

Using playback of vocalisations to survey the Nahan's francolin, a threatened African forest galliform

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Methods using playback of vocalisations have been widely used to survey elusive birds. Most of these methods suffer from the drawback that movement of birds is often elicited by the sound stimulus used, violating assumptions of distance sampling and generating unknown biases in resulting density estimates. Using playback survey data for a globally threatened forest galliform bird in Uganda, we found evidence of strong movement of birds toward the sound stimulus during playback surveys, and demonstrate that this caused a significant overestimation of bird density. We present a simple regression-based method for identifying and correcting this bias that is statistically robust and practical to implement for those surveying elusive forest birds. Based on our adjusted survey data, we estimate that about 40 000 Nahan's Francolins remain in Uganda.

Introduction

Comprehensive data are of crucial importance in the conservation of threatened species, and surveys are among the first actions required to quantify the risk of any given species' extinction (IUCN 2001, Fuller et al. 2003). Indeed, surveys are currently considered among the most important actions for many globally threatened species, reflecting the urgent need for accurate distributional data as a basis for effective conservation planning (BirdLife International 2011).

Many formal survey techniques have been developed, tested and used successfully to estimate the population density of threatened species in a wide variety of contexts (Verner 1985, Bibby et al. 2006). However, many bird species, particularly gamebirds (Galliformes), rails (Rallidae) and nightjars (Caprimulgiformes), are highly elusive and many of these rarely call spontaneously. This means that they are difficult to detect using traditional auditory or visual cues, although some of these species may be censused at very specific times of the year when males may be calling spontaneously (Kaul and Shakya 2001). Index techniques that produce relative estimates of abundance have been successfully used in grasslands to survey Red-winged Francolins *Scleroptila leuallantii* and Grey-winged Francolins *S. africanus* in South Africa (Mentis and Bigalke 1985, Little et al. 1993, Jansen et al. 1999). Call counts of Grey-winged Francolins have also been used to generate robust relative abundance estimates that could be used to measure interannual change (Little and Crowe 1992), but as yet there is no reliable method to produce absolute density estimates for elusive forest francolins. Because the frequency of detecting individuals of these kinds of species is so low, survey work using traditional methods is highly resource

intensive and inefficient because many individuals are not detected even when close to the observer.

Playback surveys, where the vocalisations of the species of interest are broadcast and responses noted, have been used to increase the number of detections per unit effort for elusive species that are known to respond to such a stimulus, allowing more efficient sampling methods to be designed. For example, using playbacks of breeding season vocalisations increased the rate of detection of American Redstarts *Setophaga ruticilla* and Black-throated Blue Warblers *Dendroica caerulescens* wintering in Jamaica by a factor of two or three compared with simple point counts (Sliwa and Sherry 1992). Rates of detection of five species of marshbirds were increased by factors of 2.4 to 7.0 by the use of playback surveys (Allen et al. 2004). All Black Rails *Laterallus jamaicensis* known from territory mapping to be present within 60 m of the observer were detected during playback surveys for the species in California (Glahn 1974), and playback surveys are regularly used in monitoring elusive marshbirds in the USA (Fancy and Sauer 2000).

Many modern census methods incorporate a detection function that describes how the likelihood of making a detection declines as the distance of an animal from the observer increases. One of the most important assumptions of these distance-based methods is that animals are detected at their initial location, i.e. their location when the count period began (Buckland et al. 2001). Given that birds are known to respond to playback stimuli by moving toward the sound source (St Clair et al. 1998, Bélsisle and Desrochers 2002), this assumption will be violated in most current implementations of playback survey methods. This will lead to overestimation of the density of animals by the

model, because individual animals will be closer to the sound source when detected than their initial location at the start of the survey period. The magnitude of overestimation by playback surveys is currently unknown, but the problem is likely to be particularly serious where absolute, rather than comparative, density estimates are required. Absolute density estimates are useful when assessing species against IUCN Red List criteria C and D, which require estimates of absolute population size (IUCN 2001).

Here we investigate movement by elusive tropical forest galliform birds toward playbacks of their vocalisations, and demonstrate that movement toward the sound stimulus causes significant overestimation of population density. We suggest a method for modelling this movement effect and incorporating it into the density model.

We used playback surveys to census Nahan's Francolins *Ptilopachus nahani* in Uganda. The species is listed as globally Endangered (Fuller et al. 2000, BirdLife International 2011), and occurs in less than 10 forest fragments in eastern Democratic Republic of Congo (DRC) and western Uganda. Its status is poorly known, and although it appears relatively common in the three Ugandan sites, little is known about its status in DRC (BirdLife International 2011). Strictly cursorial, the francolins typically occur in groups of two to four birds, and show a strong preference for closed forest (Sande 2001). Nahan's Francolins are highly secretive and very difficult to locate visually in the field. They rarely call spontaneously under natural conditions, although they respond strongly within a few seconds to playback stimuli by vocalising loudly (Dranzoa et al. 1997, Sande 2001). Playback surveys have been used several times to survey for Nahan's Francolins (Dranzoa et al. 1997, Dranzoa et al. 1999, Sande 2001, Sande et al. 2001).

Methods

We conducted field work between July and September 2003 in Mabira (0°30' N, 32°57' E), Budongo (1°47' N, 31°35' E) and Bugoma (1°20' N, 31°05' E) forests in Uganda. These forests comprise medium to high-altitude moist semi-deciduous forest affected almost throughout by selective logging, and in Mabira also by human disturbance. See Howard (1991) for a detailed description of the physical and biological features of these forests.

We walked routes of varying lengths (0.8–6.4 km) throughout each of the forests, accessing the forest from suitable points around its perimeter, and occasionally camping within the forest to allow coverage of the interior. We conducted playback surveys at points along these routes separated by at least 200 m, this distance being measured directly using a handheld GPS receiver, not as distance walked along the route itself. At each point, we played the advertising call of the Nahan's Francolin using a Marantz PD222 tape recorder and a Sony battery-powered 10 W speaker. The recording was compiled using a combination of recordings 51908 and 51909 originally made by E Sande and A Plumtre/I Owiunji, respectively, and archived by the British Library of Wildlife Sounds in London, UK. The call was played for 10 s, and any response noted in the ensuing 60 s. This process was repeated twice, to give a total of three successive playbacks. If a response

by Nahan's Francolins was elicited by any one of the three playbacks, a further two playbacks were performed to facilitate modelling of the movement of birds toward the stimulus. After each playback, the distance from the observer and the delay between the start of the playback and the response were noted for each group. Distances within 30 m were estimated to the nearest 5 m, and all other distances to the nearest 10 m. Observers were well-practised in estimating distances in the field and regularly verified the accuracy of their estimates by pacing distances to, for example, the forest edge at which a francolin group was calling.

All playback surveys were conducted between 07:00 and 13:00, because calling activity appears to be stronger during this period than in the afternoon (Sande 2001), and in the case of rain we suspended survey work. In Budongo and Mabira forests, routes were walked entirely along existing trails in the forest. The reasons for this were threefold. First, we wanted to minimise environmental impact; second, cutting our own path through the forest would have made a lot of noise, disturbing birds and probably seriously affecting the results of the survey if birds were repelled from or attracted to the survey area; and third, cutting trails is time-consuming and would have compromised our sample sizes.

In Bugoma Forest, we used a combination of existing trails and trails cut by a research group that had been in the forest several weeks before we arrived (thereby circumventing the second point above). We termed these 'random trails'. These trails were straight and cut along predetermined compass directions into the forest, thereby providing a much more randomised sample of the forest than existing trails. This also gave us the opportunity to compare the density of francolins around random trails with that around existing trails, allowing us to estimate the amount of bias caused by using existing trails through the forest.

We used a regression-based approach to model the movement of birds in relation to the sound stimulus. We checked that regression modelling outperformed simply assuming that birds had not moved relative to the sound stimulus. We did this by selecting all cases where francolin groups responded three or more times to the playback. First, we removed the original starting distances from the data set, and calculated the distance moved between the second and final response. We then built a linear regression model using distance at the final response and time elapsed between second and final response to predict the distance at second response. We used the resulting equation to predict original starting distance (data not used in building the model) from distance at second response and time elapsed between second response and the original response. We then tested for differences between predicted and observed distance at the first response, and compared this to the difference between observed distances at the first and second response. If the modelling approach outperformed assuming no movement, we would expect the former to be smaller than the latter.

To apply this regression method to the whole data set, all cases where groups responded to more than one playback were selected. A general linear model (GLM) was constructed to predict distance at the first calling bout (starting distance) using site (Budongo, Bugoma and Mabira) and track type (existing and random) as fixed factors,

distance at the last calling bout (ending distance) and time delay between the first and last calling bouts as covariates.

We used the resulting model to predict the distance of francolin groups at the start of the survey period in cases where there was a delay between the start of the first playback and the first response by birds. This assumes that movement by non-calling groups occurs at a similar rate to movement by calling groups. Although this seems a reasonable assumption, it is very difficult to test, as it requires tracking the location of groups before they have called for the first time. However, because birds tended not to move while calling (RAF pers. obs.), the effect of violating this assumption will be conservative in this case.

Adjusted and unadjusted data sets were analysed separately using the program DISTANCE (Thomas et al. 2002). Trail type (random versus cut) was entered into the model as a covariate. Observations were truncated at 200 m, and following inspection of the frequency distribution of the distances, observations were grouped into 10 intervals each of 20 m width. This eliminated all signs of heaping in the data set, producing a smooth distance histogram. Detection function models using half-normal and hazard-rate key functions were compared using Akaike's information criterion (AIC) and the results of goodness-of-fit tests, with particular attention paid to the tests near zero values, which have a large influence on resulting density estimates. The resulting detection functions were applied to the distance data to generate density estimates and their associated confidence intervals.

Results

We conducted a total of 1 104 playback surveys (Table 1). There was a response by one or more francolin groups at 239 of the sampling points, which represented a response rate of 22%. A total of 303 francolin responses was elicited from francolin groups, 94% of these from the first three playbacks, although only 23% of francolin groups responded to the first playback, and the proportion of first responses by francolin groups increased from the first to the third playback (second playback = 29%, third playback = 42%). Nearly 6% of groups first responded after the fourth and fifth playbacks that were played in order to model response times and movement of birds that responded during the first three playbacks. These additional birds were excluded from density analyses, as only three playbacks were used as part of the regular sampling protocol.

There were 164 cases where responses to two or more playbacks were given by francolin groups. These were, therefore, the cases in which movement could be detected

and modelled. Groups were significantly closer to the sound stimulus at the time of their last response compared with the time of their first response, indicating substantial attraction to the playback ($t = 4.45$, $df = 326$, $p < 0.001$). Mean time elapsed between the first and last response was 156 s ($SD = 70.8$, range 15–325 s).

Birds moved toward the sound stimulus in 153 of these 164 cases, and the average rate of movement of all groups was 0.11 m s^{-1} in the direction of the sound source ($SD = 0.16$, range 0.11 m s^{-1} away from the source to 1 m s^{-1} toward the source). Groups that first responded to the second and third playbacks were significantly closer to the observers than groups that responded to the first playback ($t = 2.19$, $df = 284$, $P < 0.03$), which suggested that they had moved toward the sound source after the first playback and before responding. The fact that some francolin groups delayed up to 3 min before responding further suggests a significant danger of overestimating densities using unadjusted distance data.

There were 31 cases of groups responding three or more times to the playback stimulus. After removing the distances at the first response from the data set, final distance explained 89% of the variation in distance at the second response. Delay between second and final response was not significant, which suggested that rate of movement did not change over time; this variable was therefore dropped from the model. To evaluate the efficacy of this regression method in predicting movement rate, this model was then used to predict distance at the first response from distance at the second response. The difference between predicted and observed distance at first response did not differ significantly from zero (one sample t -test: $t = 1.96$, $df = 30$, $P = 0.06$), whereas the difference between observed distance at first response and observed distance at second response was very different from zero ($t = 4.39$, $df = 30$, $P < 0.001$). These results indicate that our modelling protocol was accurately predicting movement of francolin groups, and that using the regression method produced a better fit to the data than simply assuming that birds had not moved at all.

All terms except track type were highly significant in the full model predicting starting distance. After dropping track type, the final model explained 78% of the variation in starting distance ($F_{4,159} = 145.23$, $P < 0.001$, adjusted $r^2 = 0.78$; Table 2). This high explanatory power partly results from the fact that start and end positions will necessarily be correlated given a limited rate of possible movement by the birds. However, the aim of the model is strictly to provide a statistical basis for predicting the initial positions of calling groups first detected after a delay, rather

Table 1: Playback surveys for Nahan's Francolin. The total number of playback surveys is given, together with the number of survey points at which one or more francolin groups responded. The total number of responding groups is given in the final column

Site	Dates	Number of survey points	Points with at least one response	Total responses
Mabira	9–31 July	363	77	107
Budongo	6–29 August	387	81	93
Bugoma	4–24 September	354	81	103
Total		1 104	239	303

Table 2: GLM predicting starting distance of francolin groups detected more than once

Variable	Type III SS	F	P
Site	0.42	5.37	0.006
Log end distance	15.69	402.58	<0.001
Time taken for movement	0.33	8.37	0.004

than to investigate general effects on movement rate. The slope of the end distance term was significantly lower than 1 (95% CI 0.71–0.87), which confirmed that francolin groups moved strongly toward the sound source. This model was used to calculate the predicted distance of each francolin group from the observer at the time of the start of the survey period. The predicted and observed distances were therefore equal only when birds responded immediately to the first playback. The resulting data set contained 286 records of responding francolin groups, together with their observed distance at their first response, and predicted distance from the observer immediately after the first playback.

DISTANCE models using half-normal key functions produced much better results than models using hazard-rate key functions. As well as having a slightly lower AIC, the models using half-normal key functions produced strong goodness-of-fit results, particularly near zero. The results were relatively insensitive to selection of different intervals for grouping data and alternative truncation options, which suggested that the final detection function chosen was giving robust results.

Using raw distance values resulted in a significantly greater estimate of the density of Nahan's Francolins than using adjusted values in the analysis (Figure 1). In two of the study areas (Budongo and Bugoma), the estimated density of francolin groups generated using adjusted distance values was outside the 95% confidence interval of the estimated density generated using unadjusted distance values, and in the third (Mabira), the 95% confidence intervals overlapped only slightly. Our data demonstrate that densities calculated using unadjusted distances will lead to a significant overestimate of population size of Nahan's Francolin for the three forests (Table 3). In total, we estimate that there are about 16 000 groups of Nahan's Francolins in Uganda (Table 3). Observed group size ranged from two to eight birds, and the mean group size for all groups seen was 2.73 (SD = 1.25). Mean group sizes were: Mabira (1.54, SD = 0.68), Bugoma (2.85, SD = 1.35), Budongo (2.30, SD = 1.02). Group size varied among the three forests (one-way ANOVA: $F_{2,153}$, $p < 0.001$), being significantly lower in Mabira than in the other two forests (Tukey *post-hoc* tests, $p < 0.001$). For sample sizes, see Table 1.

Discussion

Our data demonstrate that movement of birds toward the sound stimulus during playback surveys can lead to significant overestimation of bird densities. This has crucial conservation implications for assessing the population status of threatened species, and indicates that caution must be applied to density estimates calculated

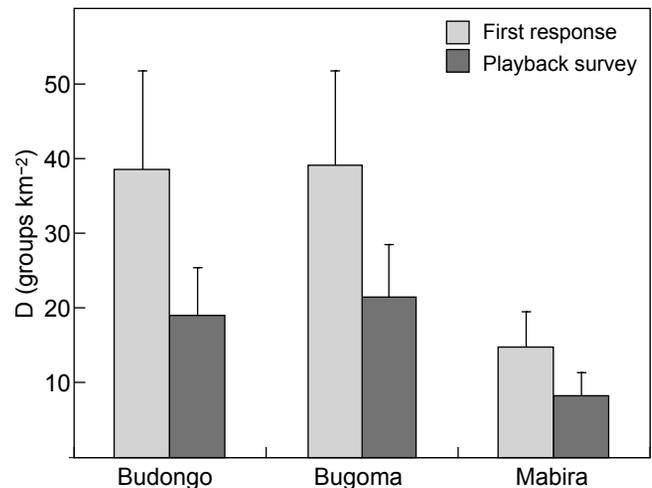


Figure 1: A comparison of density estimates for Nahan's Francolin in three Ugandan forests using the unadjusted original distance values (distance at first response; unfilled bars), and the estimated distance at the start of the survey period to account for movement toward the sound source during the playback survey (filled bars). Error bars represent 95% confidence intervals

using uncorrected distance data from playback surveys. Traditional playback methods overestimated the density of birds by a factor of nearly two. The fact that, in our study, a higher number of groups responded to the third playback than the first two exacerbates the problem of overestimation, because some birds delayed several minutes before responding and were therefore likely to move a substantial distance toward the observer before being detected.

In many situations, playback surveys are the only way realistically to sample elusive birds or those in inaccessible habitats (Glahn 1974, Fancy and Sauer 2000, Allen et al. 2004, Mulotwa et al. 2010), so constructive ways to improve their effectiveness are essential if we are to make progress in refining density estimates for these species. Our work could be extended by conducting a series of experimental playbacks in which calls of known amplitude are broadcast from specific locations and distance estimates by surveyors are compared with the true distances.

Birds that first responded to the second or third playback were significantly closer to the observer than those that responded after the first playback, strongly suggesting that these birds had commenced moving toward the observer before their first calling bout. This supports our approach of assuming movement by groups before their first calling bout was at a similar rate to movement by birds after their first calling bout. Therefore, even a survey using a single burst of playback will likely overestimate the density of animals, because not all responses will be instantaneous.

Linear regression appeared to model movement by birds well, at least in the system under study, and presents a useful way of correcting the data to account for the movement by birds. The assumption of linearity should, however, be tested when applying this method to other study systems by assessing the fit of other models to the data. Our survey work was done during the dry season in

Table 3: Comparison of density and population estimates for the three study areas using the unadjusted original distance values (distance at first response), and the adjusted distances to account for movement toward the sound source during the playback surveys. Population size estimates are calculated using mean observed group sizes for each forest. Figures in parentheses are 95% confidence intervals

Estimate	Budongo		Bugoma		Mabira	
	Adjusted	Unadjusted	Adjusted	Unadjusted	Adjusted	Unadjusted
Groups per km ²	18.95 (14.13–25.42)	38.52 (28.65–51.78)	21.52 (16.18–28.63)	38.97 (29.22–51.98)	8.30 (6.08–11.34)	14.59 (10.86–19.61)
Total number of groups	8 112 (6 049–10 878)	16 485 (12 262–22 163)	6 456 (4 853–8 589)	11 691 (8 765–15 593)	1 695 (1 241–2 316)	2 980 (2 218–4 003)
Total number of individuals	18 658 (13 913–25 019)	37 916 (28 203–50 975)	18 400 (13 831–24 479)	33 319 (24 980–44 440)	2 610 (1 911–3 567)	4 589 (3 416–6 165)

Uganda. The probability of detecting California Black Rails varied seasonally and daily depending on light conditions, day length and temperature (Spear et al. 1999, Hinojosa-Huerta et al. 2002), so there is also a case for including such variables in studies with wide geographic scope or long temporal span, particularly in seasonal environments. It seems unlikely that there is a large degree of variation in the response characteristics of equatorial forest birds, although in cases where breeding is seasonal, such variation should be investigated.

Our estimate of 8 000 groups of Nahan's Francolins in Budongo Forest accords fairly well with the estimate of 5 000–7 000 groups of birds at that site made by Sande (2001), and suggests there was relatively little change in abundance between the two surveys. Overall, we estimate that about 16 000 groups of Nahan's Francolins remain in Uganda and, by extrapolation based on observed mean group sizes for each site, about 40 000 individuals – clearly this remains an uncommon species in the country. Our surveys indicated that the Mabira population is probably not much above 2 000 groups, and that it supports the lowest density of francolins of any known site (eight groups per km²). Mabira is also under pressure from habitat destruction, with the threatened degazettement of the site having been only narrowly averted in the past few years, and it remains perhaps the most threatened site for Nahan's Francolins.

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