in Lake Opeongo from 1936 to 1938 Inclusive

It was stated on page 33 that the course of seasonal fluctuations in a given lake depends on the past history of the fishery and upon the amount of fishing activity of the current season. Some of these changes have taken place in the lake trout fishery of lake Opeongo during the three years 1936 to 1938 inclusive for which records have been collected through the medium of the Algonquin Park Creel Census. Lake Opeongo, already noted for its lake trout and fished to a considerable extent for a number of years, was made much more accessible in 1936 by the opening of the highway which now cuts across the south-west corner of Algonquin Park.

Monthly averages of the poundage of lake trout captured per 100 boat hours in the years 1936, '37, and '38 in lake Opeongo are shown in figure 10. The types of seasonal variation that would be expected in lake Opeongo under virgin conditions and in the last stages of depletion are also suggested in this figure by two curves drawn in with broken lines.

Lake trout fishing has become progressively poorer in lake Opeongo from 1936 to 1938. During early May and the first two weeks of October there has been no appreciable change, probably because no matter what their numbers, lake trout do not bite readily in those two periods. The most marked seasonal fluctuation in poundage landed per 100 hours was recorded in 1936, the first year of easy access. In that year two well-marked peaks were found, one in late June and early July, and the other in middle and late September. These are the two peaks discussed previously (page 39). The August depression, believed to result from the removal of a significant fraction of the group of trout which are feeding in deep water in early summer, can also be seen. This depression is evidence that fishing activity in the summer of 1936 was quite sufficient to cause an appreciable reduction in the numbers of lake trout present in this lake of over thirteen thousand acres.

The peaks in the 1937 cycle are not as high as those shown by the records for 1936; in particular the second peak has become much reduced. Fishing was poorer in August in 1937 than in the previous

year although the trough is not so apparent because there was no great recovery in September.

Records for the year 1938 show a still further decline in both the June and September peaks, indicating the further trend of the

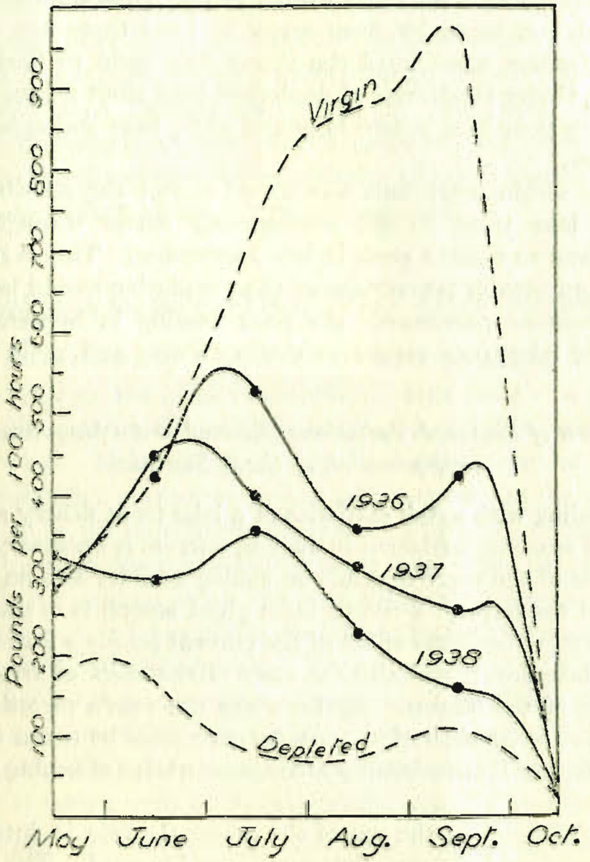

FIGURE 10.—Changes in angling success in lake Opeongo from 1936 to 1938 inclusive. Data from table 9.

lake trout fishery of lake Opeongo towards depletion. However, the number of lake trout taken from lake Opeongo in 1938 dropped by about 25 per cent and perhaps fishing there will recover somewhat in 1939.

In extreme depletion, as indicated by the lower broken curve, it is believed that there would be no late June maximum in Opeongo at all. This maximum is made up of older fish which migrate early, and under conditions of overfishing the fish are removed before they can reach such an age. Consequently when the remnants of the population leave for deep water in June there are very few actively feeding trout until the young fish begin to feed in September. Under conditions of depletion, lake trout fishing is likely to be at its poor best in late May and early June and again in mid September.

Under virgin conditions one would expect the possibilities of catching lake trout to get continuously better throughout the summer and to reach a peak in late September. This is because a greater and greater percentage of the population would be feeding as the summer progressed, the peak coming in September just before the lake trout return to shallow water and again cease to bite.

Application of Seasonal Variations Observed in Angling Success to the Interpretation of Catch Statistics

In dealing with catch statistics of a lake trout fishery an appreciation of seasonal variation in angling success is necessary. Since the nature of the cycle depends on fishing activity and on the past history of the fishery, a record for a given season is of great value in interpreting both the effect of the current season's fishing on the stock of lake trout, and also the state of the stock of trout at the beginning of the season. Again, when the year's records from a given lake are considered as a whole, care must be taken to ensure that the figures for availability are representative of fishing throughout the season.

Two examples of the use of the seasonal cycle in interpreting the effect of fishing upon the stock may be cited. The trend in the seasonal cycle in Opeongo in the past three years is much weightier evidence that the lake has been overfished during that period than would be three annual averages. Also the violence of the fluctuation in angling success shown by the records for Merchant lake in 1938 offers a strong indication that the fishery there would not stand up under a continuous drain as great as that to which it was subjected in that season. Accordingly steps have been taken to grant that lake trout population a respite by closing Merchant lake to fishing for the season of 1939.

The danger that isolated records may not be representative of the average for the year is greatest in census returns from the more inaccessible lakes fished in August. Such records may place the availability too high for these waters due to the accumulation and concentration of feeding fish. Data for two lakes, Hogan and LaMuir, discussed in a later section (page 50) and shown in figure 12, are believed to place the availability of lake trout in these two lakes at an unduly high value on this account.

Variations in the Availability of Lake Trout in Different Lakes

(*a*) *The relation of availability to size composition.* There is a relation between the total availability of lake trout in a given lake and the size composition of the lake trout population resident there at that time. This relation is such that within certain limits the total availability of trout in a given lake increases as the percentage of large fish in the population decreases. The limit to this improvement in availability is reached in most lakes when the numbers of large fish are reduced below the level necessary to ensure sufficient reproduction. In lakes where the lake trout first spawn at a length in the neighbourhood of twelve inches another factor may enter. In such lakes there may be an abundance of small fish of less than twelve inches, but these do not enter into the availability because the customary methods used for the capture of lake trout are not efficient in taking such small individuals (page 16).

In figure 11 is shown the availability of lake trout of different length groups in a series of four lakes in which there was no likelihood of reproduction being insufficient. The average lengths of the fish captured by angling in these lakes in the years shown were: Proulx 23.2 inches, Opeongo 19.1 inches, Whitegull 18.1 inches, Louisa 14.4 inches. The total numbers of lake trout captured per 100 hours were: Louisa 354, Whitegull 210, Opeongo 128, Proulx 75.

When the curves are examined in detail it is evident that a decrease in the larger size groups is more than compensated by an increase in the smaller size groups as far as this series is carried. The size composition of the Proulx lake catches which has also been mentioned in a previous section (page 19), does not extend

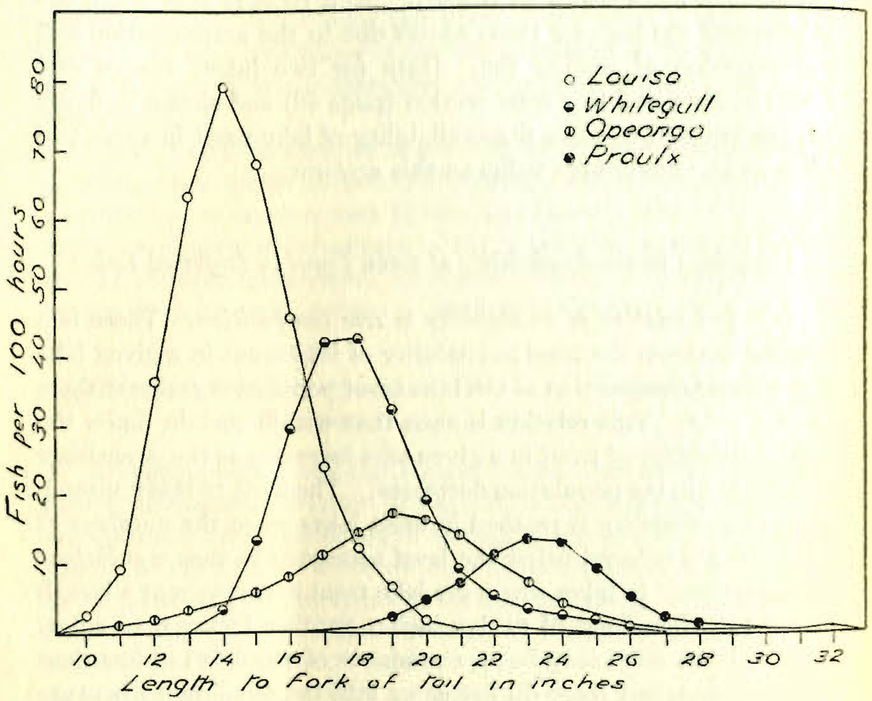

FIGURE 11.—Differences in the availability of lake trout of various sizes in four Algonquin Park lakes. Data from table 10. Smoothed twice by threes.

back beyond sixteen inches even after smoothing. Since this curve represents two years' fishing records which are quite complete, and since considerable fishing with gillnets also failed to yield any smaller lake trout, it is no doubt true that virtually no lake trout less than sixteen inches long exist in Proulx lake at present. The large fish that have been captured there have had healthy repro-

TABLE 10.—Availability of lake trout of different lengths in four Algonquin Park lakes.

Lake	Year	Length in inches																				Total availability
		12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	over 31	
Louisa......	1938	20	68	133	68	30	20				3												354
Whitegull....	1937					27	67	54	18	4	4		9										210
Opeongo.....	1936	2	2	5	5	6	11	16	23	19	15	8	7	5	1	1				1		1	128
Proulx......	1937–38								1	6	4	4	14	15	20	8	2	2	2	1			75

ductive organs and certainly spawned normally in 1937 and 1938, so that it is hardly likely that the lack of small lake trout is due to a failure of reproduction. From a consideration of the extreme condition in this particular lake, and in the light of the other examples presented in this series and of much further similar evidence which is on record, it seems impossible to escape the con-

TABLE 11.—Synopsis of the returns for lake trout in the Algonquin Park Creel Census in 1936.

Lake	No. of fish reported	Length of fish, inches			No. of fish per 100 hrs.
		Min.	Aver.	Max.	
Big Crow	6	14	....	22	....
Big Trout	1	..	....	..	....
Black Bear	2	12	....	14	....
Booth	4	..	....	..	....
Burnt Island	3	22	....	26	....
Couchon	10	21	....	30	....
Dickson	40	..	....	..	....
Gilmour	8	13	....	24	....
Grand	1	..	....	..	....
LaMuir	4	15	....	24	....
La Vieille	19	17	....	28	....
Little Dickson	16	..	....	..	....
Lost Dog	5	12	....	20	....
Louisa	2	14	....	18	....
North Tea	4	18	....	24	....
Opeongo	1,092	10	19.1	32	128
Proulx	1	21	....	21	....
Redrock	72	12	20.7	30	100
Smoke	9	16	....	24	....
Two Rivers	2	16	....	18	....
Whiskey Jack	1	..	....	..	....
Whitegull	80	16	16.8	20	312
White Partridge	32	18	....	24	....

clusion that when large lake trout are present in a lake they severely limit the chances of survival open to their smaller brethren.

(*b*) *The relation between total availability and the average size of lake trout captured in a given lake.* In comparing a series of lake trout populations it is convenient to plot the total availability of catchable lake trout in each lake in each year against the average size of the lake trout captured there in that year. This procedure has been carried out in constructing figure 12 which shows all the data yet collected for Algonquin Park.

TABLE 12.—Synopsis of the returns for lake trout in the Algonquin Park Creel Census in 1937.

Lake	No. of fish reported	Length of fish, inches			No. of fish per 100 hrs.
		Min.	Aver.	Max.	
Amable du Fond (r.)	2	24	....	24	....
Big Crow	22	17	20	24	73
Big Trout	7	18	22	28	140
Booth	35	14	19.3	25	116
Boundary	17	14	....	20	155
Burnt Island	8	14	21.6	27	16
Butt	8	..	15	..	165
Cache	168	12	14.8	23	108
Canisbay	1	..	21	..	....
Canoe	12	18	23.6	32	90
Catfish	4	24	26	32	46
Cedar	3	22	22.6	23	....
Chicadee	20	11	14.8	16	214
Couchon	18	14	....	24	....
Dickson	12	20	24.8	30	150
Foy	26	20	22	24	60
Happyisle	105	11	17.7	30	169
Head	9	13	14.5	19	180
Hilliard	4	17	19	20	....
Hogan	148	15	22	32	212
Joe	8	15	18	22	....
Kathlyn	7	..	23.1	..	33
Kenneth	5	14	14.6	15	....
LaMuir	22	17	23.2	30	200
La Vieille	32	18	21.8	34	100
Little Madawaska (r.)	2	12	....	22	....
Louisa	30	12	16.7	26	240
McCraney	17	13	....	18	100
McIntosh	4	15	16.5	20	133
Merchant	87	11	19.8	36	136
Opeongo	2,209	10	18.7	36	121
Owl	3	16	....	20	200
Pearley	2	28	....	30	....
Pine	1	..	20	..	....
Proulx	69	19	23.2	29	76
Rabbitaille	50	12	15	17	250
Radiant	16	15	22.4	32	100
Ragged	6	14	18.3	24	55
Raven	35	14	16.8	20	148
Redrock	328	11	18.1	36	144
Smoke	8	14	19.9	29	89
Source	48	13	14.6	16	117
Swan	5	19	20.6	22	89
Tanamakoon	4	13	13.5	14	....
Tepee	1	..	25	..	....
Threemile	40	15	....	25	....
Two Rivers	41	12	16.9	26	100
Whitefish	1	..	19	..	....
Whitegull	47	16	18.1	24	210
White Partridge	37	9	15.8	24	44
Wilkes and North Tea	61	15	....	24	....

In studying figure 12 it will be noted that except for Hogan and LaMuir, all the lakes lie within a region of the graph which is bounded by a line that starts at a low value for lakes in which the average length of the lake trout captured is less than fourteen inches;

TABLE 13.—Synopsis of returns for lake trout in the Algonquin Park Creel Census in 1938.

Lake	No. of fish reported	Length of fish, inches			No. of fish per 100 hrs.
		Min.	Aver.	Max.	
Annie	1	17	....	17	...
Big Crow	68	16	22.7	30	89
Big Trout	7	16	....	20	...
Bonnechere	6	14	....	18	...
Booth	15	14	20.3	26	58
Boundary	19	14	15.1	18	224
Burnt Island	1	23	....	23	...
Butt	44	16	18.8	21	190
Cache	159	10	14.3	21	90
Canisbay	56	11	15.7	22	150
Canoe	1	20	....	20	...
Chicadee	3	16	....	17	...
Cradle	17	11	14.6	19	426
Crooked (w.)	31	12	17.6	20	248
Delano	13	11	....	15	...
Dickson	15	16	20.5	25	...
Happyisle	264	12	17.7	32	113
Head	91	8	16.1	23	129
Hilliard	1	19	....	19	...
Hogan	63	16	21	30	147
Iris	7	14	....	18	...
Kathlyn	1	26	....	26	...
Kenneth	18	13	....	17	...
LaMuir	24	14	....	20	...
La Vieille	16	14	20.2	24	110
Little Crow	1	17	....	17	...
Little Island	64	11	15.3	17	114
Louisa	105	12	14.4	22	354
Merchant	441	12	20.3	32	122
Opeongo	1,304	9	18.4	32	101
Owl	4	16	....	16	...
Proulx	46	20	23.3	26	73
Radiant	13	14	....	36	...
Smoke	28	15	19.8	30	75
Source	27	10	13.6	18	91
Tanamakoon	31	11	13.8	18	94
Threemile	48	12	....	26	...
Tim	10	12	....	14	...
Two Rivers	12	12	....	17	...
Whitefish	2	13	....	16	...
Wright	6	17	....	20	...

rises steeply to a maximum of about 420 fish per 100 boat hours in lakes where the average length of the lake trout taken is sixteen inches; and then dies away more gradually to a value of 75 fish per 100 boat hours which is reached when the average length of the

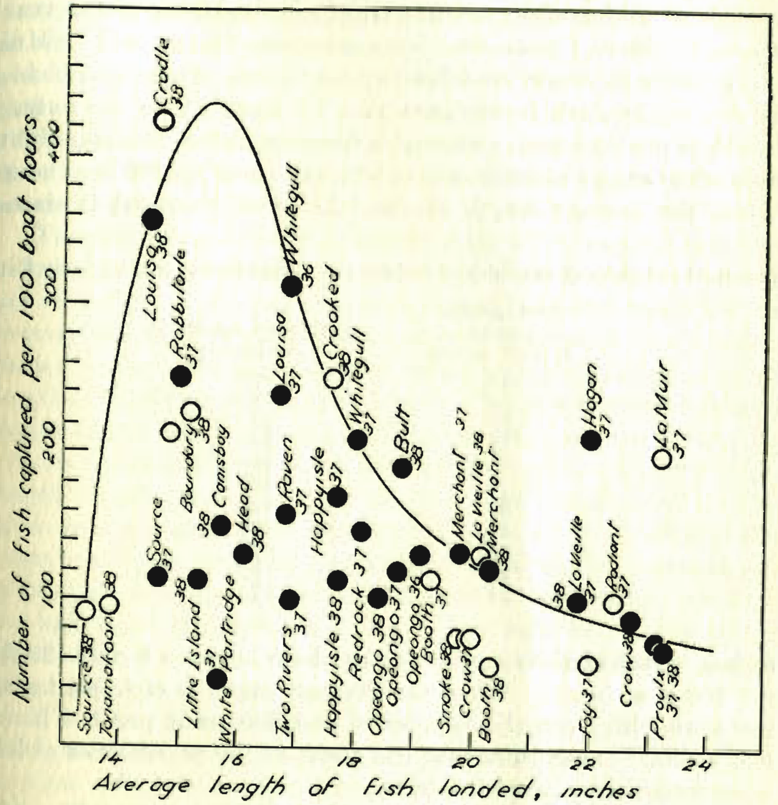

FIGURE 12.—Relation between average length of lake trout landed and the number captured per 100 boat hours in Algonquin Park lakes. Data from tables 11, 12, and 13.

lake trout captured is twenty-four inches. Since this graph contains three years' data it will also be seen that the same lake may be represented by more than one point, due to changes in fishing in it from one year to another. These changes in fishing from year to year that have been recorded for the same lake will be shown again in a later figure (figure 14) and are discussed on page 52.

The exceptionally high availability recorded for Hogan and LaMuir lakes has already been mentioned on page 43 and it is believed that these lakes depart from the general rule because the records of fishing effort are not truly representative of the year's average. Setting aside the two exceptions, Hogan and LaMuir, it is possible to obtain the following description of lake trout fishing in Algonquin Park from figure 12. In lakes where the average length of the lake trout captured is fourteen inches, the availability may stand at any value from 0 to 300 lake trout per 100 boat hours. When the average length of the lake trout captured is sixteen

TABLE 14.—Limits of availability in lake trout populations in Algonquin Park.

Average size of lake trout landed, inches	Estimated maximum availability
14	300
15	420
16	420
17	300
18	200
19	160
20	120
21	100
22	90
23	80
24	75

inches, the availability may lie anywhere between 0 and 420 fish per 100 boat hours. When the average length is eighteen inches, the availability may lie between 0 and 200 trout per 100 hours; and so on. These values for the limits of the possibilities of lake trout fishing are given in table 14.

From figure 12 it can be seen that while the possibility of a greater density of lake trout increases in some lakes with decreasing size down to an average length of about sixteen inches, this is not true of all lakes. In many waters the density of the lake trout population begins to decrease rapidly when the average length of the lake trout captured in them falls below eighteen inches. An explanation of these differences in the ability of lake trout populations to maintain a high density at a low average length lies in the

size at which lake trout become mature in different lakes. The average length which lake trout attain before they reach maturity varies from about fourteen to almost eighteen inches in different lakes. Accordingly, lakes in which the average length of the lake trout captured lies between fourteen and eighteen inches, may contain an abundance of spawning fish, or perhaps practically none at all. If the lake trout mature at a size small enough to ensure abundant reproduction, they will be plentiful in these lakes, but if the low average length of the population means that practically no fish are allowed to reach spawning size, reproduction will be poor and the availability of the lake trout in those waters will fall to a very low figure.

The maximum availability of lake trout in Algonquin Park lakes is found in those containing trout whose growth and development are such that an adequate spawning stock is maintained when the average length of the lake trout taken by anglers is about sixteen inches, and in which the fishing intensity maintains the average length of the fish captured at this level. In lakes where the average length of the lake trout captured is less than sixteen inches, the greatest availability possible falls rapidly again with decreasing length of fish caught. There are two factors concerned in this. In no lake investigated in Algonquin Park has a population of lake trout been found in which there would not likely be a considerable proportion of immature fish in the catch if the average length of the lake trout captured fell to a length of less than fifteen inches. Also lake trout under twelve inches are not easily taken by angling (page 16).

When the average length of the lake trout captured exceeds nineteen inches, it is probable that there is always sufficient reproduction, although we know that many lake trout between nineteen and twenty-five inches may be infertile. However, lakes in which the average length of the trout captured is as great as nineteen inches contain considerable numbers of lake trout twenty-two inches and longer. These large lake trout limit the density of their own species (page 46).

It has been possible to estimate the percentage of immature fish in the catches of lake trout for a number of lakes from which samples of the catch have been examined. These estimates are plotted in figure 13 and it will be seen that all lakes lying on the boundary curve of figure 12 to the right of the maximum at sixteen inches yielded catches containing few or no immature fish. On the other hand, catches from lakes which fall to the left of the maximum or

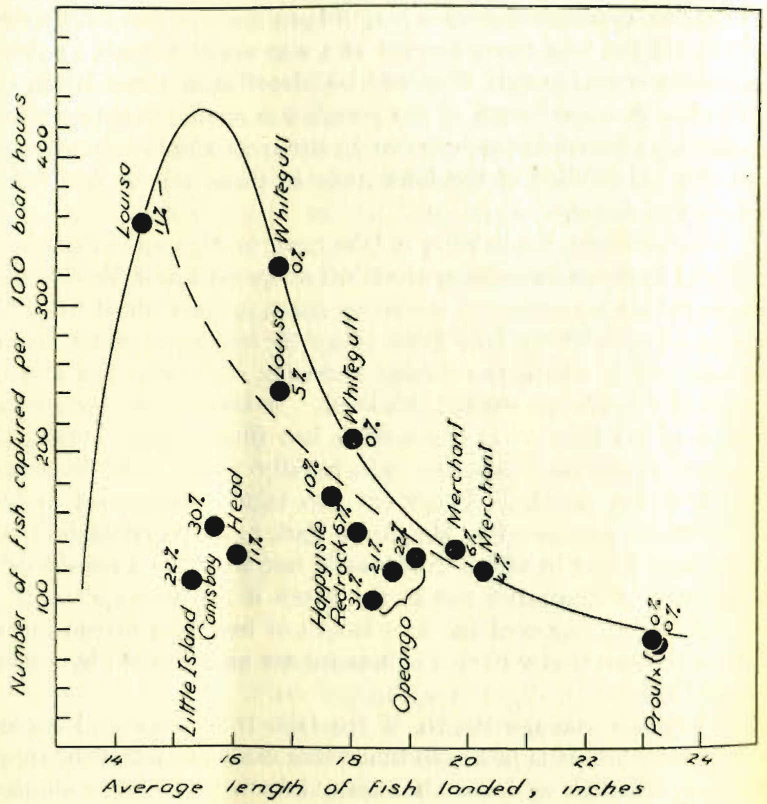

FIGURE 13.—Percentage of immature fish in the anglers' catches of lake trout from certain Algonquin Park lakes.

below the boundary line contained an appreciable proportion of immature fish.

(*c*) *Annual changes in availability of lake trout in certain lakes.* The population of lake trout in any given lake is not static. There may be considerable changes both in the availability and in the

average length of the fish captured even from one year to the next. Occasionally, if a lake were heavily overfished, this change might manifest itself in the following year by a marked decrease in the availability accompanied by little if any change in the average

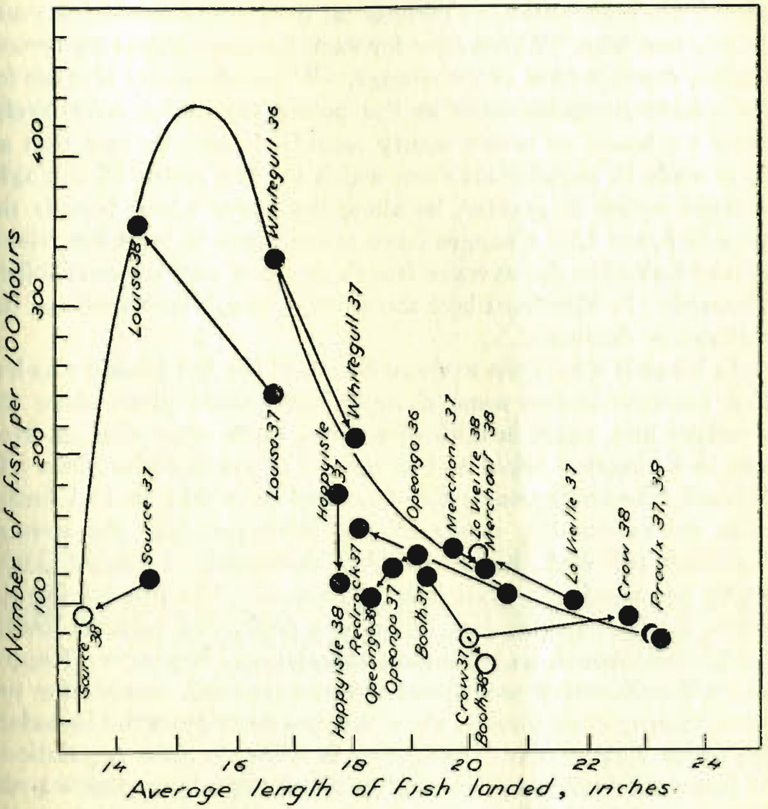

FIGURE 14.—Changes in the availability and the average size of lake trout landed, found from year to year in certain Algonquin Park lakes. Data from tables 11, 12, and 13.

length of the fish captured. This is perhaps the cause of the decline in availability found in Happyisle in 1938 (figure 14) following the removal of adult lake trout for planting in Cache lake. For this reason no further wholesale removal of adults from Happyisle is contemplated. Ordinarily the effect of fishing is not so severe in any one year, and changes in availability and average length are related to one another in an orderly fashion.

In figure 14 are shown the changes in availability and average length which have been found in a number of lakes. Except in the case of Opeongo, there are records for only two consecutive years for any one lake. The points for each lake are linked by arrows showing the direction of the change. When allowance is made for the greater probable error in the points shown by open circles which are based on rather scanty records, it may be seen that all shifts made in populations from which the fish captured averaged nineteen inches or greater, lie along the curve which bounds the lakes in figure 12. Changes have taken place in both directions. In lake LaVieille the average length dropped and the availability increased. In Merchant lake the average length increased and the availability decreased.

In lakes in which the average length of the fish landed was less than nineteen inches some changes have taken place along the boundary line, again in both directions, while other changes have been in a direction below and to the left of the boundary line. In Redrock lake the average size decreased from 20.7 to 18.1 inches while the availability increased. In Whitegull lake the average size increased and the availability decreased. In lake Louisa length decreased and availability increased. The line joining the points for lake Louisa cuts across the peak, and perhaps Louisa has passed through its maximum abundance. Neglecting Happy-isle, which has been mentioned above (page 53), records for two lakes, Opeongo and Source, show changes away from the boundary line which suggest that reproduction is failing in these populations.

From the evidence presented by the changes in availability and average length of fish captured shown in figure 14, and from the previous discussion in which populations in different lakes were compared, it seems probable that in any single lake the history of its lake trout population could be described by a curve such as that shown in the left-hand panel of figure 15. This figure illustrates a conception of the history of a trout population that is not a novel one, but that is perhaps an advantage rather than a defect. Starting with a few parent trout, and neglecting predators for the moment,

there would at first be a high survival of young. As the average size of the population became larger, the amount of spawning would become greater and the population would continue to increase up to a certain point. At a critical average length there would be enough large trout present to take sufficient toll of the young to balance the increase in egg production. This critical point would be determined by the size at which the lake trout became mature in that particular lake. When the average size of the population increases beyond the critical point, spawning is no longer the factor

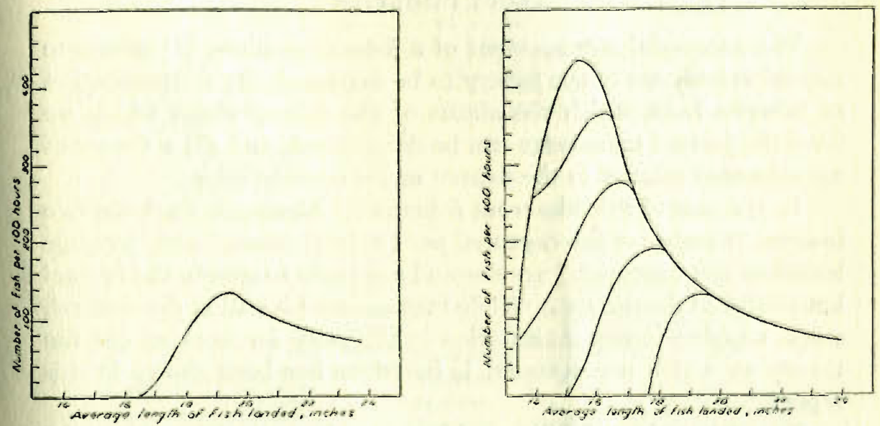

FIGURE 15.—Hypothetical curves showing the relationship between availability and the average size of lake trout landed for Algonquin Park lakes, and the relation of these curves for individual lakes to fishing conditions found in the lake trout fisheries of Algonquin Park. For explanation see text page 54.

that exerts the controlling influence over availability; at these stages the survival of young trout is limited by the density of the large ones.

The space bounded by the curve in figure 12 in which lie all the records, and presumably all the possibilities of lake trout fishing in Algonquin Park lakes, contains a multiplicity of such curves. When the curves relate to fishing instead of to the actual density, they have to be slightly modified since lake trout of less than approximately twelve inches in length are not taken as easily as are larger ones (page 16). For this reason availability will not drop as rapidly below the critical point in populations in which the fish mature at a small size as it will in those in which they are larger before they become mature; this point will be discussed at greater length later (page 66). Hypothetical curves for a few individual lakes and their relation to the curve limiting availability in all lakes are given in the right-hand panel of figure 15.

APPLICATION OF CATCH STATISTICS TO THE MANAGEMENT OF LAKE TROUT FISHERIES

The successful management of a fishery requires, (1) adequate factual knowledge of the fishery to be managed, (2) a classification of fisheries from which the status of the fishery about which we have the factual knowledge can be determined, and (3) a theory of management related to the fishery under consideration.

In the case of the lake trout fisheries of Algonquin Park the two indices, "number of fish captured per 100 boat hours," and "average length of fish captured," are deemed adequate to supply the factual knowledge of the fishery. While management is still in the research stage, supplementary information is necessary for working out the theory on which management is based, as has been shown in this report.

The curve of availability as illustrated in figure 12 provides the means of classification of lake trout fisheries. Generally speaking, if the average length of the lake trout captured in a certain lake is over sixteen inches and the availability of these fish lies on the boundary curve, the population of lake trout in that lake is limited by factors other than fishing activity. If, however, on plotting the average length of the lake trout captured against the availability, it is found that the position of the lake is far below the curve of maximum availability, it can be concluded that the lake in question has been overfished, and that some action is necessary to restore the lake trout population there to its former abundance, or to some new abundance brought about by some artificial means.

The theory relating to the lake trout populations in Algonquin Park which has been developed in the earlier sections of this report may be stated briefly as follows. Three factors are considered to

be the chief causal agents bringing about the limits to the availability of lake trout in Algonquin Park lakes. These factors are:

1. The effect of angling;
2. Variations in the size at which lake trout reach maturity in different lakes;
3. The influence of the presence of large lake trout on the chances of survival of small ones in the same waters.

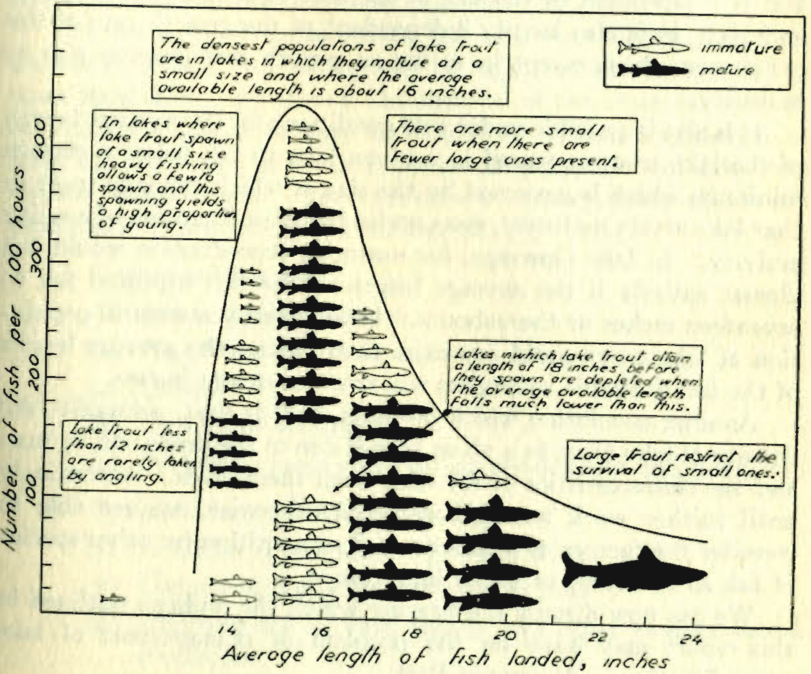

FIGURE 16.—Relation between lake trout populations and fishing conditions in the lake trout fisheries of Algonquin Park.

A recapitulation of the manner in which these factors are believed to interact is shown in the accompanying chart, figure 16.

If the explanation of conditions found in lake trout fisheries that is given here is valid, it must lead to the following conclusions. First, the fishing offered by a given lake is not due to chance but is the result of the operation of definite laws. It is impossible for lake trout to be present in an abundance that will make them more available to anglers than the limit which is shown by the curve bounding all the possibilities of fishing drawn in figures 12, 13, 14, 15, and 16. Of course that limiting value applies only to an annual mean; it is possible to get much better fishing in lightly fished lakes at certain seasons (page 42). The maximum abundance varies with the average size of the fish captured from the lake in question and is independent of the size of the lake to a large extent if not entirely. It is also largely independent of the growth rate of the trout themselves, except in so far as growth rate governs size at maturity.

It is also impossible under wild conditions for the average length of the lake trout captured in a given lake to fall below a certain minimum which is governed by the size at which the lake trout in that lake attain maturity, even under the most intensive of angling activity. In lake Opeongo, for example, reproduction would fail almost entirely if the average length of the fish captured fell to seventeen inches or thereabouts. Consequently a natural population of lake trout could not exist there unless the average length of the fish available to anglers was over seventeen inches.

Another conclusion which presents itself is that, primarily, the density of lake trout in a given lake is due to the predation by man and the characteristics of the lake trout themselves. Accordingly until further work has demonstrated otherwise, we are able to consider the factors of predation and competition by other species of fish as not being of major importance.

We can now discuss the bearing which the findings outlined in this report may have on the problem of management of lake trout fisheries in Algonquin Park.

In discussing measures aimed at the conservation of a fishery, we have to consider the administrative difficulties as well as the biological consequences of any step that is taken. There may be such a conflict between these two opposing interests as to prevent the application of a particular method of conservation or as to render its adoption useless. In other instances the measure of conservation adopted may be a compromise. In others there may be a complete harmony between what is biologically ideal and

administratively feasible. Thus there are two general principles involved in the formulation of a policy of fisheries conservation. On the administrative side the aim is to control the fishery in such a way as to ensure the best yield from it that is consistent with the demands of the public and with the possibility of effective administration. On the technical side the aim is to control production in such a way as to produce the best yield from the fishery under the system of administration in force, and under the ecological conditions obtaining in the waters in question.

The methods of conservation fall into two subdivisions also. On the one hand, the fishery may be regulated by the exertion of some legislative control over the removal of fish from the fishery; on the other hand, it may be improved by the application of technical measures such as artificial propagation and lake and stream improvement. The methods of conservation which are commonly in practice are listed below.

1. Control of the catch
   - (*a*) Minimum legal length
   - (*b*) Bag limits and close seasons
   - (*c*) Quotas
   - (*d*) Closure of waters
   - (*e*) Protection from commercial exploitation and poaching.
2. Technical improvement of the fishery
   - (*f*) Artificial propagation and restocking
   - (*g*) Control of predators and competitors
   - (*h*) Improvement of food supply and other environmental conditions.

The place that each of these various methods has in a programme of management of the lake trout fisheries of Algonquin Park is discussed below.

(*a*) *Legal length.* It has been pointed out (page 16) that a "legal" length of approximately twelve inches is brought into effect in lake trout fisheries by the operation of a natural law. Twelve inches is roughly the minimum length at which lake trout are taken by means of the tackle currently in use. However, this minimum length does not protect the lake trout fisheries of Algonquin Park to any great extent, since in many of the lakes the lake trout are well over twelve inches long before they spawn. It remains to be seen whether any minimum length longer than this would protect the lake trout populations of Algonquin Park. A legal length of fourteen inches would afford some measure of protection to the populations of lake trout in lakes like Source, Cache, and Louisa (figure 12, page 49) but would have no appreciable effect on the fisheries of lakes such as Opeongo, Merchant, and Proulx. On the other hand, if a legal length of seventeen or eighteen inches were established, much potential production in smaller lakes would be lost while the populations of Opeongo, Merchant, and Proulx lakes would then be adequately protected. Since the size at which lake trout mature differs even in neighbouring lakes, there is no possibility of establishing a series of different minimum legal lengths because of administrative difficulties. Hence a minimum legal length for lake trout in Algonquin Park is not practicable under present conditions.

(*b*) *Bag limits and close seasons.* The principles of restricting the catch taken by each angler and of protecting the population at certain critical periods of the year are of such universal application as to require no comment here.

(*c*) *Quotas.* The application of a quota implies some knowledge of the limits of production. Throughout this discussion, with the exception of a short section on "The yield of lake trout fisheries" on page 11, this report has dealt with density and not with production. Production depends on the rate of turnover as well as upon the number of individuals present in a given area. It is hoped that turnover may ultimately be calculated by determining the average age of the lake trout captured, but we are not yet certain how to interpret the growth marks on lake trout scales. Lacking this knowledge we cannot yet establish quotas for different lakes. Quotas might be established empirically but even then they would form at best an awkward means of control for such an extensive series of lakes as there are in Algonquin Park.

(*d*) *Closure of waters.* The often wide differences in lake trout fishing that have been found in the same lake in consecutive years

(page 52) suggest that a depleted population might recover rapidly if the lake were closed to fishing for a period of time. There are also theoretical grounds for believing that closure in alternate years is more beneficial than closure for a period of consecutive years. Indeed if one applies the reasoning of Thompson and Bell (1934) that has been to a large degree the basis of the successful policy which is reclaiming the Pacific halibut fishery, these considerations give promise of a great increase in spawn available under an intensive fishery with no diminution of the total poundage yielded.

A numerical example is given below which considers the case of a lake in which fish are first captured in their fourth year, which is also the year in which they become mature. The fishing intensity taken is the high figure of 90 per cent. Let us assume then that there are 100 three-year old fish present in this lake in the spring. By fall 90 of them will have been removed, leaving 10 to spawn and to be four-year old fish in the following spring. Let us further assume for the sake of simplicity, that 90 per cent of the fish available in the lake have been removed each year for a number of years so that the fishery has reached a low but steady level. Then any group that has entered the fishery will have been reduced from 100 in its fourth year to 10 in its fifth and to one in its sixth year. Accordingly there will be present in the lake in any one year, since each year there is a new generation:

100 three-year olds
10 four-year olds
1 five-year old

and the catch will consist of

90 three-year olds
9 four-year olds

and in 9 years out of 10

1 five-year old.

After the catch has been removed there will remain to spawn

10 three-year olds
1 four-year old

neglecting the five-year old that escapes capture in one year out of ten.

It might be well now to gather these considerations into one table to avoid confusion.

Age	Fish present at beginning of year	Fish captured in open season	Fish remaining to spawn
3	100	90	10
4	10	9	1
5	1	1	0
		100	11

Now suppose the lake is closed in the following year, then we have, neglecting any mortality other than that due to angling, the condition shown in the table below:

Age	Fish present at beginning of year	Fish captured in open season	Fish remaining to spawn
3	100	0	100
4	10	0	10
5	1	0	1
			111

In the first close season there will be about ten times more spawn available for deposition than there had been the year before.

In the year following the close season, the lake would again be open to fishing and this year we would have:

Age	Fish present at beginning of year	Fish captured in open season	Fish remaining to spawn
3	100	90	10
4	100	90	10
5	10	9	1
6	1	1	0
		190	21

By expending the same effort that had taken only 100 two years previously, 190 fish would be captured, and from the point of view of size the catch would be very much more worth while, for ten times as many four, five, and six-year old fish would be taken as were captured in the last preceding open year.

Due to the heavy removal of fish in the open season the amount of spawn available for deposition would fall again, although not as low as in previous open years; it would still be about double. Therefore averaging the amount of available spawn over the closed year and the open one following it, there would be a mean increase in available spawn of about 500 per cent.

In further years of alternate open and closed seasons there would be further slight gains in spawn available and in the number of fish captured, but the effect would be most marked in the first two years. Of course we are neglecting the unpredictable effect of the increased spawning in this statement. In the next table the figures are carried down to seven years, a time when conditions would have become stable, neglecting the improvement in fishing that should also be brought about by the five-fold increase in reproduction. The improvement due to increased reproduction also should begin to manifest itself by the fifth year—the second open season after the adoption of the plan.

	Closed Year 4			Open Year 5		
Age	Fish present	Fish taken	Fish spawning	Fish present	Fish taken	Fish spawning
3	100	0	100	100	90	10
4	10	0	10	100	90	10
5	10	0	10	10	9	1
6	1	0	1	10	9	1
7				1	1	0
			121		199	22

	Closed Year 6			Open Year 7		
Age	Fish present	Fish taken	Fish spawning	Fish present	Fish taken	Fish spawning
3	100	0	100	100	90	10
4	10	0	10	100	90	10
5	10	0	10	10	9	1
6	1	0	1	10	9	1
7	1	0	1	1	1	0
8				1	1	0
			122		200	22

For this plan to be advantageous two conditions are necessary. First the fishing intensity must be so high as to make negligible mortality arising from other causes after the fish have entered the fishery. Secondly the fish should enter the fishery at least in the season in which they are maturing. These conditions are to be found in many of the smaller lakes in Algonquin Park.

(*e*) *Protection from commercial exploitation and poaching.* These two principles of conservation of game fisheries in inland waters are also of too widespread importance to require any comment here. The reader may be reminded, however, of the evidence given in tables 1 and 2 in which the effects of angling and commercial fishing are compared. It should be borne in mind that angling activity alone is sufficient often to deplete a lake trout fishery even in lakes of considerable size.

(*f*) *Artificial propagation and restocking.* It is evident that natural reproduction cannot keep pace with the demands that angling makes upon the lake trout populations in many Algonquin Park lakes, if they are open to angling every year. In many instances closure in alternate years may allow an increase in spawning, but in the case of a number of lakes such closure is not feasible, since cottages and fishing camps are located on their shores. In these cases it is believed that spawning must be supplemented by the introduction of fish raised by artificial propagation. We are by no means certain what numbers of young lake trout should be planted or at what size it is most economical to introduce them; these things we must still discover by experiment. However, in spite of this gap in the information we possess at present, it is still possible to draw some conclusions regarding the benefits to be derived from planting.

Lakes in which the availability of lake trout lies upon the boundary curve (figure 12 etc.) will not produce a further abundance of lake trout in spite of any restocking, for in those waters natural reproduction is more than adequate.

Restocking, unless fish larger than the average size of those previously captured are introduced, is not likely to increase the average size of the fish taken. Under conditions where restocking is advisable, fishing intensity is likely to be so high that the average angler will not be able to catch his legal limit in a day of fishing effort. Accordingly, although the availability of lake trout would be expected to increase under a programme of restocking, the population would be likely to be removed as quickly as was the sparser population before, each fisherman taking his limit instead of a fraction of it. Time is necessary to produce large fish and they can only be present in numbers in lakes where the fishing intensity is low.

The maximum availability for a population of lake trout from which the fish captured were of a given average length, would be the same under artificial propagation as it would be for the best natural reproduction. Thus Source lake under the present conditions of fishing intensity could be expected to contain a population of lake trout with a maximum average annual availability of 380 trout per 100 boat hours, Opeongo a maximum of 200 trout per 100 boat hours.

When egg counts are made on an adequate sample of individuals taken from a given lake, it is possible to calculate the total egg loss resulting from a year's fishing. In Opeongo in 1937, for example, the egg loss amounted to 2,250,000 eggs. Such statistics may form the basis of a stocking policy.

It would be desirable to continue the experimental transfer of adult lake trout from inaccessible lakes to heavily fished ones.

(*g*) *Control of predators and competitors.* The evidence we have suggests that when populations of lake trout are not utterly depleted at least, predators and competitors play no significant part in limiting their availability for angling. It may be the part of wisdom to contrive as far as possible to keep the availability of lake trout populations up to the point where the large lake trout themselves are beginning to control the density of the population. It would appear that predators and competitors other than the lake trout themselves can largely be ignored in Algonquin Park at present.

(*h*) *Improvement of food supply and other environmental conditions.* It is now recognized that fishing can be materially improved in many instances by improving conditions in nature that are deficient. Thus lakes have been fertilized to improve the crop of plankton they produce. Shelters have been placed to allow forage fish a refuge from the game fish in order that sufficient of them will survive to ensure adequate reproduction. Spawning beds have been improved. Such measures are of undoubted advantage when a deficiency has been recognized. Sometimes, however, the results may not be entirely what may have been anticipated. It might be possible to improve the food supply of the lake trout in Cache lake by introducing a suitable forage fish. However, if the lake trout in Cache lake which now feed to a large degree upon plankton in the summer months were to turn to fish, it is likely that they would take on growth characteristics similar to those exhibited by lake trout which feed on forage fish in other lakes. Lake trout whose summer diet is largely forage fish attain a length of about eighteen inches before they are mature; in Cache lake at present lake trout are only about fourteen inches long in the year in which they spawn for the first time. If their growth rate were to increase so that they attained a length of eighteen inches before spawning, they would be at least fourteen inches long in the year previous to this and would thus be liable to capture by angling a year previous to that in which they are taken now. Consequently under such intensive fishing activity as that to which the lake trout population in Cache lake is subjected, practically all of the fish would be removed before they could reproduce. Therefore natural reproduction would be much lower than it is now, and the advantages of increased growth rate would be more than counterbalanced by the almost total failure of spawning which would attend it. However, since it is probable that Cache lake needs to be consistently restocked in any event, introduction of a forage fish would give the benefit of a more rapid turnover of the population.

A MANAGEMENT PROGRAMME FOR THE FISHERIES OF ALGONQUIN PARK

The suggestions for a programme of fisheries management for Algonquin Park which are offered here refer to the problems of administration which relate to all species of game fish in common, and in addition contain recommendations regarding lake trout in particular.

It is suggested that the lakes in Algonquin Park be classified into groups for the purposes of administration as follows:

Group I. Lakes freely accessible by road or rail, or from waters contiguous to these. This group may be subdivided as follows:

(*a*) Small lakes bordered by no cottages;

(*b*) All lakes with cottages or resorts except lake Opeongo;

(*c*) Lake Opeongo.

Group II. Lakes accessible only by a fairly extensive canoe trip or by air. These again may be subdivided:

(*a*) Lakes open to public fishing;

(*b*) Lakes reserved for fish cultural purposes.

Certain measures of conservation are generally applicable throughout the whole administrative area of Algonquin Park. These include the restrictions on bag limits and fishing seasons. Two methods of management which might be applied are not considered applicable to lake trout fisheries in Algonquin Park at present. These are the establishment of a minimum legal length and quotas limiting the number of lake trout to be removed from a given lake in any one year. Specific action applicable to each administrative group of lakes listed above is given under each appropriate heading below.

Small accessible lakes bordered by no cottages. These lakes often become very popular and are heavily fished until they are virtually exhausted. It is proposed that these lakes be open to fishing only in alternate years. This recommendation is based on considerations which arose from an application of the theories of Thompson and Bell (1934) to the conditions in lake trout fisheries in small lakes in Algonquin Park (page 61).

Lakes bordered by cottages or resorts. It is probably impractical to attempt to restrict the fishing activity on these lakes. The major effort should probably be centred about the inauguration of a consistent stocking policy for these waters. At the moment it might be advisable as far as Algonquin South is concerned, to confine this stocking to biennial plantings of lake trout fingerlings. The numbers planted should be decided upon in light of the best judgment available and the effect of the introduction of these numbers carefully followed by means of the creel census.

Lake Opeongo. Lake Opeongo, because of its large size and because the main field station of the Ontario Fisheries Research Laboratory is located there, has been considered by itself. Two methods of conservation are proposed for lake Opeongo. These are the introduction of a new forage fish, the Proulx lake cisco, and the inauguration of a restocking policy.

Relatively inaccessible lakes open to fishing. No formal policy need be inaugurated for these lakes at present. It is considered that these should be watched carefully through the medium of the creel census and the fishing intensity regulated whenever there is any necessity for such action. It is felt that fishing in these lakes should offer attractions commensurate with their inaccessibility. To do this the fishing intensity should be quite low. One of the special problems offered by the fisheries of these lakes is that of aeroplane fishing parties. We are fortunate in enjoying very complete co-operation from Mr. T. H. Higgins who pilots many of these parties, in the matter of creel census returns.

Relatively inaccessible lakes reserved for fish cultural purposes. Including these lakes in this discussion is perhaps something of a paradox. However, it appears from an analysis of the creel census returns to date that the peak production from the point of view of both numbers and poundage is not met with in trout lakes in a virgin condition, although these produce the largest fish, but is attained at a stage where the majority of the population has spawned only once or twice. It is suggested that the policy with respect to lakes reserved for the purpose of producing adult trout or eggs should be to try and maintain them at this point. To determine this level, accurate records of the lengths and numbers of fish removed, together with post-mortems and scale samples from those that might be accidentally killed during operations, would be essential.

Addendum

During the past summer, it was noted that bass fingerlings occasionally found their way into bait pails. This practice may

lead to the spread of bass into speckled trout waters from which they are now excluded. It would seem advisable that posters warning against the release of unused bait minnows might be posted on portages over which such bass fingerlings might be transported.

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