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Sweep widths and the detection of artifacts in archaeological survey

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ABSTRACT

In many parts of the world, one of the principal means for discovering archaeological resources is terrestrial archaeological survey for small scatters of generally unobtrusive artifacts on the surface. Yet archaeologists have expended relatively little research on the factors that affect detection of such artifacts or the impacts they have on the reliability of surveys. We employ mock survey of plowed fields 'seeded' with a variety of artifacts in order to evaluate the effectiveness of pedestrian survey (fieldwalking) with respect to search time and transect spacing. Our results confirm theoretical expectations about the diminishing returns on increases of search effort, while also demonstrating variation in 'sweep widths' for different artifact types and surveyor speed and the effects of walking toward or away from the sun. Preliminary results have implications for the most efficient spacing of survey transects as well as the evaluation of completed surveys, since some artifact types have extremely low probabilities of detection even at high densities of search effort.

1. Introduction

One of the principal means for locating archaeological sites in northeastern North America is by pedestrian survey of plowed fields (fieldwalking), and this method is also common elsewhere. Yet there has been little attention to the effectiveness and reliability of this method for detection of artifacts. In addition, archaeologists have experimented with various ways to express the thoroughness of survey, but have largely failed to account for varying detectability of artifacts in their definitions of "coverage."

Most of the past research on the accuracy or reliability of fieldwalking has involved assessment of results of real surveys by repeat surveys (e.g., Ammerman and Feldman, 1978; Ammerman, 1985; Hirth, 1978; Shott, 1995; Shott et al., 2002). However, since the number and distribution of artifacts in the population being surveyed are unknown, resurvey only allows us to assess the replicability of results (consistency or reliability), and not their accuracy or efficiency. Shennan (1985) also conducted statistical analyses of a completed survey to try to assess various "observation and recording variables" that might have affected the results. And a number of authors have discussed the geometric effects on probability of intersecting sites by various survey methods (e.g., Hey and Lacey, 2001; Krakker et al., 1983; Sundstrom, 1993; Verhagen and Borsboom, 2009). The only real way to assess the detection probabilities of survey, however, is by surveying a known population of "targets," an experimental approach. Some archaeologists have attempted to conduct such evaluations by "seeding" a space with artifacts in known locations prior to survey and using the proportion detected by surveyors to estimate survey thoroughness (Ebert, 1992; Schon, 2002; Wandsnider and Camilli, 1992; Wandsnider and Ebert, 1986). These last come closest to our approach, but differ in significant respects.

In previous studies (Banning et al., 2006), we used test fields seeded with a variety of artifacts to study "detection functions" for their discovery and how these functions varied by visibility and artifact obtrusiveness. One set of detection functions describes how the probability of artifact detection varies with search time; the other describes how it varies with range away from the center of a transect. With "targets" of chert flakes, terracotta sherds, and blue-and-white china, we found that the search-time functions fit the exponential curve of classic search theory (Koopman, 1980: 55, 71–74, 329), but varied substantially by artifact type and environmental context or visibility. For range, artifact detection predictably

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declined in an S-shaped curve away from the center of the transect, fitting another exponential function similar to one that classic search theory predicts for cases where detection is not assured, even at short range (Koopman, 1980: 57, Banning, 2002a: 57–59).

These earlier studies were not entirely realistic, partly owing to an attempt to emphasize variation in visibility, and because in all cases they needed more thorough experimental controls. They did, however, demonstrate the importance of taking explicit measures of search effort and range into account in the evaluation of survey effectiveness. Here we present the results of a new experiment using distributions of 19th-century artifacts on a plowed field in southern Ontario, Canada, to introduce the concept of sweep width and its role in measuring survey coverage. These results have important implications for the planning and evaluation of archaeological surveys for both research purposes and Cultural Resource Management in northeastern North America.

2. Detection functions, "thoroughness" and coverage in archaeological survey

The theory that informs the planning and evaluation of searches was originally developed for naval applications, and subsequently for search-and-rescue and mineral exploration (Drew, 1967, 1979; Koopman, 1980; Stone, 1975). With rare exceptions (notably Krakker et al., 1983; Miller, 1989), only recently has it found application in archeology (Banning, 2002a,b; Banning et al., 2006) and, even in search-and-rescue research, experiments in detectability that employ this classic literature are relatively new (Robe and Frost, 2002). In general, archaeologists' need for thoroughness stems from one or both of two risks: the risk of missing an archaeological "target" given that it exists, and the risk that a target exists, given that a survey did not detect any (Nicholson and Barry, 2005: 475–476). In what follows, we focus on the former, but our results are also relevant to the latter risk.

2.1. Search time

An obvious contributor to the probability of detecting targets such as artifacts, given that they are there, is the amount of search effort. One way to measure effort is by the amount of time dedicated to searching a given area of space. The relationship between artifact detection and search time is exponential. Several factors contribute to the declining returns on investment of additional search effort: the number of artifacts within this area is finite; we tend to find the ones that are easiest to see first; and the risk of overlap with previously searched space increases with time. Formally, we may describe the relationship among these factors with the law of random search:

$$p(t) = 1 - e^{-gt} \tag{1}$$

where $p(t)$ is the probability of detection by a certain time, t, e is the exponential constant (base of the natural logarithm, approximately 2.718), and g is a factor that summarizes the effects of target size and obtrusiveness, visibility, contrast between the artifact and its background, and other factors, any one of which can cause the steepness of the curve to vary (Banning, 2002a: 60; Koopman, 1980: 55, 71–74, 329).

Other ways to measure effort, such as coverage and total distance walked or "track length" (Frost, 1999b: 10; Koopman, 1980: 74; Stone, 1975: 25), similarly show diminishing returns on probability of detection. This is axiomatic because, at a given speed and number of surveyors, distance and coverage are both directly proportional to time invested in survey. Although archaeologists have yet to absorb fully the implications of this nonlinear relationship, some have documented it in other types of field survey (Hey and Lacey, 2001, 43; Verhagen and Borsboom, 2009: 1812).

2.2. Sweep width

The single most important summary of the detectability of artifacts is *effective sweep width* (W). This is not to be confused with maximum detection range (contra Miller, 1989: 5–6) nor dependent on transect spacing, but is rather a measure that relates detectability to the perpendicular distance away from the center of a survey transect. This distance is the *lateral range*, or shortest horizontal distance between the artifact and the transect line.

Although we can model the relationship between range and probability of target detection in a number of ways, in past experience with archaeological targets we have found rather good fit, in most cases, is to an exponential range function, with the form,

$$p_{(r)} = be^{-kr^2}, \tag{2}$$

where $p_{(r)}$ is the probability of detection at range r in meters, b is the y-intercept (expected detection right on the transect), e is the exponential constant (approximately 2.718), k is a constant that summarizes effects on detectability, r is the range, and kr^2 describes the steepness of falloff in detectability (cf. Koopman, 1980: 64). In the analyses that follow, this is the function we employ, fitting the data with the nonlinear regression function in SPSS™ and checking, integrating, and graphing the result in Maple™. Other range functions can be used to model the falloff in detection with range (Koopman, 1980: 57–65; Stone, 1975: 27–29) but we have not found them to model data from our experiments very realistically.

One way to conceive of effective sweep width in terms of the range function is as the range within which the number of artifacts that fail to be detected is equal to the number of artifacts found outside it (Cooper et al., 2003: 18–24; Frost, 1999a: 7; Koopman, 1980: 65–66). In a map view, a surface survey along a particular distance might find 88 out of 100 artifacts that lie within 2 m of the transect center and 12 artifacts outside that range (Fig. 1), so that it

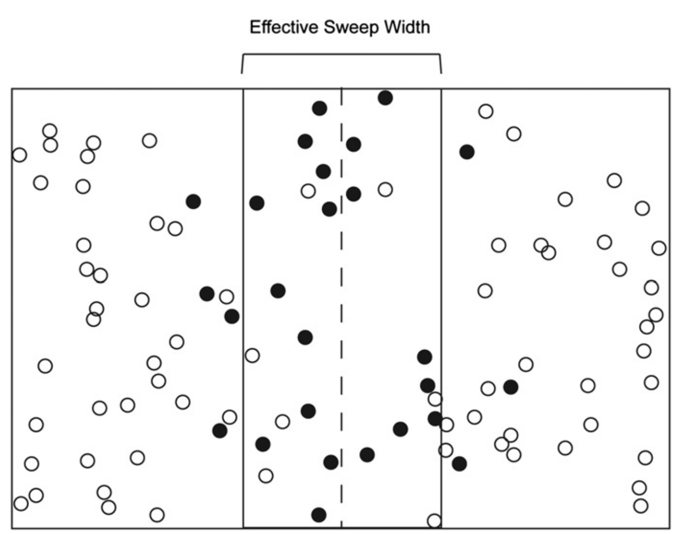

Fig. 1. Effective Sweep width for a hypothetical artifact distribution in map view (after Cooper et al., 2003: 23). Detected targets (black dots) found outside the sweep width are equal in number to undetected targets (white dots) inside the sweep width. For definite detection, all the dots within the sweep width would be black, and all those outside would be white. Center line represents the searcher's path.