CHAPTER 15

Grain, Extent, and Intensity: The Components of Scale in Archaeological Survey

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INTRODUCTION

> Archaeological entities, processes and explanations are bound by metaphysical concepts of time and space. So we may expect chronological and spatial revisions to be followed by profound disciplinary consequences. But, the very great importance of time and space measurement scales has often led the archaeologist to confuse the scales used for measurement with that which is being measured. (Clarke, 1973:13)
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> Most [archaeologists] must content themselves with finding some percentage of the sites in their chosen regions – all the major ceremonial centers, perhaps most of the larger villages, and some undetermined fraction of the tiny hamlets and seasonal camps. If you ask them whether or not they have an adequate sample, either they say ''I hope so,'' or they shrug and say ''I don't know.'' Both answers are correct. They do hope so, and they don't know. (Flannery, 1976:131–132)

Regional survey is the primary method through which archaeologists investigate large-scale prehistoric patterns. The first settlement pattern surveys investigated cultural processes existing at scales beyond those captured by excavation. For example, highly influential studies such as Gordon Willey's surveys of Virú Valley, Peru (Willey, 1953), endeavored to identify large-scale sociopolitical patterns in the distributions of sites and their inferred function within a settlement pattern. Large-scale regional frameworks have since become fundamental to archaeological investigation (Ammerman, 1981; Binford, 1964; Dunnell and Dancey, 1983; Schiffer, et al., 1978) and are essential for understanding the impacts of large-scale processes of contemporary land use and development on the archaeological record.

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The scales selected for the research design of an archaeological survey will in many ways determine the characteristics of the patterns inferred (Banning 2002; Dunnell and Dancey 1983; Hodder and Orton 1976). Scale is a concept closely tied to issues of sampling and requires explicit methodological attention for two reasons: (a) the bounds of large-scale processes and patterns are normally beyond the area directly observed by an archaeological survey; and (b) much small-scale information passes through the gaps between pedestrian surveyors (Burger et al. 2004). While such challenges are frequently acknowledged (Ebert 1992; Willey 1953), the methodological answers have proven difficult to develop. As a result, the opening quotes by Clarke and Flannery are just as relevant today as they were thirty years ago. In this chapter, we suggest that the archaeological record be investigated at multiple scales. We focus on methodological tools that ground issues of scale for quantitative analysis and present an approach to sampling that allows archaeologists to analyze the nature of changes in artifact densities that occur as a result of changes in spatial scale and observer intensity.

Archaeological survey has changed over the years with the ever-present goals of improving accuracy and efficiency. Global positioning systems (GPS) have become extremely common field devices. The application of remote-sensing and the powerful capabilities of geographic information systems (GIS) technology have also opened numerous new avenues of analysis, the full potentials of which are far from realized. However, simply applying GIS technology to existing archaeological data sets does not solve the problems of scale as many suspect it can. While numerous innovations have taken place in archaeology, survey methodologies have remained rather tradition-bound (see Wiens 1989 for a discussion of the same trend in field ecology).

One recent development that has improved our ability to investigate the nature of archaeological regions and prehistoric landuse is distributional or siteless survey (Dunnell and Dancey 1983; Ebert 1992; Ebert and Kohler 1988; Foley 1981; Thomas 1975). In these surveys, artifact distributions are continuous populations bounded by a defined space as opposed to a series of artificially divided units or ''sites,'' which makes them amenable to documentation at a range of scales. While the techniques below are relevant to any consideration of sampling the surface record they are especially designed for furthering the aims of the distributional approach.

Ecological Approaches to Scale

Many of the scale-related challenges faced by ecologists, and the tools developed to address them, are relevant to archaeology. Archaeologists and ecologists both deal with palimpsest records of historical processes. In the same way that many different human activities and taphonomic processes create overlapping records in archaeology, a similar suite of processes related to climate, geology, and human land use affect the properties of plant communities and other ecological systems. Both fields study systems open to influence from outside variables. Both conduct research that requires inferring of process from pattern. And fundamentally, both must face issues of scale when linking small-scale observations to largescale processes. In plant ecology specifically, recently developed sampling designs that consider scale greatly improve the accuracy of plant species samples (Stohlgren, et al., 1998). These sampling designs also improve the analysis of spatial distributions and plant community structure. Because plants and artifacts share ''small unit size in relation to a very large spatial context, and also . . . a patchy distribution,'' methods that lead to accurate plant community samples can also be applicable to archaeological survey (Foley, 1981:174).

An increased emphasis on scale in ecology during the late 1980s was described as ''a paradigm shift based on scale'' in relation to symposia at the annual Ecological Society of America meetings (Golley 1989:65), and it continues to be a major issue. This awareness of scale has made its way into archaeology as well (e.g., Stein, 1993; Wandsnider, 1998). While Hodder and Orton (1976) showed that archaeological patterns may change with the size of the sampling frame, ecology provides a key additional point, that as the scale of observation changes, so do the relevant processes. At local scales, predator and prey populations often have a negative correlation, suggesting a cyclical relationship of prey abundance that increases until the predator population grows to the point that the prey become exhausted. At larger scales, predator and prey populations are positively correlated, suggesting that both respond to a similar set of background ecological variables at one scale and to population dynamics at another (O'Neill and King, 1998; Schneider, 2001b). In a like manner, while climate largely determines the spatial distribution of net primary productivity (NPP) at continental scales, the primary influences within regions are aspect and soils (O'Neill and King, 1998). Both predator/prey dynamics and the distribution of NPP are relevant to our understanding of the past to some degree but the investigation of the nature of artifact distributions across regions also brings a number of unique but analogous scale-dependent issues that require direct archaeological investigation.

Perhaps the most important realization regarding the effects of scale is that resolution strongly influences the perception of patterning (Church, 1996; Levin, 1992; O'Neill and King, 1998; Wiens, 1989). ''We can no longer . . . cling to the belief that the scale on which we view systems does not affect what we see . . . '' (Wiens, 1999:371). Following from this is the methodological correlate that there is no best scale of observation (Gardner, 1998; Levin, 1992; Schneider, 1994, 1998). The combination of these two notions forms the basis of our recent investigations into archaeological survey method on the Oglala National Grassland in northwestern Nebraska. Borrowing techniques from landscape ecology offers new avenues for documenting and analyzing the patterns generated by archaeological survey.

To illustrate our perspective, we present some initial results of our surveys on the Oglala National Grassland. We adopted the Modified-Whittaker multiscale sampling plot, originally developed for plant species surveys (Stohlgren, et al., 1998; Stohlgren, et al., 1995), and found its design to be highly applicable in archaeology. We also used the multiscale layout of the Modified-Whittaker for experiments investigating the properties of the surface record to explore the degree to which intensity of observation is an additional aspect of scale relevant to survey and sampling design.

TERMS OF SCALE FOR ARCHAEOLOGICAL SURVEY

Grain, Extent, and Intensity

Scale has multiple meanings and applications in the literature (Schneider, 2002; see contributors to Peterson and Parker, 1998). This simply means that it fits correctly in a variety of circumstances, depending largely on context. We explore one variant in particular because it is quantitative, widely applicable, and especially relevant for the specific concerns of scale in archaeological survey. Schnieder (2002) defines scale as ''the extent relative to the grain of a variable indexed by time or space.'' This definition applies to both the tools of measurement and that being measured or described. The *extent* is the area surveyed, and the *grain* is the size of the sample unit (Figure 15.1). Surveys will not detect patterns that are finer in scale than the grain of the sample (Wiens, 1989, 1990). The extent of a survey also defines the population of artifacts being sampled. Grain and extent are generally thought of as variables imposed by the researcher (Milne 1992), but in archaeological survey the extent is often (but not always) a project-specific restraint leaving grain as the

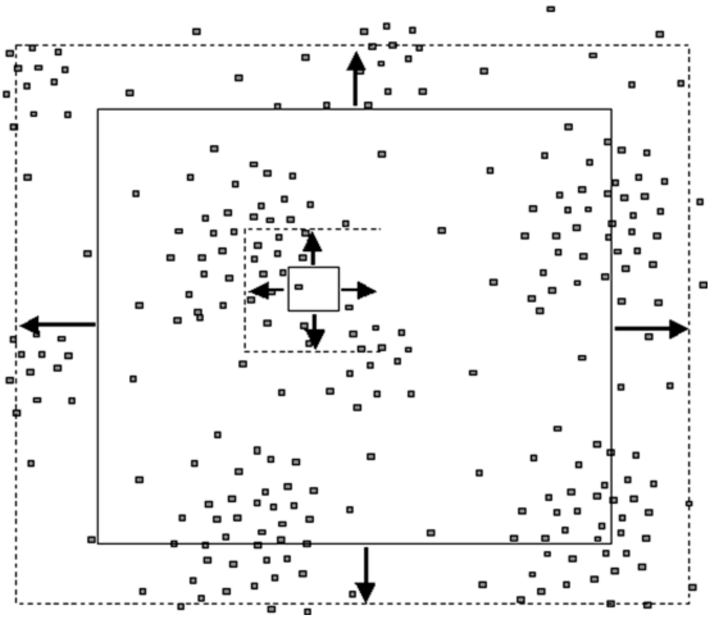

Figure 15-1. Grain relative to extent in the sampling of an artifact distribution. As extent (outer square) increases, the diversity of the total sample increases. As grain increases (smaller square) variance within the sample becomes averaged-out and small-scale patterning may be lost. (Modified from Wiens 1989, Figure 1).

primary variable for experimental or methodological manipulation, although it is usually not specified.

The off-site or distributional approaches noted above are fundamentally concerned with issues of grain. Questions about the appropriate lower limits of survey resolution generated by distributional archaeology suggest that, as a basic unit of observation, artifacts rather than sites may be the more appropriate. Operationally, this means that the grain of a distributional archaeological survey is at the artifact scale (mm-cm^2) rather than the site scale (m^2-ha). Clearly such differences in observational grain entail a number of methodological considerations that are of fundamental concern here.

The investigation of the surface record and experiments aimed at identifying relationships between method, process, and scale benefit from the use of controlled and defined sample units (Dunnell and Dancey, 1983). However, most pedestrian surveys lack specified grains or sample units. The width of a surveyor's field of vision is not an appropriate measure of grain because it is highly variable. Material properties such as mean size or density are difficult to quantify for most surveys and even closely spaced transect widths may miss significant amounts of material (Burger, et al., 2004; Wandsnider and Camilli, 1992). These issues are less important when the goal is the discovery of artifacts, but when certain phases of the survey are geared toward parameter estimation, methodological evaluation, or any specific experiment, spatial control and knowledge of sample properties become much more important. The grain is generally too spatially variable among even highly controlled pedestrian survey transects for use in the quantification of the effects of scale. In addition, transect spacing defines the intensity of coverage rather than a value for a minimum unit of observation. For example, if a hypothetical survey covered 20 km^2 with 30 m transects, the grain and the extant would be the same value, 20 km^2. Alternatively, there are methodological tools for investigating the record at multiple grains, using block surveys with discrete boundaries that enable the manipulation of the grain/extent relationship. We discuss one of these, the Modified-Whittaker multiscale sampling plot, below.

The third element of scale is, as the discussion above implies, *intensity* of observation. In the example above, the 30 m transect describes the intensity used to survey the 20 km^2 area, but it does not describe the grain. In most archaeological surveys, intensity is equivalent to transect width, which is guided by the assumption that the narrower the transect, the greater the intensity and the more accurate the sample. Even relatively narrow transects, however, may disproportionately overlook low-density scatters and isolated finds (Wandsnider and Camilli, 1992), and it is likely that all surveys overlook material (Banning, 2002:62). Because intensity influences the number of artifacts found per unit of area, it must be considered when investigating the role of scale and impressions of spatial structure within archaeological distributions.

Our suggested definition for scale may seem to counter common usages of the term. For instance, an archaeologist might describe a process as existing at the ''scale of a settlement pattern'' and discuss the challenge of linking artifact-scale observations to large-scale behavioral inference. However, such articulations are still ratios of the extent to the grain as long as the statement ''artifact-scale'' implies the range of sizes (from smallest to largest) present within a population of artifacts – in this case, the range of spatial extents between the smallest and the largest areas likely to figure in a past culture's land use strategy.

In a more general sense, scale is also important in the relation between the properties of data and the resolution of their interpretation (Stein, 1993). Moreover, the scale implies by an interpretive model should agree with the scale provided by the data under analysis. Kelly (1999:112) warns that ''fine-grained questions cannot be asked of a coarse-grained record. . . .'' Because most archaeological situations are coarse-grained, or the ''product of a qualitatively different set of time scales than is living behavior'' (Ebert, 1992:25), differences in scale may not be intuitively obvious. Therefore, archaeologists need tools for explicitly relating the scale of the record to the scales of interpretation brought to it.

Multiscale Analysis

Multiscale analysis occurs when the ''variance in a measured quantity, or the relation of two measured quantities, is computed at a series of different scales'' (Schneider, 2002:738). This generally refers to any analysis of change that occurs because of changes in scale. Numerous mathematical techniques are available for conducting multiscale analysis (e.g., Gardner, 1998; King, et al., 1991; Levin and Buttel, 1986; O'Neill and King, 1998; Schneider, 1994, 1998, 2001b, 2002; Schneider, et al., 1997; Webster and Oliver, 2001), but many are computationally dense or require detailed knowledge of the links between pattern and process. We apply two of the more straightforward of these techniques, calculating scope and spatial allometry, to our survey data below.

EXPERIMENTS WITH MULTISCALE SAMPLING ON THE OGLALA NATIONAL GRASSLAND

Solving scale problems requires the systematic evaluation of multiple grains and extents (Wiens, 1989, 2001). The first step in accomplishing this is the appropriate sampling method. The Modified-Whittaker multiscale sampling plot gathers observations at the spatial scales of 1, 10, 100, and 1,000 m^2 (Figure 15.2). This sampling design has greatly improved the accuracy of plant species surveys conducted by rangeland ecologists while also enhancing their ability to analyze community structures at landscape levels (Stohlgren, et al., 1995; 1997; 1998). Previous plant survey techniques, which are quite similar to archaeological transects, failed to accurately represent rare plant species (those composing less than 1% of the cover) and consequently over-represented the significance of dominant species. In a similar manner, Wandsnider and Camilli, (1992) demonstrated that archaeological transect surveys consistently over-represent high-density clusters of artifacts and miss disproportionately large portions of low-density and isolated material. The similarity in methodological bias inherent in the traditional approaches of both

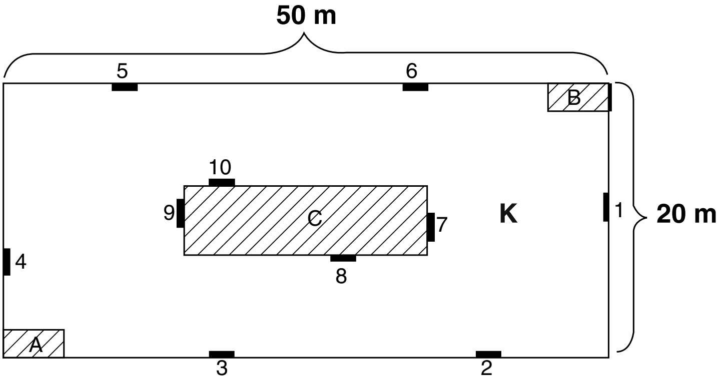

Figure 15-2. The Modified-Whittaker nested sampling plot. The subplots numbered 1–10 are 0.5 × 2.0 m (1 m^2), the A and B plots are 2 × 5 m (10 m^2), and the C plot is 5 × 20 m (100 m^2). The outer boundary of the plot, K, is 20 × 50 m (1,000 m^2). The incremental increases in area give the Modified-Whittaker its multiscale sampling capability.

fields motivated us to experiment with this method by surveying ten Modified-Whittaker plots on the Oglala National Grassland during the summers of 1999–2001 (Burger, et al., 2004).

The archaeological record of our study area is predominantly a palimpsest (as with *all* archaeological deposits) of chipped stone artifacts (primarily small, unmodified pieces of debitage) on a geomorphologically active landscape. Several material types are found and the chronological sequence represented, evidenced by temporally diagnostic projectile points, spans the full range of the chronology for the Great Plains from Paleoindian to Late Prehistoric. Fire-cracked rock is occasionally found but is relatively rare and one locality revealed a few small fragments of pottery. Structures have not been observed but hearths are occasionally found in the vertical cuts along prominent drainages.

Each Modified-Whittaker plot was covered with ‘‘nested’’ observer intensities in order to evaluate the effects of different methods on the accuracy of observations gathered on the same surface. Observation intensity can be investigated as a change in scale because the nature of the patterns we infer from survey data are constrained and perhaps determined by issues as mundane as transect width. The basic findings of our experiments with multiscale sampling provide some background for our perspective on the investigation of scale issues. Note, however, that lessons learned from a 1,000 m^2 plot may only apply heuristically to much larger spatial extents where qualitatively distinct issues may arise.

One of the first questions our survey experiments sought to answer was – how does observer intensity affect the accuracy of the archaeological document? The archaeological document is the subset of information actually observed and recorded when sampling the archaeological record (Wandsnider and Camilli, 1992). Accuracy is the ‘‘deviation between actual and measured’’, that is, between the archaeological document and the archaeological record (Wandsnider and Camilli, 1992:171). Archaeologists generally lack the ability to address the question ‘‘what did we miss?’’ during a survey. Answering the ‘‘what we missed’’ question required intensive coverage of the ground surface compared to conventional standards because we needed a measure of what was actually on the surface in order to determine how much was overlooked by coarser-grained methods. This is equivalent to attempting to quantify the difference between the sample and the target population, a necessary goal for all evaluations of methodological accuracy.

We first covered the entire 1,000 m^2 of the Modified-Whittaker plot in a walking survey. For transect spacing, the rule was that each crew member had to be able to touch the shoulder of the person next to them, resulting in an average spacing of 70 cm. During this survey we marked the location of each artifact with a red pin flag and then conducted a rather intensive recording process, documenting over 20 observations on each pin-flagged item. Additional items observed while recording were marked and recorded with a blue pin flag, distinguishing them from the systematic discoveries (after Wandsnider and Camilli, 1992).

We hypothesized that once the red (systematic) and blue (nonsystematic) discoveries were combined, the resulting document would approximate the total population of surface artifacts, so we could use it to evaluate the accuracy of other transect samples of the same ground surface. As we needed an observer intensity greater than that provided by the 70 cm walking survey in order to evaluate the accuracy of the first survey, a second crew conducted a crawl survey, moving shoulder to shoulder over subplots 1–10, A, B, and C (Figures 15.2 and 15.3).

Comparing the results of these two survey intensities over ten plots has yielded some interesting results. Since the crawl survey sampled a subset of the area covered by the walking survey, we compared only this subset, adding together the blue and red flag discoveries. There were no blue-flagged discoveries during the

FIGURE 15-3. The crawling survey is used to cover the ten 1 m^2 subplots, two 10 m^2 subplots, and the 100 m^2 C subplot for a total area crawled of 130 m^2. In comparison, the walking survey covers the entire 1000 m^2 K plot.

crawl surveys, indicating that crawling does indeed capture the total population of surface items (or very nearly so). Most notably, the crawl survey recovered on average 362% more artifacts than the walking survey (Burger, et al., 2004). Such a drastic increase has implications for calculating the artifact-scale accuracy of surveys conducted at standard transect widths of 10–30 m. This also relates directly to issues of scale. The number of items missed by a survey will increase as transect spacing widens.

In addition to discovery, surveys need to enhance our understandings of artifact distributions. The region we study is a hunter-gatherer landscape and most of the behaviors in the past were ''small-scale'' activities (Ebert and Kohler, 1988; Yellen, 1977). Failing to evaluate the difference between the scales of the sample and the target population greatly obscures the accuracy of any resulting impression of past land use. Fine-scale subsamples such as those provided by crawling the subplots of the Modified-Whittaker can therefore yield more precise estimates of chipped stone densities, and this may lead to a better understanding of the cultural and natural variables that have altered them.

The phenomenal increase in items discovered by the crawl survey dramatically changed our perspective on archaeological survey methods. We knew, as all archaeologists do, that transect surveys miss some materials, but the combined findings of the magnitude of overlooked artifacts and the multiscale capabilities of the Midified-Whittaker method convinced us that some changes to conventional survey wisdom might be worth considering.

TECHNIQUES FOR ANALYZING SCALE

Here we present three techniques for grappling with issues of scale, analytically and conceptually: space–time diagrams, scope, and spatial allometry. Each of these techniques evaluates scalar properties of multiscale samples and variables produced by methods such as the Modified-Whittaker are used to gather multiscale samples.

Space–Time Diagrams

Space–time diagrams are useful graphical tools for both heuristic and analytical needs when representing scale relationships (Figure 15.4). The first space–time diagram was the work of Steele (1978), a marine biologist interested in the relationships of phytoplankton, zooplankton, and fish distributions across time and space. Subsequent applications of such diagrams identify scale-dependent properties relating pattern and process, for example, showing that the population densities of marine fish were influenced by movement at some scales and mortality at others (Schneider, 2002).

Space–time diagrams can be very useful for describing scalar relationships in archaeology as well. Scalar differences frequently exist between behavioral records and the archaeological evidence (Figure 15.4a). Yet the taphonomic pro-

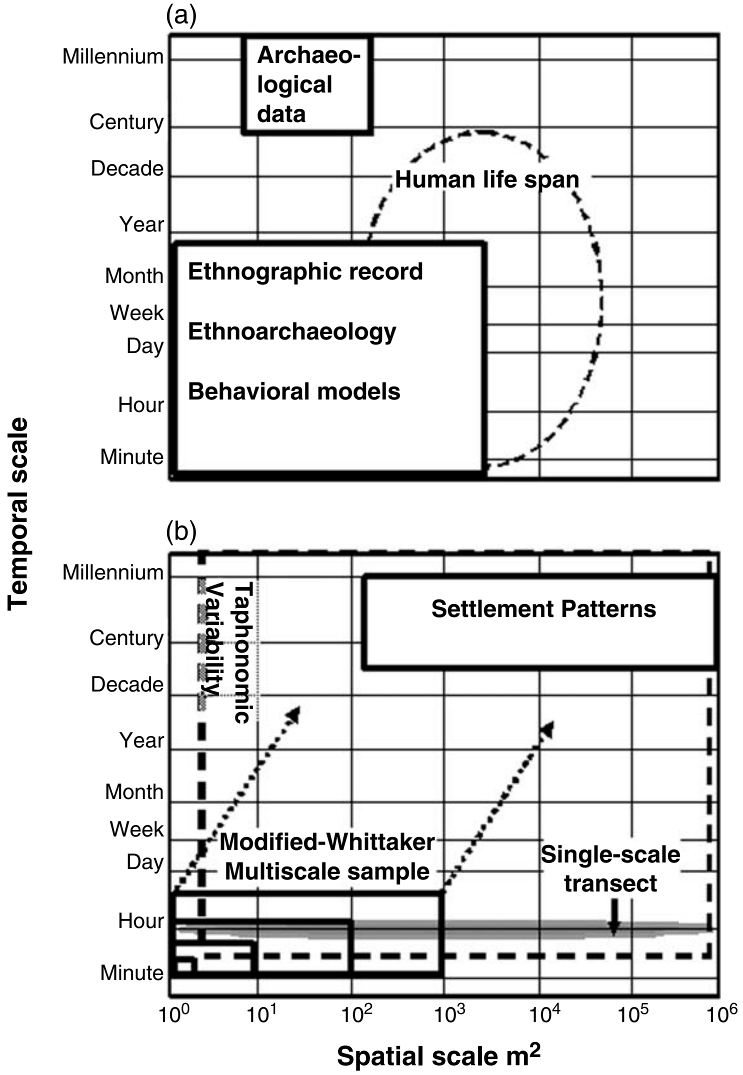

FIGURE 15-4. Space–time diagrams for landscape phenomena commonly studied by archaeologists and two methods used to study them. (a) In most archaeological situations a tremendous temporal and spatial gap exists between the resolution provided by archaeological data and the evidence used to inform them. Archaeological data typically exist beyond the time scale of a human life. (b) The dotted-line rectangle represents the range in variability of taphonomic influences on landscape patterning. The nested spatial samples of the Modified-Whittaker plot ensure stronger inferences to larger scales as indicated by the dotted-line arrows. While single-scale methods do not provide samples that can be quantified in terms of resolution, they can be thought of as a long linear extension of contiguous quadrats. The use of single-scale transects combined with multiscale sampling should generate highly informative samples. If the parameters of a specific settlement pattern were known or inferred, the gap between it and the sampling method could actually be quantified with this diagram. Note that in both diagrams the axes are log transformed.

cesses that arrange, modify, and accumulate cultural materials act at scales that encompass most of the prehistoric social phenomena archaeologists investigate (Figure 15.4b). The ability to infer the nature of these processes (social and taphonomic) at scales larger than what was directly observed may therefore be improved with multiscale sampling methods (Figure 15.4b, dotted lines), as discussed above.

To maximize the information return and efficiency of archaeological survey, we may want to consider using combinations of single-scale discovery methods and multiscale methods. For example, it may be appropriate to cover a large area in widely spaced transects (≥ 5 m) and evaluate the precision of the survey with finer-grained plots such as the Modified-Whittaker. Using space–time diagrams, we can identify any scale issues that might affect a particular project or subject, visualize differences in scalar coverage in interdisciplinary collaborations, or represent relationships between the scope of survey projects and the impacts of contemporary land use.

Scope

Scale is quantified as a ratio of large to small. Cartographic scales, for example, have values such as 1:24,000, which relate a distance on the earth to the scaled measure of that distance on a much smaller piece of paper. This same concept can be extended to any sampling design, measurement device, instrument, or spatially referenced variable (Schneider, 2001a, 2002). When scale is the ratio measure of the extent to the grain, this calculation is the ‘‘scope’’ of the variable (Schneider, 2002; Wiens, 2001). Because scope is calculated by dividing a small scale into a large scale, scope is dimensionless (the units cancel) and is therefore widely applicable for describing issues of scale. For example, the scope of a meter stick is $1\ \text{m}/1\ \text{mm} = 10^3$ (Schneider, 2002).

The spatial extents for the grains of the Modified-Whittaker plot and the extent of the surveyed area are in Table 15.1. The calculations of the actual scopes of the grains and extents of our survey demonstrate how scope is determined: the area for each frame is simply divided by the area of the unit being related to it. The larger the scope, the greater is the degree of scale-up required to bridge the gap from small to large. Scope is useful for comparing projects, experiments, or studies with respect to scale (Schneider, 2001c). Furthermore, scope is a necessary of spatial allometry, a technique derived from scaling theory that can be used to understand how a variable of interest changes as a function of grain.

Spatial Allometry

Archaeologists can use spatial allometry to investigate the influence of spatial scale and/or observer intensity on the rate of artifact discovery, which is one of the factors determining sample size, and for analyzing assemblage diversity. In our sample plots, we use spatial allometry to investigate how artifact density scales with area.

Table 15-1. Scope Calculations for Multiscale Samples on the Oglala National Grassland.

Numbered subplots = 1 m^2
Subplots A and B = 10 m^2
Subplot C = 100 m^2
K plot = 1,000 m^2
Area crawled = 130 m^2 = 1–10, A, B, C
Area walked = 1,000 m^2 = K plot
Grassland Region = 418 ha

Unit	Frame	Scope
1 Subplot	K plot	1,000
Subplots 1–10	K plot	100
Area crawled	K plot	7.7
Area walked	Grassland region	4,180
All plots	Grassland region	418

In spatial allometry, some quantity of interest is scaled against area. This is done by setting one scope equal to another that is raised to an exponent β (Schneider, 2002).

$$\left(\frac{Q(M)}{Q(M_o)}\right) = \left(\frac{M}{M_o}\right)^{\beta}$$

$Q(M)$ is one measured quantity (such as chipped stone density) that is set equal to another quantity M (such as area). The scaling exponent, β, evens out any lack of perfect similarity between the two variables. If β is equal to 1, then the relationship is isometric (Schneider, et al., 1997:132). If it is not equal to 1, it is allometric (Schneider, et al., 1997:132). Most applications of allometric scaling relate rates or processes to properties of differing magnitudes and it has been used in many contexts (Schneider, 1998, 2001a; Schneider, et al., 1997; see also Brown, et al., 2004; Peters, 1983):

$$\left(\frac{Q(M_{big})}{Q(M_{small})}\right) = \left(\frac{M_{big}}{M_{small}}\right)^{\beta}$$

The rate of change of a quantity $Q(M)$ can be equated to another quantity such as the size of the sampling frame used to measure it, M. In relating artifact density to area, artifact density is the quantity that changes with respect to M. A common application of this approach is the measurement of ocean coastlines, which, because of their fractal dimensions, are essentially infinite in length (Pennycuick and Kline, 1986). Scaling functions can correct for differences in various lengths of the same coastline obtained by different measurement methods (Pennycuick and Kline, 1986). Many common scaling relationships could be deciphered with this approach, such as volume scaling with length to the power of 3 ($V = L^3$).

Landscape ecologists have looked at a variety of factors that scale allometrically with area, such as percent bare ground or species richness (e.g., Milne, 1992).

In a like manner, archaeologists can investigate the relationships between area and artifact density. This is a means of understanding the properties of the surface record by systematically investigating changes in grain and extent. For example, the chipped stone densities from the Modified-Whittaker surveys can be scaled with area by equating the largest and smallest sample grains provided by the plot to the number of flakes found at each grain (although any two grains could be investigated in this way).

$$\left(\frac{Q(M)}{Q(M_{ref})}\right) = \left(\frac{M}{M_{ref}}\right)^{\beta}$$

$$\left(\frac{92.8cs}{0.03cs}\right) = \left(\frac{(1000\,m^2)}{(1\,m^2)}\right)^{\beta}$$

For the data from our surveys, the 1 m^2 subplot is used as the reference value (M_{ref}) because it simplifies the math to have the value of 1 in the denominator. To solve for β, take the natural log of each side of the equation:

$$\beta = \ln(92.8/0.03)/\ln(1{,}000) = 1.16$$

In this case the value of β is a little larger than 1, which means that for the combined sample of our ten 0.1 ha plots, the relationship between area and artifact density is supra-linear: the rate of artifact discovery is proportionately greater as area increases. A fourfold increase in area within the scope of this relationship (1–1,000 m) causes chipped stone density to increase by a factor of 4.99 because $4^{1.16} = 4.99$, but a twofold increase in area leads to an increase in artifact encounter by a factor of 2.23. This equation, $\mathrm{CS}=A^{1.16}$, estimates the magnitude of increase in discovery for a given grain within the scope of the calculation, not the number of artifacts found. In this way it can be used to compare rates of discovery and the area to density relationship. For the crawling survey, the chipped stone found at 1 m and 100 m leads to $\beta = 0.77$ (17.8 flakes at 100 m and 0.5 flakes at 1 m). Thus, a fourfold increase in the area crawled leads to an increase in chipped stone encountered by a factor of 2.91 ($4^{0.77}$= 2.91). The difference in the value of β indicates that the observational intensity can determine the scalar relationship between artifact density and area for a survey. Furthermore, this leads to a quantified measure of this difference that is a widely applicable means of comparison. The scale of observation can strongly influence perception of regional patterning (Figure 15.5). Within areas of similar surface context and culture history, this approach may also serve as a crude measure of spatial heterogeneity in that a perfectly homogenous distribution would necessarily have an exponent of 1 if sampled at a high level of accuracy. An important caveat here is that both the values for the scaling exponents are close to 1 and hence both scaling relationship may be close to isometric. However, the values of the exponents from walking and crawling are significantly different from each other, which demonstrates that the two high-resolution samples provoke fundamentally different impressions of the surface record.

The difference in rate of artifact encounter is counter-intuitive in one respect. The walking survey encounters new artifacts at a faster rate than the crawling

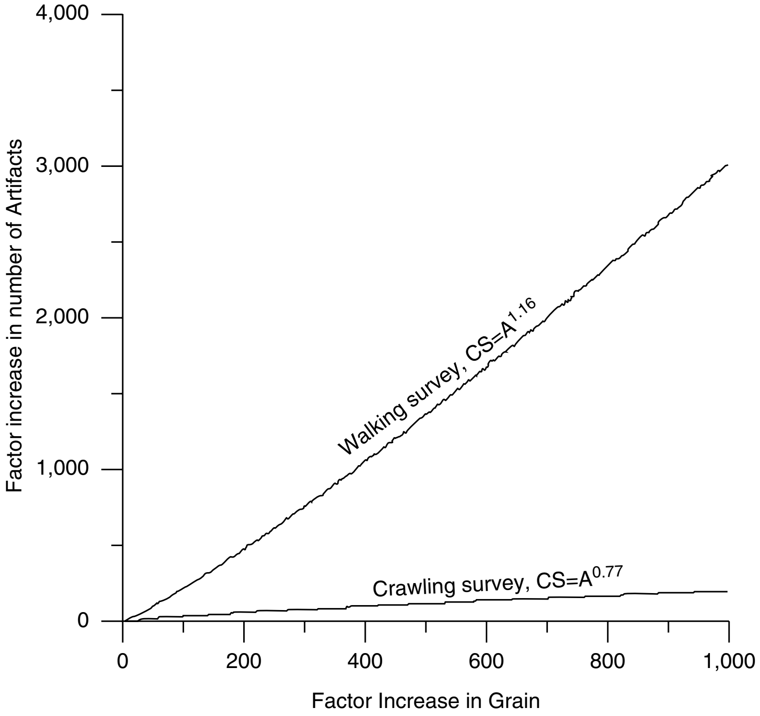

FIGURE 15-5. Curves generated from spatially allometry of area and chipped stone density. The walking survey encounters new artifacts at a rate much faster than the crawl survey even though the crawl survey finds more artifacts per unit area, which is an issue of scale. These two high resolution samples lead to very different impressions of the surface record.

survey even though the crawling survey finds many more artifacts per unit area (Figure 15.5). This indicates that the probability of encountering an artifact within a defined space is differentially affected by changes in transect width. Because the crawl survey finds essentially everything on the surface, it is less affected by changes in grain. For the walking survey, artifacts are more likely to be missed in smaller areas. As the grain increases, the number of artifacts in that area increases as well and the walking survey is more likely to make a discovery of the larger population. This artificially accelerates the rate of encounter as area increases. The probability of missing any given artifact within 1 m^2 is much greater than the probability of missing the artifact population within 100 m^2, thus demonstrating that assemblage diversity and sample size are strongly influenced by methodological decisions of scale.

Multiscale sampling leads to new directions in quantitative techniques for analyzing artifact distributions. Allometric scaling of density with area can be used to analyze the effects of scale on sample parameters. For chipped stone especially, the area-density relationship is highly variable, and our future applications will divide the sample into strata by topographic location and artifact class for comparative analysis. While the application used here considered only the number of artifacts per unit of area, we could divide a diverse sample into classes such as material type in order to compare their distributions across spatial scales (Ebert, 1992).

A further application of allometric scaling is for the analysis of assemblage diversity. The comparison of measures of diversity between samples from different locations is a challenging task whether one analyzes plant community structure or the composition of an artifact assemblage. The major difficulty with such comparisons is that the primary determinant of the number of types present is sample size (Ricklefs and Miller, 2000). As the sample increases, the probability of encountering rare variants increases. Grain, extent, and intensity determine the size of the sample; consequently, projects that have varied in any of these measures need to account for these differences to achieve reliable comparative analysis. The number of types per unit area can be analyzed with spatial allometry just as artifact density was, above. In this regard, overall assemblage diversity and the relative abundances of each type within the assemblage can be compared.

This approach could be especially useful for understanding the effects of scale on surfaces with relatively large numbers of artifact classes. In regions such as Mesoamerica, diagnostic ceramic types lead to highly diverse assemblages and the relative abundances of these types carry major interpretive weight (e.g., Sanders, et al., 1979). Intra-site samples used to derive population densities and times of occupations could benefit from plotting the rate of accumulation for the diagnostic ceramic types relative to the entire sample. Different types will accumulate at different rates. Furthermore, as Leonard (1987) suggests, asymptotic curves may indicate that a representative sample has been obtained and the researcher can use this as a tool to assess whether or not all classes of artifacts in a heterogeneously distributed population have been adequately sampled.

INVESTIGATING THE NATURE OF THE SURFACE RECORD BY CONSIDERING MULTIPLE SCALES

The Modified-Whittaker is not a discovery technique for archaeological survey. While there is a tendency to emphasize discovery in the design and interpretation of most surveys, many researchers seek to investigate the distributional properties of surface artifacts and the processes that act upon them (Banning, 2002; Dunnell and Dancey, 1983; Ebert and Kohler, 1988; Foley, 1981; Hodder and Orton, 1976; Schiffer, et al., 1978; Yellen, 1996). An important aspect of this for research and management is the development of methodological tools for identifying the degree of blurring, distorting, or destruction of the record caused by different post-deposition variables. Such experimentally based approaches require accurate samples in order to understand the crucial scales at which certain processes influence archaeological patterns. For instance, in a recent evaluation of the effects of large herbivore grazing, we divided potential scopes of impact into three ranges (Figure 15.6). The first of these is the microscale, which we define as artifact movements of less than 1 m on seasonal or annual time intervals that are caused by factors such as single

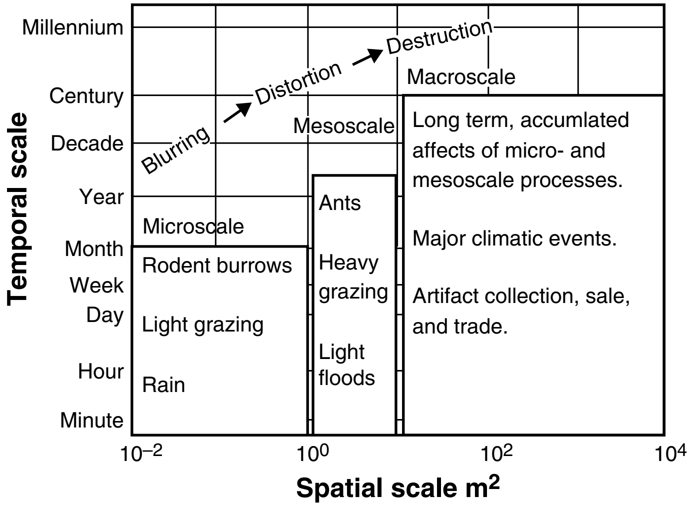

FIGURE 15-6. Space–time diagram depicting the impacts of various agents that are important to consider in both research and management.

seasons of grazing, hail storms, extreme winds, and plant roots. Such movement blurs archaeological patterning. Mesoscale impacts range from 1 to 10 m; they are caused by such processes as multiple seasons of grazing, harvester ants, or localized erosion. They may begin to distort or destroy archaeological patterns. Macroscale movements are subdivided into five levels: macrol (10–100 m); macro2 (100–1,000 m); macro3 (1–10 km); macro4 (10–100 km); and macro5 (greater than 100 km). Over time, processes that act seasonally or annually at the micro- or mesoscales can lead to macroscale disturbance. This includes artifact collection! Understanding how these processes act is an important domain of research for interpreting archaeological patterns and is needed to effectively manage archaeological landscapes.

This study is part of an ongoing attempt to provide a framework that more tightly integrates research and management concerns with other biotic and abiotic components of the landscape. During this project we became increasingly aware of the range of agents that were constantly active at multiple scales in our study region. Small animal foraging behaviors cause small-scale impacts that can distort and potentially destroy archaeological distributions over the long term. Rodent burrowing may result in a continual cycling of sediment that severely distorts vertical stratigraphy. Harvester ants will scour over 80 m^2 of ground surface for mound building materials that often include artifacts (Burris, 2004; Schoville and Todd, 2001). While many of these agents may have minor impacts over short periods of time, sustained impacts, such as grazing, may be severe (Figure 15.6). Grazing is of course linked to other variables that influence artifact visibility, movement, and collection. For example, we found that artifact movement was microscale for moderate grazing intensities over a single season; however, in an intensively grazed plot placed immediately adjacent to a water tank, the maximum movement was mesoscale – over 2 m in a single season, caused in part by a severe rainstorm and the disturbed earth near the water tank. All such variables are important concerns for interpretations of prehistoric behaviors and for managing the archaeological record as a limited, diminishing, and highly valuable resource.

DISCUSSION

The systematic misrepresentation of surface distributions that results from conventional discovery-based methods prevents surveys from addressing the range of scales that existed within prehistoric land use strategies. Thus far we have identified three critical elements of scale in archaeological survey design: grain, extent, and observational intensity. We also need to consider ''intersite space'' in our samples (Dunnell and Dancey, 1983; Ebert and Kohler, 1988; Foley, 1981; Thomas, 1975). The use of nested-intensity designs such as the Modified-Whittaker will improve the accuracy and comparability of samples, as a strategy of sub-sampling for augmenting single-scale (discover-based) methods that, by definition, prevent the identification of scale problems. They are valuable experimental tools because they allow archaeologists to investigate how survey intensity influences sample accuracy. For most archaeological concerns, understanding the relationship between the sample and the target population is a fundamental first step to building accurate interpretations and developing useful management protocols.

Integrating this Approach with Others

Because the intensity of sampling and the area sampled influence the number of artifact classes documented, a strategy that holds these two variables constant will improve our ability to evaluate and compare regions. As mentioned above, we emphasize evaluative aspects of survey that focus on the nature of the surface record rather than discovery alone, but both are necessary for systematic coverage that measures up to distributional approaches to survey. The use of coarse-grained transects to record artifact clusters is an effective means of discovery, while crawl surveys of the subplots within the Modified-Whittaker plot obtain highly accurate systematic subsamples within a consistent framework. Extreme levels of experimental control are too costly for all phases of survey, but are certainly useful for filling in the gaps left by discovery-based (i.e., coarse-grained) methods and for quality control. While our survey was developed for a hunter–gatherer landscape in an arid geomorphologically active setting, all survey situations could benefit from multiple intensities and multiple spatial scales in the sampling design. For example, if a large region had been previously surveyed in 20 m transects, the results of that survey could be used to select locations for more intensive evaluation. Covering as little as 1% of this hypothetical region with the Modified-Whittaker plot would greatly increase the information return, comparability, methodological control, and awareness for the rate of change in its distributional properties.

There is much to be gained from considering multiple scales of reference in archaeological interpretation and analysis. The resilience of an interpretation may be directly proportional to the number of spatial and temporal perspectives that support it.

CONCLUSION

> If we study a system at an inappropriate scale, we may not detect its actual dynamics and patterns but may instead identify patterns that are artifacts of scale. Because we are clever at devising explanations of what we see, we may think we understand the system when we have not even observed it correctly. (Wiens, 1989:390)

Any field that must explain complex phenomena must also consider scale. The perspective outlined here connects archaeology to other fields in the use of basic conceptual and methodological tools that address scalar issues. Achieving a precise and applicable set of techniques for scale in archaeology will have the advantages of increasing understanding for the formational histories of landscapes, allow for more accurate interpretations of prehistoric land use, and improve our ability to assess contemporary human impacts on the landscape. In the absence of attention to scalar issues, creative, yet erroneous conclusions may be easily reached regarding the causal linkages between pattern and process. With current trends of investigating the dynamics of whole landscapes (Banning, 2002), the need to bridge scalar gaps will continue to be a fundamental aspect of archaeological research.

We have presented a series of tools for dealing with scalar issues, some more widely applicable than others. Perhaps the most relevant of the techniques presented are multiscale sampling, the concept of scope, and the use of space–time diagrams. These tools are useful for depicting scalar relationships between models, methods, instruments, taphonomic processes, and cultural variables. Spatial allometry demonstrates the degree to which observer intensity can influence the parameters of the sample. Clearly, the naïve and overly optimistic notion of ''100 % survey coverage'' should be purged from archaeological survey jargon.

The use of multiscale analysis supports a variety of techniques that archaeologists could potentially use to: (1) compare different archaeological surveys; (2) quantitatively describe the properties of the surface record; (3) analyze the distributional behavior of different classes of artifacts within a landscape sample; and (4) develop heuristic and quantitative techniques for confronting problems of scale in archaeology.

Looking at the archaeological record through just one pane of a window is potentially misleading. Varying the window size and the closeness of our gaze allows us not only to be able to identify what we miss with certain vantages, but also to see how our impressions of world are affected by conventional wisdoms. This may lead to uncomfortable realizations about our prevailing interpretations of the archaeological record, but it may also lead to refreshing, more accurate, and more holistic, interpretations of a complex material record and its more interesting behavioral origins.

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