NOTES ON THE DISCRIMINATION BETWEEN *CARDIUM EDULE* L. AND *CARDIUM LAMARCKI* REEVE (LAMELLIBRANCHIA).

by

Ross H. Pohlo

Scripps Institution of Oceanography, La Jolla, Calif.
and Kristinebergs Zoologiska Station, Sweden.

Résumé

Des échantillons des deux espèces voisines de Lamellibranches *Cardium edule* L. et *Cardium lamarcki* Reeve ont été classés à l'aide d'une fonction discriminante linéaire. L'auteur discute les méthodes qualitatives et quantitatives employées par Petersen (1958) pour séparer ces espèces et présente les avantages de l'utilisation de la fonction discriminante linéaire.

INTRODUCTION

Discrimination between *Cardium edule* and *Cardium lamarcki,* two sympatric species of lamellibranchs, can be quite difficult, especially when small individuals are encountered. Petersen (1958) described qualitative differences between these species and devised quantitative methods of differentiation. One quantitative method consisted of measuring the breadth of the shell and the ligament length, and plotting these two features on a bivariate scatter diagram (figs. 1 and 2). Regression equations attemping to separate the two forms are given.

In attempting to separate specimens of both species, collected from Gullmars Fjord, Sweden, I found Petersen's quantitative criteria could be applied only with difficulty. Problems arose because a classification based on his qualitative characters was often difficult, or not possible in the smaller individuals. Some of these animals possess few distinguishing features, and others show characters which would allow them to be placed with either species. A simple, useful method of separation is to use Petersen's two discrimination lines (fig. 1 and 2), based on the shell breadth-ligament length relationship. He determined these lines by plotting the two measurements on bivariate scatter diagrams and drew straight lines that separated the scatter plots of the species. These lines were fitted by eye, that

Cahiers de Biologie Marine
Tome IV - 1963 - pp. 177-182.

is, not calculated (Petersen personal communication), but they appear to be adequate for Petersen's data. Two separate diagrams were constructed (see fig. 1 and 2), one for the larger and one for the

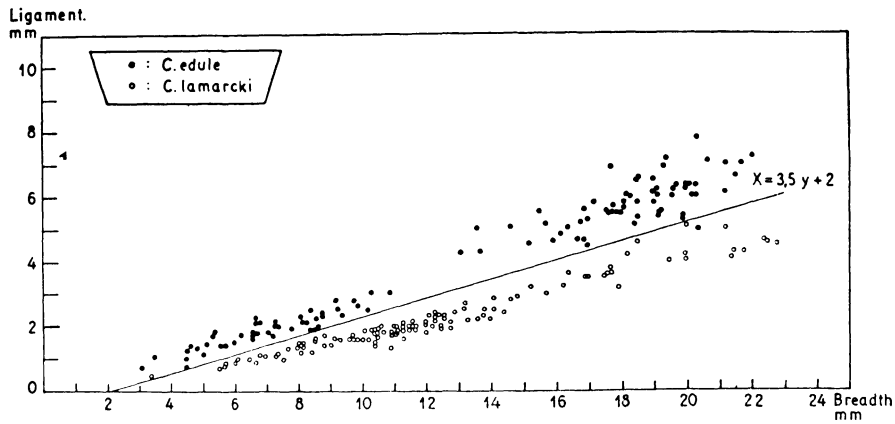

FIG. 1.

The relationship between shell breadth and ligament length in *C. edule* and *C. lamarcki* measured with a slide guage. (From Petersen, 1958.)

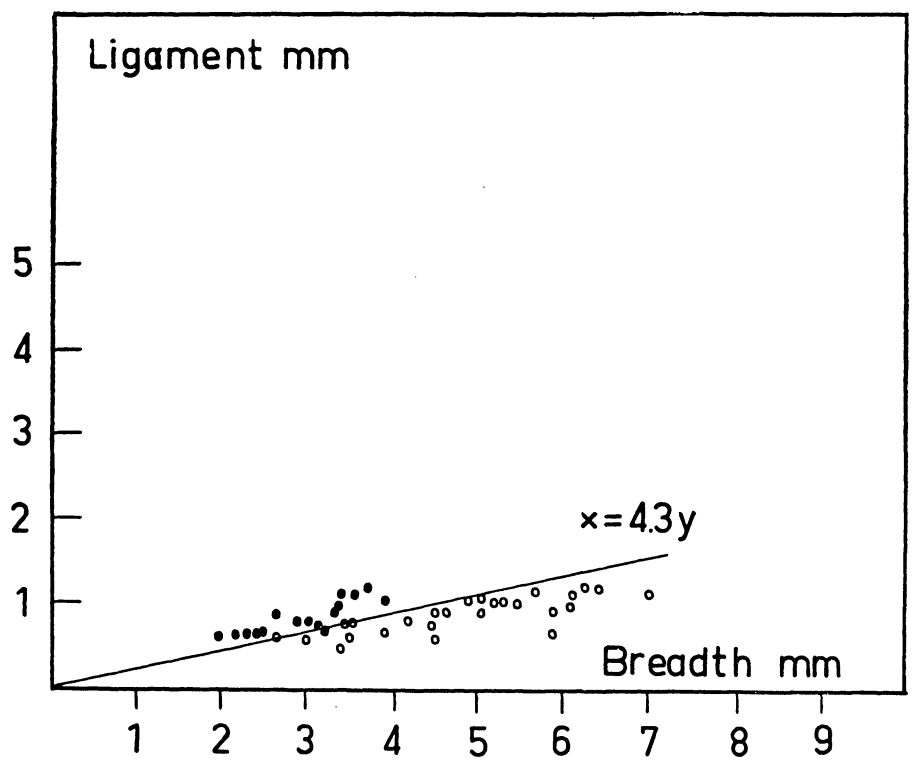

FIG. 2.

The relationship between shell breadth and ligament length measured with an ocularmicrometer. *C. edule*, solid circles; *C. lamarcki*, hollow circles. (Redrawn from Petersen, 1958.)

smaller forms. It was reasoned that two diagrams and their corresponding regression equations x=3.5 y+2 and x=4.3 y were necessary; and the difference in formula was caused by changing over from measuring with a slide guage (larger animals fig. 1) to measuring with an ocularmicrometer (smaller animals fig. 2). Although this is a useful method, several criticisms are noted. One is that two different discriminating equations are used, and this involves the individuals that are the most difficult to classify i.e., animals under 7 mm in breadth. This leads to the problem of deciding which equation is the correct one to be employed at this critical level. Further, the

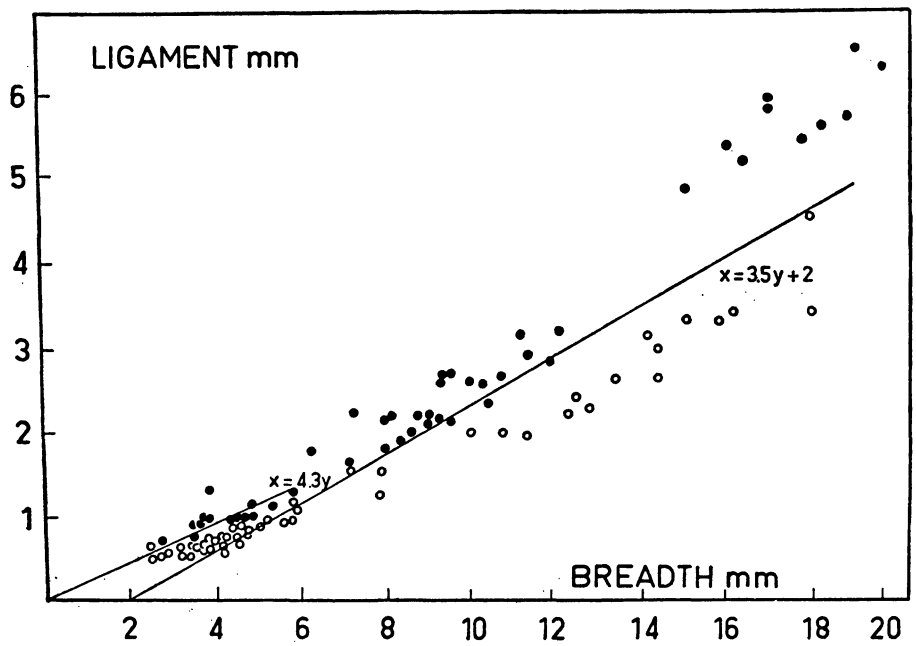

FIG. 3.

The relationship between shell breadth and ligament length in animals collected from Gullmars Fjord. *C. edule*, solid circles; *C. lamarcki*, hollow circles.

lines of separation are fitted by eye and, therefore, no probability statements concerning the confidence of classification can be made using data from other populations.

When applying Petersen's equations to animals in Gullmars Fjord, the following scatter diagram resulted (fig. 3). It must be noted that the two species were classified by means of their qualitative characters, and not on the basis of the breadth-ligament length relationship. This gives four errors in classification using x=3.5 y +2 for animals over 7 mm in breadth, and eight errors using x=4.3 y for animals under 7 mm. And again it is difficult to decide which equation is appropriate for animals approximately 7 mm broad.

THE LINEAR DISCRIMINATE FUNCTION

To remedy the above mentioned problems, to give a simple means of classifying the two species, and to present confidence statements concerning their possible misclassification, a linear discriminate function may be constructed (see Mather, 1960 or Tippet, 1952).

A sample of *Cardium lamarcki* and *C. edule* was collected on a single sand flat in Gullmars Fjord and classified by means of the qualitative characters listed by Petersen (1958). A total of fifty *Cardium edule* and forty-seven *C. lamarcki* was abtained. The shell breadth and ligament length were then measured for all individuals and plotted on a scatter diagram (fig. 3).

The first problem is to bring Petersen's two breadth-ligament length scatter diagrams together into one diagram, and to use one equation for differentiating between the two forms, regardless of the size of the individual. When all of these data are plotted on one scatter diagram, it can be readily seen that the breadth-ligament relationship is an example of allometry, that is, the scatter plot of the breadth-ligament relationship is curved. The change in measuring device, thought by Petersen to cause this curvature, probably was not the source of this effect. Animals from Gullmars Fjord were measured by a slide gauge and rechecked by an ocularmicrometer, and only slight random measuring error was noted between the two methods. In order to construct a linear discriminate function, these data were transformed to straighten out this curvature. A double logarithm transformation was found to be the most suitable. These raw data were then converted into logarithms of base 10, and a linear discriminate function was constructed.

The two linear equations are:

$$6.282055a+6.773834b=-0.127903$$
$$6.773834a+7.657378b=-0.274261$$

giving a solution of: a=0.395810 and b=—0.385956. The linear discriminate function is then:

Y=(0.395910) (log breadth) + (—0.385956) (log ligament lenth). The values for $\overline{Y_1}$ and $\overline{Y_2}$ are 0.287535 and 0.232307 respectively, where the subscript 1 referes to *C. lamarcki* and 2 referes to *C. edule*. The difference between the Y_1 and Y_2 values is D=0.055227, giving a Y value of 0.259920, so that any animal having a value under this figure is placed with *C. edule,* while those over this number are classified as *C. lamarcki.* For example, measurements taken from a specimen suspected of being either *C. edule* or *C. lamarcki* are found to have the following values: breadth=20.4 mm; ligament length=6.56 mm. A change to logarithms with a base 10 yields values of: log breadth= 1.309630; log ligament length=0.819604. Insertion of these values in the linear discriminant function, yields a value of Y=0.203066, and the animal is, therefore, classified as *C. edule.*

An F ratio of 62.9 is obtained with two degrees of freedom in the numerator and ninety-four in the denominator, which indicates that the linear discriminate function is significant at the 0.025 level. To find the chance of misclassification, the species difference is noted, this being D=0.055227. This yields a within group mean square of 0.005875. The estimated standard deviation within species is $\sqrt{0.005875}$=0.024238. A deviation of $\frac{D}{2}$ 0.027624 will cause a misclassification. Such a deviation is $\frac{0.027624}{0.024238}$ =1.14, or 1.14 times the standard deviation as estimated from ninety-four degrees of freedom. A t with ninety-four degrees of freedom exceeds this deviation slightly more than 20% of the time. But to misclassify, this deviation must occur in the right direction, so that the chance of misclassification is 1/2 of this figure, or just over 10%. The number of misclassifications in the Gullmars Fjord material was ten errors out of ninety-seven individuals, which is in agreement with the expected number. Thus, this technique gives a readily calculable means of separating these two species, and a statement of confidence can be given regarding the classification of other populations.

ACKNOWLEDGEMENTS

The author wishes to thank Dr. Bertil Swedmark for his help in the preparation of the paper, and Dr. E. W. Fager for his aid with the numerical calculations. The writer also wishes to thank Dr. G. Höpner Petersen for his helpful correspondence concerning this problem and for his permission to use his graphs in this publication. Funds for this research were supplied by the National Science Foundation, grant number G18767.

Summary

Specimens of the two closely related species of lamellibranchs *Cardium edule* L. and *Cardium lamarcki* Reeve are classified by means of a linear discriminate function. The qualitative and quantitative methods employed by Petersen (1958) to separate these species are discussed. The advantages of using the linear discriminate function are presented.

Zusammenfassung

Exemplare der eng verwandten Lamellibranchierarten *Cardium edule* L. und *Cardium larmarcki* Reeve wurden zugeordnet mit Hilfe einer linearen Diskriminanz funktion. Die von Petersen (1958) zur Trennung dieser beiden Arten verwendeten qualitativen und quantitativen Methoden werden diskutiert. Die Vorteile der Anwendung der charakteristischen Linearfunktion werden dargestellt.

REFERENCES

MATHER, K., 1960. — Statistical analysis in biology. 4th Ed. *Methuen and Co. London.*

PETERSEN, G.H., 1958. — Notes on the growth and biology of the different Cardium species in Danish brackish water areas. *Nedd. Fra Danm. Fiskeri og Havunders.*, 2 No. 22.

TIPPETT, K.H.C., 1952. — Methods of statistics. *Williams and Norgate. London.*