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# STATISTICS OF THE WHITEFISH (*COREGONUS CLUPEAFORMIS*) POPULATION OF SHAKESPEARE ISLAND LAKE, ONTARIO

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### Abstract

Systematic gill netting in Shakespeare Island Lake, a small unexploited lake in northern Ontario in which the fish relationships are comparatively simple, was undertaken with the object of determining the total population of whitefish (*Coregonus clupeaformis* (Mitchill)). Although unsuccessful in its original purpose the attempt provides valuable information concerning the whitefish population of a virgin lake.

Weight in whitefish is proportional to the power 3.3 of the length. The departure from the cube relationship is associated with the increase in proportionate depth and proportionate width with growth.

The coefficients of correlation between whitefish lengths and the mesh of gill nets in which they are captured is $0.84 \pm 0.01$ in Shakespeare Island Lake and $0.51 \pm 0.02$ in Lake Nipigon.

Size frequency polygons show modes representing second, third, and fifth-year groups. The fourth-year group is practically lacking, indicating the possibility of failure in the production of a year class in whitefish.

Examination of the data indicates that younger whitefish undergo a period of accelerated growth in summer, and that the largest fish are more rapidly caught off and frequent shallower water than those of medium size.

Male whitefish are more numerous than females and reach a larger size and greater age.


### Introduction

For the promulgation of economically efficient fisheries regulations for any body of water the prime consideration is the number of fish that the body of water can produce. This number depends upon the total fish population which the body of water can support, on the natural replacement rate, and on the method used in capturing the fish. In a number of lakes large-scale practical experiments are being inadvertently carried on by limiting the annual catch of whitefish to tonnages which are arbitrarily fixed. Experiments of this kind will doubtless yield valuable results in time, but the results are likely to be slow in becoming apparent and any great deviation of the set catch limit from the optimum is likely to result in considerable economic losses. Losses due to errors in fixing the catch size may be reduced if information is obtainable on the three points on which the productivity depends, *viz.*, total population, replacement rate, and fishing methods. The original main object of the experiment recorded in the present paper was to determine the total whitefish population of one lake so that the information derived might be applied to other bodies of water. Unfortunately, however, the time and equipment available were not sufficient to allow the experiment to be carried to a degree of completion which would justify definite conclusions concerning the total population. Nevertheless, the data collected do illustrate a number of features concerning the growth of the whitefish and the nature of the whitefish population. The more important of these are: the relationship between the length of whitefish and weight and certain body measurements; the relationship between the mesh of gill nets and the size of the fish captured in them; the length frequency in the whitefish population and its implications; and the rate of growth in the early years. The purpose of the present paper is to present the data in such a way as to elucidate these and other minor points in the life-history of the whitefish.

The experiment described in the present paper was carried out by a party of the Ontario Fisheries Research Laboratory financially assisted by the Biological Board of Canada. To both these organizations the author wishes to express his gratitude. Thanks are also due to the personnel of the party, Professor W. J. K. Harkness, Mr. R. A. McKenzie, and Dr. A. L. Pritchard, particularly the first, who has contributed to the problem by making a preliminary analysis of parts of the data and in other ways.



### DESCRIPTION OF SHAKESPEARE ISLAND LAKE

The body of water chosen for the investigation was a small lake in the south-eastern part of Shakespeare Island, Lake Nipigon. In this paper it is referred to as Shakespeare Island Lake. This lake is irregular in outline (see map), having a number of prominent bays, and is about half a kilometre (a quarter of a mile) in length. The total area is in the neighbourhood of thirty-three hectares (eighty-one acres). For its size Shakespeare Island Lake is rather deep. Soundings in the deeper part of the lake indicate depths of as much as fourteen metres (44 ft.) and general soundings would suggest that about half the area of the lake is of a depth of ten metres (30 ft.) or over. Owing to the small size and comparatively great depth, there is a well-marked thermocline with the result that summer bottom temperatures higher than 6.0°C were not obtained in the deeper parts of the lake.

The water level of Shakespeare Island Lake is about ten feet above that of Lake Nipigon with which Shakespeare Island Lake is connected by an underground channel from Exit Bay (see map). The limited fish fauna of the smaller lake warrants the assumption that this water course is not extensively used by fishes as a channel of communication between the two lakes. No permanent streams feed the lake; its water supply accordingly must come from surface run off and a few springs situated near Spring Point.

The edge of the lake is varied in nature. Gently sloping, sandy shores constitute about half the shore-line and the rest is divided between muddy or springy bottoms and more abrupt slopes strewn with large rocks. For the most part the higher aquatic vegetation of the lake is limited to the shallower water (under two metres) and is infrequent in the observed habitat of the whitefish during summer months.

Six species of fish occur commonly in the lake. They are: the common whitefish, *Coregonus clupeaformis* (Mitchill); the spot-tailed minnow, *Notropis hudsonius* (Clinton); the muskoka minnow, *Notropis heterolepis*, Eigenmann and

Eigenmann; the pike, *Esox lucius* Linnaeus; the yellow perch, *Perca flavescens* Mitchill; and the Iowa darter, *Poecilichthys exilis* (Girard). A single specimen of ling, *Lota maculosa* (Le Sueur) was taken in a gill net.

The invertebrate fauna of the lake is to a large extent composed of insect larvae. This is particularly true of the deeper water where the larvae of *Chironomus* and *Corethra* compose the great bulk of the fauna. *Hyalella*, Cladocera, and Mollusca are also commonly found in the lake. Over ninety per cent. of the food of the larger whitefish of the lake is constituted by these five groups of organisms.

One of the attractive features about Shakespeare Island Lake for a study of the kind originally proposed was that the lake was practically unfished. It was known that a fisherman or two had investigated the fish of the lake by setting a few lengths of commercial gill nets and after our experiment was begun it was discovered that during the previous autumn a trapper had caught a number of whitefish in the lake for dog food. Besides these fish which were captured in the regular four and one-half inch stretched mesh gill net (11.4 cm.) of commerce, the only fish known to have been taken from the lake were those caught in the two previous years by parties of the Ontario Fisheries Research Laboratory. These fish, some one hundred and twenty in number, were captured in experimental nets of various mesh measurement. It is unlikely that all the fish taken in the lake by man in recent years exceed five hundred in number.

## METHODS

In accordance with the original purpose of the investigation, the general procedure was based on the desire to capture and record as large a representative sample of whitefish from the lake as was possible. The method consisted of setting a gang of gill nets each day in one of five specified positions. The nets were lifted on the day following setting and the fish from each net were measured and recorded.



### *Size of nets used*

Eleven gill nets of various mesh size were joined together in a single gang for use in this investigation. The specifications of the nets are shown in table 1.

### *Care of nets*

The gill nets were set in the early part of each afternoon and were lifted on the following morning. When the net was lifted it was brought to shore and run up on a reel. This served to dry the net and remove all tangles in it. In this way alterations in efficiency due to slime on the web or knotted meshes were eliminated. Alterations in efficiency due to broken meshes were kept as small as practicable by handling the net with great care at all times.

### *Time and location of setting nets*

The nets were set in rotation in five definite positions in representative parts of the lake. These sets were numbered from 1 to 5 and their positions are indicated on the map. It will be observed that sets 3 and 5 are in the same position in the centre of the lake. They differed in that the ends were reversed. The remaining three sets followed sections of the lake's shore-line.

Seven complete series of five sets were made during the season. These series are numbered from I to VII. The dates of setting the nets in position number 1 in each of the seven series are: I, July 7; II, July 15; III, July 21; IV, July 28; V, August 2; VI, August 11; VII, August 16.

### *Method of recording catch*

The fish were removed from the net while it was being lifted, the catch of each net being kept by itself in a marked box. Measurements of each fish were made and recorded under the corresponding net, set, series, and date. For all

TABLE 1. Showing specifications of nets used

| Position of net in gang | No. | Mesh mm. | Mesh in. | Length m. | Length yd. | Depth cm. | Depth in. | Depth meshes | Cord Thread size | Cord No. threads to a cord | Material | Brand | Selvage |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 38 | 1.5 | 46 | 50 | 152 | 60 | 48 | 80 | 6 | Cotton | Sea Island | Both |
| 2 | 1 | 51 | 2 | 46 | 50 | 152 | 60 | 36 | 80 | 6 | " | " | " |
| 3 | 1 | 57 | 2.25 | 46 | 50 | 152 | 60 | 32 | 80 | 6 | " | " | " |
| 4 | 1 | 64 | 2.5 | 46 | 50 | 154 | 60 | 29 | 80 | 6 | " | " | " |
| 5 | 1 | 70 | 2.75 | 46 | 50 | 151 | 60 | 26 | 80 | 6 | " | " | " |
| 6 | 1 | 76 | 3 | 46 | 50 | 152 | 60 | 24 | 80 | 6 | " | " | " |
| 7 | 1 | 89 | 3.5 | 46 | 50 | 156 | 61 | 21 | 80 | 6 | " | " | " |
| 8 | 1 | 102 | 4 | 46 | 50 | 144 | 57 | 17 | 45 | 2 | Linen | Knox Salmon Ticket | " |
| 9 | 1 | 114 | 4.5 | 46 | 50 | 143 | 56 | 15 | 45 | 2 | " | " | " |
| 10 | 1 | 121 | 4.75 | 46 | 50 | 147 | 58 | 14 | 45 | 2 | " | " | " |
| 11 | 1 | 127 | 5 | 46 | 50 | 138 | 54 | 13 | 45 | 2 | " | " | " |



the fish determinations of length, weight, and sex were recorded. For the first one hundred and thirty-nine specimens additional records were kept of standard length, girth, depth, and width. The definitions of the measurements and a statement of the methods of measuring follow.

The length is the distance in a straight line from the front of the premaxilla to the fork of the tail. In the field this measurement was made to the closest quarter of an inch and has been subsequently changed to millimetres. All other measurements except girth were made in millimetres.

The standard length is the distance in a straight line from the front of the premaxilla to the end of the vertebral column. Both lengths were determined on a measuring board.

Girth is the greatest circumference at right angles to the long axis after puncturing the abdominal cavity. It was measured in inches by running a steel tape about the body of the specimen.

Depth is the greatest distance at right angles to the long axis between the dorsal and ventral surfaces of the punctured fish. It was measured on the measuring board.

Width is the greatest distance directly through the body of the fish. It was obtained by the use of a pair of outside calipers.

Weights were measured in pounds and ounces on an ordinary counter scale and subsequently changed to grams when desirable.

## TREATMENT OF DATA: RESULTS AND DISCUSSION

### *Relationship between length and weight*

The relationship between length and weight has been the matter of previous discussion by several authors. Crozier and Hecht (1914), Hecht (1916), and others conclude that, as a rule, the weight is proportional to the cube of the length. However, Leim (1924) for *Alosa sapidissima*, Keys (1928) for *Clupea harengus*, *Fundulus parvipinnis* and *Sardina caerulea*, and Hart (1931) for *Coregonus clupeaformis* show that for these species at least the weight is proportional to a power of the length somewhat higher than the cube. Fraser (1931) summarizes the findings of several authors on this subject and indicates that in most species in a number of phyla the weight increases according to a power of the length higher than the cube.

In order to investigate this relation the average weight for each length group of whitefish was determined, using a 0.635 centimetre (0.25 in.) length interval. Logarithms of lengths and weights were next plotted against one another as in figure 1. From the slope of the best straight line through the points the value of the exponent in the equation $weight = length^x$ may be calculated as equal to approximately 3.3. This figure is in agreement with that found by Hart (1931) for Lake Nipigon but differs somewhat from that determined for Shakespeare Island Lake (Hart, 1931) using only part of the data available. The fact that length is used in the present case and standard length in the former may be responsible for the difference in results, although there does not appear to be any reason why this should interfere with the findings. However, the exponents as determined are well over 3.0 in all cases.

*Relationship between length and girth, depth and width*

Crozier and Hecht (1914) and Hecht (1916) conclude that in its growth a fish maintains the same size relationship among all of its parts. Hart (1931) finds that this was not the case for the whitefish and other authors disagree with the conclusion as applied to other species.

To discover the relationship between length and girth, depth and width in the present study the following procedure was followed. Measurements of girth were changed to millimetres. Then all measurements of girth, depth, and width were divided by the standard length of the fish concerned in order to obtain proportionate girth, proportionate depth, and proportionate width respectively. The fish were



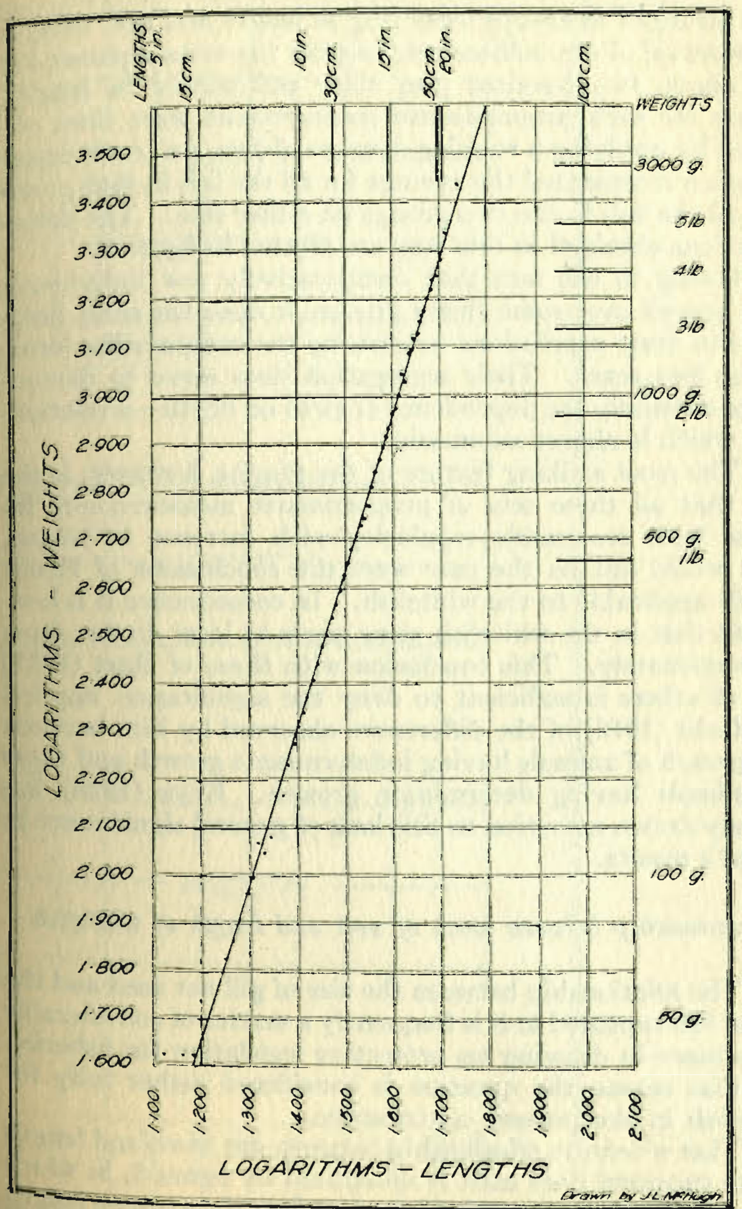


FIGURE 1. Showing logarithms of weight plotted against logarithms of length for Shakespeare Island Lake whitefish

next arranged in groups according to length and sex, using a size interval of ten millimetres, keeping the sexes separate for fish above two hundred and sixty millimetres in length. Values for each proportionate measurement were then obtained by applying a running average of five, *i.e.*, each determination represented the average for all the fish in that group and all the fish in the two groups on either side. The determinations obtained in this way are plotted in figure 2.

Owing to the fact that comparatively few individuals were spread over some thirty groups, it does not seem justifiable to draw conclusions concerning the comparative forms of the two sexes. Their segregation does serve to demonstrate definitely the dependence of girth on depth—a relationship which is almost axiomatic.

The most striking feature of the graphs, however, is the fact that all three sets of proportionate measurements increase with reasonable regularity with increase in length. This would not be the case were the conclusions of Hecht (1916) applicable to the whitefish. In consequence it is concluded that in the whitefish some parts at least do not grow proportionately. This conclusion with those of Hart (1931) and of others is sufficient to deny the significance implied by Hecht (1916) of the differences observed by him between the growth of animals having indeterminate growth and those of animals having determinate growth. Keys (1928) has already drawn attention to this lack of general significance in Hecht's results.

*Relationship between mesh of nets and length of whitefish*

The relationship between the size of gill net used and the size of fish captured in it is frequently a matter of considerable importance in drawing up protective legislation for fisheries. For that reason the question is considered rather fully for whitefish in the present contribution.

That a definite relationship between net mesh and length of fish captured does exist is illustrated by figure 3, in which the mesh of gill nets used is plotted against the average length

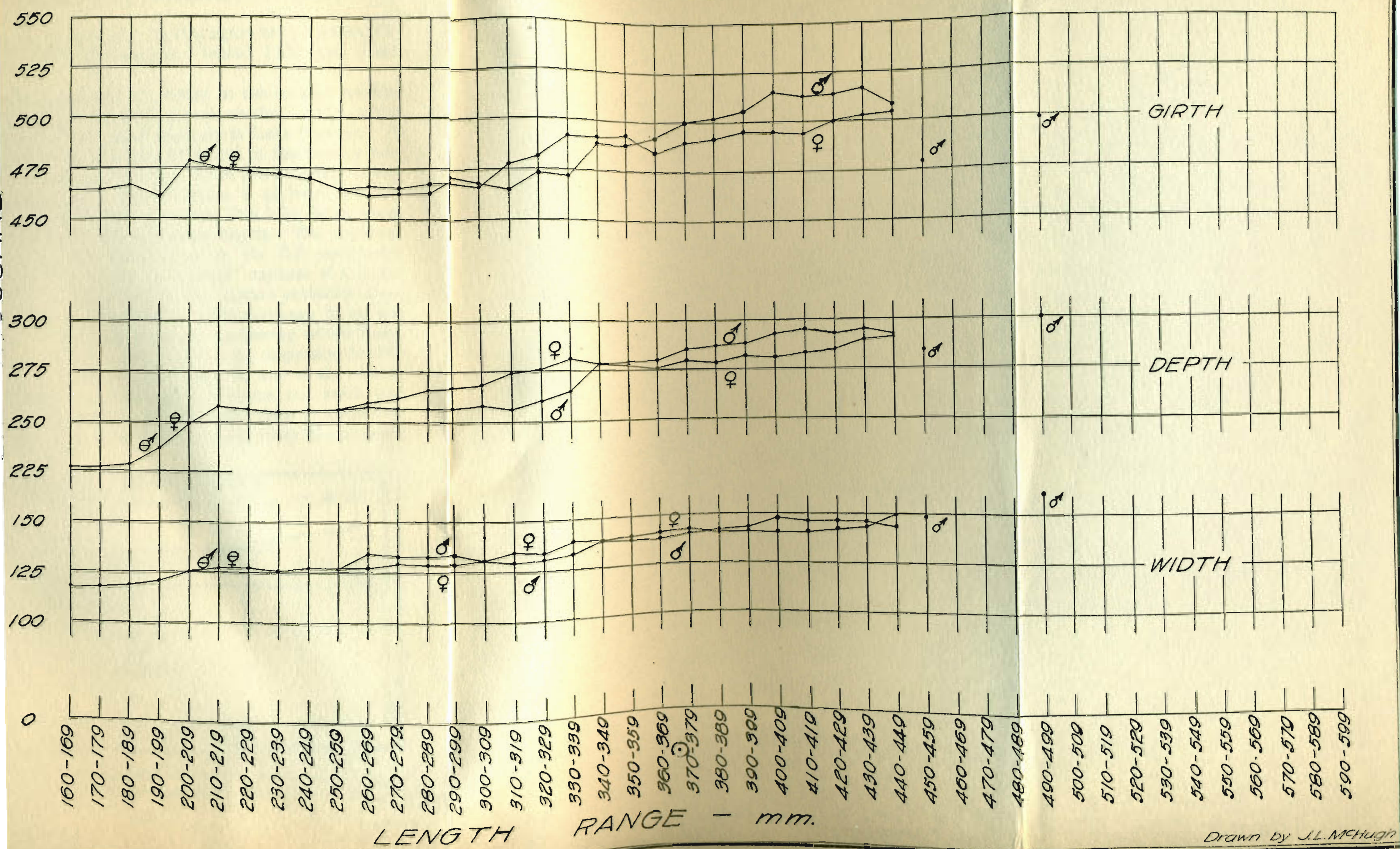


FIGURE 2. Showing proportionate girth, proportionate depth, and proportionate width plotted against length for Shakespeare Island Lake whitefish

of all the fish captured in it. In this figure are presented the data for two lakes, Shakespeare Island Lake and Lake Nipigon.

It is evident that the fish taken in the smaller meshed nets set in Shakespeare Island Lake are, on the average, larger than those from nets of equal mesh set in Lake Nipigon. A partial explanation of this may be found in the greater proportionate depth of the whitefish from Shakespeare Island Lake. (Compare figure 2 with figure 9 of Hart (1931).) Greater depth leads to the fish from this lake being more readily captured at a given mesh and length. The apparent discrepancy from this explanation in the 3.8 centimetre (1.5 in.) mesh is due to the "accidental" capture of a larger proportional number of large fish, the capture probably being connected with their comparative preponderance in an unexploited lake. This is apparent on comparing tables 2 and 3. In table 2 it will be observed that the dispersion for the fish captured in this net is larger than for any of the others.

The coefficients of correlation between net mesh and whitefish length were calculated from the data in these two tables. For the data in table 2 obtained from Shakespeare

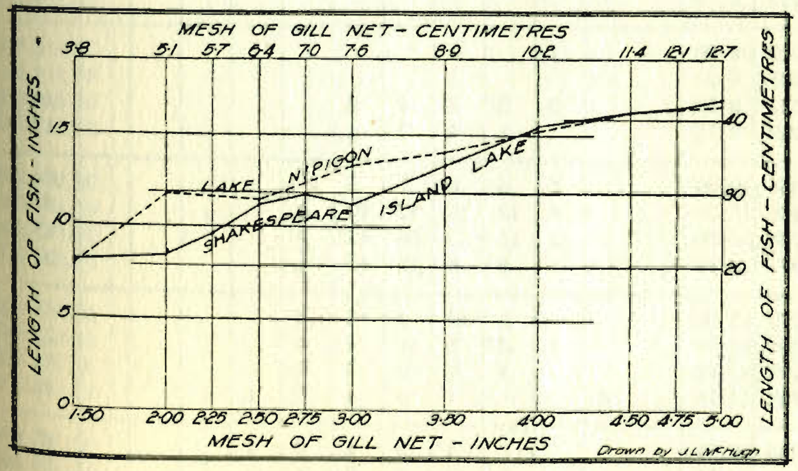


FIGURE 3. Showing the average length of whitefish taken in each size of gill net in Shakespeare Island Lake and in Lake Nipigon

TABLE 2. Showing number of whitefish of each length captured in gill nets of each mesh size set in Shakespeare Island Lake.

| Length | | Gill Net Mesh | | | | | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| mm. | in. | mm. 38 in. 1.5 | 51 2 | 57 2.25 | 64 2.5 | 70 2.75 | 76 3 | 89 3.5 | 102 4 | 114 4.5 | 121 4.75 | 127 5 | |
| 133 | 5.25 | 1 | | | | | | | | | | | 1 |
| 140 | 5.50 | 4 | | | | | | | | | | | 4 |
| 146 | 5.75 | 1 | | | | | | | | | | | 1 |
| 152 | 6.00 | 2 | | | | | | | | | | | 2 |
| 159 | 6.25 | 2 | | | | | | | | | | | 2 |
| 165 | 6.50 | | | | | | | | | | | | 0 |
| 171 | 6.75 | | 1 | | | | | | | | | | 1 |
| 178 | 7.00 | 1 | 3 | | | | | | | | | | 4 |
| 184 | 7.25 | 3 | 4 | 1 | | | | | | | | | 8 |
| 190 | 7.50 | 1 | 21 | 7 | | | | | | | | | 29 |
| 197 | 7.75 | 2 | 20 | 15 | | | | | | | | | 37 |
| 203 | 8.00 | 1 | 26 | 13 | | | | | | | | | 40 |
| 210 | 8.25 | | 5 | 4 | | | | | | | | | 9 |
| 216 | 8.50 | | 1 | 2 | 1 | | | | | | | | 4 |
| 222 | 8.75 | 1 | | | 1 | | | | | | | | 2 |
| 229 | 9.00 | | 1 | | 1 | | | | | | | | 2 |
| 235 | 9.25 | | | | 1 | | | | | | | | 1 |
| 241 | 9.50 | | 2 | 2 | 2 | 2 | 2 | | | | | | 10 |
| 248 | 9.75 | | | 2 | 4 | 7 | 4 | | | | | | 17 |
| 254 | 10.00 | | 2 | 6 | 8 | 7 | 5 | | | | | | 28 |
| 260 | 10.25 | | 2 | 12 | 10 | 12 | 10 | 1 | | | | | 47 |
| 267 | 10.50 | | 2 | 12 | 13 | 16 | 17 | 5 | | | | | 65 |
| 273 | 10.75 | | 1 | 9 | 9 | 17 | 15 | 6 | | | | | 57 |
| 279 | 11.00 | | | 8 | 10 | 9 | 15 | 6 | | | | | 48 |
| 286 | 11.25 | | 1 | 2 | 5 | 11 | 2 | 4 | | | | | 25 |
| 292 | 11.50 | | | 4 | 6 | 4 | 8 | 9 | | | | | 31 |
| 298 | 11.75 | 1 | | | 1 | 6 | 4 | 5 | 1 | | | | 18 |
| 305 | 12.00 | | | | 4 | 8 | 4 | 9 | 1 | | | | 26 |
| 311 | 12.25 | | | 1 | 2 | 4 | 2 | 1 | 6 | | | | 16 |
| 318 | 12.50 | | | 1 | 2 | 4 | 6 | 4 | 4 | | | | 21 |
| 324 | 12.75 | 1 | | | 2 | 4 | | 4 | 2 | | | | 13 |



TABLE 2—*Continued*

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 330 | 13.00 | | | | 1 | 3 | 2 | 3 | 5 | 1 | | | 15 |
| 337 | 13.25 | | | 1 | 1 | 3 | 4 | 4 | 1 | | | | 14 |
| 343 | 13.50 | | | | 1 | 2 | 3 | 4 | 4 | 1 | | | 15 |
| 349 | 13.75 | | | | | 3 | 3 | 1 | 3 | 4 | 1 | | 15 |
| 355 | 14.00 | | | 1 | | 3 | 2 | | 4 | 2 | 1 | 1 | 14 |
| 362 | 14.25 | | | 1 | | | | | 1 | 2 | 1 | | 5 |
| 368 | 14.50 | | | | | 3 | 3 | 3 | 4 | 3 | 1 | 1 | 18 |
| 375 | 14.75 | | | | | | | 1 | 3 | 1 | 5 | | 10 |
| 381 | 15.00 | | | 1 | 1 | 1 | 1 | 3 | 4 | 2 | 2 | 7 | 22 |
| 387 | 15.25 | | | | | | | 2 | 2 | 2 | 3 | 2 | 11 |
| 394 | 15.50 | | | | | 1 | 1 | 1 | 1 | 4 | 3 | 5 | 16 |
| 400 | 15.75 | | | | | 1 | 2 | 1 | 3 | 3 | 1 | 6 | 17 |
| 406 | 16.00 | | | | | 1 | 3 | 2 | 3 | 1 | 3 | 8 | 21 |
| 413 | 16.25 | | | | | 2 | 1 | | 4 | 1 | | 2 | 10 |
| 419 | 16.50 | 1 | | | 1 | | 1 | 2 | 3 | 3 | 5 | 3 | 19 |
| 425 | 16.75 | | | | | | | 2 | 1 | 1 | 4 | | 8 |
| 432 | 17.00 | | 2 | | | 1 | 3 | 1 | 4 | 3 | 4 | 3 | 21 |
| 438 | 17.25 | | | | | | 2 | | 2 | | 3 | 2 | 9 |
| 444 | 17.50 | | | | | 1 | | 1 | 2 | | 4 | 4 | 12 |
| 451 | 17.75 | | 1 | | | 1 | 1 | 2 | 4 | 3 | | 4 | 16 |
| 457 | 18.00 | | 1 | | 1 | | 1 | 4 | 4 | 3 | 2 | 2 | 18 |
| 464 | 18.25 | | | | 1 | | | | 2 | 1 | | | 4 |
| 470 | 18.50 | | | | | | 1 | 1 | 4 | 1 | 3 | 1 | 11 |
| 476 | 18.75 | | | | 1 | | | | | 2 | | 1 | 4 |
| 483 | 19.00 | | | | | | | 1 | | 2 | | 5 | 8 |
| 489 | 19.25 | | | | | | | | | 1 | 2 | 4 | 7 |
| 495 | 19.50 | 1 | | | | | | 1 | 1 | 1 | | 1 | 5 |
| 502 | 19.75 | | | | | | | | | | | | 0 |
| 508 | 20.00 | | | | | | | | 1 | 1 | | 1 | 3 |
| 514 | 20.25 | | | | | | | 1 | | | | | 1 |
| 521 | 20.50 | | | | | | | | | | | | 0 |
| 527 | 20.75 | | | | | | | | | | | | 0 |
| 533 | 21.00 | | | | | | | | | | | | 0 |
| 540 | 21.25 | | | | | | | | | | | | 0 |
| 546 | 21.50 | | | | | | | | 1 | | | | 1 |
| Total | | 23 | 96 | 105 | 90 | 137 | 128 | 95 | 85 | 49 | 48 | 63 | 919 |

TABLE 3. Showing number of whitefish of each length captured in gill nets of each mesh size set in Lake Nipigon

| Length | | Gill Net Mesh | | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| mm. | in. | mm. 38<br>in. 1.5 | 51<br>2 | 64<br>2.5 | 70<br>3 | 89<br>3.5 | 102<br>4 | 114<br>4.5 | 127<br>5 | |
| 152 | 6.0 | 2 | | | | | | | | 2 |
| 165 | 6.5 | 8 | | | | | | | | 8 |
| 178 | 7.0 | 12 | | | | | | | | 12 |
| 190 | 7.5 | 17 | | | | | | | | 17 |
| 203 | 8.0 | 13 | | | | | | | | 13 |
| 216 | 8.5 | 11 | 3 | | | | | | | 14 |
| 229 | 9.0 | 1 | 7 | | | | | | | 8 |
| 241 | 9.5 | | 13 | 4 | | | | | | 17 |
| 254 | 10.0 | | 27 | 3 | 2 | | | | | 32 |
| 267 | 10.5 | 2 | 30 | 2 | 2 | | | | | 36 |
| 279 | 11.0 | 1 | 26 | 5 | 12 | | | | | 44 |
| 292 | 11.5 | 1 | 16 | 3 | 23 | | | 1 | | 44 |
| 305 | 12.0 | | 16 | 2 | 27 | 1 | | | | 46 |
| 318 | 12.5 | | 19 | 2 | 30 | 2 | | | | 53 |
| 330 | 13.0 | | 19 | | 34 | | | | | 53 |
| 343 | 13.5 | 1 | 9 | 1 | 24 | 2 | 1 | 1 | | 39 |
| 355 | 14.0 | | 7 | 1 | 22 | 4 | 3 | 1 | | 38 |
| 368 | 14.5 | 1 | 6 | | 25 | 4 | 1 | 2 | | 39 |
| 381 | 15.0 | | 5 | 2 | 15 | 1 | 2 | 9 | | 34 |
| 344 | 15.5 | | 2 | | 13 | 1 | 2 | 19 | | 37 |
| 406 | 16.0 | | 6 | | 4 | | 3 | 18 | | 31 |
| 419 | 16.5 | | | | 5 | | 2 | 9 | 1 | 17 |
| 432 | 17.0 | | 3 | | 1 | | | 6 | | 10 |
| 444 | 17.5 | | 2 | | 1 | | | 4 | | 7 |
| 457 | 18.0 | | | | 1 | | | 5 | | 6 |
| 470 | 18.5 | | | | | | | 2 | | 2 |
| 483 | 19.0 | | | | | | | 2 | | 2 |
| 495 | 19.5 | | | | | | | | | 0 |
| 508 | 20.0 | | | | | | | | | 0 |
| 521 | 20.5 | | | | | | | | | 0 |
| 533 | 21.0 | | | | | | | 1 | | 1 |
| 546 | 21.5 | | | | | | | | | 0 |
| Total. | | 70 | 216 | 25 | 241 | 15 | 14 | 80 | 1 | 662 |



Island Lake the coefficient is $0.84 \pm 0.01$. For the Lake Nipigon data of table 3 the result is $0.51 \pm 0.02$.

It is evident in tables 2 and 3 that large fish may be taken in small meshed nets although small fish are practically never taken in nets of coarse mesh.

A study of tables 2 and 3 and figure 3 indicates that it is possible to obtain a representative series of whitefish of all lengths over seven inches in lakes where whitefish do not reach lengths over twenty-two inches by the use of a graded series of gill nets of meshes ranging from 3.8 centimetres (1.5 in.) to 12.7 centimetres (5.0 in.) by 1.3 centimetre (0.5 in.) gradations. The fact that large fish are adequately represented in the catches is attested by the very small increase in average length of the fish taken in the 12.7 centimetre (5.0 in.) net over those in the 11.4 centimetre (4.5 in.) net.

### *Size frequency of whitefish*

In the last section it was pointed out that a gang of gill nets such as that used in Shakespeare Island Lake may be expected to yield a complete series of whitefish of all sizes from seven inches up. Accordingly, it is appropriate that figure 4 be shown to indicate the length frequency of the whitefish captured in Shakespeare Island Lake.

A number of features in this graph are worthy of note. There are three distinct modes at 140 (5.5), 203 (8.00), and 267 (10.5) separated by minima at 165 (6.5) and 235 (9.25). The average values for the specimens grouped about each mode are respectively at 146 (5.75), 197 (7.81), and 267 (10.53). These are separated by intervals of 5.23 centimetres (2.06 in.) and 6.91 centimetres (2.72 in.). Beyond the mode at 267 (10.50) the length frequency polygon is characterized by a rapid falling off to a more or less constant value.

An examination of the figure reveals the fact that in all the cases where the difference between the modes and minima exceeds the sum of the probable errors (the square root of the hypothetically correct determination), the lack of regularity

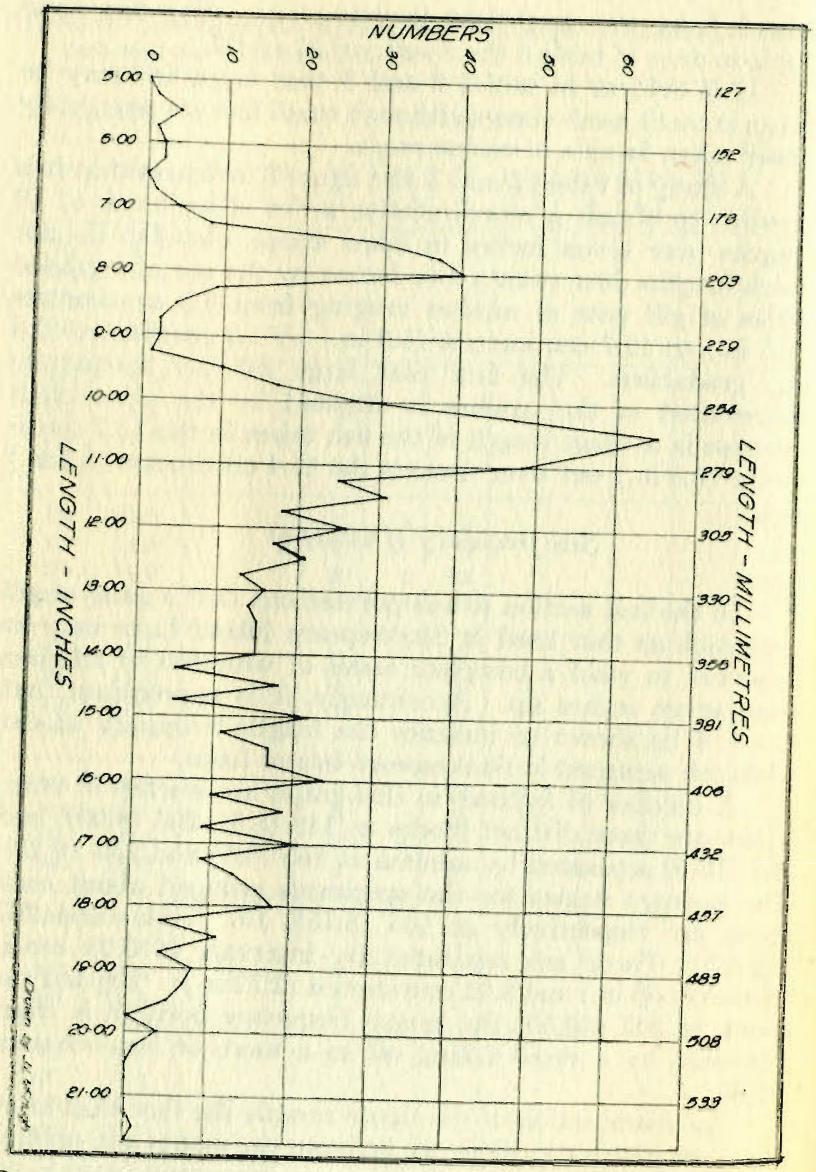


FIGURE 4. Showing the frequency of occurrence of whitefish of each length in Shakespeare Island Lake as sampled



may be explained by the personal error of the investigator in preferring to consider the lengths as being on the even inch or half-inch rather than on the quarter or three-quarter inch. There can be little doubt but that results free from personal error would show a more or less horizontal line between 330 (13.00) and 432 (17.00), gradually falling away from 432 (17.00) on to zero in the neighbourhood of 508 (20.00) or 533 (21.00).

Possibly personal errors such as those mentioned in the last paragraph are responsible for keeping the first and second modes from being closer to the average values for the groups they represent at 146 (5.75) and 197 (7.75) respectively.

The mode at 140 (5.50) is small and so poorly defined that it might be overlooked. However, there is no doubt but that the small catch of fish of lengths approximating 140 millimetres (5.5. in.) is due to the relatively low efficiency of the nets used in capturing fish in this size range. For not only is the size range under consideration below the size taken most efficiently by the finest net used (tables 2 and 3), but fish of this size are more terete in form (figure 2) and in consequence are less liable to capture in gill nets than larger and proportionately deeper fish. It is believed that the fish represented about the mode at 140 (5.50) are a disproportionately small sample of an important class of whitefish in the lake.

In figure 5 is a hypothetical frequency polygon in which is shown the appearance that a length frequency polygon should have had if Shakespeare Island Lake had been investigated by methods free from personal errors and capable of taking perfectly representative samples and if the lake had never been previously fished at all.

The changes from the empirical data were based upon the following considerations: probable error of the individual frequencies, personal errors, the probable low efficiency of our nets in capturing very small whitefish, the larger proportional amount of net used which had maximum efficiencies in capturing fish between the lengths of ten and twelve and one-half inches, the previous removal from the lake of a consider-

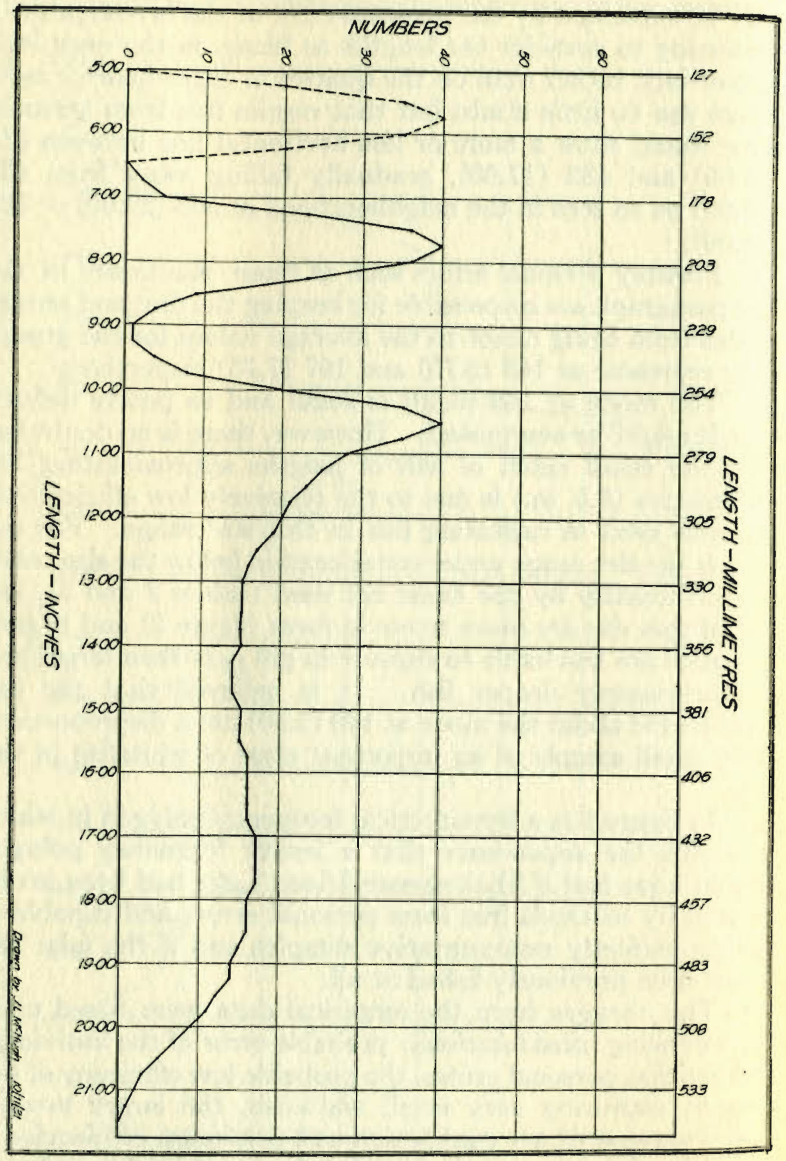


**FIGURE 5.** **Showing the frequency of occurrence of each length of whitefish which might have been expected in Shakespeare Island Lake if there had been no human interference**



able number of whitefish of larger sizes by four and one-half inch commercial nets, and the reduced rate of growth of fish over seventeen inches in length (Hart, 1931) which should, in the absence of any markedly increased mortality, lead to a "piling up" in the numbers of slow-growing fish beyond this length.

In the light of information brought forward in the foregoing discussion and in Hart (1930 and 1931) it is possible to interpret the significance of the three principal modes in the figure. In referring to data in previous papers by Hart, it must be kept in mind that the length used in the former discussion is the standard length of the present paper and may be regarded as approximately ninety-one per cent. of the length.

Hart (1930) records the measurements of a number of current year Shakespeare Island Lake whitefish. These are all definitely below the length range of figure 4, but the rate of growth as indicated by comparing specimens taken at different times suggests the reasonableness of assuming that the fish about the first mode have completed their first year and are in their second. Scale examinations bear out the assumption that all these fish are in their second year and that they are the second-year individuals recorded in Hart (1931). The position of the second mode agrees closely with the average length of third-year fish as published, and it seems reasonable to assume that the fish about this mode are in the third-year class.

The distance between the second and third modes is considerably greater than that between the first and second. Reference to figure 1 and table I in Hart (1931) indicates most strongly that such should not be the case if the second mode were composed of third-year fish and the third one of fourth-year fish. The fact that only one of the one hundred and sixty-five scales read gave a reading which placed it in the fourth-year group strengthens the view that fish in that group were few in number and that the third mode is not dependent on them. Owing to the fact that the third mode occurs at a rather higher point than the average length of the fifth-year group as shown by the scale reading of Hart (1931), it is probable that that mode is composed of a complex of the fifth-year group and one or more contiguous higher ones.

The evidence of both size frequency polygons and scale readings, then, indicates that the fourth-year group of whitefish was lacking in Shakespeare Island Lake in 1925 and more generally that the species may be subject to failures, or near failures, in the production of a year class. This conclusion is of considerable economic interest as well as of biological importance. In Lake Ontario and probably in the other Great Lakes in contrast to conditions in Shakespeare Island Lake (Hart, 1931), the commercial catch is chiefly composed of fish in three- or four-year classes. Accordingly, if in these large lakes, as in Shakespeare Island Lake, the species is subject to failure in the production of a year class, such a failure would lead to significant reductions in the magnitude of the catch. Figure 1 of Hart (1930) shows a number of fluctuations in the catch which cannot be explained on the basis of changes in fishing effort or in economic conditions and must be due to alterations in the actual numbers of the fish caused by biological factors.

### *Falling off in the catch*

The original purpose of the present investigation was to obtain information from which to estimate the total number of fish in the lake. It was hoped that it would be possible to fish the lake so completely that it would be possible from the falling off in the catch to make a reasonable estimate of the amount of fish remaining in it. This has proved impossible. Nevertheless, what information was obtained is presented.

Figure 6 is designed to illustrate the differential falling off in catch in different size classes. In this figure it can be readily seen that there has been no falling off in the group of fish in the second-year class as far as such meagre sampling may be trusted. Any trend with the advance of the season was in the nature of an increase, due no doubt to the growth of the fish and the concomitant increase in their liability to capture in the 3.8 centimetre (1.5 in.) gill net.

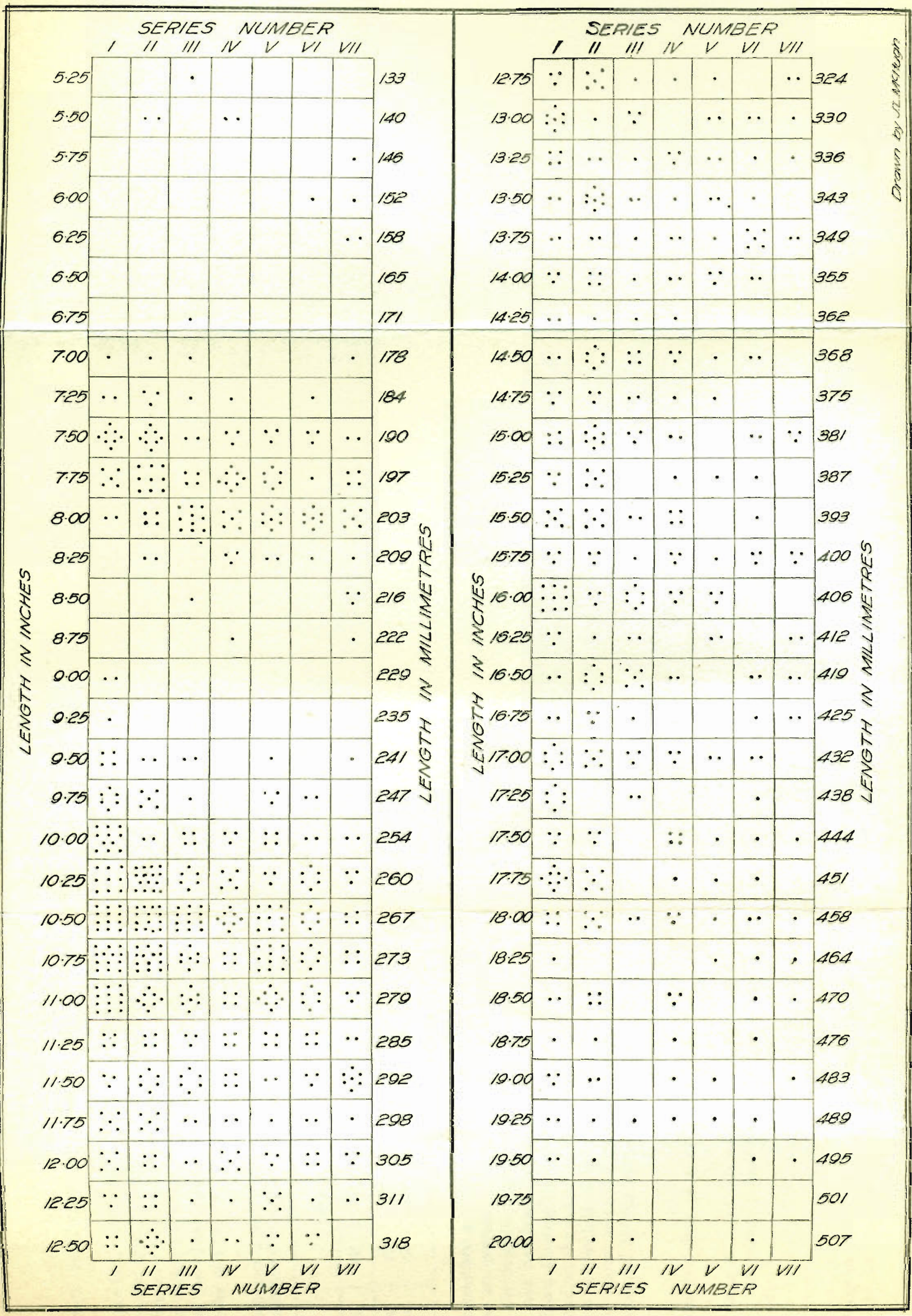


FIGURE 6. Showing the number of whitefish in each series and of each length taken in Shakespeare Island Lake

Less apparent is the fact that the falling off in catch was less rapid in the three-year group than in the whitefish population as a whole. This may be seen in the figure but is made clearer by table 4, in which are presented the percentages, smoothed by threes, of the whole catch and of the three-year class taken in each series of sets.

TABLE 4. Comparing the falling off in catch of Shakespeare Island Lake whitefish in their third year with that of all whitefish in the lake

| | Per cent. | | | | | | |
|---|---|---|---|---|---|---|---|
| Series no... | I | II | III | IV | V | VI | VII |
| III year.... | 17 | 16 | 17 | 14 | 13 | 12 | 12 |
| All........ | 23 | 19 | 16 | 12 | 11 | 10 | 9 |

In figure 7 the smoothed and the unsmoothed data for fish captured per series are plotted. From the graph it might be concluded that in the neighbourhood of half the fish over two years old in the lake had been captured. Owing to the fact that our nets did not thoroughly fish the whole lake and as little is known regarding the extent of the daily migrations of the whitefish, such a conclusion does not appear to be warranted. It would appear that the catch had almost become temporarily stabilized by the influx of fish from other parts of the lake.

*Growth curve for the first three years of life in whitefish*

It is commonly believed that fish experience a period of rapid growth during the summer months and a period of retarded growth during the winter. From the data presented in figure 6 and in Hart (1930) it is possible to deduce strong direct evidence for the occurrence of such a phenomenon in the case of the whitefish.

In figure 8 the lengths have been plotted against the age in months for whitefish in their first three years in Shakes-

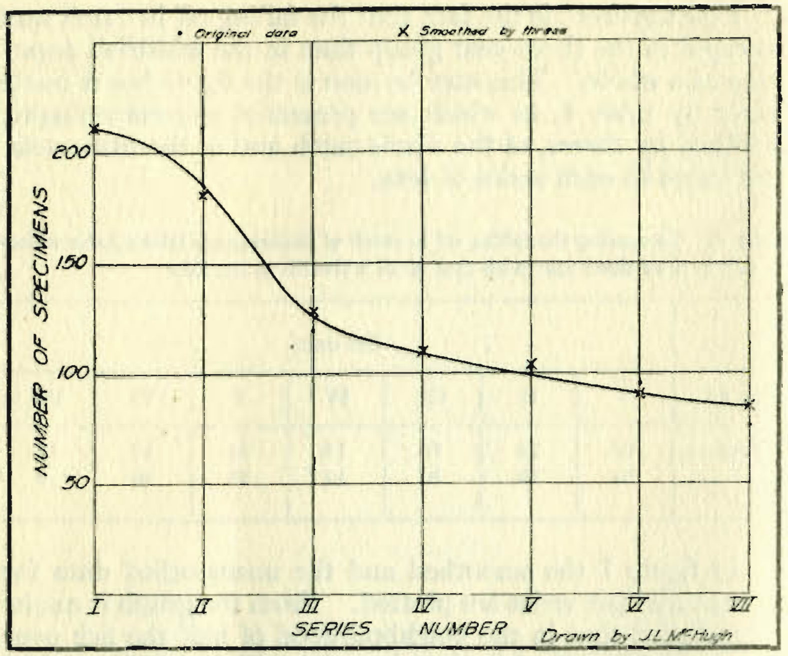


**FIGURE 7.** Showing the falling off in catch of whitefish in Shakespeare Island Lake

peare Island Lake. In doing this it has been assumed that whitefish hatch in that lake about May 1 and are at that time fourteen millimetres in length. To join the ends of the line representing the seasonal growth for each year class, it is necessary to draw a series of successive sigmoid curves. Evidently, then, it is justifiable to conclude that in whitefish there is a period of rapid growth during the summer and a longer period of retarded growth during the winter.

### *Sex ratio*

It proved possible to diagnose the sexes of all the whitefish captured over 27.9 centimetres (11 in.) in length. In many cases sexes were determined for fish under this length. An analysis of the sex ratios is given in table 5.



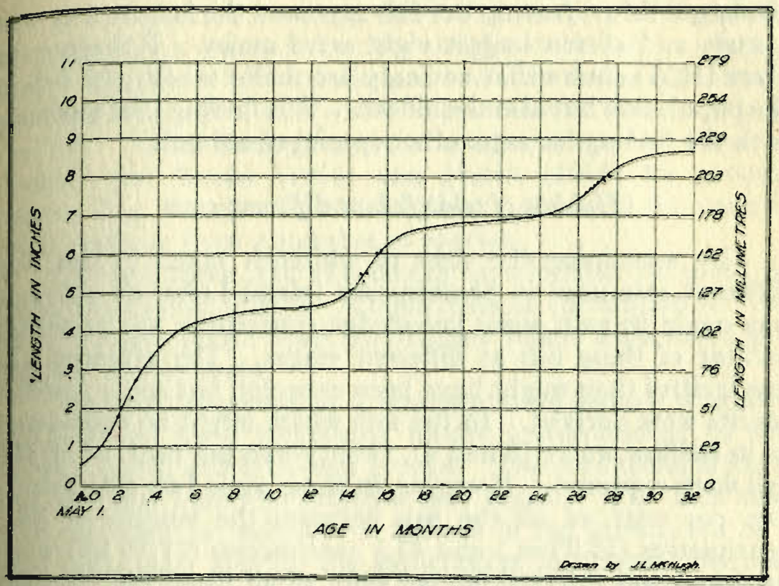


**FIGURE 8.** Showing the rate of growth of whitefish in the first three years in Shakespeare Island Lake

**TABLE 5.** Showing sex ratios in different length classes of whitefish for Shakespeare Island Lake

| | Males | Females | Female to Male Ratio |
|---|---|---|---|
| All determined...... | 429 | 380 | 1 : 1.13 |
| More than 11.00 in. 27.9 cm. | 274 | 234 | 1 : 1.17 |
| More than 17.00 in. 41.2 cm. | 64 | 37 | 1 : 1.73 |

From table 5 it may be deduced that the ovaries and testes in whitefish become superficially distinguishable at approximately the same stage in development. Otherwise the close agreement between the sex ratios of the first and second groups would not be observed.

Males are more numerous than females. This relationship holds for all sizes but is more strongly marked among the larger fish. Among the fish captured the largest fish was a male and of ten largest eight were males. Reference to Hart (1931) shows that not only are males the largest fish in the population but also the oldest. This finding is at variance with the finding for most other species of animals.

### *Habitat of whitefish at different ages*

By examining the sizes of whitefish taken in the five different sets used in Shakespeare Island Lake, an attempt was made to gain some knowledge concerning the preferred habitat of these fish at different stages. The attempt was less fruitful than might have been expected but some positive results were derived. In the sets which might be considered as in shallow water (2 and 4), twenty-two per cent. of all the fish were captured. However, in these same two sets thirty-two per cent. of all the fish between the lengths of 38.7 centimetres (15.25 in.) and 45.1 centimetres (17.75 in.) were captured and thirty-three per cent. of all those with lengths of 45.7 centimetres (18.0 in.) or more. It seems justifiable to conclude, then, that the larger fish show a stronger tendency to enter shallow water than those of medium size. Five of the ten fish in the second-year group were taken in these two sets but the numbers are too small to justify conclusions.

## SUMMARY

Since whitefish were abundant in Shakespeare Island Lake, since the lake was practically unexploited, and since the fish inter-relationships were comparatively simple there, it was an excellent body of water in which to investigate a complete whitefish population under natural conditions.

This was done by systematic netting with a gang of gill nets with various graded meshes between 3.8 centimetres (1.5 in.) stretched mesh and 12.7 centimetres (5.0 in.) stretched mesh. In so doing data were obtained to substantiate the view that representative samples of the whitefish population of the lake over 17.8 centimetres (7 in.) were being taken.



Data obtained from representative samples of the whitefish population showed that the weight increased in proportion to the power 3.3 of the length and that the proportionate size of girth, depth, and width increased with the growth of the fish. These findings are not in agreement with those of Crozier and Hecht (1914) and Hecht (1916) for several species, but do agree with the results obtained by various other authors from a number of species.

Gill net mesh and the length of whitefish captured in them are closely related. Coefficients of correlation of 0.84 and 0.51 were found from Shakespeare Island Lake and Lake Nipigon respectively.

The size frequency of a representative sample of whitefish showed three prominent modes corresponding to the second, third, and fifth-year groups. The conclusion is justified that the four-year group is very small. The fact that whitefish may be subject to failures in the production of a year class may provide the explanation for certain fluctuations in the commercial catch to be observed in the Great Lakes.

The gill nets used in the present experiment tended to "fish out" the larger, older fish more rapidly than those in the three-year group.

The growth of the whitefish in its earlier years is characterized by a series of alternate periods of rapid and slow growth. The period of rapid growth occurs during the summer.

In Shakespeare Island Lake male whitefish are more numerous than females. Males also reach a larger size and greater age.

The largest whitefish in the lake show a tendency to enter less deep water more frequently than those of medium size.

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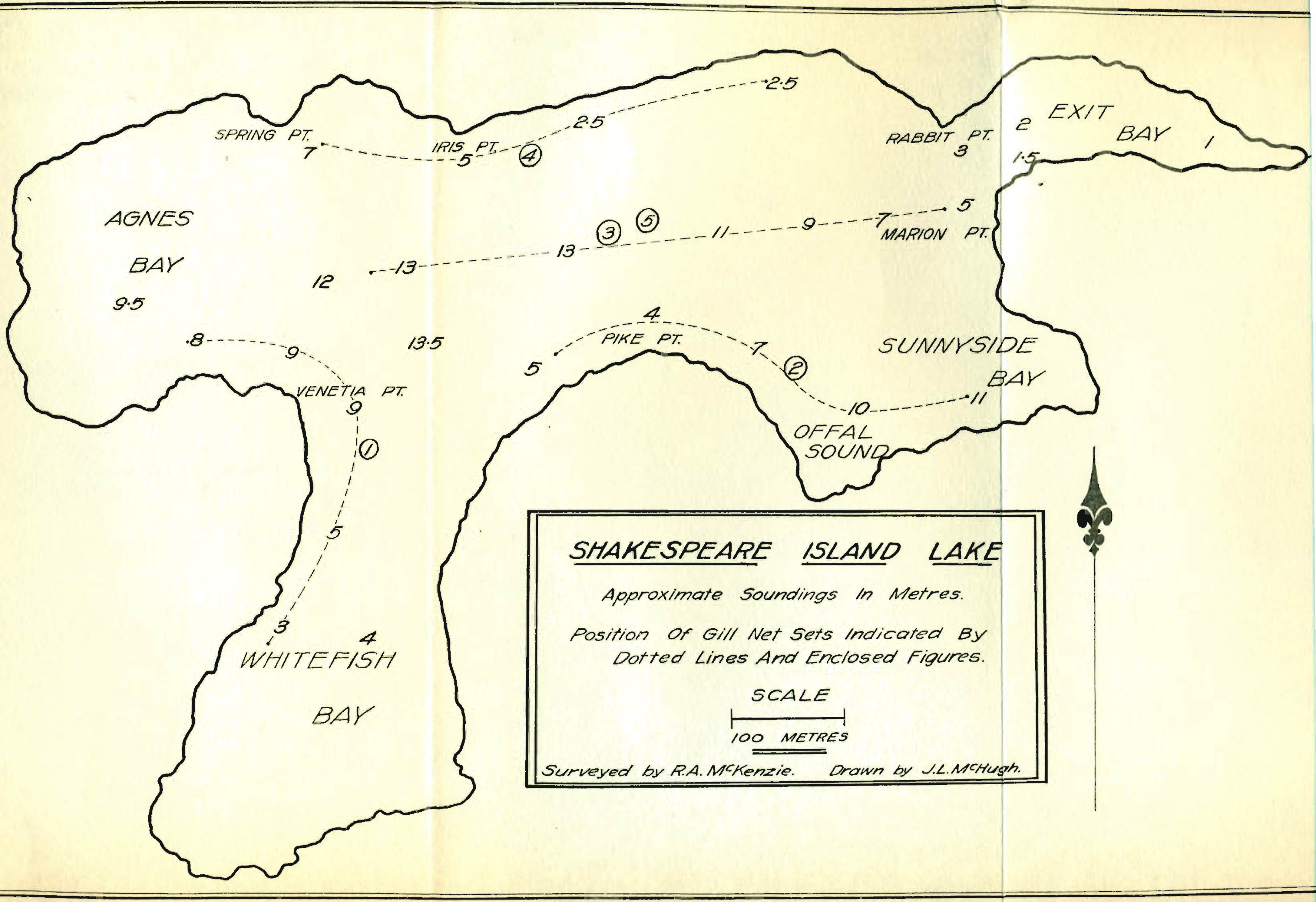


MAP of Shakespeare Island Lake