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

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1 **Abstract**

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

19

20 **Keywords:** Australia, Threatened species conservation, Marxan, Restoration, Wildlife-friendly farms,
21 Woodland birds

22

23 **Highlights**

- 24 • We compared old growth, regrowth, and planted woodland for bird conservation
- 25 • Patch-scale occupancy was higher in old growth and regrowth than in plantings
- 26 • Species occurrence in the landscape over time required all patch types
- 27 • The most cost-effective strategy ignored patch type when selecting patches
- 28 • Woodland bird conservation needs both protection of old growth and restoration

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31 **1. Introduction**

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

42 In addition to the retention and better management of remnant old growth vegetation, restoration of
43 woodland on agricultural land falls into two broad categories: (i) regrowth, where trees have been allowed to
44 regenerate or colonize following land abandonment, and (ii) revegetation plantings, where trees have been
45 deliberately planted to form new patches of woodland (Rey Benayas et al. 2008). Due to differences in design
46 and management, these alternative restoration strategies often have dissimilar native vegetation structure and
47 composition, to each other and to old growth woodland (Munro et al. 2009; Morrison and Lindell 2011;
48 Lindenmayer et al. 2012; Fuentes-Montemayor et al. 2015; Crouzeilles et al. 2016). Studies focused on
49 individual patches have shown that old growth, regrowth, and planted vegetation provide habitat for distinct
50 suites of species and are variable in species richness and abundance (e.g. Posa and Sodhi 2006; Michael et al.
51 2011; Bruton et al. 2013; Gould et al. 2013). These findings suggest that a combination of old growth,
52 regrowth, and planted woodland is needed to create wildlife-friendly landscapes that maximize the number of
53 species persisting in agricultural areas (Lindenmayer et al. 2012).

54 Yet, embracing this conservation challenge requires that land management moves beyond a focus on
55 patch-scale habitat values to consider landscape and regional scales (Thomson et al. 2009; Crouzeilles et al.
56 2015; Ikin et al. 2016a). Restoration can have variable effectiveness, and does not always lead to the
57 reestablishment of the community that was present prior to disturbance (Lindenmayer et al. 2008; Breeuwer et
58 al. 2009; Mortelliti et al. 2016; Nemet et al. 2016). Because of this, land managers wanting to undertake

59 conservation activities in the landscape have no guidance about whether it might be better to continue
60 managing restored patches where costs have already been incurred (even if that means investing in patches
61 that are not recovering - the “sunk cost” effect (Arkes and Blumer 1985)), or to focus more on old growth
62 patches where minimal costs have been incurred (and which may represent intact, undisturbed native
63 vegetation (Watson et al. 2009)). Effective landscape-scale restoration is hindered because a fundamental
64 question remains unresolved: how does different restored woodland (i.e. regrowth or plantings), in
65 comparison and combination with old growth woodland, contribute to species occurrence in the landscape
66 over time?

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

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

85 Second, we asked: What is the most complementary set of old growth, regrowth, and planted
86 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 x 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

115 characterized by cropping and livestock grazing. Farms typically have between 3% and 35% native vegetation
116 cover comprised of three main patch types: old growth woodland, regrowth woodland, and revegetated
117 woodland plantings (Cunningham et al. 2014b). Old growth woodland (>220 years old) is composed of
118 temperate box-gum *Eucalyptus* woodland and characterized by mature hollow-bearing trees, mistletoe
119 (*Amyema* spp.) and coarse woody debris. Regrowth (majority of stands regenerating prior to 1990) includes
120 *Eucalyptus* woodland sprouting naturally from germinating seeds and stems that have resprouted from living
121 trees following disturbance, such as clearing or fire. This patch type is characterized by structurally complex
122 strata, i.e. high percent cover of overstory and ground-layer strata, as well as coarse woody debris.
123 Disturbance from livestock grazing is variable within old growth and regrowth woodland, ranging from
124 fenced patches where livestock is excluded to patches that have been continuously grazed. Plantings have
125 been established over the last 30 years as part of extensive restoration projects (Lindenmayer et al. 2012;
126 Lindenmayer et al. 2016). Typically, this patch type is composed of a mix of locally endemic and widely
127 distributed *Eucalyptus* and *Acacia* species, and characterized by high stem density, low percent cover of
128 overstory strata, and high percent cover of midstory and understory strata (Lindenmayer et al. 2012). All
129 plantings in our study were established through direct-seeding and were usually fenced to exclude livestock
130 grazing. Our study design included 69 old growth patches, 61 regrowth patches, and 61 plantings (191 patches
131 in total across 43 farms). Patches ranged in area from 0.3 ha to 60.3 ha (medians: old growth 4.5 ha, regrowth
132 5.6 ha, and plantings 1.7 ha) and were separated by a minimum distance of 120 m (average 800 m).

133 We undertook bird point count surveys at every patch in the spring seasons of 2006, 2008, 2009, 2011
134 and 2013. Surveys were conducted between sunrise and mid-morning, avoiding inclement weather. Each
135 patch was visited on two days by a different observer, selected at random from a large team (Appendix A), in
136 early November in each year, with several farms surveyed concurrently each morning. Five-minute point
137 counts were conducted at the 0 m, 100 m and 200 m points of a permanent transect set within the patch, and
138 the number of all birds seen or heard in the patch within 50 m of the point (0.8 ha area) was recorded. Our
139 combined survey area per patch (2.4 ha) exceeded the size of some of our smallest patches. In these instances,
140 we still had three survey points per patch but surveyed birds within a smaller area to exclude birds outside of
141 the patch. We also excluded birds flying overhead. We defined a species as recorded in a patch in a given year
142 if it was recorded during any one of the six counts. This strict survey protocol is applied across all our long-

term studies and is designed to reduce biases in both observer heterogeneity (Cunningham et al. 1999) and false-negative errors, i.e. failure to detect species that are present (Banks-Leite et al. 2014). Despite our precautions, it was likely that our data underestimate species occurrence. To confirm that imperfect detection would not bias our findings, we used single season occupancy models (MacKenzie et al. 2003) to demonstrate that although the probability of detection varied between the six counts and with patch area, modelled estimates of occupancy did not significantly differ from unadjusted estimates (Appendix B). We thus use unadjusted estimates in our subsequent data analyses (see below).

For this investigation, we focused on threatened woodland bird species, which we defined as species dependent on woodland for foraging and nesting (Silcocks et al. 2005) listed as vulnerable (i.e. facing a high risk of extinction in the medium-term future) in New South Wales under the *Biodiversity Conservation Act 2016*, and recorded at least twice across the five survey years (11 species: Table 1). These species are threatened by similar processes, including habitat loss and fragmentation, ongoing habitat clearing and degradation resulting in the loss of important habitat structures, poor regeneration of habitat, and overgrazing by livestock (<http://www.environment.nsw.gov.au/topics/animals-and-plants/threatened-species>). Whilst all 11 species are listed as “least concern” in the IUCN Red List, seven have decreasing population trends (Table 1). The threatened woodland birds are characterized by a range of life history traits characteristic of the broader assemblage of woodland birds, including diets (insectivores, nectarivores, granivores), foraging substrates (canopy, understory, ground), seasonal movements (sedentary, migratory, nomadic), nest types (purse, dome, cup, hollow), and body weights (13 - 145 g) (Appendix C).

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2.2. Data analysis

2.2.1. Occurrence of threatened woodland birds in old growth, regrowth, and planted woodland

To discover how the bird assemblage differed between old growth, regrowth, and plantings, we first compared how well each patch type supported threatened species. For each species, we calculated the percentage of records over the five survey years falling within each patch type. We also calculated the percentage of all species records falling within each patch type in each year.

Next, we modelled the probability of occupancy by any threatened woodland bird species in each patch type (i.e. whether the patch had a species recorded for that year or not). We fitted generalized linear

171 mixed models with a binomial distribution and logit link, using the *lme4* package in *R version 3.0.2* (Bates et
172 al. 2015). We included random effects that accounted for lack of independence caused by repeat visits to each
173 patch and multiple survey years. The significance of the relationship between patch occupancy and patch type
174 was checked by comparing the model to a model containing only the random effects. We did not consider co-
175 variates that might contribute to species being recorded in a patch (for example, landscape context, patch size,
176 and vegetation structure) because these systematically differed between patch types, and thus are confounded
177 with patch type (Appendix D). We also modelled threatened species richness between patch types (i.e. the
178 number of species recorded in the patch in each year), using generalized linear mixed models with a Poisson
179 distribution and log link.

180 Lastly, we compared species composition between old growth, regrowth, and plantings, i.e. the extent
181 to which the patch types could be characterized by the threatened species they supported. We performed a
182 principal coordinates analysis (PCoA) on a matrix of patch transects by species records in each year, using
183 *PC-ORD version 6.22*. We then performed a multi-response permutation procedure (MRPP), to test the
184 significance of patch type in structuring the bird community, as well as pairwise comparisons between patch
185 types.

186 187 2.2.2. Best complementary sets of old growth, regrowth, and planted woodland to support threatened 188 woodland birds

189 To find complementary sets of old growth, regrowth, and plantings patches, we used Marxan v 2.4, a
190 decision-support software program that uses a simulated annealing algorithm to solve the minimum set
191 problem for systematic conservation planning (Ball et al. 2009). We investigated two separate conservation
192 prioritization objectives: (1) to maintain threatened woodland bird occurrence over time whilst minimizing the
193 combined area (ha) of the best set of priority patches, and (2) to maintain threatened woodland bird
194 occurrence over time whilst minimizing the total establishment cost (A\$) of the best set of priority patches.
195 We calculated the establishment cost of every patch (planning unit) based on 2015 pricing rates used by
196 Greening Australia, a large and long-running restoration practitioner. This cost included site evaluation (all
197 patches), materials and labor for patches that were fenced (20 old growth patches, 16 regrowth patches, and all
198 plantings), and site preparation (e.g. weed spraying), materials and labor for patches that were seeded (only

plantings) (Appendix E). The inclusion of private opportunity costs, although important to consider in conservation planning (Naidoo et al. 2006), was beyond the scope of this study. The area and establishment costs of the 191 patches were only moderately correlated (Pearson's correlation coefficient = 0.43), although we note this may not be true for other systems.

To incorporate temporal and spatial variation in species occurrences in patches between 2006 and 2013 (Ikin et al. 2016a; Runge et al. 2016), we created conservation features representing each species in each survey year (i.e. a feature was the series of records/non-records of one species for one survey year - five features per species, 55 in total). We set representation targets of 10% to 100% (10% increments) of each feature (equivalent to 10% to 100% of patches where each species occurred in each survey year). We parameterized Marxan to find the most cost-effective network, irrespective of spatial configuration (by setting the boundary length modifier to zero), and performed 100 runs to find the best set of patches that met the representation target for (1) the least area, and (2) the least cost.

We compared four scenarios representing alternative approaches to finding the best complementary set of remnant and restored vegetation to support landscape-scale species persistence:

1. Equal-preference scenario, which reflects the approach of maintaining complementary patches that contribute to reaching the representation target, irrespective of whether they were old growth, regrowth, or plantings. In this scenario, no patches were preselected, i.e. "locked in", in the Marxan runs.
2. Old growth-preferred scenario, which reflects the approach of maintaining all patches of old growth in the landscape and selecting complementary regrowth patches and plantings that are necessary to reach the representation target for every species. In this scenario, every old growth patch was selected, i.e. "locked in", in all Marxan runs.
3. Regrowth- preferred scenario, which reflects the approach of maintaining all patches of regrowth and selecting complementary patches of other patch types if necessary to meet targets.
4. Plantings- preferred scenario, which reflects the approach of maintaining all plantings and selecting complementary patches of other patch types if necessary to meet targets.

For the best set of complementary patches found for each scenario and representation target, we summarized species occurrence in order to compare scenarios. To do this, for a given scenario and target, we first calculated the proportion of each feature conserved (i.e. for each species in each year, the number of

occupied patches that were present in the best set, divided by the total number of occupied patches). Next, we identified each species' five year minimum (i.e. for each species, the minimum annual proportion of occupied patches during the five years of surveys). Focusing on the minimum enables comparison of the scenarios based on their worst-case representation of the potential distribution of each species. We then summarized the overall species occurrence achieved by the given scenario and target, by taking the average of the 11 species' minimum proportion of occupied patches.

Finally, we considered how the proportion of patch types in the best sets of patches differed between scenarios and representation targets. We used Chi-square tests to test if these proportions differed from the theoretical expectations (i.e. the proportions of old growth woodland, regrowth, and plantings for the 100% representation target).

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3. Results

3.1. Occurrence of threatened woodland birds in old growth, regrowth, and planted woodland

We recorded 11 threatened woodland bird species (Table 1), with at least one species recorded in 135 out of 191 patches between 2006 and 2013. These included 51/69 (74%) old growth patches, 47/61 (77%) regrowth patches, and 37/61 (61%) plantings.

We found that the complete set of patches within a single patch type had low capacity to support the full suite of threatened woodland birds over time (Fig. 2a, Table 1). Across the five survey years, the percentage of species records within a single patch type in a given year ranged from 13% in plantings in 2011 to 49% in regrowth in 2006. This corresponds to 51% to 87% of species records in a given year not captured by a single patch type. Averaged across years, 40% of species records were in old growth, 44% in regrowth, and 16% in plantings.

We found that the probability of threatened woodland bird occupancy in a patch was significantly related to patch type ($P < 0.001$; Fig. 2b, Appendix F). Probability of occupancy was approximately 15% greater in regrowth compared with old growth, but this difference was not significant ($P = 0.19$). In comparison, probability of occupancy was approximately 50% lower in plantings compared with old growth ($P < 0.001$). We found similar patterns for threatened woodland bird richness (richness significantly related to

patch type: $P < 0.001$, being non-significantly higher in regrowth compared with old growth: $P = 0.19$, and significantly lower in plantings compared with old growth: $P < 0.001$, Appendix F).

We found that the species composition of the suite of threatened woodland birds varied between the patch types (Fig. 2c). The first two axes of the PCoA explained 21% and 10% of compositional variation, respectively, and differentiated plantings from old growth and regrowth. Patch type was a significant driver of species composition ($P < 0.001$, Appendix G), with old growth and regrowth sharing a similar suite of species ($P = 0.45$) compared with plantings ($P < 0.001$ for both pairwise comparisons).

3.2. Best complementary sets of old growth, regrowth, and planted woodland to support threatened woodland birds

In comparison with individual patch types, sets of patches selected to include multiple, complementary patch types (reflecting different management approaches) had higher occurrence of threatened woodland birds maintained over time (Fig. 3). These Marxan scenarios, by design, also achieved the designated representation target for each species in every year (i.e. no species was not supported).

For both objectives of minimizing total area and minimizing establishment cost of the best set of patches, we found that the equal-preference scenario had the highest species occurrence over the five survey years per unit area and per unit cost for each representation target (Fig. 3a and b). This scenario selected patches that best contributed to reaching the representation target, irrespective of whether they were old growth, regrowth, or plantings. At equivalent representation targets, the combined patches selected for this scenario were up to 513 ha smaller in total area and \$584,000 less expensive than sets of patches selected for scenarios targeting one patch type (e.g. compared with the 10% representation targets for the regrowth-preferred and plantings-preferred scenarios, respectively). For the objective of minimizing area, the plantings-preferred scenario (which selected patches complementary to plantings to meet restoration targets) had the next highest species occurrence per area, followed by the old growth-preferred scenario and regrowth-preferred scenarios (Fig. 3a). This contrasted with the objective of minimizing cost, where the plantings-preferred scenario had the lowest species occurrence per unit cost (Fig. 3b).

In all scenarios and regardless of the representation target, all sets of complementary patches included every patch type, with the exception of sets selected for low representation targets for the regrowth-preferred

scenarios (Fig. 4). For the equal-preference scenario and the objective of minimizing area, the proportions of patch types in the selected patch sets for the $\leq 20\%$ representation targets were significantly different from that expected from the proportions across all the patches, with a higher proportion of plantings than expected (Fig. 4a). For the objective of minimizing cost, proportions of patches of each patch type were not significantly different than expected (Fig. 4b). For the old growth-preferred scenario and the objective of minimizing area, the best patch sets had a greater proportion of plantings than expected for the $\leq 60\%$ targets (Fig. 4c). For the objective of minimizing cost, the proportions of patch types in the best patch sets were not significantly different from expected from the proportions across all the patches (Fig. 4d). For the regrowth-preferred scenario and the objective of minimizing area, the best patch sets had a lower proportion of old growth patches than expected for the $\leq 70\%$ targets (Fig. 4e). For the objective of minimizing cost, the best patch sets had a lower proportion of old growth patches than expected for the $\leq 30\%$ targets (Fig. 4f). Lastly, for the plantings-preferred scenario, for both objectives, the best patch sets for achieving the 10% representation target had a significantly higher proportion of regrowth patches than expected, but proportions of patch types in patch sets for the higher targets were as expected (Fig. 4g-h).

4. Discussion

An emerging challenge in restoring agricultural landscapes for biodiversity conservation is to consider how old growth, regrowth, and planted vegetation support species persistence at landscape scales (Meli et al. 2017). Here, we found that considering complementarity between woodland patch types provides a new and more informative perspective on how best to allocate conservation resources to patch-level management compared with concentrating on either old growth protection or a single restoration approach. In particular, we found that despite patch-level differences in habitat quality (Appendix D), old growth woodland, regrowth and planted woodland provided complementary habitat for threatened woodland birds, contributing to species occurrences over time.

4.1. Old growth versus restored versus complementary vegetation

We found that the occurrence of the suite of threatened woodland birds in the landscape over time could be achieved only through a mix of old growth, regrowth, and planted woodland (Fig. 4). Each patch type

310 supported, on average, merely a third of species occurrences over the five survey years (Fig. 2a). All but one
311 species (the scarlet robin, a small insectivore that forages in the dense understory present in plantings) were
312 associated with more than one patch type (Table 1, Fig. 2c). Likewise, all patch types were needed to meet
313 typical targets for conservation assessments (Svancara et al. 2005), i.e. to support at least 30% of threatened
314 species occurrences through time (Fig. 4). Previous studies have suggested that wildlife-friendly agricultural
315 landscapes require a diversity of patch types, each a surrogate for a diversity of vegetation attributes, to
316 support species assemblages with diverse life history characteristics, such as found in our study (Lindenmayer
317 et al. 2012)(Appendix C). Our study makes an important advance by quantifying what the composition of
318 patch types should be when seeking to represent the occurrence of all threatened bird species across a
319 degraded Australian woodland landscape.

320 Species occurrence over time was best achieved through complementary sets of old growth, regrowth,
321 and planted woodland that were not based on *a-priori* assumptions of habitat quality. We found that the equal-
322 preferences scenario, which selected the most complementary patches irrespective of patch type, maximized
323 species occurrence for the least combined area and establishment costs (Fig. 3). We also found that the
324 proportion of patch types in these best sets changed depending on the conservation objectives and
325 representation targets. For low representation targets, the objective of minimizing area (which explored the
326 trade-off between conservation and food production opportunities) led to plantings being selected above the
327 other two patch types, as might be expected from the smaller areas of planting patches (Appendix D). In
328 comparison, the objective of minimizing cost (which explored the trade-off between conservation and the high
329 cost of restoration) resulted in the selection of a more equal proportion of each set of patches, despite variable
330 costs between patch types (Appendix E). The superiority of the equal-preferences scenario was unexpected, as
331 numerous previous studies (e.g. Posa and Sodhi 2006; Michael et al. 2011; Gould et al. 2013), as well as our
332 own results for patch composition (Fig. 2c), have demonstrated that old growth, regrowth, and plantings have
333 unequal habitat value for wildlife. For instance, we found that threatened woodland birds were most likely to
334 occupy, plus had higher richness in, regrowth compared with the other patch types (Fig. 2b). Our scenario that
335 selected patches complementary to regrowth correspondingly met targets for representing up to 30% of all
336 threatened species with only regrowth patches plus a marginal proportion of plantings (Fig. 4e and f); targets
337 greater than 30% required an increasing number of old growth patches in addition. However, the regrowth-

preferred scenario required up to ten times the area and nine times the cost to meet equivalent representation targets compared with the equal-preferences scenario (Fig. 3). Similarly, plantings-preferred or old growth-preferred scenarios were more expensive than the equal-preference scenario that ignored patch type, both in terms of farmland taken out of production and money spent on patch establishment.

Threatened species were never recorded in 56 of our 191 patches over the five survey years, equating to 15% of vegetated area and 26% of establishment cost not apparently contributing to threatened species conservation (dashed lines, Fig. 3). Nevertheless, there was low temporal redundancy across the landscape, with 71% of patches needed to support 100% of threatened species occurrence 100% of the time. This finding is consistent with other studies that have incorporated temporally-dynamic species ranges in conservation planning (Grantham et al. 2011; Van Teeffelen et al. 2012). Accounting for annual variation in species ranges has been found to improve the reliability and long-term adequacy of reserve networks (Lourival et al. 2011), increase levels of species protection (Runge et al. 2016), and promote the wise allocation of investment for monitoring and management (Tulloch et al. 2016).

4.2. Priorities for future research

Our application of systematic conservation planning made several necessary assumptions that simplified our system, and although unlikely to strongly alter our finding of complementarity between old growth, regrowth, and planted woodland in our study landscape, they do suggest several avenues for future research and conservation actions. First, we assumed that species were restricted to the patches in which they were recorded, although highly-mobile taxa like birds are known to use their environment at multiple spatial scales (Cunningham et al. 2014a). Our systematic sampling protocol of multiple patches in multiple patch types accounts for some of this scale issue, but we suggest that future research might evaluate the extent to which bird occurrence patterns within selected patches are influenced by vegetation connectivity and the configuration of patches in the surrounding landscape, including unselected patches. Such research might also incorporate variation in individual habitat requirements of species, which may influence patterns. This research may help to inform the priority spatial locations for new conservation actions aimed at increasing vegetation cover across the landscape.

365 Second, we assumed that patch types were homogenous in habitat quality, whereas the occurrence and
366 abundance of woodland vegetation attributes may differ with land management practices and abiotic
367 conditions (Ikin et al. 2015). Similarly, we assumed that patch type was a surrogate for other features but did
368 not fully explore the influence of key covariates that differed between patch types, e.g. patch area and
369 surrounding woody vegetation cover (Appendix D). Future prioritization research can account for
370 heterogeneity in habitat quality by including habitat maps that describe variation in habitat condition or
371 uncertainty in the ecological data (Tulloch et al. 2013). This research could also tease out the patch- and
372 landscape-scale characteristics that may be underlying patterns. In particular, this research could consider the
373 detrimental effects of livestock grazing on habitat quality, and incorporate social data on previous land uses
374 and grazing histories (Dorrough et al. 2012; Kay et al. 2016). Through these analyses, the effectiveness of
375 conservation actions that prioritize improving patch habitat quality over increasing vegetation cover in the
376 landscape can be assessed (Evans et al. 2015).

377 Third, we included only the direct public costs of establishing restoration areas in our cost-
378 effectiveness analyses; private costs associated with lost farming opportunities are also important to consider
379 but are rarely available (Naidoo et al. 2006). We suggest that future research focus on the need for more
380 comprehensive cost information that includes opportunity costs, exploring the relationship between site
381 design, total (private and public) cost, and conservation benefit (Ansell et al. 2016a; Ansell et al. 2016b).
382 Other avenues for research include: (i) exploring whether a taxon-specific focus on a small suite of threatened
383 woodland birds leads to conservation outcomes for other woodland taxa, for example reptiles, arboreal
384 marsupials and invertebrates that are known to respond differently to woodland patch types compared with
385 birds (Cunningham et al. 2007; Jellinek et al. 2013; Jellinek et al. 2014; Michael et al. 2014; Ikin et al. 2016b),
386 (ii) exploring the applicability of our findings to other woodland and non-woodland agricultural systems,
387 where patch types may be surrogates for different landscape features, and (iii) exploring how ecological
388 function can be incorporated into conservation planning to improve conservation outcomes in agricultural
389 landscapes (Klein et al. 2009; Chan et al. 2011).

390

4.3. Management and policy implications

Our finding that old growth, regrowth, and planted woodland were all necessary for species occurrence over time suggests that threatened species conservation requires a combination of regrowth vegetation and revegetation planting strategies in addition to old growth woodland protection. To minimize trade-offs between conservation and farm production priorities, it is imperative that government policy and associated funding aimed at improving biodiversity conservation does not preferentially target old growth woodland over restored vegetation, or vice versa. Instead, funding pathways should be provided for alternative conservation and management strategies. Initiatives such as Australia's Biodiversity Fund, created to support "the establishment of native vegetation or better management of existing native vegetation" (Australian Government 2013), exemplify this approach.

Concurrently, it is also important that management interventions and policy instruments consider issues specific to some patch types. For instance, similar to remnant vegetation in landscapes subject to anthropogenic disturbance worldwide (Fahrig 2003), old growth woodland patches are typically degraded in southeastern Australia compared with historical baselines (Lindenmayer et al. 2010; Watson 2011). Management interventions typically involve fencing to curtail threats posed by livestock grazing (Spooner and Briggs 2008). However, old growth patches may often be affected by other threats (e.g. invasive predators, changed fire regimes), sometimes even more so than restored fragments that might be comparatively more intensively managed for threats. Throughout Australia, clearing of old growth woodland is regulated under state-level legislation, such as the New South Wales *Native Vegetation Act 2003*. However, recent major legislative changes have led to a relaxation of vegetation clearing regulations and a shift towards voluntary compliance and self-regulation (Evans 2016), and there are indications that these policy changes may result in increased vegetation clearing (Bulinski et al. 2016). These Australia-wide policy changes may disproportionately impact regrowth. For example, of the 179,682 ha of native vegetation cleared across Australia in 2013, regrowth comprised nearly 75% (130,066 ha) (Bulinski et al. 2016). Our finding that regrowth had high patch-scale and landscape-scale value provides further evidence of its importance for threatened species conservation, and the need to retain and actively manage this patch type (Bowen et al. 2007; Bowen et al. 2009; Chazdon et al. 2009). Finally, restoration plantings often lack habitat features important for threatened woodland birds and other taxa, such as large hollow-bearing trees, coarse woody

debris, and rocks. Establishing new areas of revegetation around existing trees and manually applying ground-layer structures can reduce the lengthy timeframe for these features to accumulate naturally (Munro et al. 2009; Michael et al. 2010; Shoo et al. 2014). Other measures, such as anticipating climatic changes when choosing appropriate plant species to revegetate, can also increase planting success (Booth and Williams 2012).

4.4. Conclusions

Our study empirically demonstrates that wildlife-friendly agricultural landscapes that contain complementary old growth, regrowth, and planted vegetation have the capacity to support threatened species occurrence over time. Despite variable patch-scale value, representation targets for threatened woodland birds were best achieved through complementary sets of patches comprised of a mix of woodland patch types. Whilst the proportions of different patch types included in the best set varied depending on the conservation objectives and representation targets, all patch types were required to achieve objectives of minimizing costs or area (Fig. 4). Compared with alternative scenarios focused on a single patch type, the best sets of patches chosen without *a-priori* assumptions of habitat quality reduced the amount of farmland “lost” to conservation (Fig. 3a), an increasingly important consideration given growing demands for food security (Godfray et al. 2010). They also reduced the amount of public funds that would need to be spent on establishing restored areas by up to half a million dollars (Fig. 3b), improving the wise allocation of restoration investment (Menz et al. 2013). Our results demonstrate that the most efficient trade-off for the conservation of threatened species whilst also accounting for human needs of agriculture requires a shift from focusing on patch-scale habitat values to considering landscape-scale processes (Thomson et al. 2009; Ikin et al. 2016a). This shift can be usefully informed by the perspectives offered by complementarity-based decision-support tools for systematic conservation planning.

Acknowledgements

We thank the Australian Research Council, the Murray and Riverina Local Land Services, and the Caring for Our Country Program for funding for this project. We thank D. Michael, M. Crane, S. Okada, C. MacGregor,

446 L. McBurney, D. Blair and D. Florence for their important contribution to the collection of the field data. We
447 thank P. Barton for assistance with the multivariate data analyses.

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Table 1. List of threatened woodland bird species recorded during the study at two or more patches in the spring seasons of 2006, 2008, 2009, 2011 and 2013 (# indicates species with decreasing population trends under the IUCN Red List). See Appendix C for life history traits of species.

Common name	Scientific name	# Records	% Records		
			Old growth	Regrowth	Plantings
Black-chinned honeyeater	<i>Melithreptus gularis</i>	33	24.2	57.6	18.2
Brown treecreeper [#]	<i>Climacteris picumnus</i>	195	44.1	51.8	4.1
Diamond firetail [#]	<i>Stagonopleura guttata</i>	63	30.2	36.5	33.3
Grey-crowned babbler [#]	<i>Pomatostomus temporalis</i>	40	37.5	35.0	27.5
Hooded robin [#]	<i>Melanodryas cucullata</i>	21	38.1	57.1	4.8
Little lorikeet	<i>Glossopsitta pusilla</i>	13	38.5	38.5	23.1
Scarlet robin [#]	<i>Petroica boodang</i>	2	0.0	0.0	100.0
Speckled warbler [#]	<i>Chthonicola sagittata</i>	19	10.5	42.1	47.4
Superb parrot	<i>Polytelis swainsonii</i>	119	49.6	34.5	16.0
Turquoise parrot	<i>Neophema pulchella</i>	2	50.0	50.0	0.0
Varied sittella [#]	<i>Daphoenositta chrysoptera</i>	5	20.0	80.0	0.0

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.

Fig. 2. Comparison of old growth, regrowth, and plantings. (a) Percentage of records within each patch type per year. (b) Results of GLMM of patch occupancy as a function of patch type, showing the mean predicted probability a threatened woodland bird species will occur in a patch (black circles) and individual patch predictions (grey circles). (c) Ordination of PCoA species and patch type scores (mean $\pm$ SE). Proximity of species and patch type points shows closeness of association.

Fig. 3. Comparison of Marxan scenarios of complementary sets of old growth, regrowth, and plantings (equal-preference, old growth-preferred, regrowth-preferred, plantings-preferred) for (a) the objective of minimizing total area of the set and (b) the objective of minimizing the establishment cost of the set. Each solid line represents 10% to 100% representation targets, and shows the relationship between area or establishment cost and minimum percent occurrence of each threatened woodland bird species across the five survey years between 2006 and 2013, averaged over the 11 species. The dotted lines show increase from individual patch types to complementary sets. The dashed line extends to the combined area and cost of all 191 patches in the study.

Fig. 4. Proportion of old growth, regrowth, and plantings in the sets of complementary patches for each representation target within the four Marxan scenarios for (left panels) the objective of minimizing total area of the set and (right panels) the objective of minimizing the establishment cost of the set. * indicates that the proportion of patch types in the patch set selected addition to pre-selected, i.e. “locked in”, focal patch types were significantly different from that expected from the 100% representation target (Appendix F).

Appendix A. Contribution of observers to bird point count surveys.

Observer	2006	2008	2009	2011	2013
Observer 1	X	X	X	X	X
Observer 2	X	X	X	X	X
Observer 3	X	X	X	X	X
Observer 4	X	X	X	X	X
Observer 5	X	X	X	X	X
Observer 6	X	X	X	X	
Observer 7	X	X	X	X	
Observer 8	X	X	X	X	
Observer 9	X	X	X	X	
Observer 10	X	X	X		X
Observer 11	X	X	X		
Observer 12	X	X	X		
Observer 13	X	X	X		
Observer 14	X	X	X		
Observer 15	X		X	X	
Observer 16			X	X	X
Observer 17	X				X
Observer 18		X	X		
Observer 19				X	X
Observer 20				X	X
Observer 21	X				
Observer 22	X				
Observer 23	X				
Observer 24		X			
Observer 25				X	
Observer 26					X
Observer 27					X
Observer 28					X
Observer 29					X

Appendix B. Detection models.

We used single season occupancy models (MacKenzie et al. 2003) to model the detection (P) and occupancy (ψ) probabilities for all threatened species (i.e. the probability of recording at least one threatened species) and for the two most recorded species (Brown treecreeper and Superb parrot). To do this, we used the *unmarked* package in R version 3.0.2. We used the series of records/non-records from the six counts undertaken at each site per year for these analyses.

We first modeled P , holding ψ constant across sites. We compared three models: constant detection, detection as a function of count number (1 to 6), and detection as a function of patch area. We selected the relatively best model using the Akaike Information Criterion corrected for small samples.

We then modeled ψ between the three patch types. We compared models holding P constant and models with P as a function of count number and patch area. Again, we selected the relatively best model using the Akaike Information Criterion corrected for small samples.

For all threatened species, we found that the best model for P included detection as a function of patch area (Fig B1(a)). For the median patch area (4 ha), P was 0.34. The 95% confidence intervals, however, overlapped with P held constant or modelled as a function of count number. We did not observe a significant difference in ψ between the three models. The best model for ψ included P as a function of patch area but the 95% confidence intervals overlapped with P held constant or modelled as a function of count number (Fig B1(b)). Compared with ψ , unadjusted occurrence (from the generalized linear mixed model that accounted for temporal and spatial dependencies) was slightly lower but overlapped with 95% confidence intervals for ψ .

For the Brown treecreeper, we found that the best model for P included detection as a function of count number, but that the 95% confidence intervals overlapped with the other models (Fig B1(c)). Averaged over the six counts, P was 0.40. We did not observe any difference in ψ between models holding P constant and models with P as a function of count number and patch area (Fig B1(d)).

For the Superb parrot, we found that the best model for P included detection as a function of patch area, but that the 95% confidence intervals overlapped with the other models (Fig B1(e)). For the median patch area (4 ha), P was 0.20. We did not observe any difference in ψ between models holding P constant and models with P as a function of count number and patch area (Fig B1(f)).

All threatened species

(a)

(b)

Brown treecreeper

(c)

(d)

Superb parrot

(e)

(f)

Fig. B1. Detection (P) and occupancy (ψ) probability estimates. Left panels: Estimates of P , holding ψ constant across sites, for P held constant, P as a function of count number, and P as a function of patch area (summary estimates given). Model selection was based on ΔAIC corrected for small samples. Right panels: Estimates of ψ for P held constant, P as a function of count number, and P as a function of patch area. Unadjusted ψ for all species from the generalized linear mixed model is shown for comparison.

Appendix C. Life history traits of the threatened woodland bird species recorded during the study at two or more patches.

Common name	Scientific name	# Records	Life history				
			Diet	Foraging substrate	Movements	Nest type	Weight (g)
Black-chinned honeyeater	<i>Melithreptus gularis</i>	33	Nectar	Canopy	Sedentary	Suspended Purse	20
Brown treecreeper	<i>Climacteris picumnus</i>	195	Invertebrates	Canopy	Sedentary	Hollow	33
Diamond firetail	<i>Stagonopleura guttata</i>	63	Seeds	Ground	Sedentary	Dome	17
Grey-crowned babbler	<i>Pomatostomus temporalis</i>	40	Invertebrates	Ground	Sedentary	Dome	81
Hooded robin	<i>Melanodryas cucullata</i>	21	Invertebrates	Understory	Sedentary	Cup	22
Little lorikeet	<i>Glossopsitta pusilla</i>	13	Nectar	Canopy	Nomadic	Hollow	40
Scarlet robin	<i>Petroica boodang</i>	2	Invertebrates	Understory	Migratory	Cup	14
Speckled warbler	<i>Chthonicola sagittata</i>	19	Invertebrates	Ground	Sedentary	Dome	13
Superb parrot	<i>Polytelis swainsonii</i>	119	Seeds	Ground	Migratory	Hollow	145
Turquoise parrot	<i>Neophema pulchella</i>	2	Seeds	Ground	Sedentary	Hollow	40
Varied sittella	<i>Daphoenositta chrysoptera</i>	5	Invertebrates	Canopy	Sedentary	Cup	13

Appendix D. Summary of site attributes

Table D1. Mean site attribute values per patch type and results of ANOVAs testing for significant differences in attribute values between patch types.

Site attribute	Mean value			ANOVA		
	Old growth	Regrowth	Planting	F-value	P-value	Eta-squared
Elevation	280.39	301.03	293.16	2.07	0.13	0.02
Northerly aspect	0.09	-0.07	0.00	0.92	0.40	0.01
Topographic Wetness Index	3.35	2.84	2.78	1.99	0.14	0.02
Percent native vegetation cover within 1km	0.10	0.14	0.06	10.06	<0.01	0.10
Area (ha)	7.80	10.57	4.24	5.91	<0.01	0.06
Number of stems	6.30	14.83	29.85	25.11	<0.01	0.21
Number of strata	2.18	2.50	2.48	6.69	<0.01	0.07
Canopy height	20.64	18.40	10.33	93.71	<0.01	0.50
Trees >50cm DBH per ha	18.18	10.42	1.19	73.43	<0.01	0.44
Mistletoe per ha	8.33	8.06	3.28	0.99	0.37	0.01
Dead trees per ha	14.49	39.89	17.08	10.38	<0.01	0.10
Coarse woody debris per ha	198.91	168.99	32.65	25.01	<0.01	0.21
Percent overstory cover	30.87	30.04	14.96	14.73	<0.01	0.14
Percent midstory cover	0.24	0.66	7.02	9.90	<0.01	0.10

Percent understory cover	1.11	1.61	1.98	1.56	0.21	0.02
Percent rock cover	4.15	4.45	1.24	3.47	0.03	0.04
Percent native tussock cover	11.02	11.28	4.49	8.05	<0.01	0.08
Percent annual grasses cover	32.49	25.85	25.23	1.79	0.17	0.02
Percent broad leaf weeds cover	2.54	2.42	2.38	0.02	0.98	<0.01
Percent forbs cover	5.45	4.52	3.81	1.27	0.29	0.01
Percent mosses/lichens cover	3.25	3.28	0.86	5.24	0.01	0.05
Percent bare earth cover	16.86	14.06	16.67	0.68	0.51	0.01
Percent leaf litter cover	27.56	35.18	37.76	4.58	0.01	0.05

Table D2. Spearman correlation coefficients between site attributes. Shaded values are significant ($P < 0.05$).

	Elevation	Aspect	TWI	Veg	Area	Stems	Strata	Height	Large Trees	Mistletoe	Dead Trees	CWD	OS	MS	US	Rock	Tussock	Grass	Weeds	Forbs	Moss	Bare
Apect	-0.05																					
TWI	-0.48	0.04																				
Veg	0.28	-0.03	-0.18																			
Area	0.12	-0.06	-0.09	0.51																		
Stems	0.11	0.03	-0.07	-0.10	-0.25																	
Strata	0.07	0.07	0.00	0.09	0.04	0.47																
Height	-0.26	0.10	0.29	0.16	0.30	-0.42	-0.05															
Large	-0.13	0.05	0.27	0.10	0.19	-0.56	-0.14	0.60														
Mistl.	0.18	-0.02	-0.13	0.21	0.14	0.04	0.07	0.06	0.06													
Dead	0.24	-0.03	-0.07	0.12	0.12	0.15	0.11	0.05	-0.03	0.04												
CWD	0.15	0.02	-0.03	0.34	0.28	-0.40	-0.13	0.52	0.50	0.13	0.31											
OS	0.04	0.18	0.08	0.13	0.19	-0.12	0.19	0.54	0.38	0.12	0.05	0.41										
MS	0.13	0.18	-0.05	0.00	-0.05	0.23	0.35	-0.06	-0.17	0.09	0.01	-0.06	0.21									
US	0.24	-0.01	-0.14	0.00	0.03	0.33	0.61	-0.29	-0.19	0.07	0.09	-0.18	-0.08	0.09								
Rock	0.31	0.11	-0.31	0.28	0.25	-0.09	0.06	-0.19	-0.05	0.19	0.14	0.09	0.00	0.07	0.17							
Tuss.	0.08	0.17	-0.08	0.36	0.46	-0.16	0.06	0.18	0.23	0.24	-0.02	0.21	0.10	-0.05	0.08	0.23						
Grass	-0.16	-0.09	0.17	-0.32	-0.26	-0.21	-0.32	0.15	0.13	-0.10	-0.04	0.03	-0.08	-0.13	-0.20	-0.26	-0.38					
Weed	-0.11	-0.04	0.11	-0.01	-0.07	-0.17	-0.30	0.08	-0.01	-0.03	-0.04	-0.02	-0.30	-0.13	-0.16	-0.10	-0.09	0.22				
Forbs	0.10	0.15	0.00	0.20	0.31	-0.22	0.08	0.22	0.23	0.17	0.07	0.18	0.22	0.19	0.07	0.13	0.30	-0.09	0.02			
Moss	0.36	0.00	-0.23	0.40	0.44	-0.13	0.21	-0.07	0.10	0.18	0.14	0.22	0.18	0.13	0.24	0.44	0.49	-0.42	-0.17	0.28		
Bare	-0.20	0.09	0.08	-0.24	-0.06	-0.08	-0.07	0.01	0.03	-0.16	-0.09	0.02	0.01	-0.20	-0.12	0.01	-0.07	-0.16	-0.09	0.00	-0.10	
Litter	0.17	0.09	-0.10	0.19	0.19	0.38	0.41	0.02	-0.11	0.05	0.15	0.06	0.32	0.28	0.24	0.01	0.18	-0.55	-0.45	-0.08	0.28	-0.22

Appendix E. Items and rates used to calculate establishment costs, and the number of patches each item was calculated for. Rates provided are for the 2015 Australian Dollar. Costs were calculated with input rates for labor and materials used by Greening Australia, Australia's largest ecological restoration practitioner, in costing their on-ground works (Greening Australia, unpublished data).

Item	Description	Rate	Old growth	Regrowth	Planting
Site evaluation	Labor and travel (vehicle and fuel)	A\$460.72 per site	69	61	61
Fencing	Fencing materials and labor	A\$10,000 km ⁻¹	20	16	61
Direct-seeding	Seed, machinery	< 2ha = A\$750 ha ⁻¹	0	0	33
		2-4ha = A\$625 ha ⁻¹	0	0	11
		>4ha = A\$550 ha ⁻¹	0	0	17
	Labor, site preparation	A\$77.68 ha ⁻¹	0	0	61
Range of patch costs (nearest A\$)			A\$461 – 36,391	A\$461 –86, 8901	A\$5,408 – 73,315

Appendix F. Results of generalized linear mixed models (GLMM).

Model	Terms	Estimate	Standard Error	P-value
Occupancy	Intercept (Patch type: old growth)	-0.33	0.27	0.23
	Patch type: Regrowth	0.52	0.40	0.19
	Patch type: Planting	-0.11	0.20	<0.001
Richness	Intercept (Patch type: old growth)	-0.83	0.13	<0.001
	Patch type: Regrowth	0.24	0.18	0.19
	Patch type: Planting	-0.81	0.20	<0.001

Appendix G. Results of multi-response permutation procedure (MRPP).

	T	A	P
Overall	-7.74	0.03	<0.001
Old growth vs regrowth	0.16	<-0.01	0.45
Old growth vs plantings	-7.44	0.03	<0.001
Regrowth vs plantings	-11.06	0.04	<0.001

Appendix H. Results of chi-squared tests of independence comparing observed proportions of patch types in the best sets for each representation target with expected proportions (i.e. for 100% target).

For old growth, regrowth, and plantings scenarios, proportions are for patches selected additional to preselected, i.e. “locked in”, focal patch types. Minimum expected values were all >5.

Scenario		Representation target (%)								
		10	20	30	40	50	60	70	80	90
<i>Objective = minimize area</i>										
Equal-preference	χ^2 :	31.599	14.812	5.770	4.942	3.069	1.514	0.736	0.438	0.227
	P :	<0.001	0.001	0.056	0.085	0.216	0.469	0.692	0.803	0.893
Old growth-preferred	χ^2 :	6.839	6.839	7.720	8.601	11.826	4.084	1.323	0.210	0.297
	P :	0.009	0.009	0.005	0.003	0.001	0.043	0.250	0.647	0.586
Regrowth-preferred	χ^2 :	81.600	81.600	81.600	30.283	24.120	10.317	5.545	1.859	0.326
	P :	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	0.019	0.173	0.568
Plantings-preferred	χ^2 :	27.743	2.161	1.981	0.630	0.011	0.193	0.007	0.247	0.041
	P :	<0.001	0.142	0.159	0.427	0.917	0.661	0.933	0.619	0.839
<i>Objective = minimize cost</i>										
Equal-preference	χ^2 :	1.580	5.614	5.243	5.164	2.015	4.405	0.677	0.402	0.035
	P :	0.454	0.060	0.073	0.076	0.365	0.111	0.713	0.818	0.983
Old growth-preferred	χ^2 :	0.029	2.420	2.420	0.548	0.007	1.132	0.604	0.280	0.007
	P :	0.865	0.120	0.120	0.459	0.935	0.287	0.437	0.597	0.935
Regrowth-preferred	χ^2 :	81.600	22.370	4.559	0.342	2.245	2.051	0.125	0.195	0.000
	P :	<0.001	<0.001	0.033	0.558	0.134	0.152	0.723	0.659	0.982
Plantings-preferred	χ^2 :	22.273	0.868	0.496	0.327	0.931	0.000	0.029	0.008	0.014
	P :	<0.001	0.351	0.481	0.568	0.335	0.985	0.866	0.931	0.904