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Correlations between sample size and relative abundance of fish bones: examples from the excavations at Arbon/TG Bleiche 3, Switzerland

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ABSTRACT: A method of on-site sample selection for both animal and plant remains from waterlogged deposits is discussed. On large sites, where it is not always possible to process all sediments, a program of random sampling is advised in order to collect representative data. Sample size is further discussed and some specific effects of differential selection on fish bones are shown.

KEYWORDS: RANDOM SAMPLING, ON-SITE SAMPLING, SAMPLE SIZES, WATERLOGGED SITES, NEOLITHIC, FISH BONES, PSYCHOLOGICAL EFFECTS

RESUMEN: El trabajo valora un método para la selección en el yacimiento de muestras, tanto faunísticas como botánicas, en depósitos saturados por agua. En yacimientos extensos, donde no siempre es posible procesar todo el sedimento, se aconseja llevar a cabo un programa de muestreo al azar a fín de recoger información representativa del conjunto total. El tamaño muestral es analizado en detalle mostrándose una serie de ejemplos específicos sobre la selección diferencial en huesos de peces.

PALABRAS CLAVE: MUESTREO AL AZAR, MUESTREO IN SITU, TAMAÑO MUESTRAL, SEDIMENTOS SATURADOS DE AGUA, NEOLÍTICO, HUESOS DE PECES, EFECTOS PSICOLÓGICOS

INTRODUCTION

One of the most difficult questions posed by analysis and interpretation of faunal remains is which method of collection from archaeological sites will provide representative samples. As various authorities have shown, too many small bones are overlooked by hand-picking during excavation (Payne, 1972; Clason & Prummel, 1977; Wheeler & Jones, 1989), so sieving is essential, particularly for representative sampling of taxa which have relatively small bones, notably fish. However, because of limitations on time and money, it is simply impractical to sieve all material from substantial excavations. Consequently, there is a problem in deciding upon a general sampling strategy.

Theoretical discussions (Mueller, 1975; Van der Veen, 1985) suggests that different strategies need to be adopted for different kinds of sites. In this paper, we discuss the development of a sampling strategy for fish remains from waterlogged, lakeshore, sites of Neolithic age in Switzerland. These sites contain layers rich in organic debris, distributed quite uniformly. The method is worked out for the site of Arbon Bleiche 3 (Figure 1).

MATERIAL AND METHODS

The excavation of Arbon Bleiche 3 took place at Lake Constance from 1993 to 1995. The site is dated to 3.400 BC, which places it between the Pfyn and Horgen cultures, a key stage for understanding the ecological and economic developments in the alpine area. Dendrochronological studies indicated that the site was occupied for 17 years. Seven years after its establishment, the village was expanded by several houses. The settle-

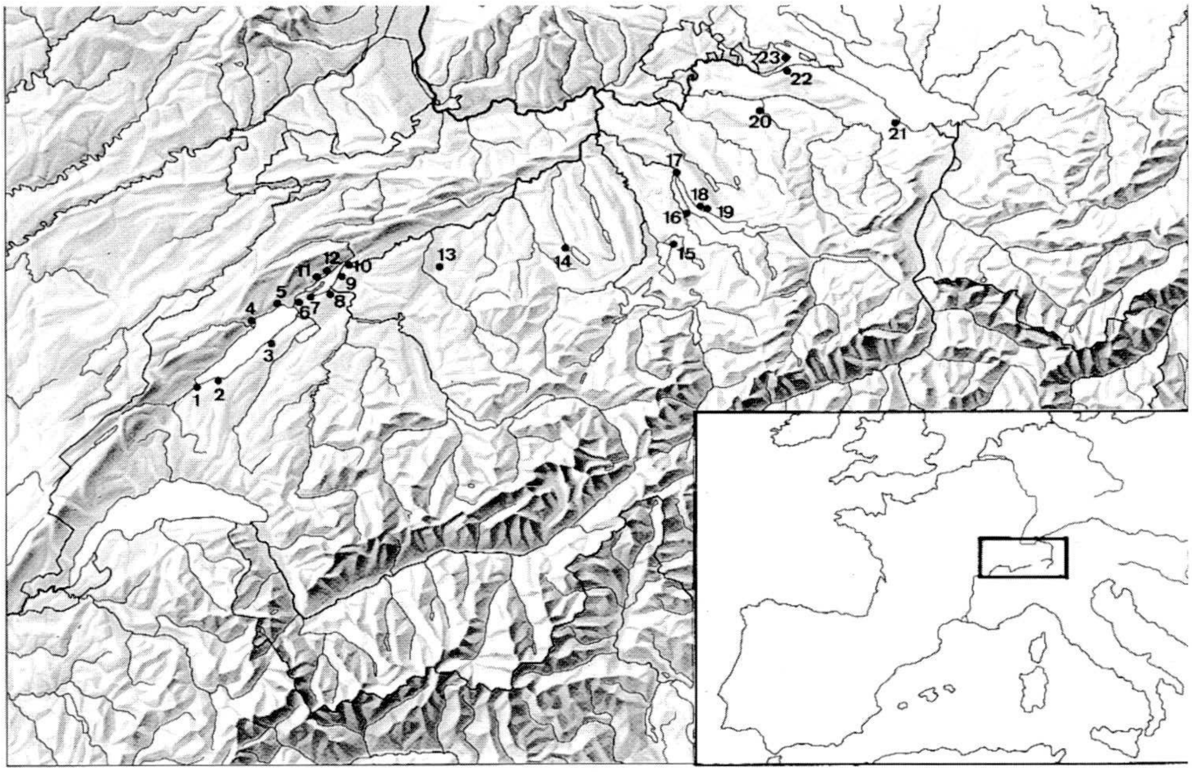

FIGURE 1

Neolithic lake shore sites in the alpine area. 1: Yverdon-Garage Martin; 2: Yvonand station III et IV; 3: Portalban-Les Grèves; 4: Auvernier-La Saunerie, Auvernier-Brise Lames, Auvernier-Port; 5: St. Blaise-Bains des Dames; 6: Thielle Wavre-Port de Thielle; 7: Vinelz-Strandboden, Vinelz-Grabung Strahm 1960, Vinelz-Hafeneinfahrt, Vinelz-Alte Station; 8: Lüscherz-Binggeli, Lüscher-Dorf-Äussere Station, Lüscherz-Fluhstation; 9: Lattrigen VI, Sutz-Rüte; 10: Nidau-BKW 5, Nidau-BKW 3; 11: La Neuville-Chavannes; 12: Twann E1-9, Twann UH, Twann MH, Twann OH; 13: Seeberg-Burgäschisee SW, Seeberg-Burgäschisee Süd; 14: Egolzwil 3, Egolzwil 5; 15: Zug-Vorstadt; 16: Horgen-Dampfschiffsteg; 17: Zürich-Kleiner Hafner, Zürich-Mozartstrasse, Zürich-Seefeld Kan.San., Zürich-Pressehaus, Zürich-AKAD/Pressehaus, Zürich-Mythenschloss; 18: Feldmeilen-Vorderfeld; 19: Meilen-Rohrenhaab; 20: Gachnang-Niederwil-Egelsee; 21: ARBON-BLEICHE 3; 22: Steckborn-Turgi, Steckborn-Schanz; 23: Hornstaad-Hörnle I (BRD).

ment was finally abandoned after a fire. There is one single cultural layer of 5 to 40 cm, containing organic material and large concentrations of charcoal and clay. The preservation of the material is truly extraordinary. In addition to thousands of hazelnut shells and bones, complete dog faeces containing fish bones, carbonized crusts of food in pots, and moss which was practically still green have been retrieved.

Working with archaeobotanical staff, a single sample was sieved in order to obtain material for both zoological and botanical analyses. The sample was divided into two fractions using a water-sieving-tower: one fraction contained material larger than 2 mm, the other material from 0.5 to 2 mm. The sieving and sorting was done in the field by students who had been introduced to the site some months earlier during a course in archaeobiological fieldwork. Specialists were responsible for the identification of questionable pieces at the excavation and later in the laboratory. From material excavated during 14 days in 1994 and 21 days in 1995 a total of 65 samples (305 liters) were analysed. These came from an area approximately 75 m^2. Each sample was taken from a quarter of a square meter.

In the first year, 44 samples were used to address the question of the minimum number of fish bones which must be identified in order to have reasonably accurate results, and to determine the ideal volumes of the samples. The excavated area was at the edge of the prehistoric settlement. Since the locations of structures like houses, streets, stables etc., was unknown a random sample was drawn from the total number of square meters. Each soil sample was about 25 liters. From every soil sample we drew one subsample of 10 liters and another of 1 liter. In 1995, we used the same basic procedure, except that we drew 3 liter samples from an area excavated at the center of the site. A random sample was also drawn, but in contrast to 1994, this time we knew about structures and could recover samples from inside and outside the houses, stables, streets and equivalent features. The samples were then sieved to fractions. Most fish bone was not found in the small fraction or the hand-collected material, but came instead from the 2 to 8 mm fraction. In the first sort, only vertebrae were identified. The results presented here are from this material.

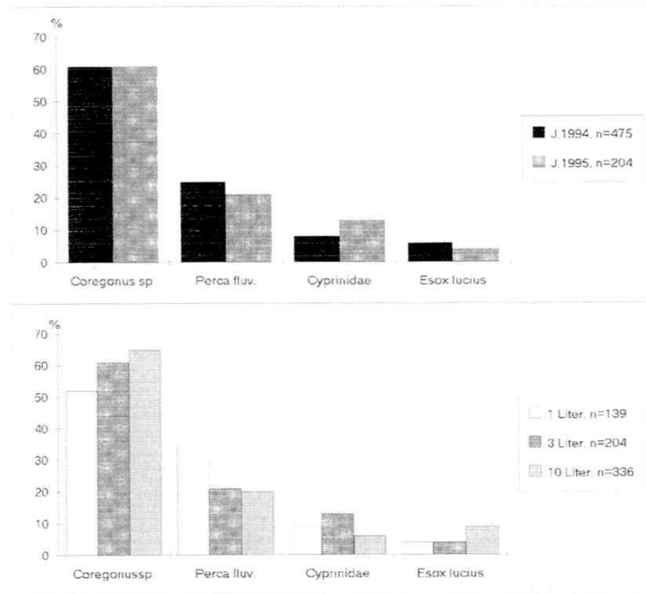

FIGURE 2
Fish bone. Arbon Bleiche 3. Overall frequency of species and the frequencies of species in different sized samples.

RESULTS

Not all of the fish remains collected from Arbon Bleiche have been identified. Nevertheless, it is unlikely that the frequency distribution of species will change significantly with additional specimens. We can therefore assume that the amount of whitefish (*Coregonus sp.*) shown in Figure 2a is real. Since this is the first time that whitefish has been identified in Neolithic settlements in Switzerland, these have to be studied separately (Hüster-Plogmann, in preparation). Beyond that, the typical Neolithic ichthyofauna is represented by perch (*Perca fluviatilis*), pike (*Esox lucius*), and several species of Cyprinidae. Amazingly, the frequency distribution of recovered fish differs only slightly from the natural distribution recorded in 1935, when Lake Constance was less polluted and euthrophic than today (Hüster-Plogmann & Leuzinger, 1995).

It has become clear that there is no significant difference between the methods of random sampling used in 1994 and 1995. As a matter of fact, although the sampling procedure was different, the frequency distribution of species appears quite similar. There are also no major differences in the distributions of species among the various sample sizes: the 10 liter, 3 liter and 1 liter samples show very similar results (Figure 2b). Certainly the amount of bones varies among the samples. But since we have the same number of samples in each group and the main species are represented in almost every sample with the frequency distribution being basically repeated in every sample, we can assume that representative samples can be drawn, whether or not we are informed about the location of features. Surprisingly, it looks like the 1 liter, or at least the 3 liter samples, are large enough to get representative results.

Another unexpected observation after a comparison of the 1 liter and 10 liter samples from 1994 was made. Assuming that the bones were randomly distributed within a sample (that is, that there are no systematic clusters of bone), the quotient of the 10 to 1 liter samples ought to be 10. In other words, we should expect 10 times more bones in 10 liters than in 1 liter. This does not seem to be the case (Figure 3). Five samples show about 10 times more bone, two show much more, but most of the samples are less than three times larger. So we actually missed bones in the 10 liter samples. We tried to analyze this loss although it is almost impossible to verify statistically. Figure 4 is a box plot showing the frequency of fish bones in the various samples (numbers per liter). Both the 10 liter and the 1 liter groups show equal or similar numbers of samples with few bones, but there are more samples with high numbers of bones in the 1 liter group.

If we were to split the perch and whitefish bones into crania and vertebrae, the frequency of headbones (Figure 5a) is similar to all bone combined: there are more samples with high numbers of bones in the 1 liter group. The head bones of small fish look quite similar to leaves, pieces of wood or stalks, so they could have been overlooked by the students. It is more likely that this happens in the 10 liter samples because it is a huge amount of material to process when one is under time pressure.

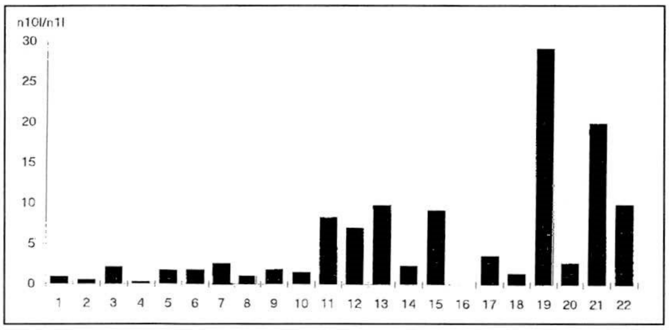

FIGURE 3
Fish bone. Arbon Bleiche 3. Ratio of fish bone in 10 liter and 1 liter samples (n10liter/n1liter).

The frequency of perch vertebrae (Figure 5b) appears to be quite similar (i.e., there are more samples with concentrations of perch in the 1 liter group). A contributing factor may be that different sized perch are represented in the material. Some bones are from individuals 30cm long, but most come from fishes smaller than 10 cm. It is possible that some of the small specimens were missed in the 10 liter samples in the same way we assume happened with the head bones.

Whitefish samples exhibit no differences between the 10 liter and 1 liter groups (Figure 5c). In my opinion, this is due to the fact that the vertebrae of *Coregonus* are very uniform in size and shape. If you have seen these vertebrae once, you will recognize them forever. Perhaps we should be much more aware of psychological effects on the sorting and identification of archaeological materials.

DISCUSSION

In this case study we tried to develop strategies for identifying optimal sample sizes and for random sampling on excavations. Our initial idea was to sample both seeds and bones with one single strategy. According to Van der Veen (1985) the required sample size depends on four variables. First of all, one has to deal with the amount of material in the target population (in her case total amount of plant refuse generated on a site), which can often be said to be infinitely large. Second is the proportion in which particular species occur. Two additional factors to take into account are the required degree of accuracy (in absolute terms), and the probability of achieving that accuracy. In Van der Veen & Fieller (1982) a set of formulae is presented for calculating in advance the required sample sizes and confidence intervals for differing circumstances. In our case, we estimated that we needed about 550 specimens to fall within a 95% confidence interval for our sample populations. This turned out to be an easy target sample for the seeds, but not for the fish bones. In particular in the center of the site, the proportion of fish bones varied too much to systematically yield enough bone material. This is the reason why we went through the entire sample collecting bones, but stopped in the case of plant remains after arriving at 550 seeds. The frequency distributions for every sample were not statistically identical.

In general, we know about correlations between the number of collected bones and the number of identified species (Grayson, 1984). If we expect our target fish population to include no more than five common species and an additional 10 rare species at the most (which is a quite realistic estimation with lakeshore settlements in Switzerland), according to our calculations, most of these should be represented within 200 to 300 identified bones. This is what we found.

Random sampling yielded similar results for both botanical and zoological materials and, as mentioned above, the results with and without knowledge of structures are comparable. Nevertheless, there are differences to be discussed.

Organic remains in prehistoric sites cannot be assumed to be homogeneously distributed. There-

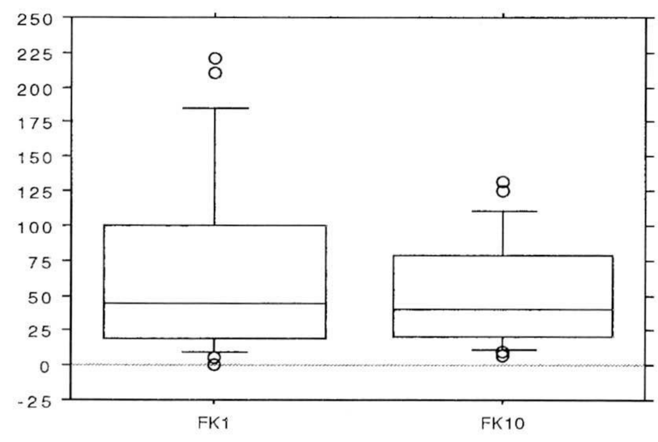

FIGURE 4
Fish bone. Arbon Bleiche 3. Frequency in 1 and 10 liter samples (n/l). Box plot showing the 10th, 25th, 50th (median), 75th and 90th percentiles of the variable. Values above the 90th and below the 10th percentile are plotted as points.

fore, one has to find a way to establish a mean value. If no information is available about the site beforehand, it seems necessary to take samples in a very intensive and regular manner. In 1994, we took 22 samples from an area of 25 square meters, which means that a quarter of almost every square meter was sampled. This is a time- and money-consuming procedure that can be hardly carried out on large areas. One has to choose the «right» spots of the site.

Another situation occurs if one has knowledge about structures and features in the site. One suggestion then is that these structures or features be divided into archaeologically recognisable categories and that samples be taken out of each category. This procedure allows bones to be related to specific features at every stage of analysis. Another advantage of this kind of random sampling is that the dependence on one particular area is quite low. It allows samples to be taken from all areas and all stages of an excavation.

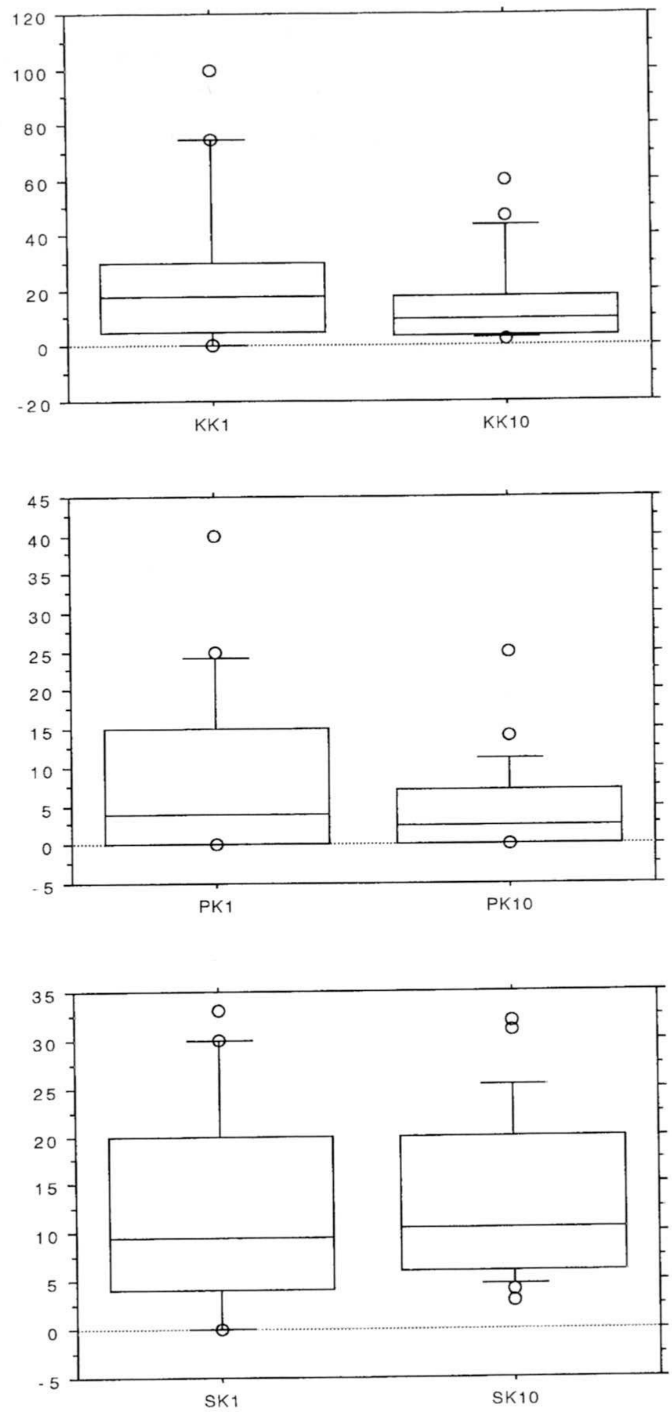

FIGURE 5

Fish bone. Arbon Bleiche 3. Frequency (n/l) of head bones (5a, KK1 liter and KK10 liter), vertebrae of *Perca fluviatilis* (5b, PK1 liter and PK10 liter) and vertebrae of *Coregonus sp.* (5c, SK1 liter and SK10 liter). Box Plots, showing the 10^{th}, 25^{th}, 50^{th} (median), 75^{th} and 90^{th} percentiles of the variable. Values above the 90^{th} and below the 10^{th} percentile are plotted as points.

CONCLUSION

The case study of Arbon Bleiche allows us to make some recommendations concerning random sampling in excavations of waterlogged lake shore sites. In principle, it is possible to obtain representative results without knowledge of the structures in a site. In that case, however, sampling must be dense and regular. A better way is to focus on structures and/or features. The volume of each sample to be taken certainly depends on its density of bones, but something between 1 and 3 liters should work. As a matter of fact, it looks as if it is worth taking low volume samples not only to achieve a good representation of data; there might be good psychological arguments for doing so as well.

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