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On the boundaries of osteometry applied to fish

JEAN DESSE & NATHALIE DESSE-BERSET
Laboratoire d'Archéozoologie,
Centre de Recherches Archéologiques: CNRS
250 Rue Albert Einstein, 06560 Valbonne, France

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ABSTRACT : The first major publication to consider fish remains from an archaeozoological standpoint, Casteel's 1976 book, already highlighted the remarkable correlation between fish size, weight and even age with bone measurements. Despite such potential it is shocking to note the under-utilization of fish osteometry by archaeoichthyologists. The first half of this paper discusses a few practical examples of automatic calculation of the size and weight of fishes of high economical importance. The validity of such calculations is then extended to archaeological samples. The second half discusses a simple model of calculation of fish size or weight extended to the level of genus and even of family, and its practical application to archaeo-ichthyology.

KEYWORDS: FISHES, ARCHAEO-ICHTYOLOGY, OSTEOMETRY, SIZE/WEIGHT RECONSTRUCTION

RESUMEN: La primera síntesis en considerar los restos de peces desde una perspectiva arqueozoológica, el volumen de Casteel de 1976, destacaba la sorprendente correlación entre tamaño del pez, su peso e, incluso, su edad con los valores osteométricos individualizados. A pesar de este potencial resulta llamativa la infrautilización de la osteometría de peces por parte de los ictioarqueólogos. La primera parte del trabajo presenta una serie de casos prácticos de retrocálculo automático de la talla y peso de una serie de peces de importancia económica. La validez de estos cálculos se amplia a muestras arqueológicas. La segunda parte valora un modelo simple de retrocálculo de talla y peso ampliándolo a nivel de género, e, incluso, de familia así como sus posibilidades de aplicación en arqueoictiología.

PALABRAS CLAVE: PECES, ARQUEOICTIOLOGÍA, OSTEOMETRÍA, INFERENCIA DE TALLA/PESO

INTRODUCTION

Archaeo-ichthyology became a specialized branch of archaeozoology about 25 years ago. Examples of pioneering works are Georges Desse's 1970-1976 publications on fish vertebrae and Casteel's 1976 textbook. In this publication, among other things, the author noted the importance of osteometry applied to subfossil fish studies, something which has been subsequently corroborated by many other authors (Heinrich, 1987; Brinkhuizen, 1989; Van Neer, 1989).

The major difficulties which formerly prevented us from addressing high level investigations on archaeological fish material (such as excavations without sieved samples or the lack of skeletal reference collections) either disappeared or became less of a problem. Since the eighties, fish bone studies have reached a high standard, as is reflected by the I.C.A.Z. Fish Remains Working Group conferences.

We are therefore surprised to note that osteometry has not been systematically applied (and is still under-employed!) to fish bones from archaeological sites. This may result mainly from difficulties in obtaining reliable taxonomic identifications for the numerous fish remains in sites. When dozens of different species occur in archaeological deposits, the majority of osteologists consider it useless or impossible to apply osteometry to bones which cannot be taxonomically identified.

The aim of the present paper is to demonstrate that osteometry, which is always able to give very interesting interpretations for our archaeological fish bone material, can be applied through simple osteometric models to a wide range of taxa. Osteometric studies can, in fact, be carried out without a (quasi) complete reference collection. The following is a brief overview of the results that can be obtained through osteometric techniques.

MATERIAL AND METHODS

The good correlation between fish length (whether standard, total or fork) and a particular fish bone measurement is now known to hold universally (Figure 1). In general, two measurements from the same fish bone correlate similarly well (Figure 2). It should be noted that measurements made on two different bones usually provide similarly high correlation values (Figure 3). The relationship between two bone measurements, or between a bone measurement and fish length, is described by a simple linear-regression curve. The relationship between fish length/fish weight or bone length/fish weight follows a logarithmic model. The use of this kind of simple formula provides archaeo-ichthyologists with a powerful tool for an archaeological interpretation of bones found on sites.

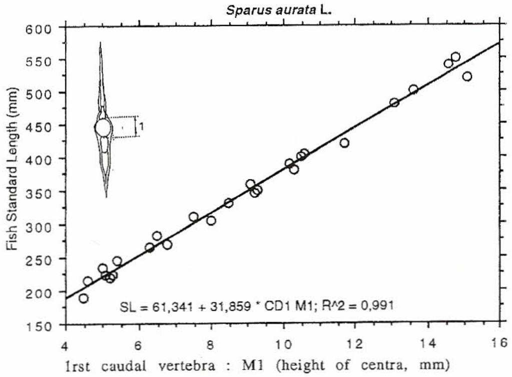

FIGURE 1

Correlation between fish standard length (SL) and fish bone measurement.

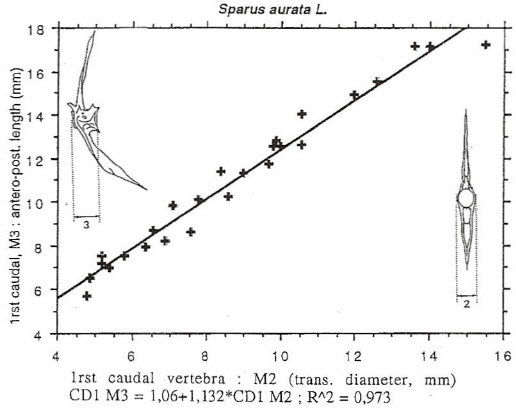

FIGURE 2

Correlation between two measurements on the same fish bone.

The correlation coefficients between bone lengths and fish lengths (or even fish weights), usually oscillate between 0.95 and 0.99. A simple example of these good correlation indexes can be appreciated from the results of three measurements taken on 31 praemaxillare of a common Mediterranean sea-bream species (gilthead, *Sparus aurata*) (Desse & Desse-Berset, 1996) that were correlated to a sample of selected bone measurements of the whole skeleton, and to the length and weight of selected specimens (Figure 4).

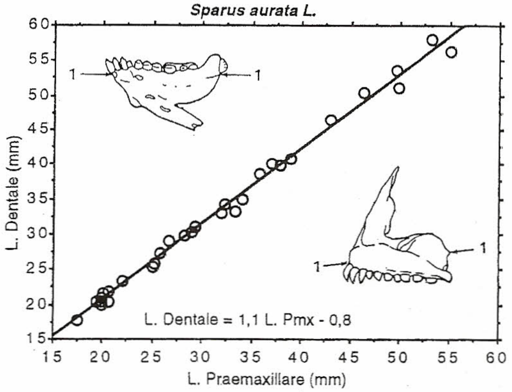

FIGURE 3

Correlation between two measurements on different fish bones of the same species.

A further, very practical, step is to calculate a simple formula which allows for an automatic reconstruction of many skeletal metrical data from a single measurement of a single bone (Figure 5). This calculation, which would have been a tremendous job a few years ago, can now be easily done with the help of modern personal computers. An application of such calculations to a sample of 31 *Sparus aurata* shows their practical utility.

	Value of «r» between:		
	Pmx M1	Pmx M2	Pmx M3
and:			
Standard Length (SL)	0,99	0,99	0,99
Total Lenght (TL)	0,99	0,99	0,99
Neurocranium: M1	0,98	0,99	0,99
Neurocranium: M2	0,99	0,99	0,99
Neurocranium: M3	0,99	0,99	0,99
Neurocranium: M4	0,98	0,98	0,99
Neurocranium: M5	0,93	0,93	0,93
Neurocranium: M6	0,99	0,99	0,98
Neurocranium: M7	0,99	0,99	0,99
Neurocranium: M8	0,98	0,98	0,98
Neurocranium: M9	0,99	0,98	0,98
Neurocranium: M10	0,99	0,98	0,97
Praemaxillare: M1	XXX	0,99	0,99
Praemaxillare: M2	0,99	XXX	0,99
Praemaxillare: M3	0,99	0,99	XXX
Maxillare: M1	1,00	0,99	0,99
Maxillare: M2	0,98	0,98	0,97
Maxillare: M3	0,96	0,99	0,97
Dentale: M1	0,99	0,99	0,99
Dentale: M2	0,98	0,98	0,98
Dentale: M3	0,98	0,98	0,97
Articulare: M1	1,00	0,99	0,99
Articulare: M2	0,99	0,99	0,99
Articulare: M3	0,98	0,98	0,98
Quadratum: M1	0,99	0,99	0,99
Quadratum: M2	0,97	0,98	0,99
Hyomandibulare: M1	0,99	0,98	0,99
Hyomandibulare: M2	0,99	0,98	0,98
Hyomandibulare: M3	0,99	0,99	0,99
Praeoperculare: M1	1,00	0,99	0,99
Praeoperculare: M2	0,99	0,98	0,98
Operculare: M1	0,99	0,99	0,99
Operculare: M2	0,99	0,99	0,99
Operculare: M3	0,98	0,97	0,97
Post-temporale: M1	0,94	0,93	0,94
1st thoracic vert.: M1	0,99	0,98	0,97
8th thoracic vert.: M1	0,99	0,99	0,99
1st caudal vert.: M1	0,99	0,99	0,99
10th caudal vert.: M1	0,99	0,98	0,98
Otolith (sagitta): M1	0,97	0,97	0,96
Otolith (sagitta): M2	0,93	0,94	0,93
Weight (g)	0,98	0,98	0,98

FIGURE 4

Correlation-coefficient («r») between three measurements of the praemaxillare (Pmx M1, Pmx M2, Pmx M3) and the main skeletal measurements of *Sparus aurata*.

y=	«r»=	Reconstitution:
Total Lenght (TL)	1,00	y= 17,3211 + 1,7714 x
Neurocranium: M1	0,99	y= -37,3926 + 8,0072 x
Neurocranium: M2	0,99	y= -18,5152 + 4,3828 x
Neurocranium: M3	0,97	y= 151,6115 +11,6939 x
Neurocranium: M4	0,99	y= 27,9853 + 25,3014
Neurocranium: M5	0,94	y= 82,0973 * x^ 0,7801
Neurocranium: M6	0,98	y= 39,6099 + 51,9345 x
Neurocranium: M7	1,00	y= 8,806 + 8,3643 x
Neurocranium: M8	0,98	y= 63,83 * x^ 0,8109 x
Neurocranium: M9	0,99	y= 68,8202 + 35,4943 x
Neurocranium: M10	0,99	y= 24,4574 + 31,1734 x
Praemaxillare: M1	0,99	y= 31,815 + 9,541 x
Praemaxillare: M2	0,99	y= 12,6993 * x^ 0,8853
Praemaxillare: M3	0,99	y= 45,4659 * x^ 0,7901
Maxillare: M1	0,99	y= 36,318 + 7,7112 x
Maxillare: M2	0,98	y= 45,1594 + 24,838 x
Maxillare: M3	0,97	y= 44,067 + 27,4795 x
Dentale: M1	0,99	y= 34,2352 + 8,9464 x
Dentale: M2	0,98	y= 27,3661 * x^ 0,8926
Dentale: M3	0,98	y= 50,4225 * x^ 0,8254
Articulare: M1	0,99	y= 24,6522 + 10,7319 x
Articulare: M2	0,99	y= 30,8836 + 12,1978 x
Articulare: M3	0,99	y= 72,6411 * x^ 0,8601
Quadratum: M1	0,99	y= 16,8152 + 19,3936 x
Quadratum: M2	0,99	y= 24,0702 * x^ 0,9415
Hyomandibulare: M1	0,99	y= 34,4368 + 16,4939 x
Hyomandibulare: M2	0,99	y= 35,7663 + 29,0515 x
Hyomandibulare: M3	0,99	y= 20,6692 + 7,3378 x
Praeoperculare: M1	1,00	y= 12,8828 + 5,3464 x
Praeoperculare: M2	0,99	y= 28,653 + 19,1089 x
Operculare: M1	0,99	y= 21,9259 + 6,9288 x
Operculare: M2	0,99	y= 45,2875 + 11,238 x
Operculare: M3	0,97	y= 39,9352 + 49,5095 x
Post-temporale: M1	0,94	y= 58,5151 * x^ 0,906
1st thoracic vert.: M1	0,98	y= 62,7561 * x^ 0,8376
8th thoracic vert.: M1	0,99	y= 36,3783 + 38,4039 x
1st caudal vert.: M1	1,00	y= 59,7994 + 31,9925 x
10th caudal vert.: M1	0,99	y= 43,6211 + 40,8131 x
Otolith (sagitta): M1	0,97	y= 10,9765 * x ^1,4658
Otolith (sagitta): M2	0,93	y= 9,7122 * x ^2,032
Weight (g)	0,99	y = 4,999 e-5 * x ^2,8934

FIGURE 5

Standard length reconstruction of *Sparus aurata* calculated from total length, main skeletal measurements and weight.

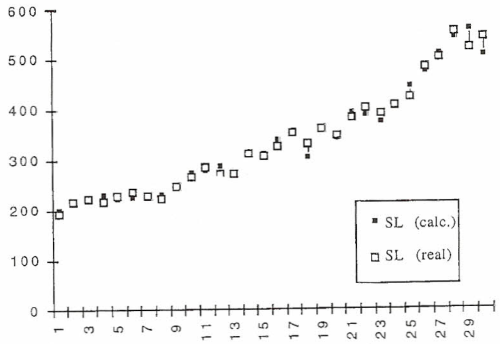

FIGURE 6

Standard length reconstruction (SL Calc.) of the sample of 31 *Sparus aurata* calculated from praemaxillare maximal antero-posterior length (Pmx M1). The error average between the real standard lengths (SL real) and the reconstructed data is worth less than 3% SL Calc. = 9,541 Pmx M1 + 31,815.

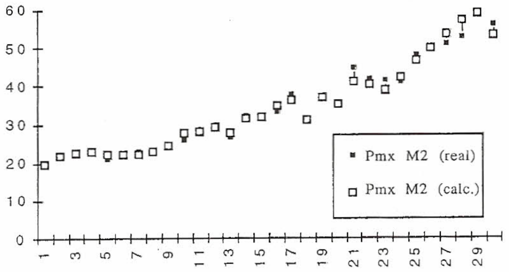

FIGURE 7

Recalculation of the praemaxillare height (Pmx M2 Calc.) from measurement of the praemaxillare maximum antero-posterior length (Pmx M1) on the same *Sparus aurata* sample. The error average, again, is less than 3%. (Pmx M2 Calc. = 1,2909 Pmx M1 + 1,0463).

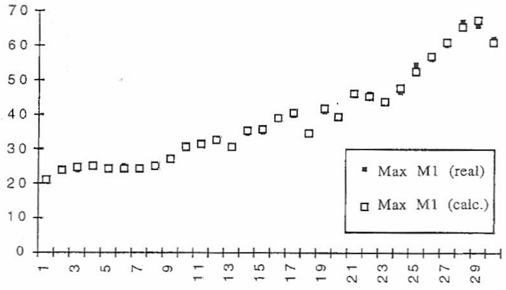

FIGURE 8

Calculation of the maxillare length (Max. M1) from the measurement of the praemaxillare antero-posterior length (Pmx M1). The error average is still very good; the highest errors concern, as always, older and bigger fish (Max. M1 Calc. = 1,2366 Pmx M1 - 0,5629).

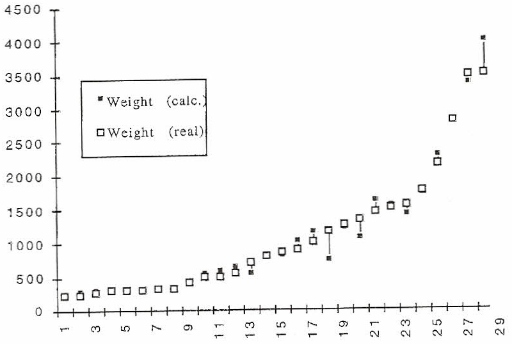

FIGURE 9

Direct calculation of the 31 *Sparus aurata* mass (weight calc.) from the praemaxillare length (Pmx M1). Weight calc. = 0,1111 * Pmx M1 ^ 2,6394.

RESULTS

The first example is related to fish standard length reconstruction calculated from the length of the praemaxillare. The error average is less than 3%, and, as expected, the highest errors for «weight-bearing» bones refer to those from the oldest, thus biggest, fishes (Figure 6). Re-calculation of the praemaxillare height from the measurement of the praemaxillare length (Figure 7) provides an even better result than that for fish length estimation. Again the error average is less than 3%. Quite surprisingly, the results of the estimation of the maxillare length from the measurement of the praemaxillare length are as good as those from previous measurements (Figure 8).

Calculation of fish weight from a bone measurement can be achieved in different ways. The first one makes use of a double regression method, with a previous calculation of fish length from the bone measurement and with the use of the fish length/fish weight relationship; this method is the one generally employed and in our analysis it provided an error average of 10.32%.

The second method applies the direct relationship between a bone measurement and fish weight. Unexpectedly, when applied to our sample, both methods provide quite similar results; we note that the direct method is not the worst! (Figure 9). The difference between the two methods is trivial (e.g., 63 g for a 2000 g fish).

Weight reconstructions are, obviously, less precise than fish length estimations, but weight estimation is much appreciated by archaeologists and useful in the case of palaeoeconomic analyses.

One could object that such good correlations depend on the choice of a particular fish species that provides exceptionally good results that cannot be obtained with other, more common, species. But our long experience demonstrates that *Sparus aurata* is not an atypical fish species, selected for the sole satisfaction of «hyper-scientific» archaeoichthyologists' modeling wishes.

This statement can be easily proved with a great number of cases obtained from very different fish species, published by Desse (1984), Heinrich (1987), Brinkhuizen (1989), Van Neer (1989), Rodríguez- Santana (1994) and Roselló & Sancho (1994) and others or those obtained by the authors on the Epinephelinae (Desse & Desse-Berset, this same issue; Desse *et al.*, 1996). In fact, so far, we have always observed good correlations in osteometric data for our modern and sub-fossil fish bones.

The «Global Rachidian Profiles» method, presented for the first time at the York I.C.A.Z. Fish Meeting in 1987, shows, in fact, a special case of such osteometric applications, most useful for fish size reconstructions and for the evaluation of minimum number of individuals in fishes calculated from isolated vertebrae (Desse *et al.*, 1989) (Figure 10).

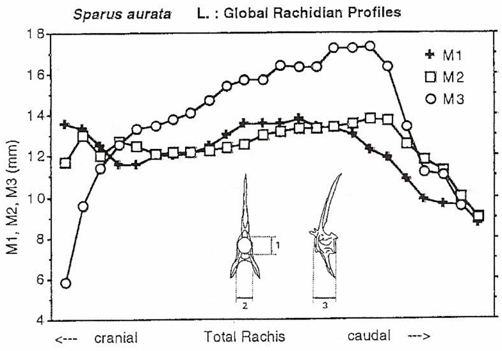

FIGURE 10
Global Rachidian Profiles for *Sparus aurata*.

CONCLUSIONS

To conclude, we shall propose a short, risky, synthesis with the «six rules» of osteometry as applied to fishes or, more precisely, to Teleosts. The first of these proposals seems to be at present universally accepted by the scientific community. If they were to be systematically tested, however, we believe that the remaining five «rules» could also be of great practical interest to fish bone analysts:

1. Osteometric homogeneity (Figure 11, a, b, c): «Bone measurements and fish lengths (total or standard) of the Teleosts are usually highly correlated. This observation holds, to a lesser degree, for bone measurements and fish weights».

2. Taxonomic proximity (Figure 12): «The relationship estimated between various bone measurements, or between bone measurements and fish length, is a general one for the species, often valid for the genus and, ocassionally, for a whole family as well».

3. Trophic individualization (Figure 13): «Modifications in trophic conditions may change the position of the points in a regression curve but do not modify the regression curve itself».

4. Diachronic homogeneity (Figure 14): «The relationship between bone measurements, or between bone measurements and fish length, appears to be constant on an archaeological time scale. Measurements of sub-fossil bones fit the same regression curves as modern samples».

5. Geographic homogeneity (Figure 15): «Osteometric homogeneity is valid for a complete taxonomic sample, even for specimens with different geographic origins».

What can one say of this apparent and paradoxical «fixism»? We can propose an interpretation which, obviously, does not belong to the archaeozoological realm of interpretation, namely:

6. «Fly-away» rule?: «The apparent consistency shown by fish osteometric data, from the Palaeolithic to modern times, may result from a kind of stabilising selection, so that when a profound change in environmental conditions appears, specimens or taxa deviating from a particular standard are forced to either evolve or disappear».

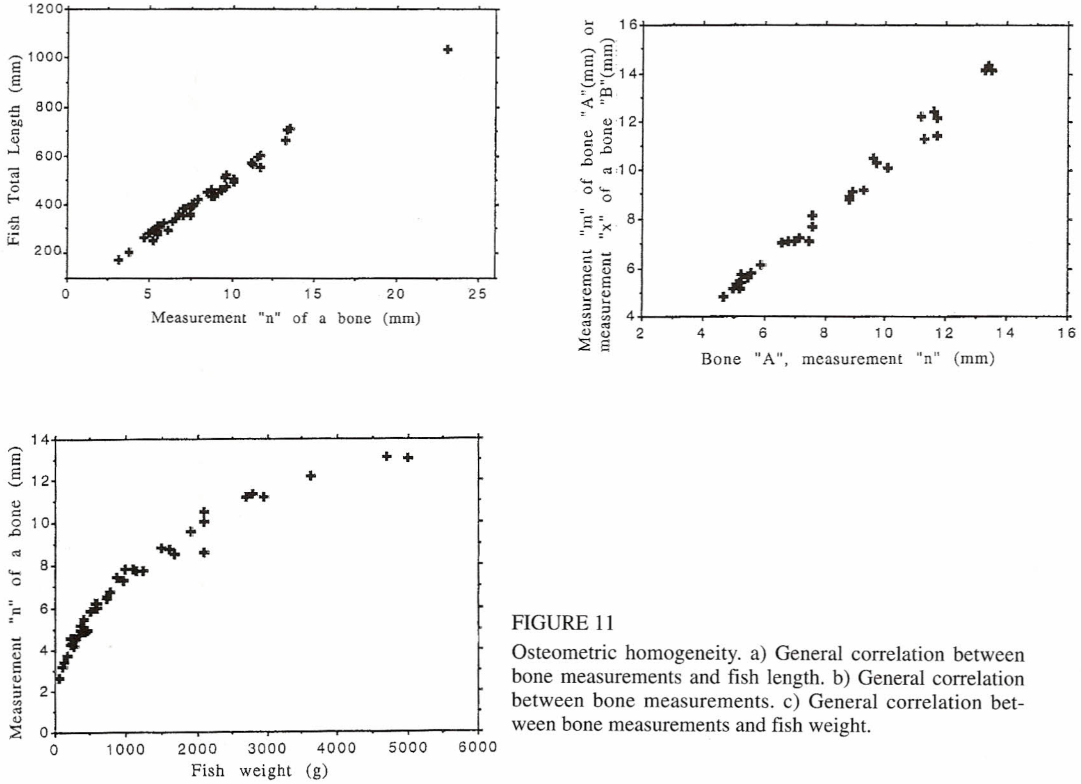

FIGURE 11

Osteometric homogeneity. a) General correlation between bone measurements and fish length. b) General correlation between bone measurements. c) General correlation between bone measurements and fish weight.

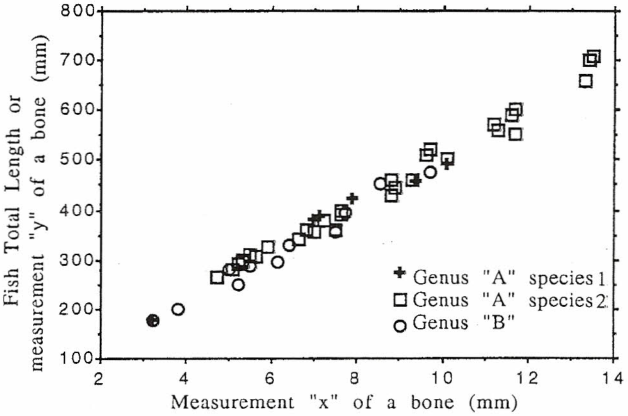

FIGURE 12

Taxonomic proximity.

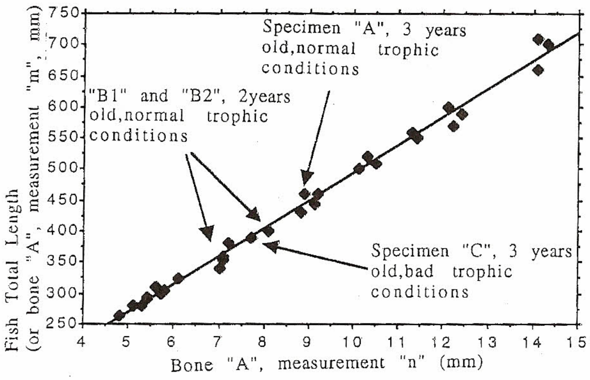

FIGURE 13
Trophic individualization.

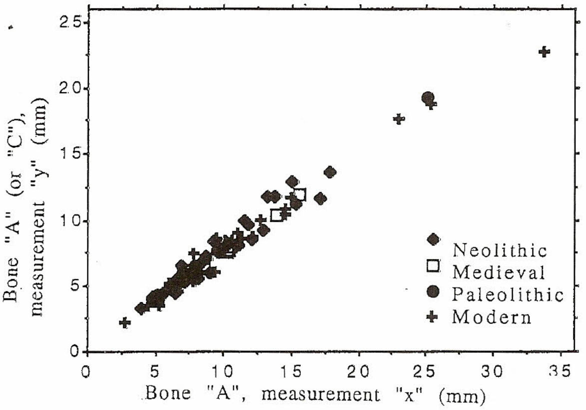

FIGURE 14
Diachronic homogeneity.

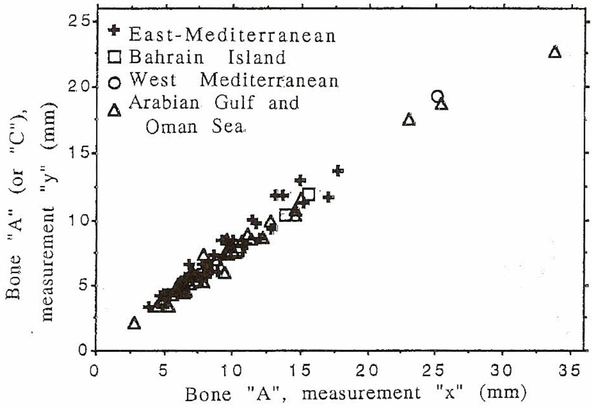

FIGURE 15
Geographic homogeneity.

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