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# The effectiveness of point counts and mist-netting in surveying Afrotemperate forest bird community structure in South Africa

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**ABSTRACT**

Point counts and mist-netting are two frequently employed survey techniques used in assessing forest avian communities, although the reliability of these methods varies according to species composition and habitat. This study investigates how effectively these two methods survey forest bird community structures within South African Afrotemperate forests. Seven forests within the Eastern Cape were surveyed from 140 duplicate point count and 63 mist-netting stations. Both methods were compared for assessing species richness, as determined from bird atlas data. Generalised linear mixed-effect modelling was used to determine functional traits which most impacted species detection, and to identify detection biases for both methods. Both methods compared consistently across the seven forests, which shared similar community structure. Point counts detected 79.2% of the total diversity versus 41.0% using mist-netting, and mixed-effects modelling corroborated that species detection is more effective using point counts. All functional traits tested (body size, primary foraging stratum, feeding guild, habitat specialisation, and dispersal behaviour) affected detection outcome. Point counts better represented all aspects forest bird community structure, including mid- and understorey birds which are presumed to be better detected by mist-netting. Use of mist-netting only slightly enhanced diversity assessments, and combined survey efforts under-represented forest-edge foragers, woodland and grassland habitat generalists (~63.6% total diversity), large birds, Palaearctic migrants, and carnivores.

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## Introduction

Birds are attractive ecological indicators for use in forest monitoring studies (Gregory *et al.* 2003; Gao *et al.* 2015), owing to their reliable and cost-effective field identification (Gardner *et al.* 2008), and the sensitivity of many species to habitat degradation (Sutherland *et al.* 2004). Point counts and mist-netting are two popular survey techniques used to infer local bird distribution, abundance and diversity. Point counts involve timed, and typically distance-defined, bird observations at a series of stations (Ralph *et al.* 1995; Buckland 2006). Mist-netting involves the catching and handling of birds by qualified persons using finely meshed nets (Karr 1981). Both methods are relatively inexpensive and can be easily executed, following appropriate training. The limitations of each method are broadly known (Pagen *et al.* 2002; Wang and Finch 2002): point count success is affected by observer skill, environmental conditions, and conspicuousness of the species present (Lynch 1995; Alldredge *et al.* 2007; Pacifici *et al.* 2008); mist-netting is more labour-intensive, yet less efficient, than point counts, being more influenced by bird body size and flight paths – typically only detecting birds within <3 m above ground – and more adversely affected by weather (Remsen and Good 1996; Dunn and Ralph 2004). Although these limitations are broadly acknowledged prior to most field surveys, reliable ecological inferences require comprehensive understanding of the detection biases associated with each method.

In select Neotropical and Indo-Malayan forest ecosystems, detection biases have been reasonably well determined (Blake and Loiselle 2001; Derlindati and Caziani 2005; Martin *et al.* 2010, 2017; Cavarzere *et al.* 2013), but have limited general applicability as environmental conditions and bird community structures vary across regions and habitats (Martin *et al.* 2017). These studies largely focussed on continuous forest, yet monitoring schemes are often implemented in fragmented forests (Newbold *et al.* 2013, 2014; Bregman *et al.* 2014; Keinath *et al.* 2017). In Afrotropical forests, fragmentation studies typically consider the habitat specialisation of the observed species. These bird communities comprise both forest-dependent species that rely on forest ecosystems for at least some ecological functions (Oatley 1989), and habitat generalists that can survive and reproduce in surrounding non-forest landscapes. Forest-dependent birds can be

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further divided to forest specialists, which are largely restricted to the interiors of intact forests, and forest generalists which tolerate a broader range forest conditions and quality, and occasionally woodlands (Bennun *et al.* 1996). Temperate forests support lower levels of forest specialists than in the tropics, and fewer sedentary species (Salisbury *et al.* 2012; Bregman *et al.* 2014). Both habitat specialisation and dispersal behaviour affect species susceptibility to fragmentation (Robinson and Sherry 2012; Newbold *et al.* 2014; LaManna and Martin 2017).

The naturally fragmented temperate evergreen (Afrotemperate) forests of South Africa occur along the southern and eastern escarpments, and south-east coast (von Maltitz *et al.* 2003; Mucina 2018). These forests are related to the Afromontane forests of tropical east Africa (von Maltitz *et al.* 2003), and share similar avian phylogenetic compositions with these forests (Lawes *et al.* 2007; Fjeldså and Bowie 2008). Recent comparisons between the first and second Southern African Bird Atlas Projects (SABAP and SABAP2) suggest that 28 of the 57 forest-dependent bird species within the country have experienced range declines from 1992–2014 (Cooper *et al.* 2017). These declines are most apparent in the Eastern Cape, which contains 46% of South Africa's Afrotemperate forests (Berliner 2005). Recent studies show forest bird communities in this province (Leaver *et al.* 2019a, 2019b; Leaver and Cherry 2020), and elsewhere in South Africa (Neuschulz *et al.* 2013; Olivier *et al.* 2013; Olivier and van Aarde 2017; Ehlers Smith *et al.* 2018; 2017; Freeman *et al.* 2018) sensitive to habitat fragmentation and forest degradation. Preventing further bird declines requires increased monitoring within these forests, and continual assessments of the contemporary forest bird community structure, conducted using accurate and effective survey methodology. Thus, the aims of this study were to determine how reliably point counts and mist-netting assess bird diversity, and represent different aspects of bird community structure in Afrotemperate forests of the Eastern Cape. South African forests appear to be dominated by canopy species, and having species-poor understorey communities (Koen and Crowe 1987; Symes *et al.* 2002; Olivier and van Aarde 2014), so species detection by mist-netting is expected to be less effective compared to point counts. Vegetation structure varies slightly between forests, with canopy heights ranging from 10–25 m, so mist-netting performance should improve in lower-canopy forests.

## Methods

### Study sites

Fieldwork was conducted in seven Afrotemperate forest sites, largely confined to the Eastern Cape of South Africa (Figure 1), within the Maputaland-Pondoland-Albany biodiversity hotspot (Mittermeier *et al.* 2005). Ngele is in southern Kwa-Zulu Natal, Gomo and Baziya are on the Transkei escarpment, and Kubusi and Fort Fordyce lie at eastern and western ends of the Amatole Mountains, respectively. These five forests are part of the southern mistbelt forest group: mid-altitude (850–1600 m) forests that occur discontinuously inland along the southern South African escarpment (von Maltitz *et al.* 2003).

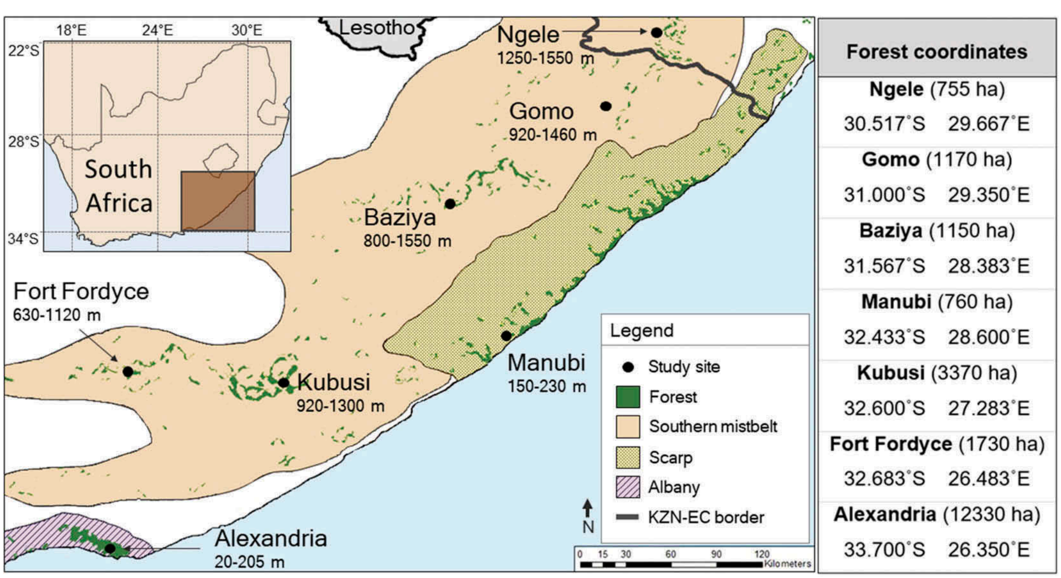


Figure 1. Map of the study region in the Eastern Cape, South Africa, showing the co-ordinates, altitude range (m), size (ha), and forest groups (von Maltitz *et al.* 2003).

Manubi lies on the Transkei coast and is a scarp forest: low- to mid-altitude (0–1300 m) forests, transitional between mistbelt and coastal forests (von Maltitz *et al.* 2003; Lawes *et al.* 2007; Mucina 2018). Finally, Alexandria is situated in Algoa Bay, and is part of the southern coastal forest group: low-altitude (0–500 m) evergreen forest along the southern South African coast (von Maltitz *et al.* 2003; Mucina 2018). All forests experience a similar climate annual temperature range of 1–29°C, and 600–1200 mm rainfall, peaking January-March. Southern mistbelt (15–25 m) and scarp forests (15–25 m) have similar canopy heights, although the understorey is more developed in mistbelt than scarp forests. Southern coastal forests have low canopies of 5–15 m, and dense undergrowth vegetation (Mucina 2018; von Maltitz *et al.* 2003).

### Data collection

Most forest sites were surveyed for two week periods during September 2017 – January 2018, although Alexandria was surveyed in October 2018. Surveys were conducted during the breeding season when bird vocalisation is heightened, and when summer migrants are present. Survey intensity was standardised across forests. For point counts, 20 duplicate fixed-radius 50 m observation stations were arranged along four linear transects, each comprising five observation stations spaced >150m apart. Stations along transects were visited within the first two hours of sunrise, and revisited on a new morning in reverse order. Visits lasted 10 min and all bird seen/heard within the station were recorded; unidentified birds were ignored. Mist-netting surveys in each forest were standardised to 3500 net-hours (1 net-hour = 12 m net open/hr), or a total of nine stations of 180 m transects of 2.5 m x 12/18 m length five-shelved, 16 mm mesh nets along forests tracts in forest-edge and interior. Two mist-netting stations were operated simultaneously for 2.5 days before relocating to new stations in another part of the forest. Nets were opened before sunrise to after sunset, closed during midday and inclement weather, and inspected every 30 minutes when open. Captured birds were identified, ringed, measured, and promptly released. Surveys were conducted when weather conditions were conducive to species detection, and safe for bird capture (calm and dry/lightly-misty). Both survey methods were conducted in close proximity. Point count transects were spaced >500 m apart, and mist-netting stations were spaced >300 m apart where feasible. Survey stations were selected to maximise coverage throughout a given forest fragment. At each forest site, eight point count stations were at the forest-edge, and twelve were within the forest interior, while for mist-netting, four stations were at forest-edge and five were in the forest interior. Surveys were conducted by a single observer, JM.

### Checklist construction

Species checklists for the contemporary bird communities of the seven forest sites were compiled using data from the second Southern African Bird Atlas Project (SABAP2, 2007–2018) (Brooks 2018), which included observations made during this study. Quarter degree grid cells (QDGC) were centred over each forest, consolidating the species lists from the nine pentads (5′x5′) therein. Recorded species were assessed in terms of their interaction with forests (e.g. foraging, breeding, or roosting), categorising any species with a non-negligible engagement with forest as forest-utilising (Harrison *et al.* 1997a, 1997b; Hockey *et al.* 2005). Migratory species were included, but nocturnal birds were excluded as these were not surveyed. The regional assemblage across the seven forest sites included 173 forest-utilising bird species (Table S1) of 54 families (Gill and Duncker 2018). Compiled SABAP2 checklists were filtered for forest-utilising species to generate complete species inventories for each forest (Table S1). Non-forest-utilising species detected during surveys were removed from analysis, but have been included in Table S1.

### Functional traits

A set of functional traits were determined for each forest-utilising species, sourced from local literature (see Table S1). Information on body mass (<50 g: small; 50–100 g: medium; >100 g: large), primary foraging stratum in/around forest (understorey; mid-storey; canopy; forest-edge; aerial), and feeding guild (carnivore; insectivore; frugivore/granivore; nectarivore) was derived from Hockey *et al.* (2005). Bird habitat specialisation (forest specialist; forest generalist; woodland habitat generalist; grassland habitat generalist) was determined from Bennun *et al.* (1996) and Harrison *et al.* (1997a, 1997b). Finally, dispersal behaviour of birds within the Eastern Cape (sedentary resident; dispersive resident; local migrant; Intra-African migrant; Palaearctic migrant) was sourced from Hockey *et al.* (2005), Harrison *et al.* (1997a, 1997b), Neuschulz *et al.* (2013), and Craig and Hulley (2019). Proportions of each functional traits across forests were compared using a series of $\chi^2$ tests (Gibbons and Chakraborti 2011).

### Statistical analysis

Analyses were performed in R version 3.4.3 (R Development Core Team 2018), largely following Martin *et al.* (2017). Proportions of total species detected per forest, and detection ratios between forest sites within functional groups, were compared for each method using $\chi^2$ tests with Yates continuity correction. Kruskal-Wallis (Gibbons and Chakraborti 2011) tests were used to determine if species richness found at each observation station varied significantly among forests for either point counts or mist-netting. Generalised linear mixed-effect (GLM) modelling was performed on survey data (Table S1) to determine the factors most affecting species detection when using combined survey methods in the seven forests. Forest-utilising species checklists for each forest were assumed to represent all species present. A logistic regression curve was fitted to determine factors influence detection outcome, which were taken as separate Bernoulli trials (1 = detected and 0 = undetected), for each method. The global model factored survey method, and all functional traits (body size, primary foraging stratum, feeding guild, habitat specialisation, and dispersal behaviour) as fixed-effects; and forest site as a mixed effect, due to similarities in community structure and consistent survey performance between forests. Sub-models progressively excluded each factor. Two null (intercept-only) models were included (1) with, and (2) without the random effects. Mixed-effects models were fitted using the 'glmer' function in lme4 R package (Bates *et al.* 2007), while models ignoring random effects were fitted with function 'glm' in the Stats R package (R Development Core Team 2018). Model selection was conducted using Akaike's Information Criteria (AIC) (Burnham and Anderson 2003) in the MuMIn R package (Barton and Barton 2018); models with non-significant terms were omitted. Akaike weights ($w_i$) gave likelihood estimates to each candidate models being the best-supported model. Model fit was assessed using conditional $R^2$, which is insensitive to the number of variables factored (Nakagawa and Schielzeth 2013). We performed additional GLM models separately for point count and mist-netting surveys. Post hoc analysis, using least-square mean difference with Tukey adjustment in the Lsmeans R package (Lenth 2016), further distinguished the biases of each method within each functional trait group.

To illustrate how effectively species detection rewards survey effort through time, we drew species accumulation curves from 100 randomisations of complete point count and mist-netting datasets across the seven forests. We then plotted species extrapolations from the data to assess how accurately forest diversity could be approximated. We used the incidence-based Chao2, and MMMeans non-parametric species estimators, which are considered appropriate for inferences on in tropical forest bird communities: MMMeans is considered more accurate, but is sensitive to variability in community structure (Herzog *et al.* 2002); Chao2 is less affected by sampling strategy, but is sensitive to sample size (Hortal *et al.* 2006). Curves were created using EstimateS version 9.1.0 (Colwell 2013).

## Results

Compiled checklists show the number of forest-utilising bird species at each forest: Manubi – 157; Kubusi – 150; Alexandria – 143; Ngele – 135; Gomo – 129; Fort Fordyce – 129; and Baziya – 121 (Table S1). Community structure was highly similar across forest sites for all functional groups (Figure S1; Table S2). All seven forests had high proportions of small and insectivorous species. Forest interiors (understorey, mid-storey, and canopy), hold mostly canopy-foraging species (71.4%), but comprise only 40.4% of total diversity – compared to 49.7% present at the forest-edge. Only 36.4% of forest-utilising species are forest-dependent, suggesting most avian diversity is from woodland and grassland habitat generalists foraging at the forest-edge. Lastly, 43.9% of species are sedentary forest residents, with the rest being more dispersive and migratory species. Total combined survey efforts detected 9017 individuals from 139 forest-utilising species. Point counts detected 7278 individuals detected from 137 species, while mist-netting detected 1739 individuals from 71 species. Table S3 (point counts) and Table S4 (mist-netting) break down species and individual totals observed at each forest.

Across the seven forests, higher species richness was recorded at point count observation stations compared to mist-netting (Figure 2). Point counts detected 59.87–75.56% of forest checklist totals ($\chi 2$ test $p = 0.908$) (Table S3). Functional group representation from point counts varied among forests for carnivores, frugivores/granivores, grassland generalists, local migrants, and Palaearctic migrants. Mist-netting detected 20.83%-28.67% of forest checklists totals ($\chi^2$ test $p = 0$ .936) (Table S4). Functional group representation from mist-netting was less consistent compared to point counts, differing among forests for mid-storey, aerial and forest-edge foragers, carnivores, frugivores/granivores, nectarivores, grassland generalists, local migrants, and Intra-African migrants. Mist-netting detected no Palaearctic migrants, and only one aerial species, the white-throated swallow *Hirundo albigularis*, at Kubusi. All aspects of forest bird

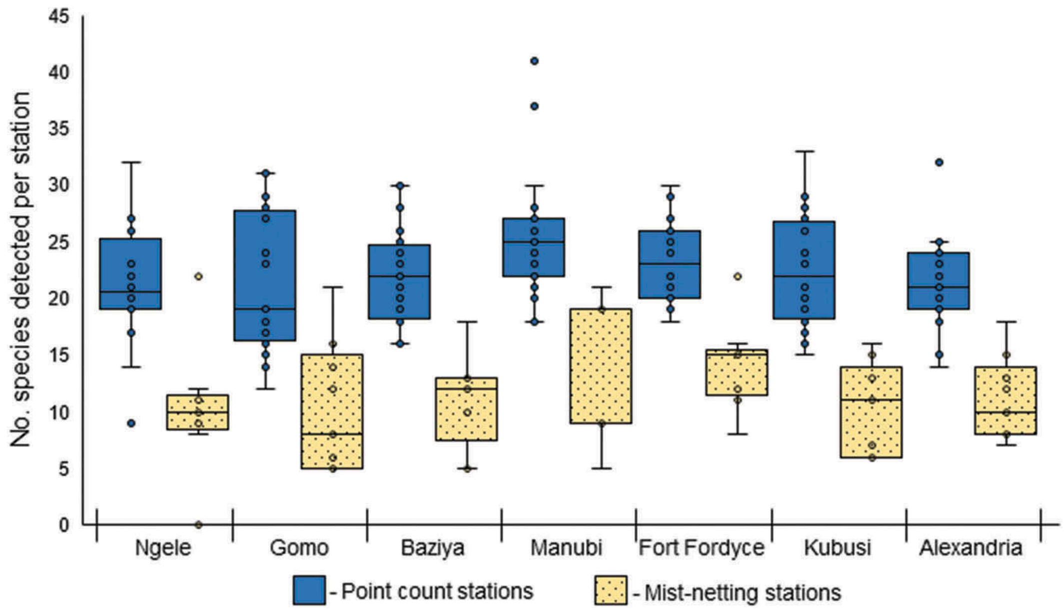


**Figure 2.** Boxplots showing species richness detected by point counts is consistently higher than mist-netting across the seven Afrotemperate forest sites. Kruskal-Wallis scores for average species richness per observation among forests were 2.46 for point counts ($p$ = 0.78), and 4.22 ($p$ = 0.65) for mist-netting, suggesting consistent survey performance across forests.

community structure were better represented by point counts than mist-netting.

The global GLM model was the best supported model (Table 1), explaining detection outcomes within the seven forest sites to be affected by survey method and all functional traits factored. Table 2 shows point counts to be more effective at species detection than mist-netting. Combined survey methods significantly under-represent large birds, forest-edge foragers and aerial feeders, both woodland and grassland generalists (most of which are forest-edge foragers), Palaearctic migrants, and carnivorous species. Factoring in feeding guild increased model explanatory power only slightly. Model selection of stand-alone point count and mist-netting surveys are shown in Table S5 and Table S6, respectively; post-hoc results of the best-supported model for each method are shown in Figure S2.

Point counts detected 79.2% of the regional forest-utilising species, compared to the 41.0% by mist-netting (Table 2). Only two species were detected solely by mist-netting: southern tchagra *Tchagra tchagra* (Gomo) and white-browed scrub-robin *Cercotrichas leucophrys* (Kubusi), both woodland generalists. Point counts required considerably less time, and effort than mist-netting. Observation time devoted to point counts was 6 hrs 40 min per forest (46 hrs 40 min total), and ~3600 hrs were invested into mist-netting (~26,000 hrs total). The species accumulation curves displaying total survey effort showed point count effectiveness plateaued below 140 species (Figure 3.1), while mist-netting effort was less productive, but steadily accumulated species throughout the study period (Figure 3.2). Chao2 and MMMeans estimates from mist-netting were well below those from point counts. For both methods, MMMeans extrapolated greater diversity from brief surveys, but at

**Table 1.** AIC model selection of generalised linear mixed-effect logistic regression model representing factors affecting species detectability in Afrotemperate forests. Included are the AIC values, AIC difference (ΔAIC), model fit (*Conditional* $R^2$), and Akaike weights ($w_i$) for each model.

| Model R code* | AIC | ΔAIC | *Cond.* $R^2$ | $w_i$ |
|---|---|---|---|---|
| **~Method+Stratum+Size+Specialisation+ Dispersal+Diet+(1\|Forest)** | 1803.39 | 0.00 | 0.53 | 0.98 |
| ~Method+Stratum+Size+Specialisation+ Dispersal+(1\|Forest) | 1811.97 | 8.58 | 0.52 | 0.014 |
| ~Method+Stratum+Size+Dispersal+(1\|Forest) | 1827.59 | 24.20 | 0.51 | 0.000 |
| ~Method+Stratum+Size+(1\|Forest) | 1855.56 | 52.17 | 0.49 | 0.000 |
| ~Method+Stratum+(1\|Forest) | 1904.37 | 100.98 | 0.46 | 0.000 |
| ~Method+(1\|Forest) | 2307.24 | 503.85 | 0.19 | 0.000 |
| Null (~1) | 2643.01 | 839.62 | 0.00 | 0.000 |
| Null (~1+(1\|Forest)) | 2645.01 | 841.62 | 0.00 | 0.000 |

*Mixed-effects models were fitted using 'glmer' function in the 'lme4' R package, and the final null model was fitted using the function 'glm' in the 'Stats' R package.

**Table 2.** Parameter estimates for the best-supported logistic regression model for determining factors affecting bird species detection by combined point count and mist-netting surveys in Afrotemperate forests. Shown are the percentage of total forest-utilising bird species detected per category (%T), coefficient estimate (Estimate), and standard error of the estimate (SE), Z-score values, and *p*-values. Results in bold are significant.

| Factor | Level | % Total | Estimate | SE | Z-score | p-value |
|---|---|---|---|---|---|---|
| Intercept | - | - | **−2.34** | **0.36** | **−6.53** | **<0.0001** |
| Method | **Point** | **79.20** | **2.49** | **0.14** | **18.33** | **<0.0001** |
| | Mist-netting | 41.04 | - | - | - | - |
| Body size | **Small** | **83.49** | **0.57** | **0.20** | **2.87** | **0.004** |
| | Medium | 92.00 | 0.00 | 0.23 | 0.00 | 0.997 |
| | Large | 64.10 | - | - | - | - |
| Primary foraging stratum | **Understorey** | **100.00** | **1.63** | **0.37** | **4.41** | **<0.0001** |
| | **Mid-storey** | **100.00** | **3.22** | **0.67** | **4.77** | **<0.0001** |
| | **Canopy** | **100.00** | **0.80** | **0.28** | **2.85** | **0.004** |
| | **Forest-edge** | **63.95** | **−0.69** | **0.26** | **−2.61** | **0.009** |
| | Aerial | 82.35 | - | - | - | - |
| Habitat specialisation | Forest specialist | 100.00 | −0.16 | 0.20 | −0.77 | 0.440 |
| | Forest generalist | 90.63 | - | - | - | - |
| | **Woodland generalist** | **71.43** | **−0.72** | **0.18** | **−3.87** | **0.0001** |
| | **Grassland generalist** | **72.50** | **−0.89** | **0.22** | **−4.00** | **<0.0001** |
| Dispersal behaviour | **Sedentary resident** | **90.20** | **0.57** | **0.23** | **2.51** | **0.012** |
| | Dispersive resident | 76.92 | −0.01 | 0.23 | −0.05 | 0.964 |
| | Local migrant | 100.00 | 0.33 | 0.30 | 1.12 | 0.262 |
| | Intra-African migrant | 90.91 | - | - | - | - |
| | **Palaearctic migrant** | **20.00** | **−1.35** | **0.44** | **−3.09** | **0.002** |
| Feeding guild | Carnivore | 69.57 | - | - | - | - |
| | **Insectivore** | **81.55** | **0.60** | **0.25** | **2.40** | **0.016** |
| | Frugivore/Granivore | 82.05 | 0.18 | 0.25 | 0.72 | 0.470 |
| | **Nectarivore** | **87.50** | **1.05** | **0.37** | **2.85** | **0.004** |

higher intensity surveys Chao2 estimated more species. Another appropriate, abundance-based metric, ACE, produced similar results.

## Discussion

Point count and mist-netting species detection performance was consistent across the seven surveyed Afrotemperate forests of the Eastern Cape, which shared highly similar bird community structure (Figure S1; Table S2). Both the GLM model (Table 2), and species accumulation curves (Figure 3) show that point counts outperform mist-netting at species detection. Mist-netting did not contribute significantly to an understanding of forest bird community structure (Table 2; Table S3 vs Table S4). Increased survey intensity using point counts better approximated estimated species diversity than did mist-netting (Figure 3). Point counts appear to suffice as a stand-alone method for surveying these Afrotemperate forests, reducing the need to undertake protracted mist-netting surveys. Although all functional traits factored contributed towards species detection, the primary foraging stratum contributed the most substantially. This holds for combined surveys (Table 2), point counts (Table S5), and mist-netting (Table S6). Forest interior foragers were reliably detected by point counts, but even combined surveys under-reported forest-edge and aerial species. Many forest-edge species are habitat generalists which have lower abundance in forests, even if common in adjacent non-forest habitats. The SABAP2 data used for checklist construction spanned 12 years, and included species which are less likely to be detected by the relatively brief sampling we conducted. Estimated species diversity (Figure 3) did not approximate total forest-utilising bird diversity, suggesting some habitat generalists are not reliably present in forests. More extensive surveys should focus on elucidating species occupancy at forest-edge transition zones, as this could benefit an understanding of how natural forest fragments are integrated into the landscape (Kupfer *et al.* 2006; Terraube *et al.* 2016), and to help monitor the effects of habitat degradation. Fortunately, forest-dependent birds were reliably detected by combined survey efforts (Table 2), and by point counts alone (Table S5).

Point count performance was less affected by bird body mass than was mist-netting (see below), although large species were less likely to be detected than smaller ones (Figure S2). Species dispersal behaviour better explained detection outcomes by point counts (Table S3). Dispersive residents – such as raptors, parrots, and hornbills – may have infrequent occurrence, or large territories. For these birds, increasing the 'grain' (observation area/period) of the survey may improve detection; this approach is also appropriate for large species, including sedentary residents. Species' active periods should also be considered to ensure these coincide with survey times. Palaearctic migrants were poorly

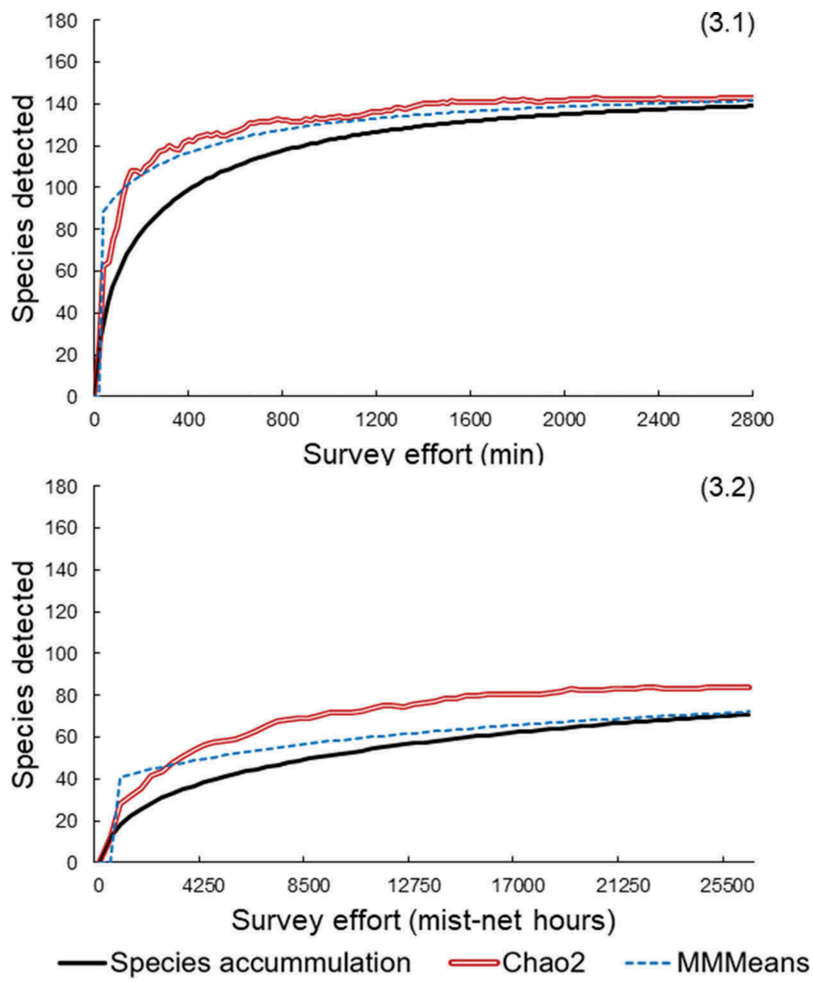


**Figure 3.** Species accumulation curves (100 randomised permutations) and species extrapolation curves (100 permutations of Chao2, and MMMeans estimations), respectively showing the number of species detected, and species presence estimated from (4.1) 2800 min of point count observations, and (4.2) 26,000 mist-net hours, across seven Afrotemperate forests.

detected by combined survey efforts (Table 3; Table S3; Table S4). These are all habitat generalists reluctant to utilise forest interiors (Hockey *et al.* 2005), and so most may be rare/absent from forests. Future studies should pay closer attention to Palaearctic migrants, given the extent to which they interact with different ecosystems within the study area and elsewhere in Africa (Thorup *et al.* 2019). Feeding guilds did not affect detection by point counts (Table S5). The inconsistent representation of carnivores and frugivores/granivores in point counts among forests may be an artefact of their relatively short duration, or alternatively related to foraging stratum or dispersal behaviour. Although point counts should suffice for species detection in these forests, use of this method for bird abundance/occupancy inference has been criticised, particularly in forest habitats (Pacifici *et al.* 2008; Nichols *et al.* 2009; Hayes and Monfils 2015). This is especially important as surveys may under-detect cryptic/reclusive species, where individuals are more difficult to detect.

GLM models better demonstrated the limitations of mist-netting for assessing functional diversity (Table S5; Figure S2). Despite the notion that mist-netting removes observer bias occasioned by dense forest undergrowth (Karr 1981; Symes *et al.* 2000; Dulle *et al.* 2016), point counts were found to outperform mist-netting at detecting forest understorey and mid-storey foragers (Tables S4 vs Table S5). Significantly lower representation of canopy foragers, which constitute 71.4% of forest interior species, reaffirms the impracticalities of using mist-netting to assess forest diversity where most species are present in the canopy (Cavarzere *et al.* 2013; Martin *et al.* 2017). Although canopy-level nets are a possibility (Derlindati and Caziani 2005), a far more feasible alternative for passive monitoring is afforded by wildlife acoustics (Blumstein *et al.* 2011), which compares favourably to point counts in temperate forests (Klingbeil and Willig 2015), and camera trapping (Trolliet *et al.* 2014). Mist-netting surveys in this study were deliberately non-specific and showed strong biased against medium and large species, frugivores/

granivores, and carnivores; mist-netting is also unsuitable for assessing aerial feeders around forests (Table S4; Figure S2). Mist-netting can be adjusted for better detection of different size classes, such as using larger/smaller mesh-size, or tailored to individual species (Bub 1991), but without these adjustments, inferences relating to larger birds should be made with caution. The effects of setting up nets along forest tracks instead of in undergrowth proper is unknown; the latter case would require extensive clearing of vegetation to the detriment of the forests. It should be mentioned that mist-netting has applications beyond only species detection, and is an invaluable tool for performing demographic studies of age structures and movement through capture-recapture and satellite tracking, morphometric analysis, and sample collection for genetic, ectoparasite, and disease studies (Dunn and Ralph 2004; Ralph and Dunn 2004). Consequently, mist-netting is more appropriate for long-term assessments of bird populations (Symes *et al.* 2000; Williams 2016), rather than brief assessments of bird communities, and can be used to create population indices of the species that are reliably detected by mist-nets: small birds, insectivores, and nectarivores, foraging in the understorey and mid-storey.

Species detection effectiveness by both survey methods was consistent among forests (Figure 2; Table S3; Table S4), despite Alexandria having a considerably lower canopy and greater understorey biomass than the other forests sites. The Afrotemperate forests in the Eastern Cape support similar bird community structures to tropical Afromontane forests in east Africa, although the latter forests hold a higher proportion of forest specialists (Ulrich *et al.* 2016; Werema *et al.* 2016; Engelen *et al.* 2017; Uwimbabazi *et al.* 2017; Chiawo *et al.* 2018). The results of this study are thus likely to be germane to surveying Afromontane forests across the continent, and possibly even to other well-wooded habitats, as Lee *et al.* (2015) reported similar survey effectiveness for point counts and mist-netting in fynbos. Further assessments are needed to assess how applicable point counts and mist-netting are for assessing nocturnal birds, which were not assessed in this study.

## Conclusion

In summary, point counts are more effective than mist-netting for assessing the bird communities of Afrotemperate forests in the Eastern Cape, detecting 79.2% vs 41.0% of forest-utilising species. Although outperformed by point counts, mist-netting is still reliable for detecting mid- and understorey species. Combined survey efforts could reliably detect forest-dependent species, and birds which forage in the forest interior. Combined survey efforts, however, under-represented forest-edge species and habitat generalists – many of which may be rare in forests, although the extent of their interactions with forests is unknown – as well as medium-large birds, dispersive residents and Palaearctic migrants. Not accounting for these survey biases could significantly misrepresent avian community structures within these forests, and misinform conservation efforts.

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## Disclosure statement

No potential conflict of interest was reported by the authors.

## Ethics

Ethics clearance was approved by the University of Stellenbosch (#SU-ACUD16-00195). Permits were obtained for working in state forests managed by the South African Department of Agriculture, Forestry, and Fisheries (DAFF) in the Eastern Cape and Kwa-Zulu Natal, in reserves managed by the Eastern Cape Parks and Tourism Agency, and for Woody Cape SANParks Nature Reserve. Bird ringing was undertaken by J.M., licensed by SAfring, with permits for bird ringing in the Eastern Cape and Kwa-Zulu Natal (OP4487/2017).

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## Data availability

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

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