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INFLUENCE OF TIME OF DAY, DURATION AND NUMBER OF COUNTS IN POINT COUNT SAMPLING OF BIRDS IN AN ATLANTIC FOREST OF PARAGUAY

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Resumen. – Influencia del horario, tiempo de duración y número de puntos de conteo de aves en el Bosque Atlántico del Paraguay. – Puntos de conteo de 10 o 20 min de duración se han utilizado para prospectar comunidades de aves del Bosque Atlántico Neotropical. Sin embargo, los factores que afectan la eficiencia del método aún no han sido evaluados para un diseño de muestreo efectivo. En este trabajo, se evalúa la influencia de varios factores que intervienen con puntos de conteo de distancia ilimitada, en una comunidad de aves en época reproductora en el Parque Nacional de San Rafael, Paraguay. Los conteos de 20 min se dividen en cuatro intervalos de 5 min, desarrollados desde 30 min antes del amanecer hasta 3 h después, siendo cada punto censado varias veces durante la estación. El número total de individuos y especies detectadas por conteo varía significativamente, siendo máximo en la primera hora después del amanecer. Sin embargo, algunas especies difieren del patrón de detección. Un 87% y 93% de las especies son detectadas en los primeros 5 y 10 min de conteo, respectivamente, pero el número de especies detectadas por primera vez es tres veces mayor durante los primeros 5 min, que en intervalos posteriores. Se observa una disminución significativa de detecciones en los dos últimos intervalos de conteo. El número de especies se incrementa con cada conteo adicional en determinado punto, pero este rango disminuye después de la cuarta visita. Sugerimos que conteos de 10 min de duración son suficientes para muestrear esta comunidad de aves, y que cuatro visitas a un punto de conteo son necesarias, pero deben realizarse a diferentes horas de la mañana para cubrir la variabilidad de actividad de las distintas especies.

Abstract. – The bird communities of Atlantic Forest have been studied using point counts of either 10 or 20 min. Nevertheless, many factors may affect the efficiency of the method and have not been evaluated in this ecosystem for a proper design of studies. We evaluated the influence of some factors in unlimitedistance point counts surveyed in a bird community studied during the breeding season in an Atlantic Forest at the San Rafael National Park, Paraguay. Counts were 20-min long, divided into four 5 min intervals, and sampled within 30 min before dawn to 3 h after sunrise, and repeated counts were surveyed at each point. The total number of individuals and species detected per count varied significantly during the morning period, being greater in the first hour after sunrise. Nevertheless, individual species differed in patterns of detection during the morning. At least, 87% and 93% of the bird species were detected in the first 5 and 10 min of 20-min counts, respectively. The number of new species detected was three times higher during the first 5 min of 20-min counts than in later intervals. Also, a significant decrease in detections occurred in the last two intervals of the counts. The number of species at a point increases with each additional count surveyed, but species decline substantially after the fourth visit. The results indicate that 10-min count

durations are sufficient for survey this bird community and that four visits to a point count during different hours of the morning would be needed to cover the variability in the activity pattern of its birds.
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Key words: Atlantic Forest, bird community, Paraguay, point counts, sampling design.

INTRODUCTION

Point counts have been recognized as one of the most appropriate methods for qualitative and quantitative studies on forest birds (Vielliard & Silva 1990). Point counts have advantages over other methods: data are collected at a fixed spot, which allows observers to concentrate fully on birds instead of worrying about access difficulties; they give more time to detect cryptic or inconspicuous species (Bibby *et al.* 2000); they encourage a better understanding of bird-habitat associations (Bibby *et al.* 1998); they yield a larger sample size as compared to mapping methods; and they detect more species as compared to mist-netting methods (Blake & Loiselle 2001). The effectiveness of point counts depends on their spacing, duration, and sample scheduling as well as on the characteristics of the surrounding habitat (Buskirk & McDonald 1995).

The Atlantic Forest of southeast Brazil, northeastern Argentina and eastern Paraguay is widely recognized as a hotspot for biodiversity conservation because of its high levels of diversity and endemisms, combined with the fact that it is one of the most threatened ecoregions in the world (Mittermeier *et al.* 1999, Myers *et al.* 2000). Information about the biodiversity of the Atlantic Forest is urgently needed, and birds have been widely recognized as indicators of such biodiversity (Vielliard 2000).

Although some bird studies in the Atlantic Forests have used 10-min point counts (Goerck 1999, Marsden *et al.* 2001, Protomastro 2001), most authors consider that a minimum of 20 min is necessary to detect rare and inconspicuous species (Aleixo & Galetti 1997, Anjos & Boçon 1999, Krauczuk & Baldo 2004). If point counts are to be employed to study bird communities in this threatened ecoregion, a standardized method will be required. In the present study, we attempt to address two questions: (1) How extrinsic factors influence the results of point counts, and (2) How we should modify sampling designs to make point counts more efficient for bird studies in this forest.

METHODS

The study was conducted in 2004 in a primary forest (26º36'25"S, 55º39'50"W, 300–350 m a.s.l.) in the southern San Rafael National Park (SRNP), located between the Itapúa and Caazapá Departments, Paraguay. San Rafael has one of the richest avifauna in Paraguay, with a total of 409 bird species corresponding to more than 58% of all the species reported for the country. The park also has more endemic Atlantic Forest birds than any other, with 70 (89%) species already recorded (Esquivel *et al.* 2007, in press). Local annual rainfall is approximately 2100 mm, and it occurs throughout the year. Mean temperature ranges from 23.8ºC (October to April) to 17ºC in the coldest months (May to September).

The study plot was approximately 100 ha in extent, an area sufficient to provide a representative subset of species of other tropical bird communities (Terborgh *et al.* 1990) that could be effectively surveyed during the breeding season (Robinson *et al.* 1990). The plot comprised primary semi-deciduous subhumid forest, with trees 20–25 m high, a

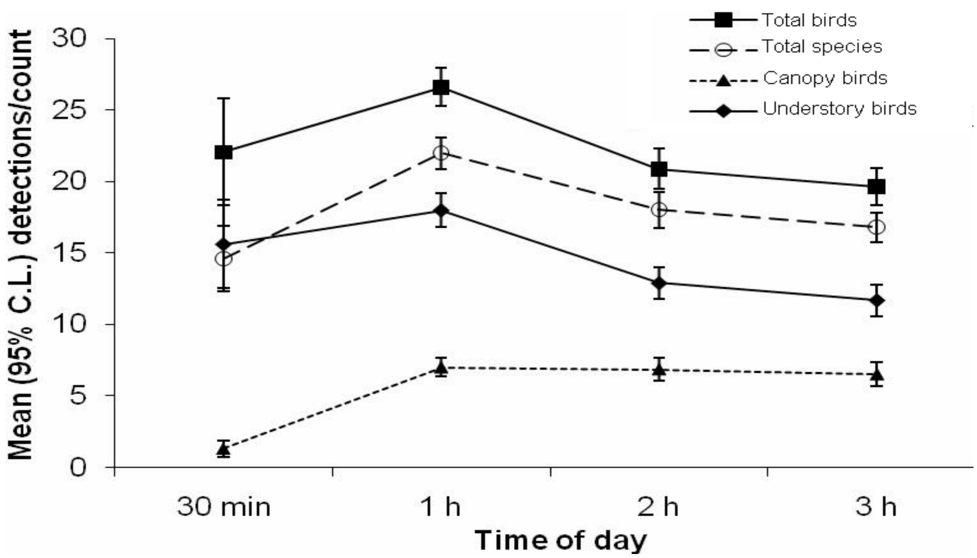

FIG.1. Mean (and 95% confidence limits) number of detections of birds obtained during 20-min point counts in four periods of the morning: from 30 min before sunrise to 3 h after sunrise.

closed canopy, and an open understory, interspersed with dense thickets of thin bamboo (*Chusquea ramossisima*). The commonest canopy tree species were *Nectandra megapotamica, Bastardiopsis densiflora, Balfourodendron riedelianum, Cabralea canjerana, Machaerium stipitatum, Ficus enormis, Apuleia leiocarpa, Alchornea triplinervia, Cedrela fissilis, Trichilia claussenii* and *Chrysophyllum gonocarpum*. The most common tree species were *Actinostemon concolor, Capparis humilis, Sorocea bonplandii, Inga marginata, Hybanthus* sp*., Piper* spp*., Acalypha gracilis, Trichilia elegans*, and *T. claussenii*. Lianas (Bignoniaceae, Apocynaceae, Dileniaceae), epiphyte plants (Orchidaceae, Bromeliaceae, Araceae) and ferns (Pteridophyta) are common. A detailed botanical description of a forest plot at Parabel (26º20'S, 55º32'W), northeast SRNP, can be found in Keel *et al.* (1993). The study area is subject to heavy hunting pressure, but logging pressure has been low and absent for at least the last 30 years.

Field work was conducted between August and November 2004, during the breeding season for most species in the region, and when more species and individuals are observed (own data). At the plots, we established five trails approximately 1.2 km long and 200 m apart. On each trail, we placed seven point-count stations 200 m apart and at least 100 m from the forest edge. Even at this distance, complete independence is not achieved for species with far-reaching calls or broad home ranges (e.g., Spot-winged Wood-quail (*Odontophorus capueira),* Helmeted Woodpecker *(Dryocopus galeatus)* or Short-tailed Antthrush (*Chamaeza campanisona*). We believe this lack of total independence between our points does not compromise the specific interpretations made (Buskirk & McDonald 1995). We conducted 20-min unlimited-distance point counts following Vielliard & Silva (1990), with detections separated into four consecutive 5-min intervals (Gutzwiller 1991). We recorded each bird or group of birds detected aurally or visually, assigned it to an interval, and estimated its distance from the point (Bibby *et al.* 2000). Despite this, we do not use distance

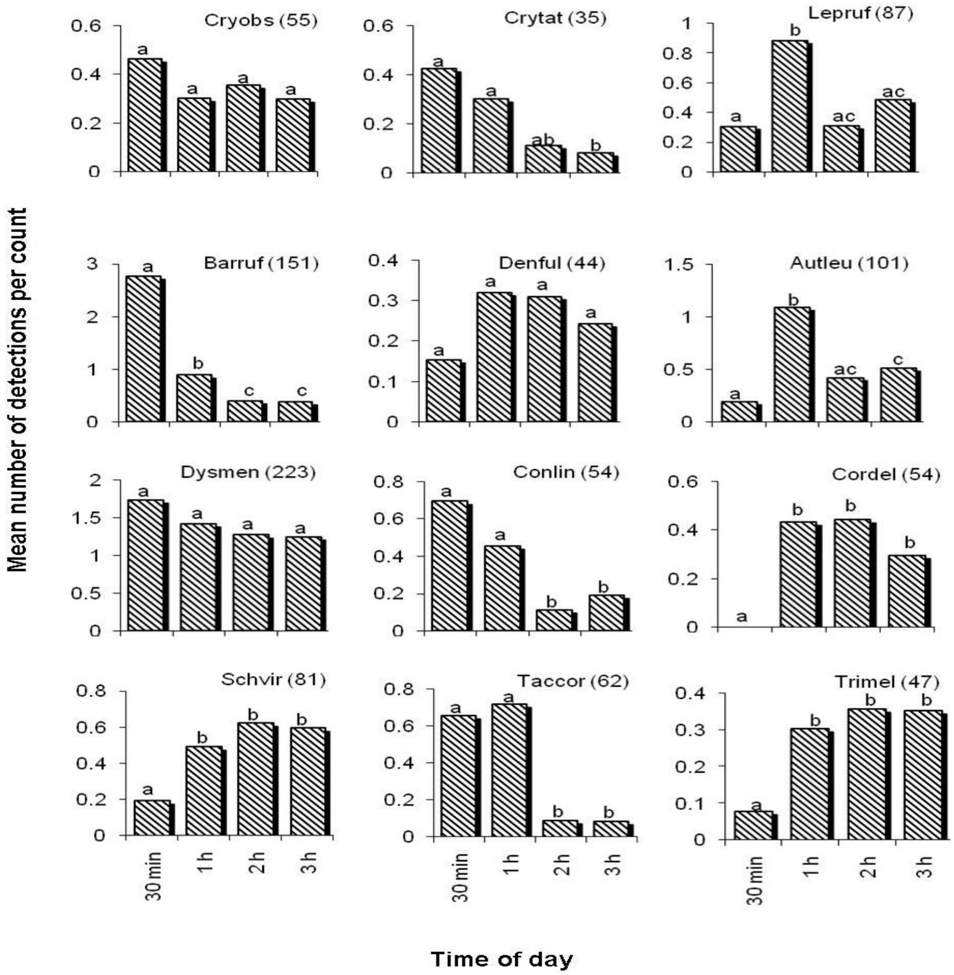

FIG. 2. Mean number of detections of understory species obtained during 20-min counts in four periods of morning: from 30 min before dawn to 3 h after sunrise. Comparisons among the morning periods were based on Kruskal-Wallis tests. Significant differences between the morning periods are indicated by lower-case letters; periods not sharing the same letter were significantly different ($P < 0.05$). Species codes are: Cryobs *Crypturellus obsoletus*, Crytat *Crypturellus tataupa*, Lepruf *Leptotila rufaxilla*, Barruf *Baryphthengus ruficapillus*, Denful *Dendrocincla fuliginosa*, Autleu *Automolus leucophthalmus*, Dysmen *Dysithamnus mentalis*, Conlin *Conopophaga lineata*, Cordel *Corythopis delalandi*, Schvir *Schiffornis virescens*, Taccor *Tachyphonus coronatus*, and Trimel *Trichothraupis melanops*. In parenthesis are the total numbers of detections of the species for all 161 20-min counts.

data in the analyses reported here, and we hope to analyze them in the near future. Each count was started one minute after arriving at the station.

Each count was assigned to the period of the morning in which it was taken: 1) 30 min before sunrise, 2) first hour after sunrise; 3) second hour after sunrise, and 4) third hour after sunrise. Each point-count station was visited several times (average = 4.60, SD = 1.52, range = 2–9), but the order was rotated to reduce bias with respect to the time of day. The time taken to walk from one station to the next one lasted between 7 and 22 min (average 12 min). No counts were conducted on rainy or windy days, and all counts were made by the same observer (AEM). We classified birds as understory or canopy birds based on Willis (1979) and Narosky & Yzurieta (2006) and personal observations.

A linear univariate model (SPSS 10.01) was used to test the relationships of point-count duration and time of day with number of species and individuals observed. Variables were tested for normality (Kolmogorov test-Shapiro-Wilk test) and equality of variances (Levene test), and were square root-transformed when the assumptions were violated. A Tukey multiple comparison among means test was used to compare the mean number of species and individuals detected per count. Non-parametric Kruskal-Wallis tests were used when necessary and for all tests of individual species.

RESULTS

Total species and detections in point counts. A total of 3602 detections of 119 species were obtained during 161 20-min counts. Another 16 species were detected at the plots during the study period but not during point counts. The mean number of species detected per count was 18.5 (SD = 4.8, range 4 to 32), and the mean number of individuals per count was 23.4 (SD = 6.1, range 6 to 39).

Time of day. The total number of species and birds varied significantly during the 3.5-h period of the morning sample (Fig. 1). The number of species detected was significantly greater during the first hour after sunrise than during the other periods of day ($P < 0.001$), as was the total number of birds ($P < 0.05$). Detections of canopy birds were significantly lower during the first 30-min period ($P < 0.001$) but increased thereafter during the 3-h period after sunrise they tended to level off. In contrast, detections of understory birds were greater ($P < 0.05$) during the first two periods of the day, thereafter declining substantially.

The mean number of detections per count during the four different periods of the morning reflects significant variations for 32 of the 38 species tested. Of these 32 species, six were detected most frequently during the 30 min before dawn, 13 during the first hour after sunrise, 8 during the second, and 5 during the third hour. Only six understory species did not show significant variations [e.g., Brown Tinamu (*Crypturellus obsoletus*), Plain-brown Woodcreeper (*Dendrocincla fuliginosa*), and Plain Antvireo (*Dysithamnus mentalis*) (Fig. 2)]. Some understory species were detected most frequently during the first two periods of the morning [e.g., Tataupa Tinamu (*Crypturellus tataupa*), Rufous Gnateater (*Conopophaga lineata),* and Ruby-crowned Tanager (*Tachyphonus coronatus*)], while others tended to peak between the first and third hour after sunrise [e.g., Southern Antpipit (*Corythopis delalandi*), Greenish Schiffornis (*Schiffornis virescens*), and Black-goggled Tanager (*Trichothraupis melanops*)]. Also, some understory species were significantly more frequently detected during one period of the morning than during all the other periods [e.g., Gray-fronted Dove (*Leptotila rufaxilla*), Rufous-capped Motmot (*Baryphthengus ruficapillus*), and White-eyed Foliage-gleaner (*Automolus leucophthalmus*)]. The patterns of detections among canopy species were more similar, since most detection events took place during the 3 after sunrise and were lower or null during the 30 min before dawn (Fig. 3). Two canopy species, the Surucua Trogon (*Trogon surrucura*) and the

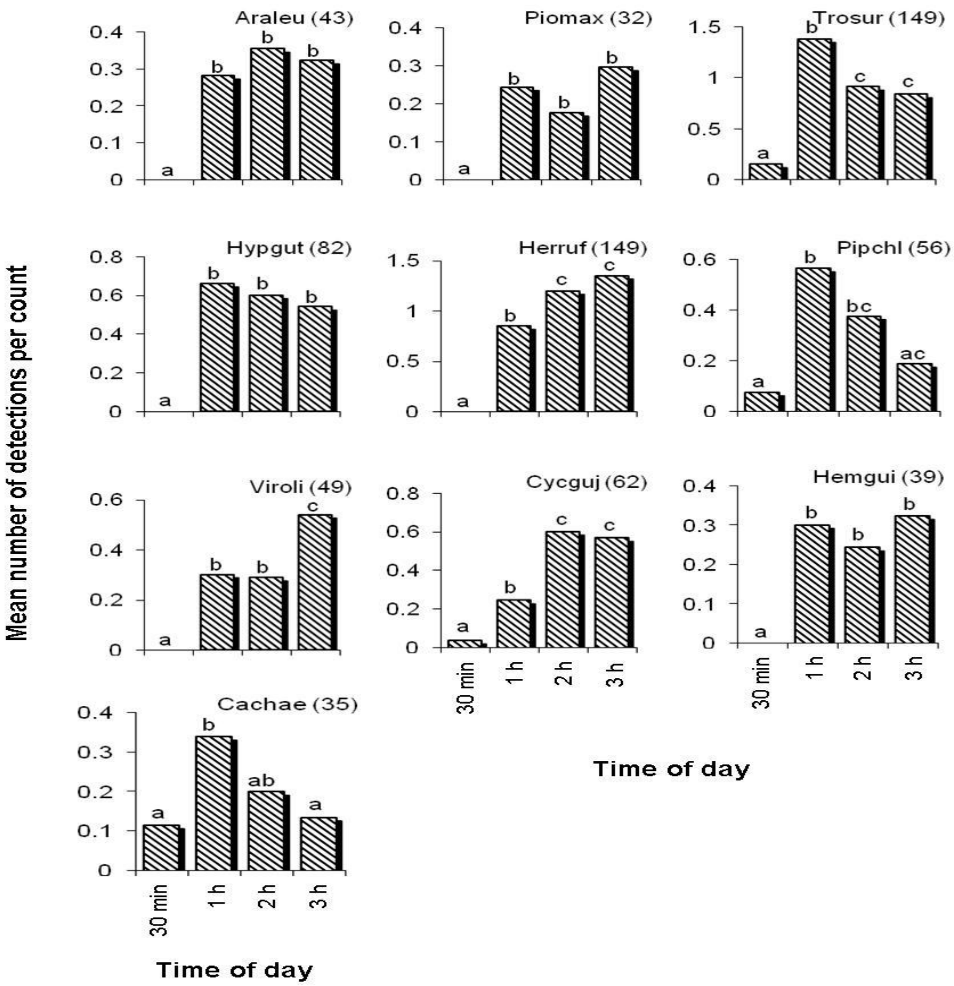

FIG. 3. Mean number of detections of canopy species obtained during 20-min counts in four morning periods, from 30 min before dawn to 3 h after sunrise. Comparisons between morning periods were based on Kruskal-Wallis tests. Significant differences between morning periods are indicated by lower-case letters: periods not sharing the same letter were significantly different ($P < 0.05$). Species codes are: Araleu White-eyed Parakeet (*Aratinga leucophthalma)*, Piomax Scaly-headed Parrot (*Pionus maximiliani)*, Trosur *Trogon surrucura*, Hypgut Spot-backed Antshrike (*Hypoedaleus guttatus)*, Herruf Rufous-winged Antwren (*Herpsilochmus rufimarginatus)*, Pipchl Wing-barred Pipit (*Piprites chloris)*, Viroli *Vireo olivaceus*, Cycguj Rufous-browned Peppershrike (*Cyclharis gujanensis)*, Hemgui Guira Tanager (*Hemithraupis guira)*, and Cachae Red-rumped Cacique (*Cacicus haemorrhous)*. In parenthesis are total numbers of detections of the species for all 161 20-min counts.

Red-eyed Vireo (*Vireo olivaceus*), were significantly more often detected during one period of the morning than in all other periods.

Count duration. About 87% (n = 103) and 93% (n = 111) of the species were detected during the first 5 and 10 min of the count, respec-

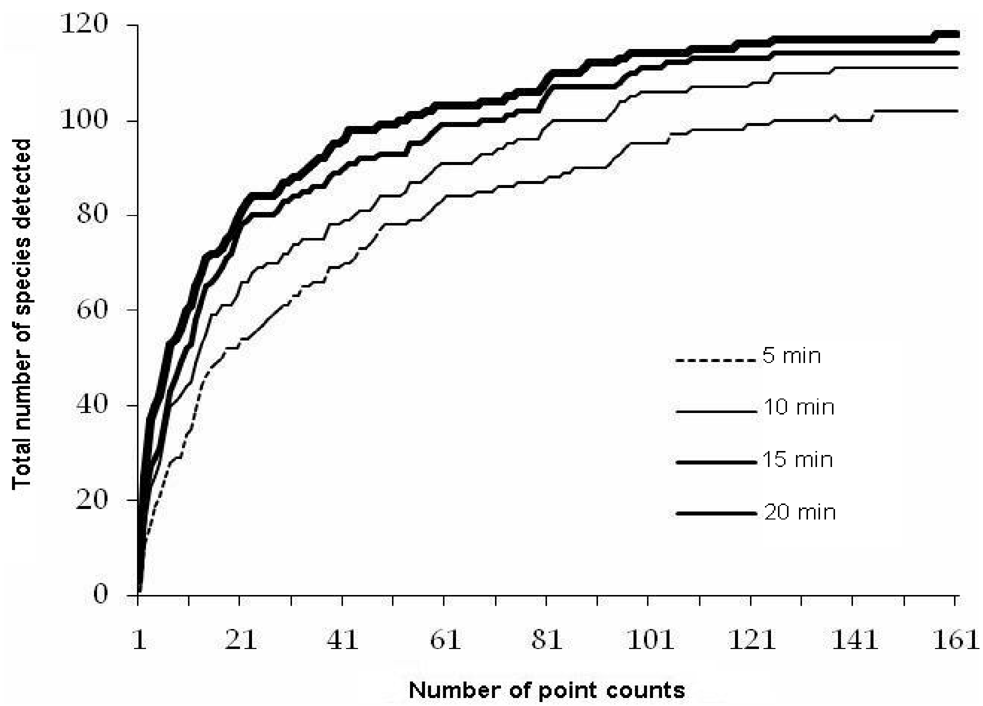

FIG. 4. Cumulative number of bird species detected during the four intervals of 20-min counts. A total of 119 species were detected in 161 counts.

tively (Fig. 4). Of 119 bird species detected, only eight were not observed during the first 10 min of sampling:e Pavonine Cuckoo (*Dromococcyx pavoninus*), Chestnut-eared Aracari (*Pteroglossus castanoti*), Saffron Toucanet (*Baillonius bailloni),* Rufous-breasted Leaftosser (*Sclerurus scansor),* Three-striped Flycatcher (*Conopias trivirgata),* White-winged Becard (*Pachyramphus polychopterus),* Bare-throated Bellbird (*Procnias nudicollis)* and Creamy-bellied Gnatcacher (*Polioptila lacteal).* Subsequent studies in the same forest plot using 10-min point counts revealed that most of those species could be detected with shorter count times (unpubl.).

Regarding the 20-min counts, 52% (range 10% to 85%) and 70% (range 13% to 94%) of all the first species detections occurred within the first 5 and 10 min, respectively, regardless of the time of day. The number of new species detected was nearly three times higher in the first 5 min of the count than in the other intervals ($P < 0.001$), except for counts conducted during the first period of the day, i.e., 30 min before dawn (Table 1). During the last interval of the count (15–20 min), significantly fewer new species were detected than in the other intervals ($P < 0.01$). Also, 49% (range = 12.5% to 83%) and 70% (range = 23.5% to 94.7%) of the individuals were detected during the first 5 and 10 min of the 20-min point counts, respectively, regardless of the time of day. The numbers of individuals in the first two intervals were significantly higher than in the last two intervals ($P < 0.01$).

Number of visits and count duration. After eight visits to a point-count station, the cumulative species-effort relationship curves had not reached a plateau, both for 5-min and for 20-

TABLE 1. Mean number of new species (S) and individuals (I) detected as a function of time of morning and count interval in 161 20-min counts (N) conducted on a 100-ha plot in a forest of the San Rafael National Park, Paraguay.

Time of morning	N	Count interval				Total
		0–5 min S (I)	5–10 min S (I)	10–15 min S (I)	15–20 min S (I)	1–20min S (I)
30 min before sunrise	25	5.1 (7.6)	2.7 (4.8)	4.2 (6.2)	3.1 (5.0)	15.1 (23.6)
1 h after sunrise	54	12.1 (14.4)	4.0 (5.3)	3.2 (4.1)	2.5 (3.4)	21.8 (27.3)
2 h after sunrise	44	9.9 (11.3)	3.5 (4.3)	2.3 (2.8)	2.1 (2.8)	17.8 (21.1)
3 h after sunrise	38	9.0 (10.4)	3.1 (4.1)	2.5 (3.2)	2.0 (2.5)	16.6 (20.2)
Total	161	9.7 (11.6)	3.4 (4.7)	2.9 (3.9)	2.4 (3.3)	18.4 (23.4)

min count period durations (Fig. 5), indicating that with greater efforts new species would continue to be recorded. However, the rates at which new species were recorded was lower with each new visit to a point-count site, since it decreased from about 42% to 38% in the second visit to less than 11% and 9% in the fifth visit of 5-min or 20-min count duration, respectively. According to these data, regardless of the effort made the relationship appears to have approached its asymptote.

On considering a sub-sampled regime of

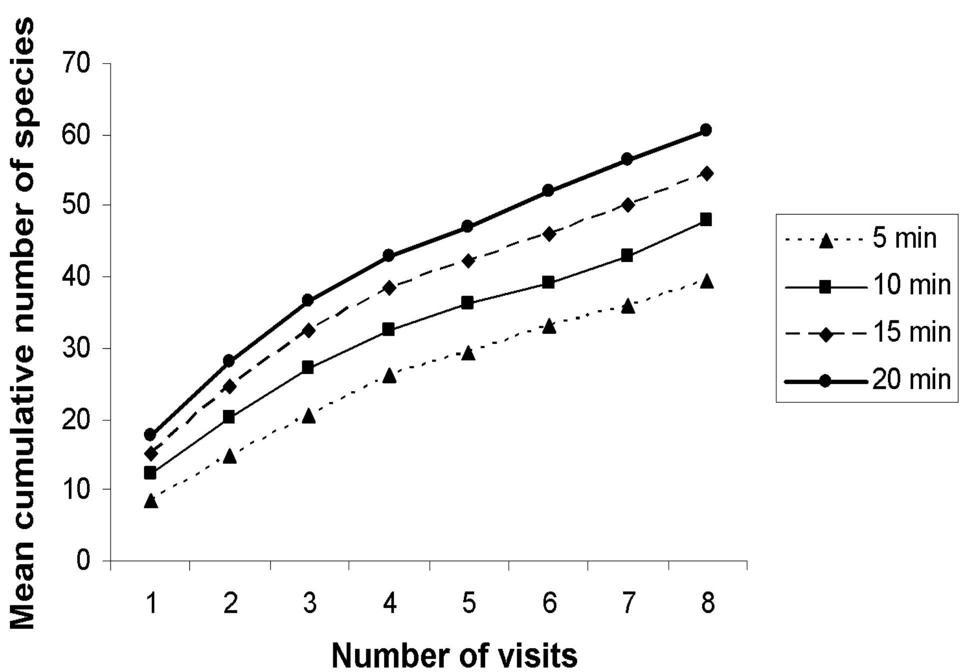

FIG. 5. Mean cumulative numbers of bird species detected in four different count period durations during eight visits to point count stations.

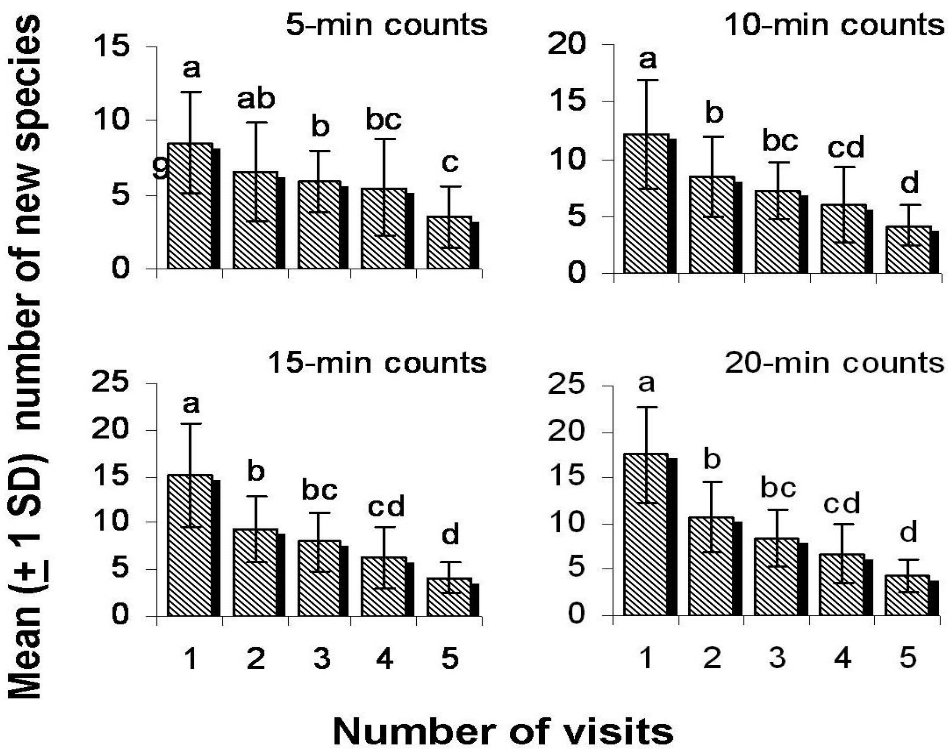

FIG. 6. Mean (± 1 SD) number of new species detected in up to five visits to a point count station during four different count period durations. Visits not sharing the same letter were significantly different (ANOVA, $P < 0.05$).

four different count durations and five visits to a point-count station in our data set (Fig. 6), the pattern of new species detected in these five visits was different in 5-min count durations, but equal among the 10-min to 20-min count durations. The number of new species detected in the first visit was significantly greater than in later visits lasting from 10-min ($P < 0.01$) to 20-min ($P < 0.001$). The rates of new species detections continued to decrease in the second and fifth visits to a point-count station, but the differences between consecutive visits was not significant ($P > 0.05$). Also, the number of new species detected was significantly lower in 5-min ($P < 0.01$) and 10-min ($P < 0.05$) count durations during the first visit, but became equal for the three longer count durations in the third visit, and for all count durations in the fourth visit to a point-count station (Fig. 7).

DISCUSSION

Point count coverage. Within the 161 counts surveyed at 35 point-count stations, we detected 88% of 135 bird species recorded in the forest plot during the study period. This number of species at the forest plot only represents 59% of the bird species recorded until recently in forest habitats (230 species) in the San Rafael National Park (Esquivel *et al.* in press). Although in this study no attempts were made to cover the variations possibly present in the different forests of the park, since it was part

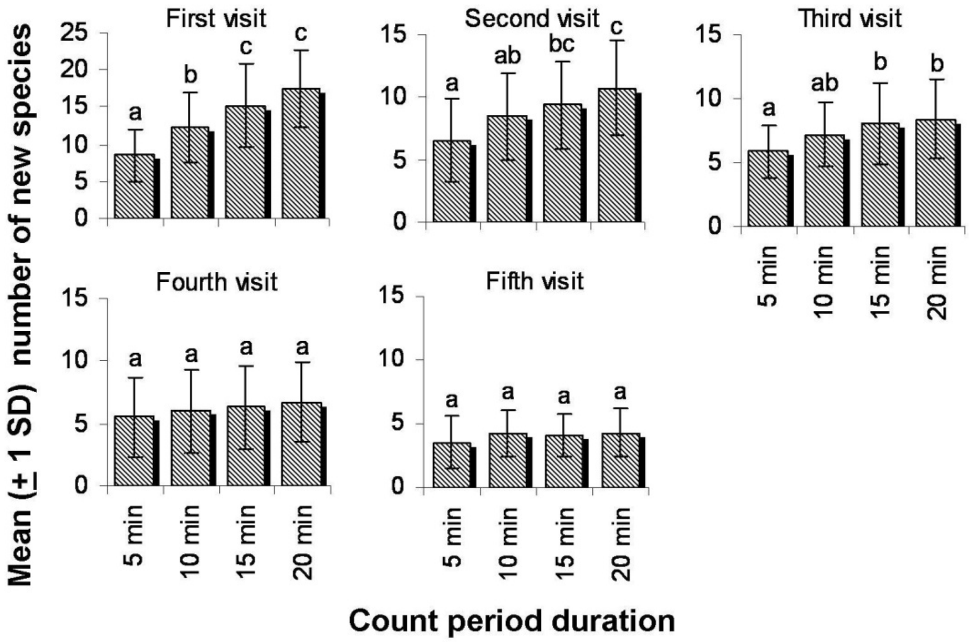

FIG. 7. Mean (± 1 SD) number of new species detected in four different count period durations in each new visit to a point count station. Count period durations not sharing the same letter were significantly different (ANOVA, $P < 0.05$).

of a larger study, the results reported here do reflect the importance of the design of point-count regimes for efficient development of the method in these bird communities.

Time of day. In temperate habitats, some studies have failed to find significant hourly variations in the numbers of bird species and individuals detected in counting methods among the first 5 h of the morning (Järvinen 1977, Verner & Ritter 1986). Robbins (1981) and Burskirk & McDonald (1995) found that counts of only 3 min failed to give equivalent total counts for more hours after sunrise, while 5 and 10-min counts provided equivalent total counts. This lack of hourly variations in temperate regions enables a larger number of counts to be made during a morning sampling.

In tropical regions, Blake (1992) suggested that point-count sampling should be concentrated during the first 3 h of the morning, since the number of species and individuals detected in 10-min counts during the first 5 h of the day in a lowland wet forest in Costa Rica declined significantly after the third hour. Lynch (1995) also found that the mean number of species detections per 15-min count declined by about 60% from the first to the third hour of the morning during winter in Mexico. Even with the 20-min count durations in our study, we found significant variations within the 3.5 h of the morning sample. Our results are fairly similar to those reported by Blake (1992), even though the morning periods studied were not the same, since his study included 5 h in morning and the 30-min period before dawn was included within the first hour. While we found that the number of birds detected was significantly greater during the first hour after sunrise than in other periods of day, in Costa Rica that number was also significantly greater during the first hour of the day than during the third, fourth and fifth hours. Furthermore, the patterns of detections of canopy and understory birds were similar in both studies for the same period of the morning, since detections of these birds underwent a significant decrease, while those of canopy birds did not, during the first 3 h of the morning.

The diurnal pattern of activity also varied among species (Skirvin 1981), higher counts being found for individual species during the four different periods of the morning.

The hourly variations in the detections of birds in tropical forests during the first hours of the morning in which counts are conducted may affect the results of point counts if such variations are not taken into account. Accordingly, the schedules and sampling regimes must be considered with care, depending on the study objectives, and it may well be unfruitful to invest time in pilot studies. If the aim of the study is to compare sites or habitats, a point-count station surveyed only during the first hour of morning could not be a point-count station surveyed in the later morning hours. However, if the aim is to determine temporal variations in a bird community, a point-count station sampled during the first hour of morning over one season, but sampled during later hours in another season, would not be appropriate for comparisons to be made. Moreover, if the study objectives require the counting of selected species during optimum hours of the day, those hours should be individually determined for each species.

Count duration. Most detections were made, and indeed most species were detected, during the first 10 min of each count of this study, suggesting that shorter point counts are more efficient than longer ones, as has been reported by other authors (Scott & Ramsey 1981, Lynch 1995). According to our data, two 10-min counts would yield an average of 26.2 species occurrences: i.e., 40% more in comparison with the 18.4 species detected during one 20-min point count. This apparent advantage of shorter point counts, however, is mitigated by an increase in the time used by the observer to travel between stations. During this study, travel time between stations averaged 12 min. Thus, in a morning sample of 210 min (3.5 hours), an observer would be able to perform 12 (not 42) 5 min counts, 9 (not 21) 10-min counts, 7 (not 14) 15-min counts, and 6 (not 10) 20-min counts. Approximately 118 species occurrences would be obtained in a morning sample using 5-min counts, 124 with 10-min and 15-min counts, and 120 with 20-min counts.

Considering a travel time of 7 min (the lower range in this study) to walk between neighbouring stations, in one morning sample an observer would be able to detect approximately 168 species occurrences in 17 5-min counts, 161 in 12 10-min counts, 151 in 9 15-min counts, and 142 in 7 20-min counts. However, if a travel time of 22 min (the upper range in this study) is required, (rough terrain in the forest), only 75 species occurrences would be observed in 8 5-min, 85 in 7 10-min, 90 in 6 15-min, and 91 in 5 20-min counts along a morning sampling. This shows that travel time is an important factor in sampling design, longer travel times favouring longer count durations (Thompson & Schwalbach 1995).

Number of visits to a point count. Smith *et al.* (1995) found that the cumulative number of species increased with each added point from five to six in the Mississippi Alluvial Valley. However, the cumulative number of species increased with each revisit up to four visits to a point-count station, while four visits did not differ from five visits. They concluded that more points visited afforded significantly greater cumulative numbers of species than more visits to each point count station. We found a similar situation when the cumulative number of species fell to fewer than 10% after the fourth visit to a count point, both with 10–15 min and 20-min counts, suggesting that the surveillance of more points would be more efficient than increasing the number of visits after four visits. This consideration is important if the study objectives need an efficient sampling design to capture variations in forests.

RECOMMENDATIONS

Researchers usually use counts of 5-, 10- or 15-min duration in both tropical and temperate habitats because shorter durations (e.g., 3-min) may afford less comparable hours during a morning sampling (Buskirk & McDonald 1995) and longer count durations (e.g., 20-min) may be inefficient or may cause successive counts to be statistically dependent (Fuller & Langslow 1984). Under the conditions of our study, even with 20-min counts, the different daily periods surveyed failed to give equal number of species and individuals, showing that hourly variations cannot be reduced by increasing count durations in this forest, as has been found in temperate habitats (Robbins 1981). Our results also show that, after 10 min of counting, the number of individuals declines substantially, while the number of species declines significantly after 15 min of counting, suggesting that 10-min counts are sufficient and more efficient, since the number of samples and total species occurrences during a morning period would be greater with this duration of counting, even with the walking time of 12 min used in this study. A clear advantage to maximizing the number of counts is that the power of statistical tests increases as sample size increases, making it easier to detect significant differences and relationships and affording clearer interpretations of the results (Gutzwiller 1991).

Since travel time is an important factor that influences the effectiveness of point counts, observers should minimize it by moving rapidly between stations, and by adopting the minimum between-point distance that will prevent double counting (Lynch 1995). Even with a distance of 200 m, we did not observe total independence for some species with far-reaching calls or large home ranges, and hence a possible approach for these species could be to tabulate occurrences between point-count stations separated by greater distances (e.g., 400 m), while other species should be tabulated in point counts separated by 200 m.

Even increasing the number of points, rather than the number of visits to a point, would be more efficient in terms of detecting new birds (Smith *et al.* 1995). It seems reasonable that the allocation of one visit to a point-count station during each period of morning (a total of four visits to a point) during one season would be necessary to cover hourly variations in bird activity in this forest.

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