Screen Size and Sample Stratification in Efficient Shell Midden Analysis

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ABSTRACT

An experiment comparing the methods of assessing shell numbers within midden material by sampling is described, and some implications for the efficient analysis of middens are discussed.

Keywords SHELL MIDDEN SORTING, SAMPLING, COST EFFECTIVENESS, SCREEN SIZE, EXPERIMENT.

INTRODUCTION

Midden analysis is a tedious and time-consuming activity, but accurate results require that a substantial and representative sample be considered. A conflict therefore arises from the desire to consider larger samples and the contents of those samples more thoroughly, as against the limited time most archaeologists find they can apply to midden sorting.

The size of the screen used to separate the material to be examined from that to be discarded is especially relevant to this problem, and many reports and reviews of midden analysis discuss this crucial issue, e.g. Meighan *et al.* 1958; Meighan 1969; Davidson 1964; Koloseike 1968, 1969; Payne 1972. Meighan suggests that it is generally impractical to use a screen finer than quarter-inch (6.3 mm): "The sorting of one complex sample to a quarter-inch size usually takes a few hours but can take much longer. Sorting to one-sixteenth of an inch will increase this time by at least 500%" (Meighan 1969:418). A quarter-inch screen can, however, be fully adequate, especially when numbers rather than weights of shells are being measured. For example, in his examination of the middens at Black Rocks, Palliser Bay, Anderson (1973a) sieved all the material excavated using a quarter-inch screen, the material retained being removed to the laboratory. As a check on the material being discarded, small whole samples and samples of the material passing the quarter-inch screen but retained by an eighth-inch screen were also examined. As the shell was largely intact it was found that almost all the relevant material was recovered in the quarter-inch screen (Anderson 1973a:58-59, Fig. 3; Anderson pers. comm.).

Nevertheless, in many middens the finer fractions do contain important amounts of shell, whether calculated from weights or numbers. Where this is the case a more rigorous approach to the finer material is called for, and Meighan acknowledges that finer screens will generally be more accurate (Meighan 1969:418).

One approach that might help to resolve the cost-effectiveness dilemma emerges from the experiment of Treganza and Cook (1948), who suggest that finer, more dispersed material is capable of accurate assessment by a small number of small samples, while material in large units is much harder to estimate, large numbers of large samples being needed.

It is reasonable to expect that the fragments of shell of different sizes in a midden will behave in the same way, and this paper is written to discuss the results of an experiment to examine the practical efficiency of the stratification of midden samples by screen size.

PROCEDURE

For the purposes of this experiment the sampling universe is taken to be the contents of one large bag of midden—approximately 30 kg—excavated from the Northland Harbour Board site at Kioreroa, Whangarei, N20/102 (Nichol n.d.). Prior examination had shown that two species—cockle *(Chione stutchburyi)* and mud-snail *(Amphibola crenata)*—were much the most common constituents, and the sampling was directed at estimating the numbers of shells of these two species contained in the bag in question.

In the first method (here called "unstratified") a series of 15 grab samples of about 100 g each were removed from the top of the bag and their weights were taken. Earlier experiments (Naus pers. comm.; Saville pers. comm.) had shown that whorls of *Amphibola* and hinges of *Chione* were the most effective elements diagnostic of individuals of the two species, and that a 2 mm screen retained the majority (94-96%) of these elements present in a sample of crushed shell. The samples were therefore wet-sieved using a 2 mm screen, and after drying the material retained was searched for the whorls and hinges, the numbers of which were recorded. No attempt was made to sort left and right *Chione* valves as the results are generally less reliable than the simple average (Nichol 1978:171-175). The total time taken was also noted.

In the second method (here called "stratified") the remainder of the bag was weighed, blown dry, weighed again, and sieved using a 6.3 mm screen. The coarse fraction, i.e. that retained by the screen, was divided into portions of roughly the same size. These were weighed and searched for the diagnostic elements, which were counted. The fine fraction became sorted during sieving, so a mechanical sample splitter was used repeatedly to produce 15 samples of somewhat more than 100 g each. These were wet-sieved using a 2 mm screen, dried, and searched as before. The time taken in each operation was noted.

RESULTS

Unstratified

The 15 samples analysed were all of slightly different weights, so the counts of animals in the samples needed to be adjusted to a constant sample size. The results, assuming samples of 100 g each, are set out in Table 1, and the 315 minutes spent on the treatment of these samples produced the estimate that the bag contained 12583 ± 1973 *Chione* valves and 1326 ± 431 *Amphibola.*

Stratified

The total weight remaining after the unstratified sampling was 29331 g, which became 21476 g on drying. 5460 g were retained by the 6.3 mm screen, and this coarse fraction contained 4473.5 *Chione* valves and 478 *Amphibola.* Table 1 includes the counts within the 43 separate samples of the coarse fraction and within the 15 samples of the fine fraction, in both cases with the results adjusted to a constant 100 g/sample. On the basis of these results, the 16016 g of fine fraction contained 6534.5 ± 1025 *Chione* valves and 689 ± 224 *Amphibola,* so the 29331 g present at the beginning of the stratified sampling contained 11008 ± 1025 *Chione* valves and 1167 ± 224 *Amphibola.* The stratified sampling therefore provided the estimate that there were approximately 11575 ± 1078 *Chione* valves and 1227 ± 236 *Amphibola*

TABLE 1
SAMPLE SIZE AND SAMPLE VARIABILITY

Species	Fraction	Average Sample size (g)	Adjusted counts /100 g	Rate of sorting (min/100 g)	C.V. for samples used	C.V. for 100 g samples	C.V. for 10 min. samples
Chione	Unstratified	100.8	47.69 ± 7.51	16.1	0.157	0.158	0.199
	Strat. fine	127.7	40.8 ± 6.4	18.0	0.157	0.177	0.210
	Strat. coarse	127.0	82.17 ± 14.69	4.8	0.179	0.201	0.124
Amphibola	Unstratified	100.8	5.62 ± 1.84	16.1	0.327	0.328	0.415
	Strat. fine	127.7	4.3 ± 1.4	18.0	0.326	0.368	0.437
	Strat. coarse	127.0	8.83 ± 5.23	4.8	0.592	0.667	0.410

TABLE 2
COSTS OF SEPARATE ACTIVITIES IN STRATIFIED SAMPLING

Weighing original material	60 min.
Sieving, 6.3 mm screen	10 min.
Sorting and counting, Coarse fraction	260 min.
Sample splitting	30 min.
Sieving, 2 mm screen	90 min.
Sorting and counting, Fine fraction	345 min.

in the complete original bag. This estimate required some 795 minutes' work, the times for the various operations being as set out in Table 2.

The two estimates are acceptably similar.

It is possible to increase the precision of the estimates using either the stratified or unstratified method. Assuming that 15 samples continue to be used, increasing the size of each sample will have the effect of reducing the coefficient of variation of the sample (C.V.), i.e. the ratio between the standard deviation and the mean. The improvement to be expected bears a relation to the increase of the size of the samples: if the C.V. is to be reduced by a factor of $1/x$, the size of the samples needs to be increased by a factor of x^2, so that quadrupling the size of the samples will halve the C.V.

In the case of unstratified sampling, all the procedures will have to be repeated for all the material analysed, so the time taken will be proportional to the total quantity of midden treated. In the case of the stratified sampling, however, only the time spent analysing the finer fraction will increase. Though the time spent using the sample splitter might actually decrease, it will be assumed here that the time spent on the finer fraction will be proportional to the quantity of this fraction treated, and that the time spent on all other operations remains constant. Using these assumptions, it is possible to relate the time spent on analysis and the C.V.s for the two species for various sample sizes in either stratified or unstratified methods, and the relationships resulting are shown in Figure 1.

It is also useful to compare the C.V.s within the different classes of material simply in terms of the cost of sorting. After all, it is this that is the really tedious aspect of midden analysis. Also, the costs of processes such as sieving and weighing are dependent on the equipment available and the matrix of the midden and might be changed under other circumstances, while the rate of sorting is the limiting factor, being entirely dependent on an individual sitting at a laboratory bench. These rates are set out in Table 1.

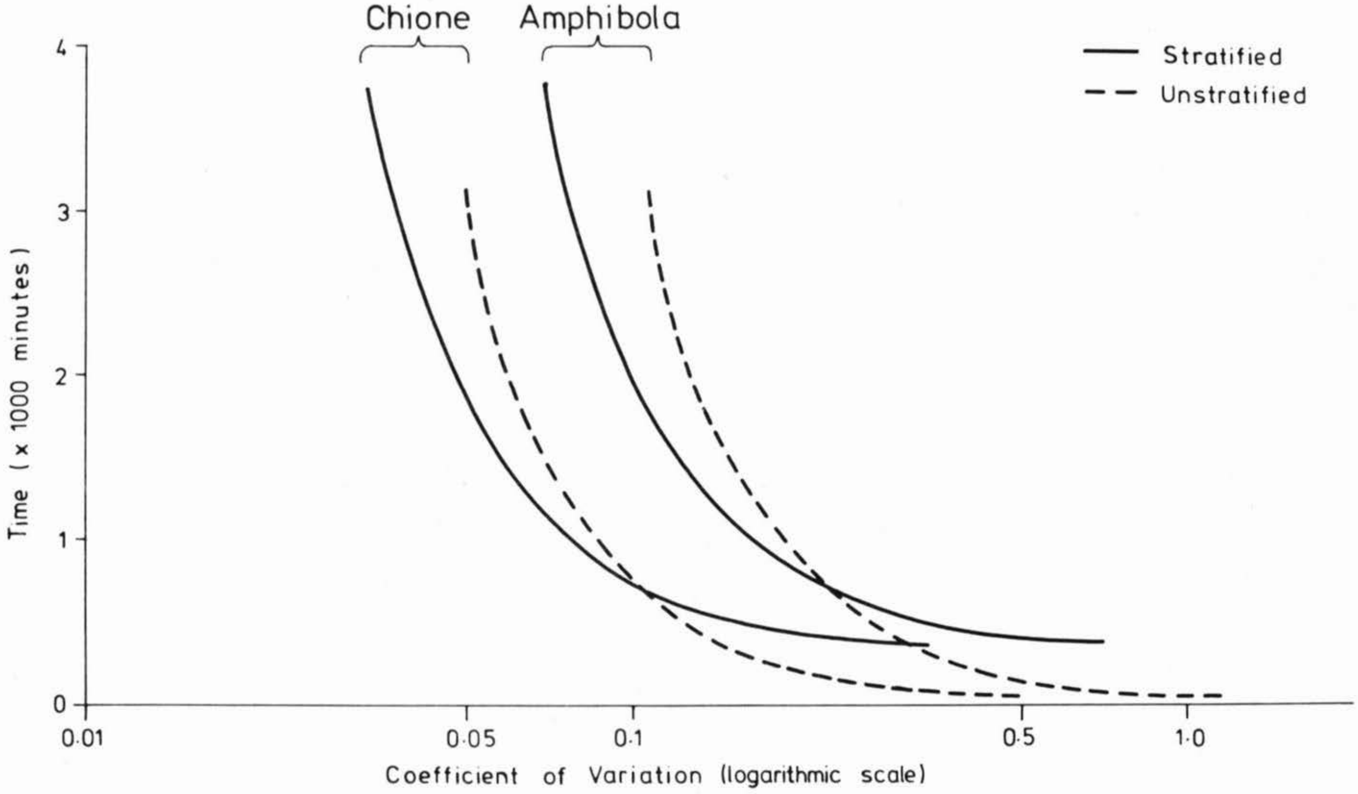

Figure 1: Relative costs of sampling strategies.

DISCUSSION AND CONCLUSIONS

The need to identify midden structure is often emphasised, for example by Davidson (1964), Ambrose (1967), Coutts (1971), Anderson (1973a, 1973b) and Grayson (1974). Anderson (1973b:122) reminds us that samples cannot be relied on to produce material representative of an entire site when, as is almost always the case, the distribution of cultural items is patterned rather than completely mixed; that any bias in the samples excavated or analysed versus the entire site cannot be measured without the excavation and analysis of the entire site; and that it is not possible to have complete confidence in any prediction of patterning within the unexcavated portion of a site on the basis of an excavated sample. Problems like this will continue to be very troublesome, but given the approach we have adopted discussion of these problems is beyond the scope of this paper. We begin with the assumptions that the structural unit has been defined and that the size of the unit is known, the problem remaining being to estimate the contents of the unit by extrapolating directly from a sample of known size. In this case we can sub-sample so as to minimise the effects of heterogeneities within the material, and set ourselves the task of estimating the contents of this sample in an economical fashion.

The real advantage in analysing coarser grades of material is shown clearly enough in Table 1: the material can be sorted comparatively rapidly. However, that does not make it legitimate to define the finer material out of existence, even though it is always troublesome and can be unproductive. 'There has been an attempt to sweep "residue" under the rug. Still the telltale lump remains to embarrass the hostess' (Koloseike 1968:373, paraphrasing Opler).

Our intention here is simply to offer an approach to the problem of the cost-effectiveness of midden sorting that leads Koloseike to almost despair of quantitative analysis of middens as a useful exercise.

> Considering the high costs of shell data production and the incompleteness of standard shell analysis the archaeologist must question whether the picture produced is worth the effort. Standard analysis for shell may be necessary at some sites. But a more impressionistic visual estimate of shell concentration, while yielding far less precise information, avoids the daunting time expense of detailed mechanical analysis. (Koloseike 1970:479-480)

Though we would hesitate to go as far as this, it does indeed make good sense to relate the effort put into an analysis to the value of the result, and this criterion can be usefully applied during both excavation and analysis. One aspect of this is that the sampling strategy adopted can be chosen to provide the degree of precision required by the analysis being performed.

More specifically, our results indicate that simple random sampling is the sensible method where the precision of the estimate need not be particularly high, but as the required precision increases stratified sampling becomes more economical, with the break-even points in the particular "midden" considered here being C.V.s of about 0.1 for *Chione* and 0.2 for *Amphibola.*

Of course the treatment applied in the stratified sampling was very unusual, in that the whole of the coarse fraction was sorted. This was possible because the "midden" considered was so very small, and the practical application of stratified sampling to almost any real midden will involve the sorting of only a sample of each fraction. A simple formula makes it possible to calculate the relative lengths of time to be expended on the different fractions. If fractions 1 and 2 have masses M_1 and M_2 and can be sorted at rates r_1 and r_2 per 100 g, and 100 g samples produce standard deviations of δ_1 and δ_2 in the counts of a species, the optimal result for that species is produced when the time spent sorting fraction 1 is a proportion

$$\frac{\sqrt{r_1}\,M_1\delta_1}{\sqrt{r_1}\,M_1\delta_1 + \sqrt{r_2}\,M_2\delta_2}$$

of the total time available. This is equivalent to a standard result in sample survey theory called Neyman allocation (see, for example, Cochran 1963:95). As a numerical example, in the case of *Chione* in the stratified sampling described above, M, r, and δ are 16016, 18 and 7.2 for the fine fraction and 5460, 4.8 and 16.5 for the coarse fraction. Here 0.29 or 29% of the time available should be spent on the coarse fraction. This proportion should be unchanged for different sizes of sampling universe, as long as the fractions have the same relative sizes and their contents have the same statistical behaviour as in the example.

The sampling strategy to be applied would also have to be adapted if the quantities of the different species were to be combined–in an estimate of total meat-weight, for example. In that situation the correct approach seems to be to reduce the material in each sample to a meat-weight before deciding the optimal sampling. An important consideration here is that among molluscs the size of the animals will commonly influence the degree to which they will fragment (Hallam 1967, Nichol 1978:116-119). In general, with small animals being more likely to break than large, coarse material will actually contain shells representing a larger proportion of the meat-weight than is reflected in simple counts of shells. Where the need for precision in meat-weight estimates is such that size-frequency distributions of shells are required, stratified sampling will usually be more advantageous than Figure 1 indicates.

Perhaps more important than making all analyses as efficient as possible, however, is that the methods used and the imprecisions involved in analyses should be made explicit. The outcome of an analysis might fall short of expectations, and though it would be unfortunate and disappointing if the expenditure of a hundred or a thousand hours of labour did not produce any apparently useful results, so long as no serious mistakes have been concealed in the procedure no real harm has been done.

The more fragmented shells make it necessary to give consideration to the smaller grades of midden material, and using a fine screen when random sampling or as part of a stratified sampling achieves this. Simple random sampling is also relatively foolproof, and even if the screen used is relatively large a simple description makes clear just what has been done. Unfortunately that is not the case when stratified sampling is used, and an aspect of its application needs to be emphasised: when combining the results of sampling of different fractions it is most important to know the sampling level applied to each. One simple and direct way of doing this was used in the analysis described–the weights of the different fractions were recorded–and we therefore suggest that a reliable platform scale be made a routine part of equipment, both in the field and in the laboratory, when middens are being examined. Bulk samples of whole material can be removed, or, depending on the ease of screening and the usefulness of retaining large quantities of sparse material, preliminary screening can be carried out in the field. In either case the weights of material discarded can be taken, and simple data will allow sensible estimates of the original whole unit to be made. Most important, being able to take samples of whole material or of separate fractions to the laboratory without losing relevant information would enable excavation to proceed without having to call on a great many people in the field.

Coutts (1972) suggests that dealing effectively with a concentrated shell midden would require a group of 37 people, but this seems quite unrealistic. First, most excavations involve much smaller numbers of people in the field at any one time. Secondly, and more important, it violates the principle suggested by Koloseike that forms the basis of the approach adopted here – that the effort to be expended on an analysis should be related to the value of the results. Coutts' approach would immediately commit the excavators to a very major investment of time and expertise, but there is no assurance that the results would justify their efforts, and sufficiently valuable analyses are very hard to find in the literature. By contrast the removal of bulk samples can be carried out by a much smaller number of personnel, and the decision whether or not to perform a detailed analysis can then be made in the laboratory as the outlines of the results come to hand. If it is then decided to proceed, the facilities of the laboratory are also ready to hand, and the detailed sorting does not have to be carried out under generally less satisfactory field conditions.

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