RELIABLE AND MAINTAINABLE TECHNOLOGIES: ARTIFACT STANDARDIZATION AND THE EARLY TO LATER MESOLITHIC TRANSITION IN NORTHERN ENGLAND

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ABSTRACT

Interpreting and explaining numerical variance in artifact assemblages has not played an important role in lithic analysis. As shown, this measure has much to offer in understanding prehistoric behavior. Variance in microlith assemblages is examined to test Myers' (1986, 1989b) model of changing hunting strategies across the Early-to-Later Mesolithic transition. It is shown that Early Mesolithic microliths are highly standardized relative to analogous items from the Later Mesolithic. This finding is related to weapons design systems and the embeddedness of microliths within seasonal activities. It is argued that Early Mesolithic microliths were produced in large numbers ahead of time within a reliable weapons system focused on intercept hunting, while Later Mesolithic microliths were produced in smaller batches, as needed, within a maintainable system optimized for encounter-based hunting.

INTRODUCTION

Poor organic preservation in early Holocene sediments throughout much of northern England ensures that, if archaeologists are to advance understanding of the Mesolithic in this region, then lithic studies must lead the way. Collecting new stone tool assemblages through additional survey and excavation will go far towards this end; however, as the following examination testifies, enough materials are already curated in museums to begin this process. Combined with methodological and theoretical advances in lithic studies, the analysis of these collections over a broad range of spatial, social, and temporal scales promises to be a fruitful avenue for expanding our knowledge of prehistoric behavior.

The present inquiry takes a small step in this direction. Microlith collections from northern England were analyzed to test a specific model that has been proposed for Mesolithic hunting patterns. The study examines metrical variability within and between collections, rather than a more traditional comparison of means or diversity. Despite its relevance to cultural evolution and other theories of culture change, variance or within type variability has received little direct attention in the archaeological literature. Few analyses have focused on comparing and explaining differences in variance between stone tool assemblages. Yet, as shown, theory exists to link behavioral systems and the role lithics play within these systems to measures of variance (in addition to more traditional studies of diversity and means). These ideas are employed to derive predictions for variance in artifact assemblages under alternative toolkit design and hunting strategies.

RELIABLE VS. MAINTAINABLE TECHNOLOGIES: EXPECTATIONS FOR ARTIFACT VARIABILITY

In an important paper discussing the design of technical systems, Peter Bleed (1986) contrasted maintainable and reliable manufacturing strategies. These two design strategies serve to optimize

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tools to their environment. Of course, reliability and maintainability are positive attributes, and any rational manufacturer should seek to maximize both. However, physical and cultural limitations may preclude this goal, and designers may have to sacrifice potential gains along one axis for advantages along the other. In other words, reliability and maintainability are not mutually exclusive (Bleed 1986; Meyers 1989b; Torrence 1989), and technical systems *can* be designed with elements of both. In practice, though, systems often display tendencies towards one or the other.

Bleed (1986) has argued that reliable systems are adaptive in environments where tools are only needed for short periods of time and the cost of failure is high, that is, under conditions of time stress. Similarly, Torrence (1989) has argued that reliable systems are advantageous in situations in which the severity of the risk is high. For this reason, they are typically overdesigned (i.e., made stronger or sharper than necessary), carefully crafted, and produced in large numbers. Tools are made well before they are needed, that is, out of phase or during down-time (sensu Binford 1980), under rigid design constraints, and with little time for repair or manufacture when the system is in use. Because the cost of failure is severe, experimentation with new technical systems is kept to a minimum; the risks are simply not worth the potential gains. Manufacturers know what works and tend to stick with these systems once they are in place. Thus, although they may sacrifice potential gains over the long term, manufacturers trade this for stability and reduced risk over the short term (see Stephens and Charnov 1982 or Jochim 1981 for similar arguments with respect to foraging patterns and risk). A reliable system is employed because it is precisely that; despite potential decreased performance, it gets the job done when the stakes are high.

These arguments have clear implications for variance in tools made under such conditions. Artifacts ought to be conservative and display relatively little internal variability. When in use, a reliable system should be carefully copied with little deviation or experimentation. These constraints create a situation in which particular shapes that are known to be successful are heavily selected for, in what has elsewhere been called "strong functional selection" (Eerkens and Bettinger 1996). Producing artifacts in large quantities during "gearing-up" phases allows craftsmen to gauge workmanship and select only those pieces known to be of the correct size and shape, further limiting internal variance (see Clark 1987 and Hayden and Gargett 1989 for a discussion of reducing variability through mass production).

Maintainable systems, on the other hand, are adaptive in unpredictable environments where the cost of failure is less and tools are needed throughout the year, that is, with little down-time (Bleed 1986). Repair and maintenance activities can be scheduled with greater flexibility, but are also more frequent and evenly spaced. As Torrence (1989) has noted, maintainable systems seek to extend the use-life of continuously needed tools by making them more serviceable or repairable, rather than replacing items, as is more typical of reliable systems. Because the severity of failure is less, failure to perform over the short term is more acceptable, provided that long-term performance remains high. That is, such systems are accepting of increased short-term variability in exchange for long-term increased performance. This difference makes experimentation more advantageous.

Components of maintainable tools are easily removed and repaired or replaced at the owner's convenience, i.e., whenever the tool is not in use. Because of this, components are likely to be made a small number at a time, as they are needed to fix the tool. Due to unpredictable patterns in breakage, components may even be made from different raw materials, depending on where the manufacturer is and what is available at the time of repair. Together, increased experimentation, the smaller number of components made per sitting, and increased variability in the location and timing of manufacturing activities, suggest higher variance for artifacts made within maintainable systems.

HUNTING STRATEGIES AND THE EARLY-TO-LATER MESOLITHIC TRANSITION

In a number of works Andrew Myers has examined the nature of the Early-to-Later Mesolithic transition in England (Myers 1986, 1987, 1989a, 1989b). Based on his analysis of lithic collections, he argued that there are significant differences in how tool kits were designed, organized, produced, and maintained between the two periods. He felt that Early Mesolithic hunters were heavily involved in, and dependent, on intercept hunting of large migrating herds of red deer (*Cervus elaphus*). Based on environmental conditions thought to be present during the Early Mesolithic (8000 to 6800 bc), he argued that large populations of red deer would have aggregated in the English uplands during the autumn, providing people with ample meat they could store for consumption during more scarce winter months. Early Mesolithic tool kits, as a result, were designed to take advantage of this dense and predictable resource. Hunters prepared plenty of their obliquely blunted microliths ahead of the hunt, thereby maximizing hunting time and minimizing manufacturing and/or repairing activities during this event. Failure to perform during the critical window in which red deer were available would have spelled disaster, quite possibly starvation, during winter months. As a result, Early Mesolithic tools were designed to maximize reliability.

The end of the Early Mesolithic witnessed a shift from a relatively open birch and pine forest to a closed oak-dominated deciduous woodland with a dense understory (Jacobi et al. 1976; Spratt and Simmons 1976; Jacobi 1978; Simmons and Innes 1987). Myers argued that red deer would no longer have been available in large numbers during their predictable autumnal migration. Consequently, Later Mesolithic (ca. 6800 - 3500 bc) groups would have had to turn to an encounter-based hunting strategy, in which hunters would take animals individually as they were encountered on the landscape. This strategy allowed the hunter to schedule tool manufacture and repair duties more flexibly, that is, whenever it was convenient, a time not necessarily dictated by the seasons. Tools still had to be efficient, but the time frame in which they were needed was much longer (i.e., not focused on a small window of time). As a result, Later Mesolithic tool kits were still designed with some degree of reliability, but were particularly focused on maximizing maintainability. Myers (1989a, 1989b) saw evidence for this through the introduction of multi-component tools with small geometric microliths serving as barbs on the side of an arrow foreshaft. The shape of these Later Mesolithic microliths was dependent only on retouch, rather than the shape of the flake blank, as is true of Early Mesolithic microliths. As such, small and simple geometric barbs that were broken could be quickly replaced by freshly knapped items. In other words, the tool was easily maintained. Examples of Early and Later Mesolithic microliths from the site of Howe Hill are presented in Figures 1 and 2 for comparison.

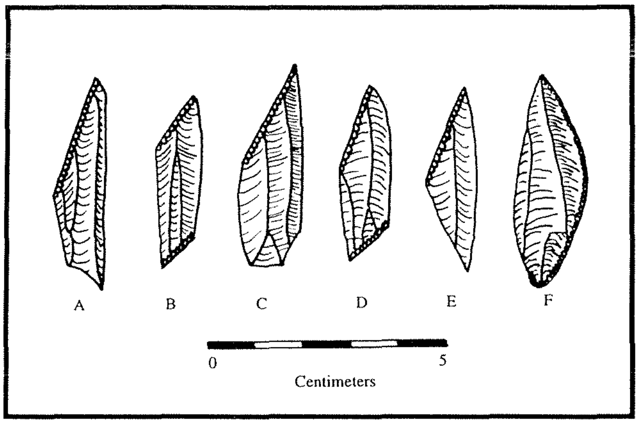

Figure 1. Early Mesolithic microliths from Howe Hill

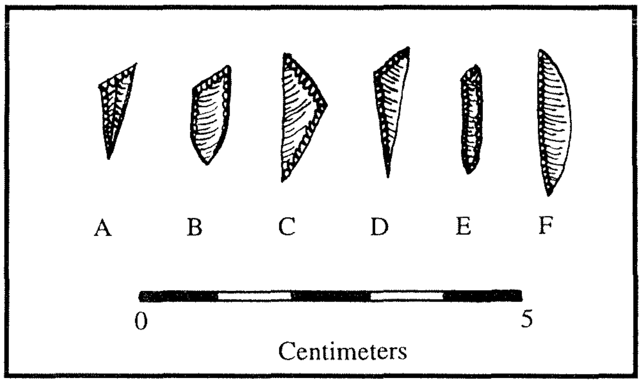

Figure 2. Later Mesolithic microliths from Howe Hill.

If Myers' model is correct, it ought to have visible effects on variance in microlith collections. Applying the conclusions reached in the previous section, we would expect Early Mesolithic microliths to be relatively standardized and less diverse than Later Mesolithic forms. This hypothesis is tested below.

ASSUMPTIONS

Before examining patterns in microlith data, several assumptions of this study must be stated. First is the assumption that microliths are representative of hunting behavior. While some have questioned this assumption based on ethnographic comparisons (Clarke 1976) and microwear studies (Dumont 1987, 1989; Findlayson 1990), most archaeologists studying the Mesolithic still interpret microliths as cutting or slicing implements hafted on the side, as barbs, or on the end, as a projectile tip, of a bone or antler shaft (Jacobi 1980: 175; Fischer et al. 1984; Myers 1986, 1987: 144). The question here is not whether microliths were used in multiple tasks as the microwear studies suggest. Indeed, it would be surprising if they were not used as makeshift tools for different cutting and scraping activities as such needs arose. Instead, it is a question of whether or not they served most often as hunting implements and were made with this primary function in mind. The finding of an arrow with hafted microliths, one at the tip and one on the side, at the Mesolithic site Loshult in Denmark (see Anderson 1979: 206 for an English description) demonstrates that at least some microliths were used with bow-and-arrow hunting technology. Furthermore, microwear and breakage pattern studies suggest that many microliths were used in such a capacity. Until more microwear and functional studies are performed with English microliths across a broad range of sites and microlith types, I assume here that these items were most often associated with hunting activities. Having made this assumption, it is expected that changes in hunting patterns had a bearing on changes in variance in microliths. Of course, hunting is embedded within a larger social system, and an attempt will also be made to assess how other factors may influence variance as well.

A second assumption is that the predictions made above are based on a theory concerning how people made microliths, while the archaeological record represents the refuse left behind after people have discarded them. Thus, microliths in sites often represent spent, broken, or otherwise unusable parts, and less often primary production. However, several factors diminish the role that use-alteration may play in obscuring patterns in metrical variance. First, the same sorts of arguments can be made about artifacts going into a weapons system as those dropping out. That is, if reliable systems, as Bleed (1986) has described them, require precisely made components to function, these components are likely to become unusable with little variance, as well. Provided that raw materials are available to replace altered components, people are likely to be as intolerable of variance at the time of production as they will be of variance during use. Thus, tools are likely to be discarded with the same attention to detail as they were made. Second, microliths are small and relatively uncomplicated, and making new ones may be more time-effective than resharpening or repairing used ones, limiting the role resharpening plays in obscuring original production patterns in variance. Finally, some microlith attributes such as thickness, direction of striking surface, and lateralization (defined below) are not sensitive to use and/or repair alteration, and will remain unchanged from the time of production to discard. In fact, there is little difference in average measurements between microlith hoards (a.k.a., groups), purportedly representing microliths lost during use, and microliths recovered from general site contexts, which most likely represent discarded items (Eerkens 1996b; see below for a discussion of hoards and sites). This suggests that microliths do not change much between production and discard. In sum, discard behavior and use alteration, although factors to consider, are not likely to significantly affect the predictions made with respect to variance.

DATA COLLECTED

To test these hypotheses, microliths from several Early and Later Mesolithic collections located in various museums across England were measured for variance. Obliquely blunted microliths dating to the Early Mesolithic were measured from 6 sites in northwestern England: Willoughton (18), Lackford Heath (26, excavated sample only), Risby Warren (21), Howe Hill (18), Seamer Carr K (7), and Brigham (15). These collections were compared against small scalene triangles, Later Mesolithic-type artifacts from this region, including March Hill (33), Howe Hill (25), Prestatyn (45), Roxby-cum-Risby (11), Manton Common (4), Broomhead 5 (18), Dunford A (15), Heathfield Moor (6), Kettlestang (7), Glaisdale Moor 1 (14), Glaisdale Moor 3 (29), and Glaisdale Moor 4 (13).

Figure 3 shows the geographic location of sites included. These sites represent a diversity of environmental locations (upland and lowland) and collection strategies (excavation and surface collection). Only collections with some degree of spatial control were selected for inclusion, that is, where location was established to within several hundred meters. Of course, any museum-based analysis is ultimately limited by what is available, and a random or stratified sample is nearly impossible to put together. However, the sample of sites does not appear to be heavily biased towards any

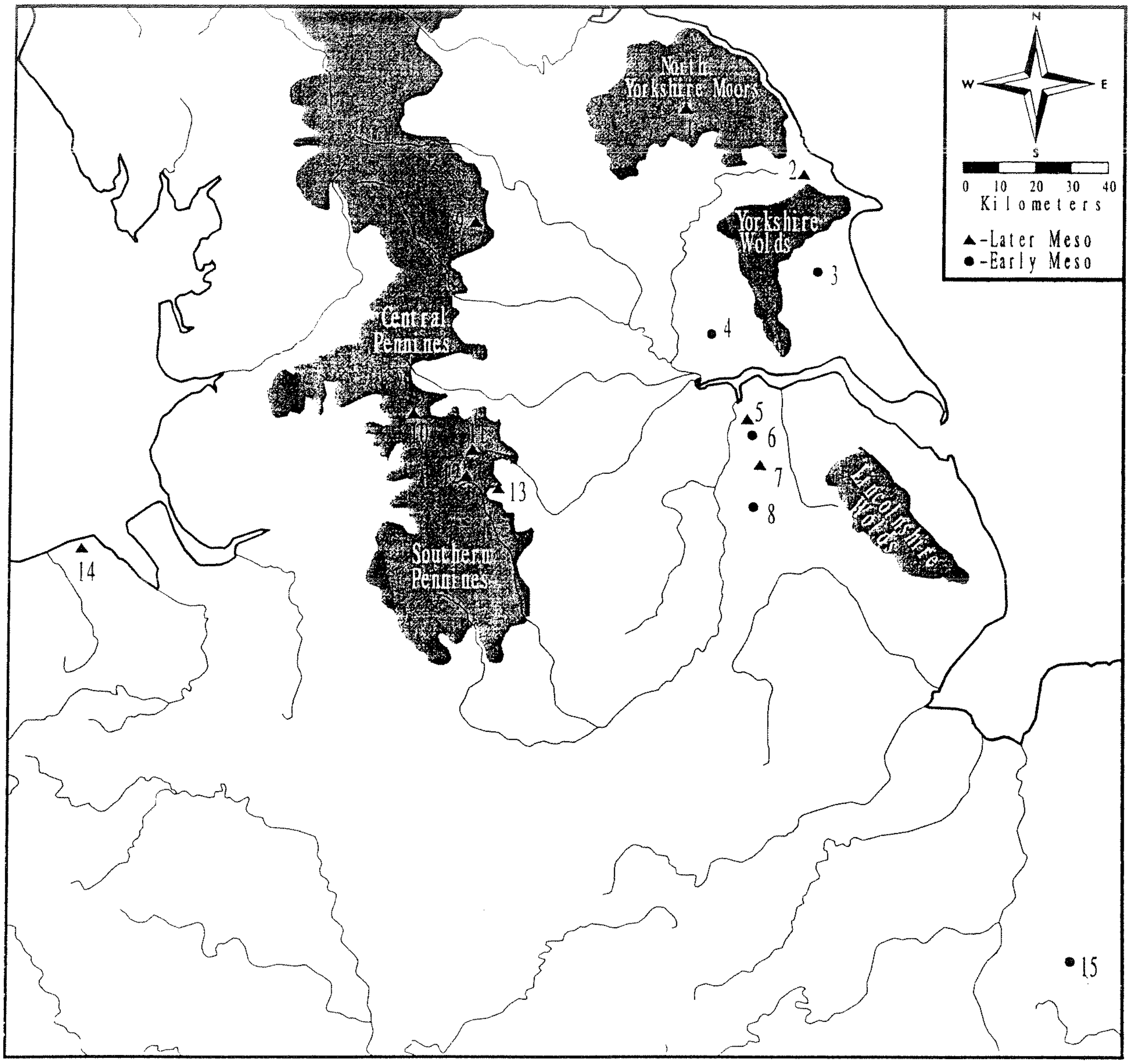

Figure 3. Distribution of sites studied: 1. Glaisdale Moor, 2. Seamer Carr, 3. Brigham, 4. Howe Hill, 5. Roxbycum-Risby, 6. Risby Warten, 7. Manton Common, 8. Willoughton, 9. Kettlestang, 10. March Hill, 11. Heathfield Moor, 12. Dunford A, 13. Broomhead 5, 14. Prestatyn, 15. Lackford Heath.

particular environmental setting, site type, or collection method.

Only microliths complete enough to be confidently typed to either obliquely blunted point or scalene triangle were included in the analysis. A number of attributes were measured on each microlith, including length, width, thickness, and length of retouch along the leading edge -- all continuous and taken to the nearest tenth of a millimeter. In addition, two categorical attributes were measured (see Figure 4): the direction of bulb or striking surface (proximal or distal) and lateralization (left or right). When the piece is laid ventral surface down, the latter measurement signifies whether the leading/oblique (i.e., distal) edge slopes down to the left (e.g., Figure 2a) or right (e.g., Figure 2c).

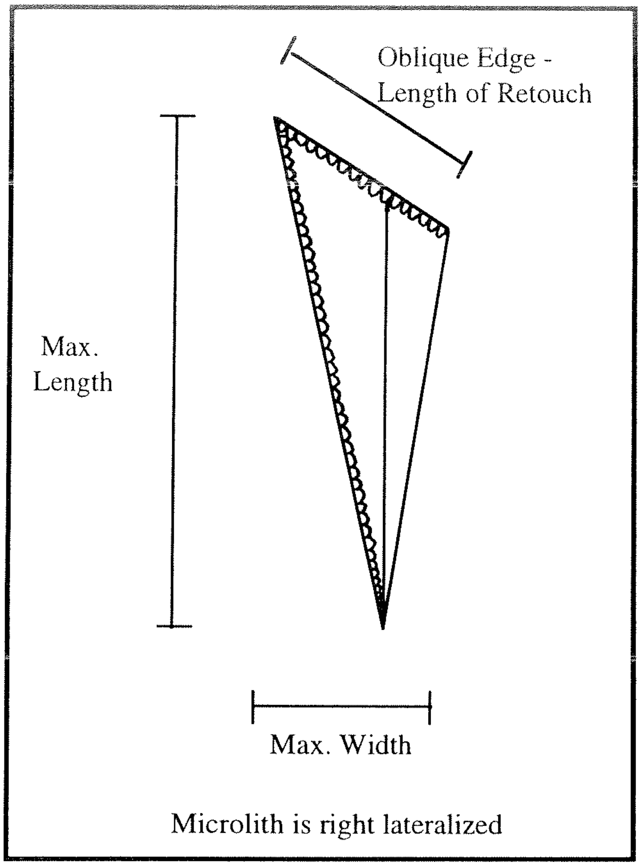

Figure 4. Attributes measured

RESULTS

Results are given in Table 1, which presents average Coefficient of Variation (CV) for continuous variables and average Index of Qualitative Variation (IQV) value for categorical attributes (see Loether and McTavish 1974: 151; values averaged across sites). Unlike standard deviation and other measures of dispersion, CV and IQV allow comparison across attributes of different magnitude, because measurements are standardized to a common scale (Eerkens 1996b). The CV standardizes measures of variance by the mean, while the IQV places values on a scale from 0, for complete homogeneity, to 1, for perfect heterogeneity. Tests of homogeneity of variance (i.e., F-test, Hartley's F-max, Bartlett, Brown-Forsythe, etc.) are not appropriate for comparing variance in obliquely blunted and scalene triangular microliths because of the great difference in mean size. Elsewhere (Bettinger and Eerkens 1997) it has been shown that variance in stone tools is often scaled to the mean, a relationship that holds for Mesolithic microliths as well (Eerkens 1996a). For this reason, CV is the most appropriate statistic for comparison of the continuous attributes.

To put the values into a broader context, variance measurements for hoards, or clusters/groups of microliths isolated from other artifactual material (versus those found simply within sites), are also given. Hoards are generally believed to have come from a single composite tool (Jacobi 1978; Myers 1989b) and probably represent the work of a single individual over a short period of time; therefore, in relation to other microlithic assemblages, they should be highly standardized (Eerkens 1996b). Unfortunately, there are no hoards from Early Mesolithic contexts, so comparisons between hoards from the two periods was not possible. Pieces from sites, on the other hand, probably represent the work of many individuals over a longer period of time, especially if sites are frequently reoccupied. Not surprisingly, microliths from general site contexts display higher variance than those from hoards or goroups.

As Table 1 shows, Early Mesolithic microliths are quite standardized. With the exception of "oblique edge-length of retouch," all measurements are equal to, or less variable than, analogous attributes on later microliths. For example, length and thickness are 44% more variable, and width 17% more variable, in later site assemblages. That length is equal to, and that thickness and bulbar position are less variable than, similar measurements on Later Mesolithic *hoards* is somewhat surprising, given the presumed scale of production (several people vs. one person), and attests to the standardization of Early Mesolithic microliths.

In particular, uniformity in thickness, which is not alterable through retouch once a blade has been struck, suggests that carefully prepared cores were used to consistently produce blades of the desired shape and size in the Early Mesolithic. In order to reduce variance, blades may have been produced in large numbers during extended blade-producing sessions (see Clark 1987). This result is consistent with that of Pitts and Jacobi (1979), who found Early Mesolithic debitage to be more regular and standardized than Later Mesolithic waste flakes. Standardized reduction techniques would have allowed knappers to produce predict-

TABLE 1. Average Coefficient of Variation (CV) and Index of Qualitative Variation (IQV) values for Early and Later Mesolithic sites and Later Mesolithc groups.

Measurement	Early Sites	Later Sites	Later Hoards
Maximum Lenght (CV)	.16	.23	.16
Maximum Width (CV)	.18	.21	.12
Max. Thickness (CV)	.18	.26	.24
Oblique Edge-Length of Retouch (CV)	.26	.23	.15
Lateralization (IQV)	.45	.45	.10
Bulbar Position (IQV)	.64	.83	.84

able blanks facilitating the manufacture of standardized, hence reliable, tools. This reasoning may also explain the standardization seen in length and width. Experimentation with stone-tipped projectiles has shown that these two measurements are crucial to the penetration of points into intended kills (Odell and Cowan 1986). Finding a successful length-to-width combination, and then standardizing these measurements and others within the manufacturing process, is consistent with a reliable hunting technology.

Why the oblique edge variable does not conform to this pattern is unclear, but part of the reason may have to do with how this attribute is shaped and measured. Oblique edge, or more accurately, length of retouch along the leading edge, describes retouch that often continues down the entire left or right side on Early Mesolithic microliths, forming a leaf-shaped artifact (as in Figure 1f). Other times, retouch terminates at the natural flake edge, forming a scalene triangular (Figure 1e) or trapezoidal shape (Figure 1b). It may be that these different shapes represent distinct functional or typological forms, as some have suggested (Radley and Mellars 1964), although they have been combined into a single analytical category here. However, if microliths were used as projectile tips, length of retouch is probably less important to overall function than attributes such as length, width, and thickness, a fact which may account for the high variance within the former. In fact, length of retouch may relate to the alteration of lengths and widths of freshly struck blades that did not conform to the hunter's notion of an ideal (and reliable) microlith shape. In other words, it may be a by-product of the need to reduce variance in blade production, i.e., to standardize length and width among finished tools.

Most early microliths were left-lateralized (86% overall), with a fair degree of standardization within sites, as evidenced by the low average IQV. This value is similar to that of microliths from Later Mesolithic sites, but is in marked contrast to microlith hoards; here most (88%) are left-lateralized, but right-lateralized forms come in bunches (i.e., are spatially correlated). In other words, the overall distribution is similar. Both early and later sites have predominantly left-lateralized, with a few right-lateralized, pieces. On the other hand, Later Mesolithic hoards have either predominantly right- or predominantly left-lateralized items. Indeed, within the 13 hoards analyzed, two account for 18 of the 19 right-lateralized pieces.

Early microliths also show a clear trend towards vertical orientation, as seen by a relatively low average IQV value for the attribute bulbar position. Approximately 2/3 (64%) of the pieces for which this attribute could be determined were struck from a platform originating towards the distal end. Often the bulb had been removed using the microburin technique, although this was not always the case (i.e., occasionally the bulb was still present). By contrast, IQV values approach 1 for Later Mesolithic microliths, indicating near-perfect heterogeneity within these collections and little concern for consistent vertical orientation in both site and hoard contexts. This may be a result of the quantity of microliths that were made in a particular sitting. Where Early

Mesolithic knappers got into a rhythm and produced large quantities of standardized blades, all oriented in the same direction prior to retouch, during a single sitting, Later Mesolithic knappers may have made microliths a smaller number at a time, and hence oriented items differently between flintknapping sessions. Alternatively, the location of bulb and distal end may have offered some slight functional advantage, and early knappers may have standardized the reduction process to locate the bulb towards one side or the other in order to increase the reliability of their tools.

In sum, the process of microlith manufacture during the Early Mesolithic seems to have produced more highly standardized shapes than those of the Later Mesolithic. In addition, flintknappers seem to have paid attention to how flakes were oriented prior to manufacture, both vertically and laterally, although there was some room for variation. This standardization is consistent with the notion that Early Mesolithic hunters were "gearing up" by producing reliable and standardized tool kits for use in a time-stressed annual hunt. These findings support Myers' model of intercept hunting during the Early Mesolithic and encounter-based hunting during the Later Mesolithic.

DISCUSSION

I have argued that changes in variance in Mesolithic microliths are largely a product of changes in the timing and technique of flintknapping, which in turn were due to changes in hunting strategies. However, variance in lithic tool kits is affected by a number of natural and cultural factors, including raw material properties, raw material availability, the number of flintknappers responsible for a collection, post-depositional changes, motor coordination of the flintknapper, knapping technology, intended function, and stylistic properties. Therefore, before concluding that weapons design systems and hunting strategies are the prime agents contributing to the patterns observed, it is important to consider the potential role of these other factors.

There are significant differences in the sources of raw materials exploited during the Early and Later Mesolithic (Radley and Marshall 1963; Raistrick 1963; Radley 1968; Myers 1987), with some arguing that materials exploited during the Early Mesolithic are superior in quality. While the workability of different raw materials has not been well studied, it is possible that this factor could have influenced microlith variance, causing early microliths of high quality material to be less variable than later microliths. However, observation of later microliths does not indicate that the material is of such poor quality that it would drastically affect the ability to control shape and, hence, increase variance. In addition, the ability of knappers to produce quite standardized *hoards* of microliths of these "poor" materials also argues against this point. Materials used in the Later Mesolithic are not coarse and unworkable. They are still fine-grained cherts and flints that can be shaped with perhaps a little more effort than the slightly higher quality materials used in the Early Mesolithic. In short, this explanation is unlikely to account for the patterns observed.

Changes in mobility may affect lithic acquisition and curation patterns, which in turn have implications for measures of variance. Restricted mobility, as in the case of social circumscription, may reduce access to raw material, necessitating economization and standardization in lithic toolkits (Binford 1979; Bamforth 1986; Henry 1989; Lurie 1989; Odell 1996; Thacker 1996). Thus, it may be that Early Mesolithic peoples were relatively restricted in their seasonal movements, had only limited access to raw materials, and had to conserve their materials, leading to lower variance in their stone tools. However, most research suggests that increased population (Smith 1992), decreased mobility (Schadla-Hall 1988), and decreased access to raw materials (Pitts and Jacobi 1979) over time, not the reverse, provide better explanations of the patterns observed.

Because of small errors in the production sequence and slight idiosyncratic differences in how people make tools, it is expected that larger numbers of people contributing to a pool of artifacts will tend to increase the amount of variance within that set. Unfortunately, the number of flintknappers responsible for a set of artifacts cannot be readily or accurately reconstructed. Thus it is possible that larger numbers of flintknappers may have camped at Later Mesolithic sites, either synchronously or over time through reoccupation of the same location and, because of differences in how they made microliths, increased levels of variance within these sites.

Of note here, however, is the trend towards smaller and less dense sites in the Later Mesolithic (Mellars 1976; Jacobi 1978). If fewer people occupied less space and produced fewer artifacts, then later sites may represent fewer people, and hence artifacts therein should contain less variance than early sites. Again, this is the opposite of the pattern observed. Although total population apparently increased, as indicated by the number and spatial distribution of sites, Later Mesolithic populations appear to have been more dispersed, with each site representing a smaller local group. Thus, if there is a difference, microliths from Later Mesolithic sites, on average, are likely to represent the work of fewer, rather than more, manufacturers.

Post-depositional changes and differences in motor coordination are two explanations that can also be readily dismissed. Other than breakage, which is clearly visible and was noted, and slight microwear alteration (Levi-Sala 1986, 1992), stone tools are unlikely to dramatically change once they are in the ground. Similarly, there is no reason to believe that earlier knappers were any more or less coordinated than later ones.

Changes in stylistic use of microliths can probably also be dismissed, as few studies have shown style to be an important factor within microlith collections in England (Reynier 1994) or further abroad (Gendel 1984; Blankholm 1990). No readily recognizable spatial differences in either shape or size have been noted in microlith collections across England, much less within the smaller section of northern England considered here. Moreover, it is unlikely that small projectile tips or insets carried much stylistic information; there simply is not much room for the input of such information. A more likely arena for stylistic loading is in the decoration of the wooden, bone, or antler foreshaft, into which microliths were set (e.g., Sinopoli 1991).

Differences in intended function can also be an important factor in contributing to artifact variance. Few studies have compared earlier and later microliths to ascertain whether they were used for different purposes. Microwear analyses in England and Scotland (e.g., Dumont 1987, 1989; Findlayson 1990; Levi-Sala 1992) have focused on reconstructing function at particular sites, and have not systematically compared microliths across large regions or blocks of time. More research is needed, at both the experimental (i.e., comparing projectile tips and side barbs with different hunting techniques) and analytical (i.e., comparing actual microliths) stages, to determine whether consistent functional differences exist between Early and Later Mesolithic microliths.

The argument supported here does argue for a change in the function, or more properly the context of function, of microliths. Earlier microliths were made with the intent of being reliable, while later ones were intended to be part of maintainable tool kits. This argument, based largely on independent evidence for changes in environment (Myers 1986, 1989a, 1989b) and theories on stone tool use (Bleed 1986), is consistent with the changes observed in microlith variance.

CONCLUSIONS

The results obtained in this study are slightly at odds with some previous impressions of microlithic collections. Later Mesolithic microliths have been described as having a "clear concern for standardization" (Myers 1989b: 84), yet it has been shown that they are clearly, on average, less standardized than their Early Mesolithic counterparts. While the results presented do not necessarily prove or disprove Myers' model of changing hunting strategies, they clearly support his hypothesis. In light of the failure of other factors to account for the observed changes in variance, the results are interpreted here as supporting a change from intercept-based hunting and a reliable weapons system in the Early Mesolithic to encounter-based hunting with a more maintainable system in the Later Mesolithic. Changes in the timing and organization of manufacturing and repairing activities may have preempted the shift from a reliable focused technology to a more maintainable one. Instead of weapons being needed seasonally, as during the Early Mesolithic, Later Mesolithic tools were needed year-round. A desire to increase the use-life of tools created a demand for tools more easily repaired and serviced. Similarly, changes in the severity of the risk of failure may have encouraged experimentation with microliths and the weapons technology, a deviation from the reliable, but perhaps less efficient, hunting technology of the Early Mesolithic.

The results obtained concur with research elsewhere in the European Mesolithic. For example, Zvelebil (1984, 1986) and Hayden and

Gargett (1988) have suggested that mainland European hunting technologies were more standardized and specialized during the Paleolithic and Early Mesolithic than later. Zvelebil (1986) also suggested that Late Mesolithic toolkits may have been designed with some degree of maintainability in mind. Similarly, Mithen (1990: 190) has suggested that, due to prevailing climatic and social conditions, Late Mesolithic foragers may have experimented more with their hunting technologies, a clear step away from a conservative and reliable design strategy.

As has been shown, understanding how people design their weapons systems can be informative of how people suit material culture to fit the natural and social environment. As such, it is intimately related to a number of concepts lithic analysts frequently discuss and try to reconstruct, such as curation vs. expediency (e.g., Gramly 1980; Bamforth 1986; Nash 1996; Odell 1996; Thacker 1996), mobility (e.g., Shott 1986; Parry and Kelly 1987; Basgall 1989; Henry 1989; Lurie 1989), and technological systems (e.g., Kelly 1988; Myers 1989b). It is hoped that this study has challenged analysts to begin interpreting numerical variability in artifact collections, that is, to begin asking why certain artifact types, attributes, or spatial clustering of artifacts (or any other subset of measurements) are more or less variable than others.

Analysis of variance provides an interesting and relatively unstudied direction for lithic analysts to test hypotheses and models of prehistoric behavior. Because evolutionary processes act upon and contribute to variance, much of neo-Darwinian theory, a rapidly growing arena for understanding material culture and prehistoric behavior, has direct and clear implications for measures of this easily computed attribute. This study has shown that potentially interesting patterns of variance may exist in artifact types, and that such studies can lead to a greater understanding of prehistoric behavior.

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