The spatial analysis of axe size and the Scottish axe distribution

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I Introduction

Studies of the British Axe Trade have mainly concentrated on the analysis of variation in the numbers of recorded axes across space; that is, their areal density. In doing so they have made use of a number of spatial models of interaction, borrowed from geographical science, in an attempt to elucidate the nature of the exchange processes which underlie the observed distribution of stone axes. Typically, analyses have involved techniques such as linear regression or surface generalisation.¹

The aim has been to evaluate the form of the relationship between an artefact's areal density and distance from its source, and hence to make inferences about exchange mechanism. Certain reasonable assumptions are also made about the data: principally, that as the distance from a distributive centre increases, the areal density of products from that centre decreases. This 'law', which has been introduced to archaeologists as The Law of Monotonic Decrement,² allows the testing of a variety of hypotheses concerning distribution mechanisms. For example, Renfrew has argued that exceptions to the regular regression relationship predicted by this 'law', and the profile of the regression line itself, may be used to identify the operation of prestige-good, down-the-line, and redistributive exchange.³ Surface generalisations have been used in a similar manner, although these allow the detection of other factors such as regional variation in artefact 'consumption' and the location of secondary distributive centres.⁴ Attempts have also been made to correlate the gradient and exponent of best-fit regressions with particular exchange processes.⁵

However, Hodder has recently thrown doubt on the ability of simple regressions of area density to detect the operation of specific exchange mechanisms.⁶ The failure of such analyses to arrive at anything like a consistent picture of the neolithic axe trade has also highlighted the limitations of these techniques. It seems that to a large extent the problems which have been encountered appear to be inherent in the use of areal density data.

On major disadvantage of the artefact density approach lies in its sensitivity to recovery bias. Distribution patterns reflect qualitative as well as quantitative variation in an artefact's area density. The
The availability and nature of museum collections, the present (and past) activity of archaeologists, the type of land use and state of urban development all vary regionally and exert a strong influence upon the known distribution of an artefact type. These factors can make a nonsense of an analysis if they are not taken into account since they necessarily become incorporated as tacit variables in any subsequent interpretation. Even when such recovery biases are explicitly acknowledged it is difficult to compensate for them, largely because their assessment involves a detailed knowledge of the history of archaeological work and land use patterns at a local and regional scale. Such information is not always available, and frequently constitutes a major research topic in itself. However, even if a qualitative statement were possible, it seems unlikely that this would ever be capable of quantitative expression; hence, the likelihood of constructing transforms to reconstitute a representative artefact distribution from its 'noisy' empirical distribution remains very slight.  

Other problems exist over and above those of distinguishing and evaluating recovery bias. Assuming a situation in which it were possible to observe the total recoverable archaeological population of an artefact, one would still be obliged to ask if the data were suitable for regression analysis. As we have seen, such models are predicted on the assumption that the density of material items declines in a fairly regular manner with increasing distance from their centre of distribution. Yet this will not always be a safe assumption to make with an archaeological dataset. The inverse power functions used to model decay in areal density assume an idealised plain which, under normal conditions, serves as a close approximation to reality when distorting factors are taken into account. Often, however, archaeological cases seriously violate this assumption; in particular, the assumption that population density remains uniform across a study area would seem difficult to justify for many archaeological examples. This can lead to situations where a regression of areal density against distance from source is turned head-over-heels.

For example, a regression curve of Group VI axes for Northern England shows a remarkable rise in axe numbers towards its upper limits owing to very high concentrations of Group VI axes in Lincolnshire; this in turn has been interpreted as evidence for the existence of a redistributive centre for Group VI axes in the Humber area. However, this picture of the axe trade
is almost certainly no more than a product of variation in population
density: population levels in Lincolnshire were probably much higher than
those between Eastern England and the Lake District leading to a situation
where the areal density of axes is actually higher at distances remote
from their source. In such a case the application of a regression model is
equivocal, and possibly quite meaningless.

The problems of using artefact density are, then, considerable, and this is
especially the case where processes such as exchange are being studied. To
a large extent it has been these problems which have limited the study of
exchange patterns in Britain. As a result interpretation of the axe dis-
tribution has been fraught with difficulties, not the least of which is the
ability of present techniques to support at least two opposed views of the
mechanisms and rational underlying axe exchange. Obviously it would be
advantageous if another approach could be discovered which was less
susceptible to recovery bias and capable of providing a complementary
picture. One such alternative is considered here.

II

White & Modjeska have recently drawn attention to facets of the axe trade
in New Guinea which they consider have potential value for an archaeological
understanding of primitive trade networks. One of their observations is
of particular interest: namely, that as the distance from an axe factory
increases, the blades from it tend to decrease in size:

"Variation in blade form may be expected to increase
directly with distance from the quarry of origin ...
the more trading steps away from a quarry, the
fewer, smaller and less finely finished blades become."

This suggests the existence of variables other than areal density which may
vary in a predictable manner with distance from source. If, as White &
Modjeska argue, axe blades necessarily suffer reduction with increasing
distance from their source, then it should be possible to posit an inverse
power relationship between axe blade size and distance that is directly
analogous to that used to model distance-density interactions. Regressions
of axe size (using appropriate indices such as blade length) against distance
from source would then be approximated by the typical decay curve (Fig 1a);
treated in three dimensions this would equate with a conical function (Fig
1b); hence, a generalised surface, centred on a production or distribution
centre, should show a series of concentric contours of increasing diameter (Fig 1c).

It ought to be possible, then, to use spatial decay in axe size much in the manner in which areal density is used. One major reservation is, however, the extent to which White & Modjeska's observations apply to axe exchange in neolithic Britain. Is there any reason to believe that axe size will behave in the manner which they suggest outside the particular context of New Guinea? The answer to this depends on the nature of the mechanisms which lead to reduction in blade size. White & Modjeska outline two breakage and resharpening - the longer the blade is such mechanisms: (a) reduction in blade size through use, in use, the smaller it will become, so that blades reaching areas remote from an axe factory are probably quite small; (b) reduction through differential retention - "... at each [exchange] step it may be expected that the blades most suitable for display (almost universally this will mean the largest) as well as work will be retained". The generality of these mechanisms seems high; they are not obviously tied to any particular cultural context, and seem to require only that axe blades be traded, employed in functional contexts, and selected for display on the criterion of largeness. Some of these conditions can, in fact, be supported from the archaeological record. For instance, evidence of blade usage and resharpening is known both from examples of poorly resharpened blades recovered in areas remote from their origin, and from numerous flakes. Moreover, the use of large blades for non-functional (probably display) purposes is well attested, some blades having been recovered which were clearly far too large for use in woodworking or tree-felling. It seems reasonable, then, to assume that axe size may behave in a manner similar to that outlined for New Guinea.

The advantages of this approach over areal density are important. One of the most important is that axe size is independent of many of the biases discussed above. For example, the lengths of a small number of blades recovered from a given area can be considered as a random sample of the axe lengths of the area unless there is reason to suspect that processes have been at work which will bias preservation or recovery of blades of a particular size range. Hence it should be possible to construct meaningful regression lines and surfaces with fewer cases. Moreover, such a regression should be largely independent of the distributional clusters which normally distort distance-density models, since the number of cases should not directly affect the size range. Gross variations in prehistoric population levels will also be less significant as a source of error.
The aim of this paper is to apply the idea that axe size may be used as an alternative to areal density with reference to one particular dataset. That is, stone axes recovered in Scotland and petrologically assigned to Groups VI (source: Langdale, Westmorland) and IX (source: Tievebulliagh & Rathlin Island, N. Ireland). The analysis presented is part of a larger study of the Scottish axe distribution currently in progress, and no attempt is made to provide a detailed interpretation of the results. Rather it is intended that the study should illustrate some of the advantages and problems of using axe size to explore distribution patterns.

III

The Scottish Axe Distribution is poorly understood. To date, only axes of Groups VI, IX have been sectioned, and the total number of blades which have been identified is small. As a result little qualitative, and no quantitative work has been attempted on distribution patterns^{15} (the material is far too dispersed to allow the use of conventional techniques of spatial analysis).

The datasets used here comprise 'whole' blades from the collections of the Dumfries, Hunterian, Kelvingrove (Glasgow), and National museums petrologically assigned to Groups VI and IX. There are 44 recorded axes for each group. This is not an exhaustive collection - a recent estimate put the number of identified group IX axes at over 60^{16} - but seems to constitute a representative sample.

Linear Regression Analysis

Simple regressions of major axe dimensions (maximum length, breadth and width) were undertaken, and correlation coefficients calculated (Table 1). These were all rather low and negative in the case of Group VI, suggesting a weak relationship between increasing distance from source and reduction in axe size. For Group XI the coefficients were consistently higher, the value for thickness being particularly large. The significance levels cited should be treated with care since the data violate a number of basic assumptions of the statistical test used (for example, Group IX (thickness) is very markedly bi-modal).
Table 1

Regression with distance from source

<table>
<thead>
<tr>
<th>Character</th>
<th>Group VI</th>
<th>Group IX</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td>-0.225</td>
<td>-0.354</td>
</tr>
<tr>
<td></td>
<td>(0.142)</td>
<td>(0.018)</td>
</tr>
<tr>
<td>Breadth</td>
<td>-0.240</td>
<td>-0.285</td>
</tr>
<tr>
<td></td>
<td>(0.116)</td>
<td>(0.061)</td>
</tr>
<tr>
<td>Thickness</td>
<td>-0.174</td>
<td>-0.508</td>
</tr>
<tr>
<td></td>
<td>(0.258)</td>
<td>(0.000)</td>
</tr>
</tbody>
</table>

Trend Surface Analysis

Trend-surface analysis is a means of generalising trends in data by fitting a polynomial function. In the case of artefact distributions this leads to a contoured surface which shows how a variable behaves across space. The aim here was to explore how various axe dimensions change across the study area.

Trend surfaces of up to fifth order were calculated for blade length for both groups, and the best 'fits' selected (Figs 3 & 4). The best-fit surface for thickness for Group XI was also calculated (Fig 5). In all cases the surfaces show a decline in axe size with increasing distance from source. The correlation coefficients obtained were much higher than those observed for the simple linear regressions, and suggest that the trend-surfaces represent good approximations to the original data. Significance levels are not given since their value is questionable when data of this nature is being modelled.

Discussion

The disparity between the simple regression coefficients and those for the trend surfaces deserves attention, since it is not immediately apparent why this difference should occur. Examination of the trend surfaces for axe length shows that spatial variation in axe length is complex for both groups,
and is not directly related to radial distance from source. In the case of Group VI, for example, axe length varies markedly along the Dumfries-Kirkcudbright-Whithorn coast. However, in terms of absolute distance from source this variation becomes indistinguishable since all cases along the coastline are at similar distances, hence blades of widely different sizes are placed together in adjacent distance bands. The low correlation coefficients obtained for the regression curves thus appears to be related to the limitations of simple regressions: variation is lumped together along an axis which does not necessarily reflect distance from source except where this equates with radial measurements.

The trend surfaces of blade length produced interesting results for both axe groups. As expected, Group IX blades decrease in length as they move East and North-east across Scotland, and hence away from their source in Northern Ireland. However, the pattern of variation is by no means simple. The contours curve steeply Northwards as they reach the West Coast implying that the decrease in axe length North along the West Coast of Scotland is less marked than that across the mainland. This might be expected since blades can be traded relatively more easily along the coastal and sea routes of the West; exchange steps are also likely to be larger. There is little evidence of decrease in axe length South-east across Aberdeenshire, as might be expected if Group IX were reaching East Scotland by way of the Great Glen. This suggests that most blades were making their way overland from the Clyde Coast, and immediately adjacent areas.

The pattern for Group VI is rather confusing. Axe length increases towards the West, the Whithorn peninsula and East into Dumfriesshire, while axes in the centre of the coastlands are smaller; overall axe length decreases as one moves Northwards from all three areas. The decline in blade size North-west from the border with England is as expected; since this is the obvious overland route from the Lake District, and blades should become smaller as they move away from this area through exchange networks. The cluster of high values on the Whithorn peninsula is, however, unexpected. These may represent direct imports into the area by sea, and certainly require further investigation. Overall the trend surfaces shows the predicted decline, with the contours centring on two areas. This might be interpreted as implying that axes were reaching South-west Scotland by two routes: overland and by sea. However, examination of residuals suggests that the decrease in axe length Eastwards along the coast is more marked than the surface allows;
this may be the result of the high values for length on the Whithorn peninsula. Reduction in blades length might perhaps, then, be explained in terms of overland exchange with an anomalous set of values around Whithorn; but at best the surface is ambiguous and requires further investigation.

The trend-surface for Group IX, thickness, seems to support the trends observed for length. It is obvious here, however, that while thickness decreases rapidly across West Scotland there is a marked hiatus in its decline across the Eastern Plain. Referring back to the trend-surface for length, it is possible to see that a similar situation exists there, although in this case the trend is less pronounced. The size of Group IX axes thus appears to decline with distance from source, but there is reason to suspect some uniformity of thickness and length over Aberdeenshire and surrounding counties. Studies of axe morphology confirm this and show that axes in East Scotland are not merely reduced versions of West Coast blades but have been considerably modified. Unfortunately there is not sufficient space here to expand upon this.

IV

Overall the surfaces behave very much as expected; they confirm the idea that axe size decreases with increasing distance from source. They also highlight the fact that distance depends very much on topography and transportation potentials: blade size decreases faster overland than along coastal routes, and such decrease need not relate directly to absolute distance from source. Hence, the use of linear regression curves can produce misleading results, as was the case here. There are also obvious problems with the surfaces. For instance, they are not as independent of irregularities in the data as might be hoped: the trend-surface for axe length of Group VI axes appears to be distorted by a cluster of high values. Moreover, surfaces expressing variation in axe size are not as easy to interpret as simple areal regressions, and the meaning of the regression function terms in terms of exchange processes is problematic. Nevertheless, these trend-surfaces do allow statements to be made about the direction of exchange, and hold the possibility of detecting redistributive centres and exceptions to expected trends. They also appear to be capable of dealing with distributions which cannot be analysed using conventional areal density measures. For example, the distribution of Group IX axes actually increases to a maximum in Eastern Scotland; hence a regression of areal density would
be quite meaningless. Trend-surfaces of axe length and thickness both show a decline in blade size away from the known source in Northern Ireland, and seem unaffected by such irregularities, or the highly dispersed nature of the distribution.

The aim of this paper has been to advocate the exploration of the neolithic axe distribution in terms other than areal density. It has been shown that spatial analysis of variations in blade size constitutes one possible alternative, and that this approach may be used to make statements about exchange patterns from distributions which cannot be studied using conventional regression models. As such, the spatial analysis of axe size constitutes an important complementary and comparative technique for the study of the neolithic axe trade.

Acknowledgements

I would like to acknowledge my debt to the Curators and staff of the Dumfries Museum, Dumfries, the Hunterian Museum in the University of Glasgow, the Kelvingrove Museum & Art Galleries, Glasgow, and the National Museum of Antiquities of Scotland, Edinburgh, for their kind help and cooperation during the preparation of this paper.

Notes


13. examples from East Anglia: see Clough & Green 1972.
14. a number of examples from Scotland are of upwards of 250 mm in length.
Text for Figures

Figure 1: (a) regression of size with distance
(b) representation of regression function as surface
(c) contour map of regression surface

Figure 2: Distribution of axes of Groups VI and IX
    circles - Group IX; triangles - Group VI

Figure 3: Trend-surface of blade length for Group VI
    Contour values are in mm \( r = 0.728 \)
    triangles - positive residuals;
    open triangles - negative residuals

Figure 4: Trend-surface of blade length for Group IX
    Contour values are in mm \( r = 0.529 \)

Figure 5: Trend-surface of blade thickness for Group XI
    Contour values are in mm \( r = 0.685 \)

References


