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AN ASSESSMENT OF THE EFFECTIVENESS OF TWO METHODS IN DESCRIBING A NEOTROPICAL CLOUD FOREST BIRD COMMUNITY

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Resumen. – Evaluación de la efectividad de dos métodos para la descripción de una comunidad de aves del bosque nuboso neotropical. – Las redes japonesas y los puntos de contéo son dos de las técnicas más utilizadas en el muestreo de comunidades de aves Neotropicales. Sin embargo, se conoce aún muy poco sobre la eficiencia de estas técnicas en el muestreo de comunidades en el bosque tropical húmedo de montaña. Con el objetivo de determinar cuál es la mejor metodología para llevar a cabo un inventario de aves, hemos comparado la eficiencia de estas dos metodologías de muestreo en el Parque Nacional Cusuco, en el noroeste de Honduras. Se utilizaron redes japonesas en 26 sitios y puntos de contéo en 126 sitios. Ninguno de los métodos utilizados registró la totalidad de la avifauna presente en la zona (37,5% y 59,3% para redes y puntos, respectivamente, en comparación con una lista de aves preliminar del sitio). Sin embargo, estos resultados demuestran que los puntos de contéo es la metodología más efectiva registrando una mayor variedad de grupos y un mayor número especies (124 frente a 78) por unidad de tiempo. No obstante, ambos métodos usados conjuntamente todavía fallaron en incorporar el 27,8% de las especies de aves inventariadas de la región. En conclusión, cualquier muestreo que pretenda registrar todas las especies que habitan el bosque tropical húmedo debería incorporar una gama amplia de técnicas de censo.

Abstract. – Mist netting and point counting are the two most commonly used techniques for surveying Neotropical avifauna communities, although their effectiveness remains poorly understood in tropical montane cloud forest. This paper seeks to determine how best to conduct bird surveys in this distinctive ecosystem by comparing the effectiveness of these two methodologies in the Parque Nacional Cusuco, north-west Honduras. Mist netting was conducted at 26 sites, with point counts being conducted at 126 sites. Neither technique succeeded in providing a wholly accurate description of avifaunal assemblages, with mist netting and point counts detecting 37.5% and 59.3% of all avian species respectively, in comparison with our preliminary checklist of the area. However, results indicate point counts as more effective overall, detecting a greater sum of species (124 species compared to 78), being markedly more time-efficient and detecting a wider range of avian subgroups. Both methods in conjunction still failed to detect 27.8% of species on the preliminary checklist. Any survey aiming to accurately survey all cloud forest species would therefore need to incorporate a wide range of integrated methodological techniques. *Accepted 22 February 2010.*

Key words: Cloud forest, mist nets, point counts.

INTRODUCTION

The need for effective survey methods in monitoring Mesoamerican bird communities has become increasingly important as growing anthropogenic pressures cause greater conservation challenges. Nearly 80% of original vegetation cover within the Mesoamerican biodiversity 'hotspot' (Myers *et al.* 2000) has been lost or modified and remaining intact forest continues to be lost at an estimated rate of 0.8–1.5% per annum (FAO 2006, Achard *et al.* 2002). If current disturbance patterns continue high extinction rates in bird species are predicted (Conservation International 2007, Brooks *et al.* 2002, Stattersfield *et al.* 1998). Effective conservation schemes are needed to safeguard regional avifauna, but to implement these extensive monitoring is required to ascertain how bird communities respond to environmental disturbance. At present, however, a full understanding of the effectiveness of different survey methods available to ornithologists is incomplete.

Mist netting and point counts represent the most frequently utilised techniques for surveying avifaunal communities in the Neotropics (Sutherland *et al.* 2004, Whitman *et al.* 1997). Mist netting involves the sampling of avifaunal communities by capturing birds in fine mesh nets, and has been developed as a systematic methodology for over 30 years (Ralph & Dunn 2004, MacArthur & MacArthur 1974). Point counting is a sampling technique that involves surveying a series of points and taking a census of avifaunal assemblages based on birds seen and heard by the observer and has become increasingly viable as a methodology through a better understanding of bird vocalizations.

These two methodological approaches are subject to well-defined limitations. Mist netting is restricted by poor time-efficiency, reliance on external factors, such as time of day, weather, and the behavioural characteristics of different bird species, and its limited capacity to survey components of avifaunal communities rarely found beyond the nets' capture range of 3–5 m above ground (Wang & Finch 2002, Rappole *et al.* 1998, Remsen & Good 1996). Point counts are similarly limited by external environmental factors, as well as from a necessarily heavy reliance on the skill and experience of individual observers, the increased probability of recording individual birds multiple times, and ineffectiveness in recording the presence of rare species. Furtive birds which rarely vocalise and certain other avifaunal groupings, such as nocturnal species, raptors, and swifts (Shiu & Lee 2003, Blake & Loiselle 2001, Bibby *et al.* 2000, Remsen & Good 1996) are also poorly recorded by point count surveys.

Several studies have attempted to compare and assess the relative effectiveness of these two methodologies (Derlindati & Caziani 2005, Wang & Finch 2002, Blake & Loiselle 2001, Whitman *et al.* 1997). However, these have largely focussed on lowland forest ecosystems and there remains a poor appreciation of how best to employ survey methods in less explored areas, such as tropical cloud forest.

Tropical montane cloud forest is a rare ecosystem of high conservation importance due to it supporting a rich biodiversity and a high prevalence of endemic organisms, in addition to the provision of a range of ecological services (UNEP 2006, Powell & Palminteri 2001). Bird communities in particular are characterised by a high prevalence of endemic species; 10% of all globally range restricted species can be found in cloud forest ecosystems (Stattersfield *et al.* 1998). Cloud forests also provide an important refugia habitat for many endangered species marginalised by destruction of lowland forest habitats (Aldrich *et al.* 1997).

Until recently the relative inaccessibility of most cloud forest ecosystems ensured their ecological integrity, but these habitats are now becoming increasingly vulnerable to exploitation due to expanding regional infrastructure, demographic pressures, and inadequate governmental protection (Powell & Palminteri 2001, Aldrich *et al.* 1997). Cloud forest is now disappearing with greater rapidity than the region's remaining lowland forests (Solorzano *et al.* 2003) which has severe implications for local avifauna.

Extensive monitoring of cloud forest avifaunal communities is required to inform future conservation policy. However, few studies have been conducted here to determine the most appropriate survey methods. This is important as cloud forests possess characteristics which may influence the relative effectiveness of point counts and mist nets beyond that described in previous studies.

Tropical cloud forest occurs in an altitudinal band ranging from between 1000–4000 m (Powell & Palminteri 2001) and the geographical conditions of these altitudes have created an ecosystem with very distinct structural form. Precipitation is high, averaging 2000–4000 mm per year (Powell & Palminteri 2001) with most of this precipitation supplied by enveloping cloud banks. This persistent cloud cover leads to heavy saturation of all vegetation strata from canopy to forest floor, reducing solar radiation and creating an almost permanently saturated canopy, which suppresses evapotranspiration, giving rise to a very moist, humid environment (Hamilton 1995). This, in combination with reduced temperatures, steeper topography, nutrient-poor soils, and higher exposure, has given rise to a very distinct floral structure. Canopy level trees are reduced in stature, with more compact crowns and higher stem density than those found in lowland forest. There is also a greater proportion of biomass at lower levels in the ecosystem, with heavier undergrowth and greater abundance of bryophytes, lichens, bromeliads, and other epiphytes (Nadkarni *et al.* 1995, Hamilton 1995). This distinctive vegetation structure has given rise to an equally distinctive avifaunal community which differs significantly from lowland bird assemblages in trophic and taxonomic composition (Renjifo *et al.* 1997). These communities may therefore be expected to respond differently to survey efforts than has been described in other forest ecosystems; specifically, denser undergrowth and reduced tree stature may increase the proportion of species within mist net capture range, while simultaneously limiting visibility which could inhibit the effectiveness of point counts. Thus the comparative effectiveness of mist netting to point counts may be greater than described in other ecosystems.

In this paper we aim to critically assess the effectiveness of these two commonly employed methodologies in surveying bird communities in this poorly understood ecosystem, testing the hypothesis that mist netting will prove to be comparatively more effective than described by studies in lowland forest sites. The findings of this assessment will then be used to prescribe the most effective approach for monitoring cloud forest avifauna communities.

METHODS

Study area. Research was conducted over an eight week period between June–August 2007 in the Parque Nacional Cusuco, Departamento Cortez, north-west Honduras (15°29.8'–15°32.1'N / 88°13.0'–88°26.3'W) (Fig. 1). The park represents a 23,440 ha area of tropical montane cloud forest divided into a 7690 ha core zone with extensive protective legislation and an encompassing 15,750 ha buffer area where land-use is controlled. Elevation ranges used in this study sites varied from 700–2200 m a.s.l. (Lenkh 2005); these elevations occupy the lower altitudinal bands of montane cloud forest as described by Powell & Palminteri (2001). This altitudinal range is a high research priority because avian species richness is higher and anthropogenic pressures are greater here than in montane forests of higher elevation (Navarro &

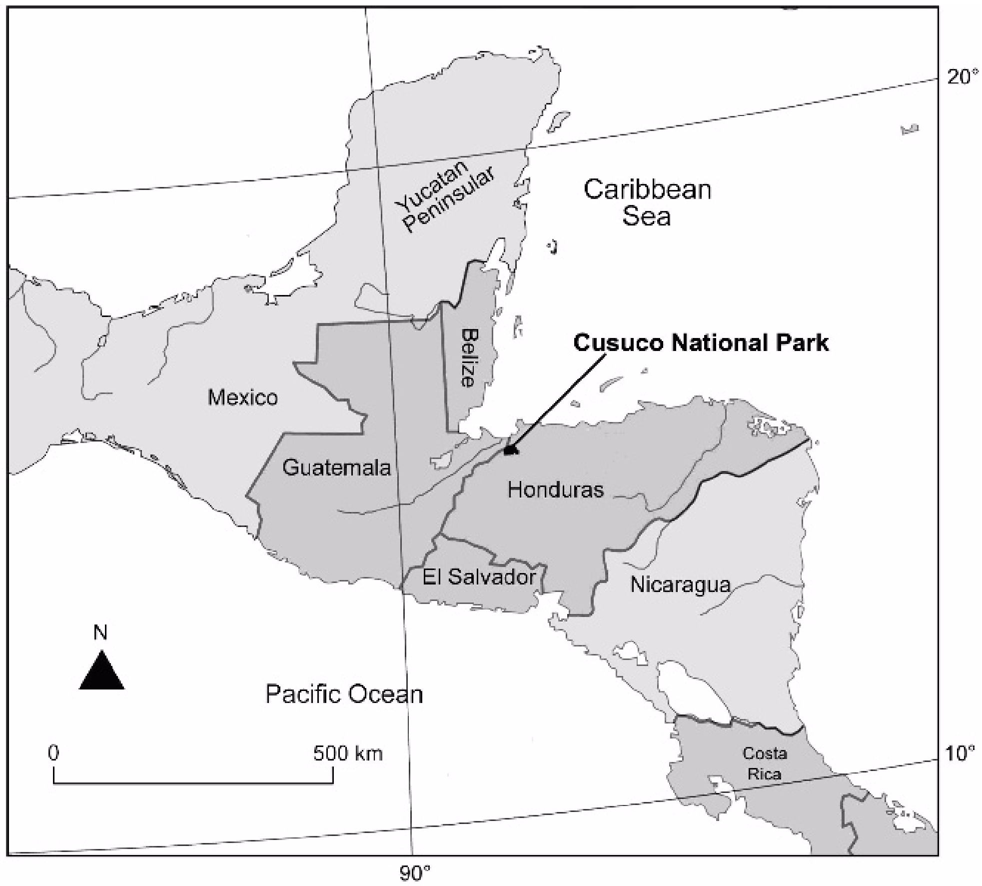

FIG 1. Map displaying northern Central America and location of Cusuco National Park.

Aldolfo 1993). Annual precipitation in the core zone is 2995 mm and 2580 mm in the buffer zone, with 45% of precipitation falling in the wettest months between October and December. Mean monthly temperatures range from 12.9ºC in December to 20.2ºC in April, with a mean of 16.7ºC in the core and 20.6ºC in the buffer zone (Fundación Ecologista 1994).

Bird surveys. Bird surveys were conducted along 28 linear transects throughout the park; twelve located in core zone primary forest, eight in the edge forest ecosystems of the buffer zone and eight on the transitional zone between the buffer and core. Each transect contained between four and seven study sites with a distance of at least 200 m separating each site. All sites along each transect were used for point counts, with a single site per transect being sampled by the mist netting teams. Vegetation structure at each of these study sites varied considerably, ranging from 30 m high *Pinus oocarpa* pine forest to Bosque enano dwarf forest with a canopy of < 2 m high, although canopy height at the majority of study sites (> 80%) was < 15 m.

Mist netting was conducted by two teams, each consisting of two experienced banders. These teams each used three 2.6 m x 20 m x

36 mm mesh mist nets. Mist nets were opened half an hour after dawn each morning (05:30 h). This half-hour delay was imposed to reduce accidental by-capture of bats. Nets were checked every 20 min and closed 3 h after opening. Each netting team surveyed a single site for two consecutive days over a 26 day period, giving a total of 26 sample sites with one repetition per site. All birds captured were marked with leg bands to avoid multiple recording of recaptures. Netting was not carried out in rain or in heavy mist.

Fixed radius circular point counts (Bibby *et al.* 2000) were conducted by three experienced ornithologists familiar with Neotropical avifauna vocalisations, with each observer working independently across three different transects. Between four and seven sites were surveyed along each transect, and each transect was repeated three times on consecutive days, giving a total of 377 samples across 126 sites. Sampling was conducted each morning from dawn (05:30 h) to 09:30 h, this being the most efficient time-period for conducting point counts due to bird detectability being high and most species being fairly sedentary (Marsden 1999, Wunderle 1994, Blake 1992). Surveying commenced immediately upon reaching each sample site with no settling-in period, allowing the recording of birds which had been disturbed by the surveyors and thus increasing the number of contacts made at each point (Lee & Marsden 2008). Each point count lasted for 10 min as sampling periods of this length have a lower chance of recording individuals multiple times than longer counts while still detecting a high percentage of species present at the points. (Lynch 1995, Waide & Wunderle 1987). All species seen and heard within a 50 m radius were recorded, excluding those flying above the canopy as these may be wandering or passage birds not associated with cloud forest habitats. A 50 m radius was used to prevent overlap with other count points and to reduce bias against smaller species, which are inaudible beyond this distance.

In addition to these two methodological approaches, a checklist of species recorded in the park consisting of all species detected by either systematic methodology or sighted opportunistically was also kept for the 8-week study period. This checklist of species represents 280 person-days (> 2240 person-hours) compared to 26 mornings spent netting (468 netting hours or 416 person-hours, including an hour each morning to raise and take down nets) and 63 person-hours point counting. It should be acknowledged that this checklist, although based on a survey effort much greater than either standardized methodology, must be regarded as a preliminary list. The survey effort represented by our checklist is fairly small compared with comprehensive surveys in better-studied areas of the Neotropics (Whitman *et al.* 1997, Bierregard 1990) and, being confined to a single season, will in likelihood under-represent certain groups of birds such as latitudinal and altitudinal migrants and uncommon 'wandering' species (Remsen 1994).

Statistical analysis. Statistical analyses largely follow those employed by Whitman *et al.* (1997) to ensure consistency of results and allow meaningful comparisons between our study area and a lowland forest site. The total number of species detected by each method was compared using a Sign test (Zar 1999). Three non-parametric species estimators (ACE, Chao 2, and MMMeans) were also calculated for each method using the software package EstimateS (Colwell 2006), these being considered appropriate estimators for tropical bird community richness (Herzog *et al.* 2002). These estimators were based on data aggregations from all sampling points together and calculated using 50 randomization runs. The mean value of these estimators was taken as an estimation of the total number of species present predicted by each sampling technique, which was compared to the checklist. Mean values of the three estimators were used as the effectiveness of different estimators vary between data sets (Walther & Moran 1998).

The efficiency of each method in detecting species was evaluated by the construction of species effort curves, comparing the number of person-hours with the number of species detected for each method. The effectiveness of both methods in detecting different subgroups of the avifaunal community was also examined. Groupings categories were designated after Whitman *et al.* (1997) and were based on family, abundance, body-size categories, diet, height strata, feeding guilds, and habitat. Family status was based on Clements (2007). Abundance categories were based on those described by Desante & Pyle (1986) and Whitman *et al.* (1997). These categories were: very rare (detected < 1% of days), rare (1–10% of days), uncommon (10–50% of days), common (1–90%), and abundant (detected > 90% of days). Body size categories were based on those utilised by Whitman *et al.* (1997) with bird species being grouped into small (< 22.5 g), medium (22.5–51 g) and large (> 51 g) categories based on Stiles *et al.* (1989) and our own field measurements. Birds were assigned to diet, height strata, feeding guild, and forest type categories after Howell & Webb (2005), Karr *et al.* (1990), Stiles *et al.* (1989), and the authors' own field observations. Differences in grouping were statistically compared using a χ^2 squared test.

Compositions of avifauna were also examined at an individual point level in order to take into account different sample sizes and allow a direct comparison of methods. All netting sites were statistically compared with corresponding point counts conducted at those sites. The numbers of species found at individual points were compared using a paired *t*-test (Zar 1999). The numbers of species in each of the previously defined grouping categories were also compared using a series of paired *t*-tests. Differences in community compositions were compared using a Jacard's Index, calculated by dividing the number of species detected at each point by both techniques with the number of species at each point detected by either technique (Whitman *et al.* 1997). Where appropriate, standard deviations were expressed as ± values of averages.

RESULTS

A total of 3028 individual birds were recorded in the sampling effort, with 513 individual birds of 78 species being captured in mist nets and 2515 individuals from 124 different species being recorded by the point counts. A total of 209 species were recorded on the checklist. 8.7% of contacts in the point count surveys were unidentified and excluded from analysis. 58% of these unidentified contacts were hummingbird species. 100% of birds caught in the mist nets were identified.

Although a substantial overlap of species detected occurred between the two approaches, each method managed to record a substantial number of species that the other failed to detect. Mist netting recorded 25 species which were not recorded by point counts, including two families which were absent from the counts, while point counts recorded 71 species which were not detected by mist nets, including 13 families (Table 1). Both methodologies failed to detect all species recorded on the total checklist, with nets and points detecting 37.5% and 59.33% of species respectively. However, point counts detected significantly more species than mist nets (Sign test, $p < 0.05$). Non-parametric species estimators also predict point counts to detect a greater number of the total species checklist than mist nets; 157 species compared to

TABLE 1. Summary of families/subfamilies and number of species detected by mist netting and point counts, as well as both or neither methodologies, in Cusuco National Park, north-west Honduras. Names of families based on Clements (2007).

Family/subfamily	Common name	No. of spp. only captured in nets	No. of spp. only recorded on counts	No. of spp. recorded with both methods	No. of spp. recorded by neither method
Tinamidae	Tinamous	0	3	0	0
Cathartidae	New World vultures	0	0	0	3
Accipitridae	Raptors	0	2	0	7
Falconidae	Falcons	0	1	1	3
Cracidae	Cracids	0	4	0	0
Eurypygidae	Sunbitterns	0	0	0	1
Phasianidae	Gamebirds	0	2	0	0
Columbidae	Pigeons	1	5	1	2
Psittacidae	Parrots	0	4	0	0
Cuculidae	Cuckoos	0	1	0	3
Strigidae	Owls	0	2	0	2
Caprimulgidae	Nightjars	0	0	0	1
Apodidae	Swifts	0	2	0	2
Trochilidae	Hummingbirds	9	0	9	1
Trogonidae	Trogons	0	3	0	1
Alcedinidae	Kingfishers	0	0	0	1
Motmotidae	Motmots	1	2	1	0
Ramphastidae	Toucans	0	2	0	1
Picidae	Woodpeckers	0	5	1	3
Dendrocolaptidae	Woodcreepers	1	2	2	3
Furnariidae	Ovenbirds	1	0	5	1
Formicariidae	Antbirds	0	2	1	0
Tyrannidae	Tyrant-Flycatchers	1	4	4	5
Cotingidae	Cotingas	0	1	0	2
Pipridae	Manakins	1	0	1	0
Troglodytidae	Wrens	0	0	5	2
Turdidae	Thrushes	0	2	4	0
Cinclidae	Dippers	1	0	0	0
Corvidae	Crows	0	3	0	0
Sylviidae	Old World warblers	1	0	0	0
Coerebinae	Bananaquit	0	0	1	0
Thraupinae	Tanagers	3	5	4	7
Emberizinae	American Sparrows	1	3	5	0
Cardinalinae	Grosbeaks	1	2	1	0
Parulinae	New World warblers	1	2	4	2
Vireonidae	Vireos	1	1	1	1
Fringillidae	Finches	0	0	0	1
Icteridae	Blackbirds	0	5	0	3

99 (Table 2). Point counting proved to be a significantly more efficient method of detecting bird species than mist netting (Fig. 2). For nets, the accumulation of new species

TABLE 2. Non-parametric species estimators for mist netting and point count survey efforts in Cusuco National Park, north-west Honduras. ACE, CHAO2, and MMMeans are non-parametric species estimators (Colwell 2006).

Parameters	Mist nets	Point counts
Sample size	26	377
Species observed	78	124
Individuals observed	504	2515
ACE	93	165
Chao2	91	173.3
MMMeans	111.6	131.8
Average of species richness estimates	**99**	**157**

detected began to level off at around 70 species after 250 person-hours, with very few new species yielded in the next 200 person-hours. Point counts, in contrast, recorded 125 species after just 50 person-hours, and while the accumulation curve had begun to level out after this, it is likely that further survey effort would yield further species detections.

Point counts were more effective overall in surveying most avifaunal grouping (Table 3), detecting a greater proportion of bird families than netting (84.2% compared to 55.3%) as well as identifying significantly higher proportions of common and uncommon species, large birds, canopy-level species and all dietary groups except nectarivores. Point counts were also significantly more effective at detecting five of the seven feeding substrate groupings. Mist nets were considerably more limited in their efficacy, being significantly better at detecting only nectarivores and water feeders, and marginally more effective at detecting rare and very rare species, small birds and species primarily occurring at shrub level. Netting was entirely unsuccessful in recording aerial and canopy level birds (0% detected) as well as all large birds, raptors (defined in this study to include the families Accipitridae, Falconidae, Cathartidae, and Strigidae), and ground-level species (each group < 10% detected).

While results demonstrate that point counting is the more time-efficient methodology overall, detecting a wider range of species in considerably less time, the use of both methods combined proved more effective than either technique in isolation. Both methods together detected > 92% of all avian families, compared to just 84.2% by point counting alone, and 23 of the 29 avian subgroups yielded a higher proportion of species when both methods were used in conjunction. Both methods combined also achieved a > 80% detection rate of species in 11 subgroups, with similar proportions being obtained in just three groups for point counting alone and only a single group for mist netting alone. This combination of methods still failed to detect 27.8% of species on the preliminary checklist. Neither technique was effectual in detecting scarce species, with 40.4% of rare and 66.6% of very rare species on the checklist remaining undetected by both methods. Both techniques were also ineffective at detecting raptors (75% of species undetected) as well as aerial and water feeders (62.5% and 66% undetected, respectively). The proportion of total species detected in edge forest environments was also poor (47.5% undetected).

Individual points. Point counts detected significantly more species than mist nets at individual points, with a mean of 9.3 (± 6 SD) species being recorded per point for nets, in comparison to a mean of 12.9 (± 3.9 SD) species per point for counts (paired *t*-test, $t = -2.785$, $p < 0.05$).

The mean proportion of species in each category detected at each of the 26 individual points (Table 4) indicates again that point counting is the more effective methodology

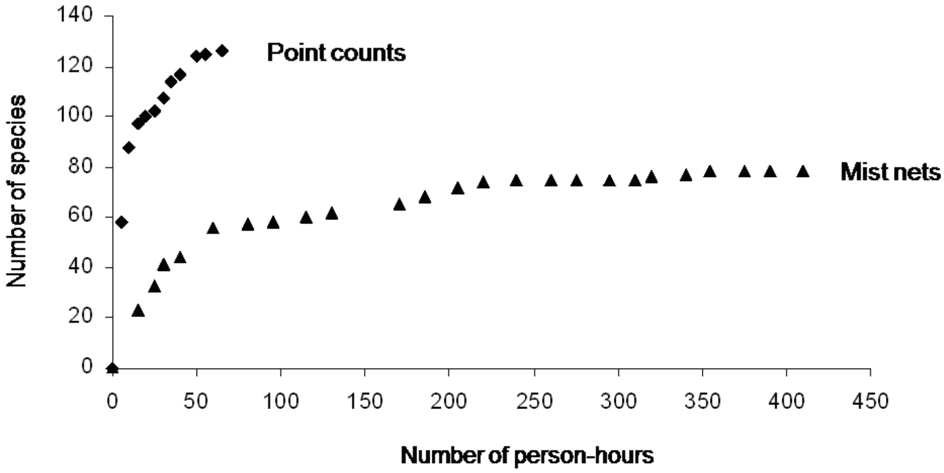

FIG. 2. Cumulative number of species detected by mist netting and point counts.

overall, although the differences in efficacy were not as pronounced as in the sum of points analysis. Point counting still detected marginally more species per point and category than mist netting (5.6 species compared to 4.4 species) but detected a substantially higher proportion of species in only 10 subgroups, compared to 19 in the sum of points analysis. At an individual points scale, mist netting proved significantly more effective in detecting very rare species, small birds, shrub-level species, nectarivorous birds, and species dependent on live foliage feeding substrates; a more successful performance in five subgroups, compared to only two groupings from the sum of points analysis.

As with the sum of points, a combination of both methods together was more successful in describing avian communities than either method alone, with 16 of the 29 subgroups detecting a substantially higher proportion of species than either method in isolation, and another nine subgroups showing minor increases in detection rates. The rate of detection per point for abundant species, small birds, shrub-level species, species which feed on live and dead foliage and species restricted to mature forest was particularly improved by combining both methods. Neither method, nor both methods together, were particularly successful in surveying the same avian subgroups defined as poorly represented by the sum of points analysis, such as rare species, raptors, and aerial and water feeders. The mean similarity (Jacard's index) between points was low (t_{25} = 2.373, $P < 0.05$) with both techniques sharing only a mean of 9.6% ± 8.9 of total species caught. This indicates only a small overlap in the species being detected by the two methods.

DISCUSSION

The results of this study demonstrate that point counts can be generally regarded as more effective and efficient than mist nets for describing cloud forest avifaunal communities; a similar finding to that concluded by studies in other forest ecosystems (Stiles & Rosselli 1998, Whitman et al. 1997). The aggregate analysis of the sum of points demonstrated that mist netting was found to be highly limited in the number of species caught, and species that were detected tended to be weighted towards discreet avian groupings, such as small understorey birds. Entire body-size and feeding-guild groupings were virtually absent from the netting surveys. Analysis of individual points suggested a less marked difference in the effectiveness of both techniques, most likely because of the smaller survey effort of the point counts, although point counting still managed to detect significantly more species in 10 of the 30 defined categories, with high netting effectiveness being limited to the same subcategories as those described by the sum of points analysis. This is in concordance with the limitations of netting described by Gram & Faaborg (1997), Whitman *et al.* (1997), and Karr (1981). These results would therefore suggest that mist netting alone cannot be considered an appropriate method of surveying avifaunal communities. Indeed, the results of this study would concur with Bibby *et al* (2000), Stiles & Rosselli (1998), Bierregard (1990), and MacArthur & MacArthur (1974), who suggest that netting surveys will usually be restricted to detecting around 40–50% of total bird species in a forest ecosystem.

The discrepancy in effectiveness between the two methodologies in cloud forest ecosystems is even greater than that found by studies in lowland forest sites. Blake & Loiselle (2001), for example, found mist nets detected 62% of species on their checklist, compared to 68% by point counts, and reported 34 species caught in nets but not detected by counts, compared to 53 species observed in counts that were not caught: a much smaller discrepancy in favour of nets than our results suggest. A less evident divide between the effectiveness of the two methodologies was also reported by Derlindati & Caziani (2005), Wang & Finch (2002), Pagen *et al.* (2002), and Rappole *et al.* (1998), although it should be noted that this last study focussed on migrant birds which may be more susceptible to mist-net capture than forest bird communities in their entirety (Wallace *et al* 1996).

Results therefore suggest that the denser vegetation and reduced canopy height inherent in cloud forest do not increase the relative effectiveness of mist netting as hypothesized. However, although mist netting may not show an improvement in effectiveness when compared to point counts, the proportion of the avifaunal community captured was higher than studies in lowland ecosystems have reported, capturing 78 species (37.5% of checklist) compared to the 58 species (28.6% of checklist) described by Whitman *et al.* (1997). This disparity could result from the differential habitat structure inherent in cloud forest ecosystems as discussed. It should also be noted that, despite detecting fewer species overall, netting was shown to be more effective for monitoring certain subgroups of cloud forest bird communities. The small overlap in species detected by both techniques, as demonstrated by the Jacard's index community comparison *t*-test, indicates that mist netting regularly captures species that point counting fails to detect.

While this study indicates point counts to be a more time-efficient methodology than nets, the person-hours calculated to demonstrate this assumed that two people were needed for running each line of mist nets compared to just a single observer needed for point counts. Two banders per netting line were considered necessary in this study to carry equipment, set nets up quickly, and ensure captured birds were extracted as fast as possible to minimise stress - particularly important when large numbers of birds were caught in a short period of time (North American Banding Council 2001, Gaunt & Oring 1999). Two banders were also needed to deal with difficult extractions and to allow simultaneous sample processing and data recording. It might have been possible, however, for a single skilled bander to run each netting line, which would considerably reduce the disparity in time-efficiency between the two methods. However, this would make the field-work considerably more difficult, could increase stress and mortality among captured birds, and, even with person-hours halved, mist netting would still be markedly less time-efficient in detecting species than point counts.

An additional consideration for the time efficiency curves is that the results do not take into account that the high level of observer skill required to use this method reliably takes at least several months of local experience to attain, an issue that is not applicable to mist nets (although banders also must invest in months or even years of training before they are competent to undertake mist netting surveys). Furthermore, even with experienced surveyors, misidentified or unidentified contacts can still occur when conducting point counts, especially in complex ecosystems, such as cloud forest where species richness is high and many birds have regional vocalisations. This may explain the low rate of detection of hummingbird (Trochilidae) species in the point counts.

A further finding of the mist netting survey worthy of comment was the methodologies' high degree of variance between study sites. While point counting yielded a similar rate of species detection across all sites along transects, the number of species and individual birds caught by nets was highly dependent on local environmental factors such as topography and terrain features. For instance, netting sites located on steep inclines captured comparatively fewer species and individual birds than areas with more level topography (Table 5). Indeed some of these sloping sites yielded an average of < 1 catch per morning. By contrast, netting sites located along ridges at the crests of topographical features achieved by far the highest capture rates for both species and individual birds. This is probably due to these ridges having the effect of 'funnelling' birds into the traps. One such ridge site yielded 98 captures, > 19% of the entire survey effort. These findings suggest that the placement of mist nets requires careful and selective positioning by the surveyor to yield the best capture rates, although the systematic sampling necessary in most ecological surveys may not always allow this.

Results demonstrate that using both methods in conjunction is considerably more effective than either method in isolation, with the proportion of species detected by both techniques being higher than either technique alone in 79% and 83% of groups, respectively (Tables 3, 4). The significant improvement of effectiveness by using a combination of both methodologies concurs with the findings of previous studies in other forest sites (Rappole *et al.* 1998, Whitman *et al.* 1997). The use of this combined method approach in cloud forest appears to yield a higher detection rate of all known species (73.3%) than with similar studies in lowland sites; Whitman *et al.* (1997), for example, described a detection rate of 61.1%. This could partly result from the increased rate of netting captures discussed previously.

While a combined methods' approach appears to be reasonably successful in cloud forest ecosystems, it still leaves a large component of the avifaunal community (27.8% of the preliminary checklist) unaccounted for. A large proportion of these undetected species are found in a discrete range of avian groups, such as raptors (75% undetected) and nocturnal birds (60% undetected) as well as aerial and aquatic feeders (50% and 66% undetected respectively). This can be partially attributed to species of these groupings having peak activity times that do not correspond to the timing of mist net and point count surveys (Bibby *et al.* 2000). In addition these species can be inherently difficult to monitor using the evaluated methodologies due to non-vocalisation and/or occurring primarily above canopy level, where both capture and visual

TABLE 3. Proportion of species in different categories detected by mist netting, point counting, both methods and neither method at all points in comparison to the preliminary check-list of birds of Cusuco National Park, north-west Honduras. Bracketed figures show actual species counts.

	Group	Mist netting	Point counting	Both	Neither	Checklist
Family	Proportion detected	(21) 55.3%	(32) 84.2%	(18) 92.1%	(4) 10.5%	38
Abundance	Abundant	(10) 76.9%	(13) 100%	(13) 100%	(0) 0%	13
(χ^2 = 5.6,	Common	(23) 41.8 %	(46) 83.6%	(49) 89.1%	(7) 12.7%	55
p = 0.2)	Uncommon	(20) 33.3%	(39) 65 %	(49) 81.7%	(13) 21.6%	60
	Rare	(18) 37.5%	(17) 35.4%	(28) 58.3%	(20) 40.4%	48
	Very rare	(5) 16.6%	(4) 13.3%	(9) 33.3%	(20) 66.6%	30
Body size	Large	(7) 8.5%	(51) 62.2 %	(56) 68.3%	(28) 34.1%	82
(χ^2 = 25.8,	Medium	(21) 38.9%	(28) 51.9%	(36) 66.6%	(18) 33.3%	54
p = <0.05)	Small	(45) 63.4%	(41) 57.8%	(56) 78.9%	(15) 21.1%	71
Height strata	Air	(0) 0%	(2) 50	(2) 50	(2) 50	4
(χ^2 = 26.4,	Canopy	(0) 0%	(25) 59.5%	(25) 59.5%	(17) 40.5%	42
p = <0.05)	Mid-storey	(22) 32.8%	(40) 59.7%	(46) 68.7%	(21) 31.3%	67
	Shrub	(53) 61.6%	(51) 59.3%	(70) 81.4%	(16) 18.6	86
	Ground	(1) 11.1%	(7) 77.8%	(8) 88.9%	(1) 11.1%	9
Diet	Carnivore/Carrion	(1) 4.4%	(5) 21.7%	(7) 30.4%	(20) 87%	23
(χ^2 = 18.9,	Fruit/seeds	(6) 20%	(23) 76.7%	(26) 86.7%	(5) 16.7%	30
p = <0.05)	Insectivores	(31) 45.6%	(40) 58.8%	(48) 70.6%	(20) 29.4%	68
	Insects and fruits	(17) 33.3%	(31) 60.8%	(12) 70.6%	(15) 29.4%	51
	Nectarivores	(20) 87%	(11) 47.8%	(21) 91.3%	(2) 8.7%	23
	All foods	(2) 18.2%	(10) 90.9%	(11) 100%	(0) 0%	11
Feeding	Water	(1) 33%	(0) 0%	(1) 33%	(1) 33%	3
substrate	Air	(0) 0%	(3) 37.5%	(3) 62.5%	(5) 62.5%	8
(χ^2 = 17.2,	Branch	(12) 19.7%	(40) 65.6%	(44) 72.1%	(17) 27.9%	61
p = <0.05)	Trunk	(6) 31.6%	(11) 57.9%	(13) 68.4%	(6) 31.6%	19
	Live foliage	(45) 60%	(46) 61.3%	(64) 85.3%	(11) 14.7%	75
	Dead foliage	(11) 61.1%	(14) 77.8%	(15) 83.3%	(3) 16.7%	18
	Ground	(1) 4.5%	(9) 40.9%	(9) 40.9%	(13) 59.1%	22
Forest type	Core	(23) 40.4%	(44) 77.2%	(51) 95.5%	(7) 12.3%	57
(χ^2 = 4.4,	Edge	(17) 21.3%	(35) 43.8%	(44) 55%	(38) 47.5%	80
p = 0.112)	Both	(37) 53.6%	(41) 59.4	(54) 78.3%	(15) 21.7	69

observation are difficult (Thiollay 1989). This is a significant limitation of the assessed methodologies, as these groups fulfil roles of high ecological importance, being either top predators in the avifaunal community (raptors) or based on a food chain totally separate from other avian groups which would otherwise be unconsidered (aquatic birds). Further, raptors in particular have been considered a valuable indicator of ecosystem integrity due

TABLE 4. Mean proportion of species in different categories detected per individual point for mist netting, point counts, and both methods in Cusuco National Park, north-west Honduras. ± represents 1 standard deviation. Bold-typed values indicate a significantly higher mean for species detected by that method (paired *t*-test, $p = < 0.05$).

		Mean ± SD number of species		
Group		Mist netting	Point counting	Both
Total		4.42 ± 2.81	5.64 ± 1.63	9.17 ± 3.1
Abundance	Abundant	18.04 ± 14.74	**32.54 ± 17.17**	42.89 ± 20.31
	Common	6.72 ± 6.17	9.73 ± 6.98	15.47 ± 10.14
	Uncommon	3.15 ± 3.04	2.96 ± 2.13	5.72 ± 3.17
	Rare	2.32 ± 3.01	0.56 ± 1.11	2.88 ± 3.33
	Very rare	**1.41 ± 2.14**	0 ± 0	1.41 ± 2.14
Body Size	Large	0.74 ± 1.10	**7.16 ± 3.69**	7.66 ± 3.77
	Medium	3.63 ± 2.38	4.45 ± 2.53	7.06 ± 3.25
	Small	**8.72 ± 6.23**	4.75 ± 2.51	11.91 ± 6.41
Height strata	Air	0 ± 0	0.96 ± 5	0.96 ± 5
	Canopy	0 ± 0	**6.41 ± 2.76**	6.41 ± 2.76
	Mid-storey	2.06 ± 2.31	**5.67 ± 2.11**	7.16 ± 2.76
	Shrub	**8.79 ± 5.41**	5.44 ± 3.22	12.67 ± 6.22
	Ground	0.43 ± 2.18	4.27 ± 6.35	4.7 ± 6.42
Diet	Carnivore/carrion	0.17 ± 0.85	1 ± 1.86	1.17 ± 1.97
	Fruit and seeds	1.54 ± 2.7	**7.43 ± 5.75**	8.58 ± 6.54
	Insectivorous	4.58 ± 3.15	5.1 ± 2.13	8.48 ± 3.67
	Insects and fruits	3.78 ± 2.97	**7.62 ± 3.41**	10.02 ± 3.74
	Nectarivorous	**14.18 ± 11.42**	1.29 ± 2.65	14.66 ± 12.07
	All	1.4 ± 3.35	**12.94 ± 10.96**	13.64 ± 10.98
Foraging substrate	Water	1.27 ± 6.47	0 ± 0	1.27 ± 6.47
	Air	0 ± 0	0.96 ± 3.4	0.96 ± 3.4
	Branch	1.34 ± 1.93	**8.02 ± 2.7**	9.1 ± 3.16
	Trunk	0.81 ± 1.94	3.24 ± 3.96	3.84 ± 4.35
	Live foliage	**8.75 ± 5.84**	5.17 ± 3.18	12.33 ± 6.41
	Dead foliage	8.13 ± 6.53	8.34 ± 5.72	14.11 ± 7.9
	Ground	0.34 ± 1.21	2.02 ± 3.42	2.19 ± 3.65
Habitat	Mature	4.44 ± 3.75	**9.02 ± 4.36**	12.65 ± 6.86
	Edge	2.02 ± 2.9	**3.75 ± 3.91**	5.29 ± 5.67
	All	7.14 ± 4.87	6.02 ± 4.28	11.66 ± 5.69

to their predations strongly influencing the community structures of other avifaunal groups. Decline in populations of top-level predators, such as raptors, are also often indicative of dysfunctional ecosystems, particularly in tropical forest ecosystems

TABLE 5. Mean number of species and individual birds captured at sites of differing topography within Cusuco National Park, north-west Honduras. Bracketed numbers show number of sites in each category. ± represents 1 standard deviation.

	Mean species captured	Mean individuals captures
Ridge (6)	15.83 ± 8.08	45.33 ± 28.63
Flat ground 0–30° (11)	9.27 ± 3.23	16.27 ± 5.83
Incline > 30° (9)	5 ± 1.94	6.89 ± 3.22

(Rodríguez-Estrella *et al.* 1998, Thiollay 1996, Terborgh 1992).

The inability effectively to detect important avian groupings would suggest that both point counts and mist nets, either individually or in conjunction, are insufficient to make full descriptions of avifaunal communities in cloud forest ecosystems, and that other techniques may be required if an observer wishes to make a complete census of bird communities in these habitats. Raptors, for example, could be more effectively monitored by conducting observations of soaring birds in clearings during optimal hours (09:00–13:00 h) (Thiollay & Rahman 2002, Thiollay 1989). point counts might also be more effective in detecting raptors if birds observed flying above canopy level were included in analysis. However, due to the necessary systematic design of survey sites, point count sites rarely corresponded with forest clearings, and thick canopy usually obscured vision. This, combined with survey times occurring before peak raptor activity, meant that few birds observed above canopy level were excluded from analysis and no species were excluded which were not also recorded at or below canopy level. Nocturnal birds could be more accurately surveyed by returning to study sites at night to conduct point counts and mist netting. This proved difficult to achieve in this study, however, due to large by-catches of bats in the nets, and because reaching the far point-count sites, which were often located across very difficult terrain, was logistically difficult. Playback calls and spot-mapping during crepuscular periods might also be effective alternative methodologies for describing nocturnal bird communities (Kavanagh & Bamkin 1995, Terbourgh *et al.* 1990). Further methods could also be employed to better represent groups of birds under-recorded by point counts and mist nets, such as using line transects to survey small, soft-vocalising canopy species and rare species (Terbourgh *et al.* 1990).

In conclusion, the results of this study have demonstrated that the unique structural characteristics of tropical montane cloud forest do not significantly influence the relative effectiveness of point counting and mist netting beyond that described by other studies as hypothesised. Findings indicate point counting as the more effective and efficient methodology for surveying cloud forest bird communities, which is in concordance with comparative studies in lowland ecosystems, and where time and resources are limited it is this approach that should be prioritized. The study has also demonstrated that a greater proportion of species can be detected if mist netting is used to supplement point count surveys, and this combined methods approach is recommended wherever possible. However, these two methods alone are still insufficient if a surveyor wishes to describe cloud forest avifauna communities in their entirety, and the inclusion of all avifaunal groups would require a more integrated approach involving multiple methodological techniques.

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