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GENERAL NOTES

A comparison of breeding bird census techniques with mist netting results.—Measuring bird abundance has long challenged ornithologists. Because absolute measures are almost impossible, we rely on several well-known techniques to estimate abundance. Internationally, two basic methods are widely used: the strip transect method and variations of it (Enemar, Vår Fågelvärld 2:1–114, 1959; Emlen, Auk 88:323–342, 1971; 94:455–468, 1977; Järvinen, Ornis Scand. 7:43–48, 1976) and the spot-mapping method (Williams, Ecol. Monogr. 6:317–408, 1936; International Bird Census Committee, Aud. Field Notes 24:722–726, 1970). Transect sampling potentially samples the entire bird community, but it necessarily emphasizes territorial males because of their conspicuousness. Spot-mapping samples only territorial males and thus cannot detect the nonbreeding component of bird populations.

Very few studies have used capture-recapture techniques to estimate song bird abundance (Nichols et al., Studies Avian Biol. 6:121–136, 1981). Borror (Ecol. Monogr. 18:412–430, 1948) used capture-recapture data to estimate the daily numbers of migrant White-throated Sparrows (*Zonotrichia albicollis*) in Ohio. However, comparisons of traditional bird censusing techniques with capture-recapture data are lacking.

In the present study we compare strip transect sampling, two intensities of spot-mapping for 12 regular species, and data from mist-net captures and recaptures for five bird species. Population estimates of Cardinals (*Cardinalis cardinalis*) from these techniques are also compared with estimates from extremely intensive mapping of a color-banded population.

Study area and methods.—The study plot was a 4.8-ha (240 × 200 m) pine-hardwood forested area in Nacogdoches County, eastern Texas. Although the area was smaller than normally recommended for spot-mapping (Oelke, Studies Avian Biol. 6:114–118, 1981), the small size permitted intensive netting of bird species and intensive mapping of color-banded Cardinals. Approximately half of the area was mature forest (18–22 m tall) and half a 5-year-old pine plantation with dense pine and deciduous foliage 2–3 m high. The area had patchy foliage and ranged from xeric sandy hill tops to moist sites along two streams. Several small openings with a main ground cover of grasses and forbs occupied about 3% of the area. Dominant tree species in the forested area were shortleaf pine (*Pinus echinata*), loblolly pine (*P. taeda*), post oak (*Quercus stellata*), and sweetgum (*Liquidambar styraciflua*). Dominant plant species in the pine plantation were loblolly pine, winged sumac (*Rhus copallina*), smooth sumac (*R. glabra*), and American beautyberry (*Callicarpa americana*).

A 40-m grid with numbered stakes and flagged poles positioned at all intersections of grid lines provided reference points for plotting bird locations (Fig. 1). Three strip transects, each 200 m long and 80 m wide, covered the entire study area (see Fig. 1 caption) and were censused as described by Conner and Dickson (Wildl. Soc. Bull. 8:4–10, 1980). While one census taker started transect sampling at one end of the study area, the other census taker started spot-mapping at the other end, thus eliminating time and weather biases. Birds were spot-mapped at distances up to 60 m outside the study plot in order to determine what proportion of partial territories were included in the study plot. Spot-mapping (10.3 total h) always took more time than transect sampling (7.3 total h). Each of the two census takers completed four transect samples and four spot-map samples, totaling eight samples for each technique and cancelling any observer bias resulting from different sampling abilities. The sampling period was 24 May–6 June 1979 between 07:30 and 09:30 CDT. When spot-mapping, observers noted simultaneous singing of conspecific males.

Transect data were recorded in the same manner as spot-map data, noting simultaneous singing of conspecific males on small grid maps of the study area. This permitted using our transect data to double the intensity of our spot-map sampling.

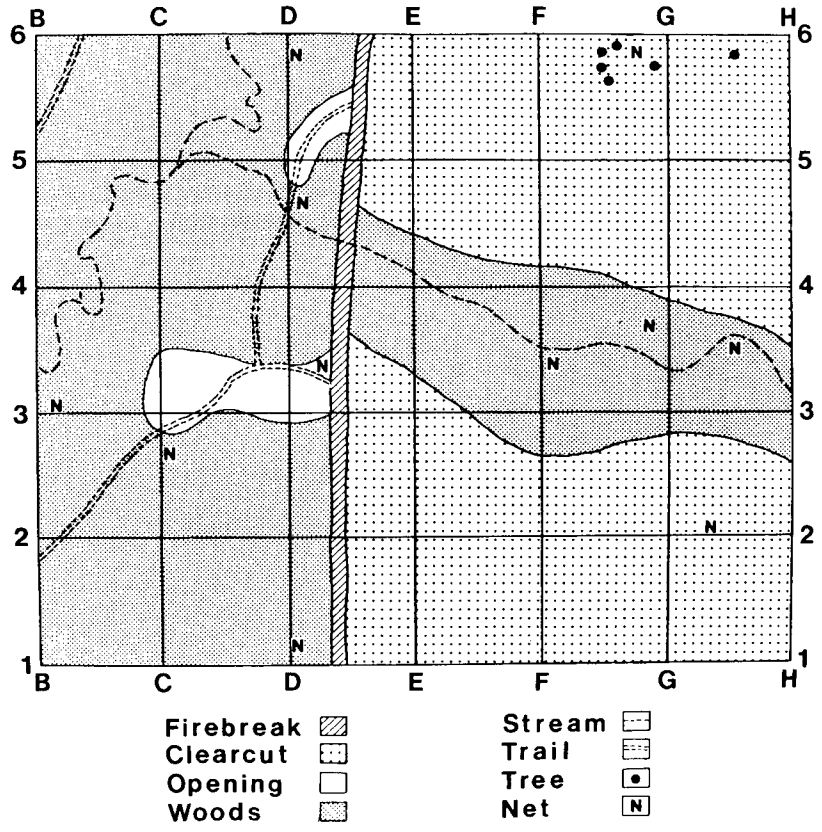

FIG. 1. Map of the 4.8-ha study area and its 40 m grid. The three 200-m transects were between points C1 and C6, E1 and E6, and G1 and G6. N indicates mist net.

We attempted to obtain an estimate as close as possible to the actual Cardinal breeding population through an intensive effort (234 total h) of spot-mapping, observing, and flushing only color-banded Cardinals from 26 April–6 June 1979. This permitted us to determine nearly exact positions of all Cardinal territorial boundaries. Poor visibility and impenetrability of vegetation did not permit extensive use of Wiens' (Ornithol. Monogr. 8, 1969) flushing technique.

Eleven mist nest (2.1 × 12.8 m with 3.8 cm mesh) distributed throughout the area (Fig. 1) were used to capture birds moving through understory vegetation (0–2 m above the ground). Typically, 5–7 nets were in operation at any one time with netting positions changed weekly. Birds were captured and banded (610 net-h) from 25 April–19 May and recaptured for population estimates from 20 May–14 June 1979. Cardinals were banded with color-bands as well as USFWS metal bands. Sufficient netting data were gathered to calculate a Lincoln index (Davis and Winstead, pp. 235–236 *in* Wildlife Management Techniques Manual, The Wildl. Soc., 1980) using capture-recapture data on adult Cardinals, Indigo Buntings (*Pas-*

TABLE 1

STRIP TRANSECT, SPOT-MAP, AND MIST NETTING ESTIMATES OF BIRD ABUNDANCES IN A 4.8-HA AREA IN EAST TEXAS (NO. BIRDS/4.8 HA)

Species	Transect sampling (N = 8)		Spot-mapping (N = 8)		Mist netting	
	Highest no. detected (A)	Highest no. males detected × 2 (B)	No. territorial males × 2 (C)	Σ territories × 2 (D)	Total birds captured (E)	Lincoln index (F)
Cardinal (*Cardinalis cardinalis*)	11	10	14	10	17	20
Indigo Bunting (*Passerina cyanea*)	8	6	8	8	24	31.4
Carolina Wren (*Thryothorus ludovicianus*)	5	10	12	8	11	16
White-eyed Vireo (*Vireo griseus*)	5	10	8	6	14	16.3
Yellow-breasted Chat (*Icteria virens*)	2	4	4	4	15	60
Yellow-billed Cuckoo (*Coccyzus americanus*)	4	4	10	6	5	—
Red-eyed Vireo (*Vireo olivaceus*)	4	8	10	6	3	—
Black-and-white Warbler (*Mniotilta varia*)	5	6	2	2	9	—
Parula Warbler (*Parula americana*)	2	4	2	2	0	—
Kentucky Warbler (*Oporornis formosus*)	2	4	2	2	8	—
Hooded Warbler (*Wilsonia citrina*)	1	2	2	1	7	—
Louisiana Waterthrush (*Seiurus motacilla*)	1	2	2	2	0	—
Total	50	70	76	57	113	—

serina cyanea), White-eyed Vireos (*Vireo griseus*), Carolina Wrens (*Thryothorus ludovicianus*), and Yellow-breasted Chats (*Icteria virens*). We assumed that species had well-established territories and thus had basically closed populations.

Transect data for each species are evaluated two ways: the highest number of individuals per species detected during any census trip (Method A), and the highest number of males of each species detected per trip (summation technique [Palmgren, Acta Zool. Fenn. 7, 1930]) multiplied by 2, assuming monogamy, to approximate both males and females (Method B, Table 1). Methods A and B tend to overestimate bird abundance per unit area because of the occurrence of partial territories on the edges of the strip transect. Potentially, all males

with partial or whole territories in the study area could be singing on the study area during a census visit. The relative degree of overestimation should decrease as transect width increases; i.e., as transect width increases, the area of the strip transect increases at a greater rate than does the edge.

Population estimates from spot-mapping are evaluated two ways for each species. Method D is the traditional spot-map estimate based on the sum of whole and fractional territories multiplied by 2 (Table 1). Method D should not be biased toward overestimations of populations even in small study plots if the partial territories located just inside the edge of study plots are accurately measured as a fraction of the whole territory. We measured fractional territories to the nearest one fourth. Method C estimates populations by multiplying the total number of territorial males detected (either whole or partial territories) by 2. Thus, Method C is biased toward overestimates of the number of male birds, especially in small study plots such as ours, because the ratio of partial territories to whole territories tends to increase as study plot size decreases.

Results and discussion.—Comparisons of transect and spot-map data revealed that total birds estimated with spot-mapping (Method C) was somewhat higher than both transect estimates (A and B, Table 1). Standard spot-mapping (Method D), which is not biased toward overestimating birds, yielded a higher estimate of total bird abundance than transect Method A. Total birds estimated with transect Method A was 88% of the total estimated with Method D.

Our transect estimate (Method B) using number of males × 2 was 92% of the estimated total number of territorial male birds (including partial territories) that inhabited the study area × 2 (Method C). This comparison (B with C) is valid because both methods estimate whole and partial territories. Other comparisons of transect sampling with spot-mapping have been less favorable toward the efficiency of transect sampling (Franzreb, Condor 78: 260–262, 1976; Dickson, Am. Birds 32:10–13, 1978).

Increasing the intensity of spot-mapping (16 vs 8 samples) did not substantially increase estimates of bird abundance. The number of territories was increased by one-half for two species: Cardinals and Yellow-breasted Chats. This supports Robbins' (pp. 142–163 *in* Proc. Workshop Management, Southern Forests for Nongame Birds, U.S.D.A. For. Serv. GTR SE-14, 1978) recommendation of 8–10 census trips per plot where available time for the observers is a factor.

A Lincoln index (mark/recapture ratio) population estimate was calculated for five species (Table 1). The high estimate of 60 resident Yellow-breasted Chats is undoubtedly incorrect and probably caused by a high incidence of active migrants in the study area. Low site tenacity of residents may have also contributed to the high turn over (Thompson and Nolan, Ecol. Monogr. 43:145–171, 1973).

Lincoln index estimates for the Cardinal (7 of 10 marked birds were recaptured), Indigo Bunting (7 of 20 recaptured), Carolina Wren (three of six recaptured), and White-eyed Vireo (four of five recaptured) populations were also higher than any of the transect or spot-map estimates (Table 1). Lincoln estimates for Indigo Buntings were somewhat higher than the other three species when compared to transect and mapping estimates. Some movement of resident buntings in and out of the area may have contributed to an inflation in this population estimate. Netting results indicated a sex ratio close to 1:1 for Cardinals, Carolina Wrens, and White-eyed Vireos. However, we netted twice as many female Indigo Buntings as males. It is likely that our netting "recapture" period sampled late female migrants for buntings, thus slightly inflating our Lincoln index population estimate and yielding a 2:1 female to male sex ratio (C. S. Robbins, pers. comm.). A less likely alternative is that Indigo Buntings on the study area were polygynous.

Lincoln index estimates for Cardinal, Carolina Wren, and White-eyed Vireo populations

in the study area may be more accurate than the estimates for chats and buntings. Our supporting data for this speculation, for Cardinals at least, are the results from 234 h of intensive spot-mapping in the study area for color-banded Cardinals. This intensive Cardinal mapping revealed a total of 10 territorial males (20 Cardinals total) to have all or part of their territory in the study area, three more males than spot-mapping (Method C) detected (Table 1). Twenty Cardinals (10 territorial males × 2) is the same population number estimated by the Lincoln index (Table 1). It is important to note that Method C and the Lincoln index estimates both sample males with whole or partial territories in the study area, thus comparisons between these two methods are fairly valid.

We also treated our 234-h Cardinal mapping data as standard spot-map data, summing whole and fractional territories, in order to compare them with standard eight-sample spot-mapping (Method D). A total of seven whole Cardinal territories were detected using the intensive (234 h) Cardinal spot-mapping, two more whole territories than detected via eight sample spot-mapping. Thus, standard spot-mapping (D) estimated about 71% of what may have been close to the actual Cardinal breeding population. Svensson (Acta Ornith. 14:322–338, 1974) and Best (Auk 92:452–460, 1975) have suggested that considerable variation can exist between persons delineating territory boundaries from spot-maps. Thus, some of the difference in Cardinal population estimates in our study may be from interpretational errors.

Our field observations also suggested that there may have been more Cardinals on the study area than even the 234 h of intensive mapping or netting demonstrated. In addition to the 10 territories that were well delineated, several "floater" males often tried to wedge new territories at junctures of three established Cardinal territories. These males, and possibly some females, were apparently not included in the Lincoln estimate from netting data. These "floating" males were usually driven off or delayed in setting up a territory until one of the established pair's nest failed or their young successfully fledged.

We also found the nest of a color-banded male (red-left) that fledged young, but sang very rarely. Territories of other males that sang regularly seemed to encompass part of the area red-left frequented. We were unable to delineate red-left's territory even with 234 h of intensive mapping.

Our observations suggest that all the techniques we evaluated underestimate bird populations. Spot-mapping Method C and transect Method B both yielded estimates that were highest and closest to estimates from our netting results. Yet, even the overestimating biases of these two methods were apparently more than compensated for by bird inconspicuousness. The netting results and intensive spot-mapping of Cardinals suggest that both transect sampling and spot-mapping census techniques underestimate bird populations because they are incomplete samples.

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