A test of the variable circular-plot method where exact density of a bird population was known

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Variable circular-plot (VCP) counts are statistically more sound than point counts because they are adjusted for the probability of detecting birds at different distances and under different conditions. However, many ornithologists use point counts rather than VCP counts because they believe that assumptions of the VCP method are almost always violated, leading to poor results, and because earlier field tests using ad hoc analysis methods gave variable and relatively poor results. We conducted the first field test of the VCP method where the exact density of a forest bird was known as part of re-establishing the 'Oma'o *Myadestes obscurus* in former range. All 'Oma'o in the new population were intensively monitored by radio telemetry so that the number present during four VCP censuses was known. Excluding the first census, when three of the four detections were of the same individual, differences in VCP density estimates ranged from -34% to +24% (mean 0%) even though <=18 'Oma'o were detected per survey. We review critical assumptions of the VCP method and make recommendations for data analysis based on our experience with the method on Pacific islands.

Key words: Avian density estimation, Myadestes obscurus, 'Oma'o, Variable circular-plot (VCP)

INTRODUCTION

VARIABLE circular-plot (VCP) counts are the standard method used on Pacific islands and in other locations for estimating population size and trend of forest birds (e.g., Ramsey and Scott 1981a; Engbring et al. 1986; Scott et al. 1986; Ramsey et al. 1987; Ralph and Fancy 1994; Jacobi et al. 1996). If assumptions are met, VCP counts, a modification of line transect sampling, are statistically more sound than point counts because they are adjusted for the probability of detecting birds at different distances and under different conditions (Burnham et al. 1981; Buckland et al. 1993; Fancy 1997). Point counts have been criticized as being scientifically unsound and unreliable (Burnham 1981) and can produce biased estimates of bird numbers and trends (Barker and Sauer 1995), and yet the use of point counts to quantify bird abundance and trends seems to be increasing (Ralph et al. 1995). One explanation for using point counts instead of distance estimation methods is that many studies cannot afford the expense of training and frequently recalibrating observers to estimate distances in the field (Pendleton 1995; Ralph et al. 1995), and some ornithologists believe that good estimates of bird density cannot be obtained because certain assumptions of the method are almost always violated (e.g., Bart 1985; Verner 1985; Buckland et al. 1993; McCracken 1994). Furthermore, field tests of the VCP method earlier in its development comparing results of density estimates using one method with those obtained using the VCP (e.g., DeSante 1981, 1986) produced variable and relatively poor results; however, none of these efforts had a known population size against which to measure error.

The VCP method involves estimating distances from the observer to all birds heard or seen within a 5 to 8 min. sampling period, and calculating the effective area surveyed at each sampling station from a function that gives the probability of detecting a bird at different distances (Buckland et al. 1993). One problem with VCP counts for most species is that it is rarely possible in a single survey to obtain a sample size large enough for a precise estimate of effective area. Buckland et al. (1993:302) recommended 60-80 detections as a practical minimum, but Verner (1985) found that 533 h of sampling would be required to obtain only 40 detections for some species. The approach described by Ramsey et al. (1987) and Fancy (1997) overcomes this problem by allowing data from many surveys to be pooled to estimate the effective area, and therefore makes it possible to estimate densities of even rare and endangered species; e.g., multiple linear regression is used to determine the effect of each covariate on detection area and regression coefficients are used to adjust detection distances in the pooled data set to a set of standard conditions (Fancy 1997).

Fancy (1997) described two field tests where density estimates derived by pooling detection distances from several VCP counts were compared to estimates obtained during studies of banded birds. In the first test, he found no differences among densities of 'Oma'o *Myadestes obscurus*, a solitaire endemic to the island of Hawai'i (Ralph and Fancy 1994), that were derived by three independent approaches: VCP counts, capture/recapture statistics, and the number of banded birds present (almost all resident 'Oma'o in the 16 ha study area were banded and closely monitored). In the second test, Palila *Loxioides bailleui* were translocated to an isolated stand of dry, open forest with distinct boundaries, and VCP density estimates

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differed from densities calculated from direct counts by 1-19% (Fancy *1997;* Fancy *et al. 1997)*. However, these field tests have the same flaw affecting most other comparisons in the literature: methods of estimation are compared with one another, not with an absolute standard (Verner and Ritter *1985)*. In this paper, we present results of the first field test of the VCP method where the exact density of birds in the wild was known. We also provide recommendations for analysis of VCP count data based on our experience with the method on Pacific islands.

STUDY AREA AND METHODS

We released 41 'Oma'o at the Pu'u Wa'awa'a Wildlife Sanctuary on the northern slope of Hualalai Volcano *(19° 44'N, 155° 53'W;* Fig. 1), where the species had been extinct since the early *1900s* (Scott *et al. 1986),* as part of a study comparing reintroduction and translocation methods. Methods for releasing and monitoring 'Oma'o were described by Fancy *et al. (1999)*. The study area was a mesic forest dominated by Ohia *Metrosideros polymorpha* and Koa *Acacia koa* trees, with a dense understorey of shrubs and ground ferns. Every 'Oma'o was intensively monitored using radio telemetry after its release, so that the number of 'Oma'o in the study area during VCP counts was known.

VCP counts were conducted on 13 August, *6* September, 10 December, and 11 December *1996* as additional 'Oma'o were released. Ten observers having >2 months familiarity with 'Oma'o calls and song, and trained in distance estimation for a minimum of two, *3* h sessions, estimated the distance to each 'Oma'o heard or seen within *8* min. sampling periods at stations on a *150* m grid extended from a single random point. Distance between stations was greater than twice the effective detection distance for 'Oma'o. In addition to 'Oma'o, four other species were recorded: 'Elepaio *Chasiempis sandwichensis,* Hawai'i Amakihi *Hemignathus virens,* Akepa *Loxops coccineus coccineus,* and Hawai'i Creeper *Oreomystis mana*. Each observer completed between *9* and 11 counts per morning, and *5-6* observers counted each census. Observer effort ranged between *9* and *40* counts for the four censuses combined. Observers recorded the initial distance from the station of any bird that flushed prior to the count, and began counts upon reaching the count station. During the first two surveys, we conducted counts from *45* stations located on a *150* m grid where all 'Oma'o were released. Areas immediately west and north of this sampling area had an open canopy and grass understorey because of recent cattle grazing, and were rarely used by 'Oma'o during the study.

'Oma'o also rarely used the area upslope from the release sites where mesic Ohia forest graded to drier shrubland dominated by Pukiawe *Styphelia tameiameiae,* Figure 1. For the two counts in December, we increased the size of the area sampled (n = 66 stations) because several 'Oma'o had moved near or outside (<= 150 in) of the original study area boundaries (Fig. 1). Telemetry data indicate 'Oma'o did not use areas 75 m beyond the study area boundaries during count periods. For each analysis, we included a 75 m buffer zone of similar habitat around the perimeter of the area counted when calculating total area surveyed. Data were analysed using the programme DISTANCE (Laake *et al.* 1994) after pooling detection distances from multiple surveys as described by Fancy (1997).

RESULTS

Total number of 'Orna'o detections was 43 for the four surveys combined (Table 1). 'Oma'o were not evenly distributed over the study area, and one observer detected 19 'Oma'o during the four surveys; mean number detected was 4.3 per observer for the four surveys. Because the number of 'Oma'o detected at Pu'u Wa'awa'a was too small to calculate a detection function, we pooled detection distances from Pu'u Wa'awa'a with a much larger sample of 'Oma'o detection distances from surveys in similar habitat at the Hakalau Forest National Wildlife Refuge, the source population for some of the 'Oma'o re-established at Pu'u Wa'awa'a. The pooled data set of 3,146 detection distances was analyzed as grouped data with 11 intervals of 11m each to lessen the effects of heaping (rounding off to the nearest 5 m) and errors in estimating distances (Buckland *et al.* 1993:111). The detection function with the best fit to our detection distances, based on a half-normal distribution, calculated an effective detection radius of 64.5 m +- 1.2 SE. No adjustments were made for the effects of different observers, weather conditions, or other covariates on detection distances because of the small number of 'Oma'o detections for Pu'u Wa'awa'a.

The true number of 'Oma'o present in the study area fell within the 95% confidence intervals estimated by the VCP method for all four surveys (Table 1). We detected four 'Oma'o during the first VCP survey, resulting in a population estimate of seven 'Oma'o, even though only two 'Oma'o were actually present. Bias caused by repeated counting of the same individual is usually small (Buckland *et al.* 1993:37), but in this case three of the four detections were of the same bird from three adjacent stations, and population size was greatly overestimated. Population estimates for surveys on 10 and 11 December 1996 when 25 'Oma'o were present differed by only 11% (t = 0.31, 130 df, P = 0.76), and overestimated true population size by 23.8% and 10.0%.

DISCUSSION

Excluding the first survey, density estimates by the VCP method differed from true densities by -34 to +24%, even though fewer than 20 birds were detected during each survey. Density estimation gave results within 1/3 of actual numbers for >=13 birds present and density >=0.1/birds/ha. This is probably the best that can be hoped for with this level of sampling effort, despite the fact that 'Oma'o are loud, sedentary, and relatively slow-moving, and therefore well-suited to density estimation. Ninety-five per cent confidence intervals show possible errors as great as a factor of one when actual numbers present are between 13 and 25 birds. For our first survey, we greatly overestimated true numbers of 'Oma'o because of double detections. Overestimation in three of the four censuses, and the large error for our first survey, suggest errors for density estimates may be higher when numbers of birds are extremely low and/or the effective detection radius used approaches half the distance between count stations, thus the distance between stations should be greater than twice the mean effective detection distance to minimize the chance of counting the same bird twice. Difference between estimates for the last two surveys was only 11%, and mean error for the last three surveys was 0%. When census information is critical and extra census effort can be justified, as for endangered species and key populations, we anticipate the mean for multiple surveys spaced closely in time will approach true densities.

Differences between actual and estimated densities would have been much greater had we not pooled data from multiple surveys to develop an effective detection radius for 'Oma'o in mesic Ohia forest. The number of detections during any one survey (maximum = 18) made it impossible to develop a precise detection function without pooling, and only 43 'Oma'o, much fewer than the 80-100 detections recommended by Buckland *et al*. (1993), were detected at Pu'u Wa'awa'a when data from all four surveys were combined. If the detection function had been based only on the 43 detection distances recorded at Pu'u Wa'awa'a, effective detection radius would have been 49.8 m ± 2.6 SE, and true density would have been overestimated by 477%, 11%, 108%, and 85%, respectively, for the four surveys. This result emphasizes the importance of obtaining large samples for estimating the effective area surveyed, as discussed below.

For some species, violation of important assumptions because of undercounting and mis-identifying birds, movement of birds during the count period, and large errors in distance estimates makes it impossible to obtain accurate density estimates (Bart 1985; Verner 1985; Buckland *et al.* 1993; McCracken 1994), and we agree with Verner (1985) that estimates of density are unnecessary for many types of studies. However, point counts suffer from most of the same problems, and density estimates are superior to total counts, even as indices of relative abundance, because density estimation methods make some adjustment for differences in detectability (e.g., Ramsey and Scott 1979; Burnham *et al.* 1980; Verner and Ritter 1985; Buckland *et al.* 1993). Further, density estimates are most appropriate when the objectives of a study include comparisons between species or within species in different habitats or times of year, because they can adjust for detectability for season, species, habitat, or other effects. Our findings support the view of McCracken (1994:177), who concluded from simulation studies that "Variable area density estimates are reliable when a sufficient number of birds are detected, critical assumptions are valid, and extreme conditions are absent."

Buckland *et al.* (1993) considered three assumptions to be essential for reliable estimation of density from line transect or variable circular-plot sampling: (1) objects directly on the line or point are always detected (i.e., g(0) = 1); (2) objects are detected at their initial location, prior to any movement in response to the observer; and (3) distances are measured accurately (ungrouped data) or placed within the proper distance interval (grouped data). All three assumptions can be relaxed by analyzing data as grouped data, which we always recommend. We discuss these critical assumptions in light of our experiences with collecting and analyzing data from VCP counts on Pacific islands.

Assumption I is the most critical but may be violated if a bird flushes from the counting point as an observer approaches. With grouped data, this is not a problem if the bird does not move beyond the first grouping interval. We recommend that observers approach the counting station vigilantly and record the initial distance from the station for any bird that flushes prior to the count; counts should begin as soon as the observer reaches the station and is ready to begin. The alternative approach is to wait for several minutes after reaching the station before starting the count, but this approach is likely to underestimate bird density near the station because of birds flushing as the observer approaches.

Grouping of data also relaxes Assumptions 2 and 3 above. Grouping reduces errors associated with estimating distances in the field and the tendency of observers to round off to the nearest 5 or 10 m (heaping). We recommend analyzing data using distance intervals that are not a multiple of 5 m (e.g., 6 m or 17 m, depending on which interval provides the best model fit to the detection function), but this should be done after field crews estimate distances to the nearest meter and without their knowledge of the interval used.

Our experience from working with different data sets is that inherent differences in visual and aural acuity among observers has a greater effect on number of birds counted and detection distances than any other factor (Scott *et al.* 1986). The "observer effect" can best be minimized by extensive observer training (Faanes and Bystrak 1981; Kepler and Scott 1981; Ramsey and Scott 1981b), and collection of a large number of detection distances, if necessary by pooling data from multiple surveys collected under similar conditions in the same habitat. We have found that most observers are able to estimate distances to within 10% after only a few hours of training (Scott *et al. 1986)*. Buckland *et al. (1993)* concluded that if distance estimates are unbiased on average, measurement errors must be large to be problematic, and we believe that distance estimation errors of this magnitude are acceptable.

CONCLUSION

We believe that recent advances in methods for analyzing VCP count data and evaluations of the method and its assumptions justify increased use of distance estimation procedures. It is critical that certain assumptions be met for density estimates to be reliable. For some species, movement during the count period, large errors in distance estimates, undercounting, or misidentification,, make it impossible to obtain accurate density estimates, and for species with a large effective detection radius, inter-station distances may have to be calibrated to reduce double detections. Pooling data allows determination of a more accurate detection radius and makes possible density estimates for rare or endangered species; however, density estimates are reliable only when a sufficient number of birds are counted. We always recommend analyzing data as grouped data because this procedure relaxes three key assumptions: that objects at the point are always detected, objects are detected at their initial location, and distances are measured accurately. Of the three censuses of 'Oma'o at Pu'u Wa'awa'a for which above conditions were met, estimated density was within 1/3 true density. This level of accuracy is encouraging, and recommends the VCP method for census of low density avian populations which meet key assumptions for detectability and movement behaviors.

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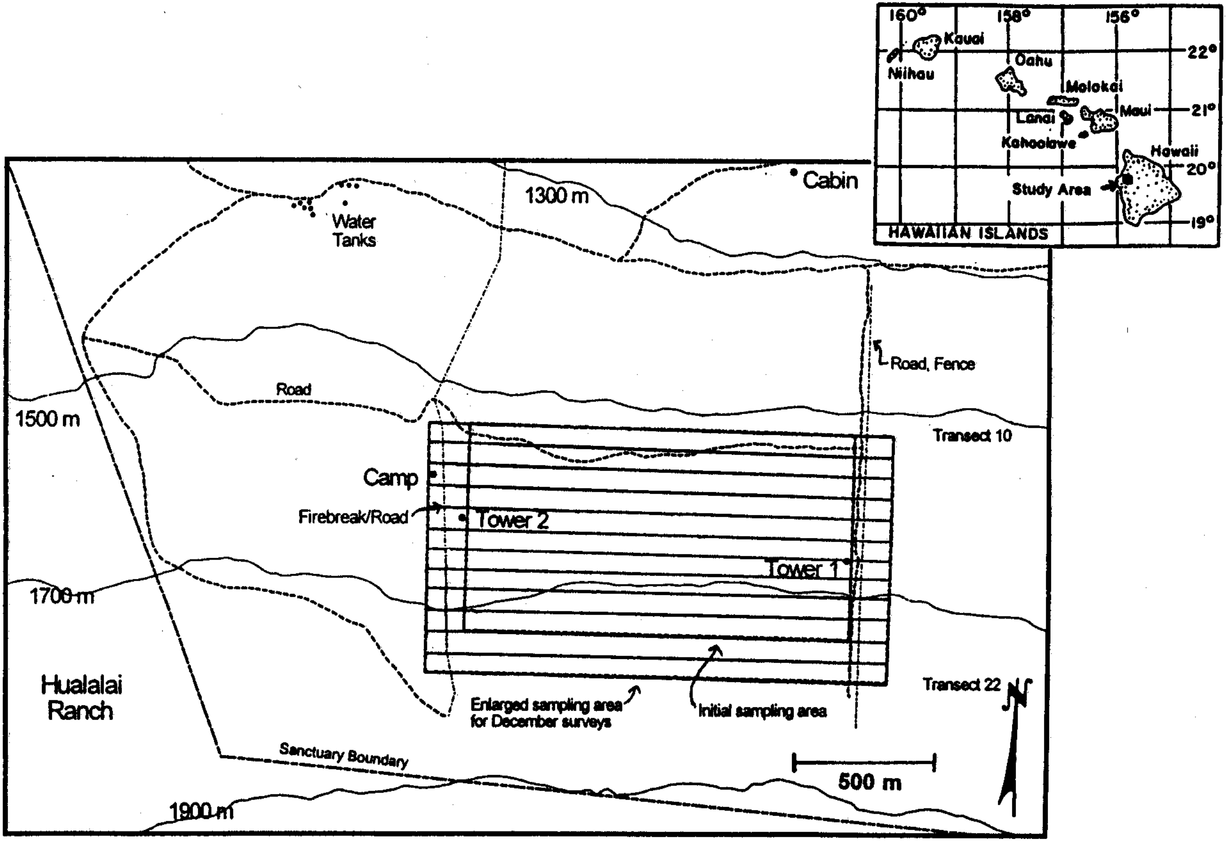

Fig. 1. Location of study area on Hualalai Volcano, Hawai`i, for test of variable circular-plot method.

Table 1. Comparison of population estimates based on variable circular-plot counts with actual number of \`Oma\`o present at the Pu\`u Wa\`awa\`a Wildlife Sanctuary, Hawai\`i.

Survey date	Stations sampled	\`Oma\`o detected	Actually present	Population estimate[1] Mean	SE	95% CI	Per cent difference
13 Aug. 1996	45	4	2	6.9	3.3	0.3–13.5	243.9
6 Sept. 1996	45	5	13	8.6	4.4	0–17.4	–33.9
10 Dec. 1996	66	18	25	31.0	8.3	14.2–47.8	23.8
11 Dec. 1996	66	16	25	27.5	7.4	12.7–42.4	10.0

[1]Using programme DISTANCE (Laake *et al.* 1994).