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The Combined Effects of Remnant Vegetation and Tree Planting on Farmland Birds

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Abstract: *Biodiversity conservation on agricultural land is a major issue worldwide. We estimated separate and joint effects of remnant native woodland vegetation and recent tree plantings on birds on farms (approximately 500–1000 ha) in the heavily cleared wheat and sheep belt of southern Australia. Much of the variation (>70%) in bird responses was explained by 3 factors: remnant native-vegetation attributes (native grassland, scattered paddock trees, patches of remnant native woodland); presence or absence of planted native trees; and the size and shape of tree plantings. In terms of the number of species, remnant native vegetation was more important than tree planting, in a 3:1 ratio, approximately. Farms with high values for remnant native vegetation were those most likely to support declining or vulnerable species, although some individual species of conservation concern occurred on farms with large plantings. Farm management for improved bird conservation should account for the cumulative and complementary contributions of many components of remnant native-vegetation cover (e.g., scattered paddock trees and fallen timber) as well as areas of restored native vegetation.*

Keywords: farmland birds, landscape restoration, native remnant woodlands, replanted native vegetation

Efectos Combinados de la Vegetación Remanente y la Siembra de Árboles sobre Aves de Tierras Agrícolas

Resumen: *La conservación de la biodiversidad en tierras agrícolas es un tema importante mundialmente. Estimamos los efectos separados y combinados de la vegetación nativa remanente y las plantaciones recientes de árboles sobre aves en ranchos (∼500–1000 ha) en la zona ampliamente deforestada para trigo y ovejas en el sur de Australia. Mucha de la variación (>70%) en las respuestas de aves fue explicada por 3 factores: atributos de la vegetación nativa remanente (pastos nativos, árboles nativos aislados, fragmentos de bosque nativo remanente); presencia o ausencia de árboles nativos plantados y el tamaño y forma de las plantaciones de árboles. En términos del número de especies, la vegetación nativa remanente fue más importante que los árboles plantados en una proporción 3:1, aproximadamente. Los ranchos con altos valores de vegetación nativa remanente fueron los más propensos a soportar especies en declinación o vulnerables, aunque algunas especies individuales de interés para la conservación ocurrieron en ranchos con plantaciones extensas. El manejo del rancho para mejorar la conservación de las aves debería considerar las contribuciones acumulativas y complementarias de muchos componentes de la vegetación nativa remanente (e.g., árboles aislados y madera caída) así como de las áreas con vegetación nativa restaurada.*

Palabras Clave: aves de tierras agrícolas, bosques nativos remanentes, restauración del paisaje, vegetación nativa resembrada

Introduction

Protected areas are a core strategy to conserve biodiversity around the world (Margules & Pressey 2000), but many studies demonstrate that reserves alone will not be sufficient to conserve all biodiversity (e.g., Craig et al. 2000). Conservation strategies will be critical in places used for commodity production such as multiple-use

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forests (Lindenmayer & Franklin 2002) and agricultural areas (Daily et al. 2003; Tscharntke et al. 2005).

Off-reserve conservation is critical in the agricultural land that was formerly dominated by temperate woodlands in the South West Slopes region of New South Wales (NSW) in southeastern Australia. This area is the most heavily modified bioregion of NSW (Benson 1999) and supports few formal large reserves. Remaining areas of temperate woodland occur almost entirely on privately owned or leased land (Prober & Thiele 1995; Lindenmayer et al. 2005), and they support many threatened, temperate, woodland vegetation communities (Department of Environment and Water Resources 2007) and many declining, temperate, woodland bird species (Reid 1999; Barrett et al. 2005).

Off-reserve conservation in this and similar regions in southeastern Australia has focused on patches of remnant native woodland (Reid 1999; Gibbons & Boak 2002; Seddon et al. 2003). In much of this previous work, researchers examined animal responses at the landscape level (e.g., Bennett & Ford 1997; Manning et al. 2004) or at the site or individual-remnant level (Freudenberger 1999) but not at the level of an individual farm. We refer to a farm as a 500- to 1000-ha land holding owned privately or leased by a given landholder or managed by a farmer for a large pastoral company. The farm is the unit of management applicable to many landholders and the scale at which they make decisions about land use (Barrett et al. 2000; Cunningham et al. 2007).

Another focus of conservation work in the temperate woodland regions of southeastern Australia has been on the value areas of deliberately planted native vegetation on farms (e.g. Martin et al. 2004; Kavanagh et al. 2005). Despite large investments in planting programs, their effectiveness for biodiversity conservation remains poorly known. The few studies that have been completed focus on the site level; farm-level impacts have rarely been examined. Moreover, although most planting efforts occur in landscapes that also support remnant vegetation, the conservation benefits arising from the cumulative effects of planted and remnant vegetation are unknown. That is, the cumulative effects of the 2 kinds of vegetation have not been explored previously.

We sought to quantify the response of individual bird species and overall bird species richness to vegetation attributes on farms, including native revegetated areas (i.e., tree plantings). We addressed the following questions that are of broad importance to the conservation of biota on farms: Which native-vegetation features on a farm are important for bird species richness and individual bird species? What is the relative value for native birds of remnant woodland versus planted native vegetation? Do areas of remnant vegetation and planted areas combine to effect bird responses? On which farms will restoration be most efficient? That is, will restored areas lead to the greatest relative increase in bird species richness on farms with limited remnant native woodland or on farms on which much of the remnant native vegetation remains? In addition to addressing these questions, we discuss, as short case studies, the effects of vegetation attributes on declining woodland bird species (sensu Reid 1999).

The importance of conservation in agricultural areas is increasingly recognized worldwide (e.g., Daily et al. 2001; Benton et al. 2003; Fischer et al. 2005). A growing number of studies from around the world indicate that the management of different components of vegetation cover within areas broadly designated for agriculture can make a significant contribution to the persistence of native species from many taxa (e.g., Laiolo 2004; Schmitz et al. 2007; Sirami et al. 2007). Nevertheless, the relative importance and the combined contribution of different vegetation components, including sites planted or restored for biodiversity, remain poorly understood.

Methods

Study Area and Survey Design

We studied the southern half of the South West Slopes region of NSW, which encompasses the Murray River and Murrumbidgee River catchments. The study area included the towns of Junee (36° 05′S, 146° 56′E) in the north, Albury (34° 52′S, 147° 55′E) in the south (a distance of approximately 150 km), and Gundagai (35° 04′S, 148° 07′E) and Howlong (35° 59′S, 146° 38′E) in the east and west, respectively (a distance of approximately 120 km).

Remnant native vegetation in the South West Slopes region is dominated by temperate-woodland (sensu Hobbs & Yates 2000) tree species such as white box (*Eucalyptus albens*), gray box (*E. microcarpa*), and other tree species such as yellow box (*E. melliodora*), Blakely's red gum (*E. blakelyi*), red stringybark (*E. macrorhyncha*), and red ironbark (*E. sideroxylon*). Wetter areas along creeks and streams support river red gum (*E. camaldulensis*).

We focused on the South West Slopes region because it has been the target of extensive planting programs over the past 2 decades to mitigate, in particular, problems associated with soil erosion and salinity. Plantings were a mix of locally endemic and nonlocal Australian ground cover, and understory and overstory plant species. All plantings we surveyed exceeded 7 years of age and many were 10–20 years old.

We surveyed 23 landscapes; a landscape was defined as a relatively homogenous circular area covering 10,000 ha. We based landscape selection on aerial photographs, satellite imagery, and ground truthing. We classified landscapes into 1 of 6 remnant × planting cover classes: >15% and <9% cover of remnant vegetation and >1%, 0.5–0.9%, and <0.2 planting intensity. We selected

4 landscapes in each of the 6 remnant × planting cover classes except for the high–high class where only 3 landscapes were available.

We selected 2 farms in each of the 23 landscapes. These 46 farms were predominately wheat cropping or sheep (*Ovis aries*)/cattle (*Bos taurus*) grazing enterprises. In landscapes with plantings, one farm with plantings was chosen and the other without plantings. On a given farm, we selected 4 sites each of 1 ha (200 × 50 m). On the 23 farms without plantings, all sites were patches of remnant native vegetation, where possible covering the full range of woodland vegetation spanning regrowth to old-growth woodland. Generally for the 23 farms with plantings, 2 sites were established in plantings and 2 in woodland remnants. We ensured that survey effort was equal across farms rather than proportional to the area of each vegetation type. This is appropriate for comparative studies of this type. For each farm, we surveyed the range of available types of native vegetation but excluded gardens surrounding homesteads and crops and pastures. For farms with plantings, medians for the area of native woodland remnants and cleared land were 32 and 915 ha, respectively. Corresponding figures for farms without plantings were 106 ha of native woodland remnants and 890 ha of cleared land. Our hierarchical design encompassed 184 sites nested within 46 farms that were nested within 23 landscapes.

Vegetation Data and Other Covariates

The farms we selected for study varied in levels of remnant native woodland cover, amount of planting of native vegetation, and other attributes. We used aerial photography, satellite imagery, and ground truthing field surveys to collate data on a wide range of vegetation attributes on farms. The key farm attributes we measured were (1) area of woodland remnants, (2) edge index for woodland remnants, which was the total of combined perimeters (meters) of remnant woodland vegetation divided by total area of remnant woodland vegetation on a farm, (3) area of plantings, (4) edge index for plantings on farms (planting edge), which was the total of combined perimeters of plantings divided by total area of plantings on a farm, (5) amount of standing and fallen dead timber scored from 1 to 4 for low to high amounts, (6) number and distribution of scattered paddock trees scored from 1 to 4 for low to high numbers, and (7) amount of native grassland within and surrounding each of the 4 sites on a farm scored from 1 to 4 as a surrogate measure of extent. Variables measuring area were log transformed prior to analysis.

Bird Counts

We recorded bird data in spring 2002, winter 2004, spring 2004, and spring 2006 at the 0-, 100- , and 200-m points along a fixed transect that was permanently established at each of 184 sites. The 4 surveys in different years and seasons ensured a wide coverage of temporal effects. For each point-interval count (sensu Pyke & Recher 1983), we recorded all bird species seen or heard during a 20-min period within and outside the fixed sites.

Cunningham et al. (1999) show that averaging the counts of 2 or more observers at the same site may compensate for extra variability due to observer heterogeneity. Field et al. (2002) showed that weather and other conditions on any given day can affect bird detectability. Our surveys involved counts conducted over approximately 14 days in which each of our 184 sites was surveyed by 2 observers on different days. No counts were undertaken on days of poor weather (rain, high wind, fog, or heavy cloud cover).

Preliminary Data Analysis

We aggregated bird data to give the number of detections of a given species over 4 sites on a farm by 4 years. A bird was considered present at a site if it was observed by at least 1 observer on at least 1 plot, and we assumed that nondetection of most birds was low. We then treated our data as proportions data—the number of detections divided by the number of possible detections (16), which yielded what we termed *occupancy rate*. Hence, for subsequent statistical analyses, the underlying response for each bird was the probability of occupancy; the observed realization of this probability was the occupancy rate.

Excluding gardens surrounding homesteads and crops and pastures, we endeavored to survey all available vegetation types on each farm. Thus, we considered our data provided reasonable measures of the occupancy rate of birds on farms that would support subsequent inferences to be made about the effects of farm attributes on bird-occupancy rates.

Statistical Methods

For those bird species we detected on 5 or more farms, we estimated a slope parameter for each of the vegetation attributes described earlier (for presence of tree planting this was simply a dummy variable: 1 if the farm had plantings and 0 otherwise) by fitting a linear logistic-regression model (McCullagh & Neldner 1989). These parameters **Q2** provided a measure of the rate of change in log odds of occupancy of a given bird species for a unit change in given vegetation attribute. We estimated parameters by weighted least-squares regression (McCullagh & Neldner 1989). We then conducted a principal component analysis (Digby & Kimpton 1987) on the slope parameters **Q3** divided by their corresponding standard errors (to standardize for the differences in scale of the input variables).

Based on the results of principal component analysis, we defined several key composite indices. These were then substituted for the vegetation attributes in linear logistic regression as above. We then used slope parameters from these analyses to classify birds into groups.

Table 1. Vector loadings from principal component analysis of bird responses to vegetation attributes.*

	Dimension		
	1	*2*	*3*
Attribute			
amount of fallen timber	0.140	0.315	−0.226
amount of native grassland	0.431	−0.178	0.638
area of plantings	0.000	−0.582	0.146
edge index for plantings	0.017	0.410	−0.134
number of paddock trees	0.529	0.087	0.068
area of woodland remnants	0.499	0.094	−0.365
edge index for woodland remnants	−0.52	0.127	0.181
effect of planting presence	0.002	−0.574	−0.576

**Dimension 1, 2, and 3 account for 54.1%, 15.5%, and 9.2% of the variation, respectively.*

Summary statistics from these groups were then calculated and interpreted.

Results

We recorded 159 bird species from repeated field surveys (for scientific names and common names see Supplementary Material), of which 124 occurred on 5 or more farms, and we deemed them suitable for detailed statistical analyses. Approximately 70% of the total variation in the effects of vegetation components on bird species was accounted for in 2 dimensions of the principal component analysis. The first dimension accounted for approximately 54% of the between-species variability (Table 1), and it was a composite measure of the native grassland, paddock trees, and remnant woodland area, offset by the edge index for native woodland remnants. The second dimension accounted for approximately 16% of the total variation in the effects of vegetation components on bird species. This dimension was predominately a composite of the planting-presence effect and the size of plantings offset by the planting-edge effect. Fallen timber also was a minor contributor. Major contributors to the third dimension (approximately 9% of variation) were the effect of planting and the effect of native grassland.

Indices of Vegetation Cover

On the basis of the above results, we constructed 3 vegetation-cover indices that accounted for the majority of variability in the effects of vegetation attributes on bird occupancy between farms. Two of these indices (1 and 3, see below) were composites, so an adjustment for different scales was made by standardizing all input variables (by subtracting the mean and dividing by the standard deviation). The 3 indices were (1) remnant native vegetation, which excluded tree plantings (paddock tree index + native pasture index + log[remnant area(ha)] – edge index of remnants) and variables associated with tree plantings (either the presence of plantings or the size and shape of plantings) (a low score corresponded to a highly modified farm); (2) planting presence (the difference in the odds of occupancy between farms with tree plantings and those with none), which is the same as the planting effect used as an input variable in the principal component analysis and was derived for each bird species by fitting a dummy variable, designating whether tree plantings were present (1) or not (0) on the farm, in the logistic-regression analysis; (3) planting size and shape given plantings are present (log[planting area (ha)] – edge index of plantings) (high score corresponded to a larger number of block-shaped planted areas, whereas a low score indicated small plantings in linear strips). For ease of interpretation, we separated the planting-presence effect from the planting-size and planting-shape index.

Farm Birds and Composite Vegetation Indices

For each bird species, the slope parameter for each of the 2 new vegetation indices (1 and 3) was estimated by fitting a linear logistic-regression model (McCullagh & Neldner 1989). These parameters provided a measure of the rate of change in log odds of detection of a species for a unit change in each of the 2 indices. The second index was the same as the original planting effect, which was an input variable in the principal component analysis.

We cross-classified all 124 bird species detected on 5 or more farms according to the significance of their response to both the remnant native-vegetation and the planting-presence indices (as determined by the absolute value of t statistic >2) and given significance, whether the response was positive, negative, or neutral (Table 2). We also identified significant responses to the planting-size and planting-shape index. The 37 taxa in the positive cells for the remnant native-vegetation index were significantly more likely ($p < 0.05$) to occur on farms where there were large areas of remnant vegetation, numerous scattered paddock trees, and large areas of native grassland (Table 2), for example, Brown Treecreeper and Sacred Kingfisher (Fig. 1). Other typical members of this group included known declining species (after Reid 1999) such as the Speckled Warbler, Hooded Robin, Crested Shrike-Tit, and Jacky Winter.

Examples of the 5 negative responders to the remnant native-vegetation index (Table 2) included the introduced House Sparrow, the Brown Songlark (a bird closely associated with cropped areas), and the Fairy Martin (typically associated with human infrastructure). None of these negatively responding species were threatened or declining (sensu Reid 1999).

Fifteen species of birds responded positively to the planting-presence index (Table 2). Birds that responded

Table 2. Cross-classification of 124 species by their response to the remnant native-vegetation index and their response to planting-effect index (see text for definitions).

Native-vegetation index	Planting-presence index: positive		negative	neutral			
Positive			Brown Treecreeper ↓ *Climacteris picumnus*	Black-chinned Honeyeater *Melithreptus gularis*	Fuscous Honeyeater *Lichenostomus fuscus*	Peaceful Dove ↑ *Geopelia striata*	Varied Sittella ↓ *Daphoenositta chrysoptera*
			Mistletoebird *Dicaeum hirundinaceum*	Brown-headed Honeyeater *M. brevirostris*	Grey Shrike-thrush *Colluricincla harmonica*	Pied Currawong *Strepera graculina*	White-browed Babbler ↓ *Pomatostomus superciliosus*
			Laughing Kookaburra *Dacelo novaeguineae*	Brush Cuckoo *Cacomantis variolosus*	Hooded Robin ↓ *Melanodryas cucullata*	Rainbow Bee-eater *Merops ornatus*	White-browed Woodswallow ↓ *Artamus superciliosus*
			Sacred Kingfisher *Todiramphus sanctus*	Crested Shrike-Tit ↓ *Falcunculus frontatus*	Jacky Winter ↓ *Microeca fascinans*	Restless Flycatcher ↓ *Myiagra inquieta*	White-necked Heron *Ardea pacifica*
			White-naped Honeyeater *M. lunatus*	Common Bronzewing *Phaps chalcoptera*	Leaden Flycatcher *Myi. rubecula*	Painted Honeyeater *Grantiella picta*	White-throated Treecreeper *Cormobates leucophaeus*
				Crimson Rosella *Platycercus elegans*	Little Friarbird *Philemon citreogularis*	Pallid Cuckoo *Cuculus pallidus*	White-winged Chough ↑ *Corcorax melanorhamphos*
				Diamond Firetail ↓ *Stagonopleura guttata*	Little Lorikeet *Glossopsitta pusilla*	Shining Bronze Cuckoo *Chrysococcyx lucidus*	White-winged Triller *Lalage sueurii*
				Dusky Woodswallow ↓ *A. cyanopterus*	Noisy Friarbird *Ph. corniculatus*	Striated Thornbill *Acanthiza lineata*	Yellow-faced Honeyeater *L. chrysops*
Negative	Brown Songlark ↑ *Cincloramphus cruralis*	House sparrow ↑ *Passer domesticus*		Australian Shelduck *Tadorna tadornoides*	Fairy Martin *Hirundo ariel*	Sacred Ibis *Threskiornis molucca*	
				Boobook Owl *Ninox novaseelandiae*	Nankeen Kestrel *Falco cenchroides*		
Neutral	Apostlebird[a] *Struthidea cinerea*	Rufous Whistler↓ *Pachycephala rufiventris*	Striated Pardalote *Pardalotus striatus*	Australasian Grebe *Tachybaptus novaehollandiae*	Eastern Yellow Robin ↓ *Eopsaltria australis*	Masked Lapwing *Vanellus miles*	Spotted Pardalote *Par. punctatus*
	Blackbird ↑ *Turdus merula*	Scarlet Robin↓ *Petroica multicolor*		Australian Hobby *F. longipennis*	European Greenfinch *Carduelis carduelis*	Masked Woodswallow *A. personatus*	Stubble Quail *Coturnix pectoralis*
	European Goldfinch	Superb Fairy-wren		Australian Magpie ↑		Noisy Miner ↑	Sulphur-crested Cockatoo ↑

Continued

Table 2. Continued.

Native-vegetation index	*Planting-presence index*					
	positive	*negative*	*neutral*			
	Car. carduelis	*Malurus cyaneus*	*Gymnorhina tibicen*		*Manorina melanocephala*	*Cacatua galerita*
	Grey Fantail[a]	White-browed Scrubwren	Australian Raven ↑	Fan-tailed Cuckoo	Olive-Backed Oriole	Superb Parrot
	Rhipidura fuliginosa	*Sericornis frontalis*	*Corvus coronoides*	*C. flabelliformis*	*Oriolus sagittatus*	*Polytelis swainsonii*
	Red Wattlebird	Yellow-rumped Thornbill ↑	Black-faced Cuckoo-shrike ↑	Flame Robin	Pacific Black Duck	Tree Martin
	Anthochaera carunculata	*Aca. chrysorrhoa*	*Coracina novaehollandiae*	*Pet. phoenicea*	*Anas superciliosa*	*H. nigricans*
	Red-Browed Finch[a]	Yellow Thornbill	Black-shouldered Kite	Galah ↑	Peregrine Falcon	Wedge-tailed Eagle[b]
	Neochmia temporalis	*Aca. nana*	*Elanus axillaris*	*Cac. roseicapilla*	*F. perigrinus*	*Aquila audax*
	Richard's Pipit ↑		Blue-faced Honeyeater	Gang-gang Cockatoo	Pied Butcherbird ↑	Weebill
	Anthus novaeseelandiae		*Entomyzon cyanotis*	*Callocephalon fimbriatum*	*Cracticus nigrogularis*	*Smicornis brevirostris*
			Brown Falcon	Golden Whistler	Red-capped Robin[a] ↓	Welcome Swallow ↑
			F. berigora	*Pac. pectoralis*	*Pet. goodenovii*	*H. neoxena*
			Brown Goshawk	Golden-headed Cisticola	Red-rumped Parrot ↑	Western Gerygone
			Accipiter fasciatus	*Cisticola exilis*	*Psephotus haematonotus*	*Gerygone fusca*
			Brown Thornbill	Grey Butcherbird	Rufous Songlark	White-faced Heron
			Aca. pusilla	*Cra. torquatus*	*Cinc. mathewsi*	*Egretta novaehollandiae*
			Buff-rumped Thornbill[a]	Grey Teal	Silvereye	White-Fronted Chat
			Aca. reguloides	*A. gracilis*	*Zosterops lateralis*	*Epthianura albifrons*
			Clamorous Reed Warbler	Grey-crowned Babbler ↓	Singing Bushlark	White-plumed Honeyeater ↑
			Acrocephalus australis	*P. temporalis*	*Mirafra javanica*	*L. pencillatus*
			Cockatiel ↑	Horsfield's Bronze-Cuckoo	Southern Whiteface	White-throated Gerygone
			Nymphicus hollandicus	*Chr. basilis*	*Aphelocephala leucopsis*	*G. olivacea*
			Common Starling	Little Corella ↑	Speckled Warbler	
			Sturnus vulgaris	*Cac. sanguinea*	*Chthonicola sagittata*	
			Crested Pigeon[b]	Little Eagle	Spotted Harrier[b]	
			Ocyphaps lophotes	*Hieraaetus morphnoides*	*Circis assimilis*	
			Dollarbird	Little Raven ↑	Spotted Pardalote	
			Eurystomus orientalis	*Cor. mellori*	*Par. punctatus*	
			Eastern Rosella ↓	Magpie Lark ↑	Straw- necked Ibis	
			P. eximius	*Grallina cyanoleuca*	*T. spinicollis*	

[a]*birds showing strong evidence ($p < 0.05$) of a positive relationship between the probability of occupancy and planting-size and planting-shape index.*
[b]*birds showing a negative response to the planting-size and planting-shape index.*
↑ and ↓, birds designated by Reid (1999) as increasing or declining, respectively.

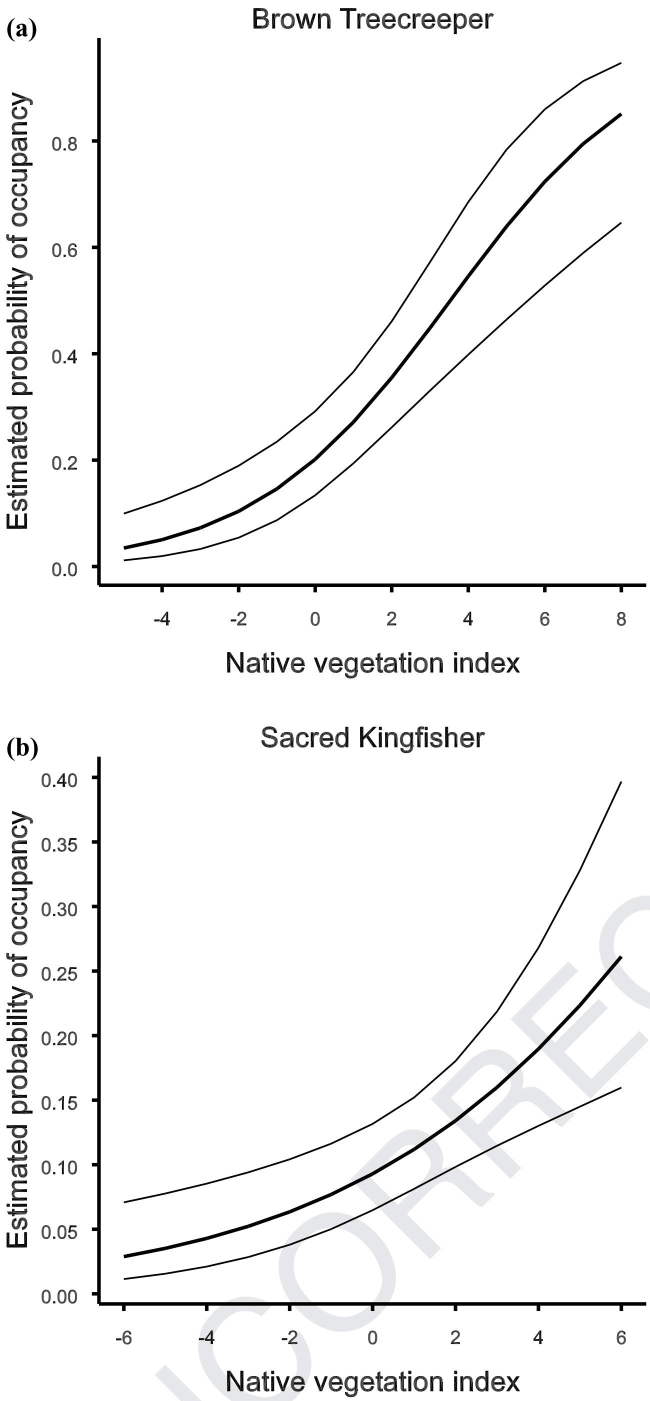

Figure 1. The predicted relationship between occupancy rate and the native-vegetation farm index, and associated 95% confidence intervals for (a) Brown Treecreepers and (b) Sacred Kingfishers.

significantly to the planting-size and planting-shape index included the Red-capped Robin and the Buff-rumped Thornbill (Table 2). A positive effect (e.g., Red-capped Robin) corresponded to bird species more likely to occur on farms characterized by many plantings, in particular, many large, elliptical, or block-shaped plantings.

Bird Species Richness and Farm Vegetation

Seventeen species (termed group 1 birds) responded positively to both the presence of tree plantings and planting size and shape (Table 2), and 37 species (group 2) responded positively to the remnant native-vegetation index (Table 2). On average, an additional 3.4 (95% CI: 1.9, 4.9) species from group 1 were present on farms with plantings, of which farms with >20 ha of plantings had 1 additional species. Furthermore, the effect of planting was significantly ($p = 0.036$) greater on farms with low to medium values for the remnant native-vegetation index (4.7 species, 95% CI: 2.9, 6.5) compared with farms with high values for the remnant native-vegetation index (0.5 species from group 1). On average, for a 2-unit increase in the native-vegetation index, 3 (95% CI: 2, 5) additional species from group 2 were added.

Summing predicted probabilities of occupancy for different levels of the indices showed the expected increase in the number of species of group 1 due to plantings was 1.6 (95% CI: 1.33,1.71) for a given farm. Conversely, the expected loss in species of group 2 due to extensive clearing of native vegetation was 7.0 (95% CI: 6.6–7.4) per farm.

Farms with a high value for the remnant native-vegetation index and that supported plantings (particularly many large planted areas) were those on which the overall number of bird species was maximized (Fig. 2).

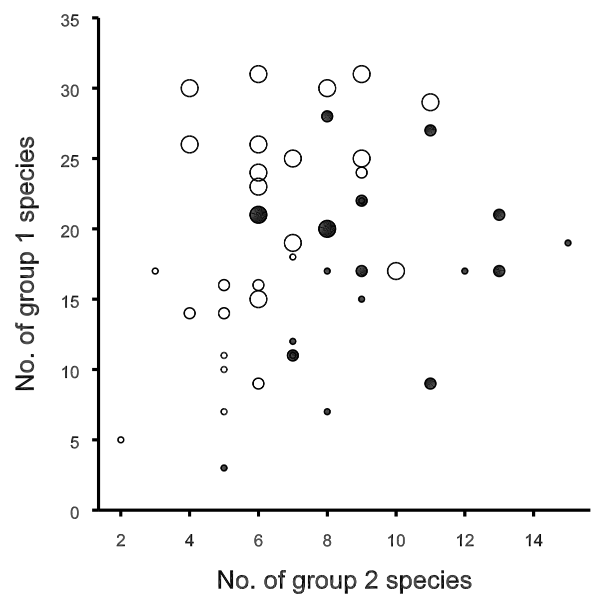

Figure 2. Number of species from group 2 (exhibit a positive response to native-plant index) versus the number of species from group 1 (exhibit a positive response to tree plantings) for 46 farms. The size of the symbols correspond to the lower, middle, and upper tercile values of the remnant native-vegetation index. Solid symbols correspond to farms with plantings.

Farms with high values for the remnant native-vegetation index were typically those most likely to support birds of high conservation value (e.g., declining or vulnerable species), although farms with large plantings also can be important for some individual species of conservation concern (Table 2).

Discussion

We classified bird species according to their responses to the effects of remnant native vegetation and planted areas and highlighted the responses of threatened and declining species. Our results offer new insights into how species respond individually and collectively to remnant native vegetation and plantings on farms. They have broad relevance to conservation programs and restoration efforts on farms elsewhere around the world, including the Americas and Europe, where biodiversity management is an important part of better-informed agricultural production (e.g., Kerr & Deguise 2004; Laiolo 2004; Vandermeer & Perfecto, 2007) and a fundamental part of agroenvironment schemes (Kleijn & Sutherland 2003; Kleijn et al. 2004).

Responses to Farm-Level Remnant Native Vegetation

Many bird species responded strongly to the joint effect of a range of different remnant native-vegetation attributes that occur on a farm—the occurrence of large blocks of woodland remnants, the number of scattered paddock trees, and the amount of native grassland. This finding highlights the importance of individual elements of remnant vegetation structure and composition and demonstrates they have a combined effect on the response of many species. Many of the species that responded positively to the remnant native-vegetation index (Table 2) have declined substantially in the past few decades (Reid 1999; Barrett et al. 2003) and for which there are major conservation concerns. Examples are the Brown Treecreeper (Cooper & Walters 2002), Jacky Winter (ACT Government 2004), and Crested Shrike-Tit (Ford et al. 2001). A range of factors may underpin these declines and no single threatening process or combination of processes appears to be common to the array of declining woodland-bird taxa (Ford et al. 2001).

Quantifying Revegetation Effects

Our results highlight the importance of tree-planting programs for bird conservation on grazing and cropping properties and the complementary role played by planted areas and existing remnant native-vegetation cover on farms (e.g., scattered paddock trees, native pastures, and woodland remnants) (Fig. 2). Furthermore, for a given farm there would be an expected increase of 2 bird species from group 1 due to the establishment of tree plantings, but an expected loss of 7 species from group 2 if remnant native vegetation was cleared. Thus, one of the key findings of this study was that not only did we identify candidate species that benefit from tree planting but we also estimated the average gain in species richness. Conversely, we nominated possible taxa lost and the average loss in species richness due to extensive clearing of remnant native vegetation.

We found an important interaction effect between remnant native vegetation and planted native vegetation on bird species richness. Plantings added more taxa to overall species richness when a farm had a low remnant native-vegetation index than when values for this index were high.

In terms of species gained, the remnant native-vegetation index was more important than the planting-presence index, roughly by a ratio of 3:1. Nevertheless, some birds responded negatively to the remnant native-vegetation index. Thus, it is plausible that some extra species may be recruited by having areas of a farm with low remnant native-vegetation index (i.e., highly modified areas) (Fig. 2), but none of them would be of conservation concern.

Individual Species of Conservation Concern

We identified interesting patterns for a number of high-profile declining woodland birds. For example, several studies have raised concerns about the decline of the Brown Treecreeper and highlighted problems with the dispersal ability of the species (Walters et al. 1999; Doerr & Doerr 2005). We identified a strong positive relationship between the remnant native-vegetation index and the probability of occurrence of the Brown Treecreeper (Table 2). Conversely, the species was less likely to occur on farms with plantings (Table 2). Perhaps, the negative-planting result was an outcome of the limited quantities of dead timber and hence suitable foraging habitat for the Brown Treecreeper in planted areas (M.C. et al., unpublished data). This accords with knowledge of the habitat requirements of the species, such as its preference for areas with large quantities of fallen timber (Laven & Mac Nally 1997). Two tentative conclusions from these findings are that (1) conservation efforts for the species might be best focused on farms that already exhibit high levels of native-vegetation cover (where birds are more likely to occur) and (2) it may take many years before farm plantings support the kinds of attributes that make such areas suitable for the Brown Treecreeper.

The extensive suite of currently declining woodland bird taxa include the Diamond Firetail, Hooded Robin, Jacky Winter, Crested Shrike-Tit, Scarlet Robin, Red-capped Robin, Rufous Whistler, Speckled Warbler, Southern Whiteface, Eastern Yellow Robin, and Flame Robin (Reid 1999; Barrett et al. 2003). The first 4 species responded positively to the native-vegetation index (Table 2). This suggests they might be lost from places where there is a decline in the attributes that contribute to the remnant native-vegetation index. Of the 11 species listed earlier, only the Scarlet Robin and Rufous Whistler responded positively to the presence of plantings. Hence, our data suggest that the negative effects of losses of attributes of native vegetation for species such as the Diamond Firetail, Hooded Robin, Jacky Winter, and Crested Shrike-Tit might not be offset by planting elsewhere on a farm, at least in the short to medium term. By contrast, the Red-capped Robin showed neutral responses to the farm-level remnant native-vegetation and planting-presence indices but a strong positive response to the planting-size and planting-shape index (Table 2). One interpretation of this is that the scrubby environments often used by this species (particularly in winter in the study area) rarely occur on farms with low values for the native-vegetation index, but may be created in large planted areas. Finally, 4 species—the Speckled Warbler, Southern Whiteface, Eastern Yellow Robin, and Flame Robin—showed neutral responses to all indices we constructed, suggesting there are other unidentified factors influencing their distribution and abundance.

Our results for a suite of bird species of conservation importance indicate that (1) remnant native vegetation on farms is critical for many declining bird species, (2) plantings provide suitable habitats per se for 3 of them, and may potentially offset the loss of remnant native vegetation, but (3) for other species, plantings may not offset such losses of native vegetation, at least not for decades into the future.

Management Implications

Approaches that enhance the conservation value of farms are not always straightforward (Fischer et al. 2008, in press). This is particularly true when different types of vegetation can occur on a single farm and the value of this vegetation for biota may have combined effects (Sekercioglu et al. 2007). Our results demonstrate that many components of remnant native vegetation can have significant positive benefits for farmland birds. Moreover, through the development of composite indices, we have highlighted their combined effects on birds as well as their cumulative (and/or complementary) contribution to bird responses made by planted native vegetation. Hence, discussions about the integration of conservation and production on farms need to extend beyond conserving patches of remnant native woodland above a certain size (Freudenberger 1999) or maintaining particular levels of vegetation cover above perceived threshold values (e.g., 30% see Lindenmayer & Luck 2005). Given this, one of our key management recommendations is to manage farms in ways that ensure they support many components of native-vegetation cover (see also Barrett et al. 1994; Barrett 2000).

We make an additional recommendation that relates to prioritizing vegetation management. That is, for most farms and most bird species, biodiversity management should focus first on conserving and enhancing existing areas of remnant native vegetation and second on planting. This recommendation is based on the relative contribution these sets of features make to bird species richness and the occurrence of particular species of woodland birds that are declining and that can occur on a farm.

The combined effects of different vegetation elements on farm birds—that is, landscape heterogeneity (sensu Forman 1995)—was highlighted in this investigation. Our findings echo the results of other studies around the world that emphasize the critical importance of landscape heterogeneity for the persistence of native biota in agriculture-dominated systems. These include investigations in northern and southern Europe (Benton et al. 2003; Laiolo 2004; Tscharntke et al. 2005), North America (Kerr & Deguise 2004), Central America (Daily et al. 2001; Ricketts et al., 2001; Mayfield & Daily 2005), and Africa (reviewed by Manning et al. 2006). For example, Benton et al. (2003) recognize that a key step toward conserving biodiversity in agricultural areas in Europe is maintaining and restoring heterogeneity within and between fields on farms.

Our findings also reinforce the additional contribution to the persistence of biota made by relatively small native-vegetation elements such as native grassland, scattered paddock trees, and small remnants (see also Schwartz & Mantgem 1997; McCoy & Mushinsky 1999; Fischer & Lindenmayer 2002; Manning et al. 2006; Harvey et al. 2007). Hence, these kinds of structures and small areas should not be ignored simply because they are small (Sekercioglu et al. 2007). The corollary is that combined losses of these vegetation elements through activities such as agricultural intensification have the potential to lead to significant losses of farmland biodiversity (Benton et al. 2003; Laiolo 2004; Tscharntke et al. 2005).

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Supplementary Material

A list of birds recorded in repeat surveys (Appendix S1) is available as part of the on-line article from http://www.blackwell-synergy.com/. The author is responsible for the content and functionality of these materials. Queries (other than absence of the material) should be directed to the corresponding author.

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Queries

Q1 Author: Please add the reference "Barrett et al. (2005)" to the list.

Q2 Author: Please note that the year "1988" in the citation "McCullagh & Neldner (1988)" has been changed to "1989" throughout to match with the entry in the list. Is it OK?

Q3 Author: Please note that the year "1980" in the citation "Digby & Kimpton 1980" has been changed to "1987" throughout to match with the entry in the list. Is it OK?

Q4 Author: The references "Bennett et al. (2000)," "Cooper et al. (2002)," "Lindenmayer & Fischer (2006)," "Pressey et al. (2000)," and "Whitfield (2006)" are not cited in the text, so please delete them from the list.

Q5 Author: Please update the reference "Fischer et al. (2008)."