ASPECTS OF THE BIOLOGY OF THE LAKE WHITEFISH, COREGONUS CLUPEAFORMIS (MITCHILL), IN HOGAN'S POND, AVALON PENINSULA, NEWFOUNDLAND

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by

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Submitted in partial fulfilment of the requirements for the degree of Master of Science, Memorial University of Newfoundland.

August, 1967

This thesis has been examined and approved by

ABSTRACT

Systematic arrangement of lake whitefish was reviewed. Morphological features of the transplanted whitefish population in Hogan's Pond were analysed and compared with the original Lake Erie population. Lake whitefish in Hogan's Pond has a smaller body size, relatively shorter snout, bigger eyes, longer fins, much shorter depth, more numerous gill rakers than Lake Erie whitefish; and has more lateral-line scales than any other population of the same species in North America, being 85.5. Osteology of <u>Coregonus clupeaformis</u> and in relation to that of other salmonid fishes were reviewed.

Samples of whitefish were collected in 1965 and 1966. Age group V and age-group VI were dominat in these collections. The mean age for 258 fish was about 5 years. Fish with length between 271 - 310 mm. (fork length) and weight 201 - 280 grams constitute more than 62 % of the total fish.

The growth rate of young fish was smooth, however, the growth rate of older fish was so poor that a great degree of emaciation was noted. The length-weight relationship for 258 can be expressed by the equation:

$$W = 0.1148\ L^{2.2779} .$$

The average coefficient of condition for 258 fish was 1.072.

The sexes were almost equally represented (53.3 % males). Youngest mature male and female whitefish belonged to age-group II with a length of about 242 mm. (fork length). All fish shorter than 220 mm. were immature, longer than 320 mm. were mature.

Average fecundity of 35 female whitefish examined was 2,954 eggs, with egg diameters ranging from 1.0 to 2.7 mm..

A rare case of hermaphroditism of <u>Coregonus</u> <u>clupeaformis</u> was found in one specimen with ovo-testis on the left gonad.

Foor supply for Hogan's Pond whitefish was found too small for them. The chief food items for these adult fish are Daphinia sp., Cyclops sp., and Amphipoda. Bottom fauna occupy only small proportions of food contents.

CONTENTS

I. INTRODUCTION

The coregonine fish fish has been a particularly interesting subject in taxonomic, evolutionary as well as life history study. Among all, the lake whitefish or common whitefish (Coregonus clupeaformis Mitchill) is the most valuable and largest species, being subjected to widely commercial exploitation in North American and European regions. Lake whitefish, however, is not native to Newfoundland, according to Scott and Crossman (1964); they were first introduced into Newfoundland from Lake Erie in 1886. Originally, 200,000 whitefish ova were gathered in Lake Erie from Lake Erie whitefish (synonym of lake whitefish) and transferred to Newfoundland in the vicinity of St. John's. The ova were hatched out in 21 days and turned out into three ponds as follows:

Murray's Pond	50,000
Hogan's Pond	100,000
South Side Hills Pond	50,000

At the present time, these transferred whitefish are surviving only in Hogan's Pond and its adjacent Mitchell's Pond (Fig. 1). There is a water bridge via a relatively small stream between Hogan's Pond and Mitchell's Pond, this makes migration feasible.

Lake Erie whitefish was previously described as Coregonus albus (LeSueur) by Jordan and Evermann (1909, 1911) and this description was accepted by many authors including Couch (1922). These authors described Coregonus clupeaformis as the lake whitefish of all Great Lakes except Lake Erie and claimed that Lake Erie whitefish was very similar to other Great Lakes whitefish, differing only in form and colour; having smaller head, higher nape, more angular form, color was almost pure olive-white, without dark shades or dark stripes along the back, flesh was softer and containing more fat. Koelz (1927) distinguished Lake Erie whitefish as having proportionally deeper bodies, fewer lateral-line scales and probably fewer fin rays. In addition, it was claimed that fry and eggs of these two races could be readily separated (Jordan and Evermann, 1911). Eggs of Lake Erie whitefish were smaller and lighter coloured, fry of the other Great Lakes whitefish were livelier and marked by two dark lines on the sides, whereas, that of Lake Erie whitefish were plainly silvery. It has been known by fishermen and anglers in Great Lakes regions that lake whitefish in Great Lakes, except Lake Erie, takes the hook readily, while Lake Erie whitefish is not known to take the hook.

All the above morphological and habitat difference may be correlated with the great differences in environmental condition between Lake Erie and other Great Lakes. Lake Erie is shallower and its southern shore is fed by warm, muddy or milky coloured river (Jordan and Evermann, 1911; Koelz, 1927). Svardson (1951) states that most of the characters employed in coregonine systematics such as head size, lateral-line scales, rate of growth, maximum size, eye size etc. were experimentally modifiable by temperature, salinity, amount of food and undefined factors of the particular body of water. Body color of lake whitefish seems also to be modified greatly by water property. The whitefish in Hogan's Pond appears to be similar in color to those of Great Lakes except Lake Erie, being with dark shades along the back, blackish fins. The water of Hogan's Pond is clear and very transparent. In addition, Jordan and Evermann (1911) report that the Manitoba whitefish (Coregonus clupeaformis) in Lake Winnipeg appears to have two types of body color. Those from dark or musky water are usually darker, with dark streaks above, and blackish fins. Those from the milky water of the same lake are all very pale, as pale as the whitefish in Lake Erie. As the water of Lake Erie is similarly milky, discolored by muddy clay-bottom stream, it is doubtful that this feature of coloration is really a specific character.

Although Lake Erie whitefish is not known to take anglers' hook, Hogan's Pond whitefish, as Scott and Crossman (1964) point out, is occasionally taken by fly fishing. Kendall (1902) reports that the whitefish in certain Maine waters which, as Jordan and Evermann (1909) and Bean (1899) describe, is identical to Coregonus clupeaformis and also take bait readily. It is therefore safe to conclude that such a behaviour as taking hook or not does not warrant a specific difference of two races.

Jordan and Evermann (1911) regarded that probably Coregonus albus is merely an " ontogenetic species, its peculiarities being due to the condition of food and water in Lake Erie ". The name, Coregonus clupeaformis, have therefore been applied to all lake whitefish or common whitefish in Great Lakes, included Lake Erie, ever since Koelz (1927).

Systematic studies of lake whitefish in Hogan's Pond show that the race differs greatly from Lake Erie race in certain characters; being with much smaller maximum size (less than 400 grams or 0.9 pound in body weight), much slender body contour, proportionally shorter snout, shorter maxilla, larger eyes, more lateral-line scales, more gill rakers and probably more pectoral fin rays.

The study which follows deals for the most part with life history study. It shows a slow growth rate and a great degree of emaciation among the larger fish, while the young fish grow smoothly both in length and weight. The fish tend to develop a slender form with increase in length and age. Data on reproduction show that Hogan's Pond whitefish reach sexual maturity at much smaller size and as early as the third year of life, which is similar to that of the Lake Erie race, while quite different from some other localities. Qualitative and quantitative analysis of stomach contents show that this fish has some feeding habits similar to rainbow trout which also occur in Hogan's Pond. They feed on bottom invertebrates; such as insect larvae, as well as on pelagic forms of minute animals mostly plantonic crustaceans.

Since the aim of this study is placed upon examining the results of whitefish transplantation, comparison on morphological features, growth condition, fecundity and some other aspects between Hogan's Pond population and Lake Erie population were made whenever the data were available.

Certain achievement on the osteology of lake whitefish in Hogan's Pond and its role in the position of classification is also made, but because time did not permit for fuller investigation in all aspects of this topic, this osteological section must in some respects go imcomplete.

Hermaphroditism of whitefish has never been reported nor mentioned. One of the Hogan's Pond whitefish was found having an ovo-testis. This fish, 28.6 cm. in fork length, weight 225 grams, is apparently a male fish with a normal right testis and a abnormal left ovo-testis. Histological examination shows both ovarian and testis portions are functionally and pecularily developed.

II. ACKNOWLEDGMENTS

I would like to acknowledge gratefully my debt to Dr. C. W. Andrews, Professor of Biology, Memorial University of Newfoundland, for his thoughtful guidance and patient supervision during the period of present study. Thanks also due to the Murray's Pond Fishing Club, for its financial support during 1966 summer period; and to Mr. J. A. MacNab, Dr. D. Baird, Mr. David Baird for using their private boats in obtaining fish samples and doing field works; and to Mr. R. J. Wiseman, Mr. G. Barbour for their assistances during the sampling period.

Cordial thanks are also due to Dr. F. A. Aldrich, Professor and Head (Pro temp) of Department of Biology, Director of Biological Station, Memorial University of Newfoundland, for his encouragement and great help; and to Dr. T. McKenney, Assistant Professor, Department of Biology, Memorial University of Newfoundland, for his personal advice.

I am grateful to Memorial University of Newfoundland for a fellowship granted for academic years 1965-1967.

III. MATERIALS AND METHODS

A. Sampling method.

All of the fish, which comprise the samples of 258, were taken by using a gang of nylon gill nets composed of three or four nets with stretched mesh size one and half inches and two inches, and were allowed to fish overnight in the water, each net is fifty yards in length and six feet in depth. On several occassions a gill net of three inches mesh size was employed, but resulted in total catch failure in this net. regardless of localities, the nets were set throughout the whole pond during fishing period from June to October, 1965; and from July to December, 1966.

The gang was set, sometime, with one end of 1 1/2 " net ties to the shore and extended to the center of the pond at the other end of 2 " net, the net was set in water of about six to seven feet in depth. This resulted in catching a larger proportion of bigger and older fish. On the other hand, sometimes, the gill nets were tied with buoy at the surface and with rocks at the bottom end, the gill nets were set far away from shore in water ranging from 15 to 20 feet in depth or reaching the bottom. Most of the fish younger than age 4 (in their fourth summer life) and smaller than 250 mm. fork length were caught by this type of set-up. The largest catch in a single day throughout the sampling period was less than twenty whitefish. The only other type of fish taken were a considerable number of rainbow trout (Salmo gairdneri). In addition, there were also evidences that eels are also present in this pond, they frequently devoured the bodies of whitefish and rainbow trout caught by gill nets.

B. Measurements and counts

All specimens collected were examined or re-examined in the laboratory and all parts selected for measurement were measured and counted on the left side whenever possible. Length, weight and body parts measurements, and sex determination were done soon after fish were brought back from field without any preservation procedure. Gonads and digestive tracts (esophagus, stomach and intestine) as well as scales from various portion of left body side were also taken either at the same time while doing measurements or in a later period.

i. Length, weight measurements:

Three measurements of length were made with the aid of wooden rule gauged in millimeters. The fish were slightly pressed in order to keep the body as nearly the normal status as possible.

a) Fork length (F.L.) were used in most growth rate study, representing the length from the tip of snout (the junction of the premaxillaries) to the forked point of caudal fin.

b) Standard length (S.L.) were employed in systematic analysis as well as in comparison with data from other authors who used S.L. in their studies, representing the length from the tip of snout to the base of caudal fin, or the last scale row on caudal peduncle.

c) Total length (T.L.) were measured from the tip of snout to the end of longest caudal fin ray.

Body weight was measured by a spring balance to the nearest 0.1 gram, representing the whole weight of fish.

ii. Body parts measurements:

All measurements were made with calipers, dividers and ruler. The method of making the measurements, the actual points from which measurements were made was based on Koelz (1927). The symbols by which the measurements are designated in Table 2 are described below:

Head (H)--Measured from the tip of snout to the external margin of the opercle, not including the opercular membrane.

Snout (S)--Measured from the tip of snout to the anterior body margin of the orbit. The dividers were used in this measurement by inserting into the eye socket.

Eye diameter (E)--The horizontal diameter of the eye ball.

Maxillary (M)--Measured from the junction of the premaxillaries to the caudal end of the maxillary bone.

Depth (D)--Vertical distance through the body at its deepest part, measured with calipers.

Width (W)--Distance through the body at the widest part.

Pectoral-pelvic distance (PV)--The distance between the anterior ends of the insertions of the pectoral and pelvic fins.

Pelvic-anal distance (AV)--Distance from the insertion of pelvic fin to the origin of the anal fin.

Fin length--Measured from the origin of the fin to the tip of its longest ray. Pectoral fin length (P), pelvic fin length(V), and anal fin length (A) dorsal fin length (D).

Fin bases (DB, AB)--The lengths of the base of dorsal and anal fins.

Snout to dorsal (SD)--From the tip of the snout to the base of first dorsal fin rays (small spiny ray).

Snout to anal (SA)--From the tip of snout to the base of first anal fin ray.

Dorsal to adipose (DA)--Measured from the anterior end of the base of the dorsal fin to the anterior end of the base of the adipose.

Adipose to caudal (AT)--Measured from the anterior end of the adipose base to the first of the upper procurrent caudal rays.

iii. Meristic counts:

Except gill rakers and branchiostegal rays which were counted on both sides, all the other counts were made on the left side.

a) Gill rakers--Counted on the first gill arch of both left and right sides. Special care was taken in removing the gill arches, no rakers were lost at the end. With the aid of dissecting microscope every visible raker was included in the counts.

b) Scales on lateral line--All those scales locating on lateral line and with pore were counted. Hand lens was used in identifying perforated scales at the caudal end of the line. When scales had been lost accidentally from the lateral line, however, the scale pockets were counted.

c) Fin rays--In the dorsal and anal fins, the first one, two or three unbranched rays are poorly developed. Only when their lengths approached three quarters of that of the longest ray were they included in the counts. Every ray in the paired fins was counted.

d) Vertebrae--The flesh was removed by either boiling or cutting off. Every vertebra between basioccipital of skull and cartilagenous urostyle (but not includes) was counted.

C. Age determination

For age determination, scales from various regions were taken with forceps and impressed between two slides and annuli were read under projector at magnification x 43. Age, as determined and recorded, represents the total number of years of life. An age 4 reading for instance, indicates that the fish had completed three years of life (therefore having 3 annuli on scale) and is now into its fourth. For the purpose of scale-length relationship and back calculation, scales from key area; that is the fourth or fifth row of scale above lateral line and right below the dorsal fin base, were used.

D. Sexes determination

Sexes of fish were determined by gross examination, since all the gonads of these specimens were visibly differentiated. Ovaries to be used for fecundity studies were taken and preserved in 5 % formalin.

E. Osteology

For the purpose of osteological studies, Dawson's method for bone staining were employed on caudal skeletons and branchial arches. Skin was removed and muscles were cleaned to a certain extent without losing or damaging any bone; preserved in 95 % alcohol; immersed in 1 % KOH; stained with Alizarin red S; immersed in Mall's solution*; preserved in pure glycerin (Dawson, 1926).

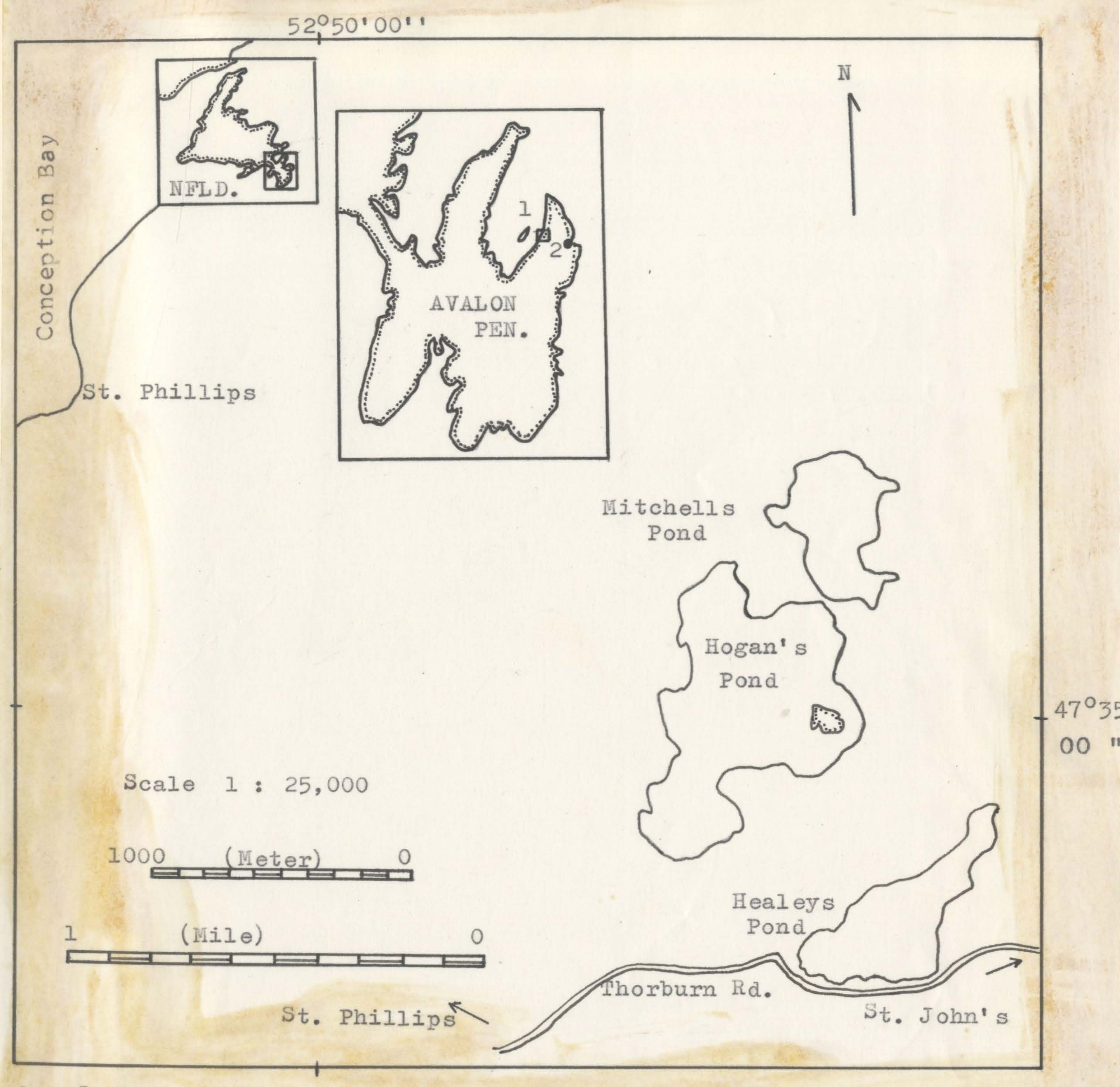
* Mall's solution: H_2O 79 %; Glycerin 20 %; KOH 1 %.

The materials and methods concerning the hermaphroditism of whitefish in Hogan's Pond are present in the corresponding section.

IV. GENERAL FEATURES OF HOGAN'S POND

Hogan's Pond situated at 47° 35' N., 52° 52' 15" W., eight miles northwest of St. John's, Newfoundland. It lies at an elevation of 470 feet (146 meters), its greatest length from south to north is about 4,300 feet (1,310 meters), its greatest width 2,500 feet (760 meters). The total area of the lake, exclusive of a small island located at its eastern shore, is about 0.23 square mile (0.58 square km.) or 147.2 acres; its shore line, including that of the small island, measures 3.15 miles (5.07 kilometers). The southern portion of the pond is much smaller in area than the northern portion (Fig. 1).

The shores are nearly everywhere a mass of rock which extend from the bank to about 30 feet (9.2 m.) away from the shore line. The water deepens gradually over the rocky shore from 4 to 6 feet (1.2 to 1.8 m.), the bottom then drop rapidly. The deepest water in the southern portion is about 25 to 30 feet (7.6 to 9.2 m.), while that of the bigger northern portion is about 35 feet (10.7). The morphometric features of the pond were studied during 1966 summer. Echo-sounding apparatus was employed in this survey. The results of this survey based on 140 soundings are shown in Fig. 2 and Table 1.



1 --Conception Bay.

2 --St. John's.

Figure 1 ---Map of Hogan's Pond, Avalon Peninsula, Newfoundland (NFLD).

Table 1 ---Morphometry of Hogan's Pond, St. John's, Newfoundland.

Maximum depth	35 feet (10.7 m.)
Maximum length	4,300 feet (1,311 m.)
Maximum width	2,500 feet (762 m.)
Perimeter	3.15 miles (5.07 km.)
Area	0.2256 sq. miles (0.5843 sq. km.) or 147.2 acres
Approximate elevation	470 feet (146 m.)

The water of this pond is clear and very transparent, one can see fairly well the rocky and muddy bottom in water of about 10 to 15 feet of depth. There is almost no vegetation in this pond.

The water temperature at surface differs only 1.5° C to 2.0° C from that at bottom, being 18.9° C at surface and 17.3° C at bottom of 36 feet deep (July 29, 1960; Scott and Crossman, 1964) and being 17.8° C at surface and 15.6° C at bottom of about 25 to 30 feet deep on August 11, 1966. The surface temperature droped to 11.1° C on October 4, 1966; 10.0° C on October 24, 1966. During the winter period, from January to late April or even to mid-May, Hogan's Pond is completely frozen at the surface, the ice do not start melting until May.

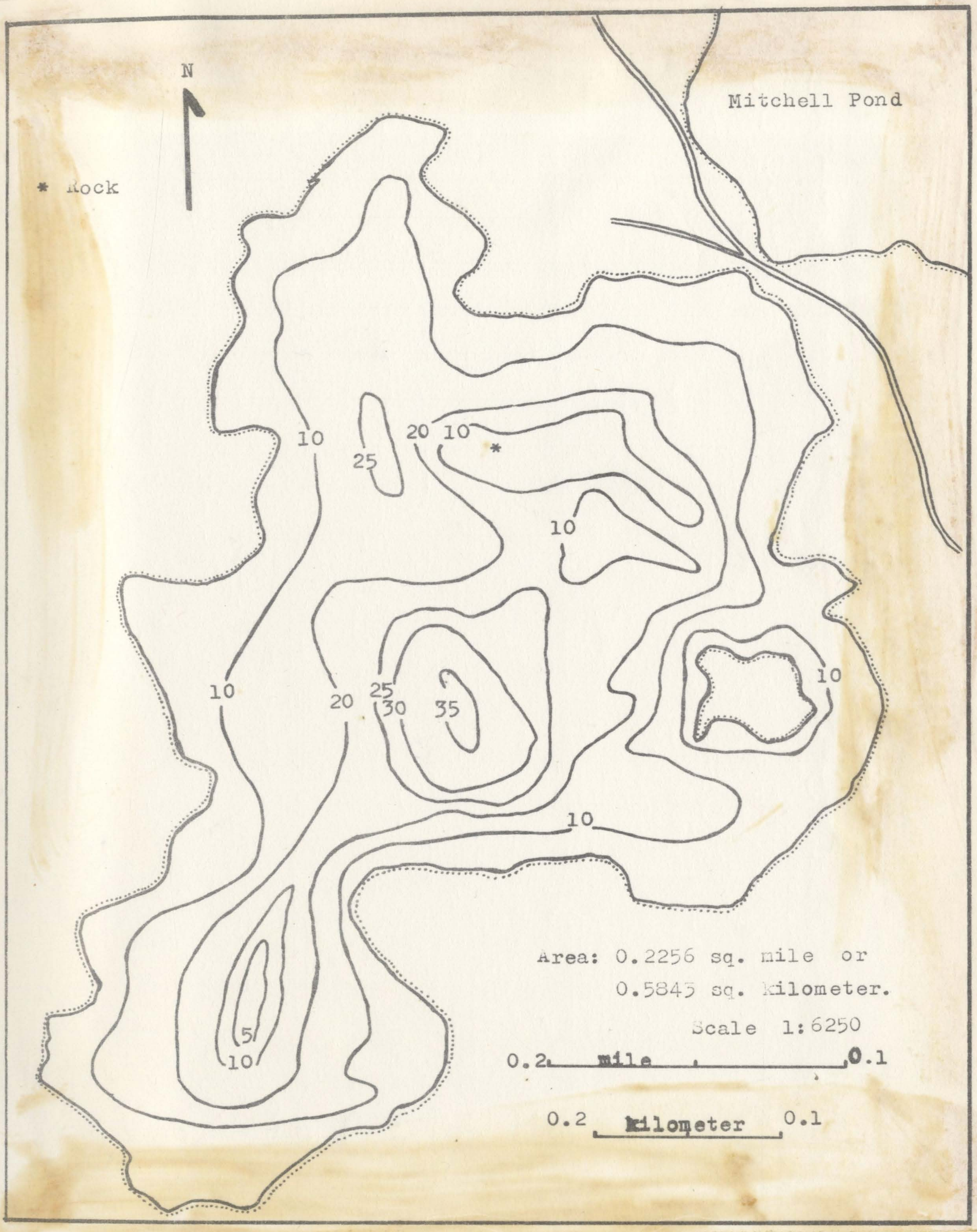


Fig. 2 ---Map of Hogan's Pond. Depth contours in feet.

V. DESCRIPTIONS AND TAXONOMIC CHARACTERS OF LAKE WHITEFISH IN HOGAN'S POND

A. Systematic position.

Any one who studies the Coregonid fishes will be confronted with variably confusing opinions among systematists as to the systematic arrangement of these fishes.

Cope (1872) considered the Coregonids as a family rank on the basis of difference of parietal structure. He proposed the Family Coregonidae for those fish of the group with united parietal (see Fig. 10) and retained Salmonidae for those with parietal separated by supraoccipital. While other ichthyologists, including Jordan and Evermann (1909, 1911), Regan (1908, 1914) and most Europen workers, considered Coregonid fishes as a subfamily rank of Family Salmonidae. In the mid-twentieth century, most American workers, including Koelz (1927), Hubbs and Lagler (1957), Bigelow (1963) and many others had accepted the Family Coregonidae in agreement with Cope's opinion. Norden (1961), on the other hand, claims that the Coregonids should be retained as Subfamily Coregoninae on the basis of his comparative osteology studies of Salmonid fishes. He claims that these two groups of fish possess a number of characters in common. These characters include the pattern of variation in caudal skeletons; 3 upturned caudal vertebrae; the similarity of the otoliths and the chromosomal number (Svärdson, 1945) and some other osteological characters which warrant to support the hypothesis that Salmonidae are composed of three interrelated groups (subfamilies), namely, Coregoninae, Salmoninae, and Thymalline.

In the present study I follow Norden's (1961) systematic arrangement. The lake whitefish is therefore classified as follow

Class Pisces

Order Isospondyli (Clupeiformes)

Family Salmonidae

Subfamily Coregoninae

Genus Coregonus

clupeaformis

Etymologically, coregonus means roundish and angular pupil (Koelz, 1927); clupeaformis simply means herring-like fish (Jordan and Evermann, 1911).

B. Synonym and common names.

<u>Coregonus clupeaformis</u> vary considerably among populations in their morphological characters which are subjected to a great deal of modifications by environmental factors, resulting in overlapping of taxonomic features between populations or races. Consequently, a variety of descriptions and taxonomic nomenclature have been applied to this species in various localities, these are

1. <u>Salmo clupeaformis</u> Mitchill, 1818* Lake Huron
2. <u>Salmo otsego</u> Clinton, 1822
   Otsego Lake
3. <u>Coregonus labradoricus</u> Richardson, 1836
   Labrador
4. <u>Coregonus sapidissimus</u> Agassize, 1850

* References cited in "Synonym and common names" appear in Koelz (1927)

		Lake Superior
5.	*Coregonus latior*	Agassize, 1850
		Lake Superior
6.	*Coregonus neo-Hantoniensis*	Prescott, 1851
		Lake Winnepesaukee.
7.	*Coregonus nelsoni*	Bean, 1884 Alaska
8.	*Coregonus clupeiformis*	Evermann and Smith, 1896
		Great Lakes
9.	*Coregonus albus*	Jordan and Evermann, 1911
		Lake Erie
10.	*Coregonus clupeaformis*	Jordan and Evermann, 1911
		Great Lakes

Koelz (1931) recognizes several subspecies of *Coregonus clupeaformis* in the Great Lakes areas. These are listed below:

1. *Coregonus clupeaformis clupeaformis* Mitchill --Great Lakes whitefish. In all Great Lakes except Lake Erie.
2. *Coregonus clupeaformis latus* Koelz --Erie whitefish. In Lake Erie.
3. *Coregonus clupeaformis neohantoniensis* Prescott -- Inalnd lake whitefish. Inalnd lakes from Athabasca to New Brunswick.
4. *Coregonus clupeaformis medorae* Koelz --Medora Lake whitefish. Known only from Medora Lake in Keweenaw County, Michigan.
5. *Coregonus clupeaformis dustini* Koelz --Lake Desor whitefish. In Lake Desor on Isle Royale and Trout Lake in Missisippi River.

6. Coregonus clupeaformis gulliveri Koelz --Gulliver Lake whitefish. Gulliver Lake is in the Lake Michigan drainage of the Upper Peninsula of Michigan.

Common names:

A variety of common names had been ascribed for Coregonus clupeaformis throughout its range in North America. Common names of coregonid fishes are more often used in scientific works than are the taxonomic names in European water, particularly in Sweden and Norway. This is due to, as Svärdson (1950) states, ".... the scientific names of various whitefish species so far are most uncertain, due to the multitude of unstable descriptions and names of populations, the status of which is mainly unknown".

In Great Lakes region, Coregonus clupeaformis is usually called lake whitefish, common whitefish, Lake Erie whitefish, Lake Superior whitefish. Else where in its geographical range, some of the other names includs Labrador whitefish, Sault whitefish Manitoba whitefish, Musquaw River whitefish, whitefish of Lake Winnepesaukee, Shad of Lake Champlain and humpback whitefish (Jordan and Evermann, 1911).

C. Distribution.

The main habitat of the whitefish is cold and oligotrophic lakes, situated below the highest altitudes (Fig. 3). Coregonus clupeaformis ranges widely in North America from New England to Ungava Bay, include Labrador Peninsula, and From the Great Lakes northward to both sides of Hudson Bay; found also in the Arctic Coast of Canada, especially in Great Slave Lake and Great Bear Lake. Introduced in lakes from Montana to southern British Columbia (Hubbs and Lagler, 1957). It is present in fresh and brackish waters in the north, but restricted to lakes or ponds in the south.

Similar form is also well known in the Meckenzie District, Yukon Territory and Alaska (Wynne-Edward, 1952). Walters (1955) reports that Coregonus clupeaformis is not found in Alaska, but he further points out that the Coregonus lavaretus (Pidschian) of Alaska is almost identical in appearance to Coregonus clupeaformis of Western Arctic Canada.

In Eurasian regions, Coregonid fishes range in the north from Kamchatka Peninsula of Russia, west to Germany and part of France. They are also found in England, Ireland. Tremendous studies of whitefish species have been carried out in Scandinavian waters. It is not known whether there is Coregonus clupeaformis in Eurasian waters or not. Some authors suggest that Coregonus clupeaformis may be conspecific with Coregonus lavaretus (Linnaeus) of Eurasia (Hubbs and Lagler, 1957).

D. Natural habits.

Lake whitefish is a rather sluggish fish, found mostly in lakes, but some of the populations are confined throughout their lives to freshwater streams. In far-northern localities it is also found in brackish waters. This whitefish prefer cold and deeper part of the lakes, moving into shallower water earl in the summer. In mid-summer seeking again the cooler depths. In the fall and winter months whitefish come inshore to spawn, some of them entering streams for spawning purpose (Lawler,1965). In the lakes early in the evening, the lake whitefish often appears at the surface to feed on insects (Kendall, 1902), but it rarely, if ever, leaps from the water.

Lake whitefish feeds to a larger extent on bottom organisms, including Crustacean, Mollusca, aquatic insect larvae and various kinds of Entomostraca; also on Zooplankton and occasionally on small fishes (Lagler, 1952); probably it feeds on almost any kind of minute animals.

Throughout most of its ranges of distribution, the lake whitefish spawn in November and December with the females scattering their eggs over rocky or sandy shoal and in crevices of stones. During spawning season the male fish which have definite breeding colors and nuptial tubercles or pearl organs, usually arrive first and last leave the spawning ground (Hart, 1931). Their eggs remain on spawning ground and do not hatch until the next April (Hart, 1931; LaGorce, 1939). Newly hatched whitefish larvae float to the surface over the spawning ground, a few days later they make their ways to shoal. Upond reaching one inch or more in body length they sink down in deeper water. Young whitefish of an inch or two long usually feed on small Crustacean (Forbes, 1882; LaGorce, 1939).

Females lay 10,000 to 75,000 or more eggs, depending largely on size (Lagler, 1952). The female whitefish in Hogan's Pond, owing to a much smaller size, lay only about 4,000 ripe eggs. The rate of growth, which depends largely on food and water condition, is generally quite rapid. A fish of 2 pounds in body weight is usually reached in 4 or 5 years. Whereas the growth condition of whitefish in Hogan's Pond is rather curtailed and slow, a fish of age 8 or 9 never reaches one pound in its body weight.

Male whitefish reach maturity (first spawning experience) at an age younger than females, and are ordinary three or four years old. In some localities first spawning experience is not achieved until the fish reached its 9 or 10 years of life.

Whitefish are so fragile that even a just caught fish will die **within** few minutes after being released from net. Mellen (1923) also reported that whitefish reared in aquarium are sometimes killed merely by transference from one tank to another, or by an accidental stroke of the brush when their tank is being cleaned.

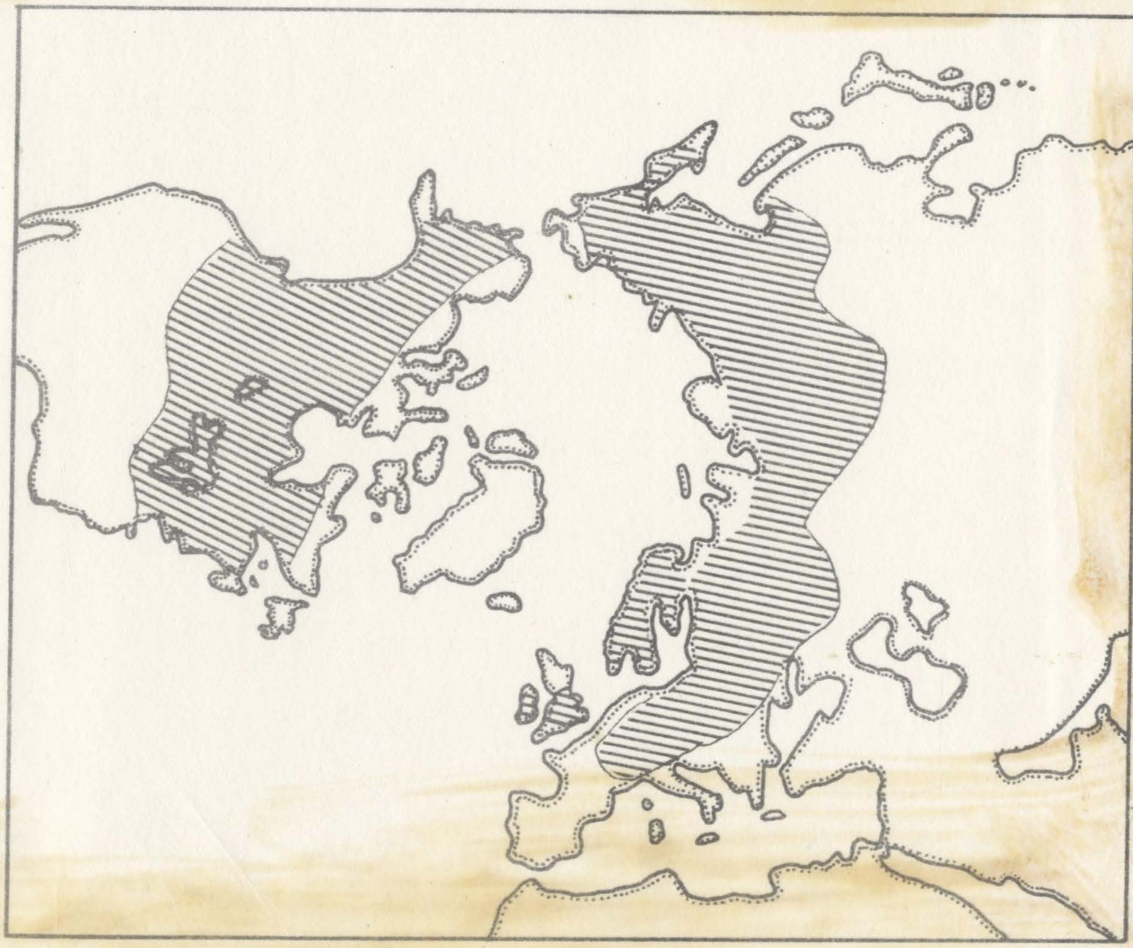


Fig. 3 ---Map of the boreal region, showing approximately the known distribution of the Coregonids (Modified after Koelz, 1927).

E. External descriptions of adult fish.

The whitefish of Hogan's Pond (Fig. 4) bears a compressed elliptical body form and is moderate in size, seldom longer than 350 mm. in standard length or 380 mm. in fork length, with a maximum body weight of about 370 grams or 0.8 pound. Its greatest depth is just in front of the dorsal fin, and usually comprises 21.7 to 24.0 percent of the standard length. Its width about 2.3 or 43.5 % of its depth. Dorsal profile of some specimens is often strongly arched from the beginning of the scales to the insertion of dorsal fin, sloping generally to caudal peduncle, but in most of the fish the predorsal contour line is quite smooth. All the whitefish in Hogan's Pond are by no means humpback at the nape, instead, they possess bow back predorsal contours. The ventral contour line descends in a gentle curve from the tip of mandibular bone to the pelvic fin and then rise gentle to the caudal peduncle. The length of caudal peduncle, measured from the anterior end of the base of the adipose to the first caudal fin ray (Koelz, 1927), is much longer than the depth of the peduncle.

Head small, conic in shape, nearly square at the tip of snout and is contained 4.9 (4.7-5.2) times in the length (standard length) of the fish. The snout, more or less projecting beyond the lower jaw, is contained 4.11 times in the length of head. Mouth small, teeth on lingual plate only. Maxilla is usually pigmented and reaching the anterior edge of eye, 3.6 times in the head when measured from the tip of snout. The premaxillae are wider (dorsal-ventral dimension) than longer, and are retrorse in position, that is, extending downward and backward, making the mouth inferior. The eye is contained 3.5 to 4.6 times in the head. There are two flesh flaps between the nostrils. The pupil is roundish, with usually a conspicuous angle.

The gill rakers on the first branchial arch are average 28.29, ranging from 25 to 32. The scales on the lateral line range from 76 to 94, and average 85.5. The lateral line is almost straight, scales are moderately large. All the fins are blackish, but in some larger fish, mostly male fish, the insertion ends of pectoral and pelvic fins are somewhat reddish.

Origin of dorsal fin about midway between snout and the base of caudal fin, moderate in height, its height is 1.6 times longer than its base, its base 9.0 in body length (S.L.). Adipose fin moderate in size. Pectoral and pelvic fins almost equal in length. Anal fin low, its height is 1.2 times longer than its base and its base is almost similar to dorsal fin base in length. Caudal fin moderate in length, deeply forked. A pelvic axillary process at the insertion end of each pelvic fin.

Body color is pale below and darker above, with dark shade or dark stripes along the back.

The differences of morphological features of lake white-fish between Hogan's Pond and Lake Erie are extremely great, particularly in body size, form and color. The body size of Hogan's Pond race is much smaller, a fish in its seventh or eight summer life usually has a length less than 350 mm. (S.L.) and weight less than 370 grams or 0.8 pound. Whereas a fish of same age in Lake Erie would weight average 3.5 pounds or 1,550 grams and longer than 450 mm. (Van Oosten and Hile, 1947). As it has just mentioned that Lake Erie whitefish differs from that in other Great Lakes only in color and body form, being paler in color and deeper in body . While the present study reveals that Hogan's Pond race no longer bears such characteristics as in Lake Erie race, the body color and body form are, on the other hand, quite similar to those of other Great Lake Races, being darker, with dark strips and narrower proportionally in body depth. This clearly confirms that certain morphological characters which are environmentally modifiable, do not sufficiently warrant specific differences when two populations are compared under different environmental factors.

Fig. 4 ---Lake whitefish (<u>Coregonus</u> <u>clupeaformis</u> Mitchill) of Hogan's Pond, Avalon Peninsula, Newfoundland.

F. Taxonomic characters.

The taxonomy of Coregonid fishes has been very confusing, particularly that of lake whitefish. Most of the morphological characters are too variable to permit the construction of a satisfactory key for their identification. Svärdson (1949) states that there are two kinds of variations involved in the speciation problem of whitefish, that is, the whitefish may vary morphologically according to the modificational effect of such different physical factors in the water as temperature, salinity; and the meristic characters may also vary according to the principal of allometric growth. Vladykov (1935) claims that space factor may also play an important role in taxonomic features, either body proportions, body size or meristic characters.

The principal taxonomic characters of adult Coregonus clupeaformis in Hogan's Pond, Lake Erie and Lake Michigan are numerically compared below, the environmental modification on these characters is clearly revealed.

i. Body proportions.

Detailed measurements were made on 118 or 30 lake whitefish taken from Hogan's Pond. Data on body proportions from Lake Erie and Lake Michigan races were based on Koelz (1927). The criteria of measurements are, therefore, based on that of Koelz's, and are listed in section III "MATERIAL AND METHODS". Standard lengths were used in this study.

Table 2 ---Body proportions of lake whitefish(*Coregonus clupeaformis*) from Hogan's Pond, Lake Erie, and Lake Michigan.

Item	Locality	Average	Range	%	No. of fish
L/H					
	Hogan's Pond	4.92	4.70-5.16	20.33	118
	Lake Erie	4.87	4.70-5.00	20.53	18
	Lake Michigan	4.66	4.50-4.80	21.46	124
H/S					
	Hogan's Pond	4.11	3.98-4.24	24.33	118
	Lake Erie	3.72	3.40-3.80	26.88	18
	Lake Michigan	3.79	3.40-3.80	26.38	124
H/E					
	Hogan's Pond	4.22	3.9-4.2	23.70	118
	Lake Erie	4.79	4.8-5.0	20.87	18
	Lake Michigan	4.43	4.6-5.0	22.57	124
H/M					
	Hogan's Pond	3.55	3.4-3.7	28.17	118
	Lake Erie	3.34	3.1-3.3	29.94	18
	Lake Michigan	3.42	3.2-3.3	29.24	124
L/D					
	Hogan's Pond	4.32	4.3-4.4	23.15	118
	Lake Erie	3.45	3.3-3.6	29.00	18
	Lake Michigan	3.92	3.9-4.2	25.51	124
PV/P					
	Hogan's Pond	1.66	1.4-2.0	60.24	118
	Lake Erie	1.88	1.6-2.0	53.19	17
	Lake Michigan	1.85	1.5-2.3	54.05	121

Table 2 (Continued)

Item	Locality	Average	Range	%	No. of fish
AV/V					
	Hogan's Pond	1.50	1.3-1.9	66.67	30
	Lake Erie	1.60	1.4-1.8	62.50	17
	Lake Michigan	1.63	1.5-1.8	61.34	126
L/DB					
	Hogan's Pond	9.0	7.73-11.32	11.11	30
	Lake Erie	7.96	7.0-9.0	12.56	10
	Lake Michigan	8.71	8.1-9.6	11.48	10
L/AB					
	Hogan's Pond	9.07	8.05-10.3	11.02	30
	Lake Erie	8.42	7.9-9.4	11.87	10
	Lake Michigan	9.77	9.4-10.4	10.23	10
L/DA					
	Hogan's Pond	2.96	2.7-3.4	33.78	30
	Lake Erie	2.59	2.3-2.7	38.61	10
	Lake Michigan	2.70	2.5-2.9	37.04	10
D/W					
	Hogan's Pond	2.28	1.7-2.6	43.85	30
	Lake Erie	2.14	1.9-2.4	46.73	10
	Lake Michigan	2.03	1.8-2.2	49.26	10
SD/H					
	Hogan's Pond	2.02	1.7-2.2	49.50	30
	Lake Erie	2.35	2.2-2.5	42.55	10
	Lake Michigan	2.29	2.1-2.4	43.67	10

Table 2 (Continued)

Item	Locality	Average	Range	%	No. of fish
SA/H					
	Hogan's Pond	3.35	3.15-3.7	28.57	30
	Lake Erie	3.82	3.6-4.0	26.17	10
	Lake Michigan	3.80	3.5-4.2	26.31	10
DC					
	Hogan's Pond	1.61	1.3-1.96	62.11	30
	Lake Erie	1.31	1.1-1.6	76.33	10
	Lake Michigan	1.46	1.3-1.6	68.49	10
AC					
	Hogan's Pond	1.19	0.9-1.4	84.03	30
	Lake Erie	1.07	1.0-1.2	93.45	10
	Lake Michigan	1.10	1.0-1.2	90.91	10

The principal differences of these body proportions between Hogan's Pond and Great Lakes specimens are the length of snout (S), the diameter of eye (E), the body depth (D), length between tip of snout to the base of dorsal fin (SD) and the proportions of length of fins to various body parts, e.g. PV/P, AV/V, DC, AC. The following discussion on body proportions gives a brief explanation of designations seen in Fig. 5 and the above numerical column (Table 2).

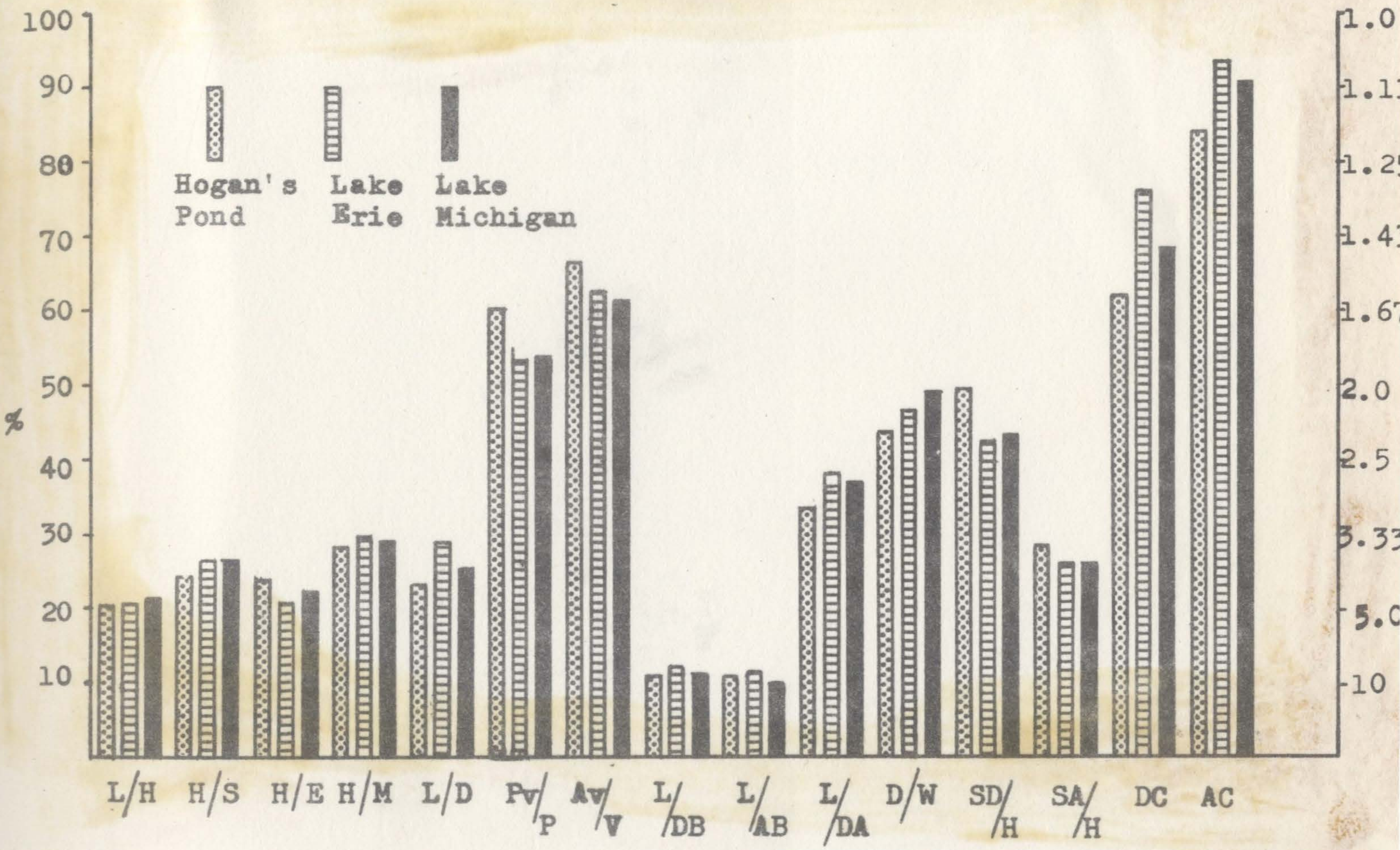


Fig. 5 ---Variations in the body proportions of lake whitefish (<u>Coregonus clupeaformis</u> Mitchill) in Hogan's Pond, Newfoundland; Lake Erie; and Lake Michigan, expressed in percentages and times of either standard length (S.L.) or head length (H). Data are in average. This figure is based on data found in Table 2. For explanation of designations see text.

L/H ---The proportion represents the head length expressed in percentage of the standard length, and is greatest in Lake Michigan race, around 21.5; while in that of Hogan's Pond around 20.3; of Lake Erie 20.5. It seems to have no difference between the races of Lake Erie and Hogan's Pond, but a slight difference from that of Lake Michigan in this respect.

H/S ---Representing the snout length expressed in percentage of the head length. It shows that Hogan's Pond whitefish have the smallest snout, around 24.3, while those of Lake Erie and Lake Michigan are 26.9 and 26.4 respectively.

H/E ---Hogan's Pond whitefish have the longest eye diameter, the length which expressed in percentage of head length is 23.7, while that of Lake Erie whitefish and Lake Michigan whitefish are 20.87 and 22.57 respectively.

L/D ---Representing the greatest body depth expressed in the percentage of standard length. In the case of Hogan's Pond whitefish, the body is much more elongate and slender proprotionally, having a depth of 23.15 % of standard length, while in the cases of Lake Erie whitefish and Lake Michigan whitefish the depths are 29.0 and 25.1 respectively. This is largely due to a poorer growth rate and a large degree of emaciation among fish in Hogan's Pond. The degree of emaciation will be described later on in the " Growth study".

PV/P ---Proportionally, the whitefish in Hogan's Pond have the longest pectoral fin, the length of which expressed in percentage of the distance PV is 60.24, while in the cases of Lake Erie whitefish and Lake Michigan whitefish the pectorals are much shorter proportionally, having the length of 53.19

and 54.05 respectively.

AV/V ---It is again the whitefish of Hogan's Pond having the longest pelvic fins proportionally, the length of which is 66.67 % of the distance AV. In Lake Erie whitefish and Lake Michigan whitefish the proportions are 62.5 % and 61.34 % respectively.

L/DB and L/AB ---Representing the length of dorsal fin base and of anal fin base expressed in the percentage of standard length.

L/DA ---In the case of Hogan's Pond whitefish, the distance between dorsal fin and adipose fin, expressed in the percentage of standard length, is much shorter than that of the Great Lakes whitefish, around 33.78 compared to 38.61 and 37.04 in Lake Erie whitefish and Lake Michigan whitefish respectively.

D/W ---The proportion of body depth to body width. Hogan's Pond whitefish have the smallest figures around 43.85, while in Lake Erie whitefish and Lake Michigan whitefish the figures are 46.73 and 49.26 respectively.

SD/H ---Representing the head length expressed in the percentage of the distance between snout to dorsal fin. Again, it is enormously varied in this proportion among localities, being 49.5 for Hogan's Pond race, 42.55 for Lake Erie race, and 43.67 for Lake Michigan race.

SA/H ---Representing the head length, expressed in the percentage of the distance between snout to adipose fin. Hogan's Pond whitefish have the longest head in this respect, around 28.57. Lake Erie whitefish around 26.17 and Lake Michigan whitefish around 26.31.

DC ---Dorsal coefficient. The length of dorsal fin divided by the fin base. It differs greatly among three races in this respect. Hogan's Pond race being smallest in this coefficient, around 62.11; Lake Erie race around 76.33; Lake Michigan race around 68.49.

AC ---Anal coefficient. The length of anal fin divided by the fin base. Hogan's Pond race has the coefficient of around 84.03; Lake Erie race around 93.45; Lake Michigan race around 90.91.

The above numerical values of body proportion further prove that morphologically whitefish are very plastic, the body proportions are enormously altered in definite direction by different environmental conditions. The opinions of Jordan and Evermann (1909, 1911) which state that "---possibly Coregonus albus (referred to Lake Erie whitefish) is merely an ontogenetic species, its peculiarities being due to the conditions of food and water in Lake Ere", are therefore evidently agreeable. Koelz (1927) replaces the one species, Coregonus clupeaformis, for all the whitefish of the Great Lakes include Lake Erie. Vladykov (1954) states that the taxonomic value of these body proportions is rather smaller than would be expected. Martin (1949) concludes that the variations in body proportions of fish; in term of relative growth, are genetically the same but exposed to different water temperature, food and other conditions, and are caused by varying size of body when certain inflections in growth occur. Mayr (1948) warns that it is unjustified to define the species on the basis of morphological characters of the specimens. Climate races of animals, as Mayr says, most probably occur, having genetic equilibrium adapted to environment but strong divergency (heterozygosity) by means of which the population may respond to environmental changes. In this way new races may rapidly occur if the population is brought to a new environment, as in the case of whitefish introduced into Hogan's Pond. Svärdson (1951) reports that two whitefish species display most striking changes in the body proportions and growth rates after they are transplanted in two small lakes. Thus it seems safe to conclude that different environmental factors strikely affect the growth rate which in turn modify the body proportions of fish, and it will be very unreliable to used any body proportion as taxonomic characters of two species.

Dymond and Hart (1929) show that Coregonus clupeaformis found in Lake Abitibi, a relatively smaller and shallow water, are deeper and more compressed with longer fin than specimens from Lake Nipigon, a larger and deeper lake. Vladykov (1935) indicated that fishes from southern localities (he seemed to refer to temperature) as well as those from shallow water did not attain larger size and possessed greater body depth than northern ones. In addition, land-locked form fishes, particularly Salmonidae, are usually smaller in size and attain maturity at an early age. Hubbs (1926) states that fishes pass through a protracted development at lower temperature usually show an extenuation not only of growth, but also of the age differentiation in form which result from the differential rate of growth in various parts of body. They usually have proportionally shorter heads and smaller eyes than related forms of more accelerated development. Hilderbrand and Cable (1930) claim that generally the size of fishes along the Atlantic coast of United States decreases from north to south.

Hogan's Pond possesses a smaller space (43,500 times smaller than Lake Erie), lower temperatures (particularly during the hatching period--April, when the whole pond is still completely cover by thick ice), and much shallower water, the whitefish in this pond bear a smaller body size, poorer growth rate, however, have a proportionally lesser body depth, larger eyes, smaller head, longer fins, more compressed body than those of Lake Erie. In some respects, these body proportions appear to be opposite to what the above statements imply. My personal opinion toward this variation is that the response of the developmental rate and growth to various environmental factors does not always proceed in the same direction or to the same degree.

ii. Meristic characters.

In systematic ichthyology, the meristic characters have always played an important prat in the description and definition of species and subspecies, or in racial investigation. Among these characters of taxonomic significance in fishes, there should be mentioned at least (a) the number of scales on lateral line, (b) the number of fin rays, (c) the number of gill rakers and (d) the number of vertebrae.

It is necessary to realize whether a meristic character is justifiable to be regarded as a racial character; that is genotypical, or whether the variation of a character within certain limits is solely or chiefly a phenotypical nature. It seems that these problem can be solved to a certain extent by the comparisons of meristic characters between the transplanted population and the original population. As Tåning (1952) point out, the variations of certain meristic characters may be evidently explained as due mostly to difference in metabolic rate caused by the temperature during the earliest stage of development and should be regarded as phenotypical expressions rather that specific genotypical constitution. The variation in the later-determined meristic character, such as the number of fin rays, seems first and foremost to be determined by the metabolism, whereas the early-determined character, such as vertebral number, is to greater extent controlled genetically. From field observations, the endeavour has been made to discover other factors than temperature, which might influence the meristic characters. Vladykov (1935) claims that three important factors, namely, temperature, space , and salinity, seem to play the principal role in causing variation in meristic characters. Generally, low temperature, larger space or highly salinity in a given area, are each correlated with a high number of segments with their components, and vice versa. Some environmental factors other than temperature, space and salinity have also shown certain influence on meristic variation. Tåning (1952) also reports that decreasing oxygen pressure leads to an increase in the number of vertebrae in trout, whereas rising carbon dioxide pressure produces a decrease.

For the purpose of comparison of meristic characters between Hogan's Pond and Lake Erie whitefish there shall be mentioned in this study only temperature and space, this is because of the time limitation and lack of information about other factors.

a) Lateral-line scales.

Comparison of lateral-line scales of Hogan's Pond whitefish and Lake Erie whitefish is given in Table 3. The difference between means is significant ($P<0.01$), being 85.50 for Hogan's Pond population and 81.72 for Lake Erie population.

Table 3 ---Number of lateral-line scales of lake whitefish from Hogan's Pond and Lake Erie *.

* Data on Lake Erie whitefish based on Koelz (1927).

Area	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	N	Mean and standard error
Hogan's Pond	-	-	-	2	1	3	2	6	9	9	16	16	L4	31	27	13	12	7	10	1	1	1	181	85.50 ± 0.223
Lake Erie	2	3	8	6	18	19	24	42	44	38	30	25	16	15	13	6	5	6	3	-	1	-	324	81.72 ± 0.199

t	df	P
12.62	503	<0.005

The variation of the mean number of scales may be correlated with the difference in metabolism rate caused by the temperature during the development of egg. Hall (1925) states that at higher temperature, a larger proportion of available yolk is required for the maintenance of embryo thus increase the growth rate of the embryo leaving a smaller amount of yolk available for tissue differentiation. The number of scales are formed at a later stage in development at certain period after eyed egg stage (Mottley, 1933), and therefore are more affected by the environmental factors (Vladykov, 1935). Mottley (1931, 1933) in his experiment on Salmon kamloops suggests that the scale count is mostly affected by temperature. The fry hatched at temperature 5° C higher than ordinary possessed an average row of scales being 18 below that of the normal average.

During the whitefish hatching period (April or early May), Hogan's Pond is still completely covered by ice, while the temperature of Lake Erie in April, according to Lawler (1965), was average 44° F (6.7° C) during 1948-1952 period, and the average temperature in April in Lake Erie showed a tendency of increasing in the last two decades.

The other factor that may also be correlated with the number of scales on lateral line is space. Lake Erie has an area about 10,000 square miles (Koelz, 1927) while Hogan's Pond is only about 0.23 square miles. Vladykov (1935) states that fish in the larger freshwater areas produce more numerous segments with their components than in the smaller bodies of water. The average scale counts of Hogan's Pond whitefish, however, shows a direct contrast with the above statement. This could be explained that the environmental factors do not operate in the same direction and hence variation in the characters of fishes is regarded as a result of the intersection of various factors. In the case of Hogan's Pond and Lake Erie whitefish, the temperature factor undoubtly prevails over the space factor. Svardson (1951) states that the number of lateral-line scales is also influenced by the size of parent fish and the size of eggs from which the individuals were hatched.

The mean number of lateral-line scales of Hogan's Pond whitefish, 85.5, was found to be higher than that of lake whitefish in any North American waters (Table 4)

Table 4 ---Lateral-line scales of lake whitefish from various areas.

Locality	No. of fish	Mean	Range	Authority
Hogan's Pond	181	85.5	76-94	Present study
Lake Nipigon	34	80.0	76-89	Koelz (1927)
Lake Michigan	191	84.6	74-93	"
Lake Superior	107	83.4	77-94	"
Lake Huron	195	83.1	73-91	"
Lake Ontario	198	83.8	75-92	"
Lake Erie	324	81.7	73-93	"
Lake Opeongo	335	83.3		Kennedy (1943)
Great Bear Lake	57	77.8	72-85	Kennedy (1953)
Lake Cliff (Maine)				
Dwarf form	62	75.1	69-83	Fenderson (1964)
Normal form	60	77.8	70-85	"

b). The number of fin rays.

Mean counts of fin rays are shown in Table 5 and 6. Since data on fin rays number of lake whitefish from other areas are unavailable, a comparison on this regard becomes impossible.

Table 5 ---Number of dorsal and anal fin rays of lake whitefish from Hogan's Pond.

Dorsal fin rays					Anal fin rays				
10	11	12	13	Mean and stand-error	10	11	12	13	Mean and stand-error
23	86	58	8	11.29 ± 0.0567	7	58	80	30	11.76 ± 0.0589

Vladykov (1935) reports that fin rays (except caudal fin rays) are generally developed later than vertebrae but earlier than the scales, and the number of fin rays is highly modifiable by temperature. In addition, Vladykov points out that the variation in the number of caudal segments is greater than that of abdominal region. If this premise is true to any fish, we may expect that anal fin rays varies within a wider range than does dorsal fin rays. However, in lake whitefish of Hogan's Pond these two fins seem to be similar to each other in the range of fin rays variation. On the other hand, this may be the case, but since the number of anal fin rays is determined earlier than that of dorsal fin rays, and thus are less modified by environmental factors (Tåning, 1952).

In the case of paired fins, pectoral fin starts to develop earlier than the pelvic (ventral) fin but the pectoral fin takes a much longer time in attaining full development than the pelvic fins, thus the determination of the number of pelvic fin rays begun earlier than pectoral rays (Vladykov, 1935). Consequently, the pectoral fin rays are more variable than the pelvic rays. This is true in the lake whitefish of Hogan's Pond, as seen in Table 6.

Table 6 ---Number of paired fin rays of lake whitefish from Hogan's Pond.

Pectoral fin rays							Pelvic fin rays			
13	14	15	16	17	18	Mean and standard error	10	11	12	Mean and standard error
1	11	53	95	14	1	15.65 ± 0.0578	7	126	42	11.2 ± 0.037

Vladykov (1935) also suggests that the number of pelvic rays does not exhibit a variation. In general, the number of pelvi rays is frequently constant not only for a smaller taxonomic units (species, genera) but also for a larger groups (families and suborders). In few cases, however, slight individual differences do exist in the number of pelvic rays in the same species. Among 175 specimens of lake whitefish, I observed that 126 specimen possess 11 rays, only 42 specimens possess 12 rays and 7 specimens possess 10 rays.

c) Gill rakers.

The number of gill rakers of whitefish is regarded as the most reliable taxonomic characteristics which is almost unaffected by environmental influences and the variation is proved to have a genetic basis (Svärdson, 1951, 1952; Lindroth, 1957; Dymond, 1943; Walters, 1955). Dymond's and Walters' conclusions were reached by the study of wild populations of lake whitefish or other whitefishes in various regions. They conclude that gill rakers of <u>Coregonus clupeaformis</u> indicate no apparent tendency for the number to be higher or lower in the north, south, east or west. Means vary from 25 to 32, which may be indicative of local raciation, because high values are found in both north and south, and low values are also found in the north and south. Walters (1955) regarded the number of gill rakers as great systematic importance in his work on Coregonid speciation in Arctic regions. A test of the genetic nature of gill rakers between species of Coregonid was done by Lindroth (1957). Offsprings of known parents of two whitefish species reared under almost identical condition, the number of gill rakers remained unaltered. Svärdson's conclusions were reached by an experiement based on transplantation of two lake-dwelling whitefish populations into lakes that had not had whitefish, and sea-run whitefish were transplanted into two lakes. The data resulting from these transplantations show the gill rakers mean shifted from 19.0 to 20.5 and 23.2 respectively for lake-dwelling whitefish; sea-run whitefish, mean 28.5 became 29.6 into two lakes, the range was essentially unchanged. Svärdson (1952) attributed this slight change of gill rakers to the possibility that " stray hybrids or specimens of unknown indigenous population may have appeared as sources of variety and error". Water quality can not be said to have influence on gill raker apparatus (Svärdson, 1951).

Data on gill raker counts of whitefish from Hogan's Pond and Lake Erie were tabulated in Table 7. The difference between means of two populations was less than one unit, and overlap is almost complete, however, a " t " test shows that difference was significant ($P < 0.01$). Since Hogan's Pond had not had any whitefish population and the original nature of lake whitefish in this pond is certainly known, this slight change can not be attributed to the stray hybrids nor indigenous population, rather it could possibly be correlated with other meristic characters. As Vladykov assumes, there is a direct relationship between gill raker and other meristic characters in many cases. Fish possessing a higher number of numerical values also have a higher number of gill rakers. He also suggests that space factor may affect the number of gill rakers as it does other characters. (Vladykov, 1935)

Generally speaking, the number of gill rakers of whitefish is genetically determined and is known to be environmentally stable. Svärdson (1951) reports that gill rakers of whitefish do not change with time nor in transplanted populations. The number of gill rakers of whitefish does not also changed with age. Gill raker begin to be visible as small knots, as Svärdson (1950, 1951) and Lindroth (1957) report, at a fish length of 2 cm. (T.L.), at a length of 8-10 cm. (that is the end of their first summer), the young have about 30 gill rakers which are the definite number or not far from the definite number. Table 8 and 9 show that the number of gill rakers does not change with age in the case of lake whitefish. The number of gill rakers in some fish, however, varies greatly with age. Vladykov (1954) reports that brook trout (<u>Salmon fontinalis</u>) with length 45-60 mm. have average 14.7 gill rakers, while specimens 148-218 mm. long have average 16.8 gill rakers. Tremendous change in gill raker number is also found in Alosa sapidissima. Hilderbrand and Schroeder (1928) report that specimens 35-70 mm. in length with 26-31 gill rakers, specimens 110-180 mm. long with 34-41 gill rakers, adults 413-580 mm. in length with 62-76 gill rakers. It should be added that there is no variation in the number of gill rakers on both sides of gill arch (Table 10).

Table 7 ---Comparison of gill raker counts of lake whitefish in Hogan's Pond and Lake Erie.

Area	No. of fish	Number of gill rakers								Mean and standard error
		25	26	27	28	29	30	31	32	
Hogan's Pond	167	4	15	27	44	45	25	6	1	28.29 ± 0.1
Lake Erie	100	3	18	21	36	20	2	-	-	27.58 ± 0.1

t	P
4.516	<0.01

Table 8 ---Variation with age in the total number of gill rakers on the left gill arch of Hogan's Pond whitefish.

Age	No. of fish	Number of gill rakers on left arch								Mean
		25	26	27	28	29	30	31	32	
II-IV	57	2	5	5	11	22	9	3	-	28.48
V-VIII	110	2	10	22	32	24	16	3	1	28.19

Standard error	t	P
0.213	1.122	>0.1
0.131		

Table 9 ---Variation with age in the total number of gill rakers on the right gill arch of Hogan's Pond whitefish.

Age	No. of fish	Number of gill rakers on right arch								Mean and standard error
		25	26	27	28	29	30	31	32	
II-IV	25	1	4	5	6	5	3	1	-	27.92 ± 0.31
V-VIII	92	3	9	23	22	20	9	6	-	28.07 ± 0.15

t	P

Table 10 ---Number of gill rakers on right and left side of first gill arch of Hogan's Pond whitefish.

Item	No. of fish	Number of gill rakers								Mean and standard error
		25	26	27	28	29	30	31	32	
Right	117	4	13	28	28	25	12	7	-	28.03 ± 0.136
Left	167	4	15	27	44	45	25	6	1	28.29 ± 0.108

t	P
1.50	>0.1

d) Vertebral counts.

Mean number of vertebral counts is shown in Table 11. Data on vertebral counts from Lake Erie whitefish are not available, a comparison on this regard between transplanted population and the original populaiton becomes impossible. Instead, vertebral counts of lake whitefish from some other areas are included in this discussion, however, a conclusion regarding to the variation of vertebral counts from different areas has not attempted.

Table 11 ---Frequency distributions and mean numbers of vertebrae of lake whitefish from Hogan's Pond and two other areas.

Area	56	57	58	59	60	61	62	63	N	Mean and standard error
Hogan's Pond	1	2	9	27	41	32	9	3	123	60.0 ± 0.11
Cliff Lake * (Maine)										
Normal form		-	3	8	21	24	3	1	60	60.3 ± 0.13
Dwarf form	-	-	3	21	25	12	1	-	62	59.8 ± 0.11
Great Bear ** Lake (N.W.T.)	range : 59-64									61.8 ± 0.16

* Data on Cliff lake whitefish based on Fenderson (1964).

** Data on Great Bear Lake whitefish based on Kennedy (1953)

The greater average number of vertebrae counts of Great Bear Lake whitefish can be correlated with higher latitude (and hence lower temperature) and larger space. Jordan (1893) clearly points out that fishes from southern region possess smaller number of vertebrae than the northern forms. He attributed this geographical variation of meristic feature to the temperature. On this, Hubbs (1922), Gabriel (1944), and Tåning (1952) claim that the number of vertebrae was higher in fish developing at lower temperature. Tåning (1952) observes that the determination of the number of vertebrae in Salmo trutta begins very early in the development, namely, in the gastrulation period. During this supersensitive period, a relatively moderate change of temperature ($3 - 6^{\circ}$ C) can produce an average difference of 1.5 vertebrae. He further concluded in his experiment that the average number of vertebrae seemed thus to be mainly determined genotypically. Vladykov (1935) reports that in many cases the number of vertebrae in fishes also bear a definite relation to the extent of the body of water in which they occur. As a rule, fishes of the same species have a lower number of vertebrae when they inhabit a basin of less extent or with shallower water.

iii. Osteological features.

Several studies concerning the osteology of Salmonidae have been achieved, but unfortunately very few of these studies deal with Coregonus clupeaformis or Coregoninae as a whole. The following osteological studies are aimed at describing the principal skeletons of Coregonus clupeaformis as to their roles in the position of classification among Salmonidae.

Salmonidae are soft-rayed teleost fishes which have three upturned caudal vertebrae. According to Norden (1961), they are divided into three subfamilies, namely, Salmoninae (trouts and salmons), Coregoninae (whitefishes and cisco), and Thymallinae (graylings). The chief osteological differences among these three subfamilies are listed in Table 12.

Coregoninae may be separated from the other two groups by the presence of a well ossified hypethmoid and the lack of teeth on the maxilla at any stage in life (Norden, 1961). Within the Coregoninae, three genera may be recognized, namely, Coregonus, Prosopium, and Stenodus (Norden, 1961). These three genera can be

Table 12---Characters of chief osteological importances in the Salmonidae.

(Data based on Norden, 1961)

Osteological character	Subfamily of Salmonidae		
	Salmoninae	Coregoninae	Thymallinae
Orbitosphenoid	present	present	absent
Suprapreopercular	present	absent	absent
Basibranchial plate	present	absent or present	absent
Teeth on maxilla	present	absent	present
Dermosphenotic	absent	present	present
Parietals	separated	fused	fused
Hypethmoid	absent in most species	present	absent
Basisphenoid	present	present but absent in Coregonus	present
Epipleural	absent or present	absent	absent
Scales	minute	large	large
Dorsal fin rays	less than 16	less than 16	17 or more than 17

distinguished from each other by the following characters as listed in Table 13.

From the taxonomic point of view, the most important section among the different skeletons of Salmonidae are the skull and caudal vertebrae (Vladykov, 1954).

List of abbreviated designations used in skull and branchial skeletons of <u>Coregonus clupeaformis</u> is found in Table 14. This is based entirely on Norden (1961) and Vladykov (1954).

a) Skull.

(1) Lateral view of skull.

Viewed from lateral aspect the head of <u>Coregonus clupeaformis</u> is fairly well invested in bones, except for the areas around the orbit, between post orbitals (PO) and Preopercle (POP) and above and below the pterotic (PTO). Fig. 6.

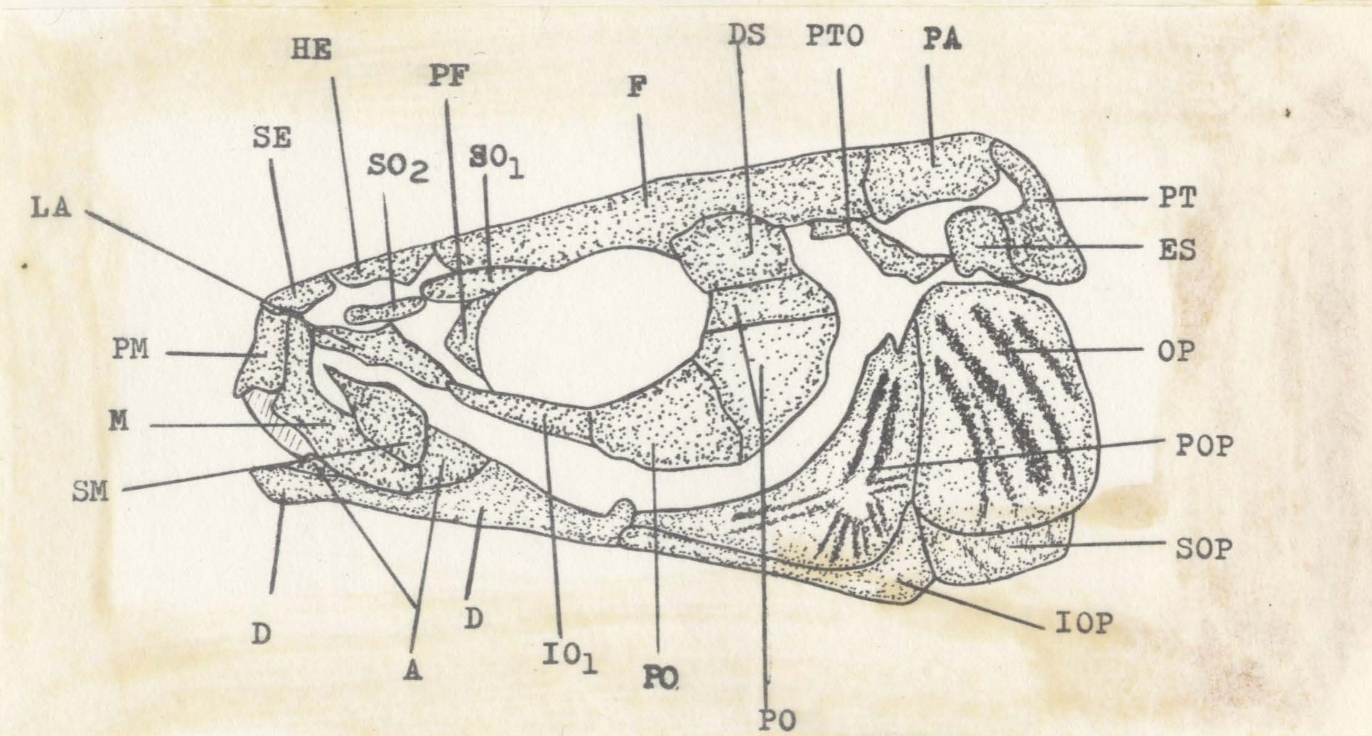


Fig. 6 ---Lateral view of skull of the lake whitefish (Coregonus clupeaformis) of Hogan's Pond.

Table 13---Characters of taxonomic importance in the Coregoninae.

(Data based on Norden, 1961)

Character	Coregonus	Prosopium	Stenodus
Nostril flaps	two	one	two
Basibranchial plate	absent	present	absent
Parr marks	absent	present	absent
Supraorbital	widely separated from Dermosphenotic	same as Coregonus	meets the Dermosphenotic
Mouth	small	small	large
Teeth	toothless	toothless	well toothed in adult in Vomer and palatine
Basisphenoid	absent or present but hardly distinguisable	present	present
Supraethmoid	short	elongate	short

Table 14---List of abbreviated designations used in the skull and branchial skeletons of <u>Coregonus clupeaformis</u>.

A	Angular	HY	Hyomandibular	PO	Postorbital
BB	Basibranchial	IO	Infraorbital	POP	Preopercle
BOC	Basioccipital	IOP	Interopercle	PP	Pharyngeal plate
CB	Ceratobranchial	LA	Lacrimal	PQ	Palato-quadrate
D	Dentary	LP	Lingual plate	PRO	Pro-otic
DF	Dorsal fontanelle	M	Maxilla	PS	Pterosphenoid
DS	Dermosphenotic	MES	Mesopterygoid	PT	Posttemporal
EB	Epibranchial	MET	Metapterygoid	PTO	Pterotic
ECT	Ectopterygoid	OP	Opercle	Q	Quadrate
EOC	Exoccipital	OPO	Opisthotic	SE	Supraethmoid
EPO	Epiotic	OS	Orbitosphenoid	SM	Supramaxilla
ES	Extrascapular	P	Parasphenoid	SO1, SO2	Ist and 2nd supraorbital
F	Frontal	PA	Parietal	SOC	Supraoccipital
FM	Foramen magnum	PAL	Palatine	SOP	Subopercle
HB	Hypobranchial	PB	Pharyngobranchial	SPO	Sphenotic
HE	Hypethmoid	PF	Prefrontal	SY	Symplectic
HH	Hyohyal	PM	Premaxilla		

In _Coregonus_ _clupeaformis_, the premaxillae (PM) retrorse (extending downward and backward), and are almost vertical at the end of the snout, while in some other species of Coregonus, e.g. subgenus Leucichthys (lake herrings), they are about equal with or do not extend forward as far as the dentary. The maxilla (M) of _Coregonus_ _clupeaformis_ is typical of Coregoninae which is distinguished from the other two subfamilies by having broad, short and toothless maxilla. The posterior half of maxilla is expanded, whereas in genera Prosopium and Stenodus and some other species of Coregonus, the maxilla is about equally expanded (Norden, 1961). The supramaxilla (SM) or jugular (Vladykov, 1954) is quite characteristic in the Coregoninae, and in all species there is a severely attenuate anterior projection. The supraorbital (SO) bone in Coregonus and Stenodus is larger than in Prosopium (Norden, 1961). The prefrontal (PF) locates in the ethmoid region which separate the olfactory capsule from the orbit (Fig. 7 and 8). There are three postorbital (PO) or circumorbitals (Ridewood, 1904) in all species of Coregoninae (Norden, 1961). Dermosphenotic bone (DS) locates above the third postorbital bone (PO). This bone is absent in Salmoninae while is present in Coregoninae and Thymallinae (Norden, 1961). The preopercle (POP) of _Coregonus_ _clupeaformis_ is a strongly arched bone, which is typical of all the species of Coregoninae, and there is no supraopercle in any species of Coregoninae (Norden, 1961). The hyethmoid (HE) or mesethmoid (Gregory, 1933) is characteristic of all species of Coregoninae, whereas it is absent in either Salmoninae or Thymallinae (Norden, 1961).

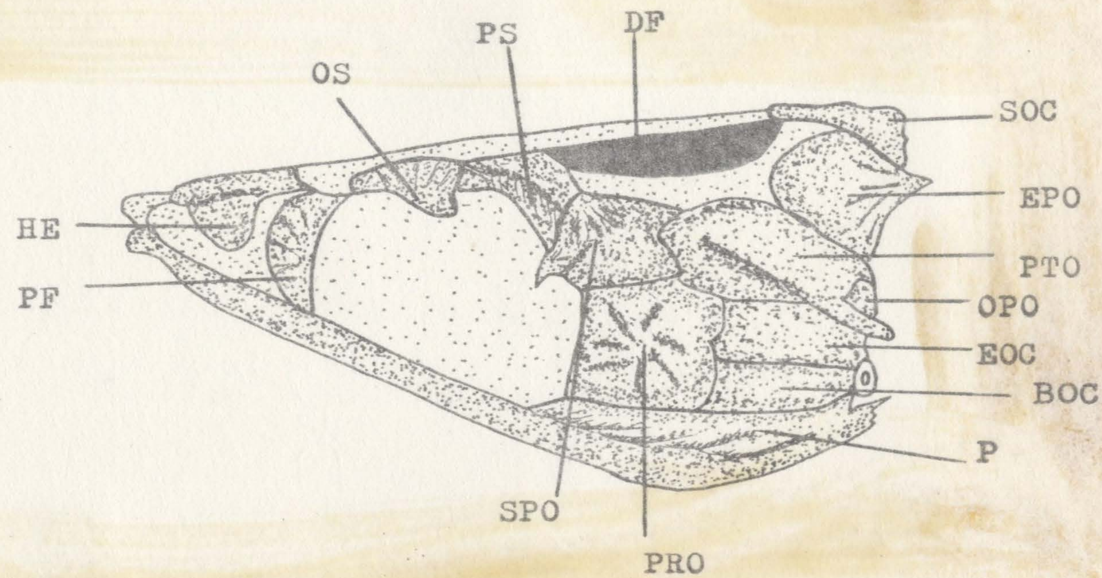


Fig. 7 ---Lateral view of chondrocranium of lake whitefish (Coregonus clupeaformis) from Hogan's Pond.

(2) Chondrocranium.

Usually, there are three bones which comprise the orbit region, namely, orbitosphenoid (OS), pterosphenoid (PS) and basisphenoid. Basisphenoid is, however, absent in Coregonus clupeaformis, but poorly developed or absent in other species of Coregonus (Norden, 1961). Basisphenoid is present in the other two subfamilies. Norden (1961) found very tiny stained basisphenoid in some specimens of Coregonus clupeaformis.

The otic region is the best ossified part of the chondrocranium. Nearly all bones meet in jagged sutures, interspaced with cartilage. There are 8 bones (6 are paired) found in the otic region of Coregonus clupeaformis. These are basioccipital (BOC), supraoccipital (SOC), and paired sphenotics (SPO), prootics (PRO), pterotics (PTO), epiotics (EPO), exoccipitals (EOC) and opisthotics (OPO). Basioccipital (BOC) is the main articulation for the first vertebra.

(3) Palatine and palatoquadrate arch.

The palatine (PAL) in Coregonus clupeaformis is rather soft, small and lies in front of the slender ectopterygoid (ECT). There are no teeth found on palatine (PAL). Norden (1961) reports that there are week, small teeth which are borne on the palatine during the stage of all Coregonines. Paired mesopterygoids (MES), ectopterygoids (ECT), quadrates (Q), metapterygoids (MET) are present in Coregonus clupeaformis. The mesopterygoid (MES) is rather soft and hardly distinguishable, never toothed. Figure 8 shows the palatoquadrate arch of lake whitefish from Hogan's Pond.

(4) Branchial skeletons.(Fig. 9)

Lingual plate bears teeth, so does pharyngeal plate. Basibranchial plate is not present in any of the species of Coregonus or Stenodus, but is present in Prosopium.

(5) Dorsal roofing bones.

The head of Coregonus clupeaformis is not completely overlain with dermal bones. The bones are thin and more or less transparent. The dorsal roofing bones of the Coregonus clupeaformis form a rather acute angle anteriorly (Fig. 10) which is typical of all Coregonine fishes (Norden, 1961). Thus the supraethmoid (SE) and premaxillae (PM) are small and narrow.

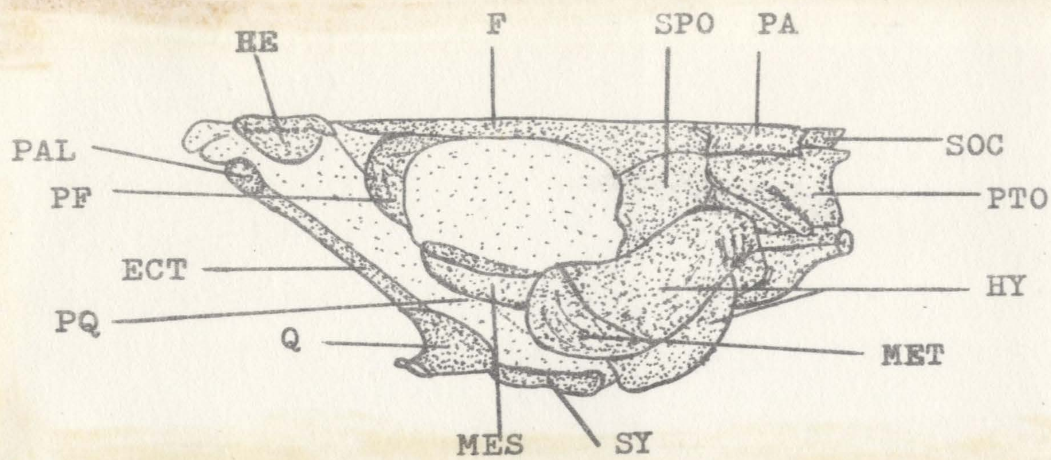


Fig. 8 ---Palatoquadrate arch of lake whitefish (<u>Coregonus clupeaformis</u>) from Hogan's Pond.

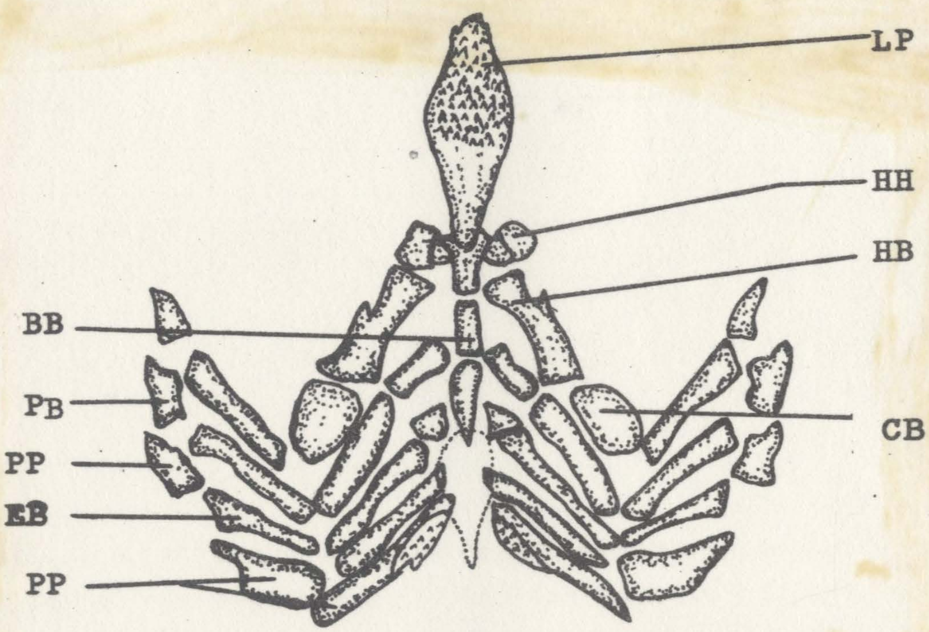


Fig. 9 ---Branchial skeletons of lake whitefish (<u>Coregonus clupeaformis</u>) from Hogan's Pond.

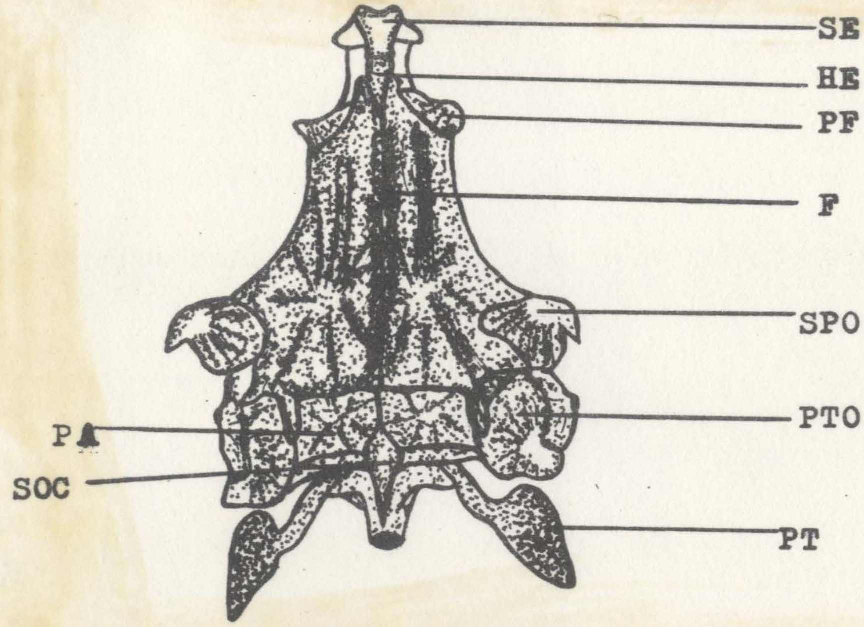


Fig. 10---Dorsal view of skull of lake whitefish (<u>Coregonus clupeaformis</u>) from Hogan's Pond.

The hypethmoid (HE), which is present only in Coregoninae, not found in either Salmoninae or Thymallinae, plays a significantly important part in the taxonomy of Salmonidae. It is a well ossified bone partly covered by supraethmoid (SE) anteriorly and by frontal (F) posteriorly and lies on ethmoid cartilage. Frontals (F) which cover most of the dorsal surface of chondrocranium, are two large subtriangular bones. The posterior margin of frontals overlap the parietals. (Fig. 11)

The parietals of <u>Coregonus clupeaformis</u> are nearly rectangular in shape, and meet at the middle line, while posterior portions are separated partly by supraoccipital (SOC). Cope (1872) regarded Coregonine fishes as a family rank on the basis of these united parietals which in trouts and salmons are separated completely by the supraoccipital. Gill (1895), on the other hand, believe that Cope's opinion was wrong, the united feature of parietal in Coregonine fishes reduced them to a subfamily rank. Norden (1961) reports that the parietal do not meet in the middle line in Stenodus leucichthys, a single species of the Genus Stenodus.

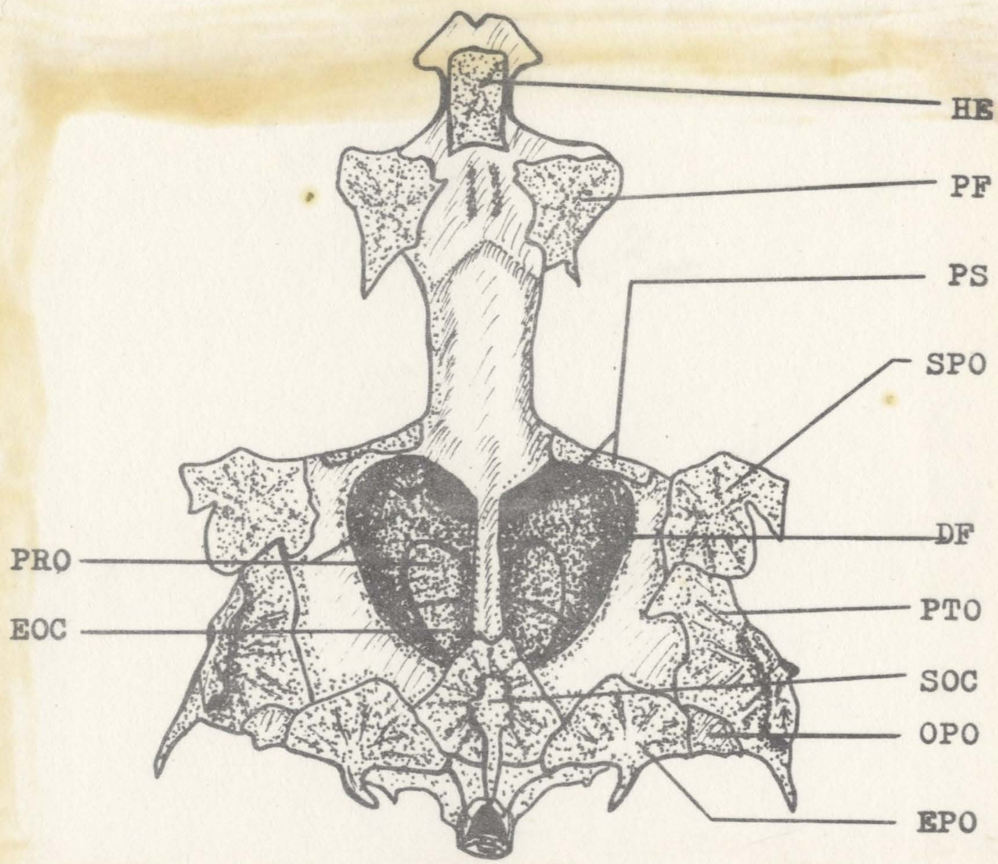


Fig. 11 ---Dorsal views of chondrocranium of lake whitefish (Coregonus clupeaformis) from Hogan's Pond.

b) Caudal skeletons.

The most important and varied structures of caudal skeletons are uroneurals (UN), epurals (E) and caudal body plate (cbp) (Fig. 12).

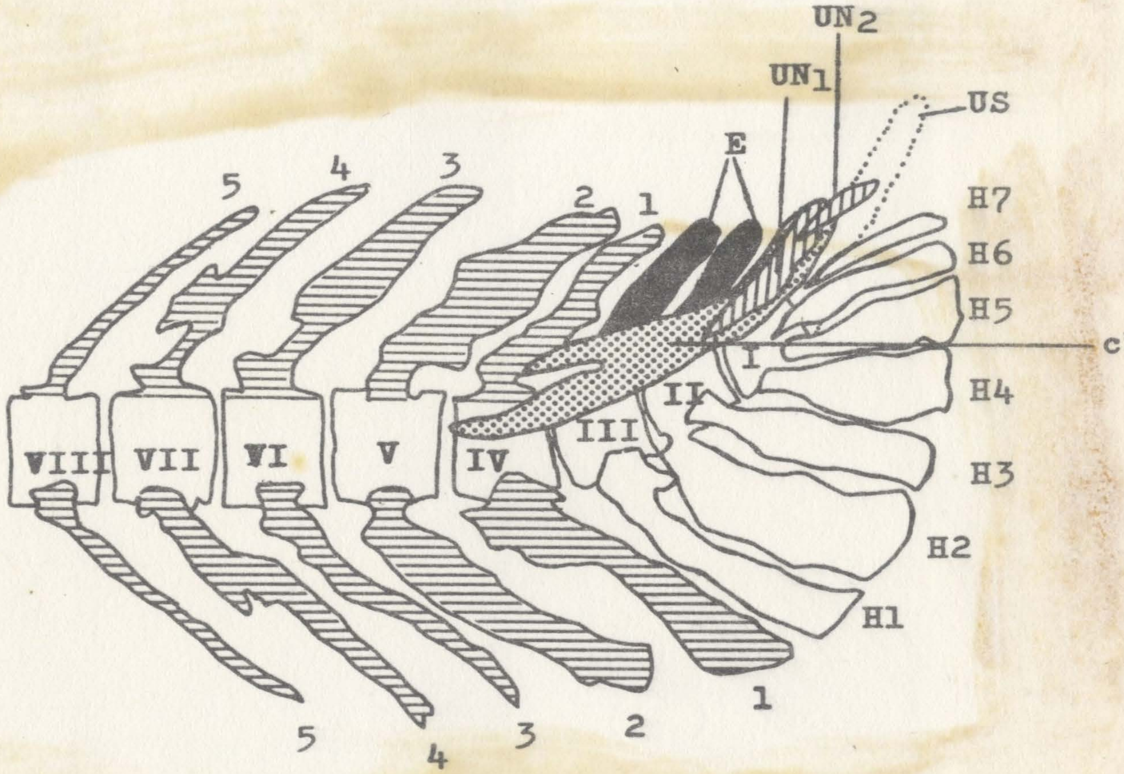


Fig. 12 ---Caudal skeletons of lake whitefish (Coregonus clupeaformis) from Hogan's Pond.

The number of uroneurals (UN), epurals (E) and position of caudal body plate are specific characteristics among Salmonidae.

Roman numerals (I-VIII) of Figure 12 refer to the last eight centra of caudal vertebrae.

Arabic figures (1-5) refer to either neural spines or haemal spines.

cbp ---Caudal body plate (First uroneural, Norden, 1961). One on each side. The caudal body plate in <u>Coregonus clupeaformis</u> covers the last four centra of vertebrae.

Epurals (E) --there are two epurals dorsal to the caudal body plate(cbp) in <u>Coregonus clupeaformis</u>.

UN_1 and UN_2 --First and second uroneurals. Paired bones on each side.

H_1 - H_7 --Hypurals or hypural plates. There are 7 in number in all species of Salmonidae (Vladykov, 1954).

US --Urostyle. A cartilagenous segment at the posterior terminal end.

In several specimens of <u>Coregonus clupeaformis</u> taken in Hogan's Pond the urostyle bear one or two tiny ossified segments which are too small to be considered as being a complete centra. Thus the <u>Coregonus clupeaformis</u> bears the general characteristic of three upturned vertebrae in the caudal region as in any other species of Salmonidae.

VI. AGE AND GROWTH STUDIES

A. Age determination.

There are several ways which have been used in age and growth studies in fish; these are (i) Length-Frequency or Peterson's method, (ii) Marking and known age method, (iii) Interpretation of layers laid down in the hard parts of fish, such as vertebrae, otoliths, spines, rays and opercles, and (iv) Scale method (Rounsefell and Everhart, 1953; Lagler, 1952). Scale method is employed solely for age determination in the present study.

The scales for determining the age were taken from left side of the fish; some from the region midway between the dorsal fin and lateral line, some from the area half way between the adipose fin and lateral line, some from the region between lateral line and anal fin, and some from just above the pelvic fin (below the lateral line) where the scales are large. The round even scales from the dorsal fin-lateral line and adipose fin-lateral line regions were found to be less variable in shape, size, having fewer percentage of regenerated scales (see Table 15) and were more satisfactory than those from other parts of the body.

The whitefish scale (Fig. 13) is of cycloid type, thin, round, without spiny projections, having concentric rings called circuli, running around a clear area in the center of scale--focus. Running from the focus there are four more or less conspicuous radiating ridges (Van Oosten, 1923, 1929).

Table 15 ---Percentages of ouucrrence of regenerated scales from various parts of the left body side of lake whitefish from Hogan's Pond.

Specimen Number	Ratio of occurrence of regenerated scales			
	Dorsal-lateral	Adipose-lateral	Lateral-anal	Pelvic region
1901	1/30	2/30	15/30	13/30
1902	0/30	2/30	8/30	5/30
1903	0/30	3/30	7/30	14/30
1904	0/30	6/30	4/30	1/30
1905	2/30	4/30	3/30	6/30
Average percentage	2 %	13.2 %	24.5 %	27.7 %

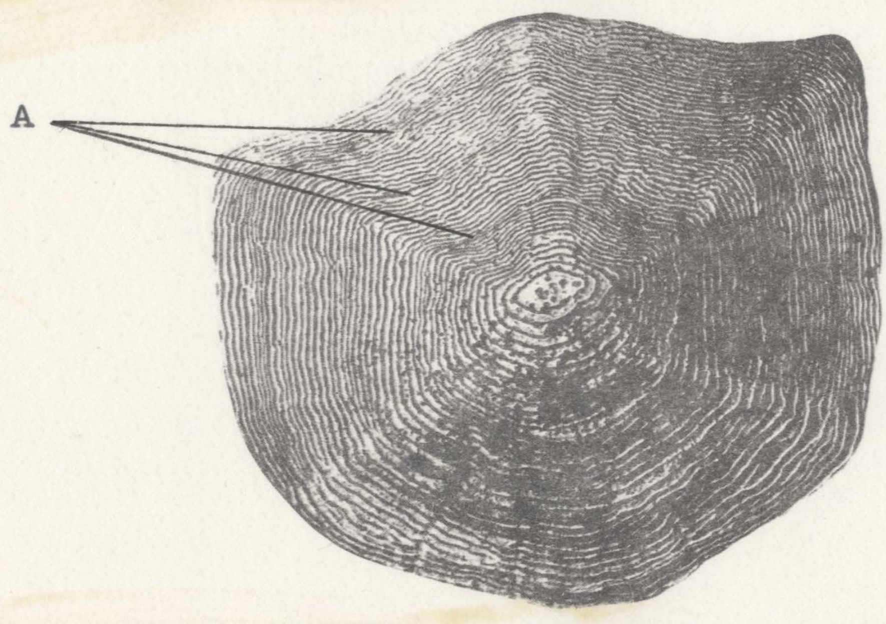


Fig. 13 ---Scale of lake whitefish (Coregonus clupeaformis)

A : Annual ring.

The first part of a scale to be developed is a part of the focus (Lagler, 1952). The circuli are produced firstly in the focus region on the bony layer (Lagler, 1952; Rounsefell and Everhart, 1953), then the circuli increase in height during the process of calcification. A circulus, according to Creaser (1926), " is not built up simultaneously in all its part, various detached portions of its length may be under construction at the same time." These parts of a circulus may eventually unite to form a more or less continuous ring.

Bands of circuli are alternately widely spaced and packed closely together which reflect change in growth throughout the year. The summer rapid growth season results in widely spaced bands of circuli and the compactly spaced bands of circuli are the indication of slow growth in the fall or winter. Huntsman (1918) points out that in the slow period of growth new circuli are formed more rapidly than scale increases in diameter or length, so that the circuli are crowded together. Seasonal cessation of growth due to severe winter or other factors (such as spawning, disease, etc.) will be accompanied by the cessation of scale development and as a result circuli tend to become short, weak and broken lines, one or more discontinuous circuli may also end on the sides of crowded circuli forming what we usually call the " crossing over " or " cutting over " (Rounsefell and Everhart, 1953).

Fishes hatched in spring time, as in the case of Coregonid fishes, which pass a long summer growth season, will be expected to have a most inner summer zone represented by well spaced bands of circuli which is immediately followed by crowded bands, short, weak, and broken lines and crossing over. These closely spaced band of circuli have been given different names. Chugunova (1959) called the part of s **scale formed** during one year (includin both widely spaced and compact circuli) an " annual zone ", and the boundary between the crowded fall-winter and well spaced spring-summer circuli was termed an " annulus " or " year ring " which was also termed as " resting zone " by Ricker (1962). Gilbert (1922) called the narrowly spaced circuli the " winter check " and the portion immediately after the winter check " new growth ", the last circulus prior to the new growth zone " annulus

The annuli of scales are truly " year marks " has been proved by numerous authors who employed the scale method for growt studies. Van Oosten (1923) examined the scales of known age lake whitefish reared in New York Aquarium and came out one of the most thoroughful investigations. He concluded that the number of annuli of the fish are actually the same number as that of the winter of the fish's life.

The age of whitefish as well as many other temperate and arctic fishes is determined by precisely counting the number of annuli or year rings. A fish whose scales bear three year rings and an outer " new growth " zone, has actually passed three complete years of life and is now in its fourth year of life and is therefore termed age-4 in the present study or age-3^{+} in many other papers.

B. The time of annulus formation.

Age and growth studies of fish based on scale method require relatively precise estimation of the time of annulus formation on the scale. Just as the formation of spaced circuli reflec the rate of growth, so the time of annulus formation is correlated with environmental factors especially the water temperature. Bilton and Ludwig (1966) studies the scales of sockeye and chum salmon in the Gulf of Alaska, these scales were taken from fish caught in a period from January to April. Among those sockeye salmon caught from January to Feburary, 30 to 55 % of the scales (depends on age) bore the last annulus at the extreme margin of the scales and without any circulus beyond the last annulus; 45 to 70 % of the scales already showed new growth. The average number of circuli beyond the last annulus ranged from 0.7 to 1.9. On the other hand, sockeye salmon caught in April showed the increasing new growth zone, more number of circuli after the last annulus, while the percentage of scales with no circuli after annulus is zero. They suggested that the time of annulus formation for sockeye salmon in that region is sometime in January. Of the scales of chum salmon caught from January 7 to Feburary 7 showed none of them have any circulus beyond the last annulus; 100 % of the scales had no circuli after the annulus. They suggested that the time of annulus formation for chum salmon began as early as November.

Since all the whitefish samples of Hogan's Pond were taken from June to December, all the scales showed more or less the " new growth " zone beyond the last annulus. Relatively precise estimation of the time of annulus formation based on the percentage of scales without circuli after the annulus and the average number of circuli after the annulus is impossible. Consequently, the time of annulus formation on the scales of Hogan's Pond whitefish can only be roughly detected by estimating the ratio of the number of circuli beyond the last annulus to the number of circuli on the preceeding " new growth " zone. Presumably, the number of circuli to be produced between the time after the formation of last annulus and the time until the fromation of next annulus is closely similar to the number of circuli on the preceeding " new growth " zone. Table 16 shows (on the far right column) that fish caught in June have average 3.85 circuli after the last annulus compared to average 9.07 circuli on the preceeding " new growth " zone. Fish caught in September the ratio is 4.48 to 9.12; in October --6.33 to 9.82; in Novenber --5.15 to 8.08; in December --6.74 to 8.43. The ratio of circuli on two zones tends to be close to 1 : 1 from June to December. Although from the above data the precise time of annulus formation of whitefish scales is far beyond estimable, we are able to suggest that the time of annulus formation is sometime in January or February. Van Oosten (1923) found the New York Aquarium whitefish began to form annual ring as early as November, December, some in January or February. The annulus is completed upon the resumption of rapid growth in the spring of the year.

Table 16 ---Average number of circuli after the last annulus and on the preceding new growth zone (2nd last annual ring) on the scales of lake whitefish (<u>Coregonus clupeaformis</u>) taken at Hogan's Pond in 1965 and 1966.

Time of catch	Average number of circuli											
	Age III		Age IV		Age V		Age VI		Age VII		Age VIII	
	Last annulus	2nd last annulus	last annulus	2nd last annulus	last annulus	2nd last annulus	last annulus	2nd last annulus	last annulus	2nd last annulus	last annulus	2nd last annulus
June	----	----	5.0	9.0	3.6	9.5	4.0	9.0	2.5	8.7	----	----
July	----	----	4.2	9.6	4.3	9.3	4.0	8.6	3.6	8.5	3.0	8.8
August	----	----	----	----	4.0	8.7	4.4	8.5	4.5	8.0	----	----
Sept.	9.3	17.3	4.6	9.3	4.6	8.3	3.8	7.5	3.7	6.5	3.0	5.0
Octo.	13.7	19.5	7.0	11.5	5.3	8.9	5.4	8.4	5.0	7.4	----	----
Novem.	----	----	----	----	5.0	9.0	4.7	7.0	5.5	8.4	----	----
Decem.	----	----	----	----	----	----	7.0	8.8	6.5	8.1	----	----

Table 16 (continued).

Time of catch	Average number of circuli — Ages combined: last annulus	2nd last annulus	Ratio of last annulus to 2nd last annulus
June	3.85	9.07	1 : 2.33
July	3.88	8.84	1 : 2.28
August	4.38	8.37	1 : 1.91
September	4.84	9.12	1 : 1.89
October	6.33	9.82	1 : 1.57
November	5.15	8.08	1 : 1.58
December	6.74	8.43	1 : 1.25

C. Frequency distributions.

i. Age frequency distributions.

The age composition of whitefish samples in Hogan's Pond taken during 1965 (June-October) and 1966 (July-December) is tabulated in Table 17 and are presented in Fig. 14 and Fig. 15.

Table 17 ---Age frequency distributions of lake whitefish (<u>Coregonus clupeaformis</u>) taken in 1965 and 1966 from Hogan's Pond.

Year	Age group							Total	Mean
catch	II	III	IV	V	VI	VII	VIII		age
1965	0	12	24	37	32	14	1	120	5.13
1966	3	17	21	41	42	11	3	138	5.07
1965 & 1966	3	29	45	78	74	25	4	258*	5.09
%	1.16	11.2	17.4	30.2	28.7	9.7	1.55		

* Three age-undetermined fish are not included.

The records of age composition point clearly to the presence of two strong year groups of whitefish. Throughout the papers I have come across it is quite common among the Coregonines that one or two age groups strongly dominated each sample. The sample in Hogan's Pond was dominated by age V group and age VI group, and constituted 58.9 % of the total specimens. The frequencies for younger and older age groups constituted only small percentages. There were only three fish or 1.16 % in age

II-group, and only 4 specimens or 1.55 % in age VIII-group. Age I-group was entirely absent.

The age groups of Hogan's Pond whitefish do not vary considerably in 1965 catch and 1966 catch. In both years, the samples were equally dominated by age V and age VI groups. Although the data are not sufficient for dependable indication of annual fluctuation of age groups, the writer believe that either one of these two age groups or both are actually dominating the whitefish population in Hogan's Pond. The total absence of age I-group or scarcity of young fish can be attributed to the sampling method. Since all the fish were taken only by gill nets, as Hile (1941) points out, gill nets have the difficulty of holding younger fish. Mraz (1964) also reports that age I-group fish rarely, if ever, appear in gill net samples. All the 120 fish of 1965 catch were taken by gill nets set up on the surface of water near the shore and resulting in totally absence of age I-group and age II-group. While during the 1966 sampling period, gill nets were set up in deeper water and far away from shore, resulted still only three age II-group fish were caught. A thoroughly sampling method with both gill nets, pound nets and trawls is necessary before making conclusion that scarcity of younger fish actually reflects the relative abundance of this segment of the population or the weak year classes.

On the other hand, the scarcity of older fish is undoubtedly reflecting high mortality rate occurs from age VI to age VIII (Table 18). Because of the scarcity and a great degree of emaciation among older fish, it is quite possible that the maximum age of this fish in Hogan's Pond is VIII or IX.

Table 18 ---Mortality of lake whitefish in Hogan's Pond.

Year	Age group				Survival P_7/P_6	Mortality	Survival P_8/P_7	Mortality
	V	VI	VII	VIII				
	P_5	P_6	P_7	P_8	(Si)	(1-Si)	(Sii)	(1-Sii)
1965	30.8	26.7	11.67	0.83	0.43	0.57	0.071	0.929
1966	29.7	30.4	7.97	2.17	0.26	0.74	0.272	0.728
1965 & 1966	30.2	26.7	9.69	1.55	0.34	0.66	0.16	0.84

Note : Method of estimating mortality is based on Roelofs(1957)

P_5 = percentage of age V fish in the catch.

P_6 = percentage of age VI fish in the catch.

S = Survival rate (P_7/P_6)

Mortality = 1 - S

Estimates of the annual survival and the annual mortality were calculated from age-frequency distributions. The mortality rate of Hogan's Pond whitefish was very high, being 84 % from age VII to age VIII in the total samples. The mortality was extremely high from age group VII to age group VIII in 1965 catch, being 92.9 %. Roelofs (1957) reports that the mortality rate of lake whitefish in northern Lake Michigan is very high, being 93.6 % from age III group to age IV group. Theorically, from Table 18 it indicates that about 66 % of fish will die when they pass from age VI to VII, whereas only 5.2 % of fish will die when they pass from age V to age VI.

The average age for 258 whitefish is 5.09, and for 1965 catch and 1966 catch 5.13 and 5.07 respectively. The mean ages for the males and the females are 5.07 and 5.15. However, it is not indicative that the females are older than the males in this population, since in 1965 catch, the males averaged 5.23 slightly older than the females which averaged 5.0 years.

Fig. 14 ---Age frequency of Hogan's Pond whitefish taken in 1965 and 1966.

Fig. 15 ---Age frequency of Hogan's Pond whitefish.

ii. Size distributions.

Comments on size distributions in this section are kept brief, since more discriminating data on growth are offered in later sections.

a) Length-frequency distribution of the age groups.

Fork lengths are used mainly for growth studies, and are therefore also used for frequency analysis. The length distributions of all age groups are shown in Table 19, which have been based on the combination of the data for 1965 and 1966 catch. A 10 mm. or 1 cm. length interval was used in this study.

The length distribution, as shown in Fig. 16, is unimodal and appears to have a relatively tight distribution with high mode. It reflects that this sample is dominated by a small number of age groups. Lengths of all 258 fish range from 201 mm. to 348 mm.. Fish smaller than 240 mm. occupy only 10.46 % (27 fish), and are represented by two age groups; age II and age III groups. Fish larger than 310 mm. constitute only 8.14 % (21 fish) but are represented by four age groups; from age V to age VIII. Fish with lengths between 271 to 310 mm. constitute 62 % of the total specimens, and about 59 % of the total 258 fish belong to age V and age VI groups, this roughly indicates a length-age relationship.

There are about 50 highly emaciated fish with slender bodie average 32 mm. longer than normally growing fish of corresponding ages. These 50 fish were either separated or combined with other fish in growth studies.

Table 19 ---Length-age distribution of 258 lake whitefish from Hogan's Pond.

(Figures in parentheses indicated male fish)

Fork length (mm.)	Age group II	III	IV	V	VI	VII	VIII	Total	%
201-210	1 (1)	1 (1)						2 (2)	0.774 (0.774)
211-220	2 (1)	6 (3)						8 (4)	3.10 (1.65)
221-230		10 (3)						10 (3)	3.88 (1.16)
231-240		7 (6)						7 (6)	2.71 (2.42)
241-250		3 (1)	6 (4)					9 (5)	3.49 (2.04)
251-260		2 (0)	4 (3)	5 (3)	2 (0)			13 (8)	5.04 (3.10)
261-270			12 (4)	13 (5)	3 (1)			28 (10)	10.85 (3.88)
271-280			10 (7)	18 (6)	17 (5)			45 (18)	17.44 (6.98)
281-290			9 (6)	22 (12)	12 (6)			43 (24)	16.66 (9.29)
291-300			2 (2)	12 (7)	14 (7)	7 (6)		35 (22)	13.56 (8.52)
301-310			2 (0)	5 (4)	19 (10)	10 (8)	1 (1)	37 (23)	14.34 (8.9)
311-320				3 (3)	6 (3)	7 (4)	2 (1)	18 (11)	6.98 (4.62)
321-330						1 (0)		1 (0)	(0.387) (0)
331-340					1 (0)			1 (0)	(0.387) (0)
341-350							1 (0)	1 (0)	(0.387) (0)
Total	3	29	45	78	74	25	4	258	
%	1.16	11.24	17.4	30.2	28.68	9.69	1.55		
Mean length	20.77	22.91	27.2	28.0	28.39	30.33	32.78		

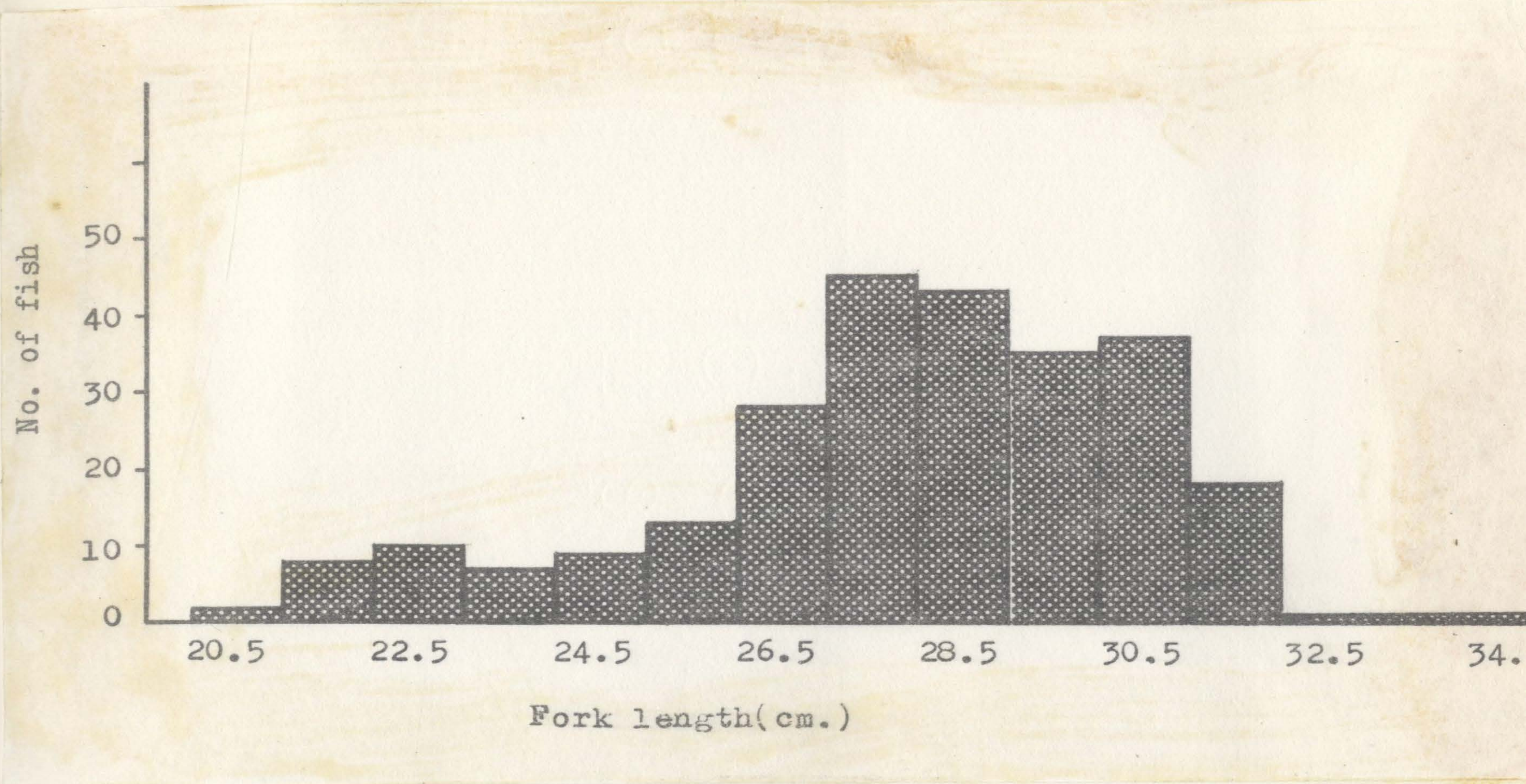


Fig. 16 ---Length frequency of 258 lake whitefish of Hogan's Pond.

b) Weight-frequency distribution of the age groups.

Due to a great degree of emaciation among larger fish in this population, weight distributions do not quite coincide with the increase of length. Male fish seem to have more emaciated fish than the females, therefore, generally speaking, female fish tend to be slightly heavier than male fish. Comparison between length distribution and weight distribution of both sexes, as shown in Fig. 18 and 19, shows that the males are more numerous at length intervals from 28.5 cm (285 mm.) to 315 mm. than the females, while they are less numerous at higher weight intervals.

Body weights of all 258 fish range from 1o2 grams to 374 grams. The highest frequencies for this weight composition are at 221 to 240 grams intervals, constituting 22.1 %. Fish at the weight intervals from 201 grams to 280 grams constituting 64.6 %. As compared to the length distributions, it is indicative that fish lengths ranging from 271 to 310 mm. usually bear the body weights ranging from 201 to 280 grams. A very poor growth condition in Hogan's Pond population was shown when compared with available data on whitefish population in Lake Erie where fish with lengths ranging from 274 mm. to 315 mm. (standard length) usually bear body weights ranging from 340 to 510 grams (Van Ooste 1947). Fish weighting over 300 grams are considered as heavy fish in Hogan's Pond population constituting only 7.5 % of the total samples or 20 fish (see Table 20 and Fig. 17).

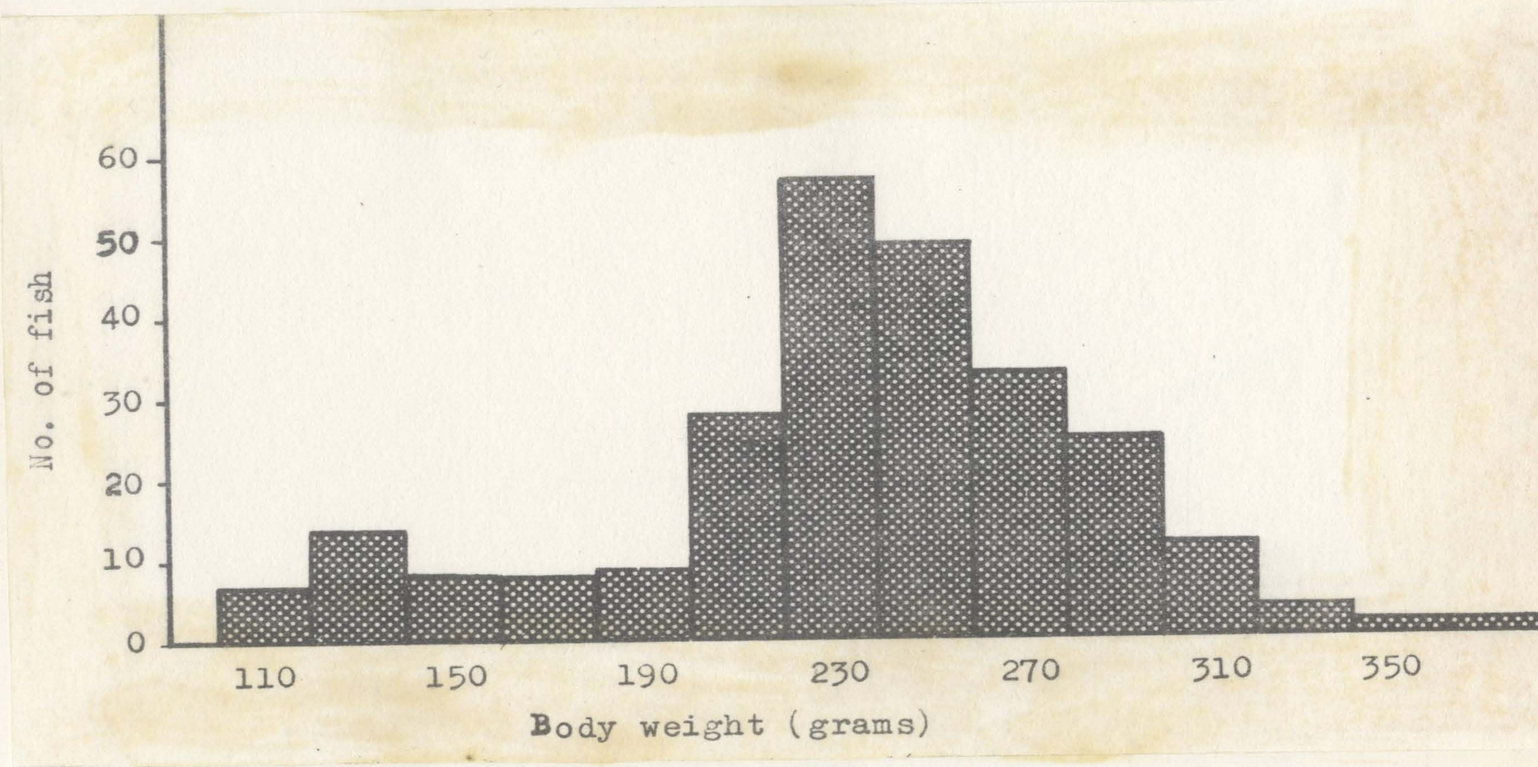


Fig. 17 ---Weight frequency of 258 lake whitefish of Hogan's Pond.

Table 20 ---Weight-age frequency of 258 lake whitefish from Hogan's Pond.

(Figures in parentheses indicated male fish)

Weight classes (grams)	Age group							Total	%
	II	III	IV	V	VI	VII	VIII		
100-120	2 (0)	5 (4)						7 (4)	2.7 (1.55)
121-140	1 (1)	13 (4)						14 (5)	5.4 (1.94)
141-160		7 (6)	1 (1)					8 (7)	3.1 (2.7)
161-180		2 (0)	3 (2)	2 (1)	1 (1)			8 (4)	3.1 (1.55)
181-200		1 (1)	3 (3)	3 (3)	1 (0)	1		9 (8)	3.5 (3.1)
201-220		1 (1)	4 (2)	13 (6)	7 (2)	3 (3)		28 (14)	10.9 (5.4)
221-240			17 (7)	19 (8)	18 (12)	2 (1)	1 (1)	57 (29)	22.1 (7.4)
241-260			9 (5)	19 (10)	20 (4)	1 (1)		49 (20)	19.0 (7.8)
261-280			7 (5)	12 (7)	8 (2)	6 (2)		33 (16)	12.6 (6.2)
281-300			1 (1)	7 (5)	11 (8)	6 (5)		25 (19)	9.7 (7.4)
301-320				1 (0)	5 (3)	5 (4)	1 (1)	12 (8)	4.65 (3.1)
321-340				1 (0)	2 (0)	1 (1)		4 (1)	1.55 (0.4)
341-360				1 (1)			1 (0)	2 (1)	0.77 (0.4)
361-380					1 (0)		1 (0)	2 (0)	0.77 (0)
Total	3	29	45	78	74	25	4	258	
Average weight	113.0	139	231	244.2	255.9	271.8	298.16		

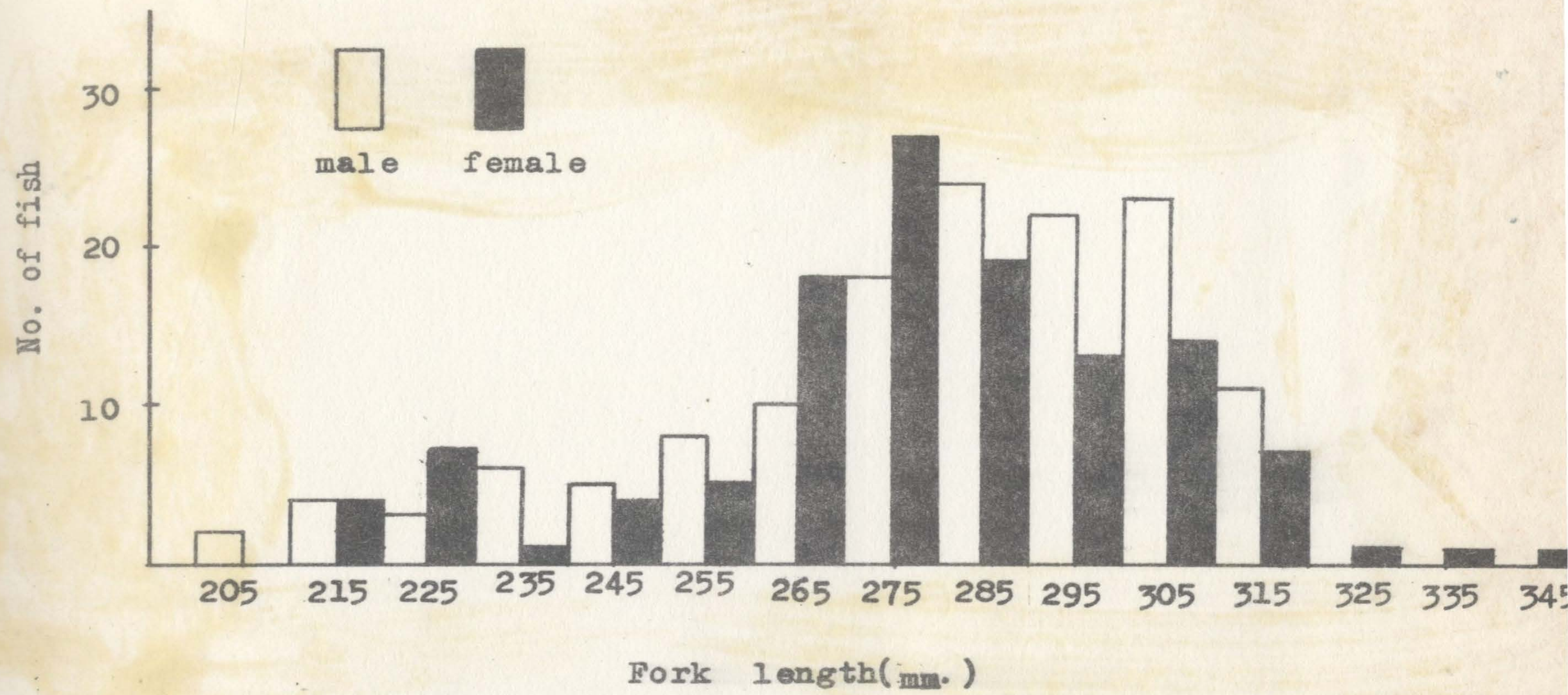


Fig. 18 ---Length-frequency of the male and female lake whitefish of Hogan's Pond.

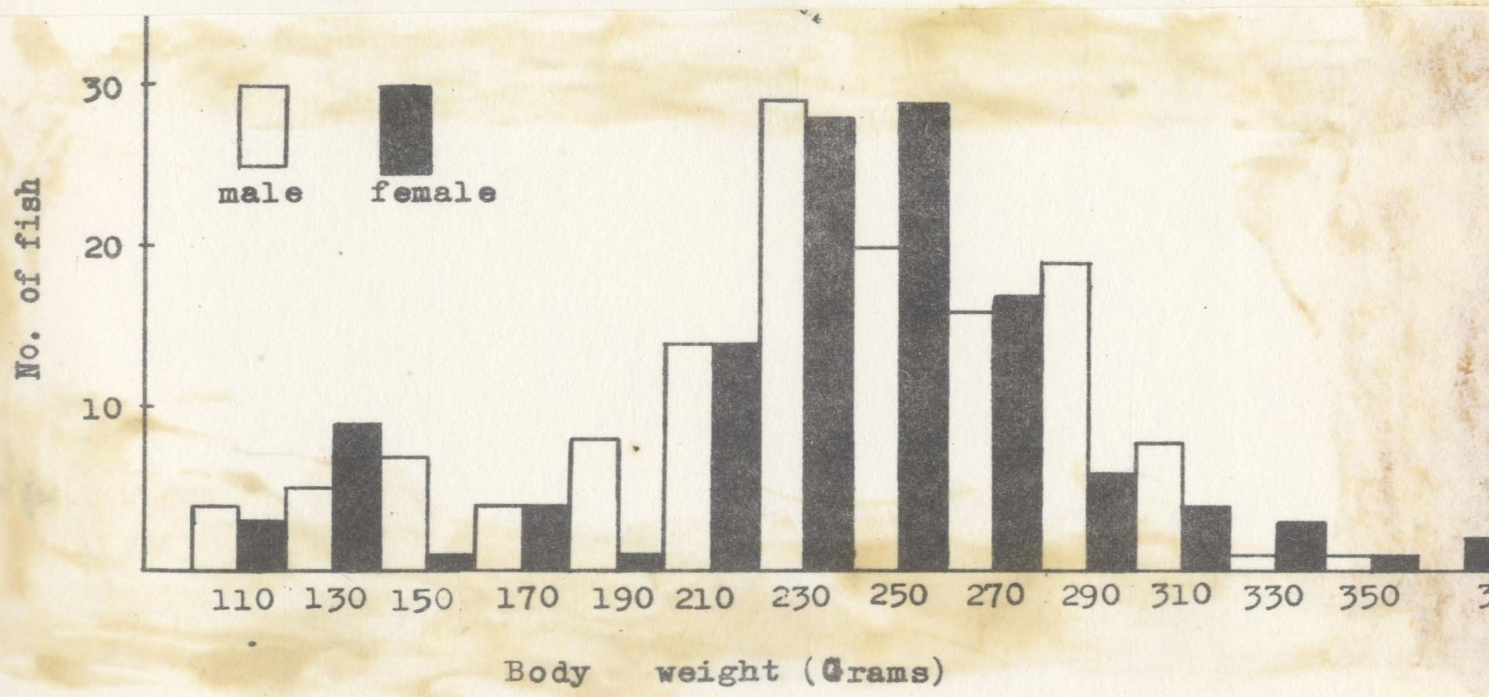


Fig. 19 ---Weight-frequency of the male and female lake whitefish of Hogan's Pond.

D. Age-length relationship.

Van Oosten (1929) states that "--- in order to obtain the norm of growth of a long lived species which is not influenced by seasonal cycles of growth or annual fluctuation in it, we must combine the rate of growth for corresponding ages of all year classes".

Mean fork length for each age group of 258 whitefish specimens are shown in Table 21 and Fig. 20. During the first two or three year of life the fish growth quite rapidly in length, with annual increments in length being 21.4 mm. in their third year of life, and 44.9 mm. in their fourth year of life, then gradually the rate of growth lessens and the increase in length with age is much less noticeable. They do, however, continue to increase in length until eight or may be nine years of age. Couch (1922) reports that whitefish in Lake Erie probably continue to increase in length through their entire lives.

The average annual increment in length is 18.7 mm.. There is a slight difference of growth in length of the age group between 1965 catch and 1966 catch, the later tend to be longer in body length than the former at each age group. So are the average annual increments in length for these two year catches also show difference, being 16.8 mm. for 1965 catch and 19.1 mm. for 1966 catch. Sexual dimorphism of growth in length is not obvious.

Table 21 ---Growth in length of the age groups of 258 lake whitefish taken at Hogan's Pond.

(Figures in parentheses indicated number of fish)

Age group	1965 & 1966 Fork length (mm.)	1965 & 1966 Increment	1965 catch Fork length (mm.)	1965 catch Increment	1966 catch Fork length (mm.)	1966 catch Increment
II	207.7 (3)		---		207.7 (3)	
III	229.1 (29)	21.4	226.7 (12)		230.9 (17)	23.2
IV	274.0 (45)	44.9	269.3 (24)	42.6	279.4 (21)	48.5
V	282.0 (78)	8.0	274.9 (37)	5.3	288.5 (41)	9.1
VI	291.8 (74)	9.8	285.9 (32)	11.0	296.3 (42)	7.8
VII	306.0 (25)	14.2	303.1 (14)	17.2	309.1 (11)	12.7
VIII	319.8 (4)	13.8	311.0 (1)	7.9	322.7 (3)	13.6

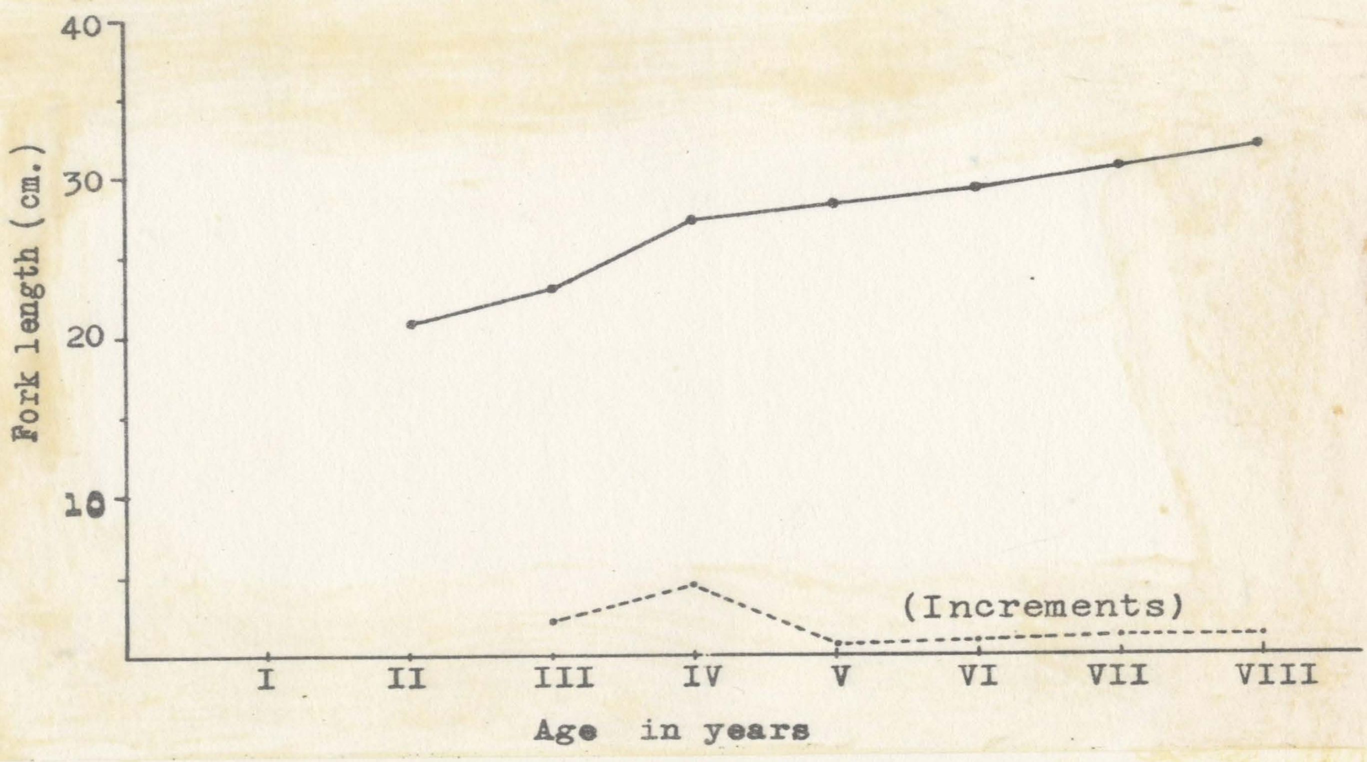


Fig. 20 ---Growth in length of the age groups of 258 lake whitefish taken from Hogan's Pond.

Age-length linear relationship for 258 fish is shown in Table 22 and Fig. 21. This relationship can be expressed by the equation:

$$\log L = 1.2249 + 0.3141 \log A$$

The body lengths of fish for a given age class can be calculated from the above equation. Similar relationships for 1965 catch and 1966 catch are found in Table 23.

There are 50 highly emaciated fish among 258 specimens with more slender body form and much lighter body weight. The separation of emaciated fish from normally growing fish is arbitrary yet quite reliable. The rate of growth in length with age of these emaciated and normal fish are shown in Table 24 and 25. Emaciated fish are more numerous among older fish than younger fish. No emaciated fish was found among fish of age II and age III-groups. The degree of emaciation is better elucidated in age-weight relationship and length-weight relationship.

Table 22 ---Age-length relationship of 258 Hogan's Pond whitefish taken in 1965 and 1966.

Body length (mm.)	Age group						
	II	III	IV	V	VI	VII	VIII
Empirical	207.7	229.1	274.0	282.0	291.8	306.0	319.8
Calculated	208.6	237.0	259.4	278.3	294.6	309.2	322.5

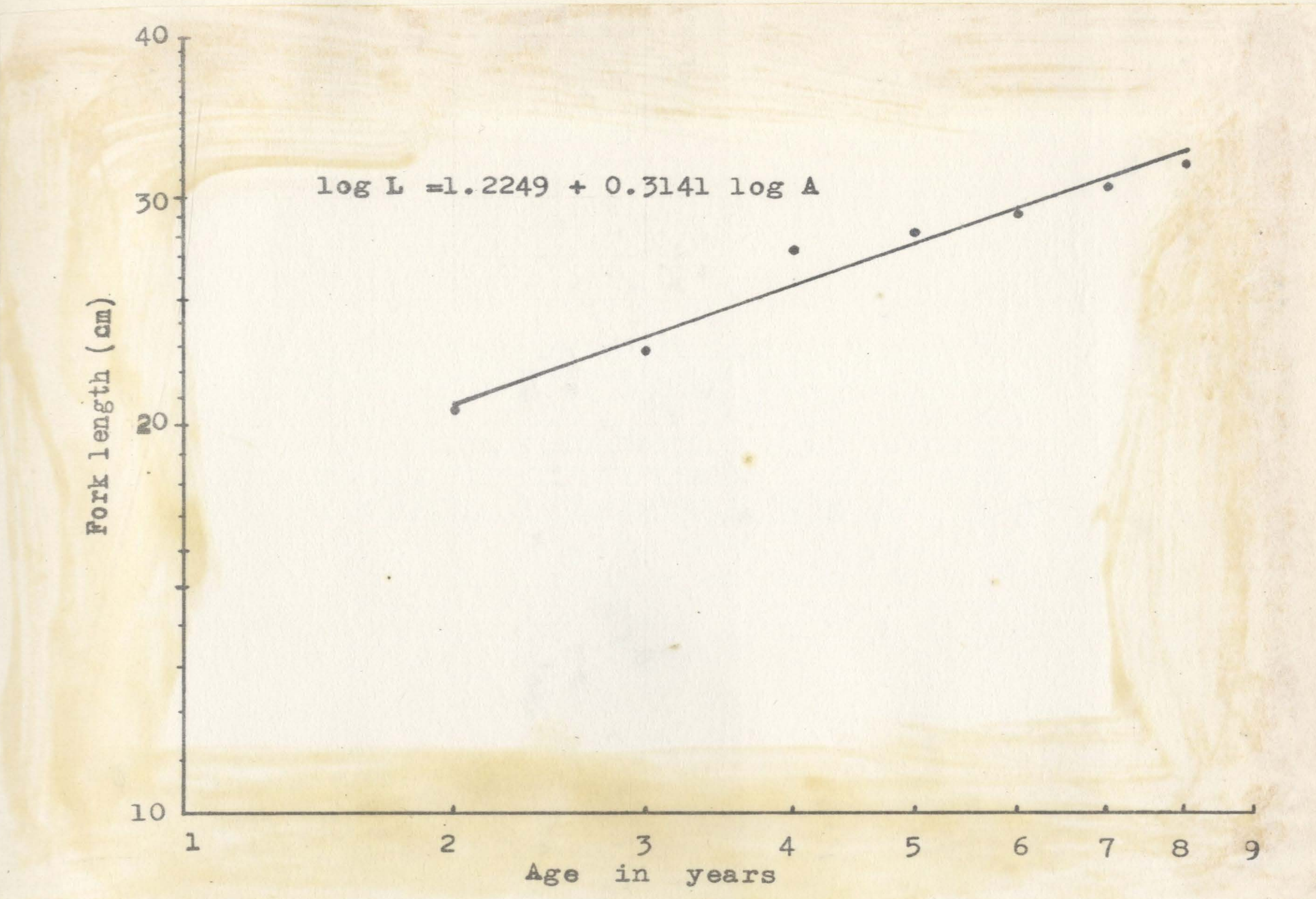


Fig. 21 ---Age-length linear relationship of 258 lake whitefish from Hogan's Pond.

Table 23 ---Age-length linear relationship of lake white-fish taken from Hogan's Pond in 1965 and 1966.

Age group	Average fork length (mm)			
	1965 catch		1966 catch	
	Empirical	Calculated	Empirical	Calculated
II	---	---	207.7	210.0
III	226.7	235.2	230.9	239.0
IV	269.3	256.1	279.4	262.3
V	274.9	273.5	288.5	281.8
VI	285.9	289.0	296.3	298.2
VII	303.1	302.4	309.1	313.9
VIII	311.0	314.6	322.7	327.7

log L = 1.2295 + 0.2972 log A---1965 catch

Table 24 ---Growth in length of the age groups of 50 emaciated whitefish of Hogan's Pond.

(Figures in parentheses indicated number of fish)

Age group	1965 & 1966 Fork length (mm.)	% *	1965 catch Fork length (mm.)	%	1966 catch Fork length (mm.)	%
IV	299.5 (4)	8.89	305.0 (1)	4.16	297.6 (3)	14.28
V	296.4 (10)	12.82	283.0 (2)	5.40	299.7 (8)	19.51
VI	307.3 (25)	33.78	303.0 (8)	25.0	309.4 (17)	40.47
VII VI	310.0 (10)	40.00	304.7 (4)	28.5	313.5 (6)	54.54
VIII	311.0 (1)	25.00	311.0 (1)	100.0	--	--

Table 25 ---Growth in length of the age groups of 208 normally growing lake whitefish of Hogan's Pond.

(Figures in parentheses indicated number of fish)

Age group	1965 & 1966 Fork length (mm.)	Increment	1965 catch Fork length	Increment	1966 catch Fork length	Increment
II	207.7 (3)		---		207.7 (3)	
III	229.1 (29)	21.4	226.7 (12)		230.9 (17)	23.2
IV	271.5 (41)	42.4	267.7 (23)	41.0	276.4 (18)	45.5
V	280.0 (68)	8.5	274.5 (35)	6.8	285.8 (33)	9.4
VI	283.9 (49)	3.9	280.2 (24)	5.7	287.4 (25)	1.6
VII	303.3 (15)	19.4	302.4 (10)	22.3	305.2 (5)	17.8
VIII	327.8 (3)	24.5	---	---	327.8 (3)	24.5

E. Age-weight relationship.

The rate of growth in weight was determined by plotting a curve between the age and weight determined by direct measurement. It is interesting to compare the rate of increase of length with age and the rate of increase of weight with age. As shown in Table 21 and Table 26, the greater increase of length with age always coincide with greater increase of weight with age. The growth in weight during first three years of life was comparatively rapid, with annual increments of about 28 grams during age II to age III, and 91.7 grams during age III to age IV. Enormously increasing the body weight and length during age III to age IV; as shown in Fig. 20 and Fig. 22, the increase in weight is greater than in length at these ages, this can be explained as the fish reach their maturity at the age of about III or IV (see spawning and maturity). Again, there is slight difference of growth in weight between 1965 catch and 1966 catch, the average annual increment in weight for 30.9 grams, and for 1965 catch and 1966 catch being 21.8 grams and 38.1 grams respectively. There is no reliable evidence to explain such difference, presumably, there was a better growth condition in 1966 spring-summer period than in 1965.

As in the cases of most animals, fishes when confronted with poor growth conditions, the continual increase in body length or age is not always accompanied with the increase in body weight. This is clearly demonstrated in 50 emaciated specimens. Table 27 and Fig. 23 clearly indicate the difference between normal growth and emaciated growth in weight.

Table 26 ---Growth in weight of the age groups of 258 lake whitefish taken from Hogan's Pond in 1965 and 1966.

(Figures in parentheses indicated number of fish)

Age group	1965 & 1966		1965 catch		1966 catch	
	Body weight (grams)	Incre-ment	Body weight	Incre-ment	Body weight	Incre-ment
II	111.3 (3)		---		111.3 (3)	
III	139.2 (29)	27.9	135.17 (12)		142.05 (17)	30.75
IV	230.9 (45)	91.7	226.39 (24)	91.22	239.12 (21)	97.07
V	244.47 (78)	13.57	239.64 (37)	13.25	249.20 (41)	10.08
VI	255.91 (74)	11.44	253.72 (32)	14.08	257.57 (42)	8.37
VII	271.84 (25)	15.93	271.17 (14)	17.45	272.80 (11)	15.23
VIII	298.16 (4)	26.32	234.5* (1)	-36.67	340.0** (3)	67.20

* One highly emaciated fish with a fork length of 311.0 mm.

** Three normal fish.

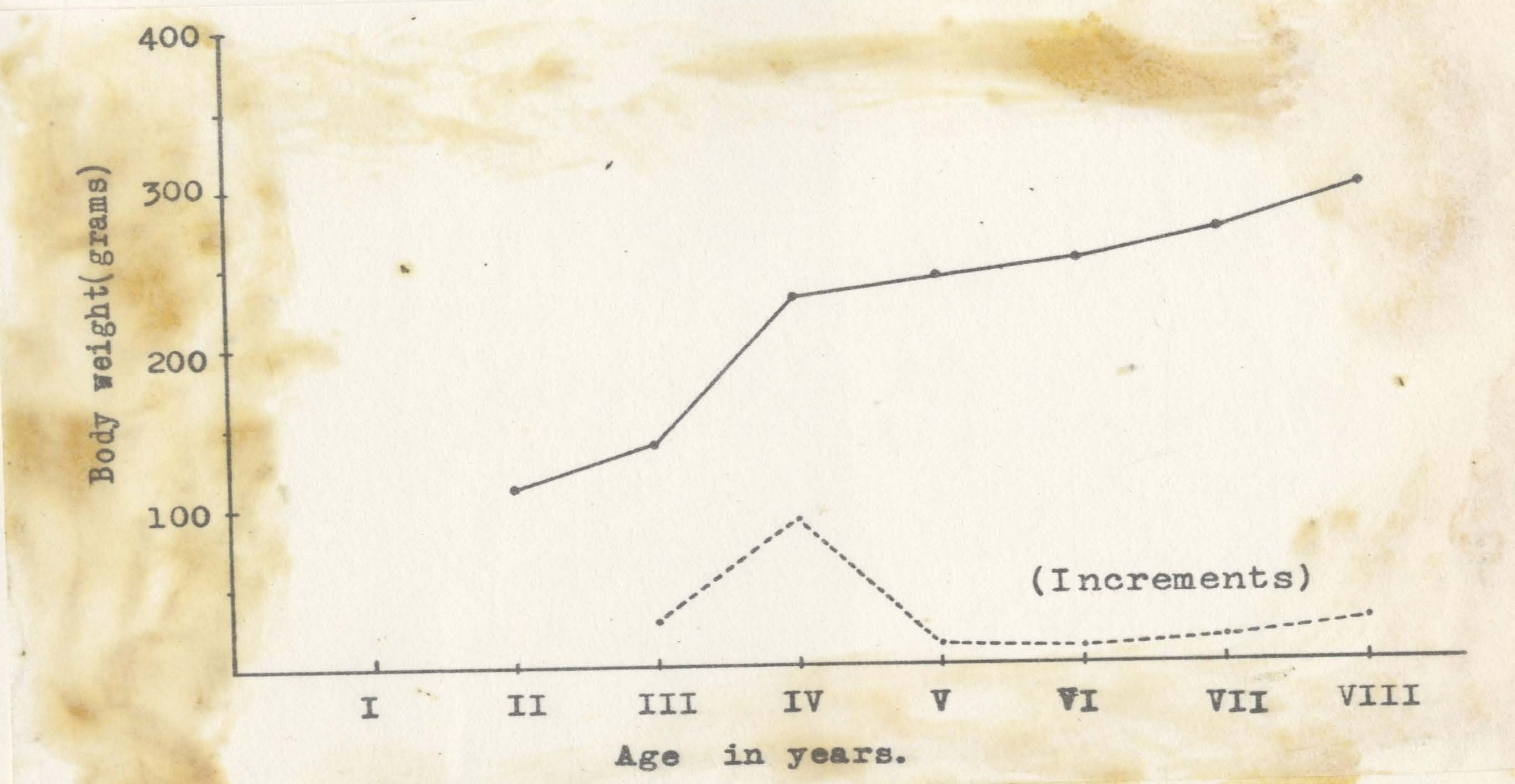


Fig. 22 ---Growth in weight of the age groups of 258 lake whitefish from Hogan's Pond.

Table 27 ---Growth in weight of age groups of 258 lake whitefish from Hogan's Pond, showing comparison of normal and emaciated growth.

Age group	No. of normal fish	No. of emaciated fish	Average body weight (grams)		
			Sexes combined	Male	Female
II	3		113.0	106.5(2)	121.0(1)
		0			
III	29		139.2	140.9(16)	137.1(13)
		0			
IV	41		231.35	236.0(24)	234.8(17)
		4	226.87*	228.1(2)	219.0(2)
V	68		247.76	248.7(32)	246.9(36)
		10	223.90	228.6(8)	205.0(2)
VI	49		265.34	269.4(20)	262.6(29)
		25	237.41	232.3(12)	242.2(13)
VII	15		297.49	297.7(12)	296.5(3)
		10	235.94	218.76(6)	261.7(4)
VIII	3		340.00	302.0(1)	359.2(2)
		1	234.50	234.5(1)	-----

* Figures for emaciated fish are underlined.

(Figures in parentheses indicated number of fish)

Sexual dimorphism of growth in weight is also not obvious, however, as shown in Table 27 the females slightly heavier than the males except at age III-group.

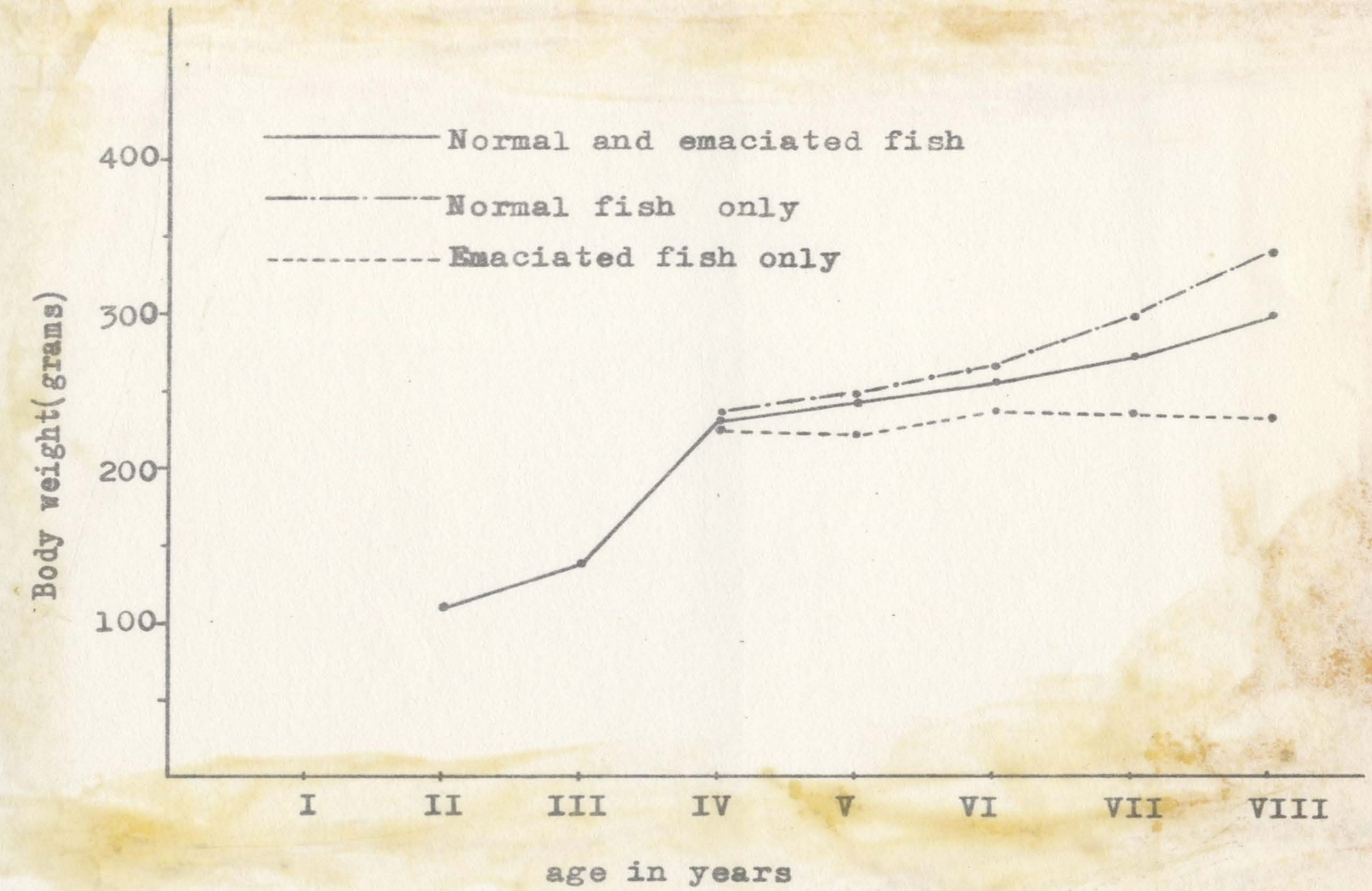


Fig. 23 ---Growth in weight of the age groups of 258 lake whitefish from Hogan's Pond, showing normal and emaciated growth.

Age-weight linear relations for 258 lake whitefish and 50 highly emaciated specimens are shown in Table 28 and Fig. 24. The relations can be expressed by the equations:

$\log W = 1.8428 + 0.7277 \log A$ ----------258 whitefish

$\log W = 2.3656 + (-0.001) \log A$ --------50 emaciated fish.

The equation for 50 emaciated whitefish indicated that there is no increasing of body weight with increase in age, the curve shows exactly parallel to the age axis (X-axis).

Table 28 ---Age-weight relationship of 258 lake whitefish and 50 emaciated lake whitefish from Hogan's Pond.

(Figures in parentheses indicated number of fish)

Age group	258 whitefish		50 whitefish	
	Empirical weight (gram)	Calculated weight (gram)	Empirical weight (gram)	Calculated weight (gram)
II	111.3 (3)	115.5		
III	139.3 (29)	155.2		
IV	230.9 (45)	191.5	226.87 (4)	231.7
V	244.47 (78)	225.1	223.90 (10)	231.7
VI	255.91 (74)	257.1	237.41 (25)	231.6
VII	271.84 (25)	287.6	235.94 (10)	231.6
VIII	298.16 (4)	317.0	234.50 (1)	231.6

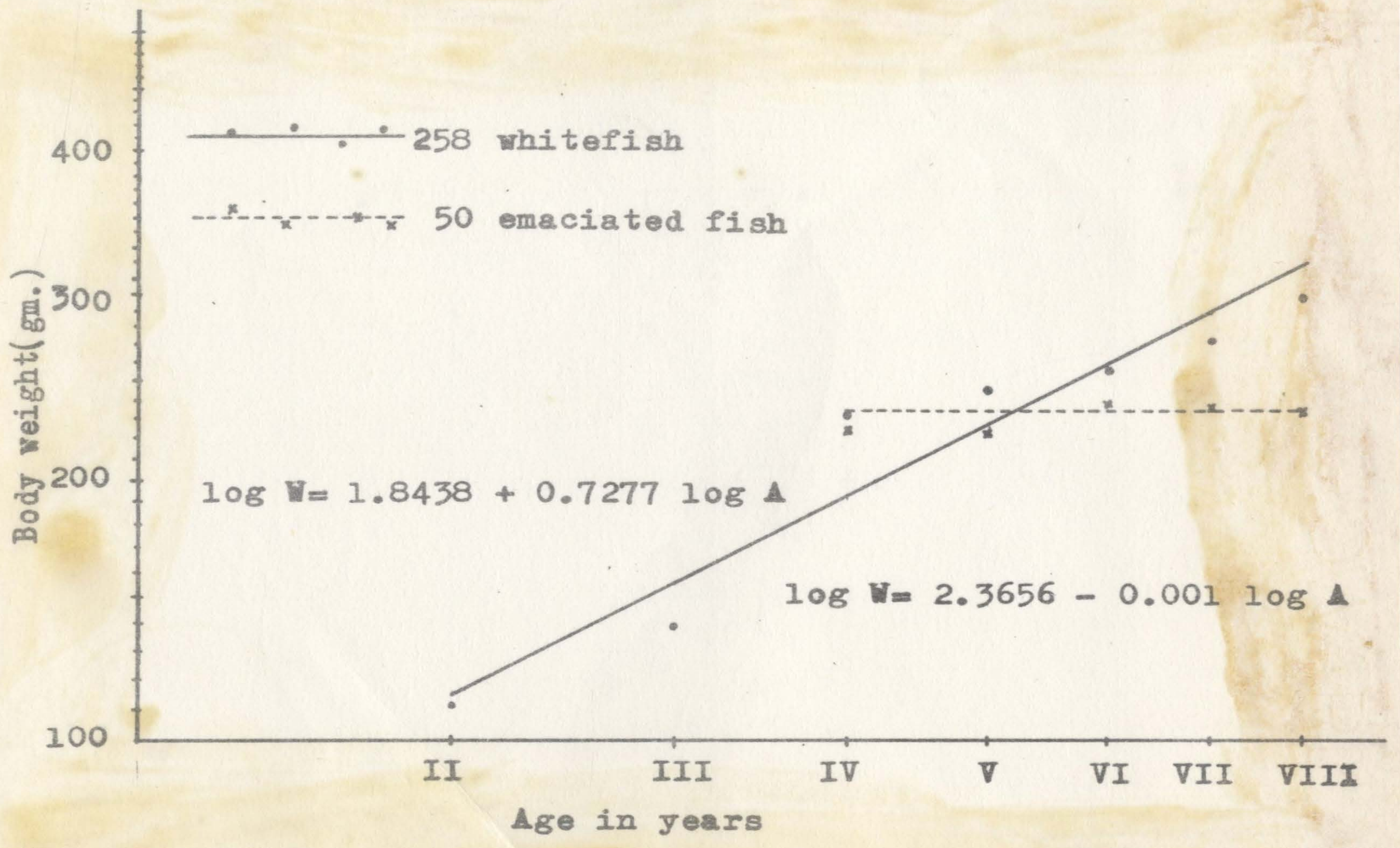


Fig. 24 ---Age-weight relationship of 258 lake whitefish and 50 emaciated lake whitefish from Hogan's Pond.

The relatively rapid growth during the very first or two years may be correlated with the temperature and food. The experiment of Hall (1925) on Coregonus clupeaformis shows that when eggs are incubated at lower temperature the embryos at the moment of hatching are significantly larger than those hatched from eggs which have been incubated at higher temperature. Undoubtedly, the temperature of Hogan's Pond at the hatching period (April or early May) must be significantly lower than that of Lake Erie during the same period.

The abundant zooplanktons may also responsible for a better growth condition during the early life of whitefish. The earliest foods of Coregonus clupeaformis, as Forbes (1882) points out, are chiefly pelagic forms of minute animals, such as Gammarus, Daphnia, and Cyclops etc. which are plentifully found in Hogan's Pond.

In addition, it is universally known that larger eggs will hatch out bigger fry. Hogan's Pond whitefish though produce fewer number of eggs, they posses larger size of eggs. The average diameters of eggs for 35 lake whitefish of Hogan's Pond range from 1.0 to 2.7 mm., whereas the average egg diameters of 13 Lake Erie whitefish taken during the last week of July and the first week of August 1948 ranged from 0.95 to 1.40 mm (Lawler, 1961).

F. Length-weight relationship.

In any object the volume increase as the cube of the linear dimensions. Assuming that the weight of fish (W) is proportional to volume and the length of fish (L) is proportional to the linear dimension, weight of fish can be considered a function of the length (Hile, 1936). If body weight and length are increasing constantly throughout the life, the relationship of the length and weight could follow exactly the cube law relationship expressed by the formula $K = W/L^3$, in which K is constant. Unfortunately, as fish, as well as most of the other animals, is constantly prone to change its length-weight proportion during life, so that the simple cube law expression does not hold throughout the life history and the growth of the fish (Rounsefell and Everhart, 1953). A more satisfactory formula for the expression of length-weight relation is $W = a\ L^n$ (Lagler, 1952), in which " a " is a constant and " n " is exponent. In practice, the length-weight relationship would be first expressed logarithmically as follow:

$$\log W = \log a + n \log L$$

Length-weight relationship is purely an academic point of view of growth (Lagler, 1952). It is often very useful in growth study, fishery management, in solving taxonomic problem (Speirs, 1952) and in estimating the condition of fish in particular waters (Beckman, 1945).

Data from 258 specimens (fork length ranging from 201 mm. to 355 mm.) were grouped in 5 millimeters fork length length classes. Both sexes, highly emaciated and normally growing fish are combined as well as separated for the purpose of comparison.

1. Sexes combined.

Mraz (1964) claims that length-weight equation, to be most useful, should include fish of both sexes, sampled at various times of a year over a period of years. Bias from seasonal and annual variations, sex difference, and maturing state of gonads is minimized by this procedure.

For 258 specimens, the general length-weight equation was fitted to the means of these length groups. The logarithmic form of the equation is:

$$\log W = -0.9398 + 2.2779 \log L \qquad \text{or}$$

$$W = 0.1148\ L^{2.2779}\ .$$

The correspondence between the empirical and the calculated weight was generally better among younger fish than among older fish. Fish with lengths ranging from 201 to 243 mm. had the calculated weight slightly greater than the empirical weights by average 6.5 grams in any 5-millimeter length groups (Table 29 and Fig. 25). This may be due partly to paucity of observation, since there are only 32 specimens within the lengths between 201 and 243 mm., but there also appears to be a definite change in proportional development at or near these lengths. The empirical weight of larger fish of fork lengths between 246.2 and 298.0 mm., on the other hand, were significantly greater than calculated weight by an average of 19.4 grams (ranging from 6.7 to 36.4 grams). This indicates that fish with lengths between 246.2 and 298.0 mm. gain more weight per unit length than do smaller ones. It could also be signified that whitefish of Hogan's Pond reach the onset of maturity at these lengths. This explanation seems to be logical by the further analysis of age and length at maturity. It is also obviously that the data from 258 specimens were affected by the presence of spawning fish as some of the fish were collected in the spawning period (October and November). Fish larger than 298.0 mm., again, showed that the calculated weights greater than the empirical weights by an average of 26.4 grams. The greatest discrepancies among these fish larger than 298.0 mm. clearly indicate a great degree of emaciation among larger fish. The low value of exponent in the equation (2.2779) makes it evident that the weight increased at a rate much less than the cube of the length.

Data on length-weight relationship from 208 normally growing fish are also listed in Table 30 and shown in Fig.25. The equation of length-weight relation for these 208 specimens is:

$$\log W = -1.5681 + 2.7362 \log L$$

or

$$W = 0.027\, L^{2.7362}$$

The data also shown similar fluctuations between the empirical and the calculated weights, that is, among younger fish the calculated weights appear slightly greater than the empirical weights; among fish of intermediate size, the empirical weights were significantly greater than the calculated weights and, again, among larger fish, calculated weights were much greater than empirical weights. However, the agreement between the calculated and empirical weights of these 208 specimens was better than that of 258 fish. The length range, 208-243.2 mm., had the calculated weights greater than the empirical weights by average 3.4 grams (as compared to 6.5 grams among the same length intervals of 258 specimens). The empirical weights of fish lengths between 246.2 and 278.6 mm. were, on the other hand, significantly heavier than the calculated weights by an average 13.1 grams. Over the remainder of length range (283.4-319.0 mm.) the calcualted weights were greater than the empirical weights again by average 10 grams, except at length group of 292.9 mm. where the empirical weights outweighted the calculated ones by 11.3 grams. It is hard to say that fish at that lengths included most fish at their mature stage or ripe condition, since the length class was represented by 12 males and 2 females and contained only one mature female and 4 mature males which were excepting to spawn in that winter. It is also worthy to note that highly emaciated fish were excluded from here and, consequently, the discrepancies of the calculated and empirical weights was much less. The higher value of exponent (2.7362) resulted from exclusion of highly emaciated fish indicates that the weight of fish increased at a rate close to the cube of the length.

Data on 50 highly emaciated fish were listed in Table 31 and also shown in Fig. 25. The equation of length-weight relation for these 50 specimens is:

$$\log W = -1.2093 + 2.4148 \log L$$

or

$$W = 0.0617\ L^{2.4148}$$

The lack of small fish and the scarcity of specimens in this respect prevent a satisfactory illustration, and the higher value of exponent (2.4148) than that of 258 fish (2.2779) is by no means an indication of better growth in weight than the latter. Table 32 shows the lengths and weights of 50 highly emaciated fish at capture.

Table 29 ---Length-weight relationship of 258 lake whitefish taken from Hogan's Pond in 1965 and 1966.

(The lengths are fork length averages for fish in 5 mm. groups)

No. of fish	Average length	Average weight (gram)	
		Empirical	Calculated
1	201.0	104.0	106.9
1	208.0	102.0	115.5
4	212.0	114.0	120.6
4	218.2	122.0	128.8
4	223.2	127.5	135.6
6	227.1	131.0	141.1
5	233.0	145.0	149.6
2	236.5	148.5	154.7
5	243.2	166.7	165.0
4	246.2	185.0	169.4
7	254.0	193.8	182.1
6	259.0	226.8	190.4
11	264.0	222.9	198.8
17	268.3	237.4	206.3
22	273.1	239.0	214.7
23	278.6	246.8	224.7
23	283.2	243.0	233.3
20	288.0	249.2	242.5
19	293.0	272.8	252.2
16	298.0	273.5	262.0
19	303.2	261.8	273.1
18	308.2	261.7	283.0

Table 29 ---Length-weight relationship (continued)

No. of fish	Average length	Average weight (gram)	
		Empirical	Calculated
13	313.3	276.3	293.6
5	317.7	277.3	303.5
2	322.0	275.0	312.6
1	335.0	297.0	342.0

$$\log W = -0.9398 + 2.2779 \log L$$

or

$$W = 0.1148 \ L^{2.2779}$$

Table 30 ---Length-weight relationship of 208 normally growing lake whitefish taken from Hogan's Pond in 1965 and 1966.

(The lengths are fork length averages for fish in 5 mm. groups)

No. of fish	Average length	Average weight (gram)	
		Empirical	Calculated
1	201.0	104.0	99.50
1	208.0	102.0	109.20
4	212.0	114.0	115.0
4	218.2	122.0	124.6
4	223.2	127.5	132.5
6	227.1	131.2	139.0
5	233.0	145.0	149.0
2	236.5	148.5	155.2
5	243.2	166.7	167.6
4	246.2	185.0	173.3
7	254.0	193.8	188.8
6	259.0	226.8	199.1
11	264.0	222.9	209.7
17	268.3	237.4	219.2
21	273.0	242.4	230.0
23	278.6	246.8	243.0
21	283.4	246.3	254.6
18	287.9	252.9	266.0
15	292.9	290.0	278.7
11	298.0	290.8	292.1
10	303.3	301.5	306.3

Table 30 (continued)

No. of fish	Average length	Average weight (gram)	
		Empirical	Calculated
7	308.8	302.4	322.1
3	313.0	324.6	334.1
2	319.0	328.5	352.1

$$\log W = -1.5681 + 2.7362 \log L$$

or

$$W = 0.027\ L^{2.7362}$$

Table 31 ---Length-weight relationship of 50 emaciated lake whitefish taken at Hogan's Pond in 1965 and 1966.

(The lengths are fork length averages for fish in 5 mm. groups)

No. of fish	Average length	Average weight (Gram) Empirical	Average weight (Gram) Calculated
1	275	172.0	184.6
2	282	209.0	196.3
2	288	215.5	206.5
4	293	208.5	215.3
5	297	238.8	222.4
9	303	217.6	233.3
11	308	239.6	243.0
10	313	261.8	252.3
4	318	251.8	262.2
1	322	275.0	270.4
1	335	297.0	297.5

Table 32 ---Lengths and weights of 50 emaciated lake whitefish taken from Hogan's Pond in 1965 and 1966.

(Figures in parentheses indicated number of fish)

Male		Female		Sexes combined	
Length (F.L.)	Weight (gram)	Length (F.L.)	Weight (gram)	Length (F.L.)	Weight (gram)
275 mm.(1)	172.0	---	---	275	172.0
282 (2)	209.0	---	---	282	209.0
290 (1)	222.0	286 (1)	209.0	288	215.5
294 (2)	206.0	293 (2)	211.0	293	208.5
298 (4)	237.4	297 (1)	243.0	298	238.8
303 (3)	211.5	303 (6)	220.7	303	217.6
308 (7)	230.0	307 (4)	256.2	308	239.6
313 (6)	253.4	314 (4)	274.2	313	261.8
318 (3)	252.0	317 (1)	251.0	318	251.8
---	---	322 (1)	275.0	322	275.0
---	---	335 (1)	297.0	335	297.0

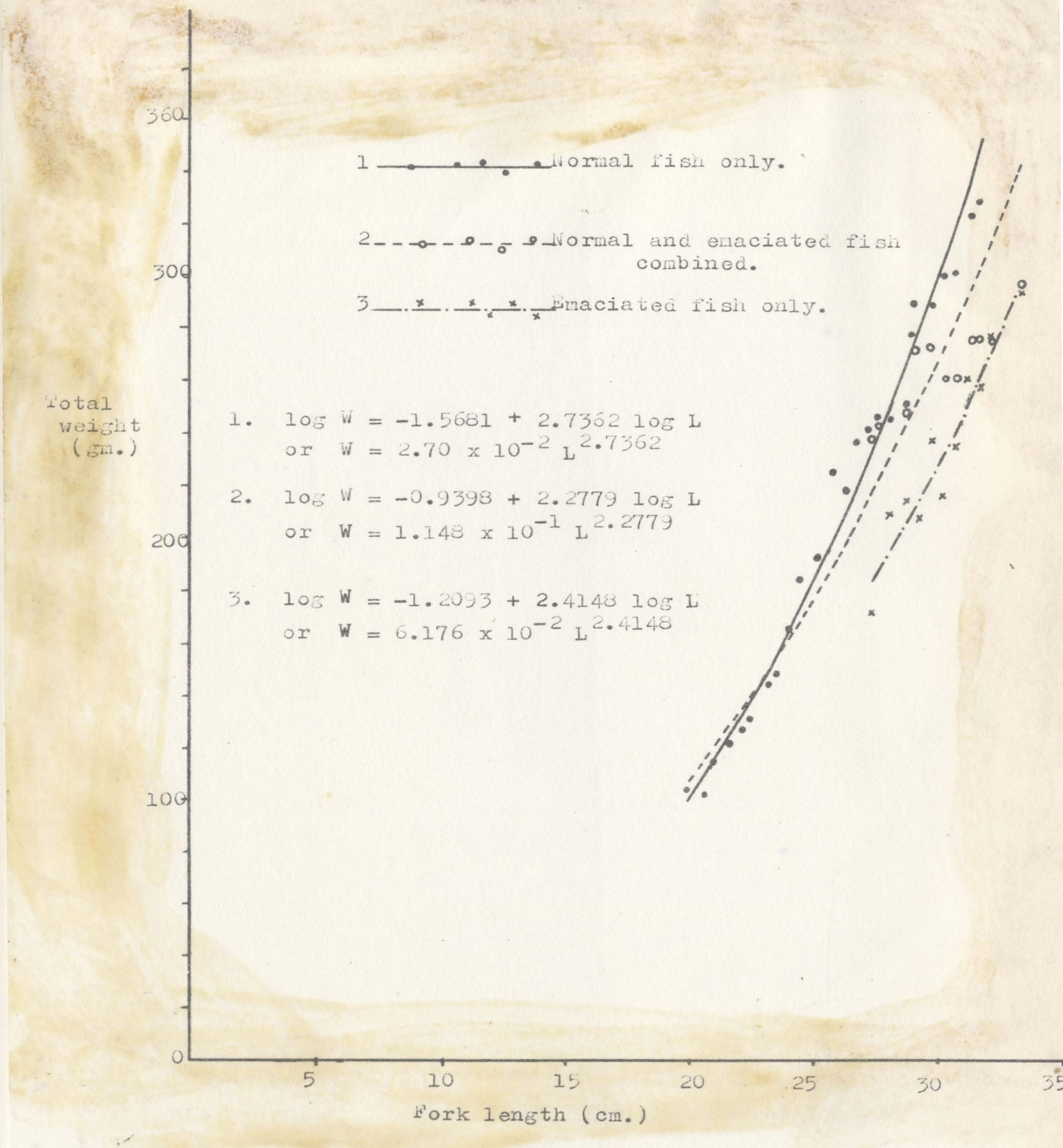


Fig. 25 ---Length-weight relationship of Hogan's Pond lake whitefish taken in 1965 and 1966.

ii. Sexes separated.

Undoubtedly the length-weight relation varies during the year and between ripe and recently spent females. The length-weight relationship of both sexes are listed in Table 33 and 34; and are shown in Fig. 26. The pattern of discrepancies of both sexes between the empirical and the calculated weights were quite similar to that of data on sexes combined.

a) Male whitefish.

The equation of length-weight relation for 136 males is:

$$\log W = -1.1844 + 2.4505 \log L$$

or

$$W = 0.0654\, L^{2.4505} \quad \text{(Fig. 27)}$$

When the highly emaciated fish were excluded the equation became:

$$\log W = -1.5954 + 2.7516 \log L$$

or

$$W = 0.02539\, L^{2.7516}$$

The length range, 208 to 243 mm. had the calculated weight greater than the empirical weights by an average of 8.0 grams; fish of intermediate size (246 to 298 mm.) had the empirical ones outweighted the calculated ones by an average of 16 grams; the larger fish had the calculated weights greater than the empirical weights again, except at length of 322 mm. where the empirical one outweighted the calculated one by 24.4 grams. The largest disagreement occurred at 318 mm. length class, represented by three highly emaciated fish, where the empirical weight below the calculated weight 62.2 grams. The agreement between the calculated and the empirical weights was better when highly emaciated fish were excluded.

Table 33 ---Length-weight relationship of 136 male whitefish taken from Hogan's Pond in 1965 and 1966.
(The lengths are fork length averages for fish in 5 mm. groups)

No. of fish	Average length	Average weight (gram) Empirical	calculated
1	201.0	104.0	102.1
1	208.0	102.0	111.1
2	211.5	111.0	115.7
2	217.5	119.0	123.9
1	223.0	123.0	131.7
2	227.0	125.5	137.6
4	233.5	144.0	147.4
2	236.5	148.5	152.1
3	243.0	162.8	162.6
2	246.0	178.0	167.5
4	253.0	190.3	179.5
4	258.5	221.0	189.2
6	263.8	213.7	198.8
4	268.2	240.2	207.3
10	272.9	230.8	216.0
8	278.5	254.9	227.1
15	283.2	242.1	236.6
10	288.6	251.4	247.7
11	292.6	274.1	256.4
10	298.1	270.1	268.1
11	303.2	272.3	279.6
11	307.9	253.5	289.7
8	312.5	265.1	301.2

Table 33 (continued)

No. of fish	Average length	Average weight (gram)	
		Empirical	Calculated
3	318.0	252.0	314.2
1	322.0	346.0	321.6

$$\log W = -1.1844 + 2.4505 \log L$$

or $$W = 0.0654\ L^{2.4505}$$

b) Female whitefish.

The equation of length-weight relation for 122 female fish is: $$\log W = -0.5809 + 2.0342 \log L$$

or $$W = 0.2645\ L^{2.0342}$$

The low exponent indicates that the weight of fish increased almost at a rate of square of the length rather than at a rate of cube of length. When the highly emaciated fish were excluded, the equation became: $$\log W = -1.5104 + 2.7029 \log L$$

or $$W = 0.03087\ L^{2.7029}$$

As far as calculated weights are concerned, female fish are slightly heavier than male fish at each corresponding length group. The empirical weights also show, in general, the same relation.

Generally speaking, lake whitefish of Hogan's Pond, regardless of sex, tend to increase more length than weight, or as the fish gets longer it becomes more slender. Alm (1946) points out that the weigh of a fish at a certain length is principally connected with the supply of food. The uncommonly poor growth of whitefish in Hogan's Pond, especially with regard to the body weight, could be attributed to the exceedingly dense population (Scott and Crossman, 1964) and the subsequent deficiency in food supply (see section " the food of whitefish in Hogan's Pond).

Table 34 ---Length-weight relationship of 122 female lake whitefish taken from Hogan's Pond in 1965 and 1966.

(The lengths are averages of fork length for fish in 5 mm. groups)

No. of fish	Average length	Average weight (gram) Empirical	Calculated
2	212.5	117.0	131.5
2	219.0	125.0	139.8
3	223.3	129.0	145.5
4	227.2	133.8	150.8
1	231.0	149.0	155.9
2	243.5	172.5	173.6
2	246.5	192.0	186.4
3	253.3	198.5	188.0
2	259.5	238.5	197.6
5	264.4	234.0	205.2
13	268.3	237.0	211.4
12	273.3	247.0	219.6
15	278.3	241.6	227.8
8	283.3	244.8	236.2
10	287.3	246.5	243.1

Table 34 (continued)

No. of fish	Average length	Average weight (gram)	
		Empirical	Calculated
8	293.6	271.3	254.0
6	297.8	280.0	261.5
8	303.1	246.5	271.0
7	308.7	271.8	281.3
5	314.6	294.2	292.0
2	317.5	281.0	298.0
1	322.0	275.0	306.6
1	335.0	297.0	332.4

$$\log W = -0.5809 + 2.0342 \log L$$

or $$W = 0.2645\, L^{2.0342}$$

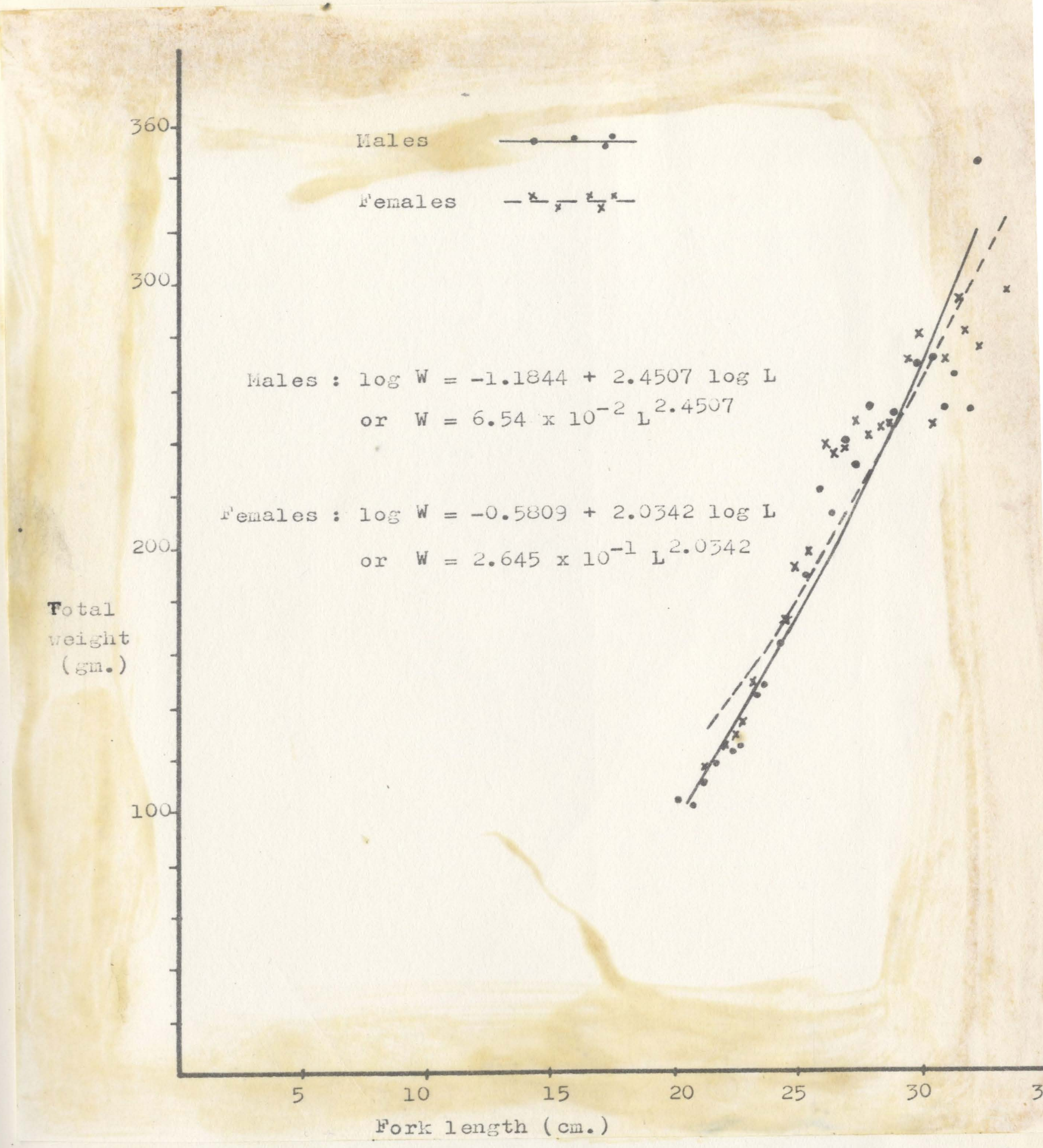


Fig. 26 ---Length-weight relationship of 136 male and 122 female lake whitefish from Hogan's Pond.

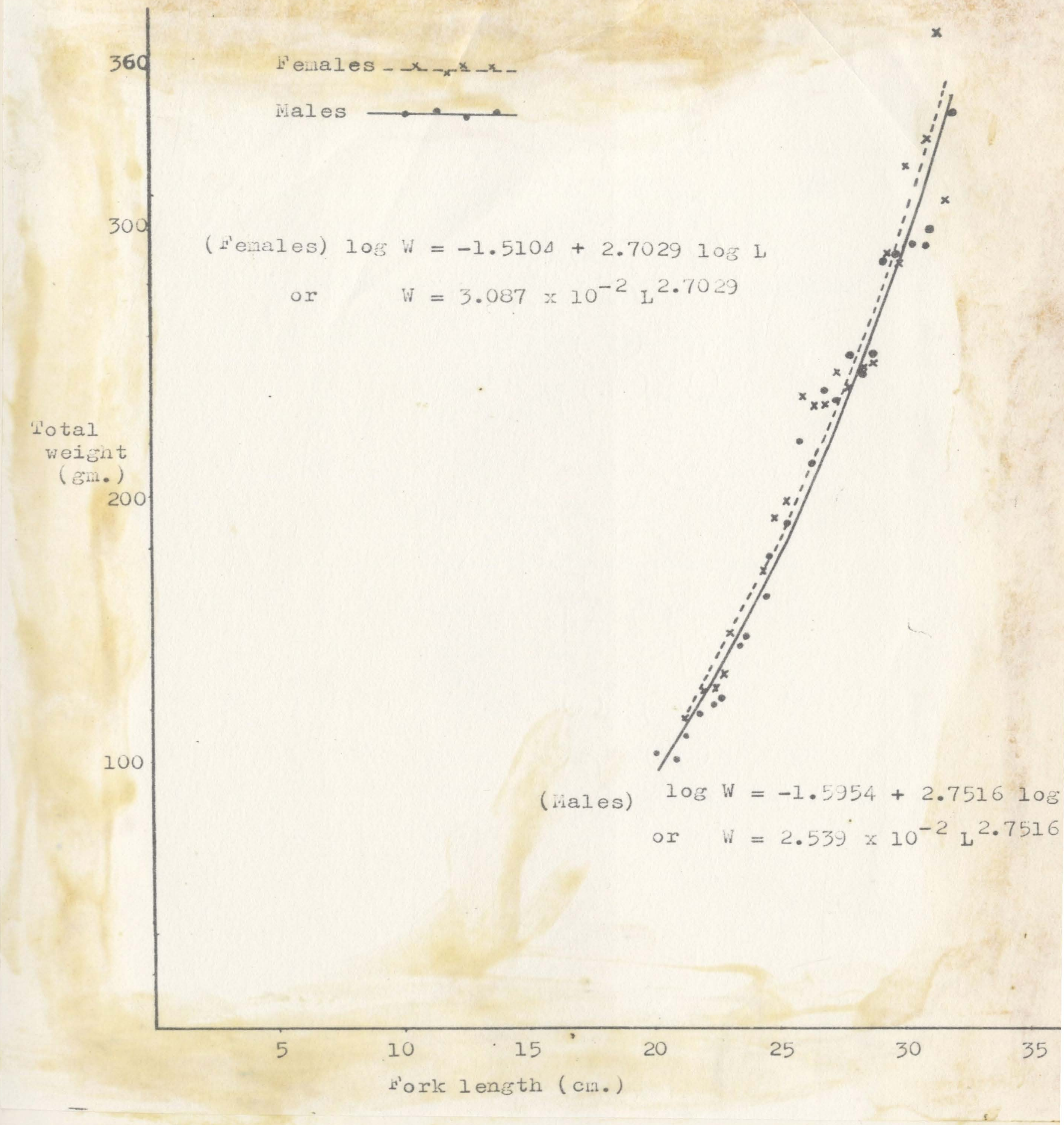


Fig. 27 ---Lrngth-weight relationship of normally growing whitefish from Hogan's Pond.

G. Coefficient of condition.

The coefficient of condition (K), or ponderal index, as computed from the relationship $K = 10^5 W/L^3$, is used to express the condition of fish directly in numerical term--degree of well being, relative robustness, plumpness or fatness. It is also used to indicate suitability of an environment or to compare fish from one lake or area with the fish of same kind from another lake or area; or to measure the effect of environmental improvement (Cooper and Benson, 1951). For the best practical purpose, values of coefficient of condition which are to be compared should at least be based on fish of same sex, length and age collected in the same season of the year (Lagler, 1952). Following the same suggestion, I have separated the 258 specimens into various length groups, age groups, and different sex groups.

In Table 35, 258 specimens were grouped into 10 mm. fork length intervals. The average value of K for 258 fish, which was calculated individually, was found as 1.072, and the K values ranged from 0.6208 to 1.4565. Beckman (1943) claims that the average value of K can be used for estimating unknown weights from known lengths only if the length-weight relationship conforms rather closely to the "cube law", that is, if the exponent in the length-weight equation deviated only slightly from the value 3. The exponents in the length-weight equations for Hogan's Pond whitefish deviated so largely from the value 3 that a great systematic error may be involved in the use of the mean K for the estimation of growth.

Fluctuations in the values of K represent changes in the condition, or relative heaviness, of the fish. Poor condition is shown by low values and good condition by the high ones. The values of K as determined for each length interval varied irregularly. Among smaller fish, except in the first two length intervals where the values of K show a tendency of decrease, the values of K slightly increases with increasing length up to the highest value (1.2457) at 256.3 mm. of length class and the second highest (1.2259) at the length of 266.6 mm. interval. After that, the values of K exhibited a tendency to decrease with increasing length with the lowest value (0.7899) at the longest length class (335 mm.). The explanation to these fluctuations is similar to that mentioned in the length-weight relationship. The growth condition of whitefish in their first or first two years of life is fairly good. The highest values of K among the fish of intermediate size was associated with the onset of maturity. The low values among larger fish reflect poor condition of growth or indicate a great degree of emaciation among the larger fish. The wider ranges of K values at each length interval among larger fish, perhaps, provide a better illustration of the degree of emaciation. In general, Table 35 appears to demonstrate that the smaller fish were in better condition than were the larger fish.

From the equation of length-weight relation, we obtain an exponent 2.2779 for 258 specimens that indicate the whitefish of Hogan's Pond increase the weight as the 2.2779 power of the length. In other word, it signifies that the values of condition (K) should decrease as about 0.722 power of the length (Van Oosten, 1947). The data of the coefficient of condition for 258 specimens, as shown in Table 35, do exhibit a general trend toward a decrease in K with increase in length. The decrease, however, was decidedly irregular.

Table 35 ---Summary data on the coefficient of condition (K) of 258 lake whitefish taken from Hogan's Pond in 1965 and 1966.

Average length	No. of fish	Range in K	Average K
204.5 mm.	2	1.1334-1.2806	1.2020
215.1	8	1.1510-1.2880	1.1873
225.5	10	1.0395-1.1673	1.1348
234.0	7	1.1031-1.2087	1.1394
244.5	9	1.0675-1.2156	1.1972
256.3	13	1.0845-1.4197	1.2457
266.6	28	1.0034-1.4565	1.2259
275.9	45	0.8270-1.4013	1.1557
285.4	43	0.8934-1.2267	1.0589
295.2	35	0.7073-1.3209	1.0635
305.7	37	0.6208-1.3426	0.9216
314.5	18	0.6686-1.1965	0.8495
322.0	2	0.8050-0.8422	0.8236
335.0	1		0.7899
Total	258	0.6208-1.4565	1.0720

The values of K, according to age and year catch, were listed in Table 36; and those according to age and sex were listed in Table 37. It may be seen that there was a tendency for the values of K to decrease with increased age of fish for both year catches and both sexes. The average value of K for 120 fish caught in 1965 (1.1324) was slightly greater than that of 138 fish caught in 1966 (1.0407). The disagreement about what have just been mentioned in age-weight and age-length relations, that fish caught in 1966 showed a better growth rate (being larger and heavier at each corresponding age group) than those caught in 1965, suggests that good condition was associated with slow growth or, perhaps, there is no definite relationship between condition and rate of growth as suggested by Van Oosten and Hile (1947), and Jobes (1943). Jobes (1943) also found that Reighard's chub (Leucichthys reighardi) in Lake Michigan, the good condition was associated seemingly with slow growth. Since the same gill nets were employed in either 1965 sampling or 1966 sampling, the selection of gill nets can not be effective in this regard.

Female whitefish were generally in better condition than male whitefish. The average value of K for 122 female whitefish (1.1412) was greater than that of 136 male whitefish (1.0660). Age II-group of both sexes showed the best condition among all groups. The K values of emaciated fish and normally growing fish, as shown in Table 36 and 37, revealed sharp difference in their conditions.

Table 36 ---Summary data on the coefficient of condition (K) of lake whitefish taken from Hogan's Pond in 1965 and 1966, showing comparison of normal and emaciated fish.

Age group	1965 catch Normal fish	Emaciated	Combined	1966 catch Normal fish	Emaciated	Combined
II	---	---	---	1.2045	---	1.2045
III	1.1623	---	1.1623	1.1421	---	1.1421
IV	1.2473	0.7789	1.1444	1.1346	0.8940	1.1003
V	1.1709	0.8213	1.1520	1.0689	0.8640	1.0920
VI	1.2015	0.7919	1.0990	1.1012	0.8431	0.9991
VII	1.0895	0.7430	0.9829	1.0321	0.8192	0.9160
VIII	---	0.7779	0.7779	1.0670	---	1.0670
Average	1.1869	0.7816	1.1324	1.1034	0.8482	1.0407

Table 37 ---Summary data on the coefficient of condition (K) of lake whitefish taken from Hogan's Pond in 1965 and 1966, showing comparisons between sexes, and between normal and emaciated fish.

Age group	Male			Female		
	Normal fish	Emaciated	Combined	Normal fish	Emaciated	Combined
II	1.2204	---	1.2204	1.2806	---	1.2806
III	1.1285	---	1.1285	1.1658	---	1.1658
IV	1.1889	0.9275	1.1688	1.2104	0.8030	1.1675
V	1.1087	0.9557	1.0581	1.1327	0.8545	1.1181
VI	1.1382	0.8073	1.0141	1.1567	0.8446	1.0624
VII	1.0816	0.7506	1.0281	1.0065	0.8458	0.9107
VIII	1.0644	0.7779	0.9222	1.0635	---	1.0635
Average	1.1335	0.8162	1.0660	1.1532	0.8132	1.1412

H. Calculated growth.

i. Calculated growth in length.

The scale method for calculating the rate of growth in fish, or back calculation, is based on the assumption that the length (diameter) of a growth zone on scale is proportional to the growth of a fish in length. In other word, the variation in length of the scale zone reflects the variation in growth of the fish in successive year. Earlier workers assumed that the scale grew proportionally at the same rate as the fish and the formula for the back calculation of body length was assumed as:

$$\frac{\text{Length of scale formed at end of year x}}{\text{Total length of scale}} = \frac{\text{Length of fish at end of year x}}{\text{Length of fish at capture}}$$

(Van Oosten, 1923).

However, the direct proportion between the growth of scale and fish is far from exact, since the scale appears only after the fish has attained some size, namely, at the time of scale formation (Huntsman, 1918), therefore the body length at time of scale formation should be employed as a correction in the direct proportional formula. Consequently, the formula for the back calculation of body length become:

$$Ln = C + \frac{(Lt-C)\ Sn}{St}$$

(Lagler, 1952; Rounsefell and Everhart, 1953)

where Ln = the length of the fish at the end of nth year of life.

S_n = the diameter or length of the scale with the nth annulus.

L_t = the length of fish at capture.

S_t = the total diameter or length of scale.

C = the intercept or the body length of fish at time of scale formation.

The length of fish at time of scale formation can be calculated from body-scale relation. Key scales taken from an exactly defined location were not available, but scale samples removed from key area of all 258 fish are believed reliable for the determination of body-scale regression (Edsall, 1960). The average scale diameter was based on the measurements of three scales from each fish at the magnification of x 43.

The body-scale relation, as shown in Table 38 and Fig. 28, is obviously linear and expressed by the equation:

$$L = 2.743 + 3.674\,S$$

where L = fork length in cm.
S = scale diameter (x43) in cm.

The length of fish at time of scale formation is, therefore, 2.743 cm. or 1.08 inches.

Numerous explanations of discrepancies in calculated lengths or "Lee's phenomenon" have been reported. Some have critized that "Lee's phenomenon" reflects on the accuracy of the scale method, so that a comparison of calculated growth is unwarranted (Hoek, 1912--listed in Van Oosten, 1929). Some have been traced to the use of incorrected formula (direct proportional formula) for growth calculation (Fraser, 1916; Mottram, 1916; and Taylor, 1916, etc.), but when body-scale relation has been determined accurately and used as a correction factor, most workers have generally attributed the discrepancy to the gear selection of the larger fish in the younger age groups and destruction of the more rapidly growing individuals (Dryer, 1963; Jobes, 1942; Mraz, 1964; Dryer and Beil, 1964). Mraz (1964) also suggests that annual fluctuations of growth rate in combination with sample differences of year class composition is a major cause. The discrepancies of calculated length in this study may be attributed chiefly to the small number of fish in certain age groups as has also been suggested by Bailey (1964), or perhaps, the gear selectivity and the combinations of two year catches which apparently displayed different growth rate.

The computed average increments of growth in length are shown in Table 39 and plotted in Fig. 29. The annual calculated increment in length was highest at the first year and thereafter decreased with increase in age. As compared to this, the actual annual increment in length clearly show that greater body length increment also occurs as the fish reaches the fourth year of life or reaches maturity. This is more obviously seen in annual increments of body weight as shown in Fig. 30.

Edsall (1960) reports that the intercept for lake whitefish of Munising Bay (Lake Superior) is 1.486 inches or 3.774 cm., whereas Dryer (1963) describes the body-scale relation of lake whitefish in Bayfield (Lake Superior) is nearly a direct proportion; the intercept is so small, only 0.04 inches, that it can be ignored, growth accordingly, may be calculated by direct proprotional formula. Here in the present study, the back calculation was based on the formula with intercept as a correction factor.

The calculated growth in fork length of 258 whitefish is listed in Table 39 and shown in Fig. 29. The sexes, normally growing and emaciated fish have been combined for calculated, since they differ only slightly in growth in body length. The results of back calculation show some evidences of "Lee's phenomenon" that is for corresponding years, the length calculated from the scales of old fish were lower than those calculated from the scales of younger fish; in other word, the amount of calculated growth at **corresponding** ages increases regularly as the scales used are taken from fish of younger age groups. For example, first-year calculated length was the highest at age-group II. Second-year calculated length decreased all the way from 216.2 mm. for age III-group to 177.2 mm. for VIII-group. Similar phenomenon occurred in third and fourth-year calculated lengths. These discrepancies of calculated lengths seem to be greater among older age groups than younger age groups. For younger age groups, the calculated lengths at end of earlier years of life show about 1-2 cm. (10-20 mm.) longer than actually measured lengths at each corresponding years, while the calculated lengths at end of earlier years of life being about 10-40 mm. shorter than **measured** lengths. Observed and calculated growth agree quite well (Fig. 29), but generally speaking, calculated length is slightly less than observed length, because the calculated length represents the size of fis at formation of the annulus during early spring, and observed lengt represents the length of the fish during the growing season when it was captured.

From a study of both measured and calculated lengths, it is concluded that whitefish of Hogan's Pond initiated a period of increased growth at their second year of life or younger.

Table 38 ---Scale-body length relationship of 258 lake whitefish taken from Hogan's Pond in 1965 and 1966.

Average fork length (cm.)	No. of fish	Scale diameter x 43 (cm.)
20.45	2	5.01
21.51	8	5.07
22.55	10	5.21
23.40	7	5.37
24.45	9	5.99
25.63	13	6.37
26.66	28	6.50
27.59	45	6.83
28.54	43	6.96
29.52	35	7.32
30.55	37	7.58
31.45	18	7.85
32.20	2	8.01
33.50	1	8.18

$$L = 2.743 + 3.674\ S$$

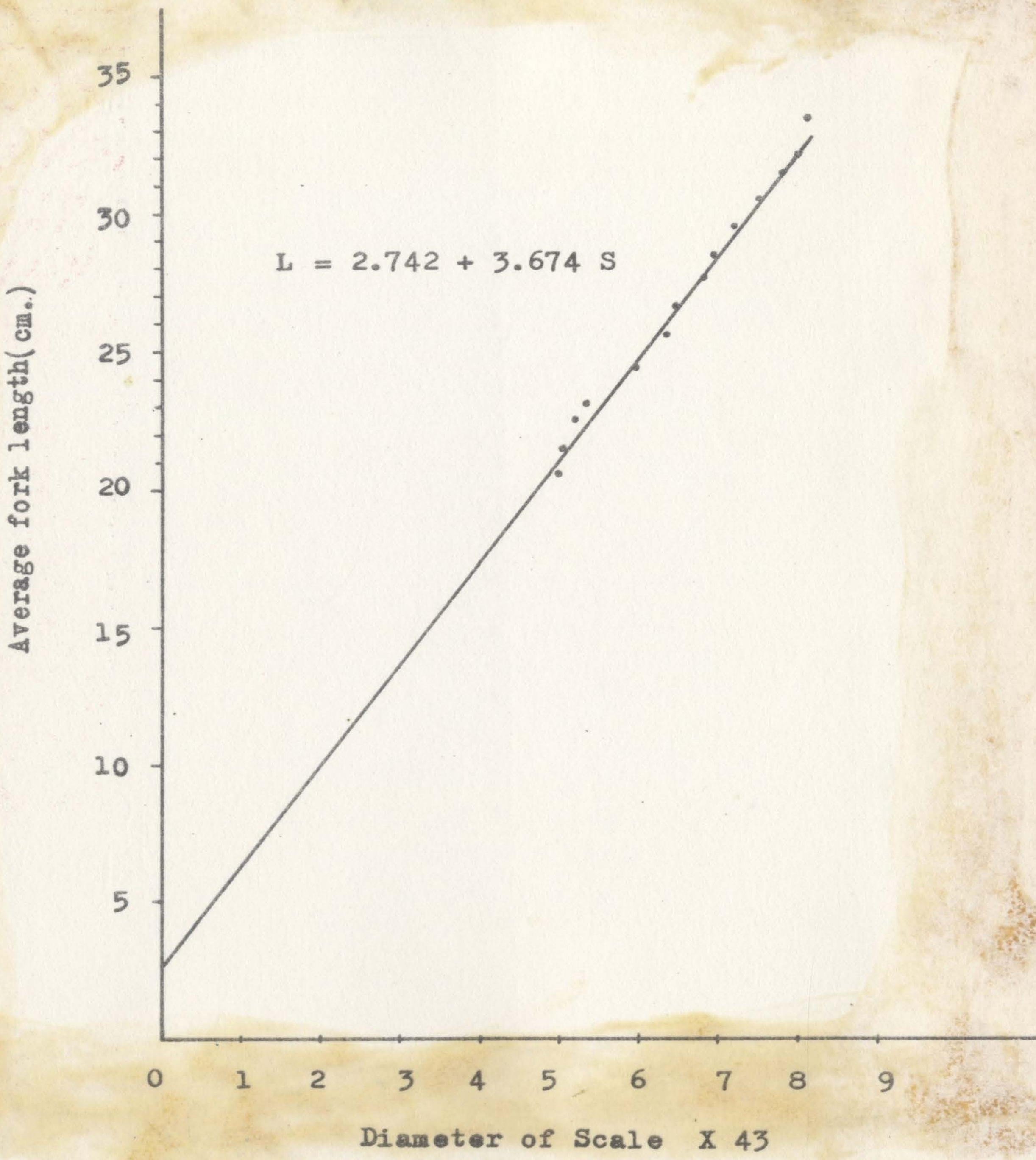


Fig. 28 ---Body-scale relation of 258 lake whitefish taken from Hogan's Pond in 1965 and 1966.

Table 39 ---Calculated fork length (mm.) of 258 lake whitefish at Hogan's Pond taken in 1965 and 1966.

Age group	Calculated length at end of year of life 1	2	3	4	5	6	7	8
II	132.5	207.7 (3)						
III	124.9	216.2	229.1 (29)					
IV	120.9	212.3	264.3	274.3 (45)				
V	122.1	193.8	243.2	276.5	281.8 (78)			
VI	123.6	180.5	224.0	257.7	283.6	292.0 (74)		
VII	127.1	179.5	214.3	249.2	274.7	303.8	306.0 (25)	
VIII	123.6	177.2	217.3	249.6	274.8	292.5	306.1	319.8 (4)
Grand average	123.3	194.2	236.5	266.4	281.4	294.9	306.0	319.8
Average increm.	123.3	70.9	42.3	29.9	15.0	13.5	11.1	13.8
Grand ave. increm.	123.3	71.0	42.4	28.9	16.9	13.8	3.8	13.8
Sum of Aver. invrem	123.3	194.3	236.7	265.6	282.5	296.3	300.1	313.9

(The last calculated length for each age group is actually the average length at time of capture. Figures in parentheses indicated number of fish in each group)

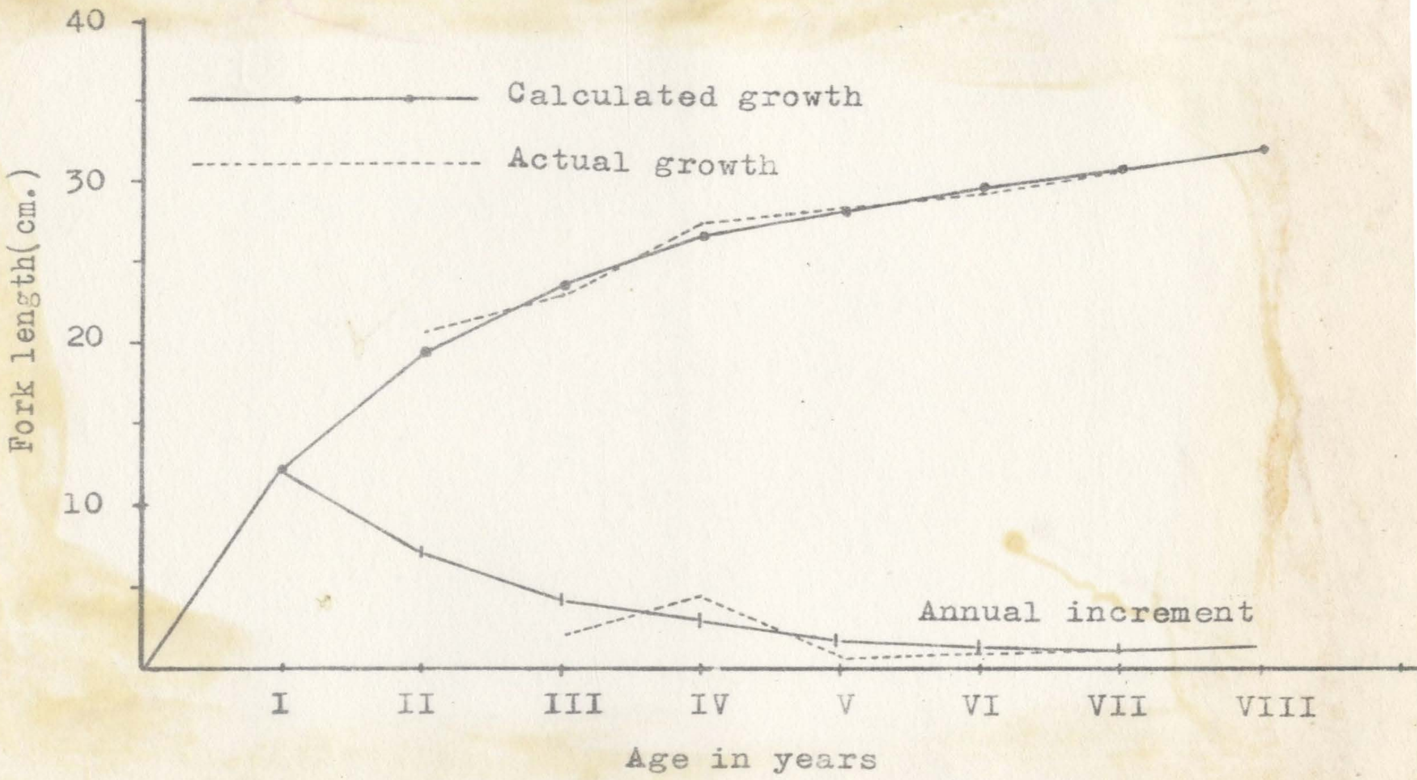


Fig. 29---Calculated growth in length of 258 lake whitefish taken from Hogan's Pond in 1965 and 1966.

ii. Growth compensation.

Growth compensation, or the tendency for the smaller whitefish yearlings (fish at its first year of life) to grow more rapidly in later years, and the larger whitefish yearlings to grow more slowly in succeeding years, so that the smaller whitefish gradually catch up to the size of larger whitefish in later years, is not obvious in these data on calculated growth in length, since the lengths of fish at the end of first year of life varied only slightly, as shown in Table 39, ranging from 132.5 mm. for age II-group to 120.9 mm. for age IV group. Although the larger and smaller yearlings reach to nearly the same size at end of their 5th or 6th year of life. Fluctuations of growth do occur at the ends of year of life for most of the age groups. Take age IV and V-groups for example, at the end of first year of life age V group showed average 1.2 mm. longer than age IV-group. At the end of second and third years of life, however, age IV-group were almost 20 mm. longer than age V-group. They eventually reached equal size at four year of life. For some age groups, the larger yearlings continued to be longer fish in all years of life. Take age IV, V, and VI-groups compared to age VII and age VIII-groups for instance, except at the end of first year of life, fish of age IV, V, VI groups continued to be longer fish than that of age VII and VIII-groups.

Generally speaking, the data demonstrate clearer evidence of "Lee's phenomenon" than "Growth compensation". Dryer (1963) also found that calculated total length of lake whitefish taken at Bayfield and Whitefish Point, Lake Michigan, showed strong evidence of Lee's phenomenon but failed to see the growth compensation.

iii. **Calculated growth in weight.**

The calculated weights at end of each year of life, as shown in Table 40, were computed by means of the logarithmical equation of length-weight relationship and correspond with calculated lengths of Table 29. All questions, such as "Lee's phenomenon" and growth compensation etc., relating to the reliability of the calculated lengths apply, therefore, to the calculated weights. The calculated weights show less agreement with the actually measured weights than the calculated lengths agree with the measured lengths (Compare Fig. 29 and Fig. 30). It is also interesting to note that the annual increment of calculated weights was highest in the second year, instead of in the first year as in the annual increment of calculated lengths. This is probably the case that whitefish of Hogan's Pond do grow rapidly in length in the first, but they do grow rapidly in body weight until in the second year. The first year's increment of body weight was even lower than that of third and fourth years. The increments of weight decline rapidly from 56.14 grams in the third year to 7.7 grams in the seventh year. The measured body weight increment, however, was the highest in the fourth year (Fig. 30). As has already been mentioned, it is possibly related to the maturity of whitefish at the age.

Table 40 ---Calculated growth in weight of 258 lake whitefish taken from Hogan's Pond in 1965 and 1966.

Age	Calculated weight at end of year of life							
group	1	2	3	4	5	6	7	8
II	41.35	115.2 (3)						
III	36.13	126.2	143.9 (29)					
IV	33.55	121.0	199.4	217.0 (45)				
V	34.33	98.4	165.0	220.9	230.6 (78)			
VI	35.30	83.6	136.8	188.1	234.1	250.1 (74)		
VII	37.60	82.6	123.6	174.4	217.7	273.6	278.2 (25)	
VIII	34.33	80.0	127.6	175.0	217.8	251.1	278.4	307.7 (4)
Grand avera.	35.08	98.1	155.8	203.4	230.0	255.8	278.2	307.7
Avera. increm.	35.08	63.02	57.7	47.6	26.6	25.8	22.4	29.5
Grand Aver. incre.	35.08	64.5	56.1	46.1	29.8	26.4	7.7	29.5
Sum of Aver. incre.	35.08	99.6	155.8	201.8	231.6	257.9	265.6	295.1

(The last calculated weight for each age group is actually the average length at time of capture. Figures in parenthese indicated number of fish in each group.)

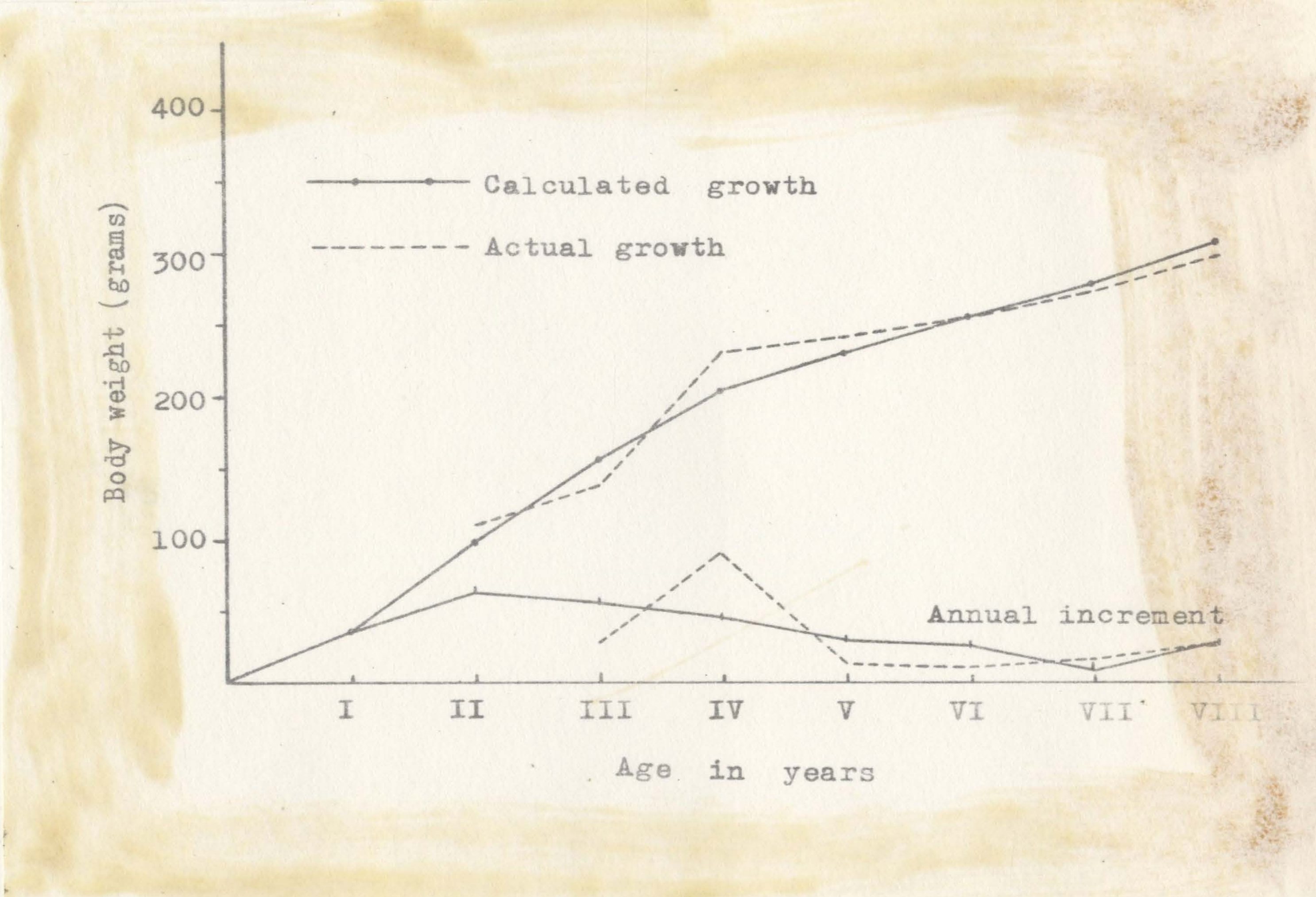


Fig. 30 ---Calculated growth in body weight of 258 lake whitefish taken from Hogan's Pond in 1965 and 1966.

I. Comparison of the growth of whitefish in Hogan's Pond with that in other waters.

In order to compare the growth of whitefish from a number of localities, the data from various sources with various measurements and units have been applied. Certain adaptation were required to permit an comparable study. A full coverage of published data has not been attempted, however, available records for the Lake Erie and other Great Lakes have been included.

i. Age-length and age-weight relations.

Growth of the Hogan's Pond whitefish at each age group does not differ greatly from that of Lake Erie in the very first few years, however, as the age increase, the discrepancies become more and more great. For instance, Hogan's Pond whitefish usually have the average fork length of 207.7 mm. and average weight of 111.3 grams in their second year of life, while Lake whitefish from Lake Erie have the average standard length of 256 mm. and weight of 250 grams (Van Oosten and Hile, 1947), or 176.3 mm. and 101.9 grams (Couch, 1922). In their sixth year of life, Hogan's Pond whitefish have the average fork length of only 291 mm. and average weight of 255.9 grams, while Lake Erie whitefish bear an average standard length of 433 mm. and average weight of 1,360 grams (Van Oosten and Hile, 1947), or 367 mm. and 1134 grams (Couch 1922). (see Table 41 and 42, Fig. 31 and 32)

ii. Calculated growth.

Since the samples of various localities were taken at different growing seasons, a comparison of growth rate at the end of each year of life give a more reliable picture. Although the whitefish of Hogan's Pond had the incomparabally poorest growth, it had a better initial growth rate than some of other localities (see Table 43). It generally takes a whitefish in Hogan's Pond at least 6 years to grow to a fork length of about 300 mm. and weight of about 300 grams, while in most Great Lakes regions, the whitefish can reach such a size at the end of their third year of life or even second year of life. In addition, in view of the growth condition and short life span, one can predict without risking any mistake that the whitefish of Hogan's Pond would have a little chance to grow to a fork length of 400 mmm. and body weight of 500 grams as long as the conditions of Hogan's Pond remain the same. The uncommonly poor growth can undoubtedly be attributed to the smaller space of Hogan's Pond, exceeding dense population and the scanty food supply.

The influence of the "space factor" on the growth and size of aquatic organisms is well known. Almost every worker will unanimously agree with the fact that small space influences growth unfavorably. In analysing the digestive tract contents, it was found that nearly one third of the fish examined have empty or almost empty stomaches and esophaguses, with few undigested feces remaining in the intestines. A larger proportion of this food taken by whitefish of Hogan's Pond was these planktonic crustaceans which are generally the food of young whitefish in other waters. The bottom organisms on which the larger whitefish mostly feed are found in a relatively smaller proportion. The growth of young whitefish in Hogan's Pond, both in length and weight, seems to be fairly normal and as rapid as that of other areas. This is probably due to the fact that the zooplanktons, particularly Daphnia, are fairly abundant in Hogan's Pond, hence the food supply is very good for younger fish.

Table 41 ---Comparison of growth in length of the age groups between Hogan's Pond whitefish and Lake Erie whitefish.

Age group	Hogan's Pond		Lake Erie [1]		Lake Erie [2]	
	average F. L.	increment	average S.L.	increment	average S. L.	increment
II	207.7 mm.		256.0 mm.		176.3 mm	
III	229.1	21.4	311.0	55.0	290.0	113.7
IV	274.0	44.9	379.0	68.0	303.0	7.0
V	282.0	8.0	404.0	25.0	346.0	43.0
VI	291.8	9.8	433.0	29.0	367.0	21.0
VII	306.0	14.2	458.0	25.0	387.0	20.0
VIII	319.8	13.8	479.0	21.0	398.8	11.8
IX			513.0	34.0	399.0	0.2
X			513.0	0	428.0	29.0
XI			516.0	3.0	515.0	87.0
⋮			⋮	⋮	⋮	⋮

1. Data on Lake Erie whitefish were based on Van Oosten and Hile (1947).

2. Data on Lake Erie whitefish were calculated from Couch(1922)

Table 42 ---Comparison of growth in weight of the age groups between Hogan's Pond whitefish and Lake Erie whitefish.

Age group	Hogan's Pond		Lake Erie [1]		Lake Erie [2]	
	Average weight	incre-ment	Average weight	incre-ment	Average weight	incre-ment
II	111.3 (g.)		250.0		101.9	
III	139.2	27.9	480.0	230.0	340.2	238.3
IV	230.9	91.7	910.0	430.0	510.3	170.1
V	244.5	13.6	1140.0	230.0	589.5	79.2
VI	255.9	11.4	1360.0	220.0	1134.0	544.5
VII	271.8	15.9	1650.0	290.0	1125.5	- 8.5
VIII	298.2	26.3	1840.0	190.0	1204.9	79.4
IX			2460.0	620.0	1219.0	14.1
X			2280.0	-180.0	2041.2	822.2
XI			2230.0	- 50.0	2735.8	694.6
XII			2440.0	210.0		
⋮			⋮	⋮		

1. Data on lake whitefish from Lake Erie were based on Van Oosten and Hile (1947).
2. Data on Lake Erie whitefish were calculated from Couch (1922)

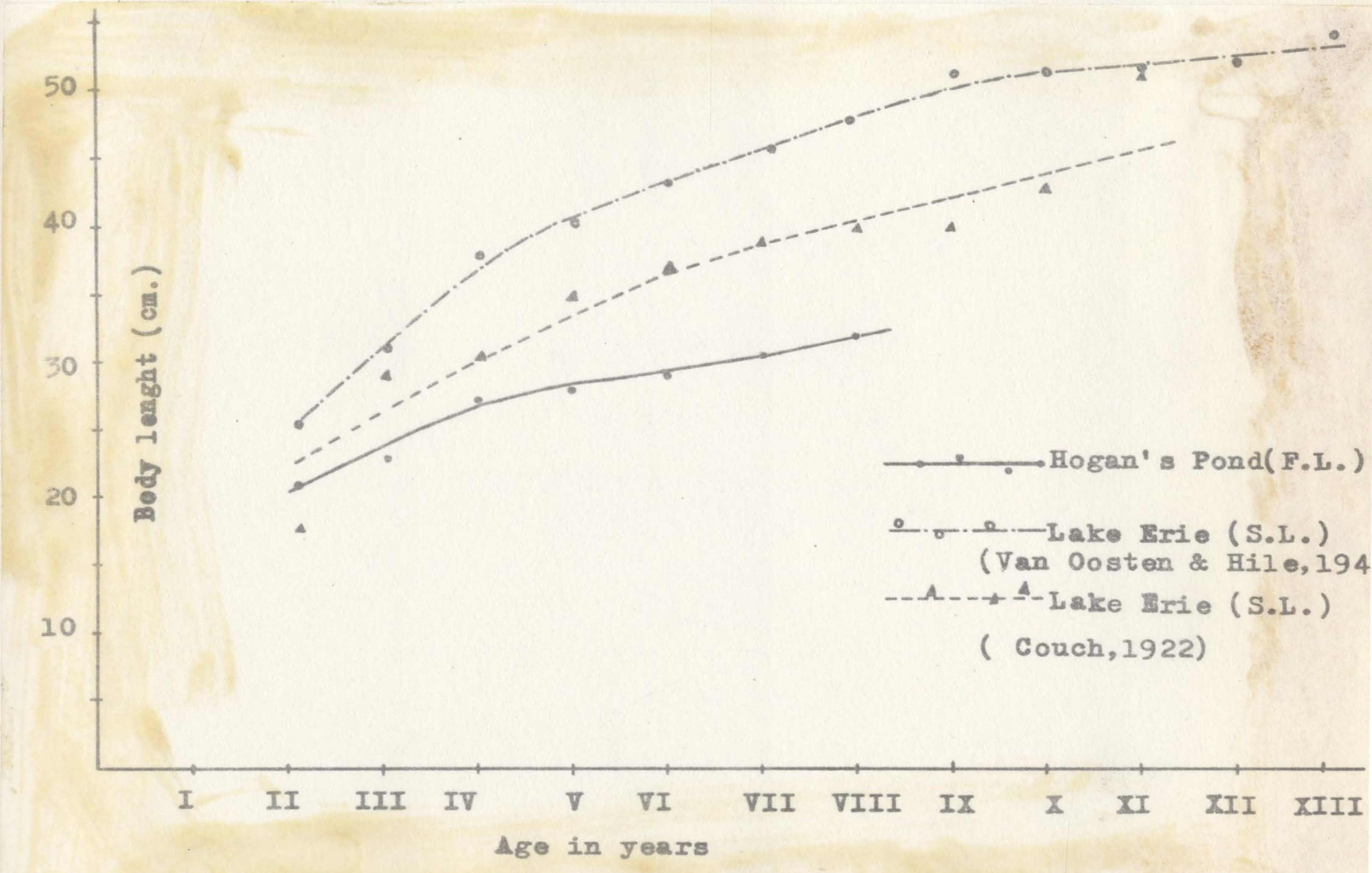


Fig. 31 ---Comparison of the growth in body length of whitefish in Hogan's Pond with that in Lake Erie.

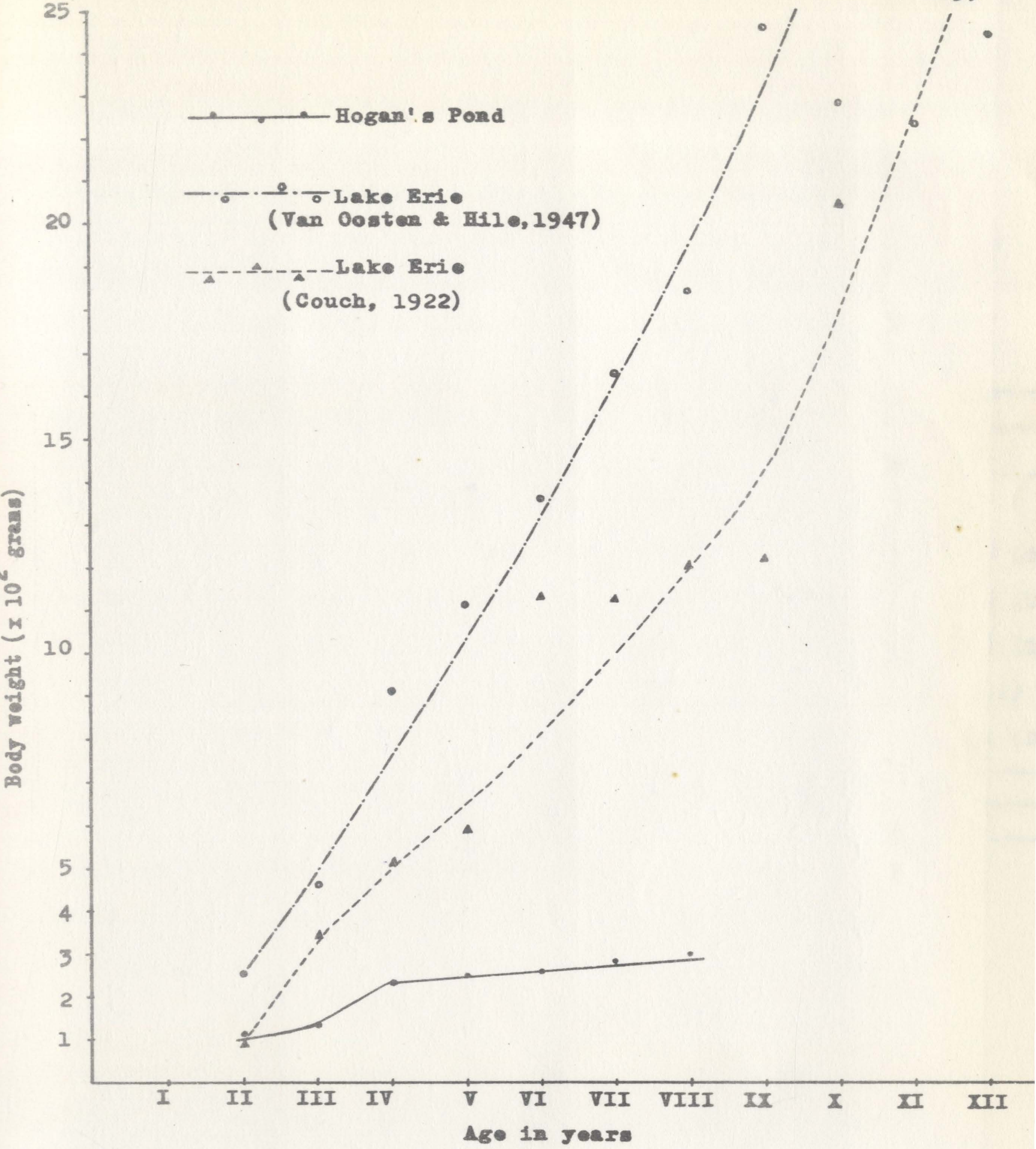


Fig. 32 ---Comparison of the growth in body weight of whitefish in Hogan's Pond with that in Lake Erie.

Table 43 ---Growth in length and weight of lake whitefish in Hogan's Pond and in certain other waters. Sources of data : Lake Erie (Van Oosten and Hile, 1947). Lake Huron (Van Oosten, 1939). Lake Ontario (Hart, 1931). Green Bay and Lake Michigan (Mraz, 1964). Bayfield and Whitefish Point, Lake Superior (Dryer, 1963)

Area	Average calculated length (mm.) at end of year									
	1	2	3	4	5	6	7	8	9	10
Hogan's Pond	123.3	194.2	236	266	281	295	306	319.8	(F.L.)	
Lake Erie	147	271	344	391	423	447	466	482	497	510 (S
Lake Ontario *	---	---	239	305	391	445	485	518	533	579 (T
Lake Huron	127	226	312	409	488	544	581	607	630	648 (T
Lake Michigan	142	249	350	436	498	538	566	592	512	(S.L.)
Bay field	130	203	277	338	381	424	465	508	544	561 (S

Area	Average calculated weight (gram) at end of year									
	1	2	3	4	5	6	7	8	9	10
Hogan's Pond	35	98	156	203	230	256	278	308		
Lake Erie	40	310	660	990	1260	1500	1720	1910	2100	2280
Bayfield	18	63	181	327	447	691	918	1227	1545	1740
Whitefish Point	32	191	459	818	1318	1618	2036			
Lake Michigan	26	119	271	777	1208	1571	1863	2154	2381	
Green Bay	28	224	635	1117	1522	1868	2109	2475	2727	

* Actual lengths at capture during growing season subsequent to indicate year.

VII. SEX AND BREEDING

A. Sex ratio.

The sex ratio data from the samples for two year catches were separated as well as combined. The actual sex ratio differs only slightly from 50 : 50 ratio. The primary sex ratio is disturbed by the fact that female and male fish often frequent different places in the lakes.

Table 44 ---Sex ratio of 261* lake whitefish taken from Hogan's Pond in 1965 and 1966.

Age group	Fish taken in 1965			Fish taken in 1966		
	No. of males	No. of females	% of males	No. of males	No. of females	% of males
II	---	---	---	2	1	66.7
III	5	7	41.7	11	6	64.7
IV	15	9	62.5	11	10	52.4
V	19	18	51.3	21	20	51.2
VI	13	19	40.6	19	23	45.2
VII	12	2	85.7	6	5	54.5
VIII	1	0	100.0	1	2	33.3
Unknown age	3	0		---	---	---
All ages	68	55	55.3	71	67	51.4

* Three age undetermined but sex-known fish were included.

Table 45 ---Sex ratio of 261 lake whitefish taken from Hogan's Pond. 1965 and 1966 catches were combined.

Age group	No. of males	No. of females	% of males
II	2	1	66.7
III	16	13	55.2
IV	26	19	57.7
V	40	38	51.2
VI	32	42	43.2
VII	18	7	72.0
VIII	2	2	50.0

With the exceptions of age-groups VI and VIII, the number of the males exceeded the number of the females in age-groups II to VII. The advantage of the males over the females was though large (72 %) at age VII-group, but it can not be considered as true sex ratio of this age group, since age VII-group was represented only by small number of fish (25). The data on sex ratio (Table 44 and 45) suggest that there was small change in the relative abundance of the sexes in age groups II-VIII.

In 1965 catch, the sex ratio showed a fluctuation among the age groups (Table 44). Much of the variations were probably due to a result of small number of fish in most of the age groups. In the samples taken in 1966, they showed the percentages of the males slightly decreased with increase of age with the exception of age VII-group. In the entire 261 specimens, all age combined, the sexes were almost equally represented (53.3 % for the males), this was particularly true for samples in 1965 where the males occupied 51.4 %.

The data of present study coincides, to some extent, with the findings in other data which claim that the percentage of the male whitefish decreased with an increase in age (Van Oosten, 1939; Van Oosten and Hile, 1947). On the other hand, it is in contrast to other findings. Mraz (1964) seems not to agree with the trend in sex ratio with increase of age. At least he finds no clear trend can established for some of the whitefish samples taken in Lake Michigan. Edsall (1960) even disapproves this suggestion by a statistical test on his whitefish samples taken from Lake Superior. In his data on sex ratio, Edsall (1960) declines to conclude whether this disagreement between the whitefish from Munising Bay, Lake Huron, and Lake Erie really represents true differences in the biological characteristics of this fish. He attributes this problem to biased sampling, differential exploitation, and problem of segregation. Mraz (1964), on the other hand, suggests that data on sex ratio often vary erratically when samples are collected near or during the spawning season. He attributes the strong preponderance of the males in October 1948 collections from Lake Michigan (77 %) and Pestigo (84 %) to prespawning segregation, but he is also confused by the equally great abundance of the males (80 %) taken from Gill Rock, Green Bay (Lake Michigan) in June 1951.

Data on Hogan's Pond whitefish seem not exactly to agree with the seasonal differentiation in sex ratio. Particularly in the samples taken in 1965 (Table 46), all the fish were caught in the period between June and October, except September. They showed strong preponderance of the males in June and July, being 78.9 % and 57.2 % respectively. While as time approaching to the spawning season the number of the males in the collections tended to be fewer than the females, with the percentage of 48.5 % in August and 47.2 % in early October. In 1966 collections, however, the samples show a correlation with the suggestion of prespawning segregation. Male fish were caught fewer than female fish in July and August (45.2 % and 42.7 % respectively), but preponderance of male fish (59.7 %) occurred in September and early October. The only conclusion that can be made based on the above two collections is that segregation by sex can be pronounced at times, perhaps the spawning season. Hart (1931) reports that male fish occupy the spawning ground in advance of the female whitefish, and remain there for a longer time. The discrepancy of 1965 collection may be attributed to sampling errors or small number of specimens taken in each month.

It is also hard to obtain the evidence as to the effect of gear or other sampling methods on the sex-ratio data. All the data which I have examined so far show mostly a great deal of variation of sex-ratio among the samples taken even by the same fishing device. But the percentage of male whitefish in most samples more or less show slightly outnumber the females.

Hart (1931) expresses doubt that the proportion of the mals and female whitefish taken in gill nets could be considered as a measure of the true sex ratio. This is because, as he points out, the difference in the size of the male and female whitefish is quite marked. To overcome the problem resulting from this disparity of sexes, Hart (1931) carried out a systematic netting in Shakespeare Island Lake. The gang of nets used in this work consisted of a series of nets, each 50 yards in length, with stretched mesh size ranging from 1.25 to 5.o inches (by units of 0.25 inches). The data he obtained from this set-up showed male whitefish 238 and female whitefish 205. Perhaps, this is the most reliable data on sex ratio so far available. Peral (1916) reports that sex ratio of Lake Erie whitefish to be 386 males to 455 females. Wynne-Edwards (1952) reports that the broad or true whitefish (Coregonus kennicotti) with the females outnumber the males by a ratio of 12 or 15 to 1. The sex ratio is similarly unequal in the common whitefish (Coregonus clupeaformis) of Yukon Territory, Meckenzie River and Alaska (Wynne-Edwards, 1952).

B. Spawning time and spawning habit.

During the spawning time, there is a considerable playing and loud splashing noise which is believed to be brought by the mating couples reaching the water surface. The mating time is usually at dusk and nightfall (Hart, 1931; LaGrace, 1937; Lindroth, 1957). Spawning takes place at Hogan's Pond the last week of October or the first week in November at temperature about 5° C, earlier than in Lake Erie--mid-November (Van Oosten and Hile, 1947) The spawning time is generally correlated with water temperatures (Lindroth, 1957), and since the water temperatures were not constant from year to year, the spawning time is also expected to vary few days from year to year. Hart (1931) reports that very low temperature may induce spawning at earlier date than usual.

The duration of spawning time of Hogan's Pond whitefish is, however, not known. Hart (1931) reports that the duration of spawning of lake whitefish in Lake Huron is a week or ten days. Lindroth (1957) states that the spawning activity of whitefish (Coregonus sp.) in Sweden waters last for about one mouth. Van Oosten and Hile (1947) report that spawning duration of Lake Erie wihtefish is from mid-November to first week December.

C. Age and size at maturity.

In all investigations dealing with fish population, the knowledge of sexual maturity is as important as that of age and growth. It has often been difficult to decide whether or not the whitefish are mature. Since the term "maturity" is defined as a fish changing from juvenile or immature into the sexually mature stage, while "ripeness" is designated as the full development of roe and milts (Alm, 1959). Consequently, maturity takes place only once in the life of each fish, and ripeness recurs several times during the life time of the individual in most species of fishes, including coregonids. Maturity terminates in the first ripeness of spawning. All fish which have once reached maturity are called mature, thus a fish can be mature without being ripe. In examining the whitefish gonads, there often appeared older or larger fish with poorly developed gonads while younger or smaller fish with well developed ovaries or testes. Since lake whitefish spawn annually, all mature fish would be expected to have ripe gonads during the spawning season or well developed gonads a few months or few weeks before the spawning time. It is wondered if these fish were actually immature or merely non-spawning mature fish, that is, they had spawned before but for some reasons

Table 47 ---Ages and lengths of mature and immature lake whitefish of Hogan's Pond taken in 1965 and 1966. (Figures in parenthese indicated the number of fish)

Age group	Sexes combined	Male	Female	Mean length	
	% of mature	% of mature	% of mature	Mature (mm.)	Immat. (mm.)
II	0 (3)	0 (2)	0 (1)	---	207.7
III	31.0 (29)	34.7 (17)	25.0 (12)	242.0	222.3
IV	57.8 (45)	53.8 (26)	63.2 (19)	275.0	267.7
V	85.9 (78)	90.0 (40)	81.6 (38)	283.8	270.6
VI	91.9 (74)	93.8 (32)	90.5 (42)	291.0	300.6
VII	96.0 (25)	100.0 (18)	87.9 (7)	306.0	307.0
VIII	100.0 (4)	100.0 (2)	100.0 (2)	331.5	---

All fish less than age III were immature and all fish older than age VII were mature. The youngest mature fish of each sex belong to age III-group. 34.7 % males and 25 % females were mature at age group III, and most of fish (90 % for males, 81.6 % for females) were mature at age V. Except at age group IV, the percentage maturity of males was consistently higher than for females of corresponding ages (Fig. 34). Elsewhere in its range, the male lake whitefish usually reaches maturity one year earlier than females. The mature fish of each sex are generally longer than the immature fish of the same age group with one exception at age VI-group. The exception may be due to the bias involved in defining mature or immature fish of some older fish as have been stated above.

Table 48 and Fig. 35 show the percentages of immature and had failed to developed their gonads in the year of their capture. Before reliable evidences can be found and in order to avoid more serious error by putting immature fish into mature group, all fish with poorly developed gonads were considered as immature.

Mature female whitefish, which were caught in June, July and August, had their ovaries well developed, and occupying more than one half the length of abdominal cavity, blood vessels were easily seen on the surface of these ovaries. Eggs diameter is around 1 mm.-1.5 mm.. Male whitefish taken in the same period, had their testes appearing a definite whitish color, and occupying more than half the length of abdominal cavity, were considered mature. They were expected to spawn in the coming winter. Fish caught in September, October, the mature ones would have ovaries or testes almost as long as the entire body cavity. Eggs diameter is around 1.5 mm.-2.0 mm., blood vessels on ovaries become more obvious, and testes become wider and milky color. Ripe ovaries (Fig. 33) have the eggs diameter about 2.5 mm.; the width of ripe testes is about 1.5 cm.. On pressing slightly the abdomen of ripe fish, the ova and sperms can be ejectedi in spurt. In spent females, the ovaries,are contracted, flaccid, contained a large number of recruited eggs which are yolkless and transparent in fresh condition; or sometimes a few ripe eggs still remained in the abdominal cavity. In spent males, parts of these testes near anus region were usually shrunken and appeared degenerated, while the anterior end of these testes remain as full as in ripe status.

Table 47 shows the percentages and lengths of mature and immature whitefish of Hogan's Pond in each age group.

mature whitefish in each size group. All whitefish shorter than 220 mm. were immature and all fish longer than 321 mm. were mature. The first mature male appeared in the 221-230 mm. group. The percentage of mature males reached 50 % at 241-250 mm. group, and all of the males were mature at lengths greater than 311 mm.. The first mature female appeared also at 221-230 mm.. At 241-250 mm. length interval, only 40 % of female whitefish were mature. Since the 100 % maturity of male fish and female fish occurred at the length groups which were represented only by one fish, it is hard to indicate precisely at which length group all the males and females reach maturity. From the data, however, it is shown that first maturity and 100 % maturity of male fish may occur at a shorter length than female whitefish.

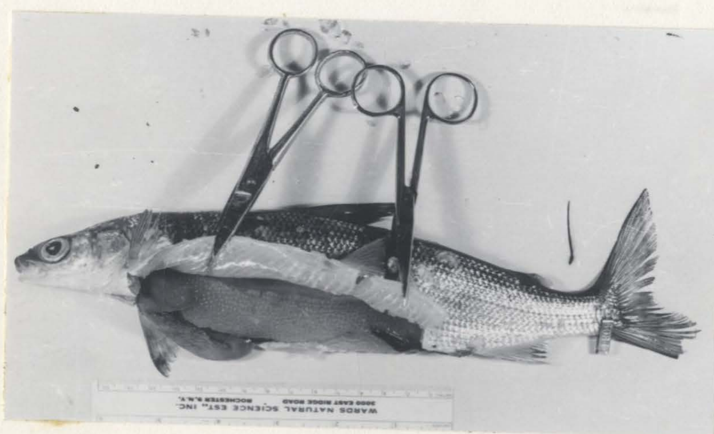


Fig. 33 ---Ripe female lake whitefish taken in November 2, 1966 from Hogan's Pond.

Table 48 ---Relation of length to maturity of lake whitefish taken from Hogan's Pond in 1965 and 1966.

(Data on maturity were not recorded for all individuals. All fish shorter than 221 mm. fork length were immature, all fish longer than 331 mm. were mature.)

Length	Sexes combined			Male			Female		
class (mm.)	No. Mat.	No. Imma.	% of Mat.	No. Mat.	No. Imma.	% of Mat.	No. Mat.	No. Imma.	% of Mat.
less-220	0	10	0						
221-230	2	8	20.0	1	2	33.3	1	6	14.1
231-240	2	5	28.5	2	4	33.3	0	1	0
241-250	4	5	44.4	2	2	50.0	2	3	40.0
251-260	9	4	69.2	5	2	71.4	4	2	66.6
261-270	22	6	78.5	8	2	80.0	14	4	77.8
271-280	37	8	82.2	13	3	81.2	24	5	82.7
281-290	35	8	81.4	20	4	83.3	15	4	78.9
291-300	32	3	91.4	21	2	91.3	11	1	91.7
301-310	35	2	94.6	21	1	95.4	14	1	93.3
311-320	18	1	94.7	13	0	100.0	4	1	80.0
321-330	1	0	100.0	--	--	---	1	0	100.0
over 331	2	0	100.0						

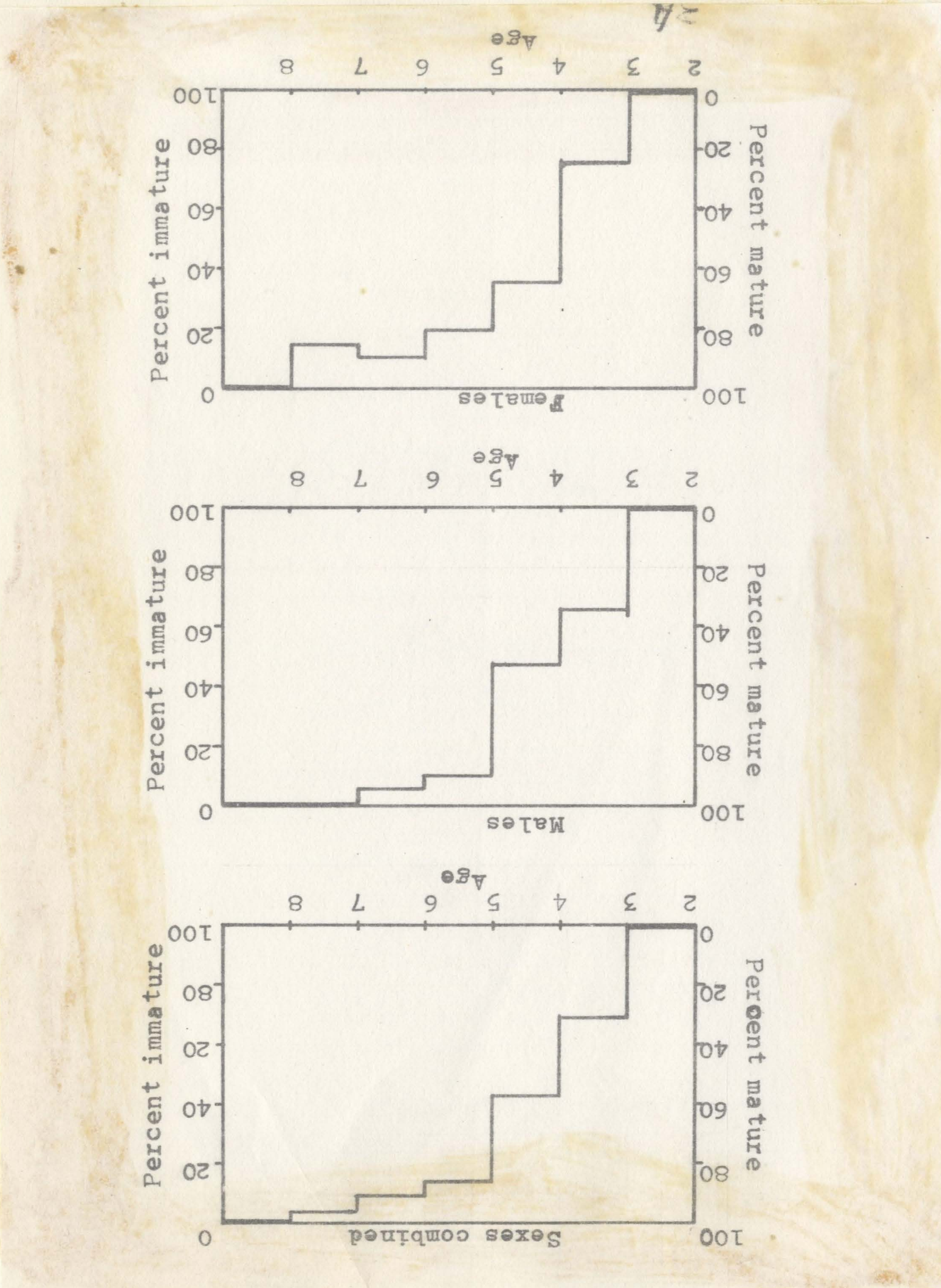


Fig. 34 ---Percentages of mature and immature lake white-
fish by age class in samples from Hogan's Pond.

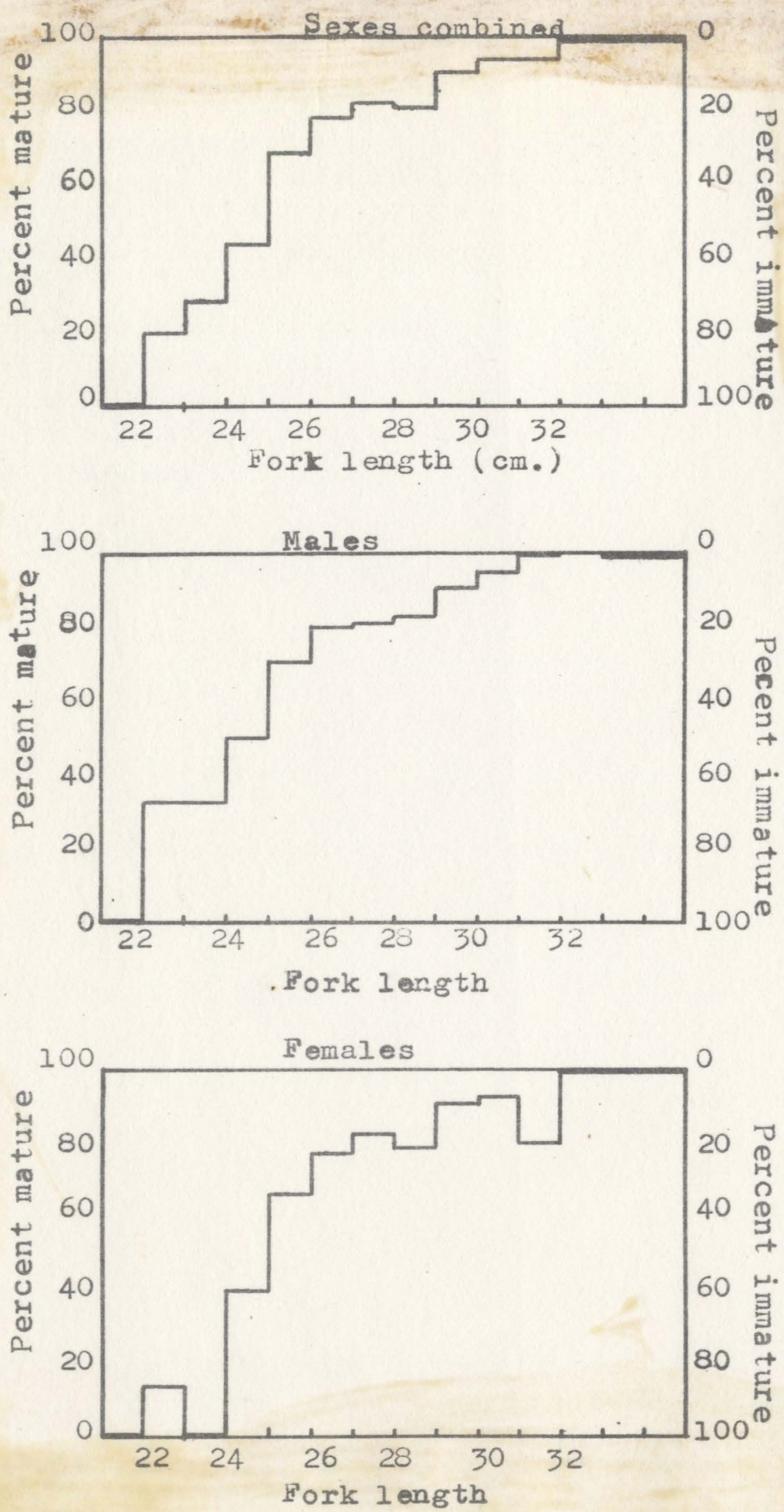


Fig. 35 ---Percentages of mature and immature lake whitefish by size class in samples from Hogan's Pond.

For the lake whitefish, information about age, length at maturity are rather common, but comparison of the varying growth in different water is rare. It is generally known that faster growing whitefish mature at a greater length and a lower age that slow growing whitefish (Edsall, 1960; Dryer, 1963; Fenderson 1964). This is truly applied to all normally growing whitefish throughout its range, however, it does not apply to the cases of extremely slowly growing whitefish populations which as Fenderson (1964) terms "dwarf whitefish", nor does it seem to agree with the whitefish of Hogan's Pond. In the case of dwarf whitefish and Hogan's Pond whitefish, early maturity and bad growth, as well as late sexual maturity and good growth are interrelated. It is also worthy to note that either dwarf or Hogan's Pond whitefish has a good growth rate in the very first year. Fenderson (1964) reports that 50 % of slow growing dwarf whitefish were mature at age 1^+, but faster growing dwarf whitefish from other areas were not found to be mature until in their third season. The whitefish of Hogan's Pond were originally the whitefish in Lake Erie. The Lake Erie whitefish, which are much faster growing population and have a longer life span, were mature at their third year of life for male fish and fourth growing season for the females. The much slow growing and much shorter life span whitefish population of Hogan's Pond instead of being expected to mature at higher age, they were mature as early as the third year of life for both sexes. Alm (1959) also reports that small species of fish in which after a few years, growth becomes slow or almost cease, maturity appears at an earlier age; and larger species, in which growth continues throughout life, reach maturity at higher age.

Rounnstrom (1944, appeared in alm, 1959) found that lillte slow growing whitefish in northern Sweden waters became mature at three years old and a length of 140-150 mm., while the big fast growing forms of whitefish were mature at 10 years old. Also Jarvi (1919, appeared in Alm, 1959) states the Coregonus albula usually spawn in its second year independent of the growth rate. Svardson (1949a) found in his experiment of two whitefish species transplanted into two new lakes. In one lake, the growth was remarkably good with an average length of 414 mm. at age 3 and 468 mm. long at age 4, as compared to the original length of 270 and 290 mm. respectively for two species at the age of 4 years. In other lake, the growth was very bad, the average length of these two species of whitefish at the age 4 years was only 180 mm., while at the age of 1 year, however, the length of those bad growth populations was average 108 mm. as compared to only 90 mm. for the two species in their original waters. A study of maturity showed that for either species the maturity was reached at a lower age in the new lakes than in the original waters. This i indicates that fast-growing whitefish as well as extremely slow growing but with good initial growth rate whitefish were mature at a lower age. Fenderson (1964) suggests that unknown physiological factors apparently compensate for extreme slow growth by accelerating maturity.

Hubbs (1926) claims that the growth rate and the reaching of a certain size have been decisive for maturity. Fast growth and fast development in the very first year can bring about an earlier cessation of growth. Fish at a good growth rate but with a poorer initial growth rate, the growth factor prevails over the factor which induces maturity, and tend to become mature at a higher age. On the other hand, fish at a poorer growth rate, but with a good initial growth rate, the factor which induces maturity gain over the growth factor and produces an early maturity. Alm (1959) claims that starvation also ignites maturity or ripeness of a fish. When a fish is starving to death, it ought to work for the upholding ot its species even at the price of its own longevity by hastened development of semen, eggs or larva, that is, to hasten the propagation of the fish and increase its intensity. With regard to Coregonids and Salmonids, the results arrived at are without doubt correct. As far as growth is concerned, the food supply, as revealed by digestive tract contents study, has been unfavorable for a long time. In this case, an earlier maturity is often to be expected. Alm (1959) claims that earlier maturity is of a result of natural selection favoring fish to assure the continued existence of species and become a genectic feature of the species as long as the condition remains the same. For those species having a shorter life span and relative small size, an earlier age at maturity is a necessity for the continued existence of the species. It seems therefore safe to conclude that whitefish of Hogan's Pond could be described genetically different from that of Lake Erie, being shorter life span, poorer growth, smaller size at maturity and relatively better initial growth rate, as long as the food condition, space factor etc. remain the same.

D. Fecundity.

Fecundity is defined as ova production (Nichola and Massmann, 1963) or reproductive potential (Hartman and Conkle, 1961), that is, total number of eggs available for seeding in a spawning population. The fecundity has been added to the list of racial criteria for distinguishing the race of fishes in different waters (Katz, 1954). The number of eggs that a fish can produce at spawning time, varied widely according to population and individuals within a population.

The fecundity of Hogan's Pond whitefish was investigated from 35 females with their ovaries well developed. The formalin-preserved ovaries were broken up thoroughly and the connective tissue were removed. The eggs were than set aside to dry on a sheet of filter paper. A sample of 400 eggs was counted and put in a 10 cc.-volume metric cylinder with 5 cc. of distilled water in it, the volume of 400 eggs was then read to the nearest o.01 cc.. For example, the total volume of 400 eggs and 5 cc. of distilled water in the cylinder read 7.53 cc., the volume of 400 eggs was then 2.53 cc.. The rest of eggs were at the same time, put in another 25 cc.-cylinder with 10 or 15 cc. of distilled water in it. The total number of eggs was then computed proportionally.

Although the volumetric method of counting eggs is subjected to certain inaccuracies, it is sufficiently accurate for the purpose of present study. The dependability of this method was tested by making actual counting the eggs of three females compared with that evaluated by volumetric method. The errors (2 overestimates, 1 underestimate) were 1.8, 2.4, and 2.7 percent respectively. The highest discrepancy was 88 eggs less than actual number. The diameters of eggs were also measured under microscope to the nearest o.1 mm..

The average number of eggs for whitefish grouped by 5 mm. length intervals increased irregularly with increased fish length (Table 49 and Fig. 36). The fish at 267-270 mm. contained an average of 2275 rggs and the single specimen at 318 mm. had 3050 eggs in its ovaries. The mean number of eggs for all fish was 2954. The number of eggs per 1 Kg. of fish varied so irregularly with length that it showed no definite tendency to be higher among the longer fish than among the shorter fish, or vice versa. The number of eggs per 1 Kg. of fish was low for fish 281-285 mm. long (9000). The highest number (13,570) was for fish 296-298 mm. long. The average number of eggs per 1 Kg. of fish for the entire 35 specimens in Hogan's Pond was 11,650 (or 5300 per pound), while that of Lake Erie whitefish was 35,230 (or 16,000 per pound) (Lawler, 1961).

The average diameters of eggs from Hogan's Pond whitefish show correlation with the total number of eggs per individual. The eggs gradually decrease in number as they increase in size (Table 50). Vladykov (1956) also found the similar relation between the total number of eggs and the average diameter of eggs for speckle trout. Svärdson (1949) states that the number of eggs is inversely proportional to the individual size of egg. Hogan's Pond whitefish though produce fewer number of eggs, they posses larger size of eggs. The average diameters of eggs for 35 specimens range from 1.0 - 2.7 mm., whereas the average egg diameter of 13 lake whitefish from Hogan's Pond taken during the last week of

July and the first week of August 1948, ranged from 0.95 mm. to 1.40 mm. (Lawler, 1961).

Comparable data on fecundity for lake whitefish from various localities are listed in Table 51. It clearly reveals that Hogan's Pond whitefish produce much fewer number of eggs per individual fish and much fewer eggs per unit weight of fish.

Svärdson (1949) regards the egg-number as some sort of adaptation, like other character, which under the influence of natural selection characterizing different fish species or races. The variations in egg-number between different species of fish are genetically based; and also within the same species, an individual variation of egg-number is correlated to the mother size and to the genetical capacity of producing eggs. Since the size of fish (growth) is greatly modified by environmental factors, the number of eggs might also be largely influenced by environment.

Table 49 ---Relation between the length of Hogan's Pond lake whitefish and the total number of eggs and the number of eggs per kilogram of weight.

(Number of fish in parentheses)

Fork length (mm.)	Number of eggs per fish: Average	Number of eggs per fish: Range	Average number of eggs per Kg. of weight.
267-270	2275 (5)	1600-3450	9260
272-275	2920 (8)	2500-3600	11600
276-280	2824 (5)	1800-3720	11720
281-285	2315 (2)	1635-3000	9000
286-287	3530 (3)	2860-4200	13320
291-295	2700 (2)	2200-3200	11250
296-298	4043 (3)	3330-5345	13570
301-305	3214 (4)	2880-3616	11430
309-310	3592 (2)	3400-3784	12900
318	3050 (1)	----	10130
All length	2954 (35)	1600-5345	11650

Table 50 ---Relation between the average diameter and the total number of eggs of Hogan's Pond whitefish. (Number of fish in parentheses)

Egg diameter (mm.)	Number of eggs per fish	
	Average	Range
1.0-1.3	3,864 (7)	3,000-5,345
1.4-1.7	3,058 (12)	2,500-3,720
1.8-2.0	2,503 (7)	1,600-3,450
2.1-2.3	2,215 (6)	1,635-2,670
2.4-2.7	2,605 (3)	2,129-3,456

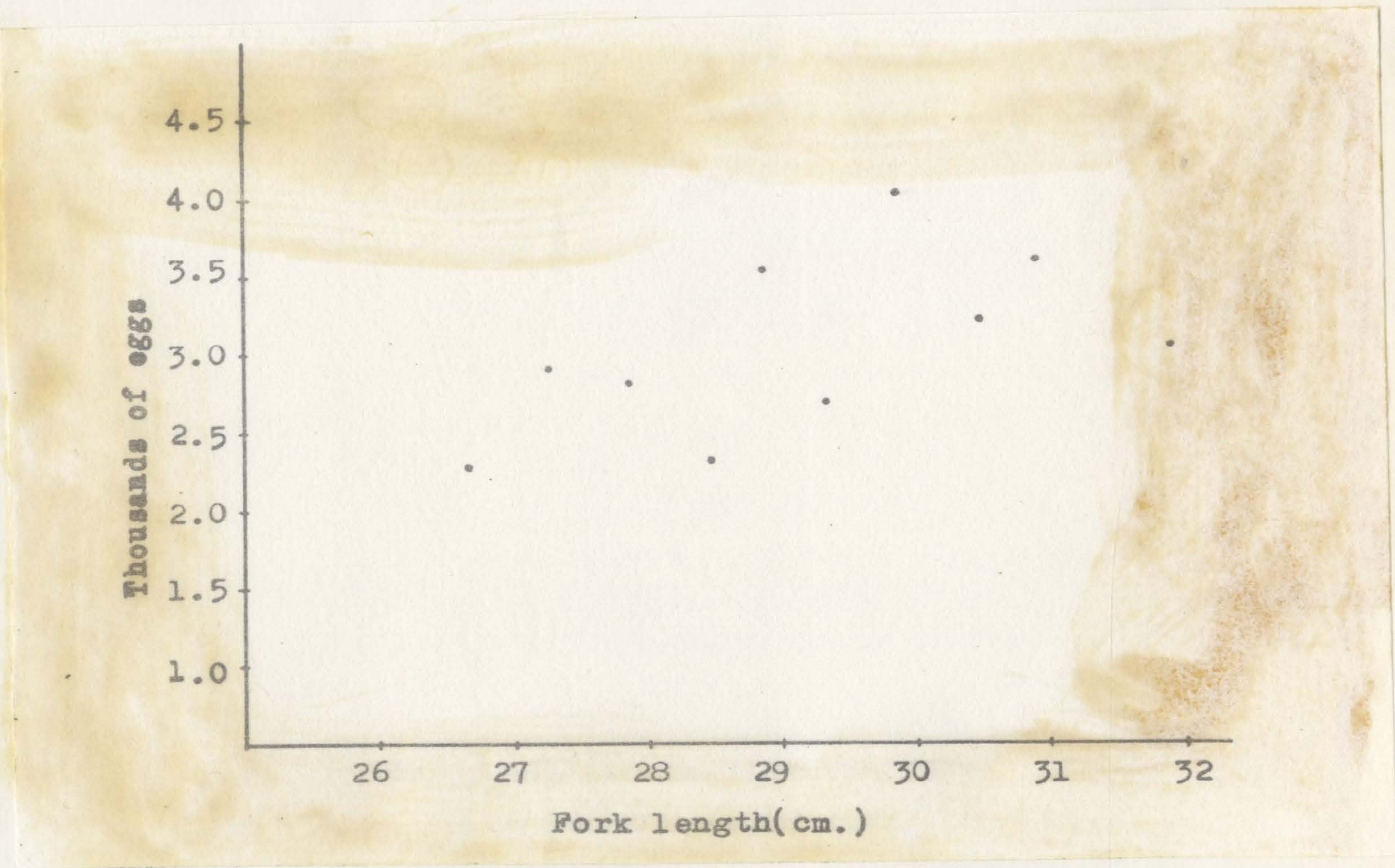


Fig. 36 ---Body length-Number of eggs relation of 35 female whitefish taken from Hogan's Pond.

Table 51 ---Fecundity of lake whitefish (Coregonus clupeaformis) from various localities.

Locality	No. of fish	Number of eggs per female	Average No. of eggs per unit of wt.	Size of fish	Authority
Hogan's Pond	35	2954	11650/Kg. or 5300/lb.	267-318 mm.	present study
Lake Erie	1	34760	35230/Kg (16000 per pound)	508 mm.	Langlois (1939)
Lake Erie	15		35230/Kg. or 16000/lb.	416-551 mm.	Lawler (1961)
Great Lakes	1	150000	13636/lb.	11 lb.	Downing (1908)
Maine	1	25076	12538/lb	2 lb.	Kendall (1902)
Great Lakes	--	8000-15000	---	Average size	LaGorce (1937)
Lake Ontario	--	----	8500-145000/Kg. (4000-6500/lb.)	ordinary size	Hart (1931)
Great Lakes	--	----	24250-26455/Kg. (11000-12000/lb.)	moderate size	Milner (1874)

E. Hermaphroditism of *Coregonus clupeaformis*.

Hermaphroditism in the teleosts is not a rare case. Several authors have reported since 1927 about the cases in the gobius, perch, eel, herring, cod, salmon, and trout. Crawford (1927) reported hermaphroditic silver salmon (*Oncorhynchus kisutch*) by accident. The fish was stripped with other salmon and detail study became impossible due to some damage. The fish was female predominately with a not fully developed testes attached dorsally to both the ovaries. Turner (1931) reported an ovo-testis in the yellow perch (*Perca flavescens*). An irregular testis somewhat larger than normal testis was located anterior and adjacent immediatedly to the ovary. Histological examination showed that both ovaries and testis were normally developing. No even transitional zone was found microscopically in the region between the ovarian and testicular portions of the gland. Gibbs (1956) in rainbow trout (*Salmo gairdneri*), Uzmann and Hesselholt (1958) in chum salmon (*Oncorhynchus keta*), and many others all lead us to believe that anamalous condition of hermaphroditism in fishes appear to be no less rare than in other normally dioecious animals.

The one specimen of Hogan's Pond whitefish with an ovo-testis was caught in 1966 November, with total length 323 mm. or fork length 286 mm., weight 225 grams. It had a normal right testis and an apparently normal but shorter left testis. On the ventral surface of anterior left testis there was a small but rather perfect ovary attached by the mesovarian which was extended from the membrane covering the testis. This fish, age 5, was taken during the spawning season, but there was no sign as to the fish had spent. Both ovary and testes were mature, the eggs in the ovary were found in the stage of active period. Eggs diameter was around 1.4-1.6 mm., whereas the diameter of ripe eggs is around 2.5-3.0 mm..

The gonads were removed and fixed in Bouin's solution. They were later embedded in paraffin, sectioned at 5 microns and stained with H-E stain (Hematoxylin-eosin stain). The right gonad turned out to be a perfectly normal testis with the lobules filled with various stages of germ cells.

The ovo-testis, as shown in Fig. 37, was found in the left gonad. As the gross morphology revealed, this was primarily testicular tissue. The ovary constituted a piece of tissue 1 cm. long on the ventral border of the testis. Although the gonads were connected by a thin piece of superficial connective tissue, the sections showed a clear demarcation between male and female cells (Fig. 38). The male section contained germ cells at the same level of development as those in the right testis. The section of the testis bordering on the ovarian tissue contained wide tubules which were densely packed with germ cells. In the rest of the testis, however, the tubules were narrower, and the cells were less abundant--a situation very similar to that in the right testis. There was a gonadal duct attached to the male portion and this looked like a normal vas deferens.

The female portion contained eggs in various stages of development. There were a few primary and secondary oocytes, but the great bulk of tissue consisted of mature ovarian follicles which were apparently undergoing absorption. An oviduct was absent.

This case of hermaphroditism was in general respects unlike any mentioned in the literatures for bony fishes. In superficial appearance the ovo-testis was probably most similar to the one in silver salmon reported by Crawford (1927). In both cases, the ovarian section was ventral to the testicular section. The usual pattern is an anterior-posterior relationship between the two parts.

Lagler and Chin (1951) reported an abundance of connective tissue in the ovo-testis, and James (1946) reported a more than usual amount of connective tissue in the testicular portion of an ovo-testis in the largemouth bass, such was not in the white-fish specimen. Most writers; including James (1946), Lagler and Chin (1951), and Ross et al (1963) mentioned an intermingling of male and germ cells in the ovo-testes of bony fishes. In the present case, however, male and female tissues were quite separated.

D'ancona (1945) claims that the development of the germ cells or the gonad as a whole, is characterized by an initial state of indeterminacy, which is the primitive condition in the teleosts. The female germ cells first become recognizable oocytes during the stage of maturative prophase, and deutoplasmo-genesis; the male cells first disclose themselves during the stage when they become to form secondary spermatogonia. Between these extremes every degree of intermediate condition is to be found, giving cells in a state of intermediate sexuality. The initial state of the gonad is one which the two opposing tendencies are balanced. D'ancona describes this state as "intersexuality". The essential difference between intersexuality and hermaphroditism is that intersexuality is characterized by the incompatibility between the two tendencies, and hermaphroditism by their mutual tolerance. This difference is probably due to the diffusible or non-diffusible nature of the sex differentiators.

From the initial indifferent condition, there is a progressive sexual orientation of the gonad with an increasing predominance of one type of germ cells over the other. This ultimate sexualization must be induced by local influence in the surrounding somatic tissues of the gonad which are chemodifferentiated into regions producing either male-inducing or female-inducing substance It is the protogonium which is destined to form sperm and ova, but there is no spatial separation of the prospective male and female protogonia. The protogonia become oogonia if they remain in the cortex of the gonad. If, they migrate into the medulla, they become spermatogonia. If, however, the migration is incomplete or delayed, the result is a condition of intermediate sexualization.

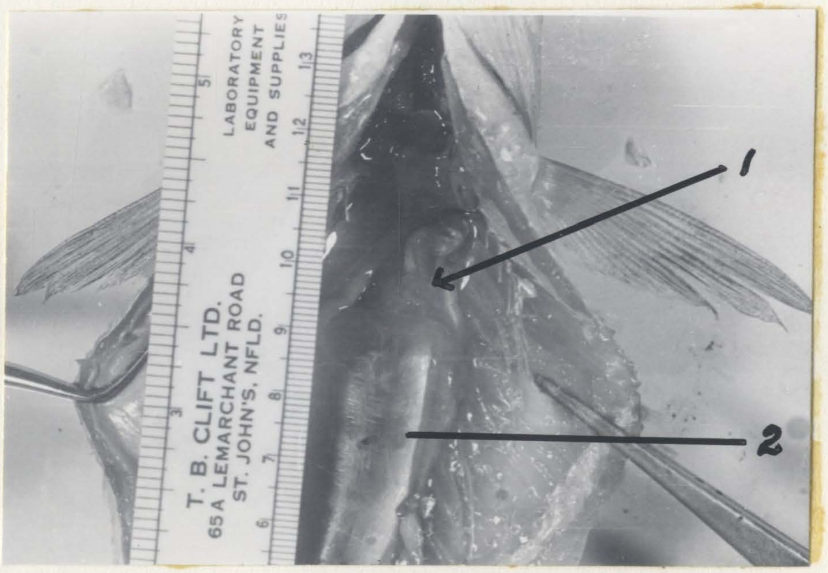
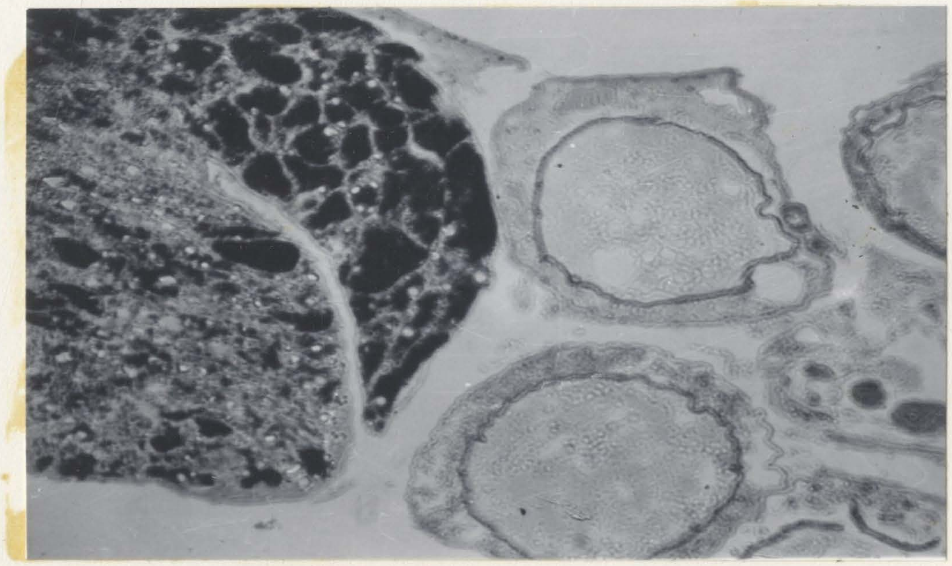
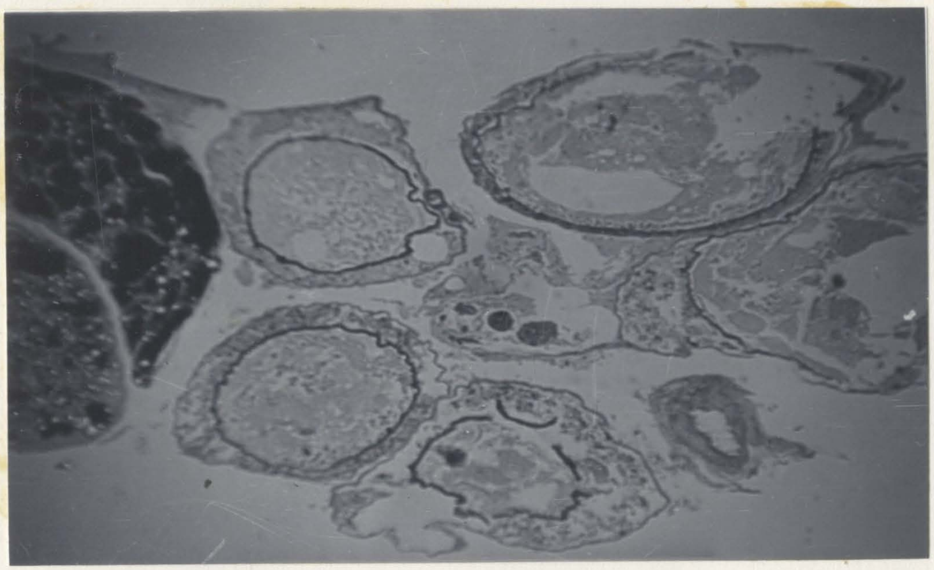


Fig. 37 ---Ovo-testis of lake whitefish (<u>Coregonus clupeaformis</u>) taken from Hogan's Pond on November 5, 1966. 1 : Ovary, 2 : Testis.



(A)



(B)

Fig. 38 ---Histological structures of ovo-testis of <u>Coregonus clupeaformis</u> taken from Hogan's Pond.

VIII. FOOD OF LAKE WHITEFISH OF HOGAN'S POND

The food of lake whitefish has been already made the subject of several studies. All these works clearly revealed that the young whitefish feed mostly on plankton. Forbes (1882) in a series of experiments in which he fed hatchery whitefish fry on natural plankton found that under these conditions the first food taken by preference consisted of small Entomostraca, particularly Cyclops and Diaptomus. Hankinson (1914, 1916) observed the food of young whitefish as consisting chiefly of the Entomostracans, e.g. Bosmina, Diaptomus and Cyclops. Mellen (1923) reports that whitefish fry are first surface feeders and then drop to the bottom. Hart (1931) reports that Cladocera, Copepods and insects form the bulk of the food in all young whitefish ranging from size of 14 mm. to the size of 80 mm. long. Bajkov (1930) claims that in the second year the young whitefish feed mostly on bottom fauna. From the third year on the young whitefish keep in deep places together with the adult fish and feed on the same food as the latter. The food of adult fish, as Bajkov points out, consists mainly of Amphipoda, Chironomid larva, Hexagenia limbata, Phryganeidae and various small mollusca.

The main food of the Hogan's Pond whitefish varies greatly from that of other localities. The food of the adult fish consist mostly of Daphinia sp., Amphipoda together with fewer bottom organisms. This is similar to the food of whitefish fry as reported by many authors. In additions, the feeding intensity of whitefish examined reveals that the whitefish of Hogan's Pond have difficulty to gain sufficient food. 13 out of 43 whitefish

(31 %) examined having empty or nearly empty digestive tracts. If only stomach contents were taken into consideration, almost half of these 43 whitefish have empty or nearly empty stomachs. Only 3 out of 43 whitefish have a relatively full digestive tract contents.

The food analysis of 43 whitefish was carried by three way, (i) the number method; which is based on a count of organisms of the particular food type present. The Daphinia sp. and Cyclops were so numerous and tiny that the actual counting of them became unpractical. Instead, the numbers of Daphinia sp. and Cyclops were considered as one type of food and were roughly indicated as percentage of the total food in the digestive tracts. The estimation was carried out by placing a glass petri dish containing the organism over a piece of white paper on which had been drawn a number of equal section in the manner of a pie diagram. The number of organism in one section was then counted after the organisms were evenly spread over the bottom of the dish. The total number was then calculated proportionally. The rest of food organisms were counted individually. The number of Daphinia sp. and Cyclops was further expressed in percentage. (ii) The weight method; the weight method is based on percentage dry weight. (iii) The occurrence method: this is expressed as a percentage calculated by dividing the number of digestive tracts containing the food type by the total number of stomach examined.

A. The number method.

10 whitefish taken in July, length 242 mm.- 317 mm. (F.L.), age 4-7.

Cladocera (Daphinia sp.) and Copepoda (Cyclops sp.)-- 99.7 %

Amphipoda (Gammarus sp. etc.) ------------------------ 208

Ostracoda (seed shrimp)--- 26 Trichoptera larva house-- 14

Trichoptera adult ---- 7 Diptera larva (Tendipeidae) -- 16

Diptera larva (Ceratopogonidae) ------------------------ 5

Diptera larva (Dixidae) --- 6 Diptera adult ---------- 19

Hydracarina -------- 2 Mollusca (Gastropoda) --------- 46

Mollusca (Pelecypoda) -- 51 Odonta nymph ------------- 7

Coleoptera (water beetle) ------------------------------ 1

Epheneroptera nymph (Mayflies) ------------------------- 2

There were 384 Acanthocephala and Cestoda parasites in the digestive tracts of these 10 specimens.

7 whitefish taken in August, length 277 mm.- 309 mm., age 5-7.

Cladocera (Daphinia sp.) and Copepoda (Cyclops sp.)--- 99.3 %

Amphipoda (Gammarus sp. etc.) ------------------------ 212

Ostracoda -------- 64 Trichoptera larva house ------ 36

Trichoptera adult --- 2 Diptera larca (Tendipeidae) -- 6

Diptera larva (Ceratopogonidae) --------------------- 2

Diptera larva (Dixidae) --- 17 Hydracarina ---------- 4

Mollusca (Gastropoda) ----- 9 Mollusca (Pelecypoda) -- 12

Odonta nymph -------------- 8 Heptageniidae (Mayflies larva) -------------------- 3

There are 183 Acanthocephala and Cestoda parasite in the digestive tracts of these 7 specimens.

5 whitefish taken in September, length 272 mm. - 299 mm., age 4 - 5.

Cladocera (Daphinia sp.) and Copepoda (Cyclops sp.) -- 97.5 %

Amphipoda (Gammarus sp. etc.) ------------------------- 91

Trichoptera larva house --- 7 Trichoptera adult ----- 1

Diptera larva (Tendipeidae) --------------------------- 330

Diptera (Ceratopogonidae) --- 6 Diptera larva (Dixidae) -- 2

Mollusca (Gastropoda) --- 21 Mollusca (Pelecypoda) --- 122

Odonta nymph --------- 3 Ephemesoptera nymph ------- 13

Heptageniidae -------- 23

There were 231 Acanthocephala and Cestoda parasites in the digestive tracts of these 5 specimens.

8 whitefish taken in November, length 278 mm. - 315 mm., age 4 - 7.

Cladocera (Daphinia sp.) and Copepoda (Cyclops sp.) --- 95.4 %

Amphipoda (Gammarus sp. etc.) ------------------------- 212

Ostracoda --------- 17 Trichoptera larva house ------- 28

Trichoptera adult --- 2 Diptera larva (Tendipeidae) -- 72

Diptera larva (Ceratopogonidae) ----------------------- 42

Diptera larva (Dixidae) --- 5 Mollusca (Gastropoda) -- 44

Mollusca (Pelecypoda) ----- 34 Odonta nymph ---------- 4

Ephenesoptera nymph ------- 8 Heptageniidae ---------- 16

There were 274 Acanthocephala and Cestoda parasites in the digestive tracts of these 8 specimens.

Of these 13 whitefish having empty or nearly empty digestive tract, 2 were taken in July, 3 in August, 3 in September, and 5 in November, length 269 mm. - 307 mm., age 4 - 8.

Cladocera (Daphinia sp.) and Copepoda (Cyclops sp.) ------
------------------------------ around 3600.

Amphipoda (Gammarus sp. etc) -------------------------- 67

Mollusca (Gastropoda) --- 13 Trichoptera larva (Tendipeidae) ------------------- 17

There were 497 Acanthocephala and Cestoda parasites found in the digestive tracts of these 13 specimens.

B. The weight method.

Daphinia sp. and Cyclops sp. compose the greatest percent by weight, having 36.5 % of the total food contents. Amphipoda ranks second in the weight composition of the food taken by whitefish of Hogan's Pond, having about 30 %.

Trichoptera adult ----- 6 % Diptera (Tendipeidae) -- 5.5 %

Mollusca (Pelecypoda) --- 4 % Mollusca (Gastropoda) -- 3.1 %

Trichoptera larva house --- 2.8 % Ostracoda ---------- 1.6 %

Mayflies nymph and larva --- 1.6 % Odonta nymph ----- 1.0 %

Hydracarina ---------- 0.6 % Diptera larva (Ceratopogonidae) -------------------- 0.6 %

Hephageniidae --------- 0.5 % Ephenesoptera ----- 0.4 %

Other indistinguishable materials --------------- 5.5 %

C. The occurrence method.

At Hogan's Pond, Cladocera (Daphinia sp.) and Copepoda (Cyclops sp.) occurred more often than any other food item and were found in all 43 digestive tracts.

Cladocera and Copepoda ------ 100 % Amphipoda ----- 86 %

Ostracoda ------- 16.3 % Trichoptera larva house -- 42 %

Trichoptera adult ---11.6 % Diptera larva (Tendipeidae) -- ------------------- 42 %

Diptera (Ceratopogonidae) -- 23.2 % Hydracarina --- 11.6 %

Diptera (Dixidae) --- 16.3 % Mollusca (Gastropoda) -- 23.2 %

Mollusca (Pelecypoda) --- 25.6 % Odonta nymph --- 35 %

Coleoptera --------------- 7% Ephenesoptera ---- 18.6 %

Hephageniidae --- 11.6 %

Other indistiguishable materials -------------------- 70 %

From the above quantitative studies we are convinced that the food supply for Hogan's Pond whitefish, particularly for adult fish, is far from being sufficient. Indeed, the Hogan's Pond whitefish show apparent marks of malnutrition. Horwood (1967) reports that the people with house on Hogan's Pond sometimes see whitefish come to surface and die. He also claims that the food supply is probably too small for them. Generally, a whitefish older than two years will feed mostly, if not entirely, on bottom fauna. Hogan's Pond population, however, have their food contents consisted chiefly of tiny Daphinia sp. and Cyclops sp. with fewer proportions of bigger Amphipoda, and scarcity of insects and mollusca, and other bottom fauna. The poor growth rate, especially with respect to body weight, and great degree of emaciation among older whitefish of Hogan's Pond are therefore attributable to the insufficient food supply in this pond. Other factors, such as overpopulation and small size of water body are also responsible for the poorer growth condition. On the other hand, the seriously overcrowded population could be considered as the reason for this malnutrition.

IX. DISCUSSION

The lake whitefish is the most valuable of the fresh water commercial species in North America. They are rather sluggish fish inhabiting in a cold and deep water and generally feed upon small animals of various kinds and almost any kind. The species is highly variable with respect to its morphological features, and it is difficult to find characteristics of taxonomic value. Morphologically, whitefish are modified by environmental factors, both physical and biological, to a great extent and so numerous climate races are developed due to the environmental modifications that the speciation of this group of fish becomes very confusing.

For several decades, Hogan's Pond whitefish have been living in isolation. They provide vivid examples of morphological elasticity and life history variations due to environmental influences. They have been evolved into an unique climate race from being brought to a completely new environment. The environmental modification in the rate of growth and the rate of differentiation so greatly alter the characters of fishes that is is unreliable to solve the speciation problem based entirely on morphological characters and natural history.

The lake whitefish is the least-known of common Newfoundland fresh water food fish species, but elsewhere it is one of the most important food fishes. Lake whitefish prefer cold and fairly deep water. They migrate from deep to shallow water in spring to feed, and a subsequent retreat to deep water in early summer to avoid the warm temperature. Again, during fall or winter, depending on geographical position of the lake and temperature, they move from deeper water to the shallower areas to spawn (LaGorce, 1939; Lawler, 1961). Consequently, a fairly deep and large body of water with adequate littoral zones or shoal areas would be necessary for the good growth condition of whitefish.

The poor growth condition of Hogan's Pond whitefish can undoubtedly be attributed to overcrowding (Scott and Crossman, 1964; Horwood, 1967), small body of water, and insufficient supply of food. The relatively rapid growth during the very first or two years, however, may be correlated with the temperature and food. Hall (1925) reports that eggs of <u>Coregonus clupeafromis</u> when incubated at lower temperature hatch out embryos which are significantly larger than those hatched from eggs which have been incubated at higher temperature. The temperature of Hogan's Pond at hatching period period (April or May) was found to be significantly lower than that of Lake Erie during the same period reported by Lawler (1961). The earliest foods of <u>Coregonus clupeaformis</u>, as Forbes (1882); Hankinson (1914, 1916); Mellen (1923) and Hart (1931) point out, consist chiefly of pelagic forms of minute animals, such as Daphinia, Cyclops, and Gammarus which are plentifully found in Hogan's Pond. Larger eggs of Hogan's Pond whitefish are also expected to produce larger fry.

It is generally accepted that earlier sexual maturity and poorer growth, as well as later sexual maturity and better growth are interrelated for dwarf whitefish and whitefish of extremely poor growth condition,such as Hogan's Pond whitefish, that is, slow growth accelerate maturity and give a comparatively short life span. The factor or factors provoking the early sexual maturity remain unknown. Alm (1946) suggests that it may be the lack of certain nourishing substances, or the degree of acidity of the water, or the content of oxygen gas or the temperature or some hitherto unknown factors. Fenderson (1964) suggests that unknown physiological factors apparently compensate for extreme slow growth by accelerating maturity. All these problems require special attention in further studies.

The whitefish of Hogan's Pond were found to be not very fecund, producing fewer number yet larger size of eggs than other populations of the same species. It seems that nature enable Hogan's Pond whitefish to balance their overcrowded population and to overcome the poor growth condition by giving them the capacity to produce small number and larger size of eggs. Svardson (1949b) claims that the nature's economy with living material would tend to use energy not needed for production of more eggs to build the the mother body or promote her growth. In addition, evidence shows that larger eggs give larger larvae, and more capable for surviving, thus under poor growth condition, natural selection will favor the fish to produce larger eggs hence decreasing in number.

The whitefish of Hogan's Pond were found to be chiefly carnivorous as they are in other areas and it would seem that the type of food eaten is governed only by its availability. Bottom fauna, such as Diptera larvae, Amphipoda and small mollusca are important foods to young and adult whitefish in most of the areas surveyed in the literature. However, is constitutes only a small proportion of the food taken by Hogan's Pond adult whitefish. It is more likely to believe that this pond is insufficient in bottom fauna as food supply than to consider that whitefish in this pond fail in competition with rainbow trout and are thus unable to gain enough bottom fauna as a major food. A thorough survey of the bottom fauna in Hogan's Pond is necessary for supporting this conclusion.

X. SUMMARY

(1) Lake whitefish in Hogan's Pond were the product of a single planting of fry of Lake Erie whitefish dating back to 1886.

(2) In taxonomy, lake whitefish should better be included in the Family Salmonidae, and under the subfamily rake of Coregoninae.

(3) They prefer deeper, cold water, and were found in shallow water in spring and in fall or winter.

(4) The differences in morphological features of Hogan's Pond whitefish and Lake Erie whitefish are very great, particularly in body size, form, and color. The whitefish of Hogan's Pond seldom grow more than 380 mm. or about 15 inches in fork length, and weight under 400 grams or 0.9 pound. They bear smaller snout, larger eyes, more slender body form, larger fins and darker color above lateral line than Lake Erie whitefish.

(5) The whitefish of Hogan's Pond have more numerous lateral-line scales (average 85.5) thna any other population of the same species described in the available literature. The number of gill rakers of whitefish is regarded as the most stable taxonomic characteristics, least effected by environmental factors, however, Hogan's Pond whitefish have a significantly higher number of gill rakers (28.29) than Lake Erie whitefish (27.58).

(6) Temperature and space are regarded as the main factors responsible for these morphological differences and meristic number variations.

(7) <u>Coregonus</u> <u>clupeaformis</u> is one of the light-boned coregonine fishes, having supraorbital, small mouth, no basibranchial plate

on basibranchial bone. Usually toothless, and two nostril flaps.
(8) The growth studies of Hogan's Pond whitefish were based on 258 specimens collected in 1965 and 1966. The determination of age based on scale method was found to be very valid to meet the purpose of growth studies. The time of annulus formation on scales of Hogan's Pond whitefish was found as sometime in Janurary or February. The average age of 258 specimens was about 5. Age V and VI were dominant in the total specimens. Mortality rate was found very high, being 84 % from age VII to age VIII in Hogan's Pond population.

(9) Growth rate was found good in younger age groups, while a great degree of emaciation was noted among older fish. Age-length relation of 258 fish is described by the equation:

$$\log L = 1.2249 + 0.3141 \log A$$

Age-weight relation of 258 specimens is expressed by the equation:

$$\log W = 1.8428 + 0.7277 \log A$$

(10) The length-weight relation of lake whitefish from Hogan's Pond is described by the equation:

$$W = 0.1148\ L^{2.2779}$$

The body weight increased to the 2.2779 power of length in this population.

(11) Differences between the Hogan's Pond whitefish and the whitefish of other areas in growth in both length and weight are great. Hogan's Pond whitefish require nearly 8 years to reach the length of about 320 mm. (fork length) and weight of about 300 grams, whereas these sizes can be reached in third or fourth or even second year of life by other population.

(12) The relation between the fork length in cm. and the magnified (x 43) scale diameter in cm. is described by the equation :

$$L = 2.742 + 3.674\ S$$

(13) The number of male fish slightly exceeded that of the females in any age group except age-group VI. The percentage of male fish was 53.3 for all age groups combined.

(14) The youngest mature lake whitefish in Hogan's Pond belonged to age-group III and all fish older than age VIII were mature. The shorter mature males and female fish appeared in the 221 - 230 mm. fork length group, and all fish fish were mature at length greater than 320 mm. fork length.

(15) Estimations of the number of eggs in 35 lake whitefish ovaries ranged from 1,600 to 5,345; and average 2,954 eggs for fish ranging from 267 - 318 mm. long. The average number of eggs for fish grouped by 5 mm. intervals increased irregularly with increased fish length. The average number of eggs is inversely proprotional to the diameter of eggs. The average diameters of eggs for 35 specimens range from 1.0 to 2.7 mm..

(16) Daphinia sp. , Cyclops sp. and Amphipoda are by far the most common food and were found in almost every digestive tract of 43 specimens examined. Other food included insect larvae and small mollusca. The food supply was found too small for Hogan's Pond whitefish.

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