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# Comparison of morphometry of ciscoes, Leucichthys by relative growth methods

Author

J. J. Keleher

Central Fisheries Research Station

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## INTRODUCTION

The morphometry of the ciscoes, Leucichthys receives much attention because of its use in their taxonomy. It is essential to have adequate and accurate methods of describing and comparing the form of these fish so that the taxonomic status of the various populations may be known. The inadequacy of proportional parts and ratios and the merits of the relative growth method to deal with the morphometry of these fish are discussed. The relationship between head length and body length of various cisco populations is reviewed and a generalization proposed.

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## PROPORTIONAL PARTS AND RATIOS

The classical method of expression of body proportions is by conversion of the actual measurements into proportional parts or ratios. Proportional parts are calculated by dividing the measurement of the part by another part (usually the standard length) and multiplying by one thousand. The proportionate head length of a fish having a head length of 69 mm. and standard length of 285 mm. is 242. Ratios are derived by dividing the part into the standard length and in the above example the head length ratio would be 4.1.

Formerly taxonomic studies were based on study of few specimens and the limitation of proportional parts and ratios was not realized. When single specimens were replaced by the series, it was discovered that proportions usually change with the size of the animal. This limitation lessens the facility of description of body proportions in samples having a wide range of size. Koelz's monograph (1929) illustrates how data were subdivided for presentatioh and analysis. Similarly Dymond (1943 p. 210) was forced to show graphically the change in proportional parts with size when discussing the relationship of various species.

An explanation for proportions changing with the size of the specimens is provided by the phenomenon of relative growth (Huxley, 1932). If the growth of the part proceeds at a different rate from that of the rest of the body, then the form of the animal and its proportions will change.

Comparisons using these proportional measurements can not be submitted to statistical tests of significance and therefore conclusions are based solely on the personal judgment of the investigator. Comparisons between ciscoes may involve hundreds of specimens; the data can not be comprehended without the aid of statistical analysis.

It must be concluded that proportional parts and ratios do not satisfy the requirements of convenient and accurate expression and comparison of the morphometry of fish. This is not a new conclusion. It is repeated because authors in recently published studies (Hubbs and Raney 1951, Trautman and Martin 1951, and Ginsburg 1952) still persist in the analysis of morphometry with these outmoded tools.

## RELATIVE GROWTH ANALYSIS

Huxley (1932) has proposed the method of relative growth to deal with the morphometry of animals. In many species there is a simple linear relationship between the growth of any part and the growth of the whole body. This relationship is graphically expressible as a straight line and algebraically in the form,

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

The rate of growth of the part compared to the standard, the body, is not uniform for the animal's entire life. The size range, where the rate is constant, is termed a growth stanza and several stanzas has been found in fishes (Martin, 1949).

With the development of the statistical techniques of analysis of variance and covariance it is now possible to utilize the theory of probability in the relative-growth of morphometric differences between populations. The papers by Mottley (1941), Martin (1949), and Kennedy (in press) are examples of statistical treatment of fish morphometry.

The morphometry of ciscoes may now be described and compared by convenient and accurate means. The proportions may be described by equations, visually presented by graphs and compared by statistical analysis. Other advantages of the method are reviewed by Martin (1949, p. 8).

## MORPHOMETRIC ANALYSIS OF CISCO POPULATIONS

### Character studied

The only character studied in the present paper is the head length. It is an important taxonomic character being used in the separation of Leucichthys artedii, L. nigripinnis, and L. tullibee. This presentation may serve as a model for the analysis of other morphometric characters.

### Method

The data have been collected from the literature or from the author's own studies and are listed in Table I. In many instances the recorded data had to be reconverted from proportional measurements, since actual measurements must be used.

The raw data for each species from a particular locality were plotted on double logarthmic graph paper (Keufel and Esser Co. No. 358-111, $2\frac{3}{4}$ cycle x 2 cycle). Each specimen is represented by one point on the graph; its horizontal position being determined by the standard length, its vertical position by its head length. When all the values for a sample are plotted, the points invariably followed a straight line trend. A straight line was then drawn through these points and continued backwards to the Y axis. The slope of this free-hand line was calculated from the formula $\frac{H}{L}$ where:

H is the vertical distance in mm. of a point to the line.

L is the horizontal distance in mm. of the same point to the line.

A straight line has two characteristics, slope and position. The second characteristic, position, is determined by the value of Y at the point where the line crosses the Y axis. The Y axis can be placed anywhere on the X axis but it must be constant for all comparisons because the position value of the relative growth line will change as the Y axis is altered. The Y axis on the type of graph paper used was at the position of X = 70 mm.

The values for the slope and for the Y axis intercept found by the preceding means are the same as the constants in the previous formula, $\text{Log } Y = \text{Log } b + K \text{ Log } X$, and henceforth the slope value will be designated as K, and the Y intercept value as b.

The morphometry of the various cisco populations are compared by considering the constants of the lines. Four different situations may arise when the two factors, slope and position, vary. In only one case--slopes same, positions same, would the lines be identical and common relationships between head length and body length.

The comparisons in the present dicussion of the constants of these relative growth lines suffer in three respects. These constants could be derived by the statistical method of least squares with greater precision but for the added work involved is not regarded as worthwhile. The number of specimens affects the accuracy of the constants. Constants derived from lines based on 100 specimens will be more accurate than those derived from 10 specimens. The data are not altogether comparable as they have been taken from both fresh and preserved fish. Since the preserved material was obtained from various sources, it was not possible to allow for the effect of preservation on the measurements.

## Results and discussion

The values of the slope and position for the relative growth lines are tabulated in Tables II to V. Table II deals with various populations of *Leucichthys artedii* while the other tables are concerned with *L. nigripinnis*, *L. zenithicus*, *L. nipigon* and some unidentified cisco populations from Manitoba.

Considering all populations, the slope varies from 0.7 to 1.1. This variation is the same as found in other species of fish (cf. Martin, 1949, p. 9). A value of one indicates that the part is growing at the same rate as the body, and is termed isometric growth. This means that the form of the animal remains unchanged during this particular growth stanza. Isometric growth was present in 8 of the 28 cases examined or 28 per cent.

It is indicated above that two groups would have identical head length relationships when simultaneously both K values are identical and both b values are identical. Within a particular species no examples of this were found. The proportion of head length to body length differs within species in every population cited. At certain particular sizes, populations may have the same proportionate head length but this proportion is not constant for the size range examined.

Certain populations of different species appear to have identical head length-body relationships. The Bay of Quinte artedii and the Winnipeg nipigon have K = 0.9 and b = 2.3. The K value of the Michigan artedii and the Attawapiskat nigripinnis is 0.9 while their b value is 2.4. The Seul nipigon and the Nipigon artedii also have the same constants, K = 1.0, b = 1.4.

Two other populations had common constants. This was the unidentified Winnipegosis ciscoes and the Green Bay artedii with K values of 0.7 and b values of 5.0. Identification of the Winnipegosis ciscoes must be made before it is known whether these populations provide an examples of identical proportions within or between species.

The most striking feature of the tables is the negative correlation between the constants b and K. The data for all species were combined and the Bravais-Pearson coefficient of correlation, r, was found to be -.88. A value of -1.0 would denote perfect negative correlation between the variables. The statistics for this calculation are presented in Table VI. Populations having a high slope value have a low intercept value while low slopes are associated with a hgih intercept.

It is interesting to speculate on the reason for the negative correlation between the slope and position of the relative growth line of the head length. It does not appear to be dependent upon the geographical location of the populations. In the L. artedii populations, the specimens from Baker Lake which is in the Northwest Territories and from Green Bay, Lake Michigan both have high intercepts and low slopes. Conversely low intercepts and high slopes are found in the Michigan state population from Blind Lake and the Lake Nipigon fish.

There is both an upper and lower limit to the proportions of every body part in fish. These limits are undoubtedly under genetic control. The result of the negative correlation between the slopes and the position of the lines tends to limit the variation in head length among cisco populations.

The specimens from which the data have been obtained are large fish and presumably represent the final growth stanza. The b values in these data are the resultant of the previous relative growth histories. They are determined by the slopes of each previous growth stanza and the size of the specimens when previous growth inflections occurred. If the previous growth stanzas have made for a high intercept value, i.e. large head, then the relative growth rate of the head is slowed down. If the previous growth stanzas have resulted in a low intercept value, i.e. small head, then in the final growth stanza, the relative proportion of the head is increased by an increased relative growth rate. It appears that there is a compensatory effect in the final growth stanza for the proportions that have arisen as a consequence of the previous relative growth history.

Table I. Number and condition of fish and source of data.

| SPECIES AND LOCALITY | NO. OF SPECIMENS | PRESERVED OR FRESH | SOURCE |
|---|---|---|---|
| L. artedii | | | |
| Attawapiskat | 18 | ? | Dymond and Scott (1941)** |
| Baker | 5 | P | Dymond (1943)** |
| Bay of Quinte, Ontario | 83 | ? | Pritchard (MSS.) |
| Blind | 22 | P | Cooper (1937) |
| Bronte, Ontario | 21 | ? | Pritchard (MSS.) |
| Erie | 89 | F | Scott (unpublished) |
| Great Bear | 97 | P | Kennedy (in press) |
| Green Bay, Michigan | 198 | F | Keleher (unpublished) |
| Michigan | 225 | P | Koelz (1929)* |
| Nipigon | 27 | F | Dymond (1926) |
| Nipissing | 2624 | ? | Fry in Martin (1949) |
| Port Credit | 48 | ? | Pritchard (MSS.) |
| South Bay, Huron | 291 | F | Keleher (unpublished |
| L. nigripinnis | | | |
| Attawapiskat | 9 | ? | Dymond and Scott (1941)** |
| Huron | 10 | P | Koelz (1929) Table 3 |
| Michigan | 48 | P | Koelz (1929)* |
| Nipigon | 29 | F | Dymond (1926) |
| L. zenithicus | | | |
| Nipigon | 10 | F | Dymond (1926) |
| Reindeer | 10 | P | Dymond (1943)** |
| Winnipeg | 154 | F | Keleher (unpublished) |
| L. nipigon | | | |
| Abitibi | 23 | F | Dymond and Hart (1927) |
| Nipigon | 24 | F | Dymond (1926) |
| Seul | 3 | P | Dymond and Pritchard (1930)** |
| Winnipeg | 109 | F | Keleher (unpublished) |
| L. sp. | | | |
| Dauphin | 98 | F | Keleher (unpublished) |
| Manitoba | 345 | F | Keleher (unpublished) |
| Rocky | 60 | F | Keleher (unpublished) |
| Winnipegosis | 98 | F | Keleher (unpublished) |
| L. tullibee | | | |
| Pine Island | 6 | P | Dymond (1928) |

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* - Remeasured by the author, July 1952.

** - From data on file at Royal Ont. Mus. Zoology and Palaeontology.

Table II. Morphometry of head length of various *Leucichthys artedii* populations.

| | SLOPE VALUE | | | | |
|---|---|---|---|---|---|
| INTERCEPT VALUE | 0.7 | 0.8 | 0.9 | 1.0 | 1.1 |
| 1.0 | | | | | |
| 1.1 | | | | | Blind |
| 1.2 | | | | | |
| 1.3 | | | | | |
| 1.4 | | | | | |
| 1.5 | | | | Nipigon | |
| 1.6 | | | | Nipissing | |
| 1.7 | | | | | |
| 1.8 | | | | | |
| 1.9 | | | | | |
| 2.0 | | | | Attawapiskat | |
| 2.1 | | | Great Bear | | |
| 2.2 | | | | | |
| 2.3 | | | Bay of Quinte, Ont. | | |
| 2.4 | | | Michigan | | |
| 2.5 | | | | | |
| 2.6 | | Erie | | | |
| 2.7 | | | | | |
| 2.8 | | Bronte, Ont. | | | |
| 2.9 | | | | | |
| 3.0 | | | | | |
| 3.1 | | | | | |
| 3.2 | | | | | |
| 3.3 | | | | | |
| 3.4 | | | | | |
| 3.5 | | | | | |
| 3.6 | | | | | |
| 3.7 | | Port Credit, Ont. | | | |
| 3.8 | | | | | |
| 3.9 | | | | | |
| 4.0 | | | | | |
| 4.1 | | | | | |
| 4.2 | | | | | |
| 4.3 | South Bay, Huron | | | | |
| 4.4 | | | | | |
| 4.5 | | | | | |
| 4.6 | | | | | |
| 4.7 | | | | | |
| 4.8 | | | | | |
| 4.9 | Baker | | | | |
| 5.0 | Green Bay, Mich. | | | | |
| 5.1 | | | | | |
| 5.2 | | | | | |

Table III. Morphometry of head length of various *Leucichthys* nigripinnis populations.

| INTERCEPT VALUE | SLOPE VALUE 0.7 | 0.8 | 0.9 | 1.0 | 1.1 |
|---|---|---|---|---|---|
| 1.0 | | | | | |
| 1.1 | | | | | |
| 1.2 | | | | | |
| 1.3 | | | | | |
| 1.4 | | | | | |
| 1.5 | | | | | |
| 1.6 | | | | | |
| 1.7 | | | | | |
| 1.8 | | | | | |
| 1.9 | | | | | |
| 2.0 | | | | | |
| 2.1 | | | | | |
| 2.2 | | | | | |
| 2.3 | | | | | |
| 2.4 | | | Attawapiskat | | |
| 2.5 | | | | | |
| 2.6 | | | | | |
| 2.7 | | Nipigon | | | |
| 2.8 | | | | | |
| 2.9 | | Michigan | | | |
| 3.0 | | | | Huron | |
| 3.1 | | | | | |
| 3.2 | | | | | |

Table IV. Morphometry of head length of various *Leucichthys* *zenithicus* (1) and *L*. *nipigon* (2) populations.

| INTERCEPT VALUE | SLOPE VALUE 0.7 | 0.8 | 0.9 | 1.0 | 1.1 |
|---|---|---|---|---|---|
| 1.0 | | | | | |
| 1.1 | | | | | |
| 1.2 | | | | | |
| 1.3 | | | | | |
| 1.4 | | | | | |
| 1.5 | | | | Seul (2) | |
| 1.6 | | | | | |
| 1.7 | | | | Nipigon (1) | |
| 1.8 | | | | | |
| 1.9 | | | | Reindeer (1) | |
| 2.0 | | | | | |
| 2.1 | | | | | |
| 2.2 | | | | Winnipeg (1) | |
| 2.3 | | | Winnipeg (2) | | |
| 2.4 | | | | | |
| 2.5 | | | | | |
| 2.6 | | | | | |
| 2.7 | | | Nipigon (2) | | |
| 2.8 | | | | | |
| 2.9 | | | | | |
| 3.0 | | | | | |
| 3.1 | | | | | |
| 3.2 | | | | | |
| 3.3 | | Abitibi (2) | | | |

Table V. Morphometry of head length of various *Leucichthys* sp. (1) and L. tullibee (2) populations.

| INTERCEPT VALUE | SLOPE VALUE | | | | |
|---|---|---|---|---|---|
| | 0.7 | 0.8 | 0.9 | 1.0 | 1.1 |
| 1.0 | | | | | |
| 1.1 | | | | | |
| 1.2 | | | | | |
| 1.3 | | | | | Pine Is. (2) |
| 1.4 | | | | | |
| 1.5 | | | | | |
| 1.6 | | | | | |
| 1.7 | | | | | |
| 1.8 | | | | | |
| 1.9 | | | | | |
| 2.0 | | | | | |
| 2.1 | | | | | |
| 2.2 | | | Rocky (1) | | |
| 2.3 | | | | | |
| 2.4 | | | | | |
| 2.5 | | | | | |
| 2.6 | | | | | |
| 2.7 | | | | | |
| 2.8 | | | | | |
| 2.9 | | | | | |
| 3.0 | | | | | |
| 3.1 | | | | | |
| 3.2 | | | | | |
| 3.3 | | | | | |
| 3.4 | | | | | |
| 3.5 | | | | | |
| 3.6 | | | | | |
| 3.7 | | | | | |
| 3.8 | | Manitoba (1) | | | |
| 3.9 | | | | | |
| 4.0 | | | | | |
| 4.1 | | | | | |
| 4.2 | | | | | |
| 4.3 | | Dauphin (1) | | | |
| 4.4 | | | | | |
| 4.5 | | | | | |
| 4.6 | | | | | |
| 4.7 | | | | | |
| 4.8 | | | | | |
| 4.9 | | | | | |
| 5.0 | Winnipegosis (1) | | | | |
| 5.1 | | | | | |
| 5.2 | | | | | |

Table VI. Statistics for calculation of correlation coefficient. X is intercept value and Y is slope value.

$\Sigma X = 79.1$  $\Sigma X^2 = 250.97$
$\Sigma Y = 25.7$  $\Sigma Y^2 = 23.17$
$\Sigma XY = 66.77$  $n = 29$

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