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CONSISTENCY OF MIST NETTING AND POINT COUNTS IN ASSESSING LANDBIRD SPECIES RICHNESS AND RELATIVE ABUNDANCE DURING MIGRATION

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Abstract. We compared consistency of species richness and relative abundance data collected concurrently using mist netting and point counts during migration in riparian habitats along the middle Rio Grande of central New Mexico. Mist netting detected 74% and point counts detected 82% of the 197 species encountered during the study. Species that mist netting failed to capture were usually large, such as quails, raptors, owls, woodpeckers, jays, and crows, or those foraging on the wing, such as swallows and nighthawks; species that point counts failed to detect were usually small, such as sparrows, warblers, vireos, and wrens, or rare species. For the 110 species detected by both techniques, relative abundance was correlated (r = 0.75). However, point counts tended to provide lower estimates for species that were more likely to be captured by mist netting. The strength of the relationship of abundance estimates from the two methods varied by habitat type (cottonwood, agriculture, and willow). The discrepancy between the two techniques was similar in both magnitude and direction in willow and agriculture habitats but was less consistent between each of these two and cottonwood, probably because of canopy height and vegetation vertical structure. The discrepancy between the two techniques in estimating relative abundance was smaller in this study than in studies on breeding or wintering grounds. Less habitat specificity and more-active foraging by migrants during stopover might underlie the high consistency between mist netting and point counts in this study.

Key words: landbirds, migration, mist netting, point count, relative abundance, Rio Grande, species richness.

Consistencia entre Redes y Puntos de Conteo para Determinar la Riqueza de Especies y la Abundancia Relativa de Aves en Migración

Resumen. Comparamos la consistencia de datos de riqueza y abundancia relativa colectados utilizando redes y puntos de conteo en hábitats ribereños durante la migración por el sector central del Río Grande en Nuevo México. De las 197 especies registradas, detectamos 74% con redes y 82% con puntos de conteo. Por lo general, las especies no capturadas en las redes fueron las de mayor tamaño corporal, como perdices, rapaces, búhos, carpinteros, urracas, cuervos y las que se alimentan al vuelo, como golondrinas y añaperos. Las aves no detectadas en los puntos de conteo fueron por lo general las más pequeñas, como garriones, reinitas, vireos, reyezuelos, y las especies raras. Para las 110 especies que fueron registradas con ambos métodos, la abundancia relativa estuvo correlacionada (r = 0.75). Sin embargo, las estimaciones basadas en puntos de conteo generalmente fueron menores para aquellas especies detectadas con mayor frecuencia en las redes. El ajuste entre la relación de las estimaciones de abundancia obtenidas mediante ambos métodos varió en los diferentes tipos de hábitat (álamo, agrícola y sauce). En los hábitats de sauce y agrícola la diferencia entre los dos métodos fue similar tanto en magnitud como en dirección, pero fue menos consistente entre éstos y el hábitat de álamo. La variación en la abundancia estimada entre hábitats posiblemente se debió a la altura del dosel y la estructura vertical de la vegetación. La diferencia estimada de la abundancia relativa entre ambos métodos fue menor en este estudio que en otros estudios realizados en áreas de invernada y anidamiento. Esta mayor consistencia entre ambos métodos en estimar la abundancia relativa puede deberse a que las aves presentan mayor actividad de forrajeo con menor especificidad de hábitat durante las paradas de descanso en las rutas migratorias.

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INTRODUCTION

Mist netting and point counts are two of the most commonly used techniques for quantifying avian species richness and relative abundance. It is a general perception that if used properly, point counts can accurately assess species richness, relative abundance, and population trends, and they have been recommended as the standard method for monitoring (Ralph and Scott 1981, Ralph et al. 1995, Dobkin and Rich 1998). Mist netting can be a more effective tool for detecting presence of undergrowth bird species, particularly secretive species or those that vocalize infrequently (Ralph et al. 1993). Although interpretation of relative abundance from capture rates may be affected by many factors (MacArthur and MacArthur 1974, Karr et al. 1990), avoiding observer biases is viewed as an advantage of mist netting over point counts for quantifying relative abundance (DeSante et al. 1993, Peach et al. 1996).

Using computer simulations, Remsen and Good (1996) concluded that because of confounding variables such as home-range size and overlap, frequency of flight, flight distance, and vertical flight variation, netting could not be used in evaluating relative abundance among species or within species among habitats even when netting effort was "constant." However, other researchers (Hagan et al. 1992, Hussell et al. 1992, Dunn et al. 1997) found that netting data collected during migration might be useful as a corroborative source for indexing long-term population trends of many migrant landbirds. Mist netting and point counts have been recently recommended for monitoring bird populations during migration (Hussell and Ralph 1995). Consistency between the two techniques in measuring avian species richness and relative abundance during migration has not been adequately quantified. Recent studies have compared mist netting and point count data collected on wintering grounds (Gram and Faaborg 1997, Whitman et al. 1997, Rappole et al. 1998) or on breeding grounds (Nur and Geupel 1993, Rappole et al. 1993, Ralph and Fancy 1995). Patterns of behavior observed during breeding or wintering seasons may differ from those observed during migration, and therefore results may not apply to the migration period. In this study, we examined mist netting and point count data collected concurrently during a study of landbird migration along the middle Rio Grande of central New Mexico. Our objectives were to examine differences between the two techniques in (1) detecting species, (2) determining relative abundance, and (3) evaluating habitat-related variations in relative abundance estimates.

METHODS

The study sites were located at the Rio Grande Nature Center (35°07′N, 106°41′W), Bernalillo County, and at the Bosque del Apache National Wildlife Refuge (33°48′N, 106°52′W), Socorro County, New Mexico. The floodplain at the sites is typically level and 2–10 km in width. Riparian woodland lies within or immediately adjacent to levees paralleling the river. The remainder of the floodplain has largely been converted to agricultural or residential areas (Wang et al. 1998).

We operated mist nets and conducted point counts in spring from 4 April–15 June 1994, 3 April–9 June 1995, and 8 April–7 June 1996; and in fall from 1 August–13 November 1994, 31 July–12 November 1995; and 3 August–10 November 1996. Our sampling periods were based partly on about 20 years of banding data collected by Rio Grande Bird Research Inc. (Albuquerque, New Mexico) and were designed to avoid sampling nonmigratory birds. We sampled birds by mist netting and point counts at three of the most common habitats in the area: cottonwood forest, agricultural fields, and willow shrubs. The cottonwood habitat is dominated by Rio Grande cottonwood (*Populus fremontii* var. *wislizeni*) in association with a variety of understory shrubs and small trees, chiefly willows (*Salix* spp.), screwbean mesquite (*Prosopis pubescens*), New Mexico olive (*Forestiera neomexicana*), false indigo (*Amorpha fruticosa*), seepwillow (*Baccharis glutinosa*), Russian olive (*Elaeagnus angustifolia*), and saltcedar (*Tamarix chinensis*). The cottonwood trees generally reach 10–15 m, and the foliage volume varies depending on the age of the forest stands. The shrub layer is most developed in areas with few trees. The willow habitat is composed of dense shrubs (*Salix* spp.), 2–4 m tall, located immediately along the banks of water channels. The agricultural fields are mostly composed of alfalfa (*Medicago sativa*) and corn (*Zea mays*) with crop heights below 3 m (Wang et al. 1998).

In contrast to breeding or wintering seasons, during migration there is a quick turnover of individuals and species at stopover sites of landbird migrants (Moore et al. 1995). To gain a complete picture of stopover ecology of migrants at our sites, we conducted mist netting and point counts continuously through the migration season.

POINT COUNTS

To minimize the probability of multiple counts of the same individuals on different days, we established two sets of point count transects. Each set had six transects, approximately in proportion to habitat availability: three in cottonwood woodland, two in agricultural habitat, and one in willow; point counts were performed at each set every other day. Transects were at least 400 m apart. Each transect was 1 km long, and point count stations were located at 200-m intervals (6 point count stations per transect). The starting point of each transect was randomly selected, and transects were positioned parallel to the river. Weather permitting, point counts were started within 0.5 hr after sunrise and completed by two technicians before 12:00 (MST). To reduce potential bias due to variation in survey time, the order of visit to habitat types and to transects in each habitat was rotated daily. To control potential bias associated with observer variation, the same three experienced technicians conducted most point counts during the three-year study period. At each point count station, an observer recorded birds seen and heard during a 5-min period. Only birds observed within a 25-m radius from the center of the point count station were included in analyses. We selected a 5-min sampling period and a 25-m radius based on recommendations of Ralph et al. (1995) and other researchers (Lynch 1995, Savard and Hooper 1995, Smith et al. 1995). These researchers found that a 5-min period was the most efficient sampling duration, and 25-m radius survey plots worked better for detecting and identifying individuals in dense vegetation.

MIST NETTING

Forty standard mist nets (12×2.6 m) were used to capture birds daily. The netting area was about 30 ha at each site (net density ca. 1.5 nets ha^{-1}). The nets were placed in proportion to availability of habitat types (20 in cottonwood, 13 in agriculture, and 7 in willow) and remained at the same or approximately the same locations through the multiyear study. To avoid sampling bias, nets were operated simultaneously through the seasons and across habitat types and were checked regularly at 20–30 min intervals. Unless rain, high winds, or temperature dictated a change, mist nets were opened 15 min before sunrise and remained open for about 6 hr every morning during the sampling period. Each captured bird was banded with a numbered aluminum leg band. Recaptured birds were not included in the current analysis. Only migratory landbirds were evaluated. We also excluded hummingbirds (Trochilidae), European Starling (*Sturnus vulgaris*), and House Sparrow (*Passer domesticus*) from analyses because they were not banded.

STATISTICAL ANALYSIS

To assess consistency in detecting relative abundance between our two techniques, we used total capture from netting and total detection from point counts of each species as indicators of relative abundance. Netting and point count data were logarithmically transformed to correct for skewness, and then were standardized by calculating a standard score for each species to adjust for the scales of the two techniques (Sokal and Rohlf 1995). This data preparation was justified given that (1) we were interested in the consistency (precision) of the two techniques rather than accuracy, so any index would serve if consistently applied; (2) standardized variables provided relative measurements, and species abundances from each technique were expressed in standard deviation units (Legendre 1998); and (3) point count and net density in each habitat was approximately in proportion to availability, and point counts and mist netting were conducted concurrently.

A three-way repeated measurements ANOVA (split-plot design [Kirk 1982]: site and season as between-subject factor, and sampling technique as within-subject factor) was used to test the effect of each factor and their interactions on the relative abundance estimates. A linear regression analysis with standardized point count detection as the dependent variable and standardized netting capture as the independent variable was performed for species detected by both techniques. Standardized residuals, which are dimensionless (Legendre 1998) and measure the relative deviations of observed values from expected values of the regression model, were used as a measurement of the consistency between the two techniques. If the two techniques were consistent in estimating the relative abundance among species, points representing each species should fall on the regression line with zero deviation and have a perfect correlation (r = 1). Because we arbitrarily assigned point count detection as the dependent variable, a negative residual would indicate that point counts resulted in a lower relative abundance measure than expected for a given species, while a positive residual would indicate that point counts provided a higher relative abundance estimate than expected.

To assess habitat effect on consistency of the two techniques in measuring relative abundance, we performed the same analyses for each habitat type. Each habitat analysis generated a standardized residual value by species. We then performed a second regression analysis on these residuals by pairing habitats: agriculture and cottonwood, willow and cottonwood, and willow and agriculture. The first habitat in each pair was arbitrarily assigned as y and the second as x. If the biases of the two techniques were consistent between two habitat types, then the pairs would plot close to $y = x$, a 45° line passing through the origin. Deviation from this 45° line would suggest that there was a habitat-related bias in estimating relative abundance. As the residuals become less similar, the cloud of points representing species on the plot would become more diffuse, and the coefficient of determination would become smaller. Positive or negative residuals of a specific species would indicate species-specific habitat bias.

We examined homogeneity and normality of regression analyses by using residuals, predicted value plots, and Q-Q normal probability plots (Montgomery et al. 2001). We used standardized residuals and Mahalanobis distance (D^2) for identifying potential outliers and used Cook's distance (C_i) for identifying potential influence points (SPSS 1999). We tested hypotheses concerning slopes and intercepts using Student's t-statistics (Zar 1999). The statistical significance level was set at $\alpha = 0.05$ unless otherwise indicated. Means are presented ± SD.

RESULTS

We detected 197 landbird species by mist netting and point counts during the study period. Fifty-two species (26%) were never captured by mist netting (count-only species) while 35 species (18%) were never detected during point counts (net-only species; Appendix). Most count-only species were larger birds such as quails, raptors, owls, woodpeckers, jays, and crows, or were species that forage on the wing such as swallows and nighthawks. In contrast, most net-only species were small birds such as sparrows, warblers, vireos, wrens, and accidental species to the area (e.g., eastern-breeding species). Many net-only species were ground or shrub foragers (Appendix).

More species were detected in fall (96 ± 2) than in spring (75 ± 2) in each year ($F_{1,8} = 48.2$, $P < 0.001$); more species were detected by point counts (103 ± 2) than by mist netting (68 ± 3; $F_{1,8} = 82.8$, $P < 0.001$); and more species were detected at Rio Grande Nature Center (91 ± 2) than at Bosque del Apache National Wildlife Refuge (81 ± 2; $F_{1,8} = 10.4$, $P < 0.05$). Although the 3-way interaction was significant ($F_{1,8} = 7.5$, $P < 0.03$), these general trends were not affected. No second-order interaction was significant. We created species accumulation curves to assess whether the number of species in each year detected by the two methods reached a maximum. Asymptotes were reached at a similar rate between the two techniques at the two sites in each year (all $r > 0.8$, all $P < 0.01$). The relationship was also similar between spring and fall and between the two sites. These patterns indicated that pooling data among years, between sites, and between seasons to compare the techniques was justified.

For the 110 species encountered by both techniques (Appendix; scientific names therein), relative abundance estimates from point count and netting were significantly correlated ($r = 0.75$, $P < 0.001$, Fig. 1). Over 96% of the 110 species had residuals that were ≤2 standard deviations apart, indicating that overall the two techniques were consistent in measuring relative abundance. Residual analyses indicated that normality and equal variance assumptions were not violated. Only one species (the Red-winged Blackbird) had a standardized residual as high as 3.3 (Fig. 1), indicating point counts tended to produce an extremely high relative abundance estimate for this species. We did not detect outliers or influence data points based on Mahalanobis distance ($\chi^2_1 < 10.8$, $P = 0.001$) and Cook's distance ($C_i < 0.5$), respectively. We also tested the effect of rare species on relationships between the two methods by excluding species that had <5 captures or detections. The model

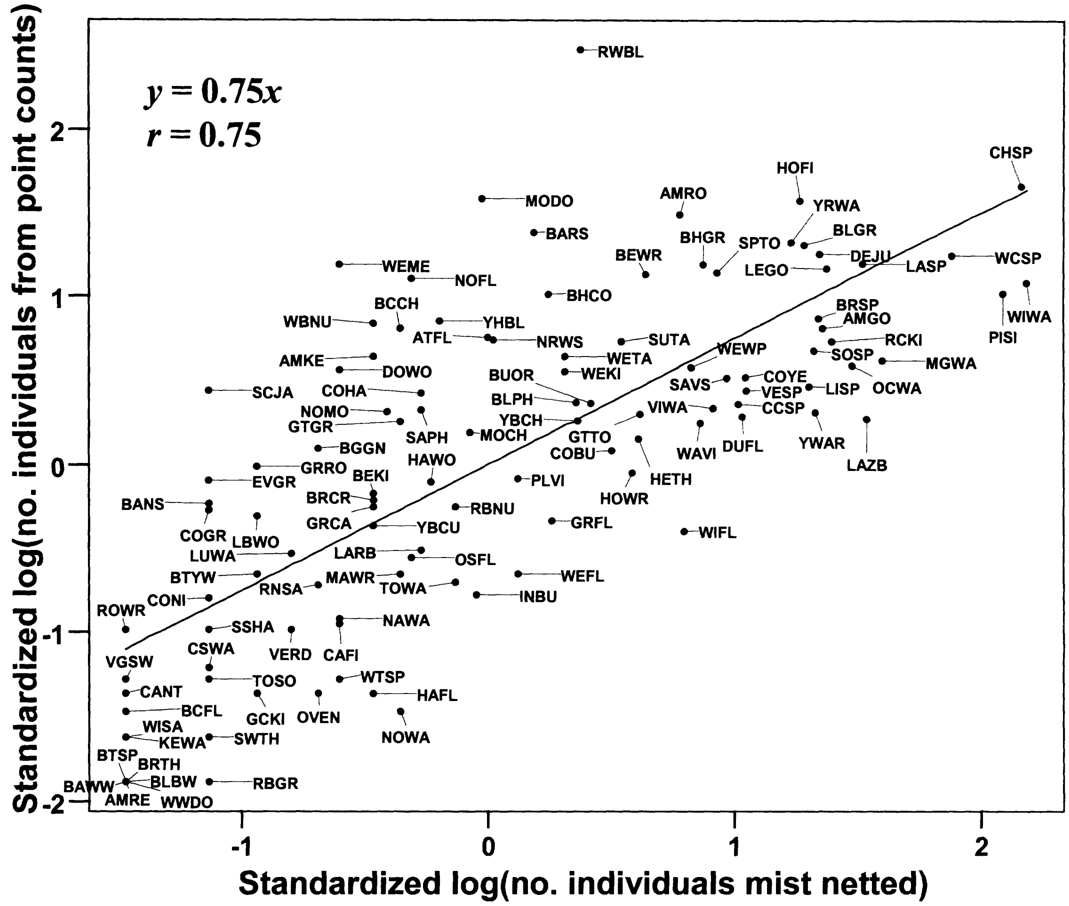
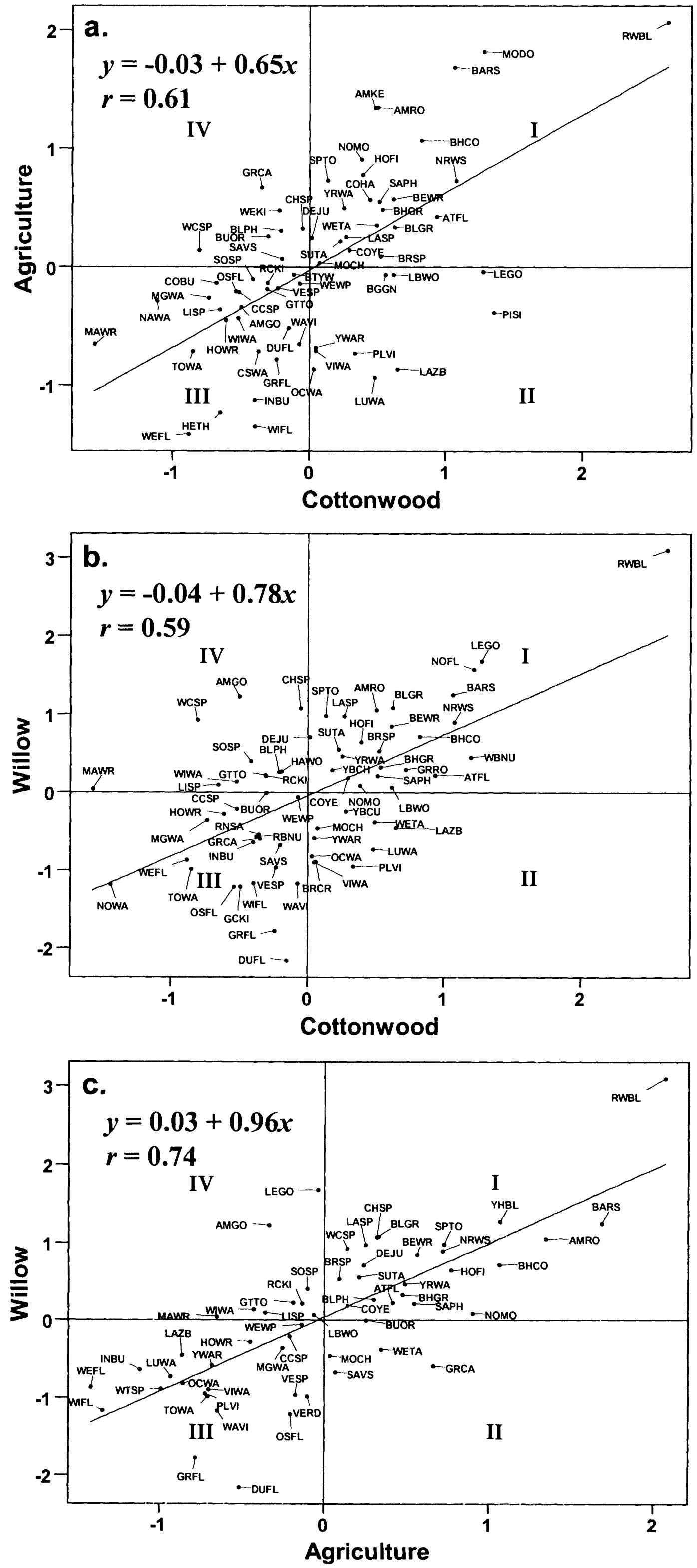


FIGURE 1. Relationship between point count detections and mist netting captures during spring and fall migration at two sites in New Mexico. Detections and captures were logarithmically (base 10) transformed and then standardized. See Appendix for species codes.

was robust to such modification; the change of the slope was not significant. The regression slope was less than one ($y = 0.00001 + 0.75x$, $r^2 = 0.56$, $P < 0.001$, Fig. 1), meaning that point counts in general provided lower estimates of relative abundance than mist netting for species that had high capture rates and higher estimates for species that had low capture rates.

The relationship between point count detection (y) and mist netting capture (x) was also significant when the analysis was performed separately for each habitat. The regression model was $y = 0.65x$ ($r^2 = 0.44$, $n = 75$, $P < 0.001$) for agriculture habitat, $y = 0.69x$ ($r^2 = 0.47$, $n = 101$, $P < 0.001$) for cottonwood, and $y = 0.42x$ ($r^2 = 0.18$, $n = 69$, $P < 0.001$) for willow habitat. Intercepts of these models were not different from zero. Each of the three models generated a residual of point count detection for each species. Again, no outliers or influence data points were detected based on Mahalanobis distance ($\chi^2_1 < 10.8$, $P = 0.001$) and Cook's distance ($C_i < 0.5$), respectively, for each habitat. Wilcoxon rank-sum tests indicated that the absolute residual of willow habitat (0.72 ± 0.54) tended to be higher than that of agriculture (0.59 ± 0.47; $Z = 1.9$, $P = 0.06$) and cottonwood (0.58 ± 0.41; $Z = 2.7$, $P < 0.01$), indicating that the discrepancy between mist netting and point counts in estimating relative abundance was highest in willow habitat.

Regression analysis of the residuals between habitat pairs generated from the above analyses showed that consistency in measuring relative abundance using our two techniques was habitat-dependent. Relative abundance tended to


a.
y = -0.03 + 0.65x
r = 0.61
Agriculture
Cottonwood
I
II
III
IV
b.
y = -0.04 + 0.78x
r = 0.59
Willow
Cottonwood
c.
y = 0.03 + 0.96x
r = 0.74
Willow
Agriculture
RWBL

have similar direction and magnitude between willow and agricultural habitats, but was less consistent between each of these two habitats and cottonwood. The regression slope was 0.65 between agriculture and cottonwood and 0.78 between willow and cottonwood, and differed from one ($t_{64} = 4.0$, $P < 0.001$ and $t_{63} = 3.6$, $P < 0.001$, respectively, Fig. 2). The slope of the regression model between residuals of agricultural habitat and willow habitat was 0.96 and did not differ from one (Fig. 2).

We examined how individual species were detected by each method and among habitats by examining where they fell on the residual plots. Dividing the plots into four quadrants (Fig. 2), points in quadrant I had positive residuals for each habitat, indicating that point counts produced higher abundance estimates than mist netting in both habitats. Points in quadrant II had positive residuals for the habitat on the x-axis, but negative residuals for the habitat on the y-axis, indicating that point counts yielded higher estimates for the x-axis habitat. Similarly, in quadrant III both residuals were negative, indicating lower abundance estimates from point counts in both habitats. In quadrant IV point counts yielded lower estimates in the x-axis habitat and higher estimates than mist netting in the y-axis habitat. The position of each point relative to the regression line and to the origin of the two axes was also informative. Species close to the regression line had a similar degree of bias in the two habitats. Species close to the origin of the two axes had residuals close to 0, indicating that not only were the two methods consistent in estimating relative abundances, but also that estimates were not affected by habitat type (e.g., Western Wood-Pewee in Fig. 2).

DISCUSSION

Limitations of the two techniques in detecting species richness were comparable in our study: point counts missed 18% and mist netting 26% of all species detected in this study. In fact, species detection rate was higher, and the discrepancy between the two techniques was lower, in this study than in other studies. For example, Whitman et al. (1997) found mist netting and point counts detected only 25% and 60%, respectively, of all forest species in their study area in northern Belize. Wallace et al. (1996) found a low correlation between detections of species from mist nets and detections from point counts; and Gram and Faaborg (1997) found that mist netting detected twice as many species as point counts in tropical semideciduous forest. Of the 37 species detected during a study in the Tuxtla Mountain region of southern Veracruz, Mexico, Rappole et al. (1998) found mist netting was more effective for detecting species (92%) than point counts (68%).

We used 25-m radius, 5-min point counts in this study. By using larger point count plots or longer point counts, it is possible that the relationship between the two techniques might change. However, we believe increasing our point-count sampling intensity would have limited effect on our results because (1) we performed point counts more frequently than is typical for many studies, and (2) species accumulation curves in each year at each site leveled off, suggesting adequate sampling intensity.

Of the 110 species detected by both techniques in this study, the relative abundances estimated from the two were related, and the residuals were relatively small. This suggests that the two methods were generally consistent in estimating relative abundance at our study sites during migration. We used point count detection as the dependent variable in our analyses, and the residuals were interpreted as deviations of point count detections relative to predictions from point counts. If we had used netting capture as the dependent variable, residuals would

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FIGURE 2. Habitat-specific biases of abundance estimates from point counts and mist net captures during spring and fall migration at two sites in New Mexico. Standard residuals were generated from regression between point detections and mist net captures (Fig. 1) for each of three habitats, and plotted for each habitat pair: (a) agriculture vs. cottonwood; (b) willow vs. cottonwood; (c) willow vs. agriculture. For each axis, positive values indicate point counts had higher estimates than netting for that habitat; therefore, quadrants I and III indicate biases of abundance estimates were similar between habitats; points in quadrants II and IV indicate biases were in opposite directions between habitats. Points near the regression line had similar degrees of bias between the two methods, and points near the origin had similar estimates between habitat types. See Appendix for species codes.

have been interpreted relative to predictions from netting; consequently, the relationships between the two techniques might change. However, the patterns of species-specific deviation between the two techniques in estimating relative abundance was similar to the discrepancy between the two in detecting species richness. Netting tended to have higher estimates than point counts for species that are rare or uncommon in the area (e.g., the Kentucky Warbler, American Redstart, Black-and-white Warbler, Northern Waterthrush, and Ovenbird), for *Empidonax* species that are difficult to identify in the field during migration, and for other small species such as warblers, sparrows, and vireos. Point counts tended to have higher estimates than netting for larger species such as blackbirds, grosbeaks, raptors, tanagers, and large flycatchers (e.g., kingbirds), and swallows (Fig. 1).

In this study, we focused our comparisons on new arrivals because these individuals typically account for the majority of birds at stopover sites (Moore et al. 1995), and multiple counts of the same birds among point counts would create dependent samples. We used two sets of point count transects and alternated between sets to reduce the probability of recounting individuals. Accordingly, we also excluded recaptured birds from analyses. However, bias could be introduced by exclusion of recaptures from the netting data, because we could not exclude such birds from our point count data. The recapture probability of migrants at our sites was low (12%; YW, unpubl.). Very few recaptured birds stayed at our sites for more than 2 days. These patterns are typical among landbirds at stopover sites (Moore et al. 1995, Finch and Wang 2000), suggesting that the bias due to excluded recaptures may have a limited effect on the comparison of the two techniques.

Our results demonstrated that the biases in estimating relative abundances of landbird migrants at stopover sites using different techniques could be habitat and species dependent. In our study, the discrepancy between mist netting and point counts in estimating relative abundance tended to have similar direction and magnitude in willow and agricultural habitats and was less consistent between each of these two habitats and cottonwood. That is, errors in netting or point count estimates of relative abundance in agricultural habitat tended to be mirrored in willow habitat, but not in cottonwood habitat. For example, in our study, point counts detected fewer Willow Flycatchers than expected from mist net captures (Fig. 1), and did so consistently in willow and agricultural habitats (Fig. 2c). In cottonwood habitat, this discrepancy was much smaller (the point is close to 0 in Fig. 2a, b), suggesting that the two techniques provide consistent indexes for the species. Several species such as the Orange-crowned Warbler, Virginia's Warbler, and Yellow Warbler showed a pattern similar to the Willow Flycatcher.

Vegetation vertical height was probably one of the major factors affecting capture rate as well as the discrepancy between the two techniques for some species. For example, the Plumbeous Vireo, a canopy species, had a positive residual in cottonwood habitat (Fig. 2a, b), suggesting that point counts rather than netting provided higher estimates of relative abundance in cottonwood habitat. However, in agriculture and willow, where vegetation is below 4 m, the pattern was reversed; the point representing the species was in the negative region (quadrant III) and close to the regression line (Fig. 2c). Lazuli Bunting and Lucy's Warbler showed a similar pattern. In other species, factors affecting the consistency between the two techniques could not be attributed to vegetation height alone. For example, in willow, point counts and netting provided relatively consistent indexes for the Wilson's Warbler. However, in cottonwood and agricultural habitat, where the vegetation structure was quite different, the point count estimates were similar between the two habitats, but both were lower than that from netting. Interestingly, Rappole et al. (1998) found that point counts were superior to netting for detecting migrating Wilson's Warblers across habitats in Mexico.

For some species, point counts and netting produced consistent relative abundance estimates regardless of habitat. These species are located around the origin in Figure 2 (e.g., Common Yellowthroat). The Black Phoebe, Bullock's Oriole, Green-tailed Towhee, Western Wood-Pewee, and Ruby-crowned Kinglet tended to show the same pattern. For other species, such as the Red-winged Blackbird and Barn Swallow, point counts provided a higher estimate than netting regardless of habitat type. This is probably related to the behavior of these species, which makes them easy to detect and difficult to capture regardless of habitat type.

Our study addressed the consistency between mist netting and point counts in determining relative abundance and species richness. Yet consistency does not necessarily reflect accuracy. We compared the two techniques to assess relative abundances of species, not actual densities, which can be highly variable and unreliable when extrapolated from these techniques (Dobkin and Rich 1998). Because we used standardized detection rate or capture rate for comparisons, actual measurement units (e.g., birds per point count station and birds per net-hr) should not affect our results. Remsen and Good (1996) found large sampling biases associated with mist netting and concluded that mist netting should not be used for estimating relative abundance during the breeding season. Silkey et al. (1999) evaluated the accuracy and the effectiveness of mist netting for monitoring landbird population change during the breeding season and found significant correlation with point count estimates in relative abundance in all but one species. Our study suggests that netting and point counts are relatively consistent and both may be effective, especially when used together, in estimating species richness and relative abundance during migration stopover. Netting may be more appropriate during migration because many migrants are food-deprived and forage actively during stopover (Loria and Moore 1990, Wang and Moore 1993), and therefore are easier to catch; at the same time, they are less territorial and less vocal, and therefore are harder to pick up on point counts.

Understanding the biases associated with each technique assists biologists to evaluate other patterns besides population trends. For example, comparing point counts and mist netting efficiencies increased our confidence that disproportionate capture rates among habitats were due to variations in habitat use because sampling biases from netting alone were not sufficient to explain all variation (Wang et al. 1998). For monitoring population trends during migration, the sensitivity of mist netting or point counts to population changes, in addition to consistency between the two, needs to be assessed (Hagan et al. 1992, Hussell et al. 1992), which is beyond the scope of this study.

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APPENDIX. Names, species codes, and status for the 197 landbird species detected at two sites along the middle Rio Grande, New Mexico, in 1994, 1995, and 1996. Taxonomy is based on AOU (1998). Status: P = species detected by point counts only (n = 52); M = species detected by mist netting only (n = 35); and B = species detected by both techniques (n = 110).

Common name	Scientific name	Code	Status
Turkey Vulture	*Cathartes aura*	TUVU	P
Osprey	*Pandion haliaetus*	OSPR	P
Mississippi Kite	*Ictinia mississippiensis*	MIKI	P
Bald Eagle	*Haliaeetus leucocephalus*	BAEA	P
Northern Harrier	*Circus cyaneus*	NOHA	P
Sharp-shinned Hawk	*Accipiter striatus*	SSHA	B
Cooper's Hawk	*Accipiter cooperii*	COHA	B
Northern Goshawk	*Accipiter gentilis*	NOGO	P
Gray Hawk	*Asturina nitida*	GRHA	P
Swainson's Hawk	*Buteo swainsoni*	SWHA	P
Red-tailed Hawk	*Buteo jamaicensis*	RTHA	P
Golden Eagle	*Aquila chrysaetos*	GOEA	P
American Kestrel	*Falco sparverius*	AMKE	B
Merlin	*Falco columbarius*	MERL	P
Peregrine Falcon	*Falco peregrinus*	PEFA	P
Prairie Falcon	*Falco mexicanus*	PRFA	P
Wild Turkey	*Meleagris gallopavo*	WITU	P
Scaled Quail	*Callipepla squamata*	SCQU	P
Gambel's Quail	*Callipepla gambelii*	GAQU	P
White-winged Dove	*Zenaida asiatica*	WWDO	B
Mourning Dove	*Zenaida macroura*	MODO	B
Yellow-billed Cuckoo	*Coccyzus americanus*	YBCU	B
Greater Roadrunner	*Geococcyx californianus*	GRRO	P
Western Screech-Owl	*Otus kennicottii*	WESO	P
Great Horned Owl	*Bubo virginianus*	GHOW	P
Lesser Nighthawk	*Chordeiles acutipennis*	LENI	P
Common Nighthawk	*Chordeiles minor*	CONI	B
Common Poorwill	*Phalaenoptilus nuttallii*	COPO	P
Belted Kingfisher	*Ceryle alcyon*	BEKI	B
Lewis's Woodpecker	*Melanerpes lewis*	LEWO	P
Williamson's Sapsucker	*Sphyrapicus thyroideus*	WISA	B
Red-naped Sapsucker	*Sphyrapicus nuchalis*	RNSA	B
Ladder-backed Woodpecker	*Picoides scalaris*	LBWO	B
Downy Woodpecker	*Picoides pubescens*	DOWO	B
Hairy Woodpecker	*Picoides villosus*	HAWO	B
Northern Flicker	*Colaptes auratus*	NOFL	B
Olive-sided Flycatcher	*Contopus cooperi*	OSFL	B
Western Wood-Pewee	*Contopus sordidulus*	WEWP	B
Willow Flycatcher	*Empidonax traillii*	WIFL	B
Least Flycatcher	*Empidonax minimus*	LEFL	M
Hammond's Flycatcher	*Empidonax hammondii*	HAFL	B
Gray Flycatcher	*Empidonax wrightii*	GRFL	B
Dusky Flycatcher	*Empidonax oberholseri*	DUFL	B
Western Flycatcher	*Empidonax difficilis*	WEFL	B
Black Phoebe	*Sayornis nigricans*	BLPH	B
Say's Phoebe	*Sayornis saya*	SAPH	B
Vermilion Flycatcher	*Pyrocephalus rubinus*	VEFL	P
Ash-throated Flycatcher	*Myiarchus cinerascens*	ATFL	B
Brown-crested Flycatcher	*Myiarchus tyrannulus*	BCFL	B
Cassin's Kingbird	*Tyrannus vociferans*	CAKI	P
Western Kingbird	*Tyrannus verticalis*	WEKI	B
Eastern Kingbird	*Tyrannus tyrannus*	EAKI	P
Loggerhead Shrike	*Lanius ludovicianus*	LOSH	P
Bell's Vireo	*Vireo bellii*	BEVI	M
Gray Vireo	*Vireo vicinior*	GRVI	M
Yellow-throated Vireo	*Vireo flavifrons*	YTVI	M
Plumbeous Vireo	*Vireo plumbeus*	PLVI	B
Warbling Vireo	*Vireo gilvus*	WAVI	B
Red-eyed Vireo	*Vireo olivaceus*	REVI	M

APPENDIX. Continued.

Common name	Scientific name	Code	Status
Steller's Jay	*Cyanocitta stelleri*	STJA	P
Blue Jay	*Cyanocitta cristata*	BLJA	P
Western Scrub-Jay	*Aphelocoma californica*	WESJ	B
Pinyon Jay	*Gymnorhinus cyanocephalus*	PIJA	P
Black-billed Magpie	*Pica hudsonia*	BBMA	P
Chihuahuan Raven	*Corvus cryptoleucus*	CHRA	P
Common Raven	*Corvus corax*	CORA	P
Horned Lark	*Eremophila alpestris*	HOLA	P
Purple Martin	*Progne subis*	PUMA	P
Tree Swallow	*Tachycineta bicolor*	TRES	P
Violet-green Swallow	*Tachycineta thalassina*	VGSW	B
Northern Rough-winged Swallow	*Stelgidopteryx serripennis*	NRWS	B
Bank Swallow	*Riparia riparia*	BANS	B
Barn Swallow	*Hirundo rustica*	BARS	B
Black-capped Chickadee	*Poecile atricapilla*	BCCH	B
Mountain Chickadee	*Poecile gambeli*	MOCH	B
Oak Titmouse	*Baeolophus inornatus*	PLTI	M
Verdin	*Auriparus flaviceps*	VERD	B
Bushtit	*Psaltriparus minimus*	COBU	B
Red-breasted Nuthatch	*Sitta canadensis*	RBNU	B
White-breasted Nuthatch	*Sitta carolinensis*	WBNU	B
Pygmy Nuthatch	*Sitta pygmaea*	PYNU	P
Brown Creeper	*Certhia americana*	BRCR	B
Cactus Wren	*Campylorhynchus brunneicapillus*	CACW	M
Rock Wren	*Salpinctes obsoletus*	ROWR	B
Carolina Wren	*Thryothorus ludovicianus*	CARW	M
Bewick's Wren	*Thryomanes bewickii*	BEWR	B
House Wren	*Troglodytes aedon*	HOWR	B
Winter Wren	*Troglodytes troglodytes*	WIWR	M
Marsh Wren	*Cistothorus palustris*	MAWR	B
Golden-crowned Kinglet	*Regulus satrapa*	GCKI	B
Ruby-crowned Kinglet	*Regulus calendula*	RCKI	B
Blue-gray Gnatcatcher	*Polioptila caerulea*	BGGN	B
Eastern Bluebird	*Sialia sialis*	EABL	P
Western Bluebird	*Sialia mexicana*	WEBL	P
Mountain Bluebird	*Sialia currucoides*	MOBL	P
Townsend's Solitaire	*Myadestes townsendi*	TOSO	B
Swainson's Thrush	*Catharus ustulatus*	SWTH	B
Hermit Thrush	*Catharus guttatus*	HETH	B
American Robin	*Turdus migratorius*	AMRO	B
Gray Catbird	*Dumetella carolinensis*	GRCA	B
Northern Mockingbird	*Mimus polyglottos*	NOMO	B
Sage Thrasher	*Oreoscoptes montanus*	SATH	M
Brown Thrasher	*Toxostoma rufum*	BRTH	B
Long-billed Thrasher	*Toxostoma longirostre*	LBTH	P
Crissal Thrasher	*Toxostoma crissale*	CRTH	M
American Pipit	*Anthus rubescens*	AMPI	P
Cedar Waxwing	*Bombycilla cedrorum*	CEDW	P
Phainopepla	*Phainopepla nitens*	PHAI	P
Blue-winged Warbler	*Vermivora pinus*	BWWA	M
"Lawrence's Warbler"	*Vermivora pinus* × *chrysoptera*	LAWA	M
Tennessee Warbler	*Vermivora peregrina*	TEWA	M
Orange-crowned Warbler	*Vermivora celata*	OCWA	B
Nashville Warbler	*Vermivora ruficapilla*	NAWA	B
Virginia's Warbler	*Vermivora virginiae*	VIWA	B
Lucy's Warbler	*Vermivora luciae*	LUWA	B
Yellow Warbler	*Dendroica petechia*	YWAR	B
Chestnut-sided Warbler	*Dendroica pensylvanica*	CSWA	B
Magnolia Warbler	*Dendroica magnolia*	MAWA	M
Black-throated Blue Warbler	*Dendroica caerulescens*	BTBW	M
Yellow-rumped Warbler	*Dendroica coronata*	YRWA	B

APPENDIX. Continued.

Common name	Scientific name	Code	Status
Black-throated Gray Warbler	*Dendroica nigrescens*	BTYW	B
Townsend's Warbler	*Dendroica townsendi*	TOWA	B
Blackburnian Warbler	*Dendroica fusca*	BLBW	B
Grace's Warbler	*Dendroica graciae*	GRWA	P
Pine Warbler	*Dendroica pinus*	PIWA	P
Prairie Warbler	*Dendroica discolor*	PRAW	M
Palm Warbler	*Dendroica palmarum*	PAWA	M
Blackpoll Warbler	*Dendroica striata*	BLPW	P
Black-and-white Warbler	*Mniotilta varia*	BAWW	B
American Redstart	*Setophaga ruticilla*	AMRE	B
Prothonotary Warbler	*Protonotaria citrea*	PROW	M
Ovenbird	*Seiurus aurocapillus*	OVEN	B
Northern Waterthrush	*Seiurus noveboracensis*	NOWA	B
Kentucky Warbler	*Oporornis formosus*	KEWA	B
Mourning Warbler	*Oporornis philadelphia*	MOWA	M
MacGillivray's Warbler	*Oporornis tolmiei*	MGWA	B
Common Yellowthroat	*Geothlypis trichas*	COYE	B
Hooded Warbler	*Wilsonia citrina*	HOWA	M
Wilson's Warbler	*Wilsonia pusilla*	WIWA	B
Canada Warbler	*Wilsonia canadensis*	CAWA	M
Painted Redstart	*Myioborus pictus*	PARE	P
Yellow-breasted Chat	*Icteria virens*	YBCH	B
Hepatic Tanager	*Piranga flava*	HETA	M
Summer Tanager	*Piranga rubra*	SUTA	B
Scarlet Tanager	*Piranga olivacea*	SCTA	M
Western Tanager	*Piranga ludoviciana*	WETA	B
Green-tailed Towhee	*Pipilo chlorurus*	GTTO	B
Spotted Towhee	*Pipilo maculatus*	SPTO	B
Canyon Towhee	*Pipilo fuscus*	CANT	B
Cassin's Sparrow	*Aimophila cassinii*	CASP	M
Rufous-crowned Sparrow	*Aimophila ruficeps*	RCSP	P
American Tree Sparrow	*Spizella arborea*	ATSP	P
Chipping Sparrow	*Spizella passerina*	CHSP	B
Clay-colored Sparrow	*Spizella pallida*	CCSP	B
Brewer's Sparrow	*Spizella breweri*	BRSP	B
Vesper Sparrow	*Pooecetes gramineus*	VESP	B
Lark Sparrow	*Chondestes grammacus*	LASP	B
Black-throated Sparrow	*Amphispiza bilineata*	BTSP	B
Sage Sparrow	*Amphispiza belli*	SAGS	M
Lark Bunting	*Calamospiza melanocorys*	LARB	B
Savannah Sparrow	*Passerculus sandwichensis*	SAVS	B
Grasshopper Sparrow	*Ammodramus savannarum*	GRSP	M
Fox Sparrow	*Passerella iliaca*	FOSP	M
Song Sparrow	*Melospiza melodia*	SOSP	B
Lincoln's Sparrow	*Melospiza lincolnii*	LISP	B
Swamp Sparrow	*Melospiza georgiana*	SWSP	M
White-throated Sparrow	*Zonotrichia albicollis*	WTSP	B
Harris's Sparrow	*Zonotrichia querula*	HASP	P
White-crowned Sparrow	*Zonotrichia leucophrys*	WCSP	B
Golden-crowned Sparrow	*Zonotrichia atricapilla*	GCSP	M
Dark-eyed Junco	*Junco hyemalis*	DEJU	B
Pyrrhuloxia	*Cardinalis sinuatus*	PYRR	M
Rose-breasted Grosbeak	*Pheucticus ludovicianus*	RBGR	B
Black-headed Grosbeak	*Pheucticus melanocephalus*	BHGR	B
Blue Grosbeak	*Guiraca caerulea*	BLGR	B
Lazuli Bunting	*Passerina amoena*	LAZB	B
Indigo Bunting	*Passerina cyanea*	INBU	B
Painted Bunting	*Passerina ciris*	PABU	M
Dickcissel	*Spiza americana*	DICK	M

APPENDIX. Continued.

Common name	Scientific name	Code	Status
Bobolink	*Dolichonyx oryzivorus*	BOBO	B
Red-winged Blackbird	*Agelaius phoeniceus*	RWBL	B
Western Meadowlark	*Sturnella neglecta*	WEME	B
Yellow-headed Blackbird	*Xanthocephalus xanthocephalus*	YHBL	B
Brewer's Blackbird	*Euphagus cyanocephalus*	BRBL	P
Common Grackle	*Quiscalus quiscula*	COGR	B
Great-tailed Grackle	*Quiscalus mexicanus*	GTGR	B
Brown-headed Cowbird	*Molothrus ater*	BHCO	B
Orchard Oriole	*Icterus spurius*	OROR	M
Hooded Oriole	*Icterus cucullatus*	HOOR	P
Bullock's Oriole	*Icterus bullockii*	BUOR	B
Cassin's Finch	*Carpodacus cassinii*	CAFI	B
House Finch	*Carpodacus mexicanus*	HOFI	B
White-winged Crossbill	*Loxia leucoptera*	WWCR	M
Pine Siskin	*Carduelis pinus*	PISI	B
Lesser Goldfinch	*Carduelis psaltria*	LEGO	B
American Goldfinch	*Carduelis tristis*	AMGO	B
Evening Grosbeak	*Coccothraustes vespertinus*	EVGR	B