

Adjusting count period strategies to improve the accuracy of forest bird abundance estimates from point transect distance sampling surveys

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Although point transect distance sampling methods have become widely used in surveys of forest birds, there has been no attempt to tailor field methods to maximize the accuracy of abundance estimates by minimizing the effects of violations of the method's critical assumptions, which are: (1) birds at distance 0 m are detected with certainty, (2) birds are detected at their initial location and (3) distances to objects are measured accurately. We investigate the effects on abundance estimates for Philippine forest birds of varying the count period from 2 to 10 min, and of including and excluding a pre-count settling down period. Encounter rates were highly sensitive to count period length but density estimates from 10-min count periods were, on average, only 13% higher than those from 2-min periods, and in several cases were actually lower than those from periods of 6–8 min. This was because birds tended to be recorded at greater distances from the recorder as the count period went on, thus 'stretching out' detection functions while having little effect on detection rates close to the recorder. For some bird groups, including canopy frugivores and upperstorey gleaning insectivores, density estimates were more than twice as high without than with a settling down period. We suggest that movement away from the recorder is more common than attraction to the recorder, and that unless pilot studies show otherwise, similar studies should not use a settling down period for surveying many species. Count periods that maximized probability of bird detection close to the central point while minimizing the unwanted effects of bird movement during the count period were: 4 min for omnivores, 6 min for nectarivores and upperstorey gleaning insectivores, 8 min for understory insectivores and canopy frugivores, and a full 10 min for sallying insectivores, ground-dwellers, carnivores and coucals/koels. We use the results to suggest 'group-specific' count period regimes that could help maximize the accuracy of density estimates from similar studies of tropical forest birds.

Keywords: bird surveys, density estimates, distance sampling, Philippines, point counts, settling down period.

Reliable estimates of the density of birds are often crucial. They are needed for identifying important areas for species (Hill *et al.* 2001), and in studies of population trends (Cahill *et al.* 2006), and of species reactions to land-use change (Marsden 1998) or direct exploitation (Lambert 1993), in assessments of extinction risk (BirdLife International 2004), and to determine the effectiveness of conservation management actions (Chari *et al.* 2003). This need is

particularly pressing for tropical forest bird species, which make up a great proportion of threatened species, especially where quantitative data are sparse (BirdLife International 2004).

Distance sampling is increasingly being used in a wide range of bird population studies (e.g. Marsden 1999, Brotons *et al.* 2005) and is generally seen as an efficient and reliable approach to density estimation (Buckland *et al.* 2001). Point transect distance sampling (Buckland *et al.* 2001) is perhaps now the most widely used density estimation method for multi-species surveys in tropical forests (e.g. Arendt *et al.* 1999,

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Marsden 1999, Simon *et al.* 2002, Riley 2003). Despite this, there has been little consideration of how best to conduct field methods to minimize problems associated with the surveying of tropical forest birds (or indeed any forest bird).

The method requires the observer(s) to stand at each survey point, although they may choose to move around the point searching for birds (Rosenstock *et al.* 2002), and record all birds seen or heard during a set period of time, the count period (Fuller & Langslow 1984). Clearly, the length of count period (usually 5–10 min; e.g. Marsden 1999, Buckland 2006) influences the probability of detecting birds, most critically in meeting the assumption that all birds at 0 m from the point are detected (Buckland *et al.* 2001). Although the accumulation of records from fixed and unlimited radius point counts has been reasonably well studied (e.g. Gutzwiller 1991, Barker *et al.* 1993, Ralph *et al.* 1995), the effect of count period duration on density estimates derived from distance sampling point transect surveys of tropical forest birds has received no attention.

Incorporating a longer count period is advantageous in tropical forests where many birds are cryptic and the vegetation structure means that birds may be hard to locate (e.g. Riley 2003). The likelihood of recording inconspicuous species, specifically at 0 m, increases with count duration (Fuller & Langslow 1984), as the observer has more time to detect and identify species in the surrounding area (Scott & Ramsey 1981, Fuller & Langslow 1984, Verner 1985). However, a disadvantage of increasing count period is the increased probability of birds moving into the area or of being double-counted due to undetected movement (Reynolds *et al.* 1980, Scott & Ramsey 1981, Fuller & Langslow 1984, Verner 1985). Both factors contribute to a positive bias in density estimation (Scott & Ramsey 1981, Granholm 1983) through violation of the critical assumption that birds are detected at their initial location and only once within a single sampling unit (Buckland *et al.* 2001). Length of count period, therefore, becomes a compromise between the need to maximize the probability of recording individual birds and with certainty at 0 m, and avoiding overestimating mobile and conspicuous species (Fuller & Langslow 1984, Bibby *et al.* 1992).

The arrival of an observer at a survey point can influence species behaviour and distribution at the point (Scott & Ramsey 1981). Birds may become more vocal (Haselmayer & Quinn 2000), be attracted to the observer (Emlen 1971, Rosenstock *et al.* 2002),

or undertake evasive movement or cease vocalizing (Emlen 1971, Granholm 1983, Rosenstock *et al.* 2002). Incorporating a 1- to 2-min period of surveying inactivity, usually termed a 'settling down period' (following Bibby *et al.* 1992), prior to the count period has been used to reduce the impact of observer presence (Reynolds *et al.* 1980, DeSante 1986, Avery & van Riper 1989) and to increase the probability of detection (Rosenstock *et al.* 2002). However, we found no studies that have investigated the effects of inclusion or exclusion of a settling down period on detection rates or density estimates in tropical or indeed temperate forest birds.

This paper explores the influence of count period strategy on the results of a multi-species bird survey from lowland forest on the island of Mindoro, Philippines. Our goal was to devise 'group-specific' survey strategies that maximize the accuracy of abundance estimates and which would be applicable to similar studies of forest avifaunas. We asked the following questions:

- (1) How do abundance estimates, encounter rates and density estimates of species and guilds change across a 10-min count period?
- (2) What is the influence of including/excluding a settling down period on abundance estimates?
- (3) How might the method's assumptions be violated by the application of these design variables and what are the implications for survey design?

METHODS

Study site and survey methods

A distance sampling point transect method (Buckland *et al.* 2001) was used to survey the lowland forest bird community of Mount Siburan Important Bird Area (12°48'N, 120°55'E; IBA PH042; Mallari *et al.* 2001) on the island of Mindoro, Philippines, over two field seasons. Data for the analysis of count period effects were collected between September and December 2002 during the main non-breeding season on Mindoro, while data for the examination of the influence of a settling down period were collected between April and June 2003, during the main bird breeding season (Dickinson *et al.* 1991).

Point transects were marked 200 m apart along transects positioned randomly to represent proportionally broad forest habitats at the study site (Buckland *et al.* 2001) identified from satellite imagery (CGCEO 2001). Fifteen transects of 7–10 points each were positioned at least 0.25 km and less than 1 km apart.

Transects were sited to avoid any edge effects associated with disproportionately sampling along roads, paths, ridge tops or watercourses: if a transect followed an existing path or watercourse, a situation that arose occasionally in difficult terrain, points were positioned 50 m perpendicular to alternate sides of the transect route in an attempt to minimize bias associated with surveying along non-random features (Jones *et al.* 1995).

One observer (D.C.L.) conducted all surveys, removing any effects of inter-observer variability (e.g. Hayward *et al.* 1991), and prior to the fieldwork spent 8 months conducting similar distance sampling surveys elsewhere in the Philippines. Two months were then spent learning (taped) vocalizations of additional bird species found on Mindoro before this study commenced. Recordings of all resident forest species were provided by various authors (Tim Fisher, Des Allen and Jon Hornbuckle) or the British Library Sound Archive (except Mindoro Bleeding-heart *Gallucolumba platenae*, which was learnt in the field). Bird surveys were conducted in the morning from 06:30 to c. 09:00 h. Points were approached stealthily and any birds that were detected moving off from near the survey point on the recorder's arrival were counted as being present during the count period, and the distance from their initial position to the centre of the point was estimated. Birds either flying into the point once the count period had begun or those flying over were excluded following the recommendation of Marsden (1999). The radial distance to the nearest metre was estimated from the survey point to each bird contact (aural or visual) during a 10-min count period at each point: distances were estimated to the central point of clusters of the same species. The accuracy of distance estimates to bird detections was improved through pre-survey training, previous experience in distance estimation, and regular checking of any 'drift' in distance estimates during surveys by using a Bushnell Yardage Pro 500 laser rangefinder. It was not possible to use a rangefinder to estimate all distances owing to reflectance difficulties associated with the forest vegetation at some sites.

In 2002, 160 point transects were surveyed (all 15 transects), while in 2003 132 points were surveyed from 13 transects. Each point was sampled twice in both field seasons with transect routes repeated in the opposite direction on different days. All of the 2003 points were exact spatial repeats of those visited in 2002 (total number of samples = 292, total effort = 584 points).

Design variables under investigation

Count period duration

The 10-min count period was divided into five 2-min intervals. Bird detections were assigned to the 2-min interval in which they were first recorded, and only to this 2-min interval. The first 2-min interval included birds detected on approaching the point or those flushed from the point.

Settling down period

A subset of 84 points, repeated in the opposite direction on a different day (survey effort = 168), were surveyed using two consecutive 10-min count periods. The first period represented point transects surveyed with no settling down period. The second 10 min represented point transects surveyed with a 10-min settling down period (the first 10-min count) prior to sampling. Birds recorded in the first 10-min count that were still detectable in the survey area at the start of the second count period were recorded in both count periods.

Data analysis

Abundance estimates

Encounter rates (individuals per point transect \pm se) and density estimates (individuals/km² \pm se) were calculated using DISTANCE v4.1 Release 2 (Thomas *et al.* 2003, www.ruwpa.st-and.ac.uk/distance). Individual points were used as the sampling units for distance analysis and detections from the two visits to points were pooled, as recommended by Buckland *et al.* (2001). Frequency histograms of distance data were explored to identify the presence of evasive movement, which violates the critical assumption that birds are detected at their initial location (Buckland *et al.* 2001), data heaping and outliers, all factors that reduce the precision of model fit. In the few cases in which heaping was exhibited, *a posteriori* grouping of the data into distance bands using cut-points as far from grouped distances as possible was used to try to ensure few observations ended up in an incorrect distance group (Buckland 2004). All data were right-truncated at 50 m to remove any outlying records: with further right-truncation at a distance r m that removed bird detections corresponding to a detection probability ≥ 0.1 (Buckland *et al.* 2001). It was generally not possible to assess cluster size for aural-only detections of birds: doing so can be imprecise (Hayward *et al.* 1991). In these instances, the mean of known cluster sizes for that species, taken from visual contacts, was substituted for the unknown values.

A number of detection models (key functions and series adjustment terms) were used for analysis of the bird data: uniform function with cosine/simple polynomial adjustment, half-normal function with cosine/hermite polynomial adjustment, and hazard-rate function with cosine/simple polynomial adjustment (Buckland *et al.* 2001). Model selection was based on comparing the relative fit of these detection models using Akaike's information criterion values (AIC) (Buckland *et al.* 2001): a lower AIC indicates a more robust model. Overall model fit was also assessed using goodness-of-fit tests. The sampling distributions of abundance estimates and variances were determined by randomly resampling the original data in DISTANCE. Samples were resampled 999 times for each analysis.

Guilds/bird groups

The number of contacts for many species was too small to obtain reliable abundance estimates: ≥ 40 contacts are recommended for point transect density estimates (Burnham *et al.* 1980). Therefore, birds were also combined into groups (hereafter referred to as guilds: Root 1967) to try to detect patterns of density estimation among similar species. Nine guilds were identified: 'Canopy frugivores', 'Coucals/Koels', 'Ground-dwellers', 'Omnivores', 'Nectarivores', 'Sallying insectivores', 'Understorey insectivores', 'Upperstorey gleaning insectivores' and 'Carnivores' (this last guild was excluded from analyses as it included only eight bird records).

Count period duration

Data from the first 2 min, first 4 min, etc., to 10 min were entered into DISTANCE (Thomas *et al.* 2003) independently to assess the influence of count period length on density estimates. Seven guilds and 16 species were detected ≥ 40 times (Burnham *et al.* 1980) and included for analysis.

Comparison of density estimates from consecutive 2-min intervals of the count period was confounded by estimates being generated in part from data collected in the preceding interval(s). In addition, many estimates were neither normally distributed (and did not lend themselves to data transformation) nor had equal variances. Consequently, density data were analysed non-parametrically. Density estimates obtained after 10 min for each guild or species were coded as 100% of that particular estimate. Density estimates from the preceding 2-min intervals were converted to a weighted percentage of the 10-min density estimate and the differences between con-

secutive density proportions were calculated. The influence of the loss in precision of density estimates associated with smaller sample sizes (e.g. Ogutu *et al.* 2006) of shorter count periods was reduced by recoding increases of $< 5\%$ or any decreases in density estimates between 2-min intervals as 0% changes in density estimation. Percentage changes in densities between consecutive 2-min intervals were ranked separately for four time intervals (2–4, 4–6, 6–8 and 8–10 min) across guilds/species, and also for each species or guild across the four time intervals. As there was only one datum for each species/guild and time interval tested, percentage changes were analysed using Friedman's matched group ANOVA using ranks without replication (corrected for ties) performed in SPSS v.12, 2002 (SPSS Inc., Chicago, IL, USA). Nemenyi's *post-hoc* tests were done by hand using the formula given in Wheater and Cook (2000).

Settling down period

Species encountered ≥ 40 times from points surveyed with and without a settling down period were considered for DISTANCE analysis (Thomas *et al.* 2003). Because only three species fulfilled this requirement (cf. 16 species for the count period duration dataset), encounter rates were also calculated for species detected ≥ 20 times from at least one set of points. All guilds were considered, although three ('Carnivores', 'Ground-dwellers' and 'Sallying insectivores') did not fulfil the minimum sample size criterion.

Abundance estimates obtained from both sets of points were compared using a *z*-test, or a two-tailed *t*-test when the calculated degrees of freedom were < 30 (Buckland *et al.* 2001). Percentage differences in abundance measures of guilds and species between each pairwise comparison of count periods were calculated with the larger of the two estimates as the numerator and the smaller estimate as the denominator. A positive direction of change in abundance estimates denotes an increase in abundance recorded from points with a settling down period, while a negative directional change denotes a lower abundance estimated from these points.

RESULTS

Count period duration and abundance estimates

The number of new detections declined significantly across the 10-min count period ($H_4 = 1282.5$, $P < 0.001$). Cumulatively, 53.3% ($n = 1512$), 77.1%

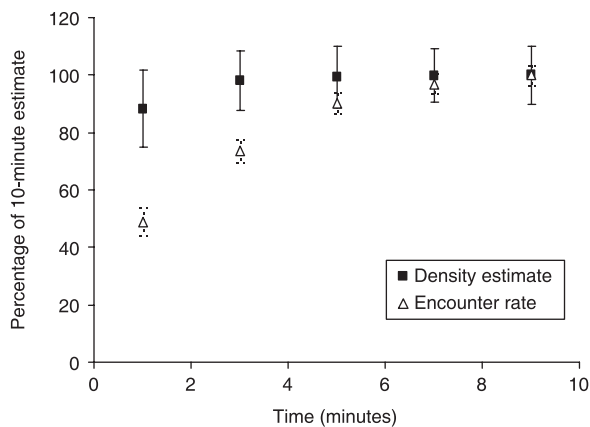


Figure 1. Percentage increase in overall encounter rates and density estimates (all species combined) with 95% confidence limits for each 2-min interval of the 10-min count period. Time is represented by the midpoint of each 2-min interval. Samples bootstrapped 999 times (Butler *et al.* 2003).

(2188), 90.0% (2553) and 96.7% (2750) of detections occurred within the first 2, 4, 6 and 8 min, respectively (Fig. 1). Overall encounter rate increased more than density over the 10-min count period. The overall density estimate (DE) (all bird species combined) increased by just 13.0% across the count period ($DE_{2\text{ min}} = 2300 \pm 159$, $DE_{4\text{ min}} = 2550 \pm 134$, $DE_{6\text{ min}} = 2580 \pm 141$, $DE_{8\text{ min}} = 2600 \pm 124$, $DE_{10\text{ min}} = 2600 \pm 136$) with 84% of this increase occurring within the first 4 min. The number of new detections recorded within each 10-m concentric band to 50 m (0–10 m, 10–20 m, etc.) from the point's centre during each 2-min interval changed significantly ($\chi^2_{16} = 420.8$, $P < 0.001$) with greater numbers of new detections made further from the point (> 30 m) later on in the count period.

Changes in guild density estimates decreased significantly across the four count period intervals

(F_{r3} matched by guild = 11.59, number of guilds = 7, $P = 0.009$). Percentage increases in guild densities were significantly greater between 2 and 4 min than between 8 and 10 min ($MSD_8 = 1.78$, $q = 3.63$, $se = \pm 0.49$). Density estimates of five guilds increased by > 20% across the 10-min count period (Table 1), and exhibited the same general pattern of change over the 10-min count period (F_{r6} matched by time interval = 19.37, number of time intervals = 4, $P = 0.004$). 'Nectarivores' and 'Ground-dwellers' underwent larger than average percentage increases, and 'Understorey insectivores' and 'Omnivores' underwent smaller than average percentage increases over the count period. Changes in density estimates of 'Ground-dwellers' were significantly greater than those of 'Omnivores' ($MSD_8 = 4.50$, $q = 4.17$, $se = \pm 1.08$).

Generally, density estimates of commonly encountered species stabilized at count periods of 6 min (Fig. 2, species grouped by guild): changes in densities were significantly greater between 2 and 4 min than between 8 and 10 min, and between 4 and 6 min than between 8 and 10 min (F_{r3} matched by species = 17.98, number of species = 16, $P < 0.001$; $MSD_8 = 1.17$, $q = 3.63$, $se = \pm 0.32$). For some species (e.g. Blue-crowned Racquet-tail *Prioniturus discurus*), however, densities appeared to increase steadily across the 10 min, while density estimates of two species (Fig. 2) actually decreased across the 10-min count period (Table 2).

The influence of a settling down period on abundance estimates

There were 790 encounters of 57 species from count periods without a settling down period, and 660 encounters of 52 species from count periods with a settling down period. The number of species and the

Table 1. Overall density estimates for each guild (individuals/km² ± se) and percentage differences in density estimates between a 2-min and full 10-min count period.

	Density estimate after 10 min	Overall % difference in density
Upperstorey gleaning insectivores (UGI, 13 species)	286 ± 35.1 (345)	+32.1
Nectarivores (N, 9)	508 ± 58.7 (293)	+25.2
Ground-dwellers (GD, 12)	61.6 ± 74.0 (106)	+24.2
Canopy frugivores (CF, 17)	332 ± 70.7 (265)	+22.8
Coucals/Koels (CL, 3)	11.3 ± 8.82 (196)	+22.6
Understorey insectivores (UI, 9)	143 ± 19.7 (233)	+9.0
Omnivores (O, 6)	1130 ± 70.2 (828)	+5.3

Guild codes and numbers of species in each guild are in parentheses; total numbers of encounters follow the density estimates.

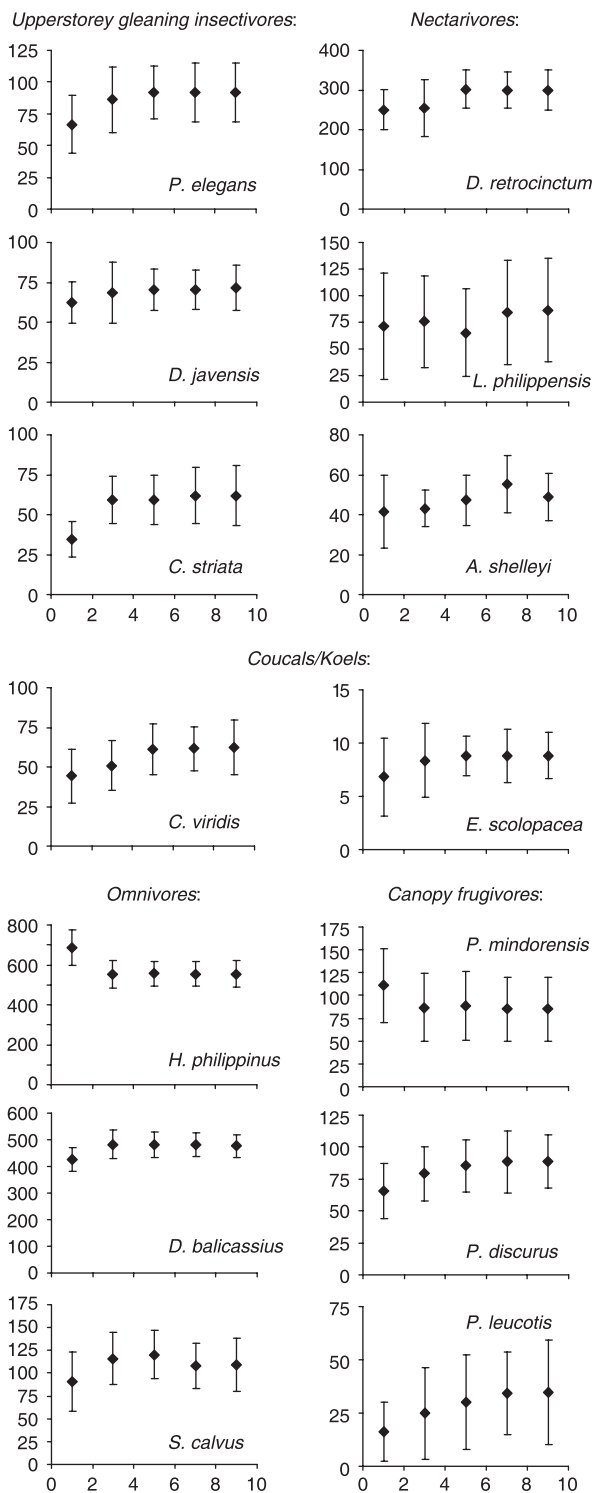


Figure 2. Density estimates (individuals/km² ± 95% CI) of commonly recorded species for each 2-min interval of a 10-min count period. Time (x-axis) is represented by the midpoint of each interval (0–2, 2–4, 4–6, 6–8 and 8–10 min).

number of individuals recorded per point were significantly higher from points without a settling down period ($z_{\text{Species ER}} = 3.01$, $P < 0.01$; $z_{\text{Individual ER}} = 2.87$, $P < 0.01$). Overall density from points without a settling down period (2300 ± 213 individuals/km²) was nearly 75% larger and significantly higher than that from points with a settling down period (1330 ± 100 individuals/km²; $z = 4.11$, $P < 0.01$).

Encounter rates of six guilds and eight species decreased using a settling down period (Table 3a). For four of these guilds and seven of these species these decreases were greater than 20%. The encounter rate for Scarlet-collared Flowerpecker *Dicaeum retrocinctum* decreased significantly when surveying points with a settling down period ($z = 2.16$, $P < 0.05$). Density estimates for five of the six guilds fulfilling the minimum sample requirement decreased by more than 50% using a settling down period (Table 3b). 'Upperstorey gleaners' ('UGI') and 'Understorey insectivores' ('UI') were recorded at significantly lower densities from counts with a settling down period ($z_{\text{UGI}} = 2.08$, $P < 0.05$; $z_{\text{UI}} = 2.21$, $P < 0.05$). Final detection model choice changed across the two count strategies for four of the six guilds (Fig. 3).

The number of detections recorded in each 10-m band from point transects differed significantly across the count strategies for all species ($\chi^2_3 = 26.45$, $P < 0.001$) and two guilds: 'Canopy frugivores' ($\chi^2_3 = 9.17$, $P = 0.027$) and 'Upperstorey gleaners' ($\chi^2_3 = 14.4$, $P = 0.002$). In all cases, a greater proportion of detections was made closer to points from surveys without a settling down period than with a settling down period.

DISCUSSION AND RECOMMENDATIONS

Count period duration

For most guilds and species, the largest increases in density estimates occurred towards the beginning of the count period, with subsequent increases becoming progressively smaller, reflecting a typical curvilinear relationship between number of new detections and time spent surveying (Fuller & Langslow 1984). New detections later in the count period tended to be further from the point and, as density is estimated over an area of increasing radius (Buckland *et al.* 2001), had less influence on density estimation than detections made earlier in the count period. However, this is based on the assumptions of distance sampling being met, i.e. the count period surveys a snapshot of

Table 2. Overall density estimates (individuals/km² ± se) and overall percentage differences in density estimates of commonly recorded species across the 10-min count period.

Species	Density estimate after 10 min	Overall difference in density (%)
White-eared Brown-dove <i>Phapitreron leucotis</i> (CF)	34.5 ± 24.6 (68)	+65.5
Elegant Tit <i>Parus elegans</i> (UGI)	92.4 ± 24.9 (61)	+61.4
Bar-bellied Cuckoo-shrike <i>Coracina striata</i> (UGI)	58.5 ± 15.2 (53)	+44.0
Lovely Sunbird <i>Aethopyga shelleyi</i> (N)	49.1 ± 11.8 (53)	+26.8
Philippine Coucal <i>Centropus viridis</i> (CL)	62.3 ± 17.3 (112)	+24.8
Common Koel <i>Eudynamis scolopacea</i> (CL)	8.9 ± 2.5 (40)	+22.5
Blue-crowned Racquet-tail <i>Prioniturus discurus</i> (CF)	88.4 ± 20.8 (77)	+21.4
Mangrove Blue Flycatcher <i>Cyornis rufigastra</i> (UI)	29.0 ± 10.0 (58)	+18.2
Colasisi <i>Loriculus philippensis</i> (N)	86.6 ± 48.6 (47)	+17.8
White-bellied Woodpecker <i>Dryocopus javensis</i> (UGI)	71.6 ± 14.2 (106)	+14.7
Black-naped Monarch <i>Hypothymis azurea</i> (UI)	92.9 ± 15.0 (119)	+10.8
Balicassiao <i>Dicrurus balicassius</i> (O)	479 ± 40.7 (302)	+7.5
Coledo <i>Sarcops calvus</i> (O)	110 ± 20.7 (86)	+5.1
Scarlet-collared Flowerpecker <i>Dicaeum retrocinctum</i> (N)	299 ± 50.6 (121)	+4.7
Philippine Bulbul <i>Hypsipetes philippinus</i> (O)	555 ± 68.9 (394)	-0.3
Mindoro Tarctic <i>Penelopides mindorensis</i> (CF)	84.8 ± 34.7 (60)	-18.5

Guild memberships of species follow the species name in parentheses, and numbers of encounters are in parentheses. See Table 1 for guild codes.

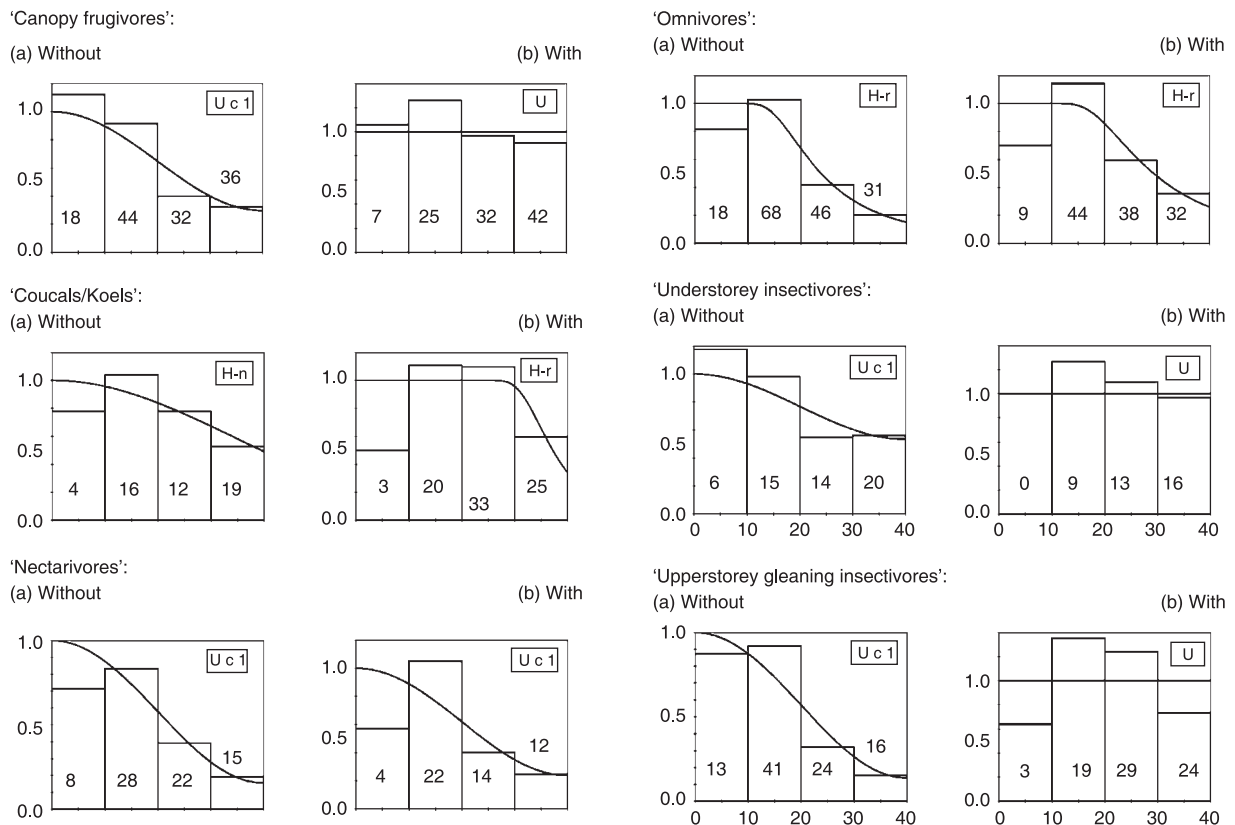


Figure 3. Detection function plots over 40 m from point transects with (a) no settling down period (Without) and (b) a 10-min settling down period (With). Radial distance (x -axis) is grouped into four 10-m detection intervals (0–10, 11–20, 21–30 and 31–40 m). Bars represent count frequencies scaled (divided) by detection distance. Count frequencies are indicated in each 10-m bar. The curves signify the fitted detection model (probability of detection = 1.0 at 0 m). The key function (U – Uniform, H-n – Half-normal, H-r – Hazard-rate) and series adjustment term (c – cosine, number of terms = 1) of the detection model are displayed in the top right corner of each figure.

Table 3. Guild and species: (a) encounter rates (individuals per point transect \pm se), and (b) density estimates (individuals/km² \pm se) from point transects with and without a settling down period.

(a) Encounter rates (ER)

Ecological unit	Without settling down period	With settling down period	Magnitude/direction of change in ER
<i>Guild:</i>			
Coucals/Koels (CL)	0.40 \pm 0.05 (67)	0.54 \pm 0.07 (91)	1.36 (+)
Ground-dwellers (GD)	0.17 \pm 0.04 (29)	0.16 \pm 0.04 (27)	1.07 (–)
Canopy frugivores (CF)	0.94 \pm 0.09 (158)	0.83 \pm 0.08 (140)	1.13 (–)
Upperstorey gleaning insectivores (UGI)	0.63 \pm 0.07 (106)	0.51 \pm 0.07 (86)	1.23 (–)
Omnivores (O)	1.07 \pm 0.09 (179)	0.83 \pm 0.08 (139)	1.29 (–)
Nectarivores (N)	0.49 \pm 0.06 (82)	0.36 \pm 0.05 (61)	1.34 (–)
Understorey insectivores (UI)	0.41 \pm 0.05 (69)	0.29 \pm 0.04 (49)	1.41 (–)
<i>Species:</i>			
Black-hooded Coucal <i>Centropus steerii</i> (CL)	0.10 \pm 0.02 (16)	0.17 \pm 0.03 (28)	1.75 (+)
Philippine Coucal <i>C. viridis</i> (CL)	0.23 \pm 0.04 (38)	0.29 \pm 0.05 (49)	1.29 (+)
Mindoro Tarctic <i>P. mindorensis</i> (CF)	0.11 \pm 0.03 (19)	0.13 \pm 0.04 (21)	1.11 (+)
Elegant Tit <i>P. elegans</i> (UGI)	0.12 \pm 0.03 (20)	0.11 \pm 0.03 (18)	1.11 (–)
Philippine Bulbul <i>H. philippinus</i> (O)	0.55 \pm 0.06 (93)	0.45 \pm 0.06 (75)	1.24 (–)
Balicassiao <i>D. balicassius</i> (O)	0.38 \pm 0.06 (63)	0.30 \pm 0.05 (50)	1.26 (–)
White-bellied Woodpecker <i>D. javensis</i> (UGI)	0.18 \pm 0.04 (30)	0.13 \pm 0.03 (22)	1.36 (–)
Black-naped Monarch <i>H. azurea</i> (UI)	0.18 \pm 0.03 (30)	0.11 \pm 0.03 (18)	1.67 (–)
Scarlet-collared Flowerpecker <i>D. retrocinctum</i> (N)	0.20 \pm 0.03 (34)	0.12 \pm 0.03 (20)	1.70 (–)*
Coppersmith Barbet <i>Megalaima haemacephala</i> (CF)	0.16 \pm 0.04 (26)	0.09 \pm 0.02 (15)	1.73 (–)
Coleto <i>S. calvus</i> (O)	0.12 \pm 0.03 (20)	0.05 \pm 0.02 (9)	2.22 (–)†

(b) Density estimates (DE)

Ecological unit	Without settling down period	With settling period	Magnitude/direction of change in DE
<i>Guild:</i>			
Coucals/Koels (CL)	127 \pm 27.6 (67)	130 \pm 25.9 (87)	1.03 (+)
Omnivores (O)	726 \pm 129 (163)	473 \pm 96.5 (133)	1.54 (–)
Nectarivores (N)	268 \pm 83.3 (78)	133 \pm 38.5 (59)	2.01 (–)
Upperstorey gleaning insectivores (UGI)	428 \pm 107 (94)	194 \pm 36.8 (86)	2.21 (–)*
Understorey insectivores (UI)	118 \pm 25.6 (69)	52.2 \pm 14.5 (46)	2.27 (–)*
Canopy frugivores (CF)	398 \pm 90.8 (158)	244 \pm 32.9 (140)	3.48 (–)
<i>Species:</i>			
Philippine Coucal <i>C. viridis</i> (CL)	69.1 \pm 18.9 (35)	86.9 \pm 22.6 (48)	1.26 (+)
Balicassiao <i>D. balicassius</i> (O)	222 \pm 46.5 (59)	138 \pm 49.6 (48)	1.61 (–)
Philippine Bulbul <i>H. philippinus</i> (O)	510 \pm 133 (86)	297 \pm 57.9 (72)	1.72 (–)

Guild codes, guild memberships of species and numbers of encounters are in parentheses. Abundance estimates that changed by < 20% are in italics. Significant differences are in bold and indicated by * ($z = 1.960$, $P < 0.05$): †*t*-test statistics were calculated where $df < 30$.

birds surrounding the point with no movement about the point, and that perpendicular distances to birds are measured accurately. Both the accumulation of the distance data, and the associations between detectability traits of species and variables derived from the density estimates suggest that key assumptions were not met fully in all instances and that length of count period is a very important design variable in influencing the accuracy of density estimates.

For multi-species studies such as this, a single optimum count period must not be so long as to seriously overestimate densities of mobile or conspicuous species and not so short that it underestimates densities of inconspicuous species (Fuller & Langslow 1984). Optimum count periods differed clearly across species in lowland tropical forest and presumably they will in temperate forests as indicated by Barker *et al.* (1993). In both cases it is unlikely that optimal

Table 4. Potential survey issues and applications of different count period strategies to distance sampling point transect surveys of various tropical forest birds.

Species group	Species traits	Survey issues	Optimum count period
Canopy frugivores	Medium/large bodied; upper vegetation layers; relatively sedentary or obviously in flight	Visual detection difficult; possible random movement of birds into detection range; evasive movement	8 min/no SDP – produces higher ERs and DEs
Carnivores	Medium/large bodied; middle/upper strata; call infrequently	Difficult to detect	10 min/no SDP – produces higher ERs (DEs were unreliable)
Coucals/Koels	Large bodied; sedentary; under/midstorey vegetation; inconspicuous	Call sporadically; easy to overlook; no evidence of evasive movement; often 'hide' in response to observer	10 min/Include SDP – produces higher ERs and DEs
Ground-dwellers	Medium-sized; relatively sedentary; inconspicuous; call infrequently	Evasive movement; easy to overlook	10 min/No SDP – produces higher ERs (DEs were unreliable)
Nectarivores	Small-bodied; middle/upper vegetation; mobile and active; regular contact calls	Double-counting; possible evasive movement; detection rates drop rapidly with distance	6 min/no SDP – produces higher ERs and DEs
Omnivores	Medium-sized; wide range of strata used; call frequently; conspicuous and mobile	Double-counting; possible evasive movement, but also birds may move into area; easy to detect	4 min/no SDP – produces higher ERs and DEs
Sallying insectivores	Medium-sized; middle/upper forest strata; visual detection enhanced in open canopy forest; infrequent vocalizations	Overall, difficult to detect; no obvious evasive movement or risk of double counting	10 min/no SDP – produces higher ERs (DEs were unreliable)
Upperstorey gleaning insectivores	Various body sizes; middle/upper forest strata; distinctive vocalizations or frequent contact calls; relatively vagile	Visual detection difficult; evasive movement away from point	6 min/no SDP – produces higher ERs and DEs
Understorey insectivores	Small-bodied; lower vegetation levels; relatively sedentary, but active; call frequently	Ease of detection drops rapidly as distance increases; possible evasive movement	8 min/no SDP – produces higher ERs and DEs

ER = encounter rate, DE = density estimate, SDP = Settling down period.

count periods will be known for each species, so it is appropriate to consider guild-specific count period durations (see Table 4). Using a shorter count period will help to minimize over-estimation of densities of mobile species because of undetected movements into and within the area (Scott & Ramsey 1981, Granholm 1983). Consequently, it will maximize the likelihood that density estimates are based on an instantaneous assessment rather than cumulative data (Granholm 1983). A longer count period will benefit the detection and estimation of abundance of quiet and sedentary species (in this study, species such as Common Koel *Eudynamis scolopacea* and Philippine Coucal *Centropus viridis*, while highly vocal during the breeding season, were difficult to detect when not calling).

An important practical point is that implementing a shorter count period should allow a greater

number of points to be surveyed within a given time, which itself may increase statistical power to detect abundance shifts, particularly in rare species (e.g. Marsden 1999). For instance, ten point transects can be surveyed comfortably during a 3-h survey period in lowland forest over rugged terrain: travel time is set at 9 min between points and includes a short period after each point confirming species detections. Reducing the count period to 5 min means 13–14 points can be surveyed in the same time, a 33–40% increase in survey effort. Increasing survey effort through visiting more points is desirable, especially in tropical forests where many species are rare (Karr 1971). Surveying more points for shorter amounts of time may be unrealistic in some surveys as some types of bird may simply require a full 10-min count period to be surveyed effectively. In this study, this applied to 'Coucals/Koels'. In other studies this

would probably apply to the most cryptic and inconspicuous bird species.

In this study, a count period of 4 min appeared most appropriate for surveying 'Omnivores', while 6-min counts for 'Nectarivores' and 'Upperstorey gleaning insectivores', 8-min counts for 'Understorey insectivores' and 'Canopy frugivores', and 10-min counts for 'Carnivores', 'Ground-dwellers', 'Sallying insectivores' and 'Coucals/Koels' appeared best suited to surveying these groups of species. A review of species' traits, survey biases and optimum count periods is given in Table 4.

Inclusion of a settling down period

Abundance measures for most guilds and species were lower from point transects with a settling down period than those without. There are two likely reasons for this. First, evasive movement or behavioural changes influencing detectability in response to the observer's presence had a strong effect on bird detections (Emlen 1971, Scott & Ramsey 1981, Granholm 1983, Rosenstock *et al.* 2002). Secondly, observer efficiency in detecting birds decreased over this extended count period (20 min) (Scott & Ramsey 1981). This latter point is unlikely as abundance estimates for conspicuous species decreased, so detection effort had not become focused solely on better known species or those with more obvious vocalizations (Scott & Ramsey 1981). Additionally, the initial location of some birds was already known from the first 10-min count period so this should, if anything, have boosted detection rates in the second 10 min. Changes in detectability, movement of birds away from the point during the initial count period, and birds moving from outside the initial survey area into contactable range (e.g. Ramsey & Scott 1978) prior to the initiation of the second count period (with a settling down period) are the most likely factors influencing differences in abundance measures from counts with and without a settling down period.

The influence of using a settling down period was so great that overall density estimated from points with a settling down period was only 58% of that obtained from points without. This not only resulted from fewer encounters, but also to a greater proportion of those birds being recorded further from the point, which contribute less to the density estimate. This was either because of evasive movement away from the observer, previously undetected birds being detected after a period of equilibration (Rosenstock

et al. 2002), cessation of vocalizations in response to the observer, or possibly movement of birds into the periphery of the survey area (Scott & Ramsey 1981, Granholm 1983). These issues are reflected by changes in guild detection functions across the two count regimes. In some guilds, 'Canopy frugivores', 'Understorey insectivores' and 'Upperstorey gleaning insectivores', this was a result of modelling proportionally more encounters further from points with a settling down period: movement of birds during a settling down period was most strongly exhibited in 'Canopy frugivores' and 'Upperstorey gleaning insectivores'. For 'Coucals/Koels', the change reflected a better developed 'shoulder' in the distance data and a decrease in detection probability near the point. Detected birds close to the point presumably moved away from the observer during the first count period and, alongside birds moving into the area, were then encountered further from points with a settling down period. These issues violate the important assumption of distance sampling that birds are detected at their initial position (Buckland *et al.* 2001) and, therefore, need to be minimized.

Our results suggest that incorporating a settling down period seriously underestimated abundance of nearly all species and that this was due to evasive movement and changes in detectability (we posit that there is a net movement of birds away from the recorder rather than towards it). We propose that surveys of these species, except coucals/koels and Mindoro Tactic *Penelopides mindorensis*, are more accurately conducted without the inclusion of a settling down period. Table 4 outlines the best application of this design variable for these groups of species according to this study.

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