UNIVERSITY OF MANITOBA

EVIDENCE FOR TWO SYMPATRIC FORMS OF CISCOES (SUBGENUS *LEUCICHTHYS*) IN CEDAR LAKE

by

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance a thesis entitled "Ciscoes (Subgenus Leucichthys) in Cedar Lake, submitted by Raymond David Schweitzer in partial fulfilment of the requirements for the degree of Master of Science.

Supervisor

Date

ABSTRACT

Two populations of ciscoes (subgenus *Leucichthys*) coexist in Cedar Lake, Manitoba. They differ principally in rate of growth. Slow growing ciscoes mature at a younger age and have significantly fewer gill rakers and scales. Of twenty-four morphometric ratios, only eye diameter is of value in distinguishing the two forms and is larger in the small form. There is little evidence of habitat segregation in Cedar Lake. Low relative abundance of fast growing ciscoes aged I and II in the bottom nets suggests vertical zonation.

The large form is *Coregonus artedii* (LeSueur). The small form could not be identified from previous records.

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TABLE OF CONTENTS

PAGE

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

Sibling species are defined by Mayr (1963) as "morphologically similar or identical natural populations that are reproductively isolated." The genus *Coregonus* consists of two holarctic groups of sibling species: the whitefish (subgenus *Coregonus*) and the ciscoes (subgenus *Leucichthys*). The whitefish group is most diverse in Europe while the cisco group is most speciose in North America and eastern Asia.

The taxonomy of the coregonids is very difficult due to their extreme plasticity, which presumably represents adaptations to the environment. Mayr (1963) points out that sibling species are discovered because they have ecological, behavioural and/or physiological differences. Morphological differences, if any, are usually biometric, i.e. they consist of statistical differences found in the measurements. Due to this marked similarity sibling species are usually discovered when sympatric.

In this study two forms of cisco from a central Manitoba lake are described under the hypothesis that they are two sibling species. The dichotomy was first noted by Dr. E. T. Garside in August, 1962. Evidence of two forms was then based on size at maturity. The larger form was identified as *Coregonus artedii* (LeSueur) with the assistance of the taxonomic keys in Hubbs and Lagler (1964) and Hinks (1943). Identity of the small form was uncertain.

LITERATURE REVIEW

Ciscoes in Manitoba (Genus *Coregonus* formerly *Leucichthys*)

Dymond and Pritchard (1930) identified four species of cisco from Manitoba waters: *Leucicthys tullibee* (Richardson), *L. nipigon* (Koelz), *L. nigripinnis* (Gill), and *L. zenithicus* (Jordan and Evermann). All were previously described by Koelz (1929) from specimens taken from one or more of the Great Lakes. Dymond and Pritchard (1930) separated the above species by the following key:

A. Gill rakers 55 or more on the first branchial arch, *L. nipigon*.

AA. Gill rakers fewer than 43 on the first branchial arch, *L. zenithicus*.

AAA. Gill rakers 43 to 54 on first branchial arch.

B. Head long, in specimens 10 inches or more in length, 3.8 to 4.0 *L. nigripinnis*.

BB. Head short, 4.1 to 4.4 *L. tullibee*

It was noted by Hubbs and Lagler (1964) that *L. nigripinnis* differs further from *L. tullibee* (=*L. artedii*) in that the body is deeper forward than medially whereas *tullibee* is deepest medially. These four species also differ in Lake Winnipeg in their growth curves. However, the upper size limit of the four species is similar: about 350 mm. standard length (Keleher, 1952).

Leucichthyes hoyi, endemic in the Great Lakes and Lake Nipigon, has been reported to occur in Lake Winnipeg by

Bajkov (1932). Its occurrence in Lake Winnipeg has not been verified since. The gill raker range of Leucichthys hoyi in the Great Lakes (Koelz, 1929) and Lake Winnipeg (Bajkov, 1932) is respectively: 37 to 50 and 34 to 50.

Koelz (1919) noted that L. hoyi resembles young artedii in the Great Lakes but that hoyi is distinguished by fewer gill rakers and lateral line scales, larger head, maxillary and ventral fins, and particularly by the lengths of the lower jaw which in hoyi is equal to or longer than the upper, and in artedii is shorter or equal.

History of Coregonus artedii (LeSueur)

Richardson (1836) first named Leucichthys tullibee from Pine Island Lake (Cumberland Lake) Saskatchewan. Six specimens were described from the type locality by Dymond (1928). The standard length varied from 295 to 354 mm. Gill raker counts ranged from 48 to 54.

Dymond and Pritchard (1930) described Leucichthys tullibee from Lakes Winnipeg, Winnipegosis, St. Martin and from lakes in the Kenora district, Ontario and from six lakes in Saskatchewan. The average standard length of tullibee in Lake Winnipeg was 347 mm. The combined gill raker range was 43 to 51.

Dymond and Pritchard (1930) noted the close relation between tullibee and artedii of the Great lakes but preferred to consider them distinct. They pointed out that "Leucichthys tullibee suggests the large, deep-bodied, quick growing form of the Great Lakes . . . which Koelz (1929) regards as subspecies of Leucichthys artedii namely L. artedii albus and L. artedii manitoulinus."

Koelz (1930) described 24 subspecies of Leucichthys artedii on the basis of 6 morphometric and 2 meristic characters. He reduced Leucichthys tullibee of Lake Winnipeg and Pine Island Lake to a subspecies: Leucichthys artedii tullibee (Richardson). The gill raker counts of 14 specimens from Lake Winnipeg ranged from 49 to 53. He also reported this subspecies as occurring in Lake of the Woods and its tributary, Rainy Lake, and from Lake Waskesiu, Saskatchewan. The gill raker range for 6 specimens taken from Lake of the Woods was 43 to 52.

Koelz (1930) named a new subspecies: L. artedii winnipegosis, from 9 specimens taken in 1922 from Lake Winnipegosis. Their standard length varied from 188 to 204 mm. Gill raker counts varied from 44 to 49. Specimens from Wabigoon Lake and three Michigan lakes were included in this subspecies.

Bajkov (1932) gave the gill raker frequency of large samples of the shallow water cisco from the three principal Manitoba Lakes: Lake Winnipeg; mode 46, range 41 to 56, Lake Winnipegosis; mode 45, range 42 to 51, and Lake Manitoba; mode 46, range 42 to 51. Bajkov adopted Koelz's terminology but considered these ciscoes to be of one subspecies: L. artedii tullibee.

Typical artedii i.e. Coregonus artedii artedii (LeSueur) of the Great Lakes, was stated to occur in Reindeer Lake, Saskatchewan by Bajkov (1932). The seven specimens were stated as having shorter heads and more slender body and commonly attaining not more than 250 mm. standard length. However this does not necessarily indicate subspecific diversity. No other data were given. Bajkov (1932) further noted that "In Lake Winnipeg (especially along the eastern shore) specimens occur which cannot be distinguished from typical *L. artedii*, together with a deeper form which cannot be distinguished from typical *tullibee* from Lakes St. Martin, Manitoba, Winnipegosis, Pine Island, and others. There are all gradations of intermediate forms which often cannot be placed definitely either in *tullibee* or *artedii*."

The Occurrence of Dwarfism Among Whitefish

Sympatric pairs of morphologically similar species that differ in growth rate and size or age at maturity have been reported by several authors.

Kennedy (1943) found two forms of *Coregonus clupeaformis* in Lake Opeonge. No difference was found between the two forms with respect to allometric growth (six characters) or vertebral number. The two groups differed in gill raker count and lateral line scale count with the large form having the higher counts.

Kennedy found that the larger form has a longer growing season than the dwarf form. Differences in vertical distribution were not outstanding. Kennedy concluded that: "Since both groups occur in the same habitats during the growing season the above differences cannot be the direct result of the environment."

Svardson (1957) suggested that the dwarf form is Coregonus pidschian (Gmelin).

Svardson (1959) referred to numerous cases of the occurrence of dwarf species which were sympatric with other whitefish species. When transplanted to barren lakes the dwarf species resumed normal growth. The dwarf populations were therefore considered to be stunted forms.

Fenderson (1964) studying forms of Coregonus clupeaformis in eleven Maine lakes found 5 sympatric populations of dwarfs. Dwarfs differed from normals in only one out of 12 morphometric characters. Lateral line scale counts differed significantly in only one lake. Normals had high counts. The sympatric populations all differed significantly in gill raker number, with normals having a higher count. One lake was unusual in that the dwarfs exhibited bimodality in gill raker number. Two of the allopatric populations were unusual in that dwarf populations had very high counts, similar to normal clupeaformis. Furthermore, an allopatric normal population was found which had an intermediate number of gill rakers. Fenderson interprets this reversal by suggesting that either phenotype may become dwarfed.

Dwarfs actually grew faster than normals in one of the lakes, but had a shorter life span. In this lake the two forms were completely separated on the basis of gill raker count.

Fenderson concluded that: "The small size, slow growth and early maturity of the dwarfed lake whitefish probably do not represent a genetically fixed phenotype . . ." He suggested that: "Dwarfism may be a physiological adaptation having survival value in the face of adverse conditions of the environment which tend to retard growth and shorten the life span of individuals at an early age. Under such conditions early maturity would be a distinct advantage in perpetuation of the species."

MATERIAL AND METHODS

Cedar Lake Investigations

Cedar Lake, 53° 15' north longitude, 100° 15' west latitude, has been investigated intensively by biologists and field personnel of the Manitoba Department of Mines and Natural Resources from 1960 to 1964. The specimens for the present study became available during the 1964 season of these investigations. Data from the summers of 1962 and 1963 are included to supplement the 1964 observations on growth, maturity, distribution and abundance.

Nylon thread gill nets were used in capturing ciscoes. The mesh sizes used were 1.5, 2.0, 3.0, 3.75, 4.25, 4.75, 5.0 and 5.25 inches (3.8, 5.1, 7.6, 9.5, 10.8, 12.1, 12.7, 13.3 cm.). Eight experimental gangs of nets were set between June 23 and August 27, 1964. All experimental gangs were set on the bottom and left overnight.

All fish caught were routinely examined by the field party at the time of capture. Only ciscoes from the four experimental gangs set in the southern part of the main basin were retained for later morphological examinations. Very few ciscoes were caught in the other nets and none appeared to be small immature fish. A total of 310 ciscoes were retained.

The ciscoes were stored in 4 per cent formaldehyde during transport. Ciscoes approximately 20 cm. in length or less were later transferred to 40 per cent isopropyl alcohol before examination.

Sex and State of Maturity

Sex of even immature ciscoes is easily determined by noting the consistency or texture of the gonads. Female gonads have a granulated appearance. State of maturity was considered to be an important criterion and therefore care was taken in its evaluation. Ciscoes were noted as definitely immature if they showed no development of the gonad above the thickness of the oviduct or Wolfian Duct, as mature if ovary or testes filled the coelom, and were given a grade of one to four for intermediate stage of development on the basis of the degree to which each filled the coelom and on the shape of the gonad.

It was later decided that all fish given a grade of two or more would mature that year. Fish given a value of one which were caught in June and July were given mature status, those caught in August were considered immature. This decision was made since it was later found that there was a lower percentage of fish given a value of one in August than in July.

Ciscoes examined during the 1962 and 1963 seasons at the time of capture were noted as mature, immature or unknown. Those marked unknown were not included in growth and maturity analysis.

Age Determination

Scales were removed from just below the dorsal fin and above the lateral line on the left side of each fish. Five to ten scales from each fish were placed between glass slides and were projected with an enlargement of 22.8 times by a Bausch and Lomb microprojector.

The assumptions underlying age determination from scales were validated by Van Oosten (1929) who studied Coregonus artedii. The principal assumption is that one annulus is laid down per year. The definitive character of an annulus was two or more anastomosing circuli in the anterior-lateral field. Very often this was associated with dark bands of closely spaced circuli (light bands of negative prints, Fig. 3) corresponding to the period of winter growth.

Accurate age determination was impeded by the occurrence in cisco scales of accessory and double annuli. Accessory annuli are additional annuli separated from the true annuli by a period of summer growth. All the fish were aged twice and the discrepant scales aged a third time and assigned a definite age. Fish scales aged from four to eight were again examined.

The fish scales collected during the 1962 and 1963 seasons were assigned a definite age on first reading by a professional scale reader of the Fisheries Branch, Manitoba Department of Natural Resources.

MERISTIC SERIES

Gill Rakers

The first gill arch on the left side was removed by cutting across the basibranchials between the first and second gill arches. The upper gill attachment was cut away from the roof of the pharynx.

Gill arches were stained in a solution of alizarin red and sodium hydroxide for 24 hours. The staining solution was modified from Hollister (1934) as follows.

a. Stock solution: 1 part glacial acetic acid.
   2 parts glycerin.
   12 parts one per cent chloral hydrate.
   - add alizarin red until orange color is reached.

b. 4 per cent NaOH

c. Mix 1 part stock and 3 parts NaOH to get orange-red solution.

Total count of gill rakers including small rudimentary rakers were made using a binocular microscope.

Lateral Line Scales

Scales in the lateral line were counted from the second most anterior scale near the head to the scale at the end of the vertebral column. The end of the vertebral column was marked by a pin driven through a small opening just posterior to the last vertebra.

Scales were counted on the left side unless many scales were lost. Scale pockets were counted if it was possible to do so accurately.

Peduncle Scale Rows

Horizontal scale rows around the narrowest part of the caudal peduncle were counted.

Measurements

All measurements were made on the left side unless impossible to do so. The measurements shown in Figs. 1A and 1B followed those of Hubbs and Lagler (1964) unless otherwise noted. Twenty-one measurements were made by three methods:

a. A vernier caliper graduated to .025 mm. was used for making the following measurements:

1. Mandible Length (Mand. L.).
2. Maxilla Width (MW) - the greatest width of the maxilla including the supramaxilla.
3. Peduncle Depth (PD).

b. Five measurements of small distances on the head were made by needle point dividers. Spread of the dividers was measured on the vernier rule and was considered accurate to 0.25 mm.

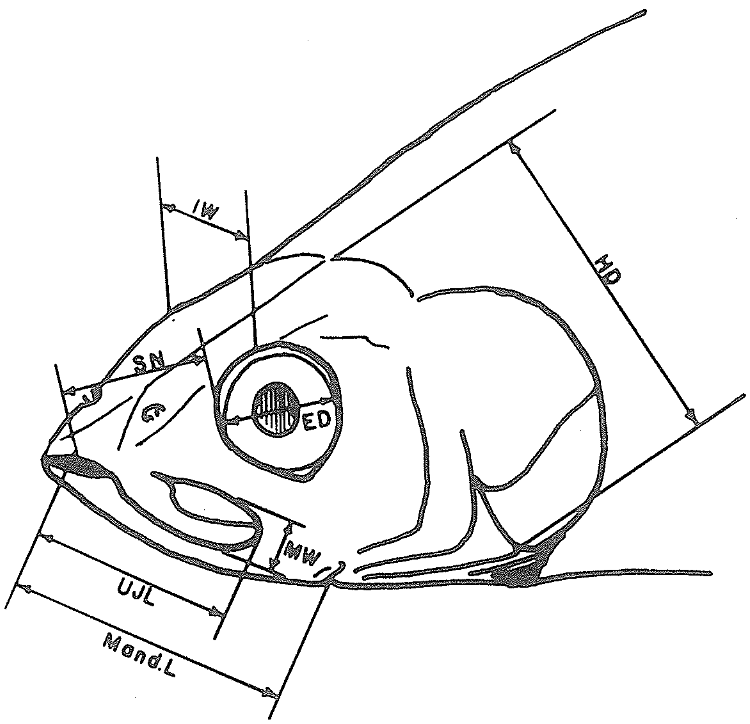
4. Head Depth (HD) measured obliquely from the midline of the occiput to ventral union of the sub and interopercular.
5. Snout Length (SN).
6. Interorbital Width (IW) - the least bony width.
7. Eye diameter (ED).
8. Upper Jaw Length (UJL) - length of maxilla.

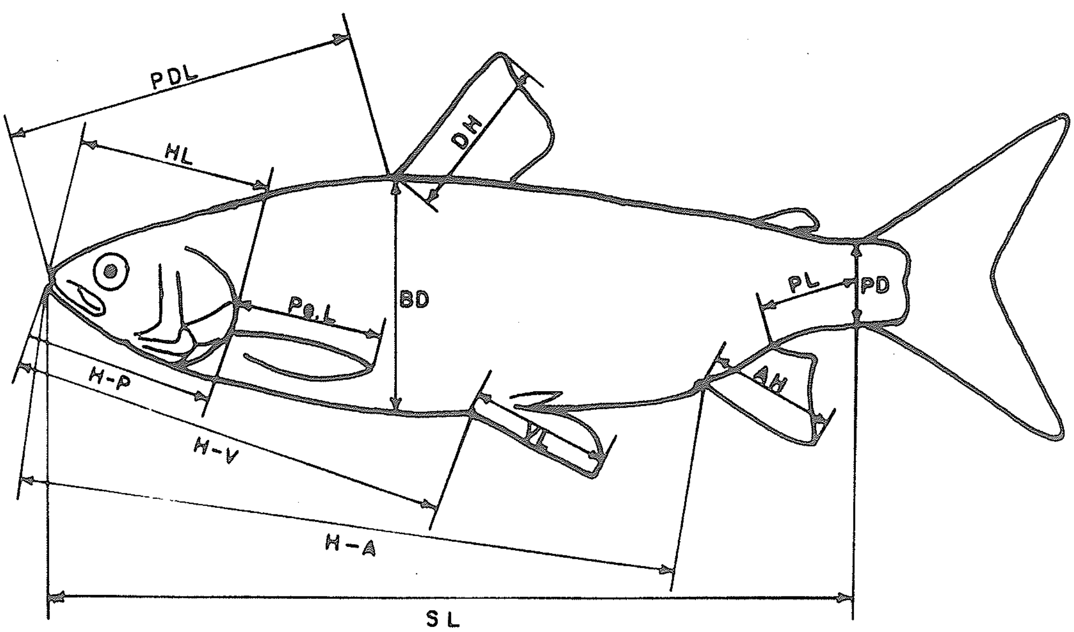
c. The remaining measurements were made by large dividers with one arm pointed, the other rounded. The spread of the dividers was measured against a rule judged accurate to 0.5 mm.

9. Standard Length (SL).

Figure 1A. Head Measurements: head depth (HD), mandible length (Mand.L), upper jaw length (UJL), maxilla width (MW), snout length (SN), eye diameter (ED), interorbital width (IW).

Figure 1B. Measurements Lateral View: standard length (SL), body depth (BD), peduncle length (PL), peduncle depth (PD), predorsal length (PDL), head to anal distance (H-A), head to ventral (H-V), head to pectoral fin (H-P), head length (HL), dorsal fin height (DH), anal fin height (AH), pectoral fin length (Pe.L), ventral fin length (VL).


IW
SN
HD
ED
MW
UJL
Mand.L


PDL
HL
DH
BD
Pe.L
PL
PD
H-P
H-V
AH
VL
H-A
SL

10. Peduncle Length (PL) - the oblique distance from the end of the anal base to the end of the last vertebra.
11. Body Depth (BD).
12. Body Width (BW) - measures the greatest width. This is found just anterior to the dorsal insertion.
13. Head Length (HL) - including opercular membrane.
14. Dorsal Height (DH).
15. Anal Height (AH).
16. Pectoral Fin Length (Pe. L).
17. Ventral Fin Length (VL).
18. Predorsal Length (PDL).
19. Head to Pectoral - the distance from the tip of the snout to pectoral fin insertion.
20. Head to Ventral - the distance from the tip of the snout to ventral fin insertion.
21. Head to Anal - the distance from the tip of the snout to anal fin insertion.

Measurements 19 and 20 were used to calculate pectoral to ventral distance (P-V). Measurements 20 and 21 were used to calculate ventral to anal distance (V-A).

The measurements were converted to ratios of standard length or head length or some other character in order to compare fish of different sizes. The following ratios were calculated for each specimen:

PD/SL	Pe.L/SL	UJL/HL
PL/SL	VL/SL	HD/HL
BD/SL	P-V/SL	IW/HL

BW/SL	V-A/SL	ED/HL
HL/SL	Mand.L/SL	PDL/H-V
HD/SL	UJL/SL	V-A/P-V
DH/SL	SM/SL	PD/PL
AH/SL	ML/HL	MW/HL

Frequency distributions of each ratio were made with the fish grouped in intervals of two centimeters of standard length. Sex and state of maturity were indicated by different symbols.

RESULTS

Growth Characteristics

Two rates of growth are apparent in Fig. 2, with the possible exception of six specimens, aged V and VI which are intermediate in size. The growth rate of large ciscoes aged IV to VIII appears to confluent with age III immature ciscoes and perhaps with the larger immature ciscoes aged I and II. Mature ciscoes of age III appear to belong to both groups. This size dichotomy is very evident in the size of the scales from fish of the same age (Fig. 3). Growth differences between the sexes were not significant; $P(t \geq [0.2438]) > .05$.

The length frequency distribution of the 548 ciscoes taken in 1962 and 1963 (Fig. 4) which were aged and measured by personnel of the Fisheries Branch, Manitoba Department of Mines and Natural Resources revealed a similar dichotomy of growth rate. The length range of the fast growing ciscoes aged V and VI suggests that the intermediate size ciscoes of Fig. 2 belong to the fast growing group. A tendency towards leptokurtosis in the length distribution of the slow growing ciscoes is evident in both Figs. 2 and 4. As a result several intermediate sized ciscoes aged III to VI (Fig. 4) appear not to belong to either stock.

Relatively low numbers of fast growing ciscoes aged I, II and III (Fig. 2 and 4) are apparent from comparison with the small form, and from the expected number usually observed on a catch curve. Low numbers of ciscoes of each age group

Figure 2. Length Frequency at Each Age of Ciscoes Collected in 1964.

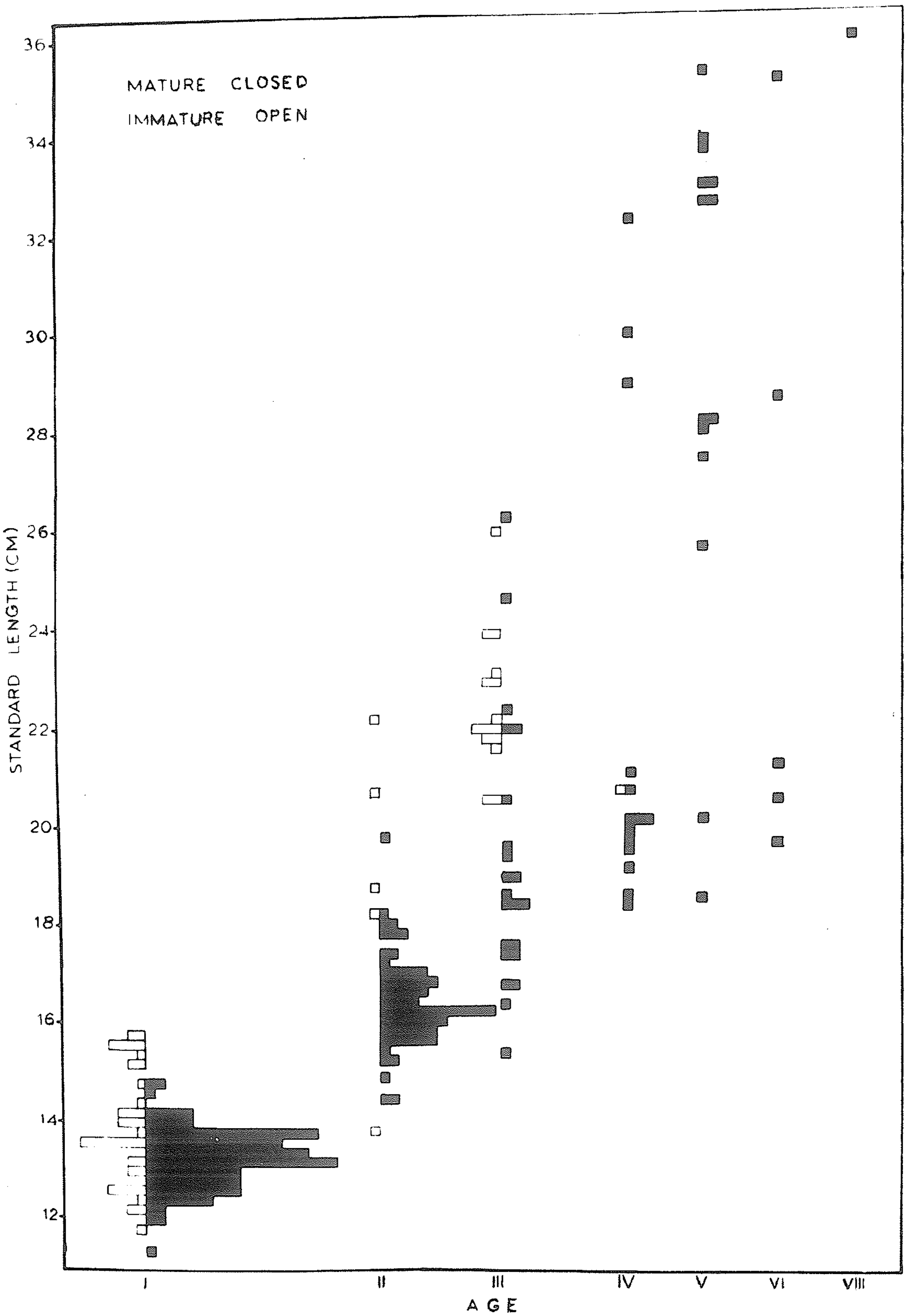
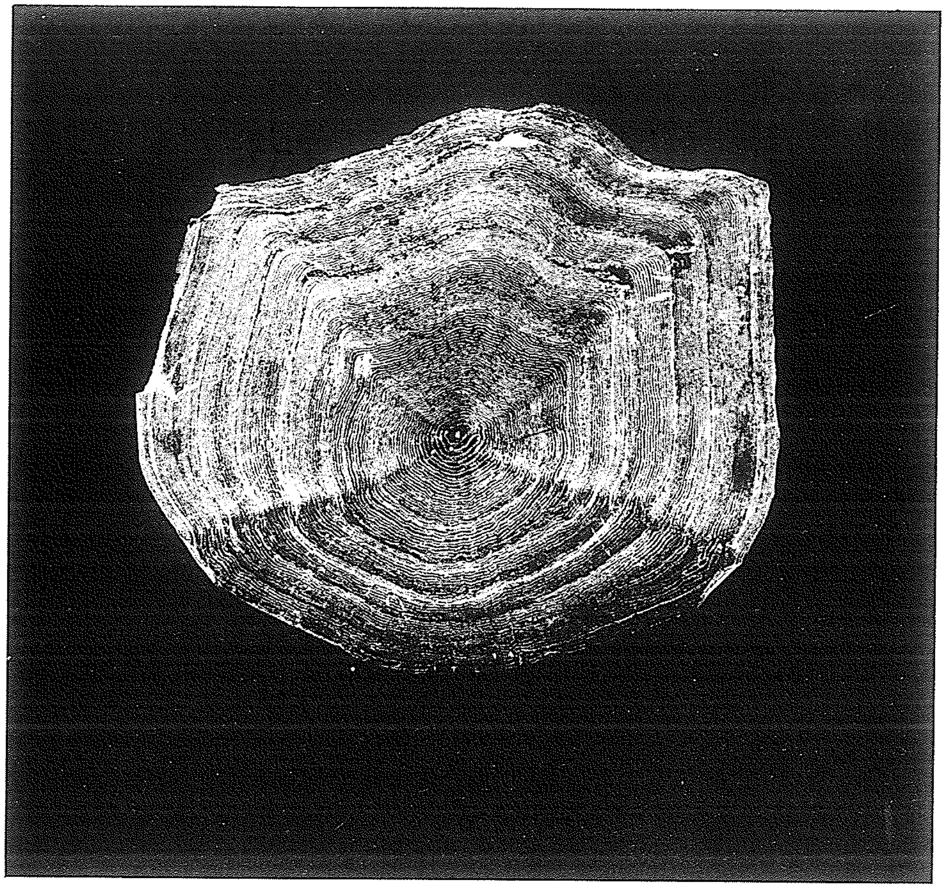

MATURE CLOSED
IMMATURE OPEN
STANDARD LENGTH (CM)
36
34
32
30
28
26
24
22
20
18
16
14
12
I
II
III
IV
V
VI
VIII
AGE

Figure 3. Scales of Ciscoes Aged VI. Top: from mature male, 287 mm. in length. Bottom: from mature male, 196 mm. in length. Enlarged x 8.5.



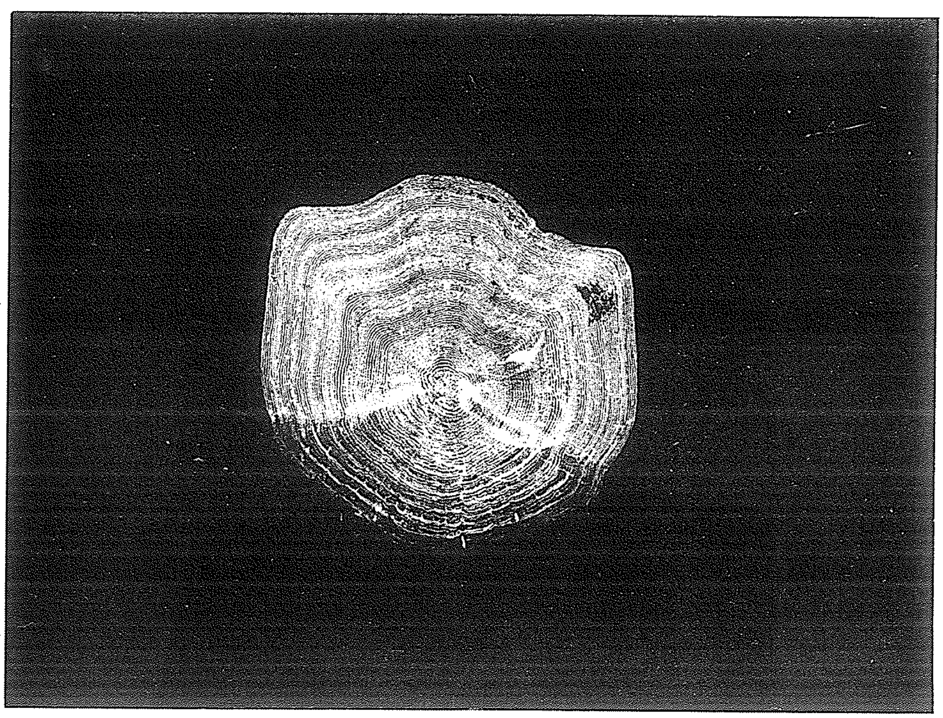
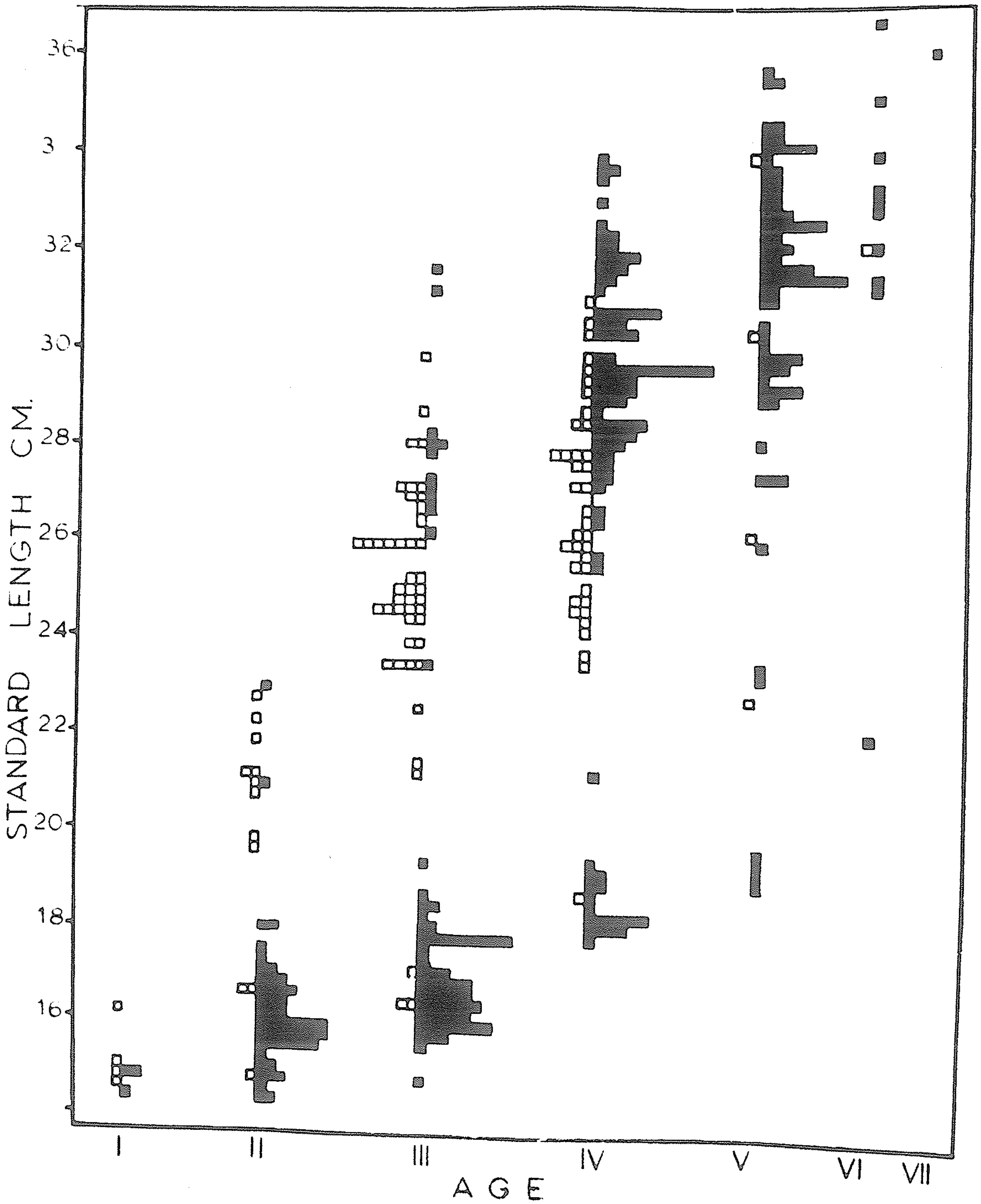


Figure 4. Length Frequency at Each Age of Ciscoes Collected in 1962 and 1963. Open bars represent immature; closed bars, mature fish.



STANDARD LENGTH CM.
36
3
32
30
28
26
24
22
20
18
16
I
II
III
IV
V
VI
VII
AGE

are common however in the length interval of 19 to 23 cm., although non-selective samplings of the length interval does not appear to be the cause of these low numbers. The length frequency distribution of ciscoes caught in the 2 and 3 inch mesh nets and the girth frequency in the same meshes (Appendix 1 and 2) overlap sufficiently in this length interval to sample the fast growing group with equal or even greater effort than that used to sample the slow growing group. Furthermore the fast growing ciscoes of age group I and the slow growing ciscoes would be sampled with equal effort by the 2 inch mesh nets.

Growing variation is normally attributable to two components: genetic and environmental variability. As the growth data of the present study were collected at different times during the years 1962 to 1964, two additional components of variation are present: seasonal and annual. The relative significance of the seasonal and genetics components of variation on the length-age distributions of Figs. 2 and 4 is not obtainable due to the use of a non-standard experimental gang and to the small sample size in comparable nets. The limited number of tests possible (Table 1) have shown that environmental variation attributable to spatial differences was not statistically significant. Variation in growth of the small form between the years 1962 and 1963 was found to be highly significant.

TABLE 1

SPATIAL AND ANNUAL GROWTH VARIATION OF TWO FORMS OF CISCO IN CEDAR LAKE

Spatial Variation	Set No.	Date	Range of Mesh Size	Mean S.L. Age III	No.	Level of t	Mean S.L. Age IV	No.	Level of t
Large Form	10	11,8/62	2" - 5"	25.7	40	not	28.2	74	not
	11	31,7/62		24.8	12	sig.	28.2	12	sig.
	12&13	21,24,8/62	3" - $4\frac{1}{4}$"	Sample too small			29.0	13	not
	14	3,9/62					30.0	11	sig.
Small Form	10	11,8/62	2" - 5"	16.7	16	not	Sample too small		
	11	31,7/62		16.6	50	sig.			
	15	5,8/63	2" - $5\frac{1}{4}$"	18.1	13	not	18.4	9	not
	16&18	7,10,8/63		18.0	9	sig.	18.3	6	sig.
1962 - 1963	10&11	11,8/62 &31,7/62	2" - 3-3/4"	16.6	65	<.01	17.9	11	<.01
Variation of Small Form	15,16 & 18	5,7,& 10 of Aug.63		18.0	21		18.4	15	

Age at Maturity

A significant difference between the slow and fast growing ciscoes is noted in the observed ratio of immature to mature at each age (Figs. 2 and 4), with the large form maturing later and thus having the greater ratios. Practically all of the small form are mature at age II and older.

From the large sample of fast growing ciscoes aged III to V in Fig. 4 it is apparent that maturity is nearly complete at age V, and 68 per cent of age IV ciscoes are mature.

The mature fish within age groups III and IV of the large form are somewhat larger than the immature ciscoes (Fig. 4). This same relationship is not apparent among the slow growing ciscoes.

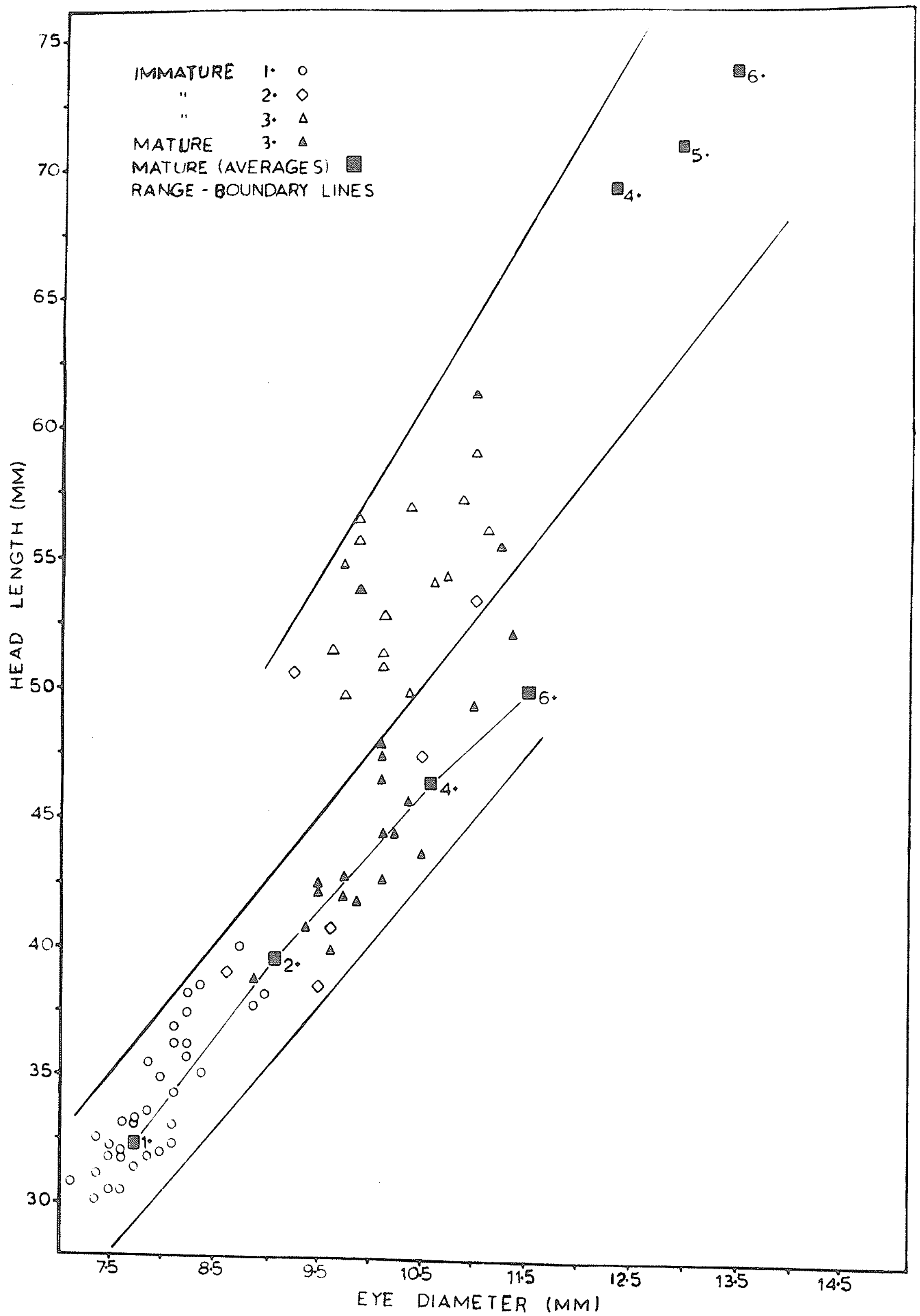
Morphometric Characters

No differences between the sexes were apparent from the frequency distributions of each of the 24 morphometric ratios.

Only head length/eye diameter showed partial separation of the fast growing ciscoes from the slow growing ciscoes with the fast growing ciscoes having the smaller eye (Fig. 5). This separation is attributed to eye diameter alone as a plot of head length on standard length gave a narrow scatter indicating very strong correlation.

Eye diameter however did not prove to be a totally dichotomous character as ciscoes aged I and II were not separated by a plot of eye diameter on head length.

Figure 5. Head Length (mm.) Versus Eye Diameter (mm.)


IMMATURE 1· ○
" 2· ◇
" 3· △
MATURE 3· ▲
MATURE (AVERAGES) ■
RANGE - BOUNDARY LINES
HEAD LENGTH (MM)
EYE DIAMETER (MM)
75
70
65
60
55
50
45
40
35
30
7·5
8·5
9·5
10·5
11·5
12·5
13·5
14·5
1·
2·
4·
6·
4·
5·
6·

MERISTIC CHARACTERS

Gill Rakers

Gill raker frequency distributions are given in Fig. 6. Fast growing ciscoes age IV to VIII have significantly higher raker counts than slow growing ciscoes of the same ages: $P(t \geq [5.757]) < 0.01$. The means are 48.0 and 44.4 respectively.

Since most of the immature and mature ciscoes aged I to III appear to belong to the fast and slow growing forms respectively, a test of the means of the meristic series of immature against mature for ages I to III may be made with the inference that the tests are being made between the fast and slow growing stocks. Immature ciscoes aged I to III have a significantly higher gill raker count than mature ciscoes in the same age group: $P(t \geq [5.757]) < 0.01$. The means are 46.9 and 45.0 respectively.

The "intermediate" sized ciscoes of Fig. 2 have been shown previously by the large sample distribution of Fig. 4 to most probably belong to the fast growing stock. However (and in lieu of the small number of intermediates), tests were made to relate these "intermediates" to either form. Most of the "intermediate" size ciscoes of Fig. 2 (solid bars of Fig. 6) are in the region of overlap of raker count. However they were not statistically different from either form.

Lateral Line Scales

The four frequency distributions of lateral line scales (Fig. 7) appear also to have been drawn from two populations. The mean counts for the large form and immature ciscoes are significantly higher than those for the small form and mature young ciscoes respectively. The lateral line scale counts of the "intermediates" are significantly higher than the counts of the small form but are not significantly different from the counts of the fast growing form. The statistics are:

Large Form, aged IV to VIII	67.7	$P(t \geq [5.289]) < 0.01$
Small Form, aged IV to VIII	62.3	
Immature, aged I to III	68.3	$P(t \geq [6.267]) < 0.01$
Mature, aged I to III	62.9	
"Intermediate", aged IV to VIII	66.8	$P(t \geq [2.246]) < 0.05$
Small Form, aged IV to VIII	62.3	

Peduncle Scale Rows

The distribution of peduncle scale rows (Fig. 8) follow those of gill rakers and lateral line scales, in that the large form and immature ciscoes have significantly higher counts than the small form and mature young ciscoes respectively. Quite unexpectedly, the large form has significantly higher counts than the "intermediate" size ciscoes. The dwarfs and the "intermediates" were not significantly different. The statistics for these comparisons are given below:

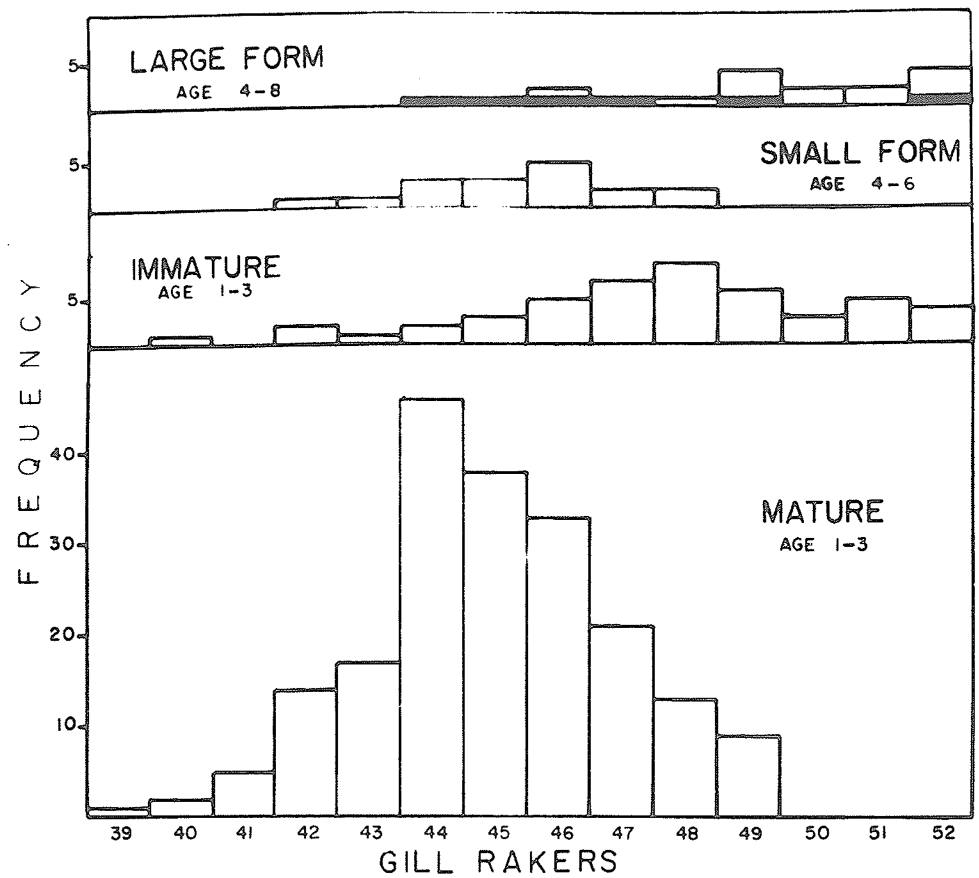
Large Form, aged IV to VIII	23.2	$P(t \geq [5.113]) < 0.01$
Small Form, aged IV to VIII	21.4	

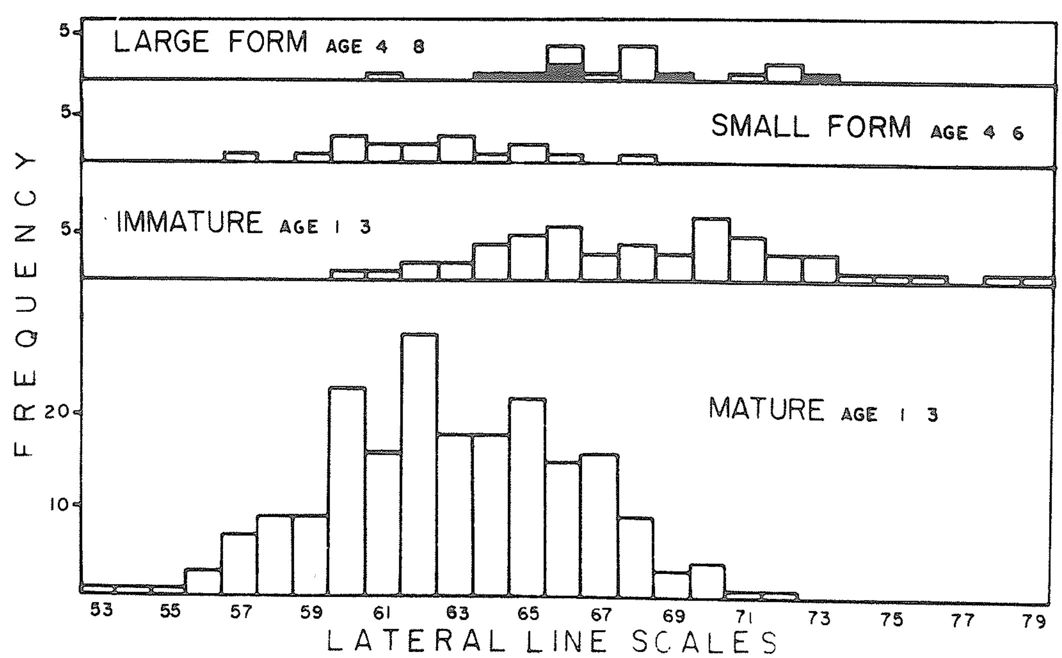
Figure 6. Gill Raker Count Frequency Distributions (n = 291).

Two upper distributions: ciscoes over III years, separated by size. In LARGE FORM, solid bars are fish with a standard length of 290 mm. or less. Lower distributions: ciscoes aged I to III years separated by state of maturity.

Figure 7. Lateral Line Scale Count Frequency Distributions (n = 295).

Two upper distributions: ciscoes over III years, separated by size. In LARGE FORM, solid bars are fish with standard length of 290 mm. or less. Lower distributions: ciscoes aged I to III years, separated by state of maturity.


LARGE FORM
AGE 4-8
SMALL FORM
AGE 4-6
IMMATURE
AGE 1-3
MATURE
AGE 1-3
FREQUENCY
5
5
5
40
30
20
10
39
40
41
42
43
44
45
46
47
48
49
50
51
52
GILL RAKERS


LARGE FORM AGE 4 8
SMALL FORM AGE 4 6
IMMATURE AGE 1 3
MATURE AGE 1 3
FREQUENCY
5
5
5
20
10
53
55
57
59
61
63
65
67
69
71
73
75
77
79
LATERAL LINE SCALES

Immature, aged I to III	22.5	$P(t \geq [7.858]) < 0.01$
Mature, aged I to III	21.2	
Large Form, aged IV to VIII	23.6	$P(t \geq [2.860]) < 0.05$
"Intermediates"	22.3	

Character Index

A character index was calculated by summing the individual meristic counts for each ciscoe. The frequency distributions of the character index for immature, mature and the two forms separated on the basis of age and size are given in Fig. 9. Statistical tests were not considered necessary.

The region of overlap between the large and small forms is quite narrow: character index 131 to 135. Only 26.5 per cent of the specimens fall in this region.

Utility of Separation

The utility of each meristic character in separating the two forms was estimated by calculating the percentage of individuals whose classification as one or the other of the two forms, based on age and growth, corresponded with their classification above or below a given meristic count. The point of maximum separation and the utility of separation are given below for ciscoes aged IV to VIII. The ciscoes of intermediate size were grouped with the large form.

Point of Max. Separation		Utility of Separation
G.R.	between 48 and 49	29/35 or 83%
LLS.	between 65 and 66	30/35 or 86%

PSR. between 22 and 23 27/34 or 79%

The points of maximum separation of immature from mature ciscoes aged I to III were found at 49 to 50 for gill rakers and 68 to 69 for lateral line scales. These are close to but not identical with separation points for older fish. The point of maximum separation of immature and mature ciscoes for peduncle scale rows was the same as that for ciscoes aged IV to VIII.

The character index was found to have a higher utility of separation for the two forms of ciscoes aged IV to VIII than had each meristic series taken separately. The utility of separation of the character index is 31/34 or 91 per cent.

Standard Length and Character Index

It was previously shown that ciscoes aged IV to VIII are clearly separated into two groups on the basis of standard length (Fig. 2) and by the character index, with the exception of three "intermediate" size ciscoes (Fig. 9). A plot of character index against standard length for age groups I to III (Fig. 10) also produces a partial separation, with larger ciscoes having a higher character index. With the exception of four or five age III ciscoes, those ciscoes in age I to III that are distinctly separated with a high character index and large size are immature.

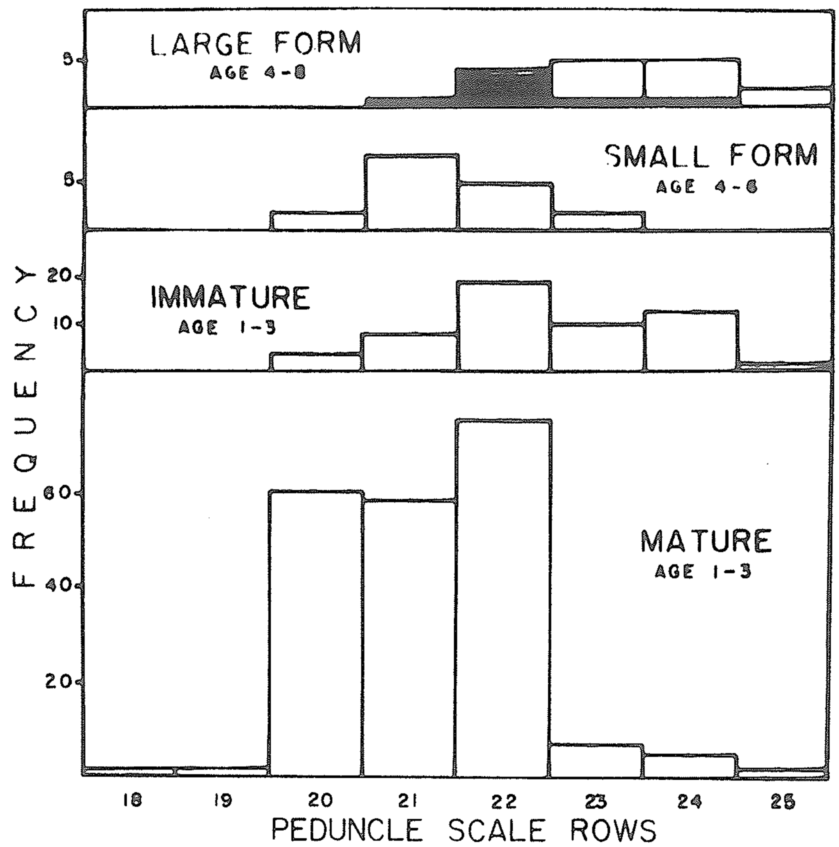
The relationship of high count and large size may appear from Fig. 10 to be the result of regression or correlation within age groups I and III.

Figure 8. Peduncle Scale Row Count Frequency Distributions (n = 302).

Two upper distributions: ciscoes over III years, separated by size. In LARGE FORM, solid bars are fish with standard length at 290 mm. or less. Lower distributions: ciscoes aged I to III years, separated by degree of maturity.

Figure 9. Character Index Frequency Distributions (n = 275).

Two upper distributions: ciscoes over age III, separated by size. In LARGE FORM, solid bars are fish with standard length of 290 mm. or less. Lower distributions: ciscoes aged I to III years, separated by degree of maturity.


LARGE FORM
AGE 4-8
SMALL FORM
AGE 4-6
IMMATURE
AGE 1-3
MATURE
AGE 1-3
FREQUENCY
PEDUNCLE SCALE ROWS

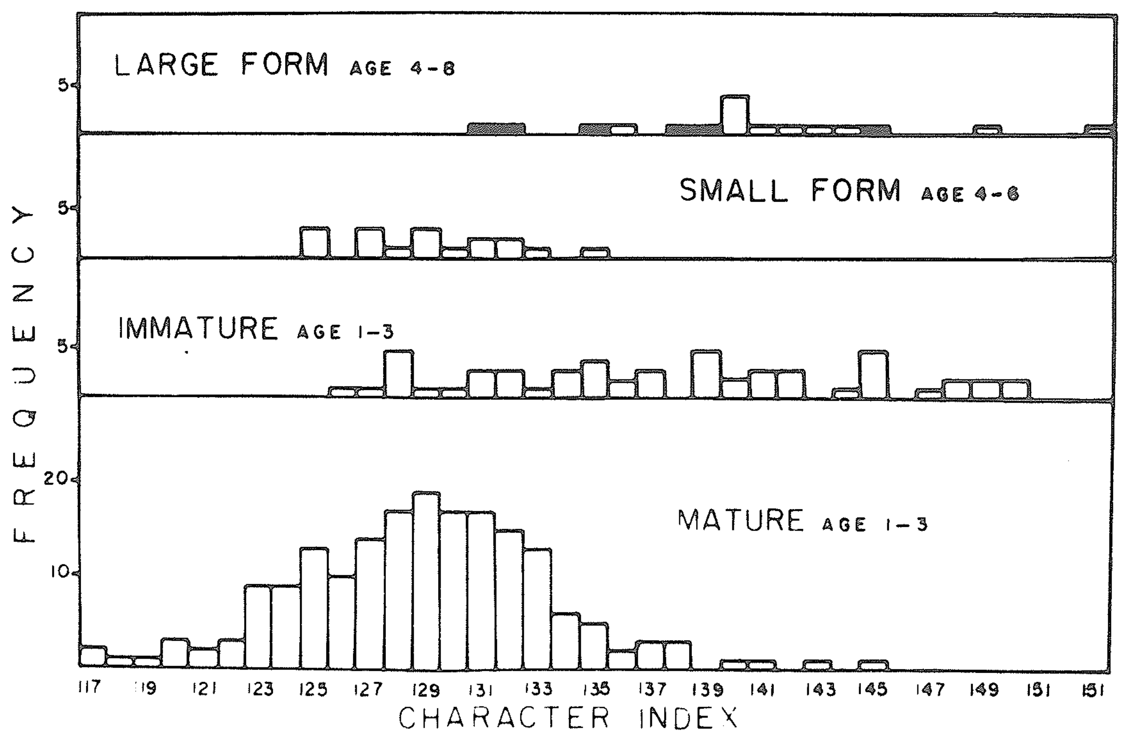
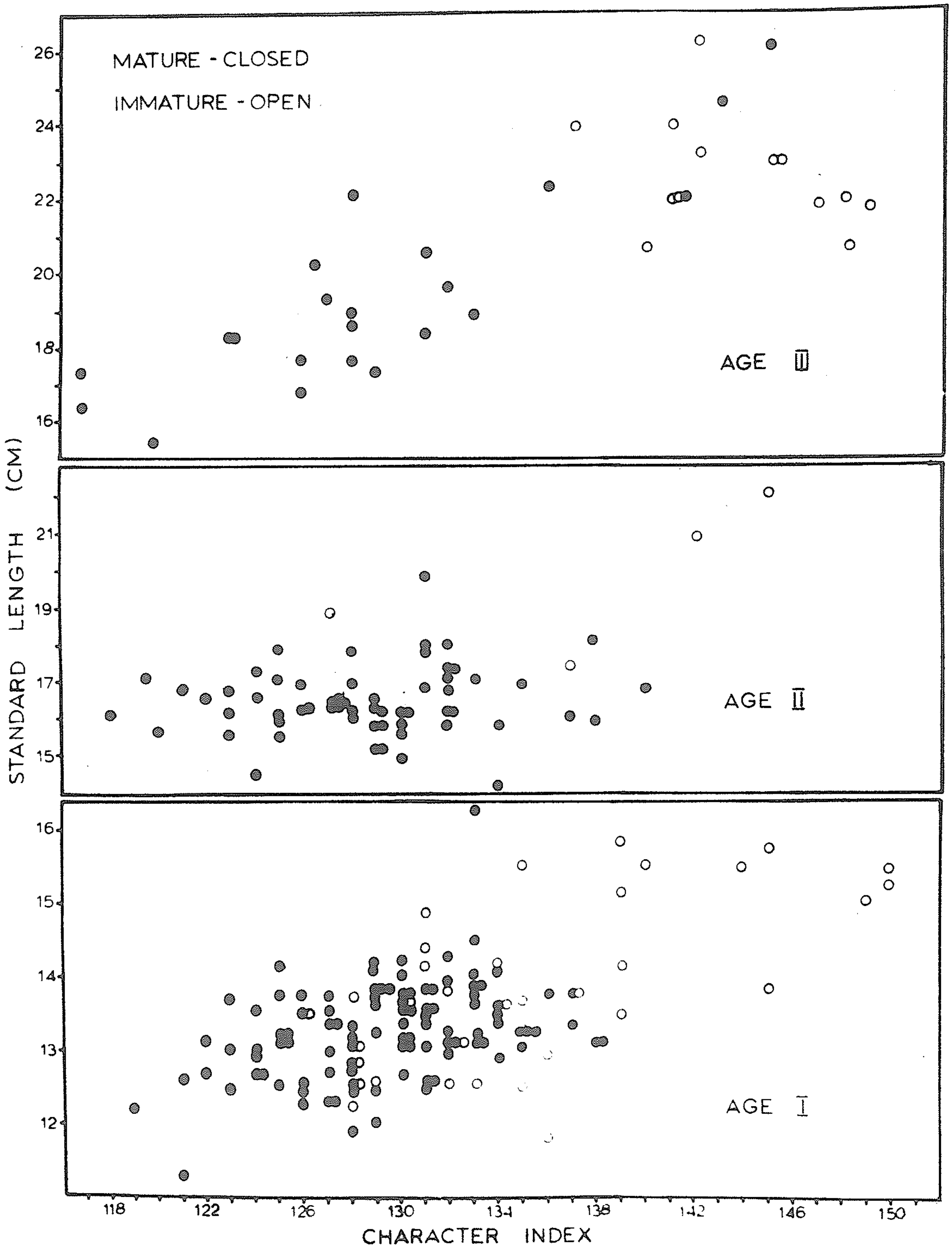

LARGE FORM AGE 4-8
SMALL FORM AGE 4-6
IMMATURE AGE 1-3
MATURE AGE 1-3
FREQUENCY
CHARACTER INDEX

Figure 10. Standard Length and Character Index.


MATURE - CLOSED
IMMATURE - OPEN
AGE III
AGE II
AGE I
STANDARD LENGTH (CM)
CHARACTER INDEX
26
24
22
20
18
16
21
19
17
15
16
15
14
13
12
118
122
126
130
134
138
142
146
150

Distribution and Abundance of Ciscoes

The number of ciscoes captured in each experimental gang of nets is given in Table 2 along with the depth of set, average catch per mesh of both forms, percentage of average catch of both forms in each net and the number of assignable fish of both forms in each net. The calculations are only approximate since ciscoes from the 1½" mesh nets and those of which appeared intermediate in size were omitted from the calculations and since there was undoubtedly some error in the assignment of individuals to their respective forms. (Assignment of individuals was made in the lab on the basis of size and age).

The positions of the experimental gangs set in Cedar Lake during the 1962 to 1964 seasons are given in Fig. 11. Ciscoes were absent from nets set near shore at depths of three metres or less. These 7 experimental gangs were unfortunately all set in the north arm or the northernmost regions of the main basin. Apart from the above, ciscoes appear to be relatively rare in these regions even at greater depths: ciscoes were absent from net sets 8b and 21 and one cisco only (length unknown) was taken in set number 5.

Estimates of relative abundance of the two forms of ciscoes in Cedar Lake can be made in several ways, but certain limitations inherent in the data make most of these estimates inaccurate. Initially it appears that the slow growing form is more abundant: in only two of the experimental gangs, 11 and 20, is the fast growing form more abundant.

TABLE 2

EXPERIMENTAL NET CATCHES OF CISCOES IN CEDAR LAKE

Set No.	Date	Depth Metres	Mesh Size (in.)						Total No.	# of Assignable Fish		% of x̄ Catch	
			2	3	3-3/4	$4\frac{1}{4}$	4-3/4	5		Large	Small	Large	Small
1	11,6,62	1.6-3.0		-	-	-	-	-					
2	13,6,62	1.6-3.2		-	-	-	-	-					
3	15,6,62	1.2-2.6		-	-	$-^{3}$	-	-					
4	20,6,62	1.2-2.6		-	-	$-^{3}$	-	-					
5	24,6,62	6.6		1	-	$-^{3}$	-	-	1	Unknown			
6	9,7,62	6.6	7	-	-	$-^{3}$	-	-	7		7		0.25
7	12,7,62	3.2-4.0	9	2	-	1	-	-	12	3	7	0.17	0.25
8a	14,7,62	1.6	-	-	-	-	-	-					
8b	14,7,62	5.0				$-^{2}$		$-^{2}$					
9	22,7,62	1.6-3.0	-	-	-	-	-	-					
10	31,7,62	5.0-6.6	80	22	10	2^{3}	-	$-^{3}$	114	34	79	1.43	2.85
11	11,8,62	4.0-5.0	70	56	49	34^{3}	15	11^{3}	235	178	36	6.10	1.30
12	21,8,62	1.6-5.0	-	3	3	3	-	-	9	9		0.39	
13	21,8,62	6.6		4	7	5			16	16		0.91	
14	3,9,62	3.2-5.0		10	9	7	2	14	42	42		2.05	

The number of nets is given as elevated figures if more than one used.

(continued)

TABLE 2 (continued)

Set No.	Date	Depth Metres	Mesh Size (in.)								Total No.	# of Assig. Fish		% of $\bar{x}^{*}$ Catch	
			1½	2	3	3-3/4	4¼	4-3/4	5	5¼		Large	Small	Large	Small
15	5,8,63	3.2		52	1	5	2	-	1	-	61	7	54	0.30	1.95
16	7,8,63	5.0		15	1	-	3	-	-	1	20	3	17	0.13	0.62
17	8,8,63	1.6		-	-	-	-	-	-	-					
18	10,8,63	4.0		14	7	7	2	-	1	-	31	14	16	0.60	0.58
19	23,6,64	9.1		39 (47)	12		4	5	1		61	23	32	1.60	1.57
20	25,6,64	6.6		1	1		1		1		4	3	1	0.21	0.04
21	28,6,64	4.0		-	-		-	-	-						
22	22,7,64	6.6		92 (112)	14		1	3	3		113	11	76	0.81	0.39
23	26,7,64	6.0					3[10]				3	3		0.17	

(continued)

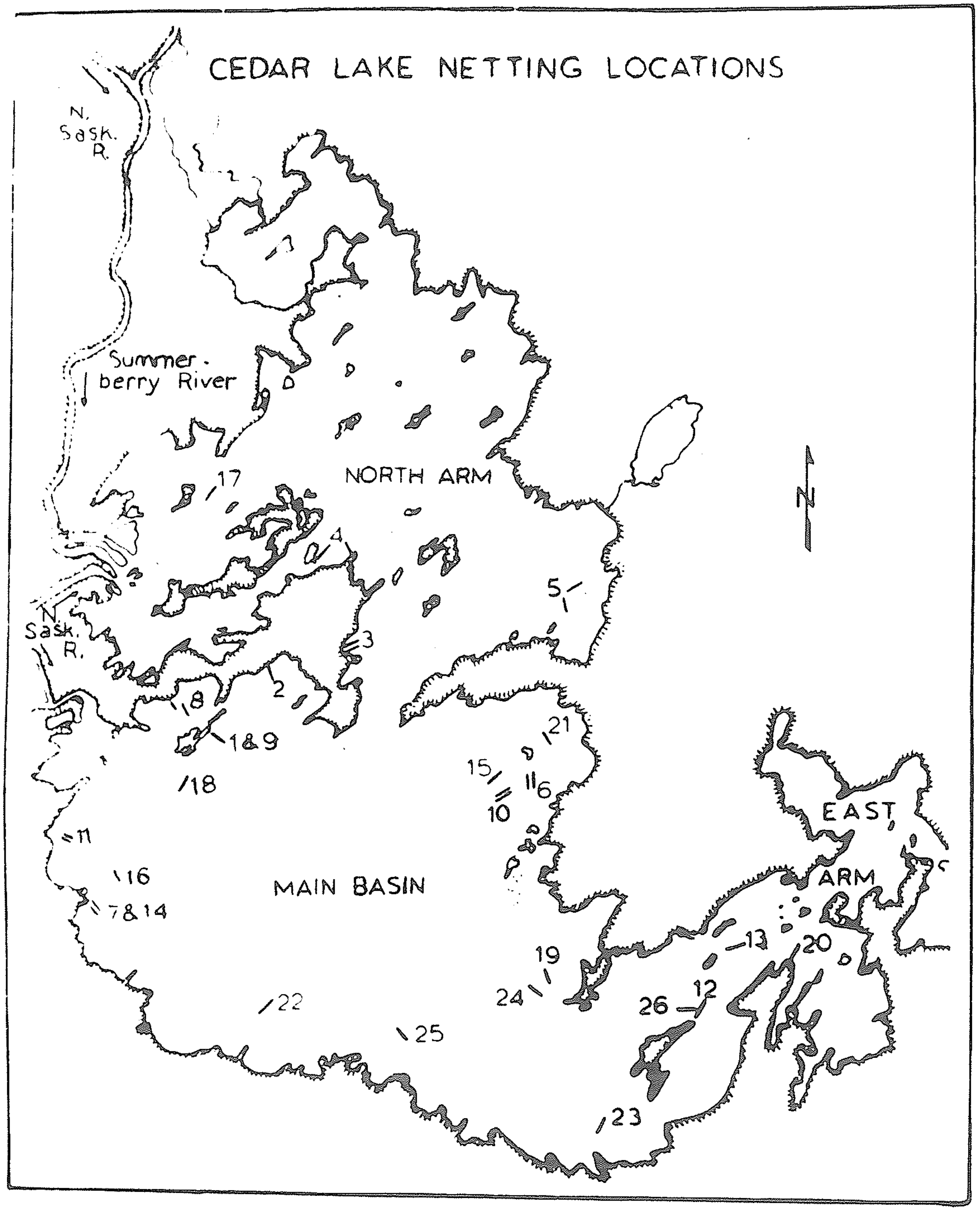
TABLE 2 (continued)

Set No.	Date	Depth Metres	Mesh Size (in.) 1½	2	3	3-3/4	4¼	4-3/4	5	5¼	Total No.	# of Assig. Fish Large	Small	% of $\bar{x}^*$ Catch Large	Small
24	19,8,64	9.1	94^2	28	1	1	1		-		125	5	17	0.23	0.61
25	22,8,64	9.1	67^2	7	4						78	4	4	0.56	0.15
26	27,8,64	8.2					5^4				5	5		0.70	
$\bar{x}^*$ catch/mesh (-nets 3m.)		Small		26.6	0.6	0.3	0.2				27.7	360	346		
		Large		2.6	8.1	7.3	1.8	1.9	1.4	0.3	23.6				

All nets were 45.7 m. in length (50 yds.) with the exception of 2" mesh; nets number 19 to 22. These were 32.9 m. in length (36 yds.) but their catch was corrected to 45.7 m. by direct proportion.

The number of nets is given as elevated figures if more than one used.

Figure 11. Cedar Lake Netting Locations.


CEDAR LAKE NETTING LOCATIONS
N. Sask. R.
Summer-berry River
NORTH ARM
N. Sask. R.
MAIN BASIN
EAST ARM
N
17
4
5
3
2
8
1&9
18
21
15
6
10
11
16
7&14
19
24
13
20
12
26
22
25
23

The average relative abundance between the two stocks is approximately equal (360 to 346). This is attributable to one exceptionally large catch of the fast growing form (Net set No. 11), and also to the use, several times, of incomplete experimental gangs with large mesh nets only. Furthermore, duplication of effort for the large form is evident from an examination of length frequency and girth frequency distributions per mesh size (Appendix 1 and 2): approximately 80 per cent of the ciscoes caught in the nets of 3-3/4 to 5 inch meshes were within the effective size range of the 3 inch mesh nets. Therefore roughly equal fishing effort would be the use of the 2 and 3 inch mesh nets only. The overall relative abundance would then be approximately 2.09:1 (387/185) in favor of the small form. However, as mentioned earlier, relatively low numbers of the fast growing form aged I, II and III were caught in Cedar Lake (most probably due to a different vertical distribution). Therefore accurate comparison of relative abundance can be made on ciscoes aged IV or older. The relative abundance is then 1:2.6 (96/37) in favor of the large form.

The density of the fast growing form does not appear to be correlated with location or with the date of capture. The most consistent catches (slightly below average) were made in the east arm of Cedar Lake. The largest and the smallest catches were obtained near the west shore, numbers 11 and 14 and numbers 7 and 16 respectively. The exceptionally large catch of August 11, 1962 (No. 11) was 43 per cent of the total catch of fast growing ciscoes, and therefore has greatly raised the figures of average catch per net set and has similarly lowered the percentage of average catch calculated for the individual nets.

The density of the slow growing cisco stock in the east arm appears very low as only one cisco was taken in the two experimental gangs capable of catching the small form (No. 12 and 20). If the catch in the $1\frac{1}{2}$" mesh nets is included in comparisons, then the population density of the small form would appear to be consistently highest in the south (Net Sets No. 22 and 25) and southeastern (Net Sets No. 19 and 24) regions of Cedar Lake. The $1\frac{1}{2}$ inch nets were not employed uniformly however, so these catches may affect the distribution of net sets, not of the slow growing ciscoes. Four of the five nets set in the western regions and one of the three nets set in the northern regions caught less than average numbers of slow growing ciscoes. There is no apparent correlation between density of the small form and date of capture.

Other spatial segregation within the two stocks with respect to age and maturity status was not apparent.

Ciscoes of both the fast and slow growing stocks were found to occur also in Moose Lake, Manitoba from data collected by the Manitoba Fisheries Branch personnel in 1962 and 1963. Moose Lake is approximately 5 Km. north of Cedar Lake and is connected to it by its outlet, the Summerberry River, and marsh which joins the north Saskatchewan River before entering Cedar Lake.

The Moose Lake data were examined briefly for depth distribution and relative abundance of the two forms. Of three shore sets (no depth given) two caught appreciable numbers of the fast growing form. The other shore set was empty. Ciscoes of both forms were found at depths from 3 to 20 metres and in all areas of the lake sampled. A cursory examination revealed that there are relatively low numbers of fast growing ciscoes aged I and II. Unfortunately all the nets were set on the bottom and therefore there are no data on vertical distribution.

An estimate of the relative abundance of the two forms was made from the ciscoes aged IV and older which were caught in the 2 and 3 inch mesh nets only. The relative abundance of ciscoes in the three principal areas varied considerably: Big Wave Bay: 113/4, East Arm: 143/43 and Pickeral Channel: 29/4 all in favor of the large form.

DISCUSSION

Growth Rate

Rate of growth of *Coregonus artedii* was shown by Hile (1936) to vary widely in different localities. He summarized the data of 11 allopatric cisco populations. A brief comparison can be made by arbitrarily using average length at age V. Most of the populations were fast growing: eight fell between 24.4 and 34.2 cm. The large form in Cedar Lake averages 32.1 cm. at age V. Three of the populations studied by Hile were very slow growing, falling between 15.8 and 18.1 cm. This is smaller than the smallest Cedar Lake ciscoes.

Hile (1936) found the growth rate of the four cisco populations studied to vary directly with the length of the growing season and inversely with the density of the cisco population. The slow growing ciscoes were therefore regarded by Hile as stunted populations of *Coregonus artedii*.

Hile (1936) maintains that certain consistent growth similarities are apparent for *Coregonus artedii* populations. These are: greatest growth in the first year, large but less in second, marked decrease in third, increments constant in later years. Carlander (1945) studying *Coregonus artedii tullibee* in Lake of the Woods found growth in the third and subsequent years to differ from the above description. He further pointed out that Hile's Clear Lake cisco population diverged in a similar manner. Both groups of Cedar Lake ciscoes would undoubtedly show greatest growth in their first year. A description of growth is not possible beyond that age due to the error in assignment of individuals to the two forms.

It is doubtful, however, if any of Hile's growth characteristics are valid taxonomic characters for ciscoes. The four cisco species of Lake Winnipeg cited by Keleher (1952) probably grow the most during their first year, although this graph does not show growth below age III. Whether or not any of the above growth characteristics are restricted to the members of the subgenus Leucichthys is not known.

The only substantial evidence supporting the use of growth data as a taxonomic character is given by Keleher (1952). He found that the four species of ciscoes in Lake Winnipeg have different growth curves. Koelz (1929) did not analyze growth rates of the 9 cisco species in the Great Lakes, but commented only on the maximum length: only Coregonus hoyi and Coregonus kiyi are distinguished by their small size from the other cisco species.

The occurrence of several ciscoes intermediate in size (Fig. 4) suggests the occurrence of hybrids assuming that the two stocks are distinct species.

Maturity

Smith (1956) summarized data on age at maturity for 14 populations of Coregonus artedii collected by 12 workers. Age at which maturity begins varies from I to IV. Maturity in the first year was reported from seven populations.

The age of maturity of ciscoes in Manitoba waters has been given by several workers. Bajkov (1930) reported that neither Coregonus zenithicus nor Coregonus tullibee (= C. artedii tullibee) spawn before reaching the age of IV. Dymond (1933) referred to Lower (1919) as stating that on the west coast of James Bay all specimens examined were mature. The smallest specimen was 8 inches long. Carlander (1945) reported that some of the Lake of the Woods tullibee were mature at age I and all were mature at age II.

Assuming one species only is involved in all the above cases and that it is Coregonus artedii, then the cause of the above variation in age at sexual maturity is unknown. It does not seem to be attributable to growth rate, as the four populations of Coregonus artedii studied by Hile (1936) differ markedly in growth rate, yet all are mature at age I.

Age at maturity has not been reported for the sympatric cisco species found by Koelz or other authors in North America, therefore its taxonomic value is uncertain.

It has been shown for individual populations that the faster growing individuals with an age group generally mature earlier in the season (Alm, 1959). Smith (1956) noted this relationship for Coregonus artedii of Green Bay, Lake Michigan. As mentioned earlier this relationship appears to be true of the fast growing stock of ciscoes in Cedar Lake. Assuming this relationship is interspecific as well as intra-specific, then maturity of the slow growing ciscoes at a younger age indicates that the two forms are most probably good species.

Morphometry

The significance of morphometric characters in coregonid taxonomy has had considerable study since other more usual taxonomic characters are unreliable. The methods of expressing comparisons have not been standardized and in most cases have been shown to be incorrect. This, however, can be attributable for the most part to lack of knowledge of all the sources of such variability and, in some cases, to low sample size.

Error in methods of comparison is attributable to several sources: allometric growth of many characters necessitates the comparison of specimens of the same standard length and correlation with growth rate can make comparison even of fish of the same standard length invalid. Furthermore the use of plotted graphs of ratio against standard length has been shown by Marr (1955) to incorporate a mechanical error of significant dimensions unless the regression is linear and passes through the origin. He suggests that graphs of part length against standard length (or other suitable part) be used although he admits that the comparison of ratios of fish of the same small size interval is also of value.

Koelz (1929) found only three morphometric characters that were fairly constant for each of the 9 cisco species of the Great Lakes. These were body contour, length of the lower jaw, length of maxillary (i.e. upper jaw). Within lakes, Koelz (1929) found a few other characters which were of value in separating species, but he cautioned that they could not be relied on alone. These were: HL/ED, HL/SN, HL/HD, P-V/P, and V-A/V. The distribution of the characters overlap considerably between species, possibly because fish of different length were compared.

Hile (1937) studying Coregonus artedii found that populations with the most rapid growth had shorter head, maxillaries, paired and dorsal fins but wider bodies and a smaller eye diameter. Martin (1949) pointed out however that the mechanics of environmental control of body form in fishes is also influenced by rate of early development.

From the dichotomy observed in the growth rate one would expect differences in relative growth conforming to Hile's analysis, i.e. fast growing individuals with smaller heads, etc., if one species were present. The fact that eye diameter alone bears this relationship in Cedar Lake would then be disconcerting unless the other correlations with growth found by Hile were not valid but were produced by different rates of development in the different habitats. Fortunately Hile (1937) presented further evidence used in support of the finding between populations. He compared the body ratios with a length group for different ages within each population. Head length/SL and eye diameter/SL were well correlated with growth rate in the four populations;

body width/SL was correlated for three populations; maxillary length was correlated within one population only. An appraisal of the relation of fin length to growth rate was not made by this method. Since the two forms of cisco in Cedar Lake did not differ in head length and body width the observed difference in eye diameter is most likely a genetic difference.

Gill Rakers

Gill raker counts have been used extensively in coregonid taxonomy. Koelz (1929) considered their distribution to be of great taxonomic significance in separating the nine cisco species in the Great Lakes. The significance of gill rakers has been investigated on whitefish by Svardson (1952). He maintains that gill raker number is regulated by a number of polygenes and that environmental effects are slight. His conclusion is based on 12 whitefish transplantations made by himself and several made by others. Svardson stated that the maximum variation was found to be plus or minus two.

Hile (1937) found the mean gill raker count of four populations of Coregonus artedii to vary from 45.1 to 48.4. Considerable subspecific diversity is suspected however.

Hubbs and Lagler's key to the coregonids of the Great Lakes region (1964) describes Coregonus artedii as having usually 43 to 52 gill rakers. This range was presumably derived from Koelz's description of Coregonus artedii artedii from the Great Lakes which had a slightly larger range, 41 to

55 gill rakers. The gill raker frequency, of the fast growing Cedar Lake ciscoes is most probably within this range and only very few slow growing ciscoes have a lower gill raker count. It is therefore apparent that identification of either form as Coregonus artedii is possible on the basis of gill rakers, with the fast growing form being most likely.

Lateral Line Scales

Scale counts, particularly along the lateral lines have had widespread use in coregonid taxonomy. However the degree of genotype control of this character appears to be much less than for gill rakers.

Koelz (1929) found the number of scales in the lateral line to be variable within a species but found them useful in distinguishing subspecies (1930). Svardson (1951, 1952) found similar variation between populations of whitefish species, but noted that within the same population the annual variation seems to be slight. Svardson concluded that the number of lateral line scales can be used to distinguish between sympatric populations and recommends that they not be used to distinguish allopatric populations.

Svardson (1951, 1952) pointed out that scale number is in part dependent on temperature: "In the main, populations that spawn early in the autumn get many scales, as they are hatched early in the spring. Conversely populations that spawn late in the autumn or during the winter get a small number of scales."

Another modifying factor, egg size, is definitely known to operate here. Toots (1951, in Svardson 1952) has shown that the size of the eggs of whitefish is positively correlated with the body length. Svardson noted that there is sufficient empiracle evidence suggesting that a smaller fry gets fewer scales.

The evidence therefore suggests that scale number is ultimately due to body length of parent fish. Lateral line scales then may not increase discrimination beyond that already achieved by growth rate.

Peduncle Scale Rows

The significance of this character has not been investigated thoroughly. A large phenotypic component is suggested by the data presented by Hile (1937). Four populations of *Coregonus artedii* vary from 20.8 to 24.3. Subspecific diversity may account for some of this variation.

Under condition of sympatry however the number of peduncle scale rows are considered to have equal weight as lateral line scales.

Horizontal and Vertical Distribution

Koelz (1929) stated that all of the coregonid species of the Great Lakes ". . . except *artedii* (which is a plankton feeder and therefore normally takes its food above the bottom), so far as known, are confined to a bottom stratum of water of a thickness of not more than five feet . . ." He further noted that "Each occupies a rather broad zone defined by the depth of water at its margins . . . The zones overlap at their margins . . ." It is apparent then that horizontal distribution in relation to depth is of some value in distinguishing species in the Great Lakes.

The data presented here does not show any horizontal segregation of the two forms. The horizontal distribution of the fast growing form may be slightly greater than the slow growing form; however this is not sufficient to produce the differences observed in growth rate through differences in feeding sites. The absence of ciscoes from shallow water of less than three meters in Cedar Lake suggests that ciscoes prefer greater depth, at least during the time interval of sampling. Since the depth at which ciscoes were found in Moose Lake shallows is not known, the information gathered there is of no help in establishing the validity of this suggestion.

The vertical distribution of <u>Coregonus</u> <u>artedii</u> in relation to size of the fish was studied by Davidoff (MS thesis, in Smith 1956) and Smith (1956). Both authors found a tendency for the larger fish to be near the surface. The opposite relationship is suggested for the fast growing form in Cedar Lake. The immature ciscoes aged I and II are most likely near the surface over deep water. If this is the case then the young of the fast growing form may be feeding on plankton or on surface insects. Further studies are in order to determine the location of the young of the fast growing ciscoe. It has been suggested by K. Stewart (per.

comm.) that an alternative hypothesis is present: namely, that the fast growing cisco population has drastically declined. The raising of the water level by the completion of the Grand Rapids Hydro-Electric Dam could not be the cause as it was not completed until 1964.

CONCLUSIONS

1. None of the morphological or ecological characters studied clearly separates all of the Cedar Lake ciscoes into two discrete groups. Nevertheless bimodality of the characters suggests that two forms are present.
2. Two growth rates are evident above age II. These are roughly confluent with immature and mature ciscoes aged I and II. This division was used throughout in studying the distribution of other characters.
3. Most of the slow growing fish mature at age I. The fast growing form begins to mature at age III. Practically all are mature at age V.
4. Mean count of gill rakers, lateral line scales and peduncle scale rows were significantly different for the large versus the small ciscoes aged IV to VIII and for mature versus immature ciscoes aged I to III. The large form and immature had the higher count.
5. A character index of meristic series had a higher utility of separation than each meristic series taken separately. A graph of character index against standard length produces a partial separation of ciscoes aged I to III. The allocation of individual ciscoes to their respective forms was still somewhat arbitrary.
6. Morphometrically the ciscoes in Cedar Lake are very similar, differing only in eye diameter. This is most likely a genetic difference as other correlations of the size of

body parts with growth rate which would be expected if one species was involved were not found.

7. The two groups do not appear to differ significantly in horizontal distribution, but may differ in vertical distribution. The young year classes of the fast growing form are conspicuously absent and are suspected to be distributed near the surface over deep water. This is, however, opposite to the distribution pattern reported by Smith (1956).
8. A small number of individuals are definitely intermediate in size (Fig. 4). This suggests the occurrence of hybridization between the fast and slow growing forms.
9. The morphological and ecological characters used here were found from the literature to vary widely within coregonid species. _Coregonus artedii_ is considered to be particularly variable. Gill rakers are perhaps the best taxonomic character. Under conditions of sympatry, all morphological and ecological characters studied here are considered to have taxonomic significance.
10. Both forms of cisco in Cedar Lake fit the description of _Coregonus artedii_ (LeSueur). This species in Manitoba generally grows to a large size. The subspecific designation _tullibee_ does not seem warranted from the gill raker range of typical _artedii_ of the Great Lakes.
11. Several cases of dwarfism have been reported among coregonid fish. That these cases are analagous to stunting is not consistent with the observations of

Alm (1959) and Smith (1956) that fast growing fish generally mature first. Svardson (1959) however presented evidence to show that dwarfism may be a physiological adaptation to the environment.

LITERATURE CITED

1. Alm, Gunnar. 1959.
   Connection Between Maturity, Size and Age in Fishes. Rpt. Inst. Freshwat. Res., Drottningholm, Vol. 40: 5-145.

2. Bajkov, A. 1930.
   Fishing Industry and Fisheries Investigations in the Prairie Provinces. Trans. Am. Fish. Soc., Vol. 60: 1-23.

3. Bajkov, A. 1932.
   The Genus *Leucichthys* (Ciscoes or Tullibees) in Manitoba Waters. Cont. Can. Biol. Fish. No. 26: 325-333.

4. Carlander, K. D. 1945.
   Growth, Length-Weight Relationship and Population Fluctuations of the Tullibee, *Leucichthys artedii tullibee* (Richardson), with reference to the commercial fisheries, Lake of the Woods, Minnesota. Trans. Am. Fish. Soc., Vol. 78 (1943): 125-136.

5. Dymond, J. R. 1928.
   A description of *Leucichthys tullibee* (Richardson) based on six specimens from the type locality. Univ. Toronto Stud. Biol. Ser., No. 51.

6. Dymond, J. R. 1933.
   Biological and Oceanographic Conditions in Hudson Bay. 8. The Coregonine Fishes of Hudson and James Bays. Contr. Can. Biol. Fish. 8, (1): 1-12.

7. Dymond, J. R. and A. L. Pritchard. 1930.
   Some Ciscoes or Lake Herrings of Western Canada. Contr. Can. Biol. Fish. 5: 469-474.

8. Fenderson, O. C. 1964.
   Evidence of Subpopulations of Lake Whitefish, *Coregonus clupeaformis*, Involving a Dwarfed Form. Trans. Am. Fish. Soc., Vol. 93 (1): 77-94.

9. Hile, R. 1936.
   Age and Growth of the Cisco, *Leucichthys artedii* (LeSueur), in the Lakes of the Northeastern Highlands, Wisconsin. Bull. Bur. Fish., Wash. Vol. 48: 211-317.

10. Hile, R. 1937.
Morphometry of the Cisco, Leucichthys artedii (LeSueur), in the Lakes of the Northeastern Highlands, Wisconsin. Int. Rev. D. Ges. Hydr. U. Hydr., 36: 57-130.

11. Hinks, D. 1943.
"The Fishes of Manitoba." Dept. Mines and Natural Resources, Province of Manitoba: VII 117.

12. Hollister, G. 1934.
Clearing and Dying Fish for Bone Study. Zoologica Stuttg., Vol. 12 (10): 89-100.

13. Hubbs, C. L. and K. F. Lagler. 1964.
"Fishes of the Great Lakes Region." University of Michigan Press: XIII 213.

14. Keleher, J. J. 1952.
Growth and Triaenophorus Parasitism in Relation to Taxonomy of Lake Winnipeg Ciscoes (Leucichthys). J. Fish. Res. Bd. Can., 8 (7): 469-478.

15. Kennedy, W. A. 1943.
The Whitefish, Coregonus clupeaformis (Mitchill) of Lake Opeongo, Algonquin Park, Ontario. Univ. Toronto Stud. Biol. Ser., No. 51: 23-66.

16. Koelz, W. 1929.
Coregonid Fishes of the Great Lakes. Bull. Bur. Fish., Wash. Vol. 43 (1927): 297-643.

17. Koelz, W. 1929.
The Coregonid Fishes of Northeastern America. Pap. Mich. Acad. Sci. 13 (1930): 303-432.

18. Martin, W. R. 1949.
The Mechanics of Environmental Control of Body Form in Fishes. Univ. Toronto Stud. Biol. Ser., No. 58.

19. Mayr, E. 1963.
"Animal Species and Evolution." Belknap Press, Harvard University Press, Cambridge: XIV - 797.

20. Richardson, J. 1836.
"Fauna Boreali Americana", (Part 3, The Fish). Richard Bently, London: 1-327.

21. Smith, S. H. 1956.
Life History of the Lake Herring of Green Bay, Lake Michigan. United States Department of the Interior, Fish and Wildlife Service, Fishery Bulletin No. 109. Vol. 57: 87-136.

22. Rounsefell, G. and W. Everhard. 1962.
"Fishery Science. Its Method and Application." John Wiley and Sons, Inc., New York. 1-444.

23. Svardson, G. 1949.
The Coregonid Problem. I. Some general aspects of the problem. Rpt. Inst. Freshwat. Res., Drottningholm, 29: 89-101.

24. Svardson, G. 1951.
The Coregonid Problem. III. Whitefish from the Baltic successfully introduced into freshwaters in the north of Sweden. Rpt. Inst. Freshwat. Res., Drottningholm, No. 32: 79-125.

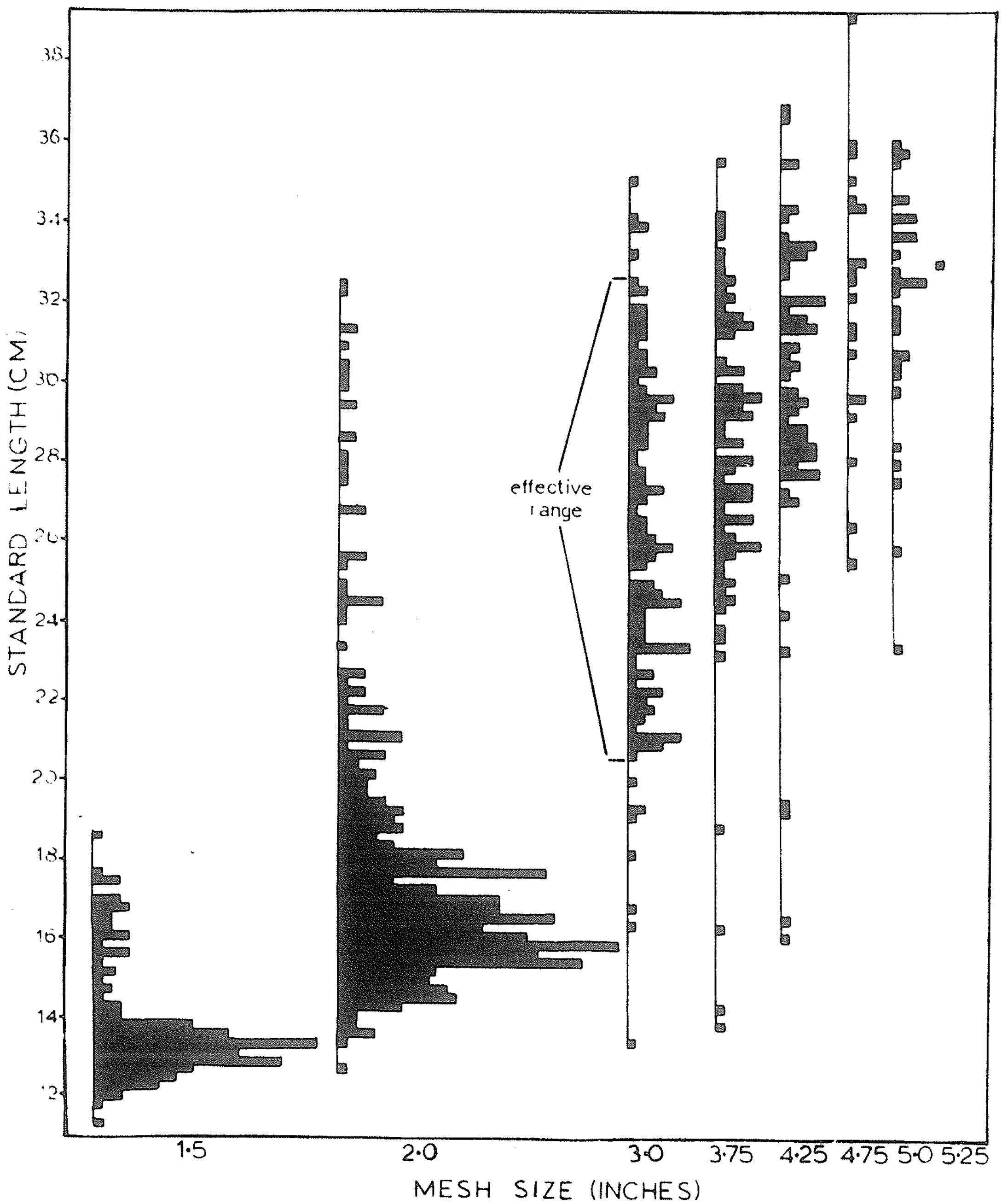
25. Svardson, G. 1951.
The Coregonid Problem. IV. The significance of scales and gill rakers. Rpt. Inst. Freshwat. Res. Drottningholm. 33: 204-232.

26. Svardson, G. 1957.
The Coregonid Problem. VI. The palearctic species and their intergrades. Rpt. Inst. Freshwat. Res., Drottningholm. 38: 267-356.

27. Van Oosten, J. 1929.
Life history of the lake herring (Leucichthys artedii (LeSueur) of Lake Huron as revealed by its scales, with a critique of the scale method. Bull. Bur. Fish. Wash., Vol. 44 (1928): 265-428.

28. Webb, D. W. 1965.
Limnological Features of Cedar Lake, Manitoba. J. Fish. Res. Bd. Can., 22 (5): 1123-1136.

APPENDIX 1.
LENGTH FREQUENCY PER MESH SIZE.



APPENDIX 2.
GIRTH FREQUENCY PER MESH SIZE.