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Tests of predictions associated with temporal changes in Australian bird populations

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ABSTRACT

Global biodiversity loss is the cumulative result of local species declines. To combat biodiversity loss, detailed information on the temporal trends of at-risk species at local scales is needed. Here we report the results of a 13-year study of temporal change in bird occupancy in one of the most heavily modified biomes worldwide; the temperate woodlands of south-eastern Australia. We sought to determine if temporal changes in bird species were different between three broad native vegetation types (old-growth woodland, regrowth woodland and restoration plantings) and between species traits (body size, migratory status, rarity, woodland dependency, or diet). We found evidence of decline for over a quarter of all bird species for which we had sufficient data for detailed analysis (30 out of 108 species). In contrast, only 14 species increased significantly. Temporal change of birds was linked to life-history attributes, with patterns often being habitat-dependent. Nectarivores and large-bodied birds declined across all vegetation types, whereas small-bodied species increased, particularly in restoration plantings. Contrasting with patterns documented elsewhere, resident but not migratory species declined, with this trend strongest in restoration plantings. Finally, our analyses showed that, as a group, common birds tended to decline whereas rare birds tended to increase, with effects for both most pronounced in restoration plantings. Our results highlight the benefit of targeted restoration planting for some species, but also demonstrate that many common species that have long-persisted in human-dominated landscapes are experiencing severe declines.

1. Introduction

The earth is facing a major global extinction crisis with significant species losses forecast for many groups of biota (Pimm et al., 2014; Ceballos et al., 2017). For example, data from the (IUCN, 2016) suggest that 13% of the world's bird species might be facing extinction in the next 50 years (Tilman et al., 2017). Global patterns of species extinction are, of course, underpinned by local and regional trends in populations (e.g. Sanderson et al., 2006; Inger et al., 2015), and detailed temporal studies of local and regional species are essential to understand broader biodiversity changes. Such information is also critical to help better determine those species in need of conservation interventions (Muir, 2010) and, in turn, guide associated investments in appropriate land use management such as landscape restoration (Crouzeilles et al., 2016) or expanded reservation (Pringle, 2017).

Globally, landscapes converted to agricultural land uses have suffered significant losses of biodiversity (Tilman et al., 2017), including birds. The effects of agriculture on biodiversity has been particularly profound in Australia (Williams and Price, 2011) with Australian bird biota under considerable pressure (Ford, 2011). Detailed long-term studies are required to determine which species are declining and/or are under threat in agriculture-dominated environments. Yet, there are relatively few large-scale, long-term studies within the vast majority of Australian agro-ecosystems that encompass many species (Lindenmayer et al., 2014). This shortfall inhibits examination of patterns of temporal change in Australian avifauna, thus limiting our ability to identify species declines, or conversely, examples of species recovery.

Here we report the results of a 13-year time series study of temporal

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change in bird populations within the endangered temperate box gum grassy woodlands of south-eastern Australia. This is an agriculture-dominated biome containing one of the most heavily modified natural ecosystems globally, with > 85% cleared or altered to create grazing pastures and croplands for agriculture (Benson, 2008). Yet, it maintains high biodiversity value supporting over 170 bird species including > 20 of conservation concern (Lindenmayer et al., 2016b). There are long-held concerns about the status of Australia's woodland birds (Ford, 2011) due, in part, to substantial historical and ongoing changes to their habitat. Extensive revegetation efforts through restoration plantings (Lindenmayer et al., 2016a), as well as natural regeneration (Sato et al., 2016), have been among the management responses to past losses of woodland cover. Native vegetation cover in the Australian temperate woodland belt is now comprised of three broad structural kinds of vegetation – old-growth woodlands, naturally regenerated regrowth woodland, and restoration plantings. These kinds of vegetation are spatiotemporally dynamic, exhibit marked differences in structure (Ikin et al., 2015) and represent different kinds of habitat for distinct assemblages of birds (Lindenmayer et al., 2012a). On this basis, one of the objectives of this investigation was to compare and contrast temporal changes in bird species in these three broad structural vegetation types.

There is an increasing body of work relating patterns of landscape change to the functional traits of species (Barnagaud et al., 2014). Some of this work has revealed that taxa with particular kinds of attributes will respond more or less favourably over time to landscape change in human-modified landscapes (e.g. Newbold et al., 2013; Lindenmayer et al., 2015). We therefore tested a series of predictions about what life-history traits of species were associated with temporal changes in birds. Specifically, we tested the following five predictions:

Prediction 1. *That large-bodied species are more likely to decline than small-bodied species.* Several studies elsewhere around the world have indicated that large-bodied species are more extinction prone than small-bodied species in human-modified environments (e.g. Haddad et al., 2015; Tilman et al., 2017). However, elsewhere in Australian woodlands, large-bodied birds are more strongly associated with heavily modified and degraded agricultural landscapes (Lindenmayer et al., 2012b) with several studies in Australia suggesting that many birds of conservation concern are small-bodied taxa (Reid, 1999; Montague-Drake et al., 2009). On this basis, we tested whether the temporal patterns in birds of different body size in our long-term study were consistent with global patterns.

Prediction 2. *That migratory species are more likely to decline than resident species.* Several studies have found that migratory species are at risk of decline and extinction due to a range of factors including habitat loss (including along migration routes), climate change, and hunting (Runge et al., 2015; Gilroy et al., 2016). By testing this prediction, we sought to determine if the temporal patterns we observed were broadly consistent with those documented in other parts of the world.

Prediction 3. *That rare species are more likely to decline than common species*. Many studies of extinction proneness suggest that rare species are at particular risk of decline (reviewed by (reviewed by Lindenmayer and Fischer, 2006)) in part due to small population sizes but also because they are often habitat specialists disadvantaged by human-induced landscape change (Colles et al., 2009). However, recent work in Europe found the opposite effect with more common species undergoing declines (Inger et al., 2015). Given this, we tested whether the patterns of temporal change we observed mirrored those quantified elsewhere such as in Europe.

We also tested a further two predictions that relate specifically to Australian temperate woodlands and particular kinds of bird species in those environments.

Prediction 4. *That insectivores are more likely to decline than other dietary groups*. Widespread land clearing associated with agricultural development in the temperate woodland ecosystems of south-eastern Australia has been associated with changes in insect populations and communities (Gibb and Cunningham, 2010; Barton et al., 2016). Many of the bird species in temperate woodland ecosystems are insectivores (Higgins, 1991–2006) and on this basis, insectivorous birds as a distinct dietary group may also be subject to greater levels of change relative to birds in other broad dietary categories (see Lindenmayer et al., 2012b). We therefore sought to determine if there were relationships between diet and temporal patterns of change in birds and test the prediction that insectivores would be more susceptible to decline than species that consume other kinds of food.

Prediction 5: *That woodland bird species are more likely to decline than open-country species*. Land-clearing removed large areas of temperate woodland vegetation leaving remnant woodland patches and "open-country" cleared paddocks and croplands which now comprise 70–85% of the land area in this region (Cunningham et al., 2014). The terrestrial bird species inhabiting our study region can be broadly classified as being woodland associated or open-country associated (i.e. not associated with woodland). Given the predominance of cleared areas in our study, we predicted a temporal decline in woodland-associated species and an increase in open-country species. Earlier work in a comparable landscape made long-term predictions of bird occurrence based on the availability of woodland versus cleared pasture environments and habitat selection for open-country and woodland habitats (Fischer et al., 2010). This study provided an opportunity to test those earlier predictions.

2. Methods

2.1. Study area

Our study region was an 18,000 km^2 agricultural area within the South-west Slopes region of New South Wales, south-eastern Australia (Fig. 1). The South-west Slopes region was formerly dominated by temperate native woodland, but has been cleared of an estimated 85% of its original cover to facilitate livestock grazing and cereal cropping (Benson, 2008). In response to conservation concerns, the region has been the target of major restoration planting programs (Cunningham et al., 2014). There has also been significant natural regeneration of temperate woodlands over the past 10 years in our study region (Sato et al., 2016). Thus, there are three broad structural kinds of woodland vegetation cover: actively replanted or restored woodland (termed restoration plantings), naturally regenerated woodland (termed regrowth woodland), and old-growth woodland. Our study comprised 203 sites, including 65 restoration plantings, 66 patches of regrowth woodland, and 72 patches of old-growth woodland. Importantly, different assemblages of birds are associated with these different kinds of woodland habitats (Lindenmayer et al., 2012a), and it was therefore appropriate to explore temporal trends in relation to these three broad kinds of vegetation cover.

Restoration plantings were areas of planted native vegetation characterized by a mix of local endemic and exotic ground cover, understorey and overstorey plant species. Woody plants were typically spaced 2 m apart, but there was not a standard set of spacing and plant species composition protocols applied in revegetation efforts. All restoration plantings were at least seven years old at the start of this investigation in 2002, and many were 10–20 years old. Restoration plantings were established to mitigate problems associated with soil erosion and/or salinity, and provide on-farm habitat for wildlife (Lindenmayer et al., 2016a). Regrowth woodland refers to existing living trees recovering after disturbance by fire, clearing or both; or regeneration of trees from seeds germinating after being dropped by overstorey trees. Old-growth woodland was dominated by large old scattered trees was typically 200 or more years old.

For the analyses reported here, we focused on a size range of patches of old-growth woodland, regrowth woodland, and restoration plantings that were broadly similar to avoid the potential for confounding between patch size and vegetation type. Within-group variability in patch attributes (size, shape, aspect etc.) exceeded between