Detection Functions in the Design and Evaluation of Pedestrian Surveys

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Abstract. The paper describes an experimental procedure to estimate the number of artefacts detected during a survey as a function of search time, artefact type and range.

1. Introduction

As archaeologists are aware, the detection of artifacts, sites or any archaeological materials in surveys is never perfect. Few, however, have explicitly or realistically evaluated the probability that their surveys detected various kinds of “targets”. Yet evaluating these probabilities is crucial if we are to have any confidence in surveys' results. This paper deals with factors affecting two kinds of detection functions.

Among other factors, detection is a function of search time or effort. The longer we search a given space with a given number of searchers or detectors, the more likely it is that we will find any “target” that exists in that space. However, this is not a linear function, but the probability of detection by time *t* is

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

where γ summarizes other influences on detectabillity, so there are diminishing returns for increased search effort (Koopman 1980: 55, 71–74).

Detection also varies as a function of range away from transects. Most archaeological surveys have operated implicitly as though detection followed the “definite detection law” (Koopman 1980: 57, 82–83). This assumes that surveyors will detect any artifact within the range R of a transect. If this were so, a transect spacing of 2R would guarantee detection of all artifacts. A more realistic detection function is the inverse-cube law, whereby the probability of artifact detection declines with the cube of the range (Koopman 1980:59). Yet another model is an exponential detection function of the form

$$p(r) = be^{-kr^2}$$

where *r* is the range, and *b* is the probability of detection at a range of zero. Military and search-and-rescue applications have employed these models for decades, but archaeologists have yet to apply them to practical archaeological situations.

Our experiments are designed as the first step in determining the detection functions for search time and range under a variety of conditions. We salted a gridded area, usually 100 m long and 20 m wide, with four different artifact types and asked both students and experienced archaeologists to walk a single transect down the middle of the grid, each taking anywhere from a few minutes to more than an hour. They recorded the artifacts they saw, thus providing us with the data we needed to calculate detection functions for different kinds of artifacts under different field conditions.

To test for effects of visibility, the four field experiments we have carried out so far took place on a grassy field at University of Toronto, a gravel strip also at University of Toronto, a gravel parking lot in Sudbury, Ontario, and a ploughed field on the Niagara Excarpment, Ontario. The targets were flakes of grey chert, sherds of red terracotta, sherds of blue-and-white glazed stoneware and aluminum washers.

2. Detection as a Function of Search Time

As expected, probability of artifact detection increased with search time, but with diminishing returns, and varied by visibility. Generally, artifact detection was best on the ploughed field, nearly as good on the grass, and poor on both gravel surfaces. However, detection functions for aggregate data including all types of artifacts are are meaningless because varying the proportions of artifact types would result in very different detection functions. It is necessary to plot detection functions separately both by visibility and by artifact type.

Within 4 m of transects, the proportion of chert flakes detected, not surprisingly, was good within 20 minutes and nearly perfect within 40 minutes on the background of the grassy field, and nearly as good on the ploughed field (figure 1a). Detection was poor on the gravel backgrounds even with search times around 60 minutes.

Visibility Class	Chert	Stnwr	Terr	Wash
Grassy field	0.0506	0.0538	0.040	0.0291
Ploughed field	0.0812	0.0866	0.0959	0.0607
Sudbury dark gravel	0.0043	0.0892	0.077	0.0366
Toronto light gravel	0.0019	0.0264	0.0239	0.0124

Table 1. Values for the detection of different artifact types as a function of search under different conditions of visibility and for ranges < 4 m.

For the stoneware, by contrast, detection was greatest on the dark gravel, nearly as good on the ploughed field, and generally better under all situations than for the chert flakes (figure 1b).

We can quantify the differences in the detection functions under various conditions simply by citing the   values, which summarize the contributions of visibility, contrast, and other factors to the exponent of the detection function (table 1).

These detection functions have important implications for the design of archaeological surveys. Since improvements in detection level off as search time increases, at some point it is more useful to shift search elsewhere than to continue searching the same place. Detection functions help establish where this point is for the most critical artifact types and in different visibility zones.

Chert	Function
Grassy field	$p(r) = 0.91\ e^{-0.07\ r^2}$
Ploughed field	$p(r) = 0.72\ e^{-0.04\ r^2}$
Sudbury dark gravel	$p(r) = 0.18\ e^{-0.04\ r^2}$
Toronto light gravel	$p(r) = 0.087\ e^{-0.09\ r^2}$

Stoneware	Function
Grassy field	$p(r) = 0.90\ e^{-0.015\ r^2}$
Ploughed field	$p(r) = 0.78\ e^{-0.013\ r^2}$
Sudbury dark gravel	$p(r) = 0.95\ e^{-0.01\ r^2}$
Toronto light gravel	$p(r) = 0.64\ e^{-0.034\ r^2}$

Table 2. Range detection functions for chert and blue-and-white stoneware under four different conditions of visibility.

3. Artifact Detection as a Function of Range

Similarly, the decline in artifact detection with range differs considerably by artifact type and visibility. For chert flakes, for example, detection is nearly perfect within 2 m on the grassy field and declines rapidly after 4m while, on the gravel surfaces, detection is very poor even at short range and the detection function slopes only very gradually (figure 2a). For stoneware, the detection functions are more closely similar in shape, varying principally in the intercept (figure 2b). We can quantify most of these functions with the form, p(r) = be-kr2 (table 2).

This has important implications for the design of fieldwalking surveys. Quantifying the effect of range allows us to determine transect spacings that will, on average, yield detection of some specific proportion of artifacts, and to vary this spacing with visibility. For example, a spacing of 16 m would yield 50% of the stoneware on the grassy field, but spacing no greater than 6 m is necessary to detect 50% of stoneware on the light gravel strip in Toronto.

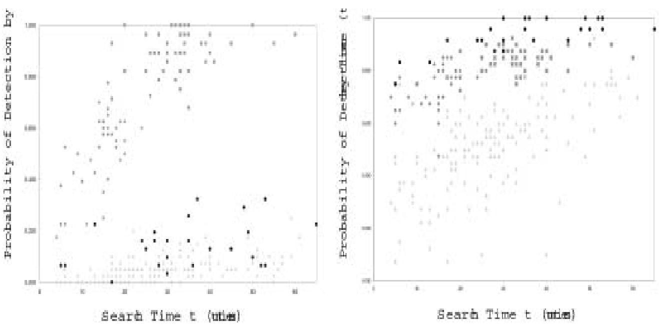

Fig. 1. Detection functions for search time for chert (a) and stoneware (b) on ploughed field, grassy field, dark and light gravel.

Conclusions

Detection functions not only provide a basis for deciding critical aspects of survey design, but allows us to discover the confidence we should place in survey results (Banning 2002: 217–223). Finally we can assess the likelihood that empty space on a survey map is really due to an absence of archaeological remains, and not merely to low intensity of survey or to poor visibility.

References

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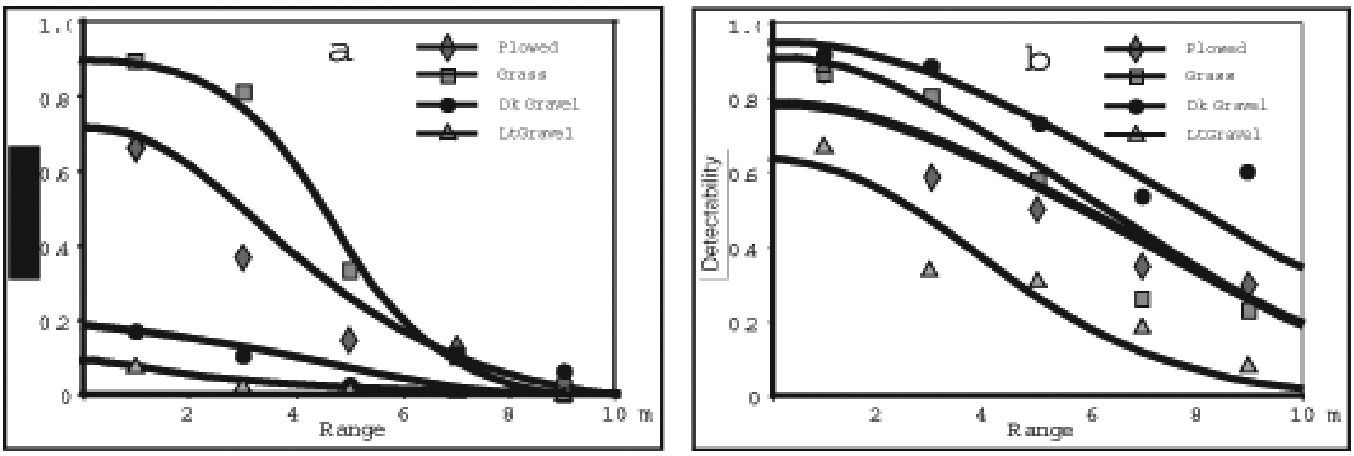

Fig. 2. Detection functions for range away from transects for chert (a) and stoneware (b) on ploughed field, grassy field, dark and light gravel.