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Title

Morphometry of Lake Manitoba ciscoes, Leucichthys tullibee

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INTRODUCTION

Ciscoes (Leucichthys spp.) serve as an intermediate host for the tapeworm, Triaenophorus crassus. They are the main second intermediate host for the perpetuation of the parasite's life cycle. The various species of ciscoes are differentially infected which suggests means of increasing the marketability of ciscoes and lake whitefish, Coregonus clupeaformis. Some difficulty was encountered in identifying the species in this region and a search for better criteria for distinguishing them was initiated. As the systematic classification within the genus Leucichthys not always has been justified, the validity of certain nominal taxa was to be considered. Aside from its value to systematics, a verification of the classification would stabilize the studies on the ecology of the parasite.

Knowledge of morphometric variation exhibited by populations in nature is a basic requirement of any taxonomic investigation. Not only must the total variation be revealed but it must be partitioned as to its causes. Studies on ciscoes have shown (Keleher, 1954) that the geographic location, age, sex and growth rate of the fish have an appreciable influence upon their morphometry. Quantitative estimates of the effects however are unavailable. A proper evaluation of the current taxonomy must await separation and quantitative estimation of the components of the entire variation.

The present study considers the ciscoes of Lake Manitoba which represent a single species. The main object is a description of this population so that comparisons between it and nominal species and other populations can be made. The extent to which geographic location, sex and age of the specimens is responsible for morphometric variation in 21 characters is presented. The sample of ciscoes from Lake Manitoba is similar in morphometry to specimens of Leucichthys tullibee from the type locality. Accordingly the Lake Manitoba ciscoes are identified as Leucichthys tullibee.

MATERIALS AND METHODS

During December, 1951 704 fish were obtained from commercial gill nets at five different localities by purchase from fish dealers. The localities, from South to North, were: Delta, Langruth, Wapaa, Guynemer, and Meadow Portage. The estimated air distance from Delta to Meadow Portage is 115 miles. Approximately half of the specimens were examined for Triaenophorus crassus (Keleher, 1952); the remainder were used for the morphometric study. A die was thrown to decide the purpose of each fish. Each was set aside in turn and if the die rolled "odd" the fish was examined for the parasite. Table I indicates the date and location of the fish used for the morphometric study.

All the fish were purchased in the frozen state. They were thawed in cold water and immediately afterwards were either measured or examined for the parasite. This was done between December 18, 1951 and January 24, 1952. The data are from non-preserved specimens and were taken within two months of the fish's capture.

Measurements and counts (cf. appendix) were made by the writer and were recorded initially by a second person on large museum sheets. They later were transferred to individual specimen cards and the measurements were converted to two-place logs, being checked at a subsequent date. All the data were entered onto I.B.M. punch cards to derive certain quantities (Keleher, 1953). Some gross errors were detected through the I.B.M. analysis. The measurements for each part were arranged in vertical columns and listed according to increasing standard length of the fish. Suspected values were checked against the fish which were preserved and retained.

The analysis of the measurements was undertaken by the method of relative growth. Martin (1949) has capably discussed the subject particularly as it

Table I. Ciscoes collected from Lake Manitoba in 1951 for morphometric study.

Date	Location	Loc. No.	Tag Numbers	No. of Fish
Dec. 8	Delta	1	5199-5240	42
9	Langruth	2	5241-5253	13
			5265-5283	19
			5295-5306	12
10	Wapaa	3	5430-5462	33
11	Meadow Portage	5	5307-5387a	79
13	Delta	1	5284-5294	11
			5389-5429	41
13	Langruth	2	5110-5157	48
14	Guynemer	4	5158-5193	36
			5254-5264	11
				345

[a]Except Nos. 5310, 5320.

applies to fish. There is a simple linear relationship in many animals between the size of the part (Y) and the size of the body (X) when the variates are transformed into common logarithms. This relationship appears graphically as a straight line and takes the form of the power function or regression:

$$\text{Log } Y = \text{Log } b + K \text{ Log } X$$

The value "K" in the equation determines the slope of the line and the value of "Log b" determines its position. The value of the slope is of special interest in a relative growth analysis. If the slope is 1, the "rate of change" of the size of the part is a constant proportion to the "rate of change" of the body as a whole. The body form does not change and consequently proportionate parts or ratios give a satisfactory expression of morphometry. Usually the slope has a value other than 1 (Martin, 1949). The parts then have a "rate of change" different from that of the body and the relative growth method is better suited than proportions or ratios to describe the morphometry. Marr (1955) has discussed the merits of the two methods for taxonomic studies.

The average size of a measurement at any size of the body can be computed from the equation. The average size at this arbitrary standard length is a calculated adjusted value because it is derived from the equation and the slope of the line has been discounted. The length of the fish whose measurements are to be calculated should be within the size range of the sample so as to avoid the dangers of extrapolation.

It is now possible by means of the analysis of covariance to utilize the theory of probability in the relative growth analysis of measurements. This statistical method is detailed in many statistical texts. The outline by Kennedy (1953) has been followed in this study. Judgment as to the validity of differences between regressions are not subjective but have been made against the standard of chance.

The meristic counts have been presented by frequency distributions and means. Comparisons between groups were made by the analysis of variance.

Both the measurements and counts have been examined for variation attributable to geographic location, sex and age. The possible effect of each factor was examined separately. Only a one-way classification for the statistical test appeared possible because the number of fish was not constant nor proportionate for each of the sub-divisions (Table II). Not all the possible measurement data were used for each factor, but that which were employed have been indicated.

No serious departure from independence in the sex of the fish assignable to any of the categories was found. The 345 fish consisted of 157 males and 188 females which is within the statistical limits for a 1:1 ratio (X^2 = 2.79, P05 = 3.84). Tests of significance of each sex compared to location and age did not give significant values of P.

MEASUREMENTS

Initially the requirement of a linear relationship between the variates was examined by graphs. Each point represented the average measurements for fish of a particular location, age and sex. These 80 graphs showed that this requirement was satisfied, and the specimens consequently were all in the same growth stanza (Martin, 1949).

The intra-lake factors were examined in the following sequence: location, sex, and age. Tests for location and sex differences were restricted to only the age 5 fish. They represented 45 per cent of the age composition of the sample. To include another 25 per cent, i.e. the age 6 fish, would have doubled the work. Examination of the differences between the sexes involved fish from all locations that did not show significant differences. Age com-

Table II. Number of Lake Manitoba ciscoes according to location, age and sex. For names of locations see Table I.

	LOCATION					
Sex and Age	1	2	3	4	5	Total
Spent Females						
3	2	6	-	-	2	10
4	12	11	5a	1	6b	35
5	30	23	14c	9	15	91
6	19	9	8d	8	6	50
7	-	-	-	1	1	2
TOTAL	63	49	27	19	30	188
Males						
2	-	-	-	-	1	1
3	3	6	-	2	8	19
4	4	9	2	2	13	30
5	18	16	4	8	19	65
6	6	14	-	9	6	35
7	-	1	-	4	1	6
TOTAL	31	46	6	25	49E	157

The numbers include the following number of ripe females.

a - 3
b - 2
c - 12
d - 6

E = includes 1 fish of unknown age

parisons were limited to 3 age groups because they comprized at least 90 per cent of the data. Fish from different locations and both sexes were used where possible. Table III lists the tests that were performed for each factor.

INTRA-LAKE FACTORS

Adjusted mean size: The results of the analysis of covariance for adjusted mean size are given in Table III. A statistically significant result was obtained in 24 of the 71 comparisons. However 2 tests were a duplication of previous ones with a larger sample. When the sexes were combined the caudal peduncle length still remained statistically significant between locations, but the average size of the snout was not significant between locations.

The stability of the different measurements is indicated by the number of factors which produce significant differences. Only one measurement, dorsal base, was not affected by any of the factors. Five measurements varied for two factors; 9 varied for a single factor. One measurement, body depth varied for all three factors.

The age factor was responsible for the largest number of measurements (11) showing changes in average size. Differences between the sexes were responsible for variation in 7 measurements while location differences were found in 4 measurements.

The head parts were affected by the least number of factors. All of them varied only with age. The trunk measurements were influenced by all factors while the fin measurements were altered by sex and age but not locations.

Some measurements are affected by certain intra-lake factors. Its extent is seen by examining the mean size of a body part at 225 mm. standard length (Table IV). This standard length was chosen because it represents the average length of all specimens used in the morphometric study. Attention is now directed

Table III. Results of analysis of covariance tests for mean size of body parts of Lake Manitoba ciscoes.

Category	Between Locations		Between Sexes	Between Ages 4, 5, and 6		
Body Part	Age 5 Males	Age 5 Females	Age 5 fish from all locations	Males	Females	Both Sexes
HL	NS	NS	NS	-	-	**
HD	NS	NS	NS	-	-	**
EE	NS	NS	NS	-	-	**
ST	NS	*	NS	-	-	**
MX	NS	NS	NS	-	-	**
IB	NS	NS	NS	-	-	**
CL	*	NS	NS	-	-	NSa
CD	NS	**	*a	NS	-	-
BD	NS	*b	**b	**	-	-
BW	NS	**	**a	NS	-	-
DH	NS	NS	*	NS	*	-
DB	NS	NS	NS	-	-	NS
AH	NS	NS	*	NS	NS	-
AB	NS	NS	**	**	NS	-
PT	NS	NS	NS	-	-	*
PC	NS	NS	**	NS	**	-

- \- not tested
a - only location 1 tested
b - location 3 females omitted
* - adjusted means differ at 5% level of significance
** - adjusted means differ at 1% level of significance

Table IV. Calculated mean size in mm. of body parts of ciscoes at 225 mm. standard length.

	Age 5 Females from Location					Age 5		Age Groups[a]		
	1	2	3	4	5	M	F	4	5	6
HL	-	-	-	-	-	-	-	57.0	58.1	58.5
HD	-	-	-	-	-	-	-	38.6	39.3	38.6
EE	-	-	-	-	-	-	-	15.4	15.7	16.0
ST	-	-	-	-	-	-	-	13.9	14.3	14.4
MX	-	-	-	-	-	-	-	17.9	18.4	18.6
IB	-	-	-	-	-	-	-	14.7	14.9	15.0
CL	-	-	-	-	-	-	-	-	-	-
CD	22.6	22.3	23.5	23.1	22.7	23.5	22.5	-	-	-
BD	65.1	64.5	-	60.8	62.0	66.3	63.8	64.3	67.8	66.8
BW	31.7	30.4	-	28.9	30.0	33.3	31.5	-	-	-
DH	-	-	-	-	-	55.1	54.4	52.9	54.4	55.8
DB	-	-	-	-	-	-	-	-	-	-
AH	-	-	-	-	-	38.1	36.7	-	-	-
AB	-	-	-	-	-	29.0	28.4	27.4	28.4	27.3
PT	-	-	-	-	-	-	-	-	-	-
PC	-	-	-	-	-	48.0	46.2	45.1	46.1	46.7

[a]Sexes combined except for BD and AB (males only) and DH and PC (females only)

to the differences between the means of a given category. As usually several means can be compared, the greatest difference has been listed in Table V. The left section of the Table records the absolute difference; the right section, termed the greatest percentage difference, is the absolute difference divided by a hundredth of the smallest mean. The differences are not regarded as large. They have been found to be "significant" because of the large sample size from which they were derived.

The largest differences were found between locations. They ranged from 1.2 to 4.3 mm. which is a percentage difference of 5 to 9. The differences encountered between sexes and between ages were smaller. The range was from 0.3 to 2.5 mm. or from 1 to 6 per cent. It is not valid to compare the over-all differences found in one factor with those found in another because diverse measurements are involved. In a few instances the effect of each factor on a specific part can be discussed. The three location differences (caudal peduncle depth, body depth and width) are greater than these differences between the sexes. Similarly the differences in the age factor are as large or larger than those in the sex factor. The factors rank in the order of location, age, and sex according to their decreasing influence on the size of the body parts.

These factors are not necessarily directly responsible for the variation in the parts. They merely may be the expression of some other cause. A suspected influence would be the growth rate. Martin (1949) states:

> Thus it appears that two processes, rate of development of body parts and rate of growth, are correlated with body form in fishes. These two processes appear to have opposing relationships to body form since relatively small body parts may be associated with either retarded development or with subsequent rapid growth.

The growth rates for each factor may be compared by an examination of average lengths listed in Table VI. The females are generally the larger in the

Table V. Differences in calculated mean size of body parts of ciscoes at 225 mm. standard length. For calculated mean size see Table IV.

	Greatest Actual Diff. (mm.)			Greatest Percentage Diff.		
	Location	Sex	Age	Location	Sex	Age
HL	-	-	1.5	-	-	3
HD	-	-	0.7	-	-	2
EE	-	-	0.6	-	-	4
ST	-	-	0.5	-	-	4
MX	-	-	0.7	-	-	4
IB	-	-	0.3	-	-	2
CL	-	-	-	-	-	-
CD	1.2	1.0	-	5	4	-
BD	4.3	2.5	2.5	7	4	4
BW	2.8	1.8	-	9	6	-
DH	-	0.7	2.9	-	1	6
DB	-	-	-	-	-	-
AH	-	1.4	-	-	4	-
AB	-	0.6	1.1	-	2	4
PT	-	-	-	-	-	-
PC	-	1.8	1.6	-	4	4

Table VI. Average standard length of Lake Manitoba ciscoes.

Age	Location	Loc. No.	Females	Males	Larger Sized Sex
4	Delta	1	210	212	M
	Langruth	2	195	208	M*
	Wapaa	3	214	224	M
	Guynemer	4	216	218	M
	Meadow Portage	5	232	232	-
	ALL		210	221	
5	Delta	1	231	219	F**
	Langruth	2	221	216	F
	Wapaa	3	223	230	M
	Guynemer	4	231	232	M
	Meadow Portage	5	252	241	F**
	ALL		231	227	
6	Delta	1	237	231	F*
	Langruth	2	228	226	F
	Wapaa	3	232	-	-
	Guynemer	4	247	230	F**
	Meadow Portage	5	256	241	F*
	ALL		239	230	

*F value exceeds the 5 per cent level of P.
**F value exceeds the 1 per cent level of P.

statistically significant comparisons. They are assumed to have the faster growth rate. Table IV (page 8) shows the measurements which varied between the sexes. The females, in all cases, have a smaller average body part. This agrees with Martin's statement regarding growth rate and size of body parts. Females differ from males in some measurements not because of their sex but as a consequence of a dissimilar growth rate.

Fish collected from Meadow Portage have the fastest growth rate because they attained a larger average size at each age than the fish from the other locations. Conversely the Langruth sample has the slowest growth rate. The males do not show any real differences between locations in the size of their body parts (Table III, p.8). The morphometry of the females is compared by locations in Table IV (p.8). The means of the Meadow Portage sample are not the smallest and the Langruth sample is not the largest. Changes in body form associated with locations do not appear to be correlated with the growth rate.

The mean size of the parts varies between age groups. The values of 7 parts are smallest in the age 4 fish, intermediate in the age 5 fish and largest in the age 6 fish. The depth of the head and body and length of the anal base do not follow this trend. The increase in standard length with age does not explain the changes in morphometry because allowances have been made for this dissimilarity. The slopes of the lines representing each age group were not shown to be different (see below). Diverse growth rates of the year-classes rather than a direct dependence upon age might account for the variation in morphometry. To conform to the negative correlation between growth rate and body form, the 1945 year-class (the present age 6 fish) should have a slower growth rate than the 1946 or the 1947 year-classes. The size of the fish at previous ages was not reckoned so this hypothesis could not be examined.

Slope: Tests for differences in slope were made on the same fish which were examined for variations in average size (Table III, page 8). The slopes were statistically significant in only two instances, and both times the F value exceeded the one per cent level of P. One was the test between the sexes for body width. The slope for the males was 0.76 while for the females it was 0.98. The second significant result was obtained in the test of the pectoral length between age groups. The slope for the age 4 fish was 1.02, for the age 5 and age 6 fish it was 0.61 and 0.68 respectively. The indicated heterogeneity of slopes for the pectoral length is ascribed to the high value for the age 4 fish. In view of the many comparisons that suggested no real differences between the slopes, the preceding exceptions are disregarded. It can be inferred from Martin's study (1949) that the size at inflection is the mechanism responsible for producing differences in morphometry associated with the intra-lake factors.

GENERAL DESCRIPTION

A summary of the data for the measurements is given in Table VII. The equation describes the regression of the part on the standard length. The other quantities were used to derive the equation, and are required for statistical tests between this population and others. Various statistics concerning the body parts can be obtained from these data. For fish of a given standard length, the average size and its fiducial limits or the expected range of a single measurement can be calculated. The data in Table VII appear to be the best method for presenting the original measurements. It is not feasible to list approximately 3,400 individual items and grouping them by size or age would conceal the individual variation. Proportionate parts or ratios may be secured by solving for the actual measurements and converting.

The equations provide a general description of the Lake Manitoba ciscoes. They have been derived by grouping all the fish irrespective of their location, sex

Table VII. Regression equation and other statistics for Lake Manitoba ciscoes. X = log standard length and Y = log part.

Log Body Part			N	SX	SY	SX^2	SXY	SY^2
HL	=	0.783 X - 0.0815	345	811.03	606.91	1907.1557	1427.1828	1068.0821
HD	=	0.802 X - 0.2983	"	"	547.52	"	1287.5792	869.4092
EE	=	0.486 X + 0.0502	"	"	411.47	"	967.5686	491.0511
ST	=	0.707 X - 0.5091	"	"	397.76	"	935.4666	459.0944
MX	=	0.657 X - 0.2817	"	"	435.68	"	1024.5809	550.6414
IB	=	0.888 X - 0.9146	344	808.73	403.55	1901.8657	949.2397	474.0909
CL	=	0.886 X - 0.7805	345	811.03	449.29	1907.1557	1056.7076	586.4175
CD	=	0.943 X - 0.8584	"	"	468.64	"	1102.2282	637.1418
BD	=	0.744 X + 0.0597	"	"	624.01	"	1467.3592	1129.2547
BW	=	1.013 X - 0.8864	"	"	515.78	"	1213.0860	772.0502
DH	=	0.708 X + 0.0723	269	632.71	467.43	1488.6309	1099.7490	812.6523
DB	=	0.786 X - 0.3596	345	811.03	513.40	1907.1557	1207.3602	764.6530
AH	=	0.792 X - 0.2990	256	602.17	400.36	1416.8839	942.0889	626.6152
AB	=	0.843 X - 0.5328	344	808.68	498.42	1901.6332	1172.1790	722.8696
PT	=	0.819 X - 0.2722	282	663.58	466.71	1561.9320	1098.5921	772.8893
PC	=	0.791 X - 0.1953	335	787.65	557.61	1852.4697	1311.4856	928.6545

and age. As these intra-lake factors are responsible for variations in the measurements heterogeneous material, in effect, have been combined. No alternative has been found to overcome this difficulty. This problem and its implications are considered in the discussion.

The slope for each measurement of the Lake Manitoba ciscoes is the value of "K" in the equations in Table VII. It is 0.783 for the head length. Although the fiducial limits of these slopes have not been determined, none, except the body width, appear to have a value of 1.0 indicating that there is not a constant body form.

The average size of each part corresponding to three different standard lengths is presented in Table VIII. The measurements of the Lake Manitoba ciscoes may be compared directly with other populations. As the upper length limit of our data is at 290 mm., the calculation of the parts at 300 mm. standard length represents an extrapolation. This was done in order to compare the morphometry of these ciscoes with Leucichthys tullibee from Pine Island Lake.

MERISTIC COUNTS

Counts were made of the number of gill-rakers, dorsal and anal rays, branchiostegals and lateral line scales. The method of counting is presented in the appendix. Frequency distributions and other statistics of counts are presented in Tables IX and X. The sample size of the gill-raker count is higher than the others because data from the ciscoes examined for the parasite have been included.

The data were partitioned so that variation associated with sex, age and location could be examined by the analysis of variance. No significant differences in the dorsal ray, anal ray, branchiostegal and lateral line scale counts were found. It was concluded that the intra-lake factors did not in-

Table VIII. Calculated average size in mm. of body parts for Lake Manitoba ciscoes.

Standard Length	200 mm.	250 mm.	300 mm.
HL	52.5	62.5	72.1
HD	35.2	42.2	48.8
EE	14.7	16.4	17.9
ST	13.1	15.4	17.5
MX	17.0	19.7	22.2
IB	13.4	16.4	19.3
CL	18.1	22.1	26.0
CD	20.5	25.3	30.0
BD	59.1	69.8	79.9
BW	27.8	34.9	42.0
DH	50.3	58.9	67.0
DB	28.1	33.5	38.7
AH	33.4	39.8	46.0
AB	25.5	30.8	35.9
PT	40.5	49.2	57.1
PC	42.1	50.3	58.1

Table IX. Frequency distributions of meristic counts of Lake Manitoba ciscoes.

Gill-rakers		Scales			Dorsal R.	Anal R.	Branchiostegals
Count	No.	Count	No.	Count	No.	No.	No.
40	1	-	6	-	-	-	-
41	3	49	1	-	-	-	-
42	-	50	-	-	4	6	4
43	2	51	-	7	-	-	20
44	2	52	1	8	-	-	209
45	12	53	1	9	2	-	106
46	33	54	7	10	65	14	6
47	63	55	7	11	204	106	-
48	91	56	7	12	67	178	-
49	118	57	15	13	3	41	-
50	125	58	26	-	-	-	-
51	87	59	33	-	-	-	-
52	70	60	31	-	-	-	-
53	53	61	45	-	-	-	-
54	21	62	42	-	-	-	-
55	11	63	35	-	-	-	-
56	9	64	30	-	-	-	-
57	3	65	18	-	-	-	-
-	-	66	16	-	-	-	-
-	-	67	14	-	-	-	-
-	-	68	8	-	-	-	-
-	-	69	1	-	-	-	-
-	-	70	1	-	-	-	-

Table X. Meristic counts of Lake Manitoba ciscoes and *Leucichthys tullibee* from Pine Island Lake.[a]

	No.	Range	Mean	SX	SX^2
Gill-rakers					
Lake Manitoba	704	40-57	49.9	35,104	1,754,510
Pine Is. Lake	6	48-54	50.7	304	15,426
Scales					
Lake Manitoba	339	49-70	61.3	20,800	1,282,688
Pine Is. Lake	6	65-76	70.3	422	29,774
Dorsal Rays					
Lake Manitoba	341	9-13	11.0	3,755	41,611
Anal Rays					
Lake Manitoba	339	10-13	11.7	3,975	46,677
Branchiostegals					
Lake Manitoba	341	7-10	8.3	2,826	23,542

[a]Data from Dymond (1928)

fluence these counts.

The gill-rakers showed differences between ages, between locations but not between the sexes. The tests for ages were significant at the 5 per cent level in the Meadow Portage sample and at the 1 per cent level in the Delta and Langruth samples. The tests for locations were significant at the 5 per cent for only the age 5 fish. The statistics for these tests are listed in T-ble XI. It appears, from an examination of the means, that there is a general increase in the number of gill-rakers from ages 4 to 7. The increase is of an order of 2 gill-rakers. The age 6 fish, however, have approximately the same average count as the age 5 fish. The difference in counts found between locations is believed to be associated with dissimilar age compositions.

IDENTIFICATION

The Lake M-nitoba ciscoes are identified by comparing their morphometry with that of nominal species. The nominal species most similar to these ciscoes are Leucichthys tullibee, Leucichthys artedii and Leucichthys nigripinnis. At the present time the comparison is limited to L. tullibee. While data are available to effect comparisons between L. artedii and L. nigripinnis, they have not yet been arranged in the form necessary for an analysis by the relative growth method.

We believe an identification of the Lake Manitoba ciscoes could assist in deciding the taxonomic status of L. tullibee. This species is based upon a description of ciscoes from Pine Island Lake, Saskatchewan by John Richardson. These specimens are no longer extant and no specimens could be obtained in 1946 from the lake. The description published in 1936 is inadequate now to characterize the species. Fortunately 6 specimens were collected from the type locality in the

Table XI. Statistics of gill-raker counts for Lake Manitoba ciscoes.

Age		Location No. 1	2	3	4	5	Total
3							
	N	12	20	1	2	21	56
	SX	583	973	54	99	1,045	2,754
	SX^2	28,367	47,465	2,916	4,901	52,079	135,728
	M	48.6	48.6	-	49.5	49.8	49.2
4							
	N	27	36	12	11	45	131
	SX	1,319	1,787	582	528	2,211	6,427
	SX^2	64,605	88,851	28,280	25,376	108,859	315,971
	M	48.8	49.6	48.5	48.0	49.1	49.1
5							
	N	86	62	32	31	66	277
	SX	4,350	3,119	1,590	1,558	3,232	13,849
	SX^2	220,518	157,147	79,226	78,416	158,586	693,893
	M	50.6	50.3	49.7	50.2	49.0	50.0
6							
	N	61	45	27	32	25	190
	SX	3,044	2,261	1,364	1,604	1,257	9,530
	SX^2	152,232	113,845	69,116	80,664	63,359	479,216
	M	49.9	50.2	50.5	50.1	50.3	50.2
7							
	N	15	10	-	10	7	42
	SX	765	516	-	503	359	2,143
	SX^2	39,095	26,694	-	25,349	18,437	109,575
	M	51.0	51.6	-	50.3	51.3	51.0
Total							
	N	202a	174b	72	90c	166d	704
	SX	10,115	8,703	3,590	4,491	8,205	35,104
	SX^2	507,733	436,211	179,538	224,607	406,421	1,754,510
	M	50.1	50.0	49.9	49.9	49.4	49.9

Includes -- a - 1 age 8, g.r. 54.
b - 1 age ?, g.r. 47.
c - 3 age 8, g.r. 49, 50, 50; 1 age 9, g.r. 50.
d - 1 age ?, g.r. 50; 1 age 2, g.r. 51.

winter of 1926-27 and a description of them has been published (Dymond, 1928). The relationship of L. tullibee to L. artedii and L. nigripinnis has not been definitely settled. It was reduced to a subspecies of L. artedii by Koelz (1931). More recently Dymond (1943) implied that it was more closely related to L. nigripinnis.

A difficulty in comparing the Lake Manitoba ciscoes with the description of Leucichthys tullibee from the type locality is that the data are not strictly comparable. Our measurements are derived from unpreserved material while Dymond's were made from preserved fish. His measurements were taken after the fish were in 65 per cent alcohol for two weeks, previously being "temporarily" in a 5 per cent solution of formaldehyde.

The average size of the specimens differ. The Lake Manitoba fish average 225 mm.; the Pine Island Lake fish average 324 mm. This difficulty in itself can be handled by the analysis of covariance but there is no overlap in size. Our comparison therefore assumes that the fish are in a similar growth stanza and that each group can be compared at a size which is not found in either.

Dymond presented the proportional parts of L. tullibee. They have been rearranged to obtain power regressions (Table XII). The average measurements of a fish at 300 mm. standard length have been computed (Table XIII). The second and third columns of this Table compare the Pine Island Lake and Lake Manitoba fish. Only twelve measurements are presented because the fins of L. tullibee were damaged in handling. Analysis of covariance showed that 7 differences reached the 5 or 1 per cent levels of significance. The percentage difference in average size between these two populations was greater for each measurement except body width than the percentage differences found between the intra-lake factors of the Lake Manitoba ciscoes (Table V, page 10).

Table XII. Regression equation and other statistics for <u>Leucichthys tullibee</u> from Pine Island Lake. Original data are by Dymond, 1928. X = log standard length and Y = log part.

Log Body Part	N	SX	SY	SX^2	SXY	SY^2
HL = 0.857 X - 0.2644	6	15.06	11.32	37.8062	28.4180	21.3622
HD = 1.036 X - 0.8704	6	"	10.38	"	26.0596	17.9644
EE = 0.571 X - 0.1699	6	"	7.58	"	19.0290	9.5802
ST = 1.178 X - 1.6668	6	"	7.74	"	19.4340	9.9962
MX = 0.893 X - 0.8231	6	"	8.51	"	21.3651	12.0747
IB = 0.928 X - 0.9826	6	"	8.08	"	20.2860	10.8872
CL = 0.714 X - 0.3038	6	"	8.93	"	22.4183	13.3079
CD = 0.821 X - 0.5307	6	"	9.18	"	23.0464	14.0512
BD = 1.536 X - 1.8804	6	"	11.85	"	29.7521	23.4199
BW = 1.393 X - 1.7781	6	"	10.31	"	25.8859	17.7281
DH	-	-	-	-	-	-
DB = 1.000 X - 0.8617	6	15.06	9.89	37.8062	24.8295	16.3125
AH	1	2.47	1.59	6.1009	3.9273	2.5281
AB = 0.714 X - 0.1738	6	15.06	9.71	37.8062	24.3761	15.7203
PT	2	5.02	3.53	12.6034	8.8639	6.2345
PC	1	2.55	1.80	6.5025	4.5900	3.2400

Table XIII. Comparison of average size of body parts of <u>Leucichthys</u> <u>tullibee</u> from Pine Island Lake with Lake Manitoba ciscoes at a standard length of 300 mm.

Body Part	Average Size mm.	Difference (P.I.L. - L.M.)	Percentage Difference
HL	72.2	0.1	-
HD	49.6	0.8	-
EE	17.6	-0.3	-
ST	17.8	0.5*	3
MX	24.5	2.3**	10
IB	20.7	1.4**	7
CL	29.2	3.2	-
CD	31.8	1.8	-
BD	84.0	4.1**	5
BW	47.0	5.0**	11
DH	-	-	-
DB	41.2	2.5*	6
AH	-	-	-
AB	39.3	3.4*	9
PT	-	-	-
PC	-	-	-

* adjusted means differ at 5 per cent level of significance.
** adjusted means differ at 1 per cent level of significance.

Tests for differences in slope between the two groups were made. Only the slopes for body depth were statistically significant which affirms that it is proper to compare these fish even though they are not the same size.

Only two of the meristic counts were compared (Table X, page 17). The differences between the gill-raker count (0.8) and the scale count (9.0) were significant. The F value for gill-rakers exceeded the 5 per cent level of P and the F value for scales exceeded the 1 per cent level.

A comparison between the Lake Manitoba ciscoes and L. tullibee from the type locality did not show real differences in 5 measurements. In 7 measurements and 2 counts the Pine Island Lake fish could be considered different from the Lake Manitoba ciscoes. In all these cases the Pine Island Lake fish had the higher value. These differences between the two groups are greater than differences found within the Lake Manitoba ciscoes. In view of the extreme variability in the morphometry of the same species in different lakes the Lake Manitoba ciscoes are identified as Leucichthys tullibee. This conclusion agrees with the identification made by Bajkov (1932).

DISCUSSION

The formulation of a general description of the Lake Manitoba ciscoes presents certain problems. They occur because there are various subgroups within the sample which have their own distinct body form. Each of 3 age groups had a different head length regression. How can a regression be derived that will apply to all? The problems of expressing the morphometry of the population by a heterogeneous sample are considered.

The first difficulty concerns sampling. If subgroups are heterogeneous they should be selected in numerical proportion to their representation in the population. All our data have been combined therefore implying that the age 5 fish are the most numerous age group in the lake. This is certainly incorrect according to biological theory. The morphometry of the ciscoes can never be described if each age group is to contribute its relative proportion to the description. We cannot decide upon the correct percentage of each age group in the lake let alone collect the specimens in this proportion. This point may appear theoretical but it does point out a real obstacle. If samples taken at one time are not representative of the population, most likely two separate samples from the same population will show significant differences. The 1951 sample was composed of 45 per cent age 5 fish. A sample collected a year later might contain 30 per cent age 5 fish. A comparison of the morphometry would probably show differences between the 1951 and the 1952 samples.

The obvious solution to the disposition of heterogeneous subgroups is not the feasible one. This is the second problem. Each distinctive subgroup could be kept apart and a separate description provided. In the Lake Manitoba study this would necessitate at least a separate equation for head length for each age group. This makes generalization impossible and eliminates the only means of comprehending and comparing extensive data. If we use separate equations for each distinctive subgroup, which equation should have priority? No single age group should be used to represent the Lake Manitoba ciscoes. Vladykov (1954) has stated the problem aptly, "In effect, a developing egg of speckled trout has the same right as an adult to be considered as <u>S. fontinalis</u>".

If there are differences within the sample, we see no alternative to combining all data.

In view of these considerations, a statistical test of significance appears inadequate to decide if two samples belong to the same biological population. This is also the conclusion of other investigators.

Wilder (1952) found significant differences in the measurements of certain populations of speckled trout. He referred them to the same taxon because greater differences could be obtained by rearing trout under dissimilar temperature conditions. A statistical test of significance does not measure the divergence of the groups according to Ginsburg (1940). They may be considered distinct but the test cannot decide the degree of taxonomic difference. Ginsburg used the degree of intergradation of the characters in judging the taxonomic status of the samples.

Godsil (1948) and Schaefer (1952) had to decide if a sample of yellowfin tuna from the Hawaiian Islands was taxonomically the same as heterogeneous samples from the eastern Pacific. Godsil's decision was based on distinguishing between statistical and biological differences. Schaefer analyzed the data differently but stated that no method currently was available to evaluate the situation with any precision.

Do these considerations invalidate statistical analysis of data in taxonomic studies? We cannot agree with this view. Statistical tests only indicate the probability that the observed differences are due to chance. This is worth-while because it lessens the subjective judgement of differences. The statistics assist in the decision of identity. Once identity is rejected, the proper taxonomic category is chosen by evaluating the degree of difference with the aid of biological theory and experience.

SUMMARY

1. An investigation of the morphometry of the Lake Manitoba ciscoes was based on 345 specimens collected from 5 different locations in 1951.
2. The body form was studied by means of 16 measurements and 5 meristic counts and was examined for variation associated with the factors of sex and age of

the fish and location of the samples.

3. The measurements were treated by the method of relative growth. The average size of all the measurements except dorsal base was affected by one or more of these factors. A differential growth rate between the sexes probably accounts for females having smaller body parts than males. It could not be established that the growth rate was responsible for differences in body parts present in fish from certain age groups or locations.

4. The only count that was influenced by the factors was the gill-rakers. They showed an average increase over 3 ages of about two. They differed between locations.

5. Sex, age or location do not influence the slope of the relative growth line. The slope for each measurement reveals that a constant form for each part is not found.

6. A description of the Lake Manitoba ciscoes is provided by means of regression equations. From them, the average size of a body part at an arbitrary length of fish can be obtained. Regression equations are provided also for a description of Leucichthys tullibee from the type locality.

7. The Lake Manitoba ciscoes are identified as Leucichthys tullibee. They were found to differ from L. tullibee from the type locality in 7 measurements and two counts.

8. A discussion of problems relating to the description of the morphometry of this population is presented.

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APPENDIX

MEASUREMENTS

Most of the measurements were taken with calipers and are measured in millimeters. Values over 20 are rounded to the nearest whole number, but values under 20 are measured in half millimeters.

Standard Length: The straight-line distance from the lower middle edge of the premaxillary (hereafter termed snout tip) to the upturning of the abdominal vertebrae as indicated by probing.

Head Length: The caliper distance from the snout tip to the most posterior portion of the subopercle. The fleshy flap extending from the subopercle is disregarded.

Head Depth: The caliper distance from the occiput to the ventral junction of the subopercle and interopercle.

Eye: The horizontal diameter of the eyeball.

Snout: The caliper distance from the snout tip to the anterior rim of the eye socket.

Maxillary: The caliper distance from the snout tip to the end of the maxillary.

Interorbital: The least distance between the lateral edges of the supraorbitals.

Caudal Peduncle Length: The distance along the lateral line from the vertical at the posterior insertion of the anal fin to the upturning of the abdominal vertebrae (terminal of standard length).

Caudal Peduncle Depth: The least caliper distance measured vertically of the caudal peduncle.

Body Depth: The greatest depth of the body measured just anteriorly to the dorsal fin as measured with calipers.

Dorsal and Anal Fin Height: The straight-line distance from the anterior insertion of the first rudimentary ray to the end of the longest principal ray.

Dorsal and Anal Fin Base: The caliper distance from the anterior instertion of the first rudimentary ray to the insertion of the last principal ray.

Pectoral and Pelvic Fin Length: The straight-line distance from the insertion of the first ray to the tip of the longest ray.

MERISTIC COUNTS

Dorsal and Anal Fin Ray: The number of branched rays.

Branchiostegal: The number of branchiostegals on the left side.

Lateral Line Scales: The number of lateral line scales from their beginning at the shoulder region to the scale at the termination of the standard length.

Gill-raker: The number of visible gill-rakers on the first left gill arch.