Occupancy and density of a habitat specialist and a sympatric generalist songbird species in Tasmania

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Abstract Patterns of distribution and abundance of species are dependent on their particular ecological requirements. Taking specialisation into account is important for interpreting population parameters. Here, we evaluate population parameters of an endangered habitat specialist, the forty-spotted pardalote (*Pardalotus quadragintus*; dependent on white gum *Eucalyptus viminalis* in south-eastern Tasmania), and a sympatric congeneric habitat generalist, the striated pardalote (*Pardalotus striatus*). We used occupancy models to estimate occupancy of both species, and distance sampling models to estimate population density and size on North Bruny Island. Within their shared habitat (i.e. white gum forest), we also fitted hierarchical distance sampling models to estimate density in relation to fine-scale habitat features. We show that forty-spotted pardalotes only occurred in forests where white gums were present, with a mean density of 2.7 birds per hectare. The density of forty-spotted pardalotes decreased in areas with abundant small trees and trees with dead crowns, but they increased in areas where larger white gums were abundant. The striated pardalote was widespread, but where white gums were present, they occurred at 2.1 birds per hectare, compared to 0.6 birds per hectare in forests where white gums were absent. Within white gum habitat, the relative abundance of forty-spotted pardalotes and dead trees had a positive effect on the density of striated pardalotes while small trees had a negative effect. Our study reveals that although widespread, the generalist is most abundant in the limited areas of habitat suitable for the specialist, and this indicates the need of future research to look at whether this pattern of occurrence exacerbates competition in resource depleted habitats.

Key words: density, endangered species, forty-spotted pardalote, generalist species, occupancy, specialist species, striated pardalote.

INTRODUCTION

Ecological habitat breadth theory suggests that generalists have more potential habitat available to occupy than specialists due to their ability to exploit diverse resources (Futuyma & Moreno 1988). Specialisation naturally limits populations as a result of their restricted distribution and life history requirements (MacArthur 1972). Consequently, generalists are typically more widespread and common than specialists, and habitat changes often have greater impact on specialists (Jiguet *et al.* 2007), making them rarer and of higher conservation concern (Julliard *et al.* 2003; Clavel *et al.* 2010). Further, species with multiple, discrete habitat requirements may be even more vulnerable (e.g. separate feeding/breeding habitats; Biesmeijer 2006; Devictor *et al.* 2008; Webb *et al.* 2017).

Therefore, variation in habitat quality across different spatial scales has important ramifications for the distribution and abundance of specialists and generalists (Prugh *et al.* 2008; Ye *et al.* 2013).

Comparing patterns of occupancy and abundance of specialists and generalists may offer useful insights into why species occur where they do and identify important habitat features that limit their populations. This is especially important in systems where a generalist and a specialist coexist and share resources, since habitat disturbance can lead to higher competition (Auer & Martin 2013; Boström-Einarsson *et al.* 2014), and specialists are known to be more vulnerable to changes in their environment (Keinath *et al.* 2017). In this context, we use a suite of approaches to quantify and compare population parameters of two sympatric passerines: the generalist striated pardalote (*Pardalotus striatus*), and the specialist forty-spotted pardalote (*P. quadragintus*). Forty-spotted pardalotes are sedentary Tasmanian endemics that suffered severe range contraction (Threatened Species Section 2006) and are now listed as endangered (IUCN

2016), whereas striated pardalotes are widespread throughout Tasmania and Australia and therefore of least concern (IUCN 2016).

Both pardalotes are small, cavity-nesting and leaf gleaning, but forty-spotted pardalotes forage nearly exclusively on white gums (*Eucalyptus viminalis*) for arthropods, lerps (crystallized honeydew produced by psyllids) and *manna* (sugary exudates produced by white gums; Woinarski & Bulman 1985), whereas striated pardalotes exploit similar foods from several tree species (Woinarski & Rounsevell 1983). Although many Australian birds feed on *manna*, forty-spotted pardalotes are the only reported species able to mine *manna* from white gums with their elongated bill tips (Case & Edworthy 2016). Both species compete for tree cavities for nests and for foraging resources (Woinarski & Bulman 1985; Case & Edworthy 2016; Edworthy 2016). Woinarski and Rounsevell (1983) found that the occurrence of forty-spotted pardalotes was contingent on the presence of white gums, and striated pardalotes also preferred areas with this tree species. They also found that both pardalotes selected areas with more hollows and mature trees which was attributed to their breeding requirements, however, patterns of occupancy and abundance in relation to forest type have never been quantified. Thus, these ecologically similar species offer an excellent opportunity to explore habitat requirement differences between specialists and generalists.

For both pardalotes, we aimed to (i) evaluate patterns of occupancy in areas where white gums are present/absent; (ii) estimate average population density and size; and (iii) identify fine-scale habitat characteristics that might affect density within white gum forest. Based on Woinarski and Rounsevell (1983), we predicted that forty-spotted pardalotes would be restricted to forests where white gums are present and that the patterns of occupancy and abundance of striated pardalotes would be higher within white gum habitat. In white gum forest, we looked for fine-scale habitat variables related to forest maturity (e.g. hollow availability, foraging habitat) that could affect density of both species, and predicted that both pardalotes were likely to be more abundant where more mature trees were present. We also tested whether the relative abundance of one species affected the other, and predicted that since forty-spotted pardalotes are *manna* miners (i.e. can stimulate manna production; Case & Edworthy 2016), and striated pardalotes can feed on *manna* opportunistically, the abundance of forty-spotted pardalotes would have a positive effect on the density of striated pardalotes. We did not expect the abundance of striated pardalotes to affect forty-spotted pardalotes, as specialists are known to thrive in their optimal habitat. We consider our results in context of the conservation management of threatened habitat specialists living in environments degraded by anthropogenic activities.

METHODS

Study area

The study area was north Bruny Island, representing approximately a quarter of the current global distribution of the forty-spotted pardalote (Fig. 1). We used existing mapping (Brown 1986; TASVEG 3.0, DPIPWE 2013) to stratify forest type across the study area into: (i) *white gum forest* – white gums present (818.61 ha); and (ii) *other Eucalyptus forest* – white gums absent (5118.29 ha). Non-forest habitats (pasture, shrubland) were excluded (Fig. 1). We established 100 random survey sites (*n* = 50 in white gum forest, 50 in other *Eucalyptus* forest), spaced >200 m apart and >50 m from habitat polygon boundaries (to exclude potential edge effects). We ground-truthed habitat classifications of sites by checking for presence/absence of white gums within 200 m of the centroid. After ground-truthing, our final study design included 53 white gum forest sites and 47 in other *Eucalyptus* forest.

Data collection and field methods

We conducted fieldwork immediately after the breeding season. The same observer visited all sites three times, between January and May 2016 to conduct a 10-min point count. All sites were surveyed for the first time between January and February, the second visit was conducted between March and April and the third visit in May. Although part of the striated pardalote population is resident year-round (F. Alves, unpubl. data, 2015), some migrate to mainland Australia to winter (Woinarski & Rounsevell 1983). Therefore, for striated pardalotes we conducted analyses using only the two first rounds of surveys (before migration). As forty-spotted pardalotes are sedentary, all survey repeats were included in their analyses, except for hierarchical distance sampling modelling where only one round of surveys was used for both species (see below). We controlled for some of the factors that could affect detection probability (surveys were conducted in good weather conditions, minimal wind or rain, by the same observer). We built detection histories for occupancy models (Mackenzie *et al.* 2006) and also followed a Distance Sampling protocol to estimate population density and size for both pardalotes (Buckland *et al.* 2001; Thomas *et al.* 2010). For the Distance Sampling protocol, we kept track of the position and movements of birds detected during surveys to minimise the probability of double counting (Thomas *et al.* 2010). We recorded radial distance using a laser range finder. To quantify forest characteristics at each site within white gum forest, we recorded the following: (i) number of tree species within a 100 m radius; (ii) mean diameter at breast height (DBH) of the 10 nearest trees to the centroid; (iii) form of the 10 nearest trees, scored as: 1 = sapling; 2 = regrowth; 3 = advanced regrowth; 4 = mature crown; 5 = mature with major gaps in crown due to limb loss; 6 = senescent crown major gaps and major limbs dead or dying; 7 = tree alive but crown dead and mostly collapsed, dominated by epicormic growth, 8 = tree dead; (iv) number of hollows visible from the ground in the 10 nearest trees; (v) number of white gums within 20 m radius
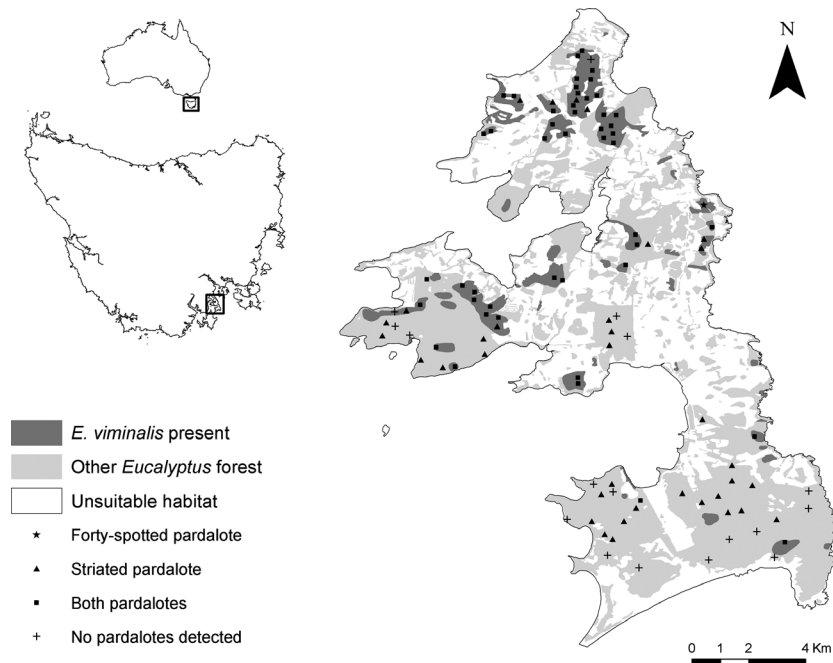
Fig. 1. Study area on North Bruny Island. Point symbols identify the species detected in each site.

with DBH: 1–15 cm; 16–30; 31–45, 46–60, 61–90, ≥91; and (vi) number of stems of all tree species (including white gums) within 20 m using the same DBH classes. These variables were chosen as they are a good surrogate for hollow availability and canopy size (Lindenmayer *et al.* 2000). We also tested the relative abundance of one species on each other.

Data analyses

Occupancy modelling

We followed Mackenzie *et al.* (2006) and fitted single-season occupancy models to estimate site occupancy (Ψ) and detection probability (P) using the package 'unmarked' in R (Fiske & Chandler 2011; R Core Team 2019). Although we controlled for some factors that affect detection (see above), to account for possible temporal variation in availability (i.e. visual and auditory cues) across the survey period, we tested the effect of survey visit (i.e. a factor with three levels: first, second and third) and time after sunrise (in minutes) on the detection parameter. For striated pardalotes, we also tested habitat type (white gum forest and other *Eucalyptus* forest) on the detection component, and we only used data from the two first visits as birds started to migrate. Finally, we tested habitat type on the occupancy parameter for both species.

Conventional distance sampling

For the analysis of population density and size, we used the software *Distance v. 7* (Thomas *et al.* 2010). We followed the exploratory steps described in Thomas *et al.* (2010) to check data behaviour and assumptions. Striated pardalotes

were detectable over greater distances (maximum recorded 120 m) than forty-spotted pardalotes (maximum 100 m). Thus, we analysed data for each species separately as recommendations for data truncation (Buckland *et al.* 2001; Thomas *et al.* 2010) would advise a different distance for each species. Since forty-spotted-pardalotes were restricted to white gum habitat the analysis for this species was restricted to this habitat. For forty-spotted pardalotes, we used exact distances collected in the field and truncated data above 60 m as detections declined at greater distances (Thomas *et al.* 2010). We fitted detection functions using ΔAIC < 2, and assessed model fit using histograms, q–q plots and also goodness of fit measures (Thomas *et al.* 2010). For striated pardalotes, we only used detections from the two first rounds of surveys (see above). We followed the same procedure as above, but we first ran an exploratory analysis by fitting a separate detection function for each habitat type. Since detection probabilities were the same among forest types (P = 0.23 in white gum forests and P = 0.23 in other *Eucalyptus* forest), we used a global detection function for the pooled data and derived separate abundance estimates for each habitat type (Buckland *et al.* 2001). Because striated pardalotes were detected at greater distances our q–q plots showed some rounding problems, so we grouped data into distance intervals (Thomas *et al.* 2010) and truncated 10% of it. The remaining steps were the same as for forty-spotted pardalotes.

Hierarchical distance sampling

In conventional distance sampling, data are pooled across sampling units to estimate average density (Buckland *et al.* 2001), which results in the loss of information at the level of sample units (Royle *et al.* 2004). Therefore, to look for effects of habitat variation within white gum forest (where

the two species co-occur) we fitted hierarchical distance sampling models (HDS) to examine local variation in density driven by habitat variation. We first assessed collinearity using Pearson's correlation matrix and removed correlated covariates (Pearson's $r > 0.7$; Dormann *et al.* 2013). We removed *tree forms 1* and *4*, and *number of hollows* which were correlated to *mean DBH*. White gums within *DBH of 16–30* and *31–45* were correlated, so instead of removing this variable we created a new one by merging them (*16–45 DBH*), white gums with a DBH from *46–60* and *61–90* were also correlated and combined (new covariate: *46–90 DBH*).

We fitted HDS models as outlined in Royle *et al.* (2004) using the package 'unmarked' in R (Fiske & Chandler 2011; R Core Team 2019). Spatial variation in abundance at each plot was treated as a Poisson random variable. These models do not allow replication of a surveyed site, so we used the survey period with most detections (i.e. enough detections to fit detection functions; Buckland *et al.* 2001; the second round for striated pardalotes and third round for forty-spotted pardalotes) to test the effect of site-specific habitat covariates on density. We also tested the relative abundance of each species on each other, using the relative abundances recorded in the survey period used for HDS analysis of each species. Data were grouped in 10 m distance intervals up to 60 m for forty-spotted pardalotes and 70 m for striated pardalotes. Histograms showed that detections dropped substantially above these distances, and therefore, they were discarded for the modelling process. We fitted null models with the three detection functions available (half-normal, uniform and hazard) and selected the one with the smallest AIC for subsequent analyses. We then standardised covariates to have mean zero (Royle *et al.* 2004), and fitted single covariate models where habitat covariates were affecting the density parameter. We then applied a stepwise procedure and fitted new models with all covariates whose models had ΔAIC < −2 when compared to the null model. Goodness of fit was evaluated using parametric bootstrap (Dixon 2002) with 1000 replicates.

RESULTS

Occupancy modelling

We recorded forty-spotted pardalotes at 47 of 53 white gum forest survey sites (naïve overall occupancy 0.89), and we did not record any in the other *Eucalyptus* forest. We had three plausible models (within 2 ΔAIC; Table 1), all of them included the effect of habitat type on occupancy and differed in modelling of detection probability, however, here we present the result of the simplest one since they had the same occupancy probabilities. The probability of occupancy was best described by habitat type (white gum or other *Eucalyptus* forest) affecting the occupancy parameter and constant detection probability (Table 1), in which occupancy in white gum forest was estimated at 0.92 (SE 0.05) and detection

probability 0.68 (0.04). In other *Eucalyptus* forest, occupancy was estimated at 0.

Striated pardalotes were recorded at 50 of 53 sites in white gum forest (naïve occupancy 0.94) and at 27 of 47 sites in other *Eucalyptus* forest (naïve occupancy 0.57). According to AIC, the best model included the effect of habitat type in both parameters (occupancy and detection). Detection probability was estimated at 0.75 in white gum forest (SE 0.04) and 0.32 (SE 0.05) in other *Eucalyptus* forest while occupancy was estimated at 0.99 in both habitat types (white gum forest: SE 0.002; other *Eucalyptus* forest: SE 0.01).

Conventional distance sampling

We recorded 167 detections of forty-spotted pardalotes across the three survey periods and the best model estimated a density of 2.7 birds per hectare in white gum forest and a population of 2229 across white gum forest on North Bruny Island (Table 2). We recorded 185 striated pardalotes across two survey periods, 44 in other *Eucalypt* forest and 141 in white gum forest. The best models estimated a density of 0.6 birds per hectare in other *Eucalypt* forest and 2.1 birds per hectare in white gum forest with a total population of 5082 across both forest types (Table 2). All models presented in Table 2 had non-significant goodness of fit test statistics (Cramer–von Mises test) and are therefore deemed plausible models (Burnham *et al.* 2004). Detections function plots are given in the supplement (Appendices S1 and S2).

Hierarchical distance sampling

In the round of survey used for the HDS analyses of forty-spotted pardalotes (i.e. third round), we had 65 detections, and the best model included a negative effect of trees in the DBH category of 1–15 cm and trees with dead crowns (tree form 7), and a positive effect of white gums from 46 to 90 cm (Appendix S3; Fig. 2). Density of forty-spotted pardalotes increased with decreasing abundance of small DBH trees (up to 3.2 birds per hectare) and trees with dead crown (up to 2.6 birds per hectare), and increased with increasing abundance of large white gums (up to 4.2 birds per hectare; Fig. 2). Both tests included in the parametric bootstrap were non-significant, suggesting the model provided adequate fit to the data (Freeman–Tukey test: $P = 0.44$; chi-square test: $P = 0.85$).

We had 87 detections of striated pardalotes in white gum forest during the round of survey used in HDS (i.e. second round). We had two plausible models (within 2 ΔAIC; Appendix S3), both fitted

Table 1. Occupancy models for forty-spotted pardalotes and striated pardalote estimated by point surveys; AICw, Akaike weight; p, detectability; Ψ, occupancy

Model	No. of parameters	Ψ	p	AIC	ΔAIC	AIC$_w$
Forty-spotted pardalote						
Ψ(habitat type); p(.)	3	0.92	0.67	212.38	0.00	0.54
Ψ(habitat type); p(survey visit)	5	0.92	0.60 (1st); 0.74 (2nd); 0.70 (3rd	213.94	1.56	0.25
Ψ(habitat type); p(mas)	4	0.92	0.75 (min); 0.59 (max)	214.32	1.94	0.21
Ψ(.); p(.)	2	0	–	311.21	98.83	0.00
Striated pardalote						
Ψ(habitat type); p(habitat type)	4	0.99 (both habitats)	0.75 (white gum); 0.32 (other forest)	246.04	0.00	1.0
Ψ(habitat type); p(survey visit)	4	–	–	260.06	14.03	0.00
Ψ(habitat type); p(.)	3	–	–	264.05	18.01	0.00
Ψ(.); p(.)	2	–	–	278.78	32.74	0.00
Ψ(habitat type); p(mas)	4	–	–	282.66	36.63	0.00

Survey visit (i.e. factor: 1st 2nd3rdand minutes after sunrise (mas) were tested in the detection probability parameter. Habitat type was tested in the occupancy parameter for both species and in the detection parameter for striated pardalotes. The detection probabilities for time after sunrise represents predictions for minimum and maximum time after sunrise surveyed. Ψ(.); p(.) denotes a constant model.

the data (Goodness of fit: Freeman–Tukey test: $P > 0.05$), and thus, we present the results of the second ranked one (Goodness of fit: Freeman–Tukey test: $P = 0.48$; chi-square test: $P = 0.85$; Appendix S3), which included the effect of three covariates. This model included a positive effect of the number of forty-spotted pardalotes and dead trees (tree form 8), and a negative effect of trees in the DBH category of 1–15 cm. Density of striated pardalotes increased with increasing abundance of forty-spotted pardalotes (up to 3.1 birds per hectare) and dead trees (up to 2.2 birds per hectare), and

increased with decreasing abundance of small DBH trees (up to 1.3 birds per hectare; Fig. 2).

DISCUSSION

We compared occurrence and abundance of an endangered habitat specialist with those of a common generalist. We confirm that the occurrence of forty-spotted pardalotes is contingent on the presence of white gums and show that although striated pardalotes occurred throughout the study area, their

Table 2. Conventional distance sampling models for forty-spotted pardalote and striated pardalote with detection function, AIC, delta AIC, probability of detection (P), Cramér–von Mises goodness of fit test (C-vM), density (D; individuals per hectare), coefficient of variation (CV) and population size (N) in the study area

Detection function + adjustment term	Habitat	AIC	ΔAIC	P (95% CI)	C-vM P-value	D (95% CI)	CV	N (95% CI)
Forty-spotted pardalote								
Uniform + cosine	White gum forest	1335.84	0.00	0.53 (0.43–0.65)	0.88	2.7 (2–3.7)	15.23	2229 (1654–3005)
Hal-normal + cosine	White gum forest	1349.78	13.94	0.56 (0.45–0.7)	0.94	2.6 (1.9–3.5)	15.52	2102 (1551–2850)
Hazard-rate + simple polynomial	White gum forest	1351.98	16.14	0.60 (0.43–0.84)	0.94	2.4 (1.6–3.6)	20.49	1968 (1320–2936)
Striated pardalote								
Half-normal + cosine	Other *Eucalyptus* forest	651.53	0.00	0.43 (0.35–0.53)	0.41	0.6 (0.41–1.04)	23.42	3390 (2142–5365)
	White gum forest					2.1 (1.6–2.7)	14.48	1692 (1273–2248)
Uniform + cosine	Other *Eucalyptus* forest	652.35	0.62	0.41 (0.36–0.48)	0.35	0.7 (0.45–1.07)	22.34	3545 (2284–5502)
	White gum forest					2.2 (1.7–2.8)	12.66	1769 (1379–2270)

abundance was highest in white gum forest. We found effects of forest characteristics on the abundance of both species and show that the relative abundance of forty-spotted pardalotes has a positive relationship with the density of striated pardalotes. Our population estimate for the forty-spotted pardalote on North Bruny Island is substantially higher than previous estimates for the entire island (e.g. 16 individuals, Brown 1986; 1920 individuals, Bryant 1997; 450 individuals, Bryant 2010), but previous estimates are not comparable due to differing methodology (i.e. previous studies did not account for detection probability). Also, our study was conducted immediately after the breeding season so it likely included recently independent juveniles. Nonetheless, we used a standardised, repeatable method for estimating population density, which provides a solid baseline against which future population estimates can be compared.

Although it is unsurprising that the occurrence of preferred habitat predicts the occurrence of a specialist species, we found effects of fine-scale habitat features on the density of forty-spotted pardalotes. Not all white gum forest in the study area was equally suitable for forty-spotted pardalotes, showing that even where white gums occur, variation in forest characteristics affects abundance. Forty-spotted pardalotes are sedentary and the negative effect of smaller trees on their abundance is likely to be related to nest site availability. Hollows suitable for wildlife in these forests are more likely to occur in larger trees (Lindenmayer *et al.* 2000; Stojanovic *et al.* 2012). The positive effect of white gum size and the negative effect of trees with dead crowns (tree form 7) are likely related to forty-spotted pardalotes' feeding strategy (i.e. foliage gleaning) and foraging behaviour of 'mining' white gum *manna* (Case & Edworthy 2016). Although the size of white gums does not
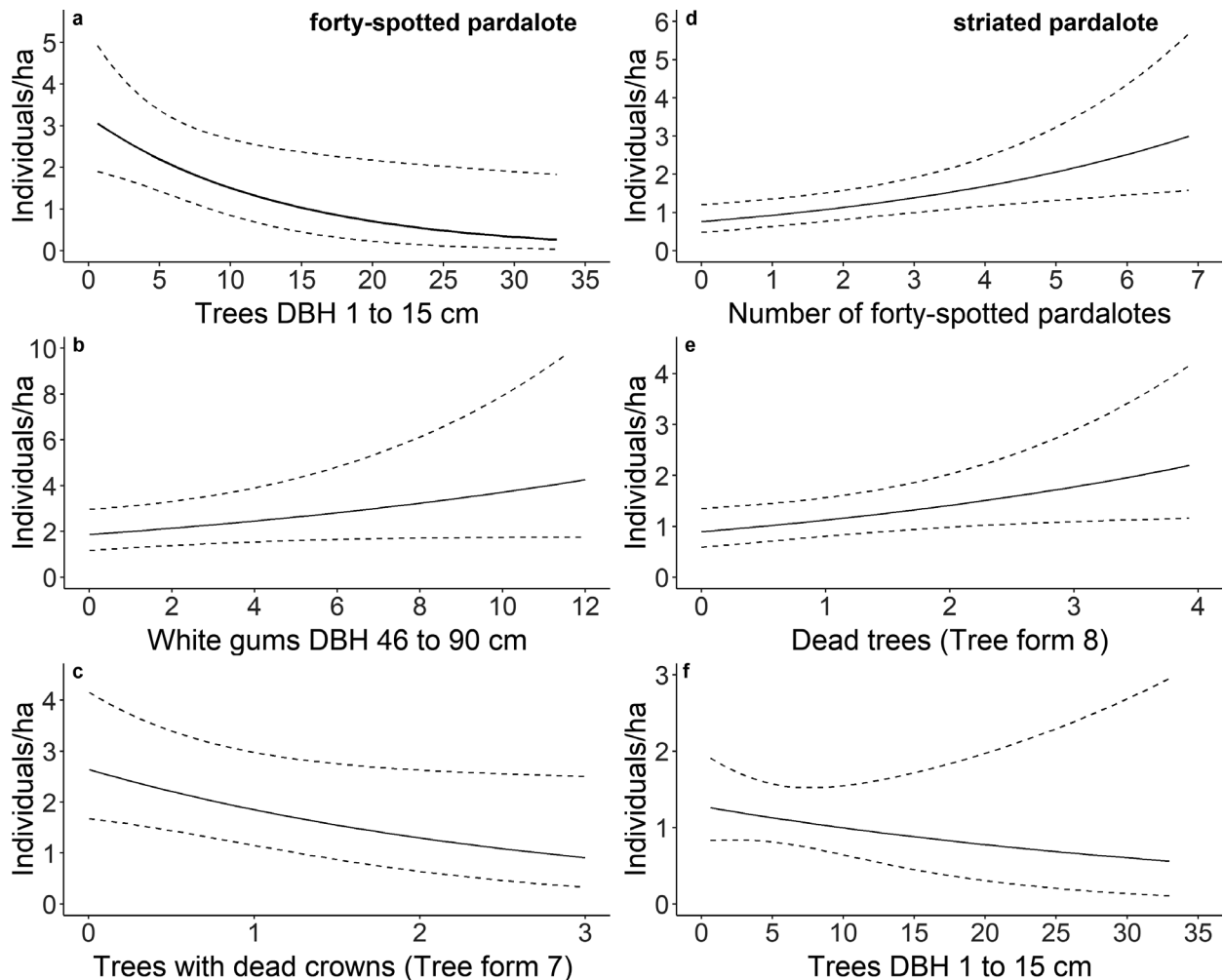
Fig. 2. Results from hierarchical distance sampling models. Plots on the left (a–c) represent density estimates for forty-spotted pardalotes and the ones on the right (d–f) for striated pardalotes. Solid lines are estimates and dashed lines confidence intervals.

have discernible effects on *manna* production (Case & Edworthy 2016), smaller trees have less canopy area than larger trees, and combined with hollow availability, may explain fine-scale patterns of abundance in forty-spotted pardalotes.

Occupancy was the same across habitat types for striated pardalotes, but density was different. They were more abundant in white gum habitat which is likely the reason we found differences in detection probability between habitats in occupancy models, since abundance can influence detection probability (McCarthy *et al.* 2013). It can also be that striateds are more vocal in the habitat they share with its competitor, and therefore more likely to be detected (i.e. more available for detection; Nichols *et al.* 2009). Increasing density of striated pardalotes with increasing number of dead trees likely also reflects hollow availability (Harper *et al.* 2005; Rayner *et al.* 2014). The higher density of striated pardalotes in white gum habitat support our prediction based on the patterns reported by Woinarski and Rounsevell (1983). The positive effect of the abundance of forty-spotted pardalotes on striated pardalotes' density could reflect high *manna* availability where forty-spotted pardalotes are more abundant, and striated pardalotes usurp food-rich territories of forty-spotted pardalotes (Case & Edworthy 2016). We are aware of the limitations of our study as we did not measure *manna* availability, but the density patterns we found reveal opportunities for future research on this matter.

The lack of an effect of striated pardalotes' abundance on forty-spotted pardalotes can be a limitation of our study, since the data available (i.e. enough detections) to model forty-spotted pardalotes' density in HDS models is from when part of the striated pardalote population had already migrated (see Methods). However, the negative effect of small stems (DBH 1–15 cm) on both species indicates further research into competitive exclusion in resource depleted habitats is warranted. Density of forty-spotted pardalotes was 0.26 individuals per hectare while striateds were 0.56 when small stems were most abundant. Specialists are known to be more sensitive to disturbances, but since pardalotes compete for resources (Woinarski & Rounsevell 1983; Edworthy 2016), it can also indicate higher competition in highly disturbed areas. Competition is a natural process, but in degraded environments, it can increase to unsustainable levels and result in the exclusion of the subordinate species (Clavel *et al.* 2010; Auer & Martin 2013; Boström-Einarsson *et al.* 2014). In their optimal habitat, specialists are usually the dominant species, but in degraded habitats they can become the subordinate one (Futuyma & Moreno 1988; Kassen 2002). Whether striated pardalotes can exclude forty-spotted pardalotes where cavities are limited (e.g. disturbed forest) is beyond the scope of this study, but it would be worth, for example, investigating whether forty-spotted pardalotes miss breeding opportunities in disturbed areas as a result of competition, and whether increased competition affects adult body condition or can result in the exclusion of forty-spotted pardalotes.

From a conservation perspective, variance in abundance of the habitat specialist with forest characteristics accords with evidence from other species that forests with large, cavity bearing trees are important for conservation. Even within preferred habitat where the food plant grows, mature forest supports more forty-spotted pardalotes than recently disturbed forest. Accounting for variation in critical habitat (e.g. tree cavities, tree DBH), features may improve population estimates of both species, with important implications for detecting changes in their abundance. These results are a step towards understanding patterns of distribution and abundance of forty-spotted pardalotes, and improving conservation planning for this endangered species.

ACKNOWLEDGEMENTS

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SUPPORTING INFORMATION

Additional supporting information may/can be found online in the supporting information tab for this article.

Appendix S1. Detection function in conventional distance sampling for forty-spotted pardalote.
Appendix S2. Detection function in conventional distance sampling for striated pardalote.
Appendix S3. Hierarchical distance sampling models fitted.