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# Old growth, regrowth, and planted woodland provide complementary habitat for threatened woodland birds on farms

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ABSTRACT

A central challenge for threatened species conservation in agricultural landscapes is to understand the relative contributions of old growth, regrowth, and planted woodland to species persistence. We offer a new perspective into solving this problem by using a systematic conservation planning approach to integrate spatial biodiversity and economic information with patch complementarity. We applied this to an eight-year study of woodland birds vulnerable to extinction across an extensive agricultural region of Australia. We used regression and ordination analyses to show that species were more likely to occur in regrowth and old growth woodland patches compared with plantings. We then set objectives of finding sets of complementary patches for supporting species across the landscape, and explored biodiversity trade-offs resulting from production- or cost-focused objectives. We found that species persistence could be achieved only through sets of patches containing all patch types (old growth, regrowth, plantings). Scenarios that selected sets of patches irrespective of patch type maximized species occurrence over time for the lowest combined area and establishment costs. Patch sets had a higher proportion of plantings for the objective of minimizing area, but a more equal proportion of patch types for the objective of minimizing cost. Our findings demonstrate what the relative composition of old growth, regrowth, and plantings should be when considering vegetation management interventions for threatened species conservation. Government policy and associated funding aimed at improving biodiversity conservation in agricultural landscapes needs to promote both regrowth woodland and revegetation planting strategies in addition to old growth woodland protection.

## 1. Introduction

As the world's population rises and concerns over food security increase (Godfray et al., 2010), conservation biologists are debating how best to reconcile trade-offs between food production and environmental sustainability (Foley et al., 2011; McShane et al., 2011; Tilman et al., 2011; Phalan et al., 2016). Concurrently, there have been worldwide efforts to restore degraded ecosystems for biodiversity conservation and environmental resilience (Menz et al., 2013). International targets include the restoration of 150 million ha of degraded lands (Rio + 20, UNCSD, 2012) and 15% of degraded ecosystems (Aichi Biodiversity Target 15, CBD COP, 2010). Much of this restoration will occur on agricultural lands, which account for ~35% of the world's land surface (Foley et al., 2007) and which are one of the major drivers of biodiversity loss, with agricultural expansion and intensification imperiling over 60% of threatened and near-threatened species in the IUCN Red List of Threatened Species (Maxwell et al., 2016).

In addition to the retention and better management of remnant old growth vegetation, restoration of woodland on agricultural land falls into two broad categories: (i) regrowth, where trees have been allowed to regenerate or colonize following land abandonment, and (ii) revegetation plantings, where trees have been deliberately planted to form new patches of woodland (Rey Benayas et al., 2008). Due to differences in design and management, these alternative restoration strategies often have dissimilar native vegetation structure and composition, to each other and to old growth woodland (Munro et al., 2009;

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Morrison and Lindell, 2011; Lindenmayer et al., 2012; Fuentes-Montemayor et al., 2015; Crouzeilles et al., 2016). Studies focused on individual patches have shown that old growth, regrowth, and planted vegetation provide habitat for distinct suites of species and are variable in species richness and abundance (e.g. Posa and Sodhi, 2006; Michael et al., 2011; Bruton et al., 2013; Gould et al., 2013). These findings suggest that a combination of old growth, regrowth, and planted woodland is needed to create wildlife-friendly landscapes that maximize the number of species persisting in agricultural areas (Lindenmayer et al., 2012).

Yet, embracing this conservation challenge requires that land management moves beyond a focus on patch-scale habitat values to consider landscape and regional scales (Thomson et al., 2009; Crouzeilles et al., 2015; Ikin et al., 2016a). Restoration can have variable effectiveness, and does not always lead to the reestablishment of the community that was present prior to disturbance (Lindenmayer et al., 2008; Breeuwer et al., 2009; Mortelliti et al., 2016; Német et al., 2016). Because of this, land managers wanting to undertake conservation activities in the landscape have no guidance about whether it might be better to continue managing restored patches where costs have already been incurred (even if that means investing in patches that are not recovering - the “sunk cost” effect (Arkes and Blumer, 1985)), or to focus more on old growth patches where minimal costs have been incurred (and which may represent intact, undisturbed native vegetation (Watson et al., 2009)). Effective landscape-scale restoration is hindered because a fundamental question remains unresolved: how does different restored woodland (i.e. regrowth or plantings), in comparison and combination with old growth woodland, contribute to species occurrence in the landscape over time?

We address this important knowledge gap with a study of woodland birds vulnerable to extinction (hereafter, “threatened”) within a large agricultural region of southeastern Australia. Although common species are important for functioning ecosystems (Winfree et al., 2015) and justify conservation attention in themselves (Gaston and Fuller, 2008), we focus on threatened species because it is this group that land managers are legally bound to consider when undertaking activities. We used data from five breeding seasons between 2006 and 2013, and explicitly incorporated temporal dynamics in species occurrences over the five survey years. Similar to plant and animal communities in many disturbed landscapes (Grantham et al., 2011; Runge et al., 2014), woodland birds in our study region vary in their occurrence between years (Lindenmayer and Cunningham, 2011; Tulloch et al., 2016). Only by deliberately accounting for temporal dynamics and considering the conservation value of patches at a landscape-scale can the importance of old growth, regrowth, and planted woodland for supporting species occurrence over time be accurately compared.

First, we asked: In comparison to old growth woodland, how well do regrowth or plantings support the occurrence of threatened woodland birds over time? In an earlier study of the full suite of woodland birds found in the region, Lindenmayer et al. (2012) found that: (i) regrowth and plantings supported distinct species assemblages in comparison to each other and old growth woodland, (ii) many species were observed significantly more often in regrowth and plantings compared with old growth woodland, but (iii) species richness was similar between the three patch types. Although this earlier study was not focused on threatened species and occurred over a different time frame, we expected to find similar patterns in our current study.

Second, we asked: What is the most complementary set of old growth, regrowth, and planted woodland needed to support the occurrence of threatened woodland birds over time? Complementarity, in this context, is the concept that old growth, regrowth, and plantings enhance bird communities through contributing different features (e.g. availability of food and nesting resources) to the landscape (Chadès et al., 2015). The concept underpins systematic conservation planning approaches to locating and designing cost-effective protected areas that represent biodiversity and maintain species persistence (Margules and Pressey, 2000). Increasingly, systematic conservation planning approaches have been applied in the field of restoration, including the identification of high-priority areas to restore (e.g. Tambosi et al., 2014; Yoshioka et al., 2014; Jellinek, 2017). Instead of locating areas to restore, we used the concept of complementarity to consider alternative objectives that choose from old growth, regrowth, and planted woodland patches in agricultural land to find the best set of patches that maintain threatened woodland bird occurrence over time. Our first objective – to minimize the combined area of the set of patches – reflects the reduced value that vegetated areas may have for agricultural production and a goal of maximizing land available for food production (House et al., 2008). Our second objective – to minimize the establishment cost of the complementary set of patches – reflects the high cost of restoration and the goal of maximizing efficient spending of public funds (Menz et al., 2013). By seeking to minimize area or cost in favor of farm production or smaller restoration budgets, both objectives could lead to trade-offs in terms of reducing threatened species occurrences in selected patches. We explored the likely consequences of trading off biodiversity to benefit production or to minimize a restoration budget using scenarios of increasing budgets and area selected.

Given that species-rich individual patches may not necessarily contribute to landscape-scale diversity (Ikin et al., 2016a), we expected that species occurrence and richness in a given patch would not necessarily predict how the patch contributes to complementarity between old growth, regrowth, and planted woodland. As such, our novel evaluation of complementarity between woodland patches provides a new perspective to inform how best to invest in landscape-scale vegetation management to achieve wildlife-friendly farms and threatened species conservation.

## 2. Methods

### 2.1. Data collection

We conducted our study within a 150 km × 120 km area in the South West Slopes Bioregion of New South Wales, Australia (Fig. 1). This region is part of the wheat-sheep belt of southeastern Australia and is characterized by cropping and livestock grazing. Farms typically have

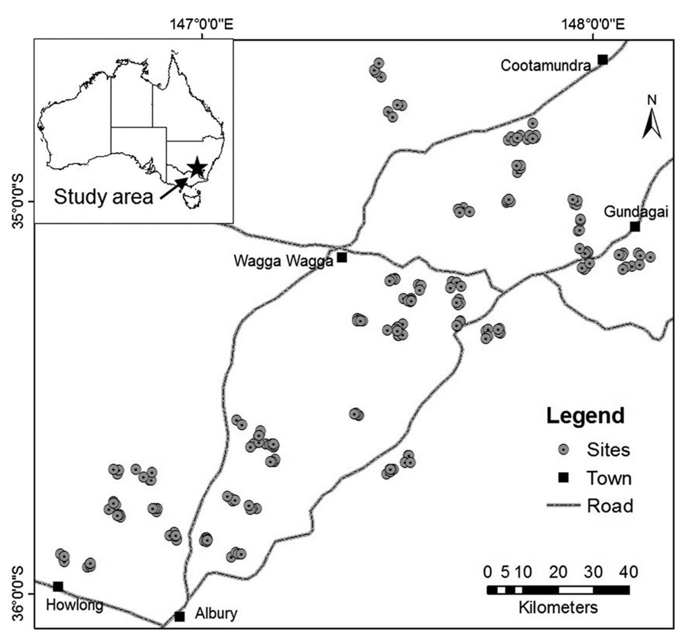


**Fig. 1.** Map of the study area in the South West Slopes region of southeastern Australia (inset). Sites are grouped in clusters of old growth, regrowth, and plantings. Note that site points are not drawn to scale.