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Comparison of Combinations of Sighting Devices and Target Objects for Establishing Circular Plots in the Field

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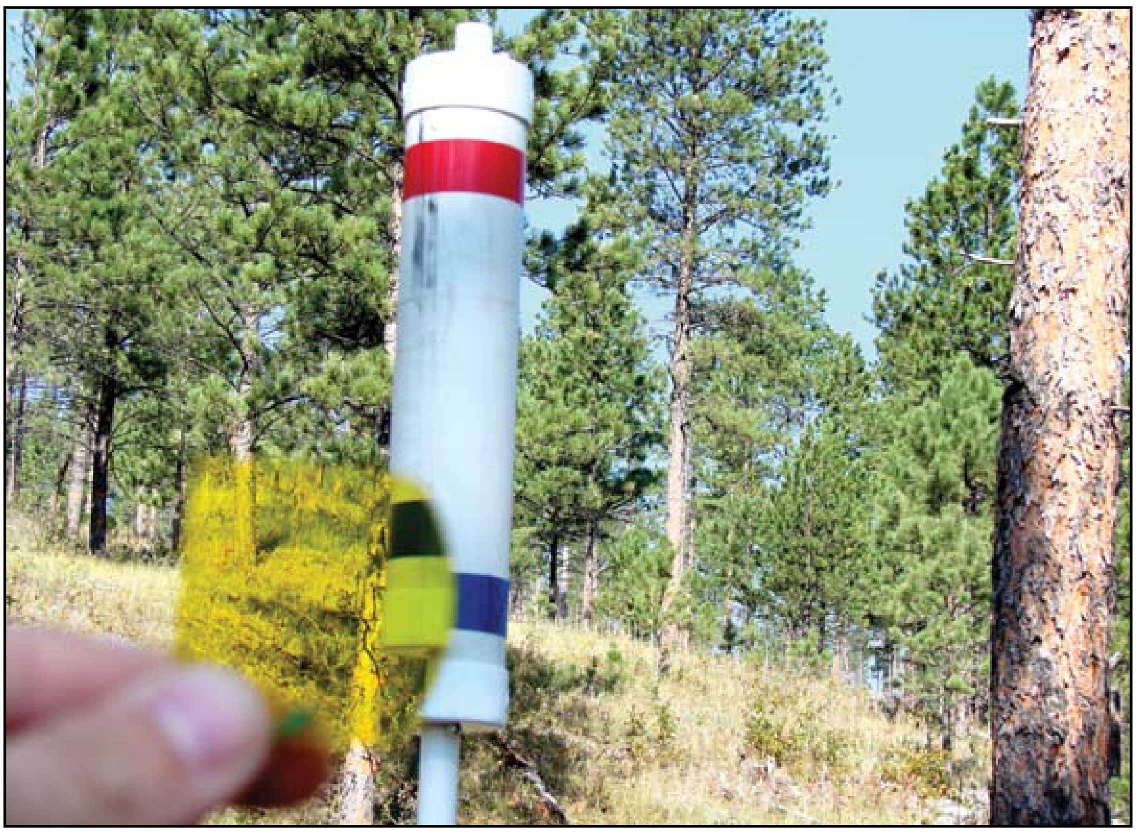

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Abstract—Many aspects of ecological research require measurement of characteristics within plots. Often, the time spent establishing plots is small relative to the time spent collecting and recording data. However, some studies require larger numbers of plots, where the time spent establishing the plot is consequential to the field effort. In open habitats, circular plots are easily established using a rope or tape. In tall or dense vegetation, however, considerable time can be spent ensuring that measures of plot radii are straight-line measurements. To rapidly establish fixed-radius plots in the field, common forest survey techniques can be used with a target object calibrated to the desired size of the plot. Although mentioned in past publications, the accuracy of establishing plots with these methods has not been evaluated. We tested the accuracy and precision in establishing fixed-radius plots using different sighting device/target object combinations. A laser rangefinder aimed at 10.2-cm PVC pipe was most accurate and precise, but expensive, and required careful handling. Wedge prisms used with a 10.2-cm PVC pipe or cylinder were accurate, precise, inexpensive, and easy to use.

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Cover photos: View through a 10 BAF prism of 10.2-cm PVC pipe (*top* and *lower right*). Blue and red bands are at specific to the radius of circular plot. When the offset blue band in the prism aligns with the red band, the plot boundary is directly beneath the prism. A field technician demonstrates the field application (*lower left*) of the prism and target device.

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Introduction

Many natural science studies use plots with identifiable boundaries from which to collect measurements. Sometimes researchers need to establish a large number of plots where the time spent sampling within the plot is relatively short compared to time spent establishing the plot. Examples include characterizing vegetation for reference data when developing predictive models from aerial photographs or satellite images (Mannel and others 2006), or intensive sampling to characterize spatial patterns of vegetation surrounding items of particular interest such as a nest.

Circular plots have the lowest edge-to-area ratio, are prevalent in the literature, and may be less biased compared to plots of other shapes (McKelvey and others 2002). Typically, a rope or tape measure is secured to the plot center and the circumference or plot boundary is delineated (Cox 1990; Lounsbury and Aldrich 1986). Establishing fixed-radius plots using ropes or tapes is easy in grasslands and open areas. But in tall or dense vegetation, considerable time can be expended ensuring that the rope or tape measure is a straight line (Lounsbury and Aldrich 1986).

During a study relating satellite images to field plots, we encountered the need to establish a large number of fixed-radius plots in forest vegetation that were georeferenced at the center. We used a wedge prism and target object to establish fixed-radius plots. While evaluating the accuracy of this method, we encountered some alternative methods that used wedge prisms or angle gauges to establish the boundaries of circular plots (Korhonen 1979; Nyland and Remele 1975; White and Lewis 1982). Despite the ease associated with these methods for establishing circular plots, we had not seen them applied in the scientific literature nor did we find any papers that made accuracy assessments of the plot boundaries estimated using these methods. In this paper, we evaluate the accuracy and precision of two sighting devices in conjunction with three target objects for establishing the boundary of fixed-radius plots.

Materials and Methods

Wedge prisms are commonly used for variable-radius plots to quantify forest vegetation (Bell 1993; Moorhead 1990; Varnedoe and others 2000). The user holds the prism at a comfortable distance from the eye toward a tree while looking through the prism and over the prism. The image viewed through the wedge prism (typically a tree) is displaced to the side of the image viewed over the prism, and if the images overlap, the item is included in the variable-radius plot. Using this technique, the larger the object (typically tree diameter), the further it can be from the prism and be included in the variable-radius plot. Angle gauges are viewed at a distance from the observer's eye that is maintained by string or lamp chain held in the teeth of the observer while extending the arm. If the object viewed extends beyond the gap in the angle gauge, it is included in the variable-radius plot. For each of these sighting devices, the investigator can calculate a plot radius associated with each object that was measured.

Wedge prisms are commercially available in 5-, 10-, or 20 ft^2/ac English basal area factor (BAF) and 2-, 3-, or 5 m^2/ha metric BAF. For our application, we solved the equation to calculate the plot radius using the following formula for English BAF wedge prisms or angle gauges:

$$d = \sqrt{\frac{r^2 \times 4BAF}{43560 - BAF}}$$

where d represents the diameter or width of a target object and r represents the plot radius. We constructed target objects for which d corresponded to a specific plot radius. We note here that the units of *r* and *d* can be either English or metric; however, they must be consistent.

We tested the accuracy of wedge prisms and angle gauges for establishing fixed-radius plots using four target objects. Three of the target objects we developed were a range fork, a cylinder, and horizontal discs. The two-pronged fork was constructed from 3.8-cm PVC pipe with *d* measured from the center of each prong so that the prongs would completely overlap at the correct plot radius (fig. 1A). The cylinder was constructed from two 1.9-cm plywood discs of diameter *d* with brightly colored plastic stapled around the circumference (fig. 1B). The fourth target object, a 10.2-cm PVC pipe (fig. 1C), had two bands of 5.1-cm duct tape of differing colors at the specified distance *d* apart (Nyland and Remele 1975, White and Lewis 1982).

We used each target object and sighting object to establish plot boundaries of radii 9.22 m, 11.34 m, and 13.41 m. The 11.34 m fixed-radius plot represented a 0.04 ha plot (James and Shugart 1970) that has been used extensively in studies of avian ecology in forested environments (Noon 1981). At each plot radius, we also used a laser rangefinder (Impulse laser rangefinder user's manual, 1998, Technology Inc., Englewood, CO) aimed at the PVC pipe.

We placed the target object at the center point of the desired plot and laid eight measuring tapes on the ground at 45° incremental compass directions. Four observers used the wedge prism and angle gauge with each target object, and the laser rangefinder and PVC pipe to estimate the plot boundary. When each observer indicated the plot boundary, we used a string and plumb bob from the sighting device to measure the estimated plot boundary on the tape.

We used analysis of variance (SPSS 2001) to evaluate the sources of variation from sighting devices, target objects, plot radii, and observers. Because of significant

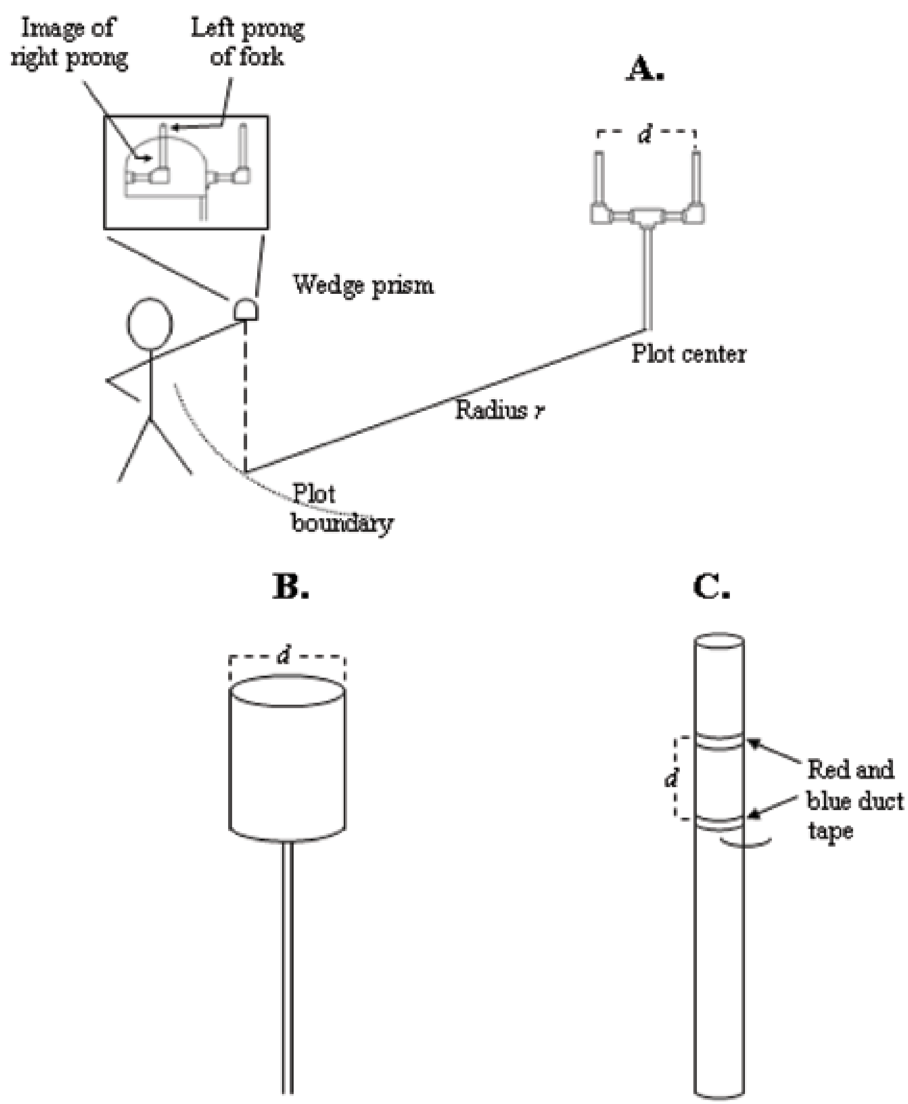

Figure 1. A. View of the fork target object through a wedge prism. The cutout shows the deflection of the forks and how they line up to indicate the correct plot radius. **B.** Cylinder constructed of plywood and brightly colored flexible plastic with diameter *d* such that when the deflected edge just touched the edge viewed over the prism it indicated the correct plot radius. **C.** A 10.2-cm PCV pipe with brightly colored duct tape spaced at distance *d,* which overlaps at the correct plot radius.

Table 1. Comparison of accuracy and precision of wedge prism, angle gauge, and laser rangefinder with sighting objects to establish fixed-radius plots.

Sighting device/target object	Average deviation (m) from plot radius	± SE
Angle gauge/cylinder	0.352	0.0289
Angle gauge/10.2-cm PVC pipe	0.434	0.0304
Wedge prism/cylinder	0.003	0.0174
Wedge prism/fork	-0.094	0.0162
Wedge prism/10.2-cm PVC pipe	0.070	0.0164
Laser rangefinder/10.2-cm PVC pipe	-0.007	0.0037

interaction among sighting device and target objects, we combined these treatments into six sighting device and target object combinations. Combining sighting devices and target objects into one treatment provided a balanced analysis. For our analyses, observers were the experimental unit. We then used analysis of variance to test for equality among the sighting device/target objects, plot radius distance, and observers. The response variable for tests was deviation between the observed and calculated plot radii. Tests were considered significant at $\alpha \leq 0.05$. Precision is defined as the reciprocal of the standard error (Steel and Torrie 1980) associated with each sighting device and target object.

Results

No differences (P=0.48) were evident among observers in deviations from calculated plot radii using the sighting device/target objects. Significant differences were evident among sighting device/target objects ($F_{5,15}$=16.2, P<0.01) and among plot radii ($F_{2,6}$=15.4, P<0.01). The angle gauge overestimated the radius plot boundaries for the cylinder and PVC pipe (table 1) and the overestimation increased with the plot radius (fig. 2). The laser rangefinder/PVC pipe provided the most accurate estimates for all plot radii. Wedge prisms provided accurate estimates of plot boundaries for all target objects. The interaction between sighting device/target object × plot radii was significant ($F_{10,30}$=3.1, P≤0.01) and appeared to be caused by underestimation of the plot boundary using the wedge prism and fork.

The laser rangefinder was the most precise sighting device, followed by the wedge prism and the angle gauge. For wedge prism/range fork, angle gauge/cylinder, wedge prism/cylinder, and angle gauge/10.2-cm PVC pipe, the precision decreased as the size of the radius (plot) increased (fig. 2). Precision using the wedge prism/10.2-cm PVC pipe was consistently high at all plot radii and perhaps increased for the largest plot radius.

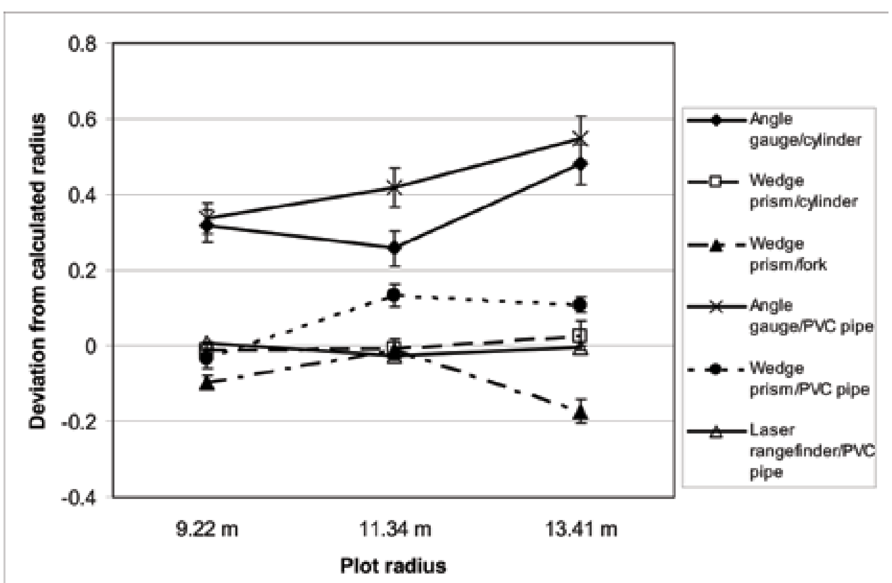

Figure 2. Deviations ± SE from the calculated plot radii for six combinations of sighting device/target objects used to establish fixed-radius plots.

Discussion

The advantage of all of the techniques we tested was that the plot boundary only needed to be established for objects of interest that were near the boundary. Thus in a forest, the plot boundary only needed to be estimated for a few trees in each plot.

Laser Rangefinder

The laser rangefinder aimed at a 10.2-cm PVC pipe provided very accurate and precise estimates of the plot boundaries. We encountered some difficulty holding the laser rangefinder without movement while aiming it. To quickly aim the laser rangefinder, a target ≥10.2 cm was required. Plots with large radii might require target objects ≥10.2 cm in diameter. Nonetheless, the laser rangefinder was bulky, expensive (>$2,500), and required careful handling under field conditions. The accuracy of less expensive laser rangefinders (± 1.0 m) or optical rangefinders is not acceptable for establishing plot boundaries.

Wedge Prism

The wedge prism was easy to use and provided accurate and precise estimates of plot boundaries. Each target object we evaluated had advantages and disadvantages (table 2). We found the wedge prism worked best with the cylinder. The wedge prism and 10.2-cm PVC pipe also provided accurate and precise estimates for the 9.22-m radius plot. Pipes < 10.2 cm in diameter are difficult to see (Korhonen 1979), and we found it was more difficult to line up the colored tape rings on the PVC pipe when the plot radii were >9.22 m. A larger pipe could alleviate this problem (Nyland and Remele 1975). Since wedge prisms could be attached to the observer's field jacket with a string, it was easy for the observer to collect and record measurements. One wedge prism did not have the correct refraction as engraved on the prism from the manufacturer. We don't know how pervasive this is, but we recommend testing prisms with a calculated distance before taking them to the field.

Angle Gauge

The angle gauge was difficult to hold steady. The plot radii were over estimated with angle gauges and the associated precision was lower. The impossibility of focusing on a near and far object with one eye closed complicated the use of this sighting device. We also were concerned about personal hygiene associated with holding the lighting chain or string in our teeth when using this sighting device.

Range Fork

The range fork worked well with the wedge prism. It was easy to determine when the forks were lined up except with the 13.41-m radius plot. We attributed the ease of lining up the forks to their length. Longer and larger diameter PVC forks were more visible at greater distances. The fork also required someone to hold and turn the fork toward the observer as they moved around the plot boundary. The forks must be precisely perpendicular to the observer; any deviation from perpendicular to the observer underestimated the plot radius. This explains the underestimation of plot boundaries in our test.

PVC Pipe and Cylinder

The 10.2-cm PVC pipe and cylinder could be viewed from all directions, without any rotation, and could be used by one person in the field. The cylinder and 10.2-cm PVC pipe could be used with a spike on the

Table 2. Advantages and disadvantages of target objects when used with a wedge prism as the sighting device for establishing fixed-radius plots.

	Fork	PVC Pipe	Cylinder
Precision[1]	Good	Good (r ≤11.4 m)	Good
Visibility	Very good	Good	Good
Convenience	Good	Very good	Poor
Measurements from all sides	No	Yes	Yes
Single person application	No	Yes	Yes

[1] Precision inverse of standard error of deviation from calculated radius.

end of a pole when data was recorded by one person. The wedge prism used with the cylinder was accurate and precise, but the cylinder was bulky and inconvenient.

Management Implications

The laser rangefinder was the most accurate and precise method for establishing fixed-radius plots. However, laser rangefinders are expensive and require careful handling. Considering cost, ease of applicability, and accuracy, we recommend the wedge prism as the best sighting device. The wedge prisms used with a 10.2-cm PVC pipe is recommended as an inexpensive method for establishing fixed-radius plots by one person. For plots larger than 11.34 m, the wedge prism used with a cylinder was accurate and precise probably because the target object was larger. The range fork was easy to disassemble and carry. However, the range fork required two persons in the field, one to hold the fork perpendicular to the other using the wedge prism—thus, partially negating savings in field personnel time.

The time savings associated with using a sighting device/target object for establishing fixed-radius circular plots depends on how busy the plot is. It is difficult to use a rope pinned at the plot center in dense timber or shrubs. The rope must constantly be rethreaded through obstructing vegetation to check the items near the plot boundary for inclusion. Generally, this must be done whether or not an object near the plot boundary needs to be checked for inclusion. The sighting device/target object, however, is easily carried around the plot and is only brought into use when objects of interest lie near the plot boundary. For establishing a large number of plots quickly, we recommend wedge prisms or laser rangefinders and ≥10.2-cm PVC pipe.

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