

A FIELD EVALUATION OF TECHNIQUES USED TO ESTIMATE DENSITY OF BLUE JAYS

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Abstract.—We evaluated the ability of three techniques to estimate density of Blue Jays (*Cyanocitta cristata*) on a series of 3.1-ha plots in eight habitat types in south-central Florida. Estimates generated from fixed-radius point counts ($r = 30$ m and 100 m) and the variable circular-plot technique were compared to actual density of adult jays as measured from number of active nests in each plot during the study period. Based on analyses at the level of the plot ($n = 29$), estimates from all three techniques were positively correlated with actual density ($r_s \geq 0.53$, $P \leq 0.003$). On average, the 100-m fixed-radius technique underestimated density ($P = 0.008$), whereas the other techniques neither under-nor overestimated density ($P > 0.4$). The slope of the regression of estimated density on actual density was significantly less than 1.0 for the 100-m fixed-radius ($P < 0.001$) and variable circular-plot ($P = 0.001$) techniques, indicating those techniques tended to overestimate density when actual density was low, and underestimate density when actual density was high. Magnitude of error increased with actual density for all three techniques. Overall variability in density estimation was greater for the 30-m fixed-radius technique; however, because the direction of error was random across the range of actual density, correlations between estimates and actual density for this technique were stronger than for other techniques when plot-based values were averaged across habitats. Overall, the 30-m fixed-radius technique performed better than the other techniques based on analyses at both the levels of plot and habitat.

EVALUACIÓN DE CAMPO DE LAS TÉCNICAS UTILIZADAS PARA ESTIMAR LAS DENSIDADES DE *CYANOCITTA CRISTATA*

Sinopsis.—Evaluarnos la habilidad de tres métodos para estimar la densidad de *Cyanocitta cristata* en una serie de parcelas de 3.1 ha en ocho tipos de habitat diferentes en la Florida sud-central. Los estimados generados de conteo de mpuntos usando radios fijos ($r = 30$ m y 100 m) y la técnica con parcelas circulares variables se compararon con la densidad actual de aves adultas tomadas del número de nidos activos en cada parcela durante el periodo de estudio. Basándonos en el análisis a nivel de la parcela ($n = 29$), los estimados de las tres

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técnicas fueron correlacionados positivamente con la densidad actual ($r_s \geq 0.53$, $P \leq 0.003$). En general, la técnica del radio fijo de 100 m subestimó las densidades ($P = 0.008$), mientras que las otras técnicas ni subestimaron ni sobreestimaron las densidades ($P > 0.4$). La pendiente de la regresión de densidad estimada contra densidad actual fue significativamente menor que 1.0 para las técnicas del radio fijo de 100 m ($P < 0.001$) y de las parcelas de círculos variables ($P = 0.001$), indicando que esas técnicas tienden a sobreestimar densidades cuando las densidades son bajas, y de subestimar densidades cuando la densidad actual era alta. La magnitud del error aumentó con la densidad actual para las tres técnicas. La variabilidad general al estimar densidad fue mayor para la técnica del radio fijo de 30 m; sin embargo, como la dirección del error era aleatoria a través del alcance de densidad actual, las correlaciones entre los estimados y la densidad actual para esta técnica fueron mayores que para las otras técnicas cuando los valores basados en parcelas se promediaron entre hábitats. En general, la técnica del radio fijo de 30 m fue más efectiva que otras técnicas basadas en análisis tanto al nivel de parcela como al de hábitat.

Many studies characterize how density of avian populations varies across environmental conditions or through time. Consequently, ornithologists have searched for methods of estimating bird densities that may be conducted easily and rapidly and yield accurate results (e.g., Emlen 1971, Fowler and McGinnes 1973, Kendeigh 1944, Ralph and Scott 1981, Williams 1936). Unfortunately, the efficacy of most techniques is poorly understood. Here we evaluate the efficacy of 30-m and 100-m fixed-radius point counts and the variable circular-plot method, three techniques commonly used to estimate bird density, by comparing estimates generated from them to actual density of breeding Blue Jays (*Cyanocitta cristata*) across an array of habitats in south-central Florida.

The evaluations presented here provide a measure of the efficacy of point counts when applied to relatively large, essentially non-territorial, and highly mobile passerines. Such an evaluation of the techniques is valuable for at least the following reasons. (1) Although many studies have compared various density estimating techniques (e.g., Anderson and Ohmart 1981, Edwards et al. 1981, Hamel 1984, Hutto et al. 1986, Szaro and Jakle 1982, Verner and Ritter 1985, 1988), we know of only two that evaluated techniques by comparing estimates of density generated from them to independent, reliable density values (DeSante 1981, 1986), and each tested only the variable circular-plot method. (2) Although the variable circular-plot technique is designed to reduce bias imposed by variation in habitat structure (Reynolds et al. 1980), density estimates generated from point count data have yet to be compared with actual density values for a single species across a range of habitats. (3) Blue Jays are perhaps typical of medium to large passerines in that their home range is larger than the plot size or range of detectability reported in many studies estimating abundance of species in avian communities (e.g., Granholm 1983, Hutto et al. 1986, Szaro and Jakle 1982) and studies evaluating efficacy of census techniques with such species are rare. (4) Density of Blue Jays has been of interest in several studies designed to determine changes in avifauna or relative abundance of potential nest predators in different habitat types or under varying levels of human influence (e.g., Engels and Sexton 1994, Greenberg et al. 1995, Lent and Capen 1995, White et al. 1996, Wilcove 1988).

In the present study we did not test the spot-map method, another commonly used technique, because home ranges of individual Blue Jays overlap substantially, jays often share what appear to be communal foraging areas (Cox 1984, Hardy 1961), and jays do not sing or engage in conspicuous territorial displays. Thus, we suspected *a priori* that spot-mapping was inappropriate for estimating Blue Jay density.

METHODS

Study site.—We conducted our study at Archbold Biological Station, Highlands County, Florida. We identified eight habitat types used by Blue Jays at Archbold (Woolfenden 1969; K. A. Tarvin, unpubl. data). Blue Jay nests have been recorded from each of the eight habitats, although the jays nest in some only infrequently. Descriptions of habitat characteristics are presented in Table 1. Photographs of sandpine, scrubby flatwoods, ridge sandhill, and bayhead habitats appear in Woolfenden (1969).

Study species.—Between 50% and 75% of the Blue Jays inhabiting Archbold at the time of this study were individually color-marked. Adult Blue Jays at Archbold are year-round residents that are relatively sedentary throughout the year (K. A. Tarvin and G. E. Woolfenden, unpubl. data). Although breeding pairs weakly and inconsistently defend small areas during the breeding season (Hardy 1961), home ranges overlap (Cox 1984, Hardy 1961). Published information regarding territory or home range size of Blue Jays is non-existent, but our observations indicate that the home range of Blue Jays at Archbold varies from 3–20 ha, depending on the individual, habitat type and season. Even so, we have found up to four simultaneously active nests within a radius of 75 m in some areas.

Measuring actual density of breeding pairs.—We determined density of breeding jays within a set of 3.1-ha circular plots (radius = 100 m). We used aerial photographs to determine the number of non-overlapping 3.1-ha circular plots that could be established in each of eight habitat types at Archbold. Within each habitat type, all potential plots were numbered, and four were selected at random to be sampled (only two potential plots were representative of bayhead habitat; both were used as sample plots) for a total of 30 plots. A plot size of 3.1 ha was chosen as a compromise between the need for plots large enough to contain multiple breeding pairs, yet small enough that we could find all active nests within the plot given the available person-hours during the study period. Although size of our plots was perhaps smaller than optimum, the sampled plots contained between 44% and 100% of the habitat available for sampling in five of the eight habitat types (Table 2). Our sampling method may not accurately represent the mean and variance of actual Blue Jay density in the remaining habitats, but measured means and variances of Blue Jay densities in those habitats were low (Tables 1 and 2).

Parties consisting of 1–5 persons searched plots for nests during mornings and late afternoons from 20 Mar.–31 May 1995. During a search, we positioned ourselves such that, with minimum movement, at least one of us would be able to see any jay moving through the plot or hear its

TABLE 1. Characteristics of habitat types sampled in this study.

Habitat ^a	Description	Nests per plot	Range of detectability (m) ^b
Bayhead	Mesic forest dominated by large slash pines (<i>Pinus elliottii</i>) forming a distinct canopy over tall, dense midstory and shrub layers.	2-5	40
Sandpine	Xeric forest dominated by large sand pines (<i>P. clausa</i>) forming a distinct canopy over a tall, dense shrub layer.	0-3	100
Ridge Sandhill	Xeric forest dominated by slash pines and sand pines of variable age. Shrub layer variable in height, with occasional small, open patches of wire grass (<i>Aristida stricta</i>), lichens (<i>Cladonia</i> spp.), and bare sand.	0-2	100
Flatwoods	Mosaic of communities with a patchy overstory dominated by slash pine. Shrub layer patchy. Where shrubs not present, ground cover comprised of grasses, St. John's Wort (<i>Hypericum</i> spp.), or bare sand.	0-1	200 ^c
Park	Human modified landscape consisting of a patchy canopy of large slash pines, low grasses, and occasional patches of dense shrubs.	2-3	50
Pasture	Human modified landscape consisting of improved pasture grasses with intermittent slash pines.	1-2	100
Scrubby Flatwoods	Low open shrub layer consisting primarily of oaks and palmettos. Few pines scattered through habitat. Small seasonal ponds scattered infrequently.	0	300
Burned Areas	Recently burned ridge sandhill habitat. Few live pines remaining; shrub layer consisting of resprouted vegetation, generally 0-1.5-m high with infrequent patches 2-4-m tall.	0	300 ^c

^a Habitat designations modified from Abrahamson et al. 1984.

^b Calculated following Reynolds et al. 1980.

^c Habitat type extended only about 100 m from the plot centers in these habitats.

intrapair calls (*kut* or *kuet* calls; Hardy 1961). Each observer was responsible for a sector of the plot, and the sector monitored by one observer slightly overlapped sectors monitored by other observers. Plots having vegetation structure that limited our ability to see jays from long distances or travel through quickly and easily were searched by parties of three or four (rarely five) members; plots easy to move through with midstories and canopies that did not obstruct our views were searched by parties of one or two. We searched each plot multiple times during the study period for a total of more than 480 person-hours.

TABLE 2. Sampling intensity used to measure estimated and actual density of Blue Jays in different habitats, March through May, 1995.

Habitat ^a	Plots per habitat	Potential plots per habitat ^b	Point counts		Nest searches	
			Point counts per plot	Total registrations ^c	Observers per search	Total person-hours
Bayhead	2	2	7-8	37	3-5	60
Sandpine	4	7	6-8	79	3-5	112
Ridge Sandhill	4	8	5-8	80	3-5	105
Flatwoods	4	23	4-7	31	1-3	55
Park	4	7	5-8	82	2-4	86
Pasture	4	18	3-6	22	1	21
Scrubby Flatwoods	4	55	3-5	10	1-2	18
Burned Areas	4	9	4-5	45	1-2	26

^a Habitat designations modified from Abrahamson et al. 1984. See Table 1 for habitat descriptions.

^b Represents number of 3.1-ha circular plots (radius = 100 m) that could fit entirely within a given habitat type. Thus, the total amount of each habitat on the study site is underestimated by the number of potential plots that could be established within them.

^c Includes all detections, regardless of distance.

We calculated actual density of breeding Blue Jays by multiplying the number of nests in each plot by 2 to account for both members of the breeding pair. This measure may overestimate absolute density because jays nesting within plots likely spend some time outside those plots. However, because our plots were chosen using a stratified random procedure, we expect such error to be mediated by jays that spend time within plot boundaries, yet nest outside the plot. Our method may underestimate absolute density if non-breeding jays spend most of their time within plots. Because plot size was constant, we report all densities as number of individuals per 3.1-ha plot.

Field methods used to estimate density.—Densities of breeding Blue Jays were estimated using 8-min point counts conducted by a single observer from the center of the plot. Point counts were conducted at the beginning of nest searches, after party members settled into their respective sectors, usually within 1-5 min of our arrival on the plots. Most of the counts (64%) began between 0500-1100 h EST; the remainder started between 1530-2000 h. We did not attempt to randomize the timing of point counts across plots because analyses of point count data collected on the same study site in 1993 and 1994, in which the order of counts was assigned randomly within the same time frames used in the present study, revealed no significant influence of time of day on total number of Blue Jay detections (K. A. Tarvin, unpubl. data). A count of 8 min was a compromise between an attempt to avoid counting individuals more than once, and an attempt to increase the likelihood of detecting Blue Jays during a given count (Granholm 1983, Scott and Ramsey 1981). During point counts, all individual Blue Jays detected visually or aurally were tallied, and dis-

tance from observer was estimated. Each plot was sampled from 3–8 times during the study period for a total of 165 counts (Table 2). KAT conducted 62% of the point counts; the remainder were conducted by JMJ, KAD, and MCG. We did not attempt to control for observer bias.

Generation of density estimates.—We estimated density in three ways.

(1) 30-m fixed-radius point count: Some studies using fixed-radius point counts use a radius that is small relative to the home range, and perhaps detectability, of Blue Jays (e.g., Fowler and McGinnes 1973, Granholm 1983, Hutto *et al.* 1986, Szaro and Jakle 1982). To evaluate the efficacy of such a method when applied to large birds, our first technique considered only Blue Jays detected within 30 m of plot centers. We calculated the mean number of jays detected at each site over the 2.5-mo sampling period, and standardized resulting values to number of jays per 3.1 ha to facilitate comparison with other techniques.

(2) 100-m fixed-radius point count: A 30-m radius is small relative to the home range of Blue Jays, and is unlikely to contain more than a single breeding pair. Thus, as a second technique, we considered all jays detected within 100 m of plot centers and calculated the mean number of jays detected at each plot over the sampling period. A plot with a radius of 100 m is equal to 3.1 ha; therefore, standardization of mean values was unnecessary.

(3) Variable circular-plot: We tested the efficacy of the variable circular-plot technique (Reynolds *et al.* 1980) by using point count data to calculate the distance at which our ability to detect Blue Jays declined in each habitat. For each plot, we calculated the mean number of jays detected within the habitat-specific sampling area (Table 1), then standardized those values to jays per 3.1 ha. The calculated range of detectability in two habitats (flatwoods, burned areas) extended well beyond the boundaries of the habitats themselves (i.e., the range of detectability in plots in those habitats extended through more than one habitat type). In those cases, we considered only jay detections that fell within the largest radius that remained within the focal habitat in all directions, ensuring that our density estimates were based on detections of jays within the focal habitats.

Analysis.—Because values of actual density were not distributed normally, and we found no transformations that rendered them normal, we used nonparametric statistics for most tests. We evaluated four aspects of each technique. First, we used Spearman's rank correlation coefficients to test whether density estimates generated by each technique were significantly correlated with actual density across plots. Second, we tested whether, on average, a given technique over- or underestimated density by using the Wilcoxon matched-pairs signed-ranks test for paired observations to compare estimated and actual density values across plots. Third, we wished to know whether error associated with estimates generated from each technique varied across the range of actual density. We defined error e as

$$e = d_e - d_a$$

where d_e = estimated density and d_a = actual density. To test whether the direction of error varied across the range of actual density, we used Spearman's rank correlation to test for a relationship between e and actual density. This procedure is analogous to a nonparametric method described by Conover (1980: 266) to test whether the slope of the regression of one variable on another is different from a hypothesized slope of 1.0. We also used Spearman's rank correlation to determine whether the magnitude of error (the absolute value of e) varied with actual density. Finally, we used linear regression to generate a coefficient of determination to index the overall variability in density estimates from each technique.

In addition to plot-based analyses, we used Spearman's rank correlation to examine relationships among density estimates, error, and actual density at the level of habitat. Because the sample size for such analyses was 8, we lacked sufficient statistical power to perform further habitat-based analyses.

We attempted to evaluate the extent to which habitat complexity imposed error on our density estimates. Aerial photographs were used to delineate regions of contiguous forest canopy cover, and a geographic information system was used to calculate the total area of each plot covered by forest canopy. We used Spearman's rank correlation coefficients to examine relationships among forest canopy cover, jay detectability, and jay density.

RESULTS

We found Blue Jays nesting in 16 of the 30 plots. We found no nests in burned or scrubby flatwoods habitats. One plot in bayhead habitat contained five nests but was determined to be an outlier (Grubbs' statistic for outliers = 3.185, $P < 0.01$; Sokal and Rohlf 1981: 413) and was not included in analyses. In remaining habitats, the number of nests per plot ranged from 0–3 (Table 1). Actual density of Blue Jays varied significantly across habitats (Kruskal-Wallis $\chi^2 = 18.43$; $df = 7$; $P = 0.01$). Density estimates also varied across habitats (30-m fixed-radius: $\chi^2 = 16.84$, $P = 0.02$; 100-m fixed-radius: $\chi^2 = 19.15$, $P = 0.01$; variable circular-plot: $\chi^2 = 21.01$, $P = 0.004$); however, rank of habitats by density varied among techniques.

Density estimates from each of the three techniques were positively correlated with actual density (Table 3). Estimates varied substantially in accuracy, and in both direction and magnitude of error. Neither the 30-m fixed-radius nor the variable circular-plot techniques over- or underestimated density overall, although the 100-m fixed-radius point count significantly underestimated density on average (Table 3). The slope generated from the regression of estimated density on actual density differed from 1.0 for both the 100-m fixed-radius and variable circular-plot techniques, indicating they tended to overestimate density when actual density was low, and underestimate density when density was high (Table 3, Figs.

TABLE 3. Comparison of trends in density estimates with actual density of Blue Jays across twenty-nine 3.1-ha plots.

Technique	r_s (P) ^a	Z (P) ^b	Slope (b)		r^2 ^c
			b^c	P ($b = 1$) ^d	
30-m fixed-radius	0.53 (0.003)	0.53 (0.599)	0.86	0.334	0.33
100-m fixed-radius	0.59 (0.001)	-2.66 (0.008)	0.26	<0.001	0.42
Variable circular-plot	0.64 (<0.001)	-0.83 (0.409)	0.66	0.001	0.42

^a Spearman's rank correlation (2-tailed test).

^b Wilcoxon's matched-pairs signed-ranks test (2-tailed test).

^c Derived via least squares estimation using actual density as the independent variable. In all cases slopes were different from 0 (2-tailed $P \leq 0.003$).

^d Nonparametric test of slope (2-tailed test) from Conover (1980: 266).

1 and 2). The slope for the 30-m fixed-radius technique did not differ from 1.0 (Table 3, Figs. 1 and 2). Magnitude of error, however, increased significantly with actual density for all three techniques (Fig. 3). The 30-m fixed-radius point count was the most variable of the three techniques, giving rise to the lowest coefficient of determination (Table 3).

Habitat-level analyses indicated all three techniques generated estimates that were significantly correlated with actual density (Fig. 4). The slope for the 100-m fixed-radius technique was significantly less than 1.0, indicating the direction of error of estimates from this technique was influenced by the magnitude of actual density (Fig. 4). Direction of error of estimates was not related to actual density for the remaining techniques (Fig. 4).

Sources of error.—Error in density estimates became greater as actual density increased, and in some cases was directional. If high-density habitats (e.g., bayhead, park) were more heavily forested than low-density

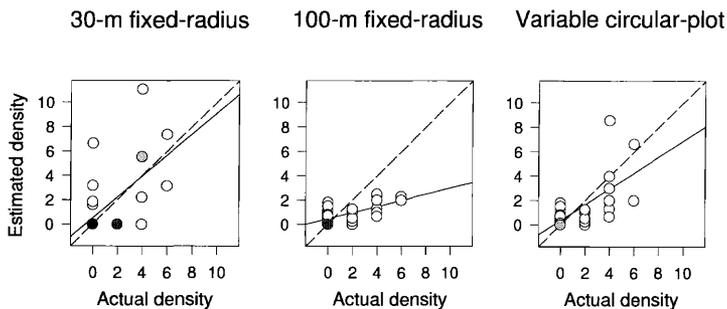


FIGURE 1. Efficacy of three density estimating techniques. Dashed lines represent a slope of 1.0 (perfect congruence between a density estimator and actual density); solid lines represent the least squares regression line through the data. Slopes for the 100-m fixed-radius and variable circular-plot techniques differ from 1.0 (see Table 3). For each graph, $n = 29$ 3.1-ha plots. Open circles represent 1-2 plots, light gray dots represent 3-4 plots, dark gray dots represent 6 plots, and the black dot represents 10 plots.

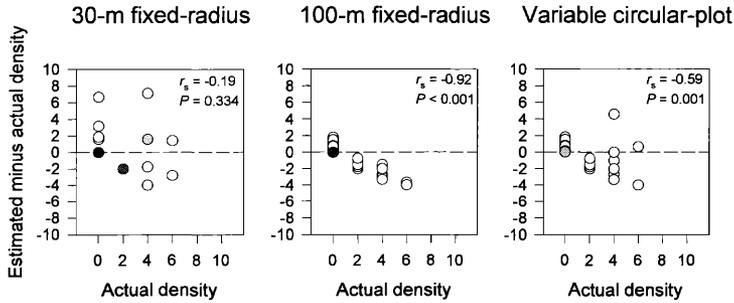


FIGURE 2. Relationship between the direction of error associated with density estimates and actual density for three density estimating techniques. Overestimates appear above the dashed line, underestimates appear below the line. For each graph, $n = 29$ 3.1-ha plots. Open circles represent 1-2 plots, light gray dots represent 3-4 plots, dark gray dots represent 6 plots, and the black dot represents 10 plots. Spearman's rank correlation coefficients and associated 2-tailed probability values are also shown.

habitats, the pattern of error could be explained as a decrease in detectability resulting from increasing habitat complexity. To evaluate this possibility, we tested for a positive correlation between percent canopy cover within plots and actual density of jays. The correlation was not significant ($n = 29$ plots, $r_s = 0.32$, 2-tailed $P = 0.094$), but the power of the test was low. Thus, habitat effects may have been in part responsible for the pattern of error.

Range of detectability was correlated inversely with amount of forest canopy cover ($n = 29$ plots, $r_s = -0.51$, 2-tailed $P = 0.004$; see also Table 1). However, range of detectability also was correlated inversely with mean density of jays across habitats ($n = 29$ plots, $r_s = -0.75$, 2-tailed $P < 0.001$), indicating differences in detectability among habitats may reflect differences in actual density as well as differences in habitat structure.

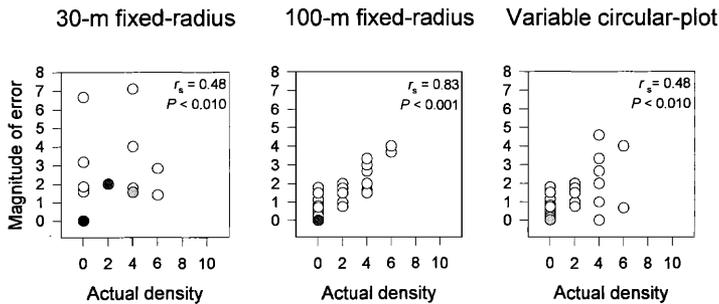


FIGURE 3. Relationship between the magnitude of error associated with density estimates and actual density for three density estimating techniques. Error is measured as the absolute value of the difference between estimated and actual density. Open circles represent 1-2 plots, light gray dots represent 3-4 plots, dark gray dots represent 6 plots, and the black dot represents 10 plots. Spearman's rank correlation coefficients and associated probability values are also shown.

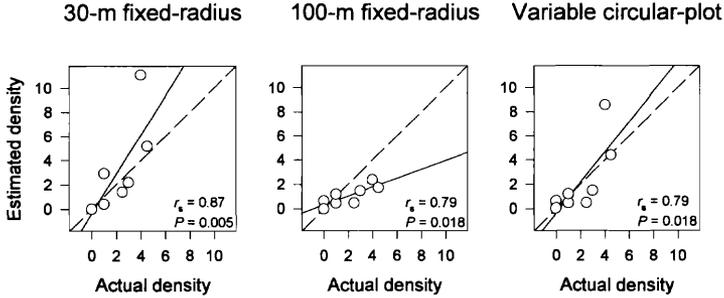


FIGURE 4. Efficacy of three density estimating techniques when data from plots are averaged across eight habitats. Dashed lines represent a slope of 1.0, or of perfect congruence between a density estimator and actual density; solid lines represent the least squares regression line through the data. The slope for the 100-m fixed-radius technique is different from 1.0 ($P = 0.005$); slopes for the others do not differ from 1.0 ($P > 0.66$). Spearman's rank correlation coefficients and associated 2-tailed probability values for the relationship between estimated and actual density are also shown.

If Blue Jays are repulsed by the presence of observers, the number of observers in plots during point counts also could account for the discrepancies between estimates and actual density, because nest-searching parties tended to be larger in more complex habitats (Tables 1 and 2). If repulsion occurred, we might expect negative correlations between mean number of observers per plot and density estimates. However, mean number of observers per plot was positively correlated with density estimates generated from all three techniques (for each technique, $n = 29$ plots, $0.71 > r_s > 0.54$, 2-tailed $P \leq 0.002$). The positive correlations likely reflect the positive relationships between density estimates and actual density, rather than the attraction of jays to observers.

DISCUSSION

The value of our analyses is dependent on whether our measures of actual density were accurate. We are confident that we found all active nests within each plot during the study period. Blue Jays emit conspicuous calls (*kut* or *kuet* calls, Hardy 1961) during nest building and provisioning. Such calls may be detected from more than 70 m distant, even in habitats having complex structure. Furthermore, male jays at Archbold typically provision incubating females at a rate greater than once per hr (K. A. Tarvin and M. C. Garvin, unpubl. data). Because our nest searches were typically 1 hr in duration, because the duration of successful jay nests at Archbold is about 40 days post-laying plus a 1–3 wk building period (K. A. Tarvin, unpubl. data), and because we visited each plot at least once per week, we are unlikely to have missed nests.

Although each of the three density estimating techniques reflected general trends in actual density, each suffered shortcomings in the form of inconsistent responses across the range of actual density and high overall variability in predictive power. The 30-m fixed-radius technique exhibited

the best overall performance of the three techniques because its estimates were correlated with actual density, the rate of increase of its estimates more closely tracked the rate of increase of actual density, and it neither over nor underestimated actual density on average. Although the magnitude of error associated with the 30-m fixed-radius technique increased with actual density, the direction of error was random, giving rise to a stronger correlation between estimated and actual density when averaged across habitats than was found for the other techniques.

Error associated with estimates generated from the 100-m fixed-radius technique, and to a lesser extent, the variable circular-plot technique, was strongly affected by actual density, a pattern reflecting a decrease in detection efficiency as the number of jays present increases (Bart and Schoultz 1984). The pattern indicates that small but real differences in density across habitats may not be detected by these techniques because the magnitude of errors of underestimation increases as density increases. Differences in habitat-specific density that are detected may be considered real, however, because the character of error was fairly consistent as density increased.

The greater or lesser tendency of each technique to overestimate density when actual density is low is probably best explained by the fact that jays may forage in habitats in which they rarely nest. This seemed especially true for several plots in ridge sandhill and burned habitats that were adjacent to citrus groves, and in scrubby flatwoods habitats adjacent to flatwoods. On several occasions in different habitats, we noticed flocks of 4–8 jays moving through plots and away from groves. Jays in those flocks may have been breeding in the groves or may have been floaters that were foraging in native vegetation. Similarly, jays moving through scrubby flatwoods habitats to reach patchily distributed flatwoods may register on point counts, even though the time they spend in scrub is relatively short.

Other assumptions associated with point count techniques, especially the variable circular-plot, were not met, and conceivably, those violations could have led to errors in our estimates. Most observations that occurred during late morning or early afternoon took place in habitats which we knew *a priori* had few jays, and in which no nests were found (scrubby flatwoods, burned areas). Density estimates from plots in those habitats actually were inflated relative to actual density, contradicting predictions based on effects of time of day (Blake 1992, Grue et al. 1981, Robbins 1981, Skirvin 1981, but see Gutzwiller 1993). The most important bias in our study probably arises from differences in the ability of observers to detect Blue Jays and estimate distances (Cyr 1981, Scott et al. 1981, Verner and Milne 1989). The magnitude of errors associated with such differences in our study is unknown. Additional error may have emerged because, after reaching a site, we usually waited for a short period of time for observers to settle in plots for nest searching prior to beginning the point count. Repulsion of jays from the center of plots during this short period could lead to underestimations of density (Verner 1985).

Studies by DeSante (1981, 1986) examined the efficacy of the variable circular-plot technique at estimating density of multiple species within a single habitat type. Our findings are similar to those of DeSante in that the variable circular-plot technique tended to overestimate density when density was low, and underestimate density when it was high. Our results differ from those of DeSante in that, overall, the technique did not underestimate density. The variable circular-plot technique is generally thought to be more suitable for estimating relative abundance of birds across habitats than are fixed-radius point counts, because the former employs the use of habitat-specific ranges of detectability to reduce bias imposed by habitat complexity (Reynolds et al. 1980). An unexpected finding of our study is that calculations of the range of detectability may be influenced to a greater extent by the actual density of birds than by habitat complexity. This finding, coupled with the fact that estimations of distance from observer to detected bird become less accurate as the distance between them increases, may account for the superior overall performance of the 30-m fixed-radius technique over the variable circular-plot in our study. These results should be interpreted with caution, however, as Verner and Ritter (1988) suggested that the number of registrations needed to determine detection distances for a species should exceed 100. We obtained fewer than 40 registrations of Blue Jays in 4 of the eight habitat types, and for no habitat did the number of registrations exceed 82 (Table 2).

Our study is limited by our focus on a single species at a single geographic location in a single year, yet we know of no other studies that similarly test the efficacy of point counts across a wide range of habitat types. We hope future studies will provide replication across species and locations to shed light on the generality of our findings.

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