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Habitat variables associated with encounters of Hottentot Buttonquail *Turnix hottentottus* during flush surveys across the Fynbos biome

Alan TK Lee[1]*, Dale R Wright[2] and Brian Reeves[3]

[1] Percy FitzPatrick Institute of African Ornithology, DST-NRF Centre of Excellence, University of Cape Town, Cape Town, South Africa
[2] BirdLife South Africa, Centre for Biodiversity Conservation, Kirstenbosch Botanical Gardens, Cape Town, South Africa
[3] Eastern Cape Parks and Tourism Agency, East London, South Africa
** Corresponding author, email: alan.tk.lee@googlemail.com*

The Hottentot Buttonquail *Turnix hottentotus* is an endangered **terrestrial turnicid and is endemic to the Fynbos biome, South Africa. Due to its secretive nature and apparent rarity almost nothing is known about the species, but its range has been subject to anthropogenic modification, invasion by alien plant species and is vulnerable to climate change. To model covariates associated with the presence of Hottentot Buttonquail we undertook flush surveys across the Fynbos biome, covering 275 km. Habitat variables at encounter sites were recorded in vegetation plots, as well as locations without encounters. There was a critical number of observers needed during a flush survey in order to account for buttonquail presence, with no encounters with less than five participants. After accounting for this, we found probability of encounters decreased with increasing time-since-fire. Probability of encounters were also negatively associated with increasing percentage grass and other vegetation cover. We also found no association between percentage cover of Restionaceae plants and encounter probability, considered previously to be the best indicator of Hottentot Buttonquail presence. This information will be of use to those interested in managing habitat for this species and should inform future conservation efforts.**

Variables d'habitat associées avec la rencontre du Turnix hottentot *Turnix hottentottus* pendant les relevés de chasse dans le biome de Fynbos

Le Turnix d'Hottentot *Turnix hottentottus* est un Turnicidé terrestre en voie de disparition et est endémique au biome de Fynbos, en Afrique du Sud. En raison de sa nature discrète et de sa rareté apparente, on ne sait presque rien de l'espèce, mais son aire de répartition a été sujette à des modifications anthropiques, à l'invasion d'espèces exotiques végétales, et est vulnérable aux changements climatiques. Pour modéliser les covariables associées à la présence de Turnix d'Hottentot, nous avons effectué des relevés de chasse dans le biome de Fynbos, couvrant 275 km. Les variables d'habitat sur les sites de rencontre ont été enregistrées dans des parcelles de végétation, ainsi que dans des endroits sans rencontre. Il y avait un nombre critique d'observateurs nécessaires lors d'une enquête de chasse afin de tenir compte de la présence des Turnix, sans rencontrer moins de cinq participants. Après avoir tenu compte de cela, nous avons trouvé que la probabilité de rencontre diminuait avec l'augmentation du temps écoulé depuis le dernier feu. Cette probabilité était aussi négativement associée à l'augmentation du pourcentage de couverture herbeuse et autre couvert végétation. Nous n'avons également trouvé aucune association entre le pourcentage de couverture des plantes Restionaceae et la probabilité de rencontre, considéré comme le meilleur indicateur de la présence du Turnix d'Hottentot. Ces formations seront utiles à ceux qui s'intéressent à la gestion de l'habitat de cette espèce et devraient éclairer les futurs efforts de conservation.

Keywords: Cape floristic region, fynbos, habitat association, rare birds, Turnicidae

Online supplementary material: Supplementary information for this article is available at http://dx.doi.org/10.2989/00306525.2017.1343209

Introduction

Remarkably little is known about the Hottentot Buttonquail *Turnix hottentottus*, one of 18 species of Turnicidae (Debus and Bonan 2016). Hottentot Buttonquail is classified as Endangered by the IUCN (BirdLife International 2015) and is endemic to the Fynbos biome of South Africa (Taylor et al. 2015). The Fynbos biome is a fire-driven Mediterranean-type ecosystem dominated by proteaceous, ericaceous and restionaceous shrublands (Cowling et al. 1997). The Fynbos biome is the smallest of the six floral kingdoms in the world and is contained entirely within the political boundaries of South Africa (Cowling 1995). Conversion to agriculture, urbanisation and the invasion of a variety of alien plant types pose major conservation threats to the ecological integrity of the area (Rebelo and Siegfried

1990). The biome is threatened by climate change due to decreases in winter rainfall and increases in temperature (Klausmeyer and Shaw 2009), which together with increased alien plant biomass are leading to changes to fire regimes and intensity (Slingsby et al. 2017).

Hottentot Buttonquail is the only *Turnix* reported from the Fynbos biome, with the two other southern African Buttonquails, Common *T. sylvaticus* and Black-rumped *T. nanus*, found in the northern and eastern parts of southern Africa (Harrison et al. 1997). The only survey that has focused on the Hottentot Buttonquail was conducted in 1994 by Ryan and Hockey (1995) on the Cape Peninsula. The authors suggested it was one of the most common bird species in restionaceous fynbos 4–5 years old post-fire after conducting 6 h of flush surveys through two types of restionaceous fynbos as well as upland mixed fynbos. In the restionaceous fynbos the bird was the joint third-most commonly recorded species together with Yellow Bishop *Euplectes capensis*, whereas none were recorded from the upland mixed fynbos. The bird is usually solitary, but may be encountered in pairs (Lee 2013). It was considered to be resident and possibly sedentary (Allan and Colahan 1997), but it may be locally nomadic (Dean 2005), with probability of occurrence considered to be dependent on fires, rainfall and subsequent vegetation density (Fraser 2014).

The purpose of this study was to model the species probability of occurrence in relation to a variety of site-specific environmental variables from across the Fynbos biome. This information will be of use to those interested in managing habitat for this species, especially in the light of ongoing threats to the biome, and this species' small population size and fragmented range.

Methods

In order to determine the presence of Hottentot Buttonquail we conducted 131 'flush' surveys across the Fynbos biome from October 2015 to February 2016, with 275 km of survey lines covering a combined sample area of 802 ha (Figure 1). The flush survey was a multiple-observer team walking side-by-side and spaced ideally no more than 5 m apart. Median transect length was 1.8 km, but ranged from 0.2 to 12.3 km, depending on terrain and suitable available habitat. At least one of the authors was involved in all surveys to confirm species identification. Extensive use was made of experienced field-ranger teams supplied by the regional conservation bodies: CapeNature in the Western Cape and Eastern Cape Parks and Tourism Agency in the Eastern Cape. Any participant that flushed a bird would shout, to alert the principal authors to a bird's presence and allow multiple observers to confirm a bird identification.

While transect lines were generally randomly located preferentially across natural habitat to cover a range of potential variables, for safety reasons, survey lines were generally located away from very steep terrain (slope angle >60°). We visited areas where Hottentot Buttonquail had been previously recorded (e.g. Arabella Estate and Grootvadersbosch Nature Reserve, Western Cape), as

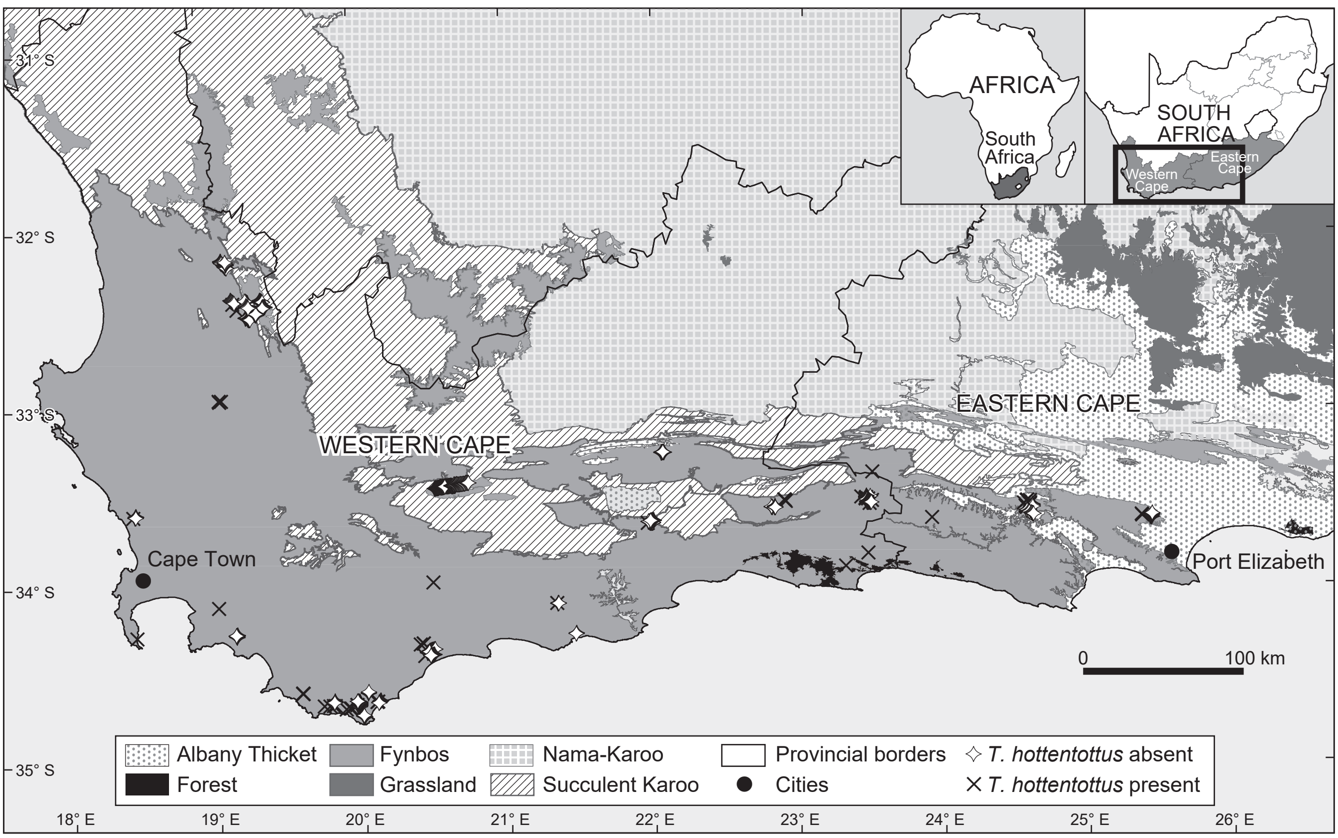

Figure 1: Map of the study area in South Africa indicating biome types (Mucina and Rutherford 2006). Locations of Hottentot Buttonquail *Turnix hottentottus* encounters are indicated, superimposed on points indicating survey lines

well as many sites where the species had not been officially recorded, with the aim of sampling representative habitat from across the entire Fynbos biome. While transects were preferentially placed through natural habitat, we noted any severe alien vegetation infestation or other disturbance as a factor of presence or absence, which we call 'modified'.

The following habitat variables were recorded from plots of approximate dimensions 10 × 10 m for each sighting, as well as every 200–400 m along the transect line where no encounters were recorded in order to model background information. Aspect was classified into one of eight classes (north, north-east etc). Slope was classified from 0° (horizontal) to 90° (perpendicular cliff); time since last fire in years was recorded based on a combination of local knowledge, fire history maps where available, or counting growth nodes on species of Proteaceae. Altitude, latitude and longitude were recorded via GPS. Percentage basal cover of vegetation, percentage soil (sand cover) and percentage rock cover were visually estimated. Of the vegetation cover we recorded cover and mean height for six very broad vegetation classes or dominant families: Proteaceae, Ericaceae, Restionaceae, Asteraceae (daisy), Poaceae (grass) and the group of all other vegetation. From these we calculated what we termed a 'heterogeneity index' based on the presence or absence of each class in a plot, which ranged from 1 (low heterogeneity, i.e. plot dominated by a single family or functional group) to 6 (high heterogeneity). The median and range of these variables are provided as supplementary information (Supplementary Table S1).

Impact of number of observers on the probability of encountering buttonquail during a flush survey

We initially investigated likelihood of encounter as a function of the number of participating observers. We examined the influence of the observer group size and area surveyed in a binomial regression, illustrated using the dplyr R package (Wickham and Francois 2014). The number of observers influenced the area covered in a survey, and as no encounters with buttonquail occurred for any surveys with fewer than five observers ($N = 42$ of 131), we deemed these surveys to be possibly unrealistic in presenting absence data for Hottentot Buttonquail. To determine if the excluded surveys were biased from those which remained, we conducted modelling (described below) on both the full and truncated data sets.

Statistical modelling of coefficients of occurrence

We tested correlations among predictor variables using Spearman's ranked correlation tests and dropped strongly correlated variables: percentage sand-cover and rock-cover in favour of vegetation cover (sand: rho = −0.41, $p < 0.01$; rock: rho = −0.61, $p < 0.01$); mean vegetation height (across all plant groups) in favour of fire (rho = 0.57, $p < 0.01$); as well as the categorical variable aspect, for which there was no significant difference in encounters between groupings (Kruskal–Wallis chi-square = 4.48, df = 6, $p = 0.612$). We then created a global model using logistic regression of probability of presence at the habitat plot level, with variables scaled and centred using the scale() function in R, as follows: presence ~ altitude + years-since-fire + veg cover + Proteaceae cover + Restionaceae cover + Ericaceae cover + grass cover + Asteraceae cover + other vegetation cover + heterogeneity + slope + modified. We calculated an average model based on a model list filtered from the global model using the dredge function in the MuMIn package (Barton 2011) in R version 3.3.3 (R Core Team 2015). We present full model-averaged coefficients with shrinkage for the models within 2 AIC of the top model (Table 1). We illustrate probability of occurrence modelled against significant predictor variables individually using dplyr (Wickham and Francois 2014). We further modelled the influence of percent vegetation cover using a loess fit using the gam R package (Hastie 2013), as this variable displayed a clear non-linear association with encounters.

Results

Covariates associated with the probability of encountering Hottentot Buttonquail

During surveys across the fynbos we obtained 37 encounters with Hottentot Buttonquail, consisting of 31 individuals and six cases of two birds. There were no

Table 1: Summary output of the average model of 47 models within 2 AIC of the top model predicting occurrence of Hottentot Buttonquail as a function of habitat variables using presence/absence data for surveys with >4 observers. Coefficient estimates for each covariate are displayed with standard error (SE), *z*-score, and *p*-values < 0.05 highlighted in bold. *N* is the number of models within the top 47 models in which the covariate was included. For comparison we also include the alternate estimates and SE (Alt est ± SE) for the non-truncated data (i.e. including surveys with <5 observers). We highlight those with coefficient results with $p < 0.05$ in bold

Covariate	Estimate	SE	*z*	*p*	*N*	Alt est ± SE
(Intercept)	−3.73	0.33	11.17	0.000	47	−4.23 ± 0.32
Grass Cover	−0.95	0.36	2.68	**0.007**	47	**−1.09 ± 0.35**
Other Veg Cover	−1.03	0.37	2.76	**0.006**	47	**−1.08 ± 0.35**
Restio Cover	−0.85	0.38	2.22	**0.026**	47	**−0.88 ± 0.36**
Years Since Fire	−1.55	0.52	2.99	**0.003**	47	**−1.45 ± 0.47**
Slope	−0.24	0.26	0.92	0.358	30	**−0.85 ± 0.35**
Erica Cover	−0.22	0.26	0.87	0.385	32	−0.40 ± 0.24
Veg Cover	−0.13	0.19	0.65	0.520	22	−0.03 ± 0.11
Modified	−5.15	477	0.01	0.991	18	−2.72 ± 323
Heterogeneity	0.08	0.17	0.51	0.607	18	0.08 ± 0.16
Daisy Cover	−0.07	0.19	0.38	0.702	14	−0.11 ± 0.21
Protea Cover	−0.05	0.19	0.28	0.777	9	−0.04 ± 0.16
Altitude	−0.00	0.05	0.07	0.947	3	−0.02 ± 0.09

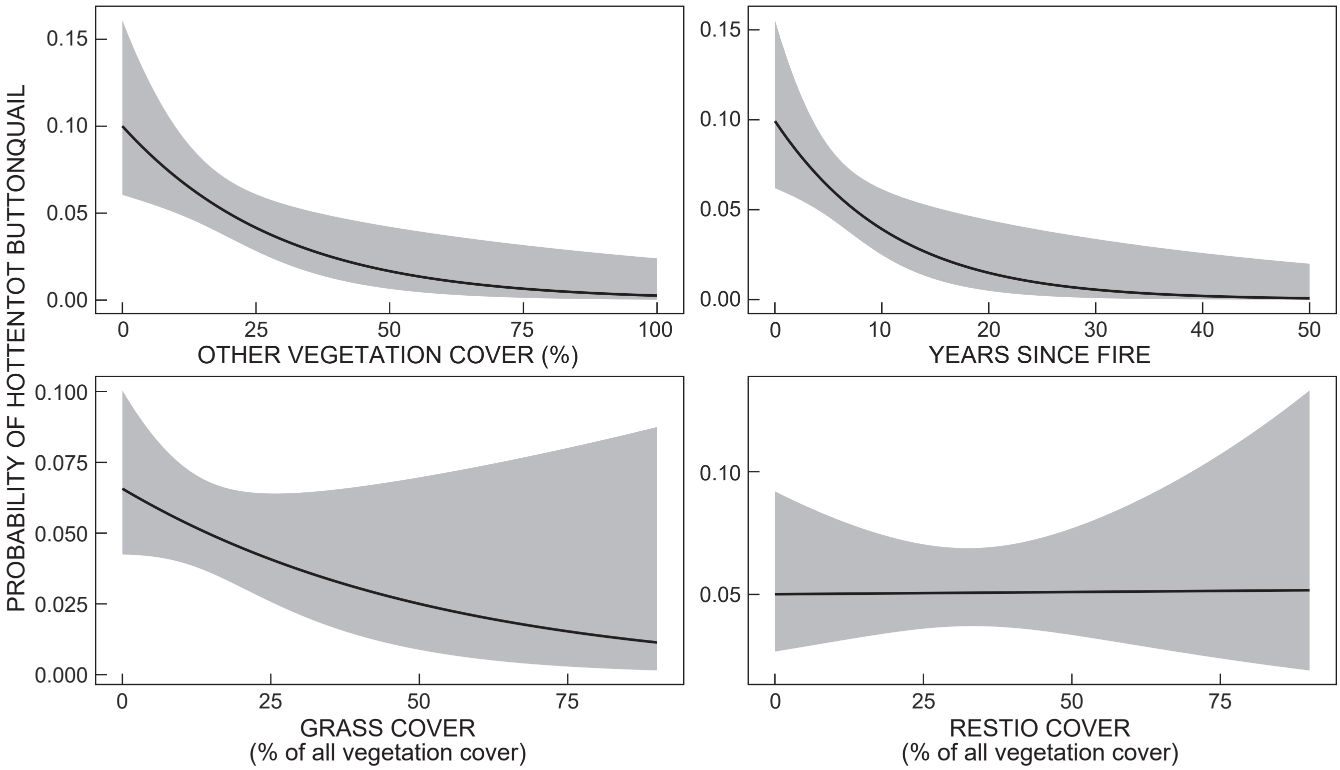

Figure 2: Relationship between environmental variables and the probability of encountering Hottentot Buttonquail from flush surveys. These were the four habitat variables with a significant relationship as determined from our modelling process. Black lines indicate logistic regression slopes, shading represents the standard error

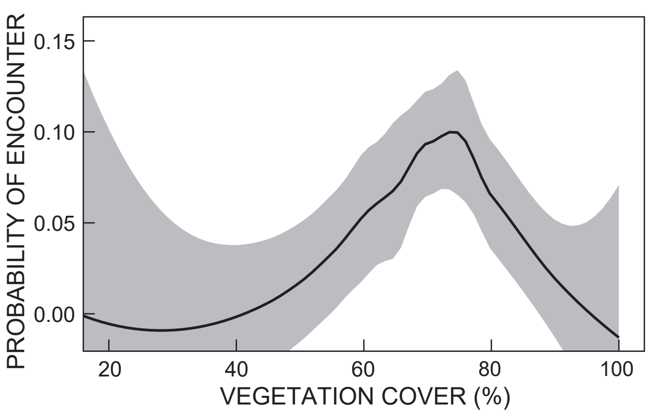

Figure 3: Relationship between percentage basal vegetation cover and the probability of encountering Hottentot Buttonquail from flush surveys illustrated using a loess smoother. Shading represents the standard error

significant positive covariates associated with buttonquail encounters in the average model (Table 1). Four variables were significantly negatively correlated with the probability of presence of encountering Hottentot Buttonquail: percentage grass, Restionaceae and other vegetation cover as percent of all vegetation cover, and time in years since last fire (Table 1, Figure 2). While probability of encounter increased with decreasing time since fire, it should be noted that there were no encounters with buttonquails in recently burnt veld (time since fire < 1 year, $n = 4$ surveys). Although percentage Restionaceae cover was a significant negative predictor of occurrence in the summary model, it was not significant if considered as the only predictor of occurrence (estimate = 0.0003 ± 0.009, $z = 0.04$, $p = 0.97$). There was reasonable explanatory power for percentage vegetation cover and probability of encounter using the loess regression ($F = 5.6$, $p = 0.001$, Npar df = 2.5), with high encounter rates at 70%, but decreasing towards 25% and 100% (Figure 3). The probability of presence of Hottentot Buttonquail was not significantly influenced by the modified score, although the association was negative and sample size of plots marked as modified was small.

Impact of number of observers on the probability of encountering buttonquail during a flush survey

There were no encounters with Hottentot Buttonquail during flush surveys with fewer than five participants (Figure 4). The number of observers was significantly positively correlated with the area covered during a survey (rho = 0.41, $t = 4.9$, $p < 0.001$, df = 121). When modelling the probability of encounter as a function of number of observers as well as area covered, while area had a strong effect (estimate = 0.14 ± 0.05, $z = 2.98$, $p = 0.003$), number of observers remained a significant covariate (estimate = 0.28 ± 0.12, z = 2.28, $p = 0.02$). In terms of the impact on the modelled covariates of Hottentot Buttonquail presence, the only significant variable included in the model not accounting for observer numbers was slope, with increasing slope having a negative impact on probability of encounter (Table 1). This indicates that more surveys were conducted on steeper

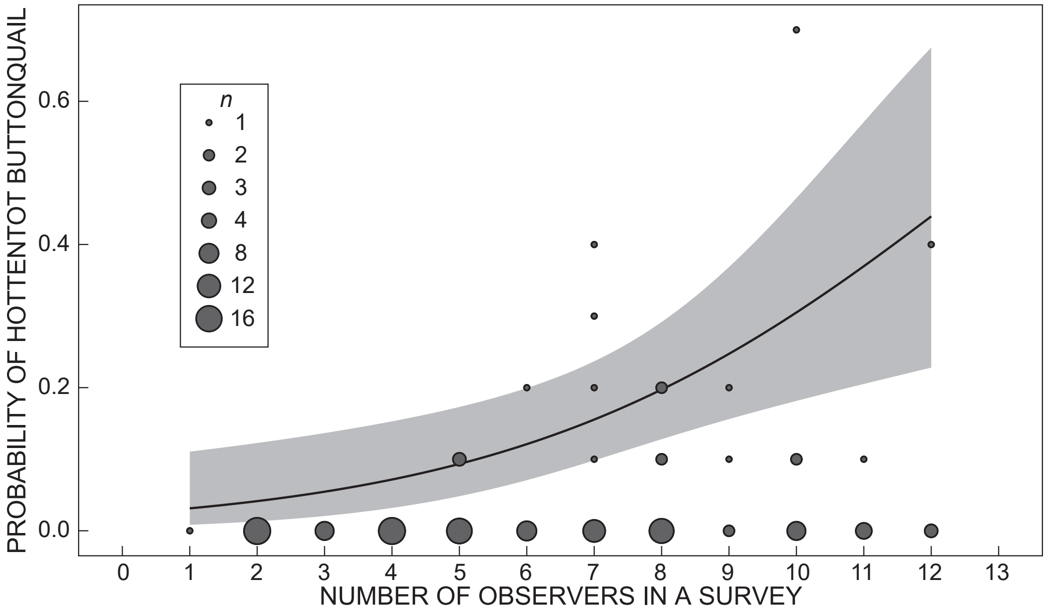

Figure 4: Probability of encountering Hottentot Buttonquail as a function of the number of participants in a flush survey, indicated by a binomial regression (black line) with associated standard error as grey shading. The number of birds encountered (divided by 10) is indicated for each group size of observers is indicated as points, with the point size weighted by the number of times the specified number of birds was recorded (*n*, i.e. point size is large across the groups for zero birds encountered, as most surveys encountered zero birds)

slopes with less than five observers, with no encounters of Hottentot Buttonquail. Whether this is due to the influence of slope on probability of occurrence, or due to a lower chance of encountering Hottentot Buttonquail as a function of smaller observer group size is unclear.

Discussion

The Hottentot Buttonquail is so rarely encountered that it was one of the most scarcely reported birds in the ongoing Southern African Bird Atlas Project (Lee 2013), and is one of the most sought-after birds in South Africa's birdwatching community (T Hardacker, BirdLife South Africa National Rarities Committee, pers. comm., 2015). Much of what is known or inferred for the species results from the brief survey on the Cape Peninsula reported by Ryan and Hockey (1995), where it was found in two types of restionaceous fynbos, leading to a pervasive assumption that restios are a good indicator of the species' possible presence. However, we found no support for a positive association between buttonquail presence and percent cover of Restionaceae. Rather, buttonquail presence was best explained by time since fire, with highest encounter rates in the interval 2–5 years. Certainly, sprouting restios and geophytes dominate early growth fynbos (Cowling et al. 1997).

Vegetation cover is also strongly linked to fire cycle, with birds absent from freshly burnt sites with low vegetation cover, but also rare or absent in old fynbos where basal cover exceeded 80%. On the one hand, a lack of vegetation implies a lack of food resources and cover for the Hottentot Buttonquail, while on the other hand, senescent fynbos in need of a fire will pose many obstacles to the movement of this terrestrially foraging species. The negative association between presence and grass cover supports our assertion that all buttonquails flushed were Hottentot Buttonquail, as the Black-rumped Buttonquail is associated with the Grassland biome (Christian 2004) in South Africa.

That Hottentot Buttonquail presence is explained by time since fire, or variables associated with fire, makes sense given that the endemic passerines of the fynbos all show different densities in relation to fire return intervals (Lee and Barnard 2015). Thus, management of habitat suitability for Hottentot Buttonquail is strongly linked to fire management. Alien plant abundance together with changes in fire regimes due to climate change pose the biggest threats to the persistence of fynbos (Slingsby et al. 2017), and hence to the survival of the Hottentot Buttonquail. Conversely, a culture of fire suppression leading to dense vegetation, especially evident in vicinity to human settlements, may well explain the apparent disappearance of Hottentot Buttonquail from the Cape Peninsula over the duration of SABAP2, prior to recent fires.

While the modified habitat covariate was not significant in our final model, it is worth noting that we encountered no buttonquail in fallow lands and indeed for any transformed landscape. Lee et al. (unpublished data) received no reports of Hottentot Buttonquail from transformed landscapes in a public call for information on the species. Agricultural landscape conversion decimates plant biodiversity, as does infestation with alien vegetation (Higgins et al. 1999). Not only were no buttonquails found in transformed lands, two survey lines with high buttonquail encounter rates crossed fallow land where none were encountered: the birds were only found in unmodified habitats. In Australia, radio-tracked Black-breasted Buttonquail *Turnix melanogaster* did not use agricultural land or young pine plantations surrounding their territories in natural habitat (Smith et al. 1998). Given limited movements and predation risks on that species, their long-term future in agricultural landscapes was described as bleak (Smyth and Pavey 2001).

In a previous survey conducted across the Fynbos biome using point count methodology, no Hottentot Buttonquail were recorded (Lee et al. 2015 supplementary information). By contrast, using flush surveys composed of teams of multiple people, we encountered 37 groups of the species, highlighting the need for a specialised survey technique in order to record presence and abundance of this terrestrial, skulking species. However, our results also suggest that the number of participants in a flush survey may be important, with increasing probability of encounter with increasing number of participants. Smaller groups not only cover a smaller area, but it is possible that smaller fronts of people may give buttonquails time to skirt the edges of the survey line, i.e. move out of the way. At the study outset, this was not realised to be an issue as we had flushed buttonquail as single observers during other field surveys. As steeper slopes were surveyed by smaller teams only, it is unclear whether the lack of detection on steep slopes is active avoidance of steep slopes by buttonquail, which is feasible given the small size and terrestrial nature of these birds where navigation of steep, rocky slopes can be imagined to be difficult, or whether birds on steep slopes were simply better at avoiding survey teams.

Our knowledge on vital aspects of the life history and biology of the Hottentot Buttonquail, as well as many other *Turnix* species, remains to be improved upon. It is possible, for instance, that dietary habits may be specialised, further restricting range and site occupancy. Movement and migrations of this species, while suspected (Blackshaw and Blackshaw 1998), remain to be confirmed and explained. Further habitat association variables should additionally be confirmed using occupancy modelling approaches, now that baseline occurrence information is available to do so.

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