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Classifying animals into ecologically meaningful groups: A case study on woodland birds

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ABSTRACT

Ecologists often classify species into binary groupings such as woodland or non-woodland birds. However, each ecologist may apply a different classification, which might impede progress in ecology and conservation by precluding direct comparison between studies. This study describes and tests a method for deriving empirically-based, ecologically-relevant species groups, using Australian woodland birds as a case study. A Bayesian hierarchical model investigates how vegetation and species traits drive birds' preference for woodland vegetation, characterised by low density trees with an open canopy structure. Birds are then classified according to their affinity to areas with high tree cover and woodland vegetation. Interestingly, no traits are strongly associated with species occurrence in woodland habitats, but occurrence in open country and forests differ depending on dispersal ability and foraging habits. Our results suggest that Australian woodland birds may be united by their avoidance of both sparsely-treed and densely-treed habitat, rather than by shared traits.

Classifying species according to our groupings provides results consistent with literature on how woodland birds respond to clearing, grazing and urbanisation. Thus, our model is consistent with current ecological understanding regarding woodland birds; it also provides more nuanced inference across 'closed-woodland', 'open-woodland', 'forest' and 'open country' groups. We propose that our modelling approach could be used to classify species for other locations and taxa, providing transparent, ecologically-relevant animal groupings.

1. Introduction

Destruction and degradation of suitable habitat is thought to threaten woodland birds worldwide (Gregory et al., 2007; Rayner et al., 2014) and, as a result, considerable resources are spent on both managing and monitoring these bird assemblages (Birdlife Australia, 2015; Douglas and Fox, 2015; EBCC, 2014; Forestry Commission England, 2009; Ingwersen and Tzaros, 2011). However, decisions about how to manage woodland birds are complicated by conflicting evidence about the relationship between woodland birds and their habitat, and the nature and magnitude of any decline in woodland birds (Rayner et al., 2014). For instance, there is disagreement about how Australian woodland birds respond to vegetation extent (Mac Nally and Horrocks, 2002; Major et al., 2001) and fragmentation (Amos et al., 2013; Radford et al., 2005). This disagreement could be attributed to regional composition differences (Polyakov et al., 2013), or differences in the temporal (Yen et al., 2011) or spatial scale (Lindenmayer et al., 2010) of sampling. However, it could also reflect underlying disagreement about exactly what constitutes a 'woodland bird'.

Fraser et al. (2017) demonstrate that inconsistency in classifying species as 'woodland birds' can change the direction and magnitude of trends in indices of 'woodland bird' prevalence, even when the data and analyses are the same. Inconsistent classification of woodland birds persists for three main reasons.

1. Classification of vegetation can be inconsistent (Bruelheide and Chytrý, 2000; Čarni et al., 2011; de Cáceres and Wiser, 2012). In Australia, botanists typically distinguish between vegetation types according to the canopy cover of the vegetation's tallest (dominant) strata (Specht, 1970). In this context, vegetation is classified as 'woodland' if it has a trees over 10 m tall and a foliage projective cover < 30%. Vegetation is classified as 'forest' if it has trees over 10 m tall and a foliage projective cover > 30%. However, bird researchers don't always subscribe to these classifications, often not assessing the structure of the vegetation, and may classify habitat based on coarse scale maps or on the presence of trees (Fraser et al., 2015).
2. Habitat preference is a continuum from species that only occur in

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one habitat type to species that are equally prevalent in several habitats. Some species may be easy to classify but many are difficult to reliably assign to a single category (Regan et al., 2002). Classification imprecisely simplifies the habitat preference continuum that depends on a range of different factors, including where and for how long the species occurs in other habitats, whether it depends on woodlands for critical life stages, and so on.

3. There are no dedicated species lists or guidelines to assist researchers and managers when determining which species they should classify as woodland birds. In the absence of such guidance, researchers idiosyncratically classify woodland birds, and have variously considered: any species that occurs in a woodland; any species that is more common in woodlands than other habitats; or species that possess particular life history traits that mean they depend on woodlands (e.g. nesting and foraging requirements) (Fraser et al., 2015).

This spectrum of classification schemes means that researchers classify woodland birds inconsistently (Fraser et al., 2017, 2015). Inconsistent classification creates a barrier to understanding the ecology of, and managing woodland birds. There are three possible solutions to this problem: study trends in all bird species individually; study trends in all birds within woodland habitats; and classify bird species into transparent and reliable categories that make ecological sense.

Studying species individually is appealing in that it avoids deconstructing the continuum of habitat preference and therefore preserves the unique relationship of different species to their environment. Many studies take this approach by studying individual species and providing fine-scale assessments of that species' response to certain drivers. However, this kind of analysis provides information that is too detailed to answer some broad-scale, community-level questions. For example, studying trends of multiple individual species might find that some species were increasing and others decreasing (e.g. Reid, 1999), but evaluating shared patterns between species might be difficult (e.g., landscape-wide declines in a group of species sharing the same habitat).

Studying all bird species occurring within a particular habitat type similarly avoids the ambiguity of dividing species into groups based on their habitat preferences. In the case of woodland birds, this makes intuitive sense because the overriding concern about these species relates to the destruction of woodland habitat (Ford, 2011a, 2011b; Haslem and Bennett, 2008; Radford and Bennett, 2007). Some researchers conduct their studies on this basis (Fraser et al., 2015) but the approach does not account for landscape-scale changes in bird prevalence caused by habitat destruction. For example, consider a landscape with 50 patches of woodland each with an average of 10 bird species: if half of these patches are cleared but the remaining 25 have the same average bird richness, a study that is only conducted on birds in woodland habitat would not detect a decline.

Grouping species together can discern broader scale responses. If species are grouped according to their habitat preference, it is possible to investigate whether species that prefer a particular habitat (e.g. woodlands) are more likely to be in decline compared to species with different habitat preferences. This can be useful for multi-species conservation efforts because it identifies a group of vulnerable species and the habitat types that could be targeted for protection or management. Further, the process of delineating a faunal group can facilitate its protection. For example, identifying an Australian 'woodland bird' community has allowed researchers to apply for Federal protection for the whole group under the *Environment Protection and Biodiversity Conservation Act 1999* (HF pers. obs.). However, as established above, it is important that these groups are identified transparently, based on sound ecological theory.

In this study, we aim to develop a definition of woodland birds that provides a consistent basis for understanding woodland bird ecology, monitoring and conservation. We explore the definition of 'woodland bird' by examining the relationship between species traits and relative occurrence in woodlands and other habitat types. By considering traits and relative occurrence of birds, we hope to identify a list of bird species that prefer woodland habitats and are thus likely to be threatened by the destruction and degradation of woodlands in Australia (Bradshaw, 2012; Ford, 2011a, 2011b). We use a hierarchical model to examine which species demonstrate a preference for woodlands, which traits are associated with a preference for woodland vegetation, and how these change depending on study regions and how 'woodland' vegetation is defined. We aim to understand the traits associated with birds' preference for woodland habitats and develop a justifiable and objective classification of woodland birds. We demonstrate the application of this method for an Australian case study, but this approach has broad relevance to other regions and taxa. For example, woodland, farmland and generalist bird groups are inconsistently classified across Europe (Fraser et al., 2017). This inconsistent classification can inhibit the acquisition of important ecological knowledge by introducing uncertain terminology and precluding direct comparison between studies (Herrando-Perez et al., 2014). The approach used in this article could be applied to other inconsistently classified groups to provide scientific, objective classification schemes.

2. Methods

We compiled information on the occurrence of all Australian bird species (excluding waterbirds) and their nesting, foraging and dispersal traits, as well as the distribution of 'woodlands' as determined using three different definitions. We used these data to fit a hierarchical model of species occurrence (see Pollock et al., 2012) in which the relationship between species occurrence and vegetation is mediated by species traits. Based on the results of this model, we developed a classification in which species are grouped according to habitat preference. Finally, we applied our classification to three existing woodland bird case studies to examine how the inference based on our classifications compared with and added to the original findings of the case studies. Each of these aspects of our methods is described below.

2.1. Hierarchical models

We used hierarchical generalised linear models in R version 3.3.3 (R Core Development Team, 2017) to examine the variables correlated with woodland occupancy in four datasets; one for the whole of Australia and one for each of the three ecoregions in which woodland vegetation occurs - ecoregion 4, *temperate broadleaf and mixed forests*; ecoregion 7, *tropical and subtropical grasslands, savannas and shrublands*; and ecoregion 12, *Mediterranean forests, woodlands and shrublands* (Fig. 1). These statistical models suit datasets with a hierarchical structure, partitioning explained and unexplained variation between different levels of a dataset (Gelman and Hill, 2007). Separate ecoregion analyses were conducted to account for regional differences in woodland bird species composition at this scale.

We primarily aimed to investigate birds' preference for woodland vegetation, and how the strength and nature of that preference is mediated by species' traits (full model code available in Appendix 1). For each of the four datasets, we modelled the observed presence or absence Y_{ij} of each species i (number of species = 458, 298, 308, and 234 respectively for Australia, ecoregion 4, ecoregion 7 and ecoregion 12) at each site j (number of bird sites = 5891, 2640, 632, and 1314 respectively) as a random sample from a Bernoulli distribution:

$$Y_{i,j} \sim Bernoulli(p_{i,j})$$

where $p_{i,j}$ is the predicted probability that species i is present at site j. The logit of the predicted probability $p_{i,j}$ is a species-specific function of woodland preference, which is comprised of an association with 'woodland' habitat (w, the percentage of land within a 500 m radius of the survey site that is supports 'woodland' vegetation according to the