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Interactions between almond plantations and native ecosystems: Lessons learned from north-western Victoria

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Five years of research on interrelationships between fauna use of almond plantations and native vegetation in north-western Victoria shows that almond plantations have a strong influence on fauna dynamics and in some cases may provide important habitat for threatened species.

Key words: *agricultural ecosystem, almonds, ecosystem services, mallee, regent parrot, threatened species.*

Figure 1. Almond plantations in north-western Victoria. Photo by Hugh McGregor (Inset photo: James Abell).

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Introduction

Worldwide, clearing and modification of native ecosystems for agriculture is a major threat to biodiversity conservation (Foley *et al.* 2005). In Australia, agricultural production covers more than 60% of the continent (Australian Bureau of Agricultural and Resource Economics and Sciences 2010). The most extensive land uses are livestock grazing of native grasslands or improved pasture and dryland cropping (e.g. wheat

Figure 2. Regent parrot (left) and malleefowl (right) – two endangered species frequently observed in almond plantations. Photos by Hugh McGregor and Manu Saunders.

and barley). In recent decades, some agricultural regions have experienced greater diversification of land uses and increasingly rapid changes in land-use type with substantial implications for biodiversity conservation (Watson *et al.* in press).

While agricultural land and native ecosystems are strongly interacting components of broader agro-ecosystems, surprisingly little is known about the contribution of agriculture to species conservation in Australia or how species behaviour may impact production (Triplett *et al.* 2012). Studies of biodiversity in agricultural landscapes in Australia have mostly focussed on patches of native habitat explicitly excluding all non-native vegetation. This misleading dichotomy between 'habitat' and 'nonhabitat' remains despite the recognised importance of farms in providing food for native fauna (Walcott 2004) or promoting the persistence of some species (Fuller *et al.* 2004). For example, in Europe, conservation management of certain species (e.g. Yellowhammer *Emberiza citronella*; Marsh Fritillary Butterfly *Euphydryas aurinia*) depends on the targeted manipulation of on-farm resources, and there is a concerted effort to reduce the intensification of land use to stem declines in species occurring on farmland (e.g. Vickery *et al.* 2004).

Here, we summarise the findings of multiple research projects conducted in almond plantations and surrounding native vegetation in north-western Victoria (Fig. 1). These projects aimed to document the composition and behaviour of fauna communities using almond orchards and interactions with adjacent native vegetation. We also describe broader lessons learned as members of a large academic–industry–government collaboration. Prior to our research, little was known about animal use of almond plantations. The plantations in north-western Victoria abut important conservation areas within the Mallee region, including habitat for threatened species such as the malleefowl (*Leipoa ocellata*) and regent parrot (*Polytelis anthopeplus*), both of which have been recorded using almond groves (Fig. 2). We focus specifically on the findings of our research projects rather than provide a detailed critique of the almond industry. Nevertheless, our comments should be viewed within a broader context that reflects on other positive and negative aspects of growing almonds such as the impact of water extraction for irrigation on river health or the impact on native ecosystems of importing millions of European honeybees (*Apis mellifera*) for almond pollination.

Biodiversity on Farms and Implications for Conservation and Production

Study area and land-use history

Our work was conducted in the region surrounding the town of Robinvale—an area that supports a diverse array of agricultural land uses (Fig. 3). The study area is part of the 'mallee'; a term that describes the region, a plant community and a multistemmed life form of *Eucalyptus*. The mallee region of south-eastern

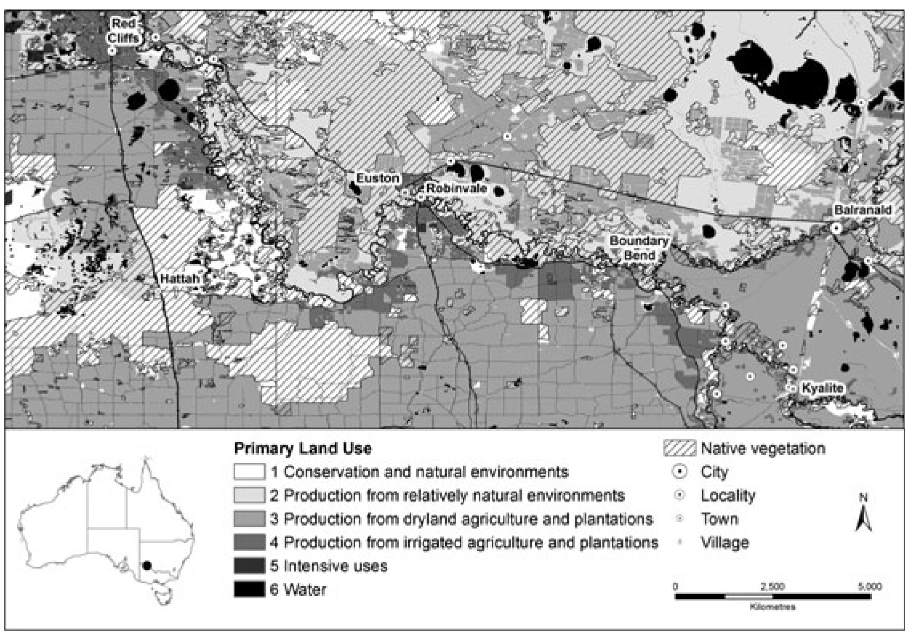

Figure 3. Map of the study area showing major land uses.

Table 1. Summary of land-use change in the Victorian mallee – Robinvale district*

Time period	Land-use development
1840–1890	Initial exploration of region; first livestock grazing carried out – peaked in the 1880s; initial attempts at dryland cropping 1870–1880s. Expansion of agriculture characterised by a cycle of failure and resettlement, principally as a result of climate extremes
1890–1930s	Land clearing expands and accelerates, assisted by the invention of the mallee roller and stump-jump plough. Increased grazing pressure in association with drought, locust and rabbit plagues cause extensive soil erosion leading to abandonment of many landholdings (e.g. soldier settlement blocks developed after World War I)
1940–1970	Development of irrigation along waterways, decline in grazing industry, further development of dryland farming systems using stubble retention and protection of land for biodiversity conservation. Influxes of European migrants post-World War II accelerate grape and horticultural development
1970–present	Expansion of irrigation, development of sustainable agriculture and expansion of biodiversity conservation practices. New influxes of Pacific islander migrants provide workforce for new land-use economies at large scales (>10 000 ha)
1990s–present	Rapid expansion of large-scale irrigated horticulture via large company and international investments (75% increase, from 40 185 ha in 1997 to 70 315 ha in 2009). Abandonment of traditional land uses in some areas (e.g. cereal cropping, grazing and citrus) due to booming wine and almond industries

*Adapted from Kenyon (1982); Land Conservation Council (1987); Cooke (2006); Mallee Catchment Management Authority (2008, 2010); Migration Memories (2009).

Australia spans semi-arid to temperate climates (mean annual rainfall of 250–450 mm) and is dominated by mallee plant communities that are characterised by eucalypts with a mallee growth form (i.e. multistemmed trees or shrubs that possess a lignotuber at or beneath the soil surface) (Pell *et al.* 2001; White 2006).

The region's post-settlement land-use history is considerable and has been reviewed by various authors (Table 1). Land uses have undergone numerous changes over time, ranging from a predominance of livestock grazing in the mid–late 1800s, through to cereal cropping in the 1900s, and the spread of irrigated horticulture post-World War II (e.g. grape, citrus and olives). Since the 1970s, intensification practices have led to considerable variation in agricultural land uses, which frequently change in relation to climate, commodity prices and socio-economic factors (Cooke 2006; Duncan *et al.* 2008). The area of almond plantations in north-western Victoria grew rapidly from 2000 to 2012, expanding from 2000 ha to over 20 000 ha. Almond production is predicted to reach an annual yield of 88 000 tonnes by 2016 (Almond Board of Australia 2013).

Native vegetation in the mallee region is now restricted to sandy soils mostly unsuitable for conventional agriculture and is predominantly confined to conservation reserves (Cooke 2006). In the Murray mallee bioregion, where soils are better suited to agriculture, most native vegetation on private land is cleared (<5% remains) and is primarily confined to linear strips in roadside corridors (Mallee Catchment Management Authority 2008). Continuous grazing by livestock and other introduced herbivores of public lands often results in the loss of cryptogramic soil crusts, an understorey dominated by exotic annual grasses and a lack of regeneration of woody species (Sandell 2006; Read *et al.* 2008).

The rapid and large-scale spread of treed horticulture throughout north-western Victoria means that traditional views of mallee 'agriculture' characterised by large, open cropping paddocks are no longer relevant in certain areas. Instead, many blocks of former cropping land, bounded by the roadside vegetation network, have been effectively 'infilled' by the establishment of thousands of hectares of horticultural trees. Understanding the interrelationships between the flora and fauna communities of new land covers and native vegetation is the vital for effective conservation management in the region.

Design of projects

We highlight major outcomes from various projects conducted within almond plantations and surrounding native vegetation during 2008–2012. Project 1 was a broad-scale comparison of bird communities in almond orchards and adjacent black box (*Eucalyptus largiflorens*), mallee and red gum (*Eucalyptus camaldulensis*) woodlands. Thirty variable-width line transects per vegetation type were sampled using distance sampling methods four times over 12 months to record species richness and abundance. Project 2 was targeted sampling of a small suite of birds (mostly parrots and cockatoos) that have been recorded eating almonds. Bird occurrence and abundance in almond plantations were surveyed during the almond growing seasons of 2009/10 (four plantations, 15 transects) and 2010/11 (eight plantations, 32 transects) (see Luck *et al.* 2013). We also recorded crop damage rates attributable to certain bird species. Project 3 was an exclusion experiment to quantify both the amount and cost of damage birds inflict on almond crops, and the value of the ecosystem service provided by birds postharvest. A total of 120 trees (60 netted to exclude birds; and 60 left open) were included

Box 1. Conserving Threatened Species: The Case of the Regent Parrot

In north-western Victoria, the regent parrot is restricted to semi-arid mallee shrubland and red gum forests. It has experienced a marked range contraction and reduction in population size since European settlement (Higgins 1999). Regent parrots nest in tree hollows in red gum forests and make daily movements away from these breeding areas to roost and forage in mallee vegetation, where they feed on a variety of food items, dominated by immature seed from *Acacia*, *Dodonea* and chenopods as well as nectar from *Eremophila* and *Eucalyptus*. However, the parrot also feeds on agricultural crops such as wheat, barley, oats, grapes, olives and almonds (Burbidge 1985; Luck *et al.* 2013; unpublished data). Consequently, the increased availability of almonds in north-western Victoria is likely to have resulted in a substantial change to the spatial location and temporal availability of food resources across the landscape compared to annual crops such as wheat. This is because almonds are available to birds for around 6 months of the year (even longer considering residual nuts left on trees and the ground postharvest), and almond plantations are more accessible than annual crops because they provide roost and shelter sites. At particular times of the year, almonds can form a large part of the diet of regent parrots (unpublished data), although we do not know what proportion of the population relies on almonds for food.

Breeding by regent parrots only occurs in landscapes with extensive mallee vegetation remaining in close proximity to red gum forests (Burbidge 1985). Furthermore, the spatial structure of landscapes affects the distribution of nesting sites. The probability of nesting increases with greater connectivity between red gum forests and mallee vegetation. When flying, regent parrots largely follow vegetated corridors and are reluctant to fly over more open land (Higgins 1999; Baker-Gabb & Hurley 2011). However, regent parrots readily use almond groves as movement corridors, and we routinely recorded them feeding in this crop throughout the 15 000 ha plantation estate (Luck *et al.* 2013). The rapid expansion of almonds has affected the spatial structure of landscapes and possibly the movement patterns of the regent parrot.

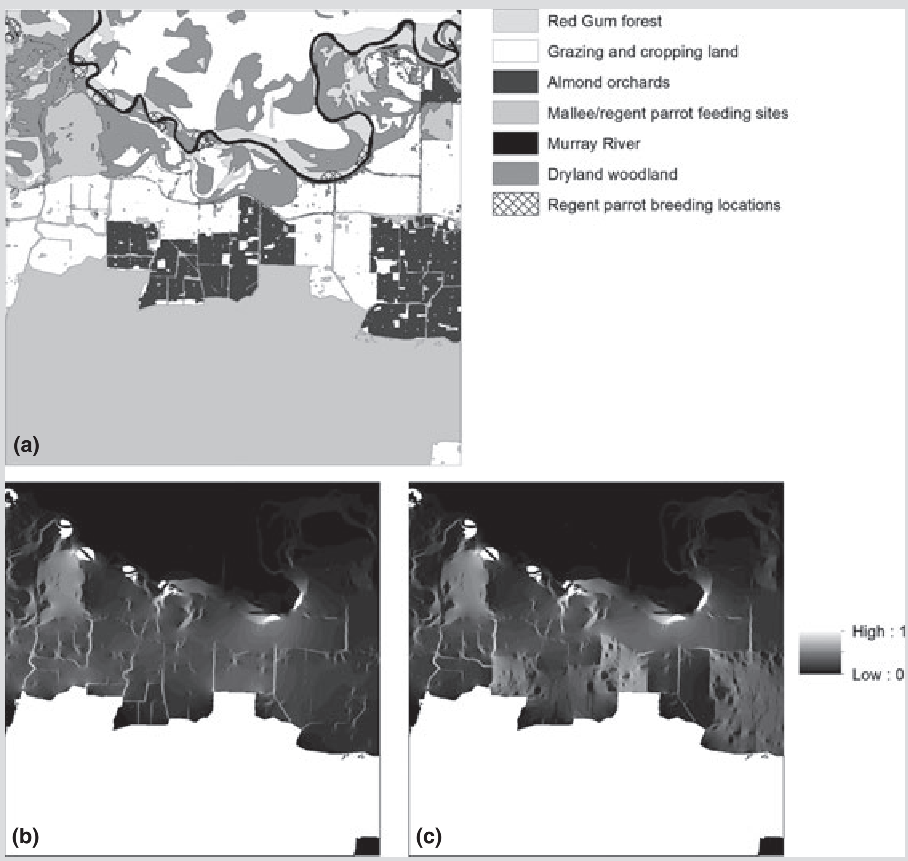

Figure 6. Regent parrot breeding and feeding locations and the influence of land cover on possible movement patterns. (a) Distribution of breeding and feeding locations and agricultural land covers. (b) Modelled scenario for regent parrot movements, where only red gum forest and mallee woodland facilitate movement. (c) Modelled scenario whereby almonds facilitate movements similar to red gum forest and mallee woodland.

Box 1. (Continued)

We modelled the expected intensity of movement through a landscape from a breeding location to large mallee blocks using circuit theory (McRae *et al.* 2008) and the software program Circuitscape (McRae & Shah 2011). Our analysis highlights the effects that almond groves could have on the intensity of parrot movement through the landscape, particularly affecting its' reliance on roadside corridors (Fig. 6). In the first modelled scenario, red gum forest and mallee woodland facilitate movement, but dryland woodland, cleared agricultural land and almond orchards are 10 times more resistant to movement (Fig. 6b). Assuming no movement through almonds, regent parrots are entirely reliant on roadside corridors of native vegetation to move between their breeding sites and feeding sites. However, if almond orchards facilitate movement (as field data suggest), the presence of orchards between red gum and mallee woodlands will, in some cases, enhance landscape connectivity for the parrot (see Fig. 6c).

Changing land covers in the production landscapes of north-western Victoria, particularly the expansion of almonds, has the potential to benefit regent parrot conservation. As broad-acre cereal crops are replaced with orchards of almonds, increased tree cover may improve connectivity between isolated remnants of core habitats. Moreover, almonds appear to provide a food resource that is especially important during times of low food availability in adjacent native vegetation (Luck *et al.* 2013). The expansion of almond crops could potentially result in a range expansion and population increases for the regent parrot, a possibility to be monitored over time. Contrastingly, we hypothesise that large-scale clearance of almonds could result in local population declines unless steps are taken to restore more areas of native vegetation used by parrots for movement and feeding. Conservation managers need to be acutely aware of the interrelationships between native species and agricultural land uses, and understand how changing economic and social conditions within the agricultural industry may impact on species conservation.

in the experiment pre- and postharvest, and nut loss from birds or other factors (e.g. wind and storm damage) was measured and quantified in monetary terms (unpublished data).

In Project 4, we explored how the juxtaposition between almond plantations and native vegetation may impact on the life history of the threatened regent parrot. The regent parrot is an intriguing case because, despite historic population declines (Baker-Gabb & Hurley 2011), large numbers of the species have been recently recorded feeding on almonds. We focus specifically on how the presence of almond plantations may change the connectivity of the landscape for the regent parrot using a mix of field observations of parrot movements and modelling of flight paths (Box 1).

Project 5 was an examination of insect communities in conventional and biodynamic almond orchards and adjacent mallee vegetation, focussing particularly on potential pollinators. Almond trees rely entirely on cross-pollination by insects to produce nuts and flowering trees attract a wide range of native pollinators (Hill *et al.* 1985; Cunningham *et al.* 2002; Klein *et al.* 2012). However, little is known about the capacity of Australian almond orchards to support native pollinating insects or the impact that almond orchards may have on insect populations in native habitats. We sampled insects using pan traps during two flowering seasons (July–September 2010 and 2011). In 2010, we sampled 30 sites in conventional almond plantations, 27 sites in biodynamic almond plantations and 43 sites in mallee woodland. In 2011, we sampled 50 conventional almond sites and 18 mallee sites (see Saunders & Luck 2013; Saunders *et al.* 2013). Finally, Project 6 involved a large (~400 km^2) and innovative survey of the regent parrot by research scientists, local field naturalists and industry staff (Box 2).

Major outcomes

We recorded a cumulative total of 58 native bird species and one introduced species (common blackbird *Turdus merula*) using almond plantations (Table S2). Based on spring and summer surveys, cumulative species richness in almonds (59) was less than in nearby red gum forests (66 species), but more than mallee woodland (54) and black box woodland (53) (Fig. 4). The regent parrot and yellow rosella (*Platycercus elegans flaveolus*) were the most abundant species in orchards, while honeyeaters were most abundant in mallee and black box woodland (Fig. 4). We also recorded 35 insectivorous bird species in almonds, and these species may help to control outbreaks of pest insects such as the carob moth (*Ectomyelois ceratoniae*).

Thirteen bird species have been recorded feeding on almonds, but little is known about the relative contribution of different species to crop damage. Our work suggests that cockatoo species occurring in large flocks such as the sulphur-crested cockatoo (*Cacatua galerita*) and galah (*Eolophus roseicapillus*) are especially damaging, consuming up to 30% of the standing crop of nuts on affected trees (as we recorded in one location), but this damage is extremely localised – only occurring on a few

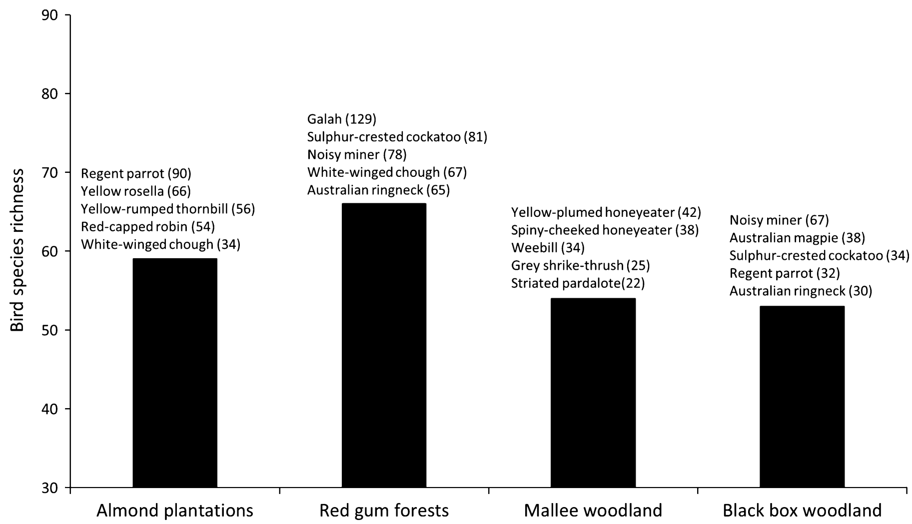

Figure 4. Cumulative bird species richness and common bird species recorded in almond plantations compared to major native vegetation types in the study area. Data are from spring and summer surveys conducted in 2010 and 2011, based on 30 transects (~2 ha each, surveyed for 20 minutes) in each vegetation type. Lists above columns show the five most abundant bird species in each vegetation type; numbers in brackets are number of individuals recorded per survey.

trees per orchard block (an average block contains approximately 4000 trees) (Luck *et al.* 2013). Conversely, the regent parrot and smaller parrots such as the yellow rosella and Australian ringneck (*Barnardius zonarius*) cause much less damage (consuming approximately 1–2% of nuts on affected trees), but over a much wider area. Across all bird species, we found that damage to almond crops is relatively low in many cases being <4%, on average, of nuts on affected trees with >40% of 32 transects having <1% damage across all trees.

While there is substantial spatial variability in bird damage to almonds, we were unable to disentangle the principal drivers of this variability. Small parrots were more likely to occur in almond orchards located close to riverine vegetation, but no such associations were identified for other species (Luck *et al.* 2013). However, we also identified substantial interannual variability in bird use of almonds, possibly driven by differences in climate and broader food availability. In the dry growing season of 2009/10 (October–March), at the tail end of an extended drought in northern Victoria, the density of birds that feed on almonds was 2.67 birds per km whereas in the wet season of 2010/11, bird density was 0.78 birds per km. We hypothesise that much higher rainfall in 2010/11 led to greater availability of food resources for parrots both in native vegetation and from other crops (e.g. wheat production increased dramatically in 2010/11 compared to 2009/10).

While bird consumption of almonds can reduce crop yield preharvest, almond consumption postharvest can benefit growers. During harvest, some nuts fail to drop from trees. These residual nuts (referred to as 'mummy' nuts) can act as reservoirs for fungal and insect pathogens that may affect future crop yields. To reduce this threat, growers may remove mummy nuts using a mechanical tree shaker or by hand poling (manually knocking nuts from trees). However, birds also eat mummy nuts left on trees, thereby providing an ecosystem service to growers because it reduces the need for mechanical or manual removal of nuts. We found that the economic benefit of this ecosystem service outweighs the cost of bird damage to almonds preharvest by around $25–$275/ha, resulting in a positive net return to growers from bird activity in almond orchards (unpublished data).

In addition to birds, we also found various native insect pollinators in almond plantations under certain circumstances (Table S1). We use the term pollinators here because it is standard practice in the pollination literature to use the general, descriptive term 'pollinators' when referring to the taxa we surveyed. However, it is important to note that we did not record the actual contribution of these species to almond pollination, other than observing species visiting almond flowers. We compared wild pollinator communities in mallee vegetation with communities in two types of almond plantation—broadacre monoculture plantations (MONO) managed conventionally (insecticide free), and small, plant-diverse farms (GRASS) managed either conventionally or biodynamically, but maintaining herbaceous ground cover across the orchard floor (Saunders & Luck 2013; Saunders *et al.* 2013). Bees, flies and wasps were more abundant in GRASS orchards compared to mallee vegetation or MONO plantations (Saunders *et al.* 2013). We also found a positive relationship between the proportion of ground cover vegetation in each site and total pollinator insect abundance (Fig. 5).

In 2011, we compared pollinator communities between monoculture plantations and adjacent mallee vegetation before, during and after the critical almond flowering period, and investigated whether site-scale vegetation heterogeneity (within 10 m of trapping sites) and resource availability (i.e. food resources or nesting sites) influenced pollinator communities. Flies preferred heterogeneous sites in July when plantations were devoid of resources, but their abundance and richness increased significantly in plantations during

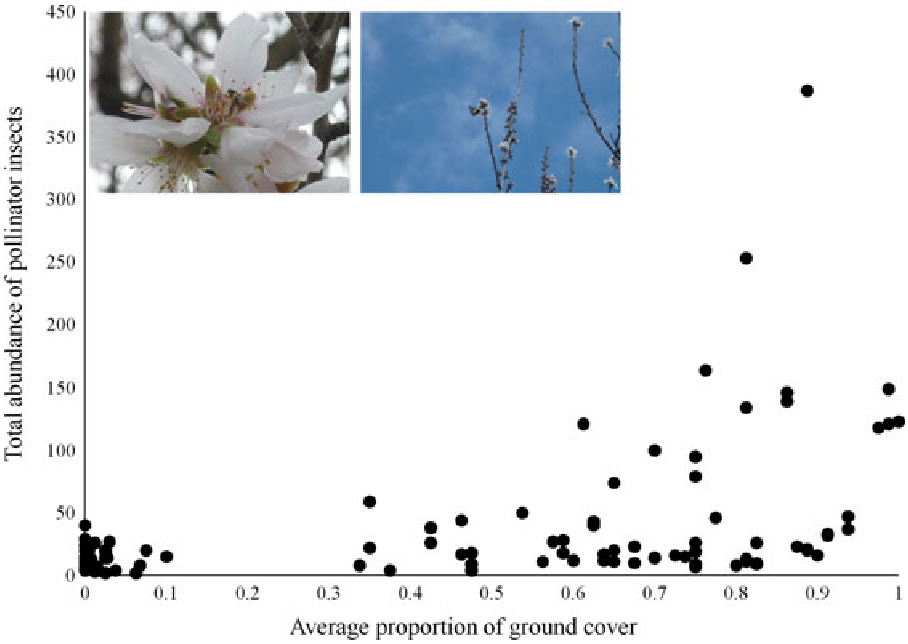

Figure 5. Total abundance of potential pollinators was higher at sites with a greater proportion of ground cover vegetation. Photos by Manu Saunders.

flowering in August, remaining high in September. Wasps preferred more heterogeneous sites, however, both before and during the mass-flowering event, and did not increase in plantations until September, coinciding with an increase in the diversity of available resources including spent flowers, leaves, fruits and herbivorous insects. Native bees did not appear in monoculture plantations until after flowering in September, but were present in low numbers in mallee vegetation while almonds were flowering. We also collected non-*Apis* bees during almond flowering in 2010, but only in plant-diverse orchards and mallee vegetation.

Implications of research findings

A surprisingly large number of bird species use almond orchards, particularly where they are adjacent to native vegetation. Treed horticultural crops attract birds for various reasons, including providing roosting, feeding and nesting sites, as well as cover from predators and adverse climate conditions. Almond plantations may contribute to supporting local bird populations, underscoring the need to manage agro-ecosystems holistically based on an understanding of the interactions occurring between agricultural land uses and native ecosystems. Importantly though, almond plantations are likely only acting as a supplementary resource to remnant native vegetation, which is the principal and vital habitat supporting most native species using almonds.

At least 13 bird species in our study area eat almonds, apparently when other food resources are limited. This has substantial implications for both crop management and bird conservation. Wholesale clearance of almond plantations, without concomitant increases in other food resources, would reduce overall food availability for many resident fauna including threatened species like the regent parrot. Conservation management agencies, farmers and agriculture industries need to understand how different land uses may contribute to species persistence and ensure management strategies incorporate the complex interactions occurring between native and agricultural systems.

While bird consumption of almonds can impose costs on growers by reducing crop yield, consumption of almonds left on trees postharvest can benefit growers by reducing threats from fungal and insect infestations. In agricultural landscapes, there are many circumstances where the activity of the same suite of species can yield both costs and benefits dependent on context. For example, while bees can benefit growers by pollinating crops, they may also pollinate agricultural weeds that subsequently impact negatively on production. Researchers and land managers tend to examine benefits (through ecosystem services) and costs separately, and greater attention is required to quantifying cost-benefit trade-offs.

Under certain circumstances, commercial almond plantations in the mallee have high potential to supplement native vegetation in the conservation of at least a proportion of native insects, and pollen-limited almond crops can benefit from the diverse wild pollinator communities in mallee woodlands. Native bees are the most recognisable group of wild pollinators, but we recorded numerous fly, wasp and butterfly species on almond flowers. Flies and wasps are especially valuable, as they double as biological control agents, parasitising herbivorous pest species that can damage almond crops.

Maintaining wild pollinator communities throughout plantations will depend on sustained ecological management of almond systems, in particular, the preservation of vegetation heterogeneity and resource diversity, in addition to the maintenance of nearby native vegetation. In conventional orchards with little ground cover, native pollinators occur only in small numbers and cannot compensate for the pollination services delivered by European honeybees, which are trucked into orchards in their millions. A decline in managed honeybee stocks would seriously impact production of pollinator-dependent crops like almond, and the benefits of providing wild pollinator habitat in agroecosystems is being increasingly recognised (e.g. Rader *et al.* 2011; Adamson *et al.* 2012; Fabian *et al.* 2013).

It appears almond plantations in north-western Victoria are helping to support at least a proportion of the regent parrot population, as large numbers of the species are regularly recorded using the plantations for feeding and as movement corridors. Almond orchards may supplement existing native vegetation corridors, and provide habitat to feed in, or move through, depending on landscape context (Boxes 1 and 2). Further work is required to explore this relationship in depth, but our results raise the intriguing and problematic possibility of a production land use providing support for a threatened species (which could also be occurring through the use of wheat fields for food by regent parrots). In this context, integrated management among conservation agencies and industry bodies is needed to promote species persistence. Most importantly, further research needs to determine whether any species are using almond orchards for breeding or throughout their entire life cycle, rather than just for particular purposes (e.g. food) at certain times of the year.

Broader Lessons Learned

Working with industry partners and government agencies

Our projects were a collaboration between Charles Sturt University (CSU), Select Harvests Limited (SH; major almond grower), the Victorian Department of Sustainability and Environment (DSE) and the NSW Office of Environment and Heritage (OEH). Research–industry–management partnerships such as these are critical for developing sustainable land practices, and ours represented an opportunity to conserve endangered species and improve land management practices over large scales. Ecological research within farmland is vital for forging closer collaborations between scientists, government agencies, farmers and agribusiness, and for promoting the idea that species conservation and management is something to consider across all land uses – not just within the shrinking pockets of remnant native vegetation.

When our research began, one of the major challenges for CSU was to address the needs of the industry partner. SH had entered the relationship following problems with their existing bird management program, and the fact that one of the birds deemed a ‘pest’ was an endangered species (regent parrot). The difficulty for SH at the time was that there was no formal recognition of regent parrots using almonds. Rather, this species was thought to be largely confined to remnant vegetation. Consequently, conservation managers were reluctant to identify the potential benefits of almond plantations for regent parrots or other native species. There were substantial knowledge gaps and resultant communication barriers between conservation and land managers, contributed to in part by a lack of systematic monitoring outside the reserve system. This impacted on the effective management of the landscape in ways that protected native species and reduced crop losses.

As studies of other conservation partnerships have shown, individuals and groups are more likely to comply and commit themselves to long-term conservation strategies when their knowledge and opinions are heard and incorporated into decision-making processes (Andrade & Rhodes 2012). Therefore, a major aim of our research program was to foster better communication and knowledge sharing between SH and other land managers. CSU and its partners developed this relationship via regular onsite meetings, producing visually attractive and accessible summaries of research progress, attending industry conferences and undertaking training events with SH. This included workshops in bird identification and flock size estimates, leading up to a major field day in 2010 (Box 2). Experts in native bird ecology and pest bird management provided valuable contributions and shared knowledge with SH, and provided advice in relation to the company’s bird monitoring program. Ideas and information were exchanged with land managers about the interactions between native species and almonds, and on aspects of crop management that may influence bird populations.

Major challenges for staff at CSU were in managing organisational differences in understanding the importance of rigorous scientific methods (e.g. systematic sampling, replication and adequate sample size) to obtain robust estimates to quantify specific management issues and in balancing project ownership requirements across organisations. This is greatly facilitated when appropriately trained people are employed in the same position for the duration of the project. Unfortunately, staff turnover at SH created substantial barriers to effective project communication and engagement. This is an issue likely faced by many researchers working with industry partners in rural areas where both changing economic conditions and remote location can impact on job security and desirability. Clear protocols for transfer of information to new employees are needed within industry groups wishing to work collaboratively with researchers to solve management issues.

The collaboration underpinning our research expanded to include other partners such as the Mallee Catchment Management Authority and Almond Board of Australia. Conservation managers around Robinvale now better understand the possible costs and benefits of almond planta-

Box 2. 'Regent Rally' – Community Field Days to Survey Regent Parrots

The 'regent rally' was undertaken in October 2010 in the Robinvale almond production area. Over 50 staff from the industry partner SH, 15 local field naturalists, four researchers from CSU and staff from DSE and OEH stationed themselves at 65 sites between Hattah and Kenley, in a zone south of the Murray River (Fig. 7). The regent rally had the following aims: (i) to identify stakeholders and foster community engagement in the research project; (ii) raise environmental awareness at SH through knowledge sharing and technical assistance with survey methods; and (iii) to provide baseline ecological information on regent parrots (particularly distribution and abundance) to help inform future research and management. To the best of our knowledge, this is the first survey of its kind in Australia where such a large group of farm employees have conducted systematic and directed conservation-related bird surveys on company time.

The regent rally involved two main components. On day 1, training in regent parrot identification and bird flock size estimation was conducted by David Watson, primarily for almond industry workers. Many workers in this industry are migrants with limited education opportunities and local experience, while others have long-term knowledge of land management issues. Methods were developed to ensure reasonable consistency and accuracy in field bird surveys considering differences in skills and experience. This included pairing industry employees with those more confident in bird identification, such as farmers presently employed with the SH environment monitoring program.

In the evening of day 1, an informal dinner was held to foster camaraderie between SH workers and other community participants. Here, team leader Peter Spooner explained the broader aims and significance of the research, the survey methods and assigned groups or individuals to particular locations in the landscape. Field day coordinator Neil MacFarlane (mid-Murray field naturalists) did a splendid job in coordinating local community members and providing expert advice on survey locations. SH workers were assigned to their respective farms to survey regent parrots – primarily at the margins of large almond blocks. Field naturalists and other participants surveyed outside of almond orchards in locations deemed suitable for observing regent parrots (e.g. north-south orientated roadside corridors emanating from the Murray River).

On day 2, in a logistically complex exercise, participants counted regent parrots as they flew overhead at four time intervals at their respective locations (Fig. 7). The final tally was around 500 regent parrots recorded in each survey timeslot. These data, as well as information on the behaviour and flight directions of individual birds, were used to inform conservation managers and guide subsequent research work by two PhD students. This was the first time regent parrots had been simultaneously surveyed in remnant native vegetation and production areas across such a large survey area.

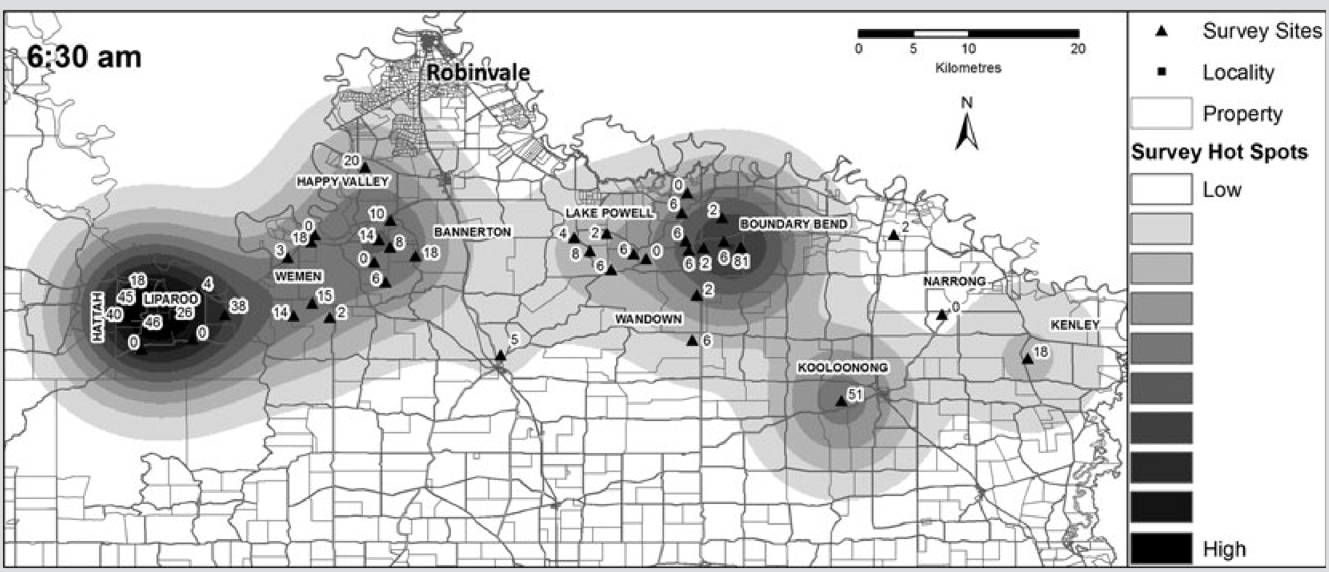

Figure 7. Survey locations for the 'regent rally', showing the number of individual regent parrots recorded at each survey point during the 6:30 am timeslot. Many survey points are within almond plantations.

tions for native species, and almond growers are more aware of both the positive and negative impacts that birds and insects might have on crop production. New ideas for restoration, conservation and farm management practices are being formulated, demonstrating the positive influence that multi-agency, ongoing research can have on developing sustainable land management practices.

Managing production landscapes to achieve conservation outcomes

Production landscapes dominated by treed crops present diverse challenges and opportunities for conservation managers. Just as parrots can be problematic for almond growers, orchards and their management create conundrums for ecologists because they are outside the normal prescription 'toolbox' for ecological restoration and management. Yet, it is clear that the presence of orchards on former cropping lands in the mallee provides benefits for some species. The first challenge lies in identifying the costs and benefits, in both conservation and production terms, associated with particular crops and the way they are or can be managed.

While conservation and production are generally considered in isolation, we believe that our research highlights substantial opportunities for integrating these activities to develop positive co-benefits for stakeholders. For example, almond growers could highlight the conservation values of orchards in their product promotion – particularly the support they provide to iconic endangered species. This may open up new markets with subsequent financial benefits. Similarly, with further demonstration of the value of almond crops to native species, conservation agencies may consider entering into innovative partnerships with growers which involve, among other things, payments to growers to help compensate for crop damage. While such an idea may seem extreme, it is not such a far stretch from past schemes that provided financial incentives to farmers to manage land for conservation (e.g. Bush Tender). The establishment of almond orchards may in some contexts (e.g.

Table 2. Comparison of the vegetation characteristics, management and biodiversity values of almond orchards and mallee woodlands

	Almond orchard (conventional block)	Mallee woodland (conservation reserve)
		
Vegetation characteristics		
Structure	*Over-storey*: single-stemmed, complex-branching tree; height 4–10 m *Middle-storey*: nil *Under-storey*: minimal herbaceous and grass cover, bare ground and some litter	*Over-storey*: multistemmed, complex-branching tree; height 6–12 m *Middle-storey*: sparse shrub and young trees *Under-storey*: hummock grass, succulents, herbs, lichens, bare ground and leaf litter
Phenology	*Deciduous*: brief, major seasonal flowering pulse (~4 weeks between July – August)	*Evergreen*: seasonal and sporadic flowering and seed set driven primarily by seasonal rainfall
Habitat/resource values	Shade and water resources for ground-dwelling species during hot summers Fruits: Sep–Jan/mature nuts: Feb–Mar and unharvested 'mummy', nuts: all seasons Good structural complexity for birds Shelter values for some fauna Crops of different age classes; no hollows	Shade available all year Fruits/flowers: available in all seasons from different species at different times Excellent structural complexity Patches of different age classes, old-growth trees providing hollows
Management of vegetation		
Disturbance regimes	Regular pruning, spraying and inspection from fruiting to harvesting and fire suppression	Low- and high-density grazing, rabbits and fire management
Pest management	Regular fox baiting, bird control via shooting to scare and gas guns, herbicide application and fungicide application	Irregular fox and rabbit control and sporadic weed management
Biodiversity interrelations		
Bird communities	*Species richness*: 59	*Species richness*: 54
Insect communities	Native pollinators in low abundance Pollinators trucked in during almond flowering period	Diverse insect community including various native pollinators present during almond flowering

strengthening known movement corridors for regent parrots) be complementary to native vegetation restoration, providing a win-win scenario for farmers and conservation managers (Table 2).

Our case study involved working with a national corporation. Recently, large areas of almond plantations (~12 000 ha) around Robinvale were purchased and are now managed by an international corporation based in South Korea (Olam International Ltd., Temasek Boulevard, Singapore). The corporatisation of food production is a major global trend with substantial social, economic and ecological ramifications (Brown 2005). It presents particular challenges for conservation management agencies whose programs are largely aimed at small-scale initiatives with individual farmers. These challenges include the potentially different emotional attachment that corporations have to particular parcels of land compared to family-run farms, and production decisions driven almost entirely by profit margins and shareholder expectations – and often made in offices remote from the production location, sometimes in another country. However, working with corporations also presents conservation managers with new opportunities based around, for example, the sensitivity a corporation has in relation to its market image (e.g. possible desire to promote a 'green image'), greater financial resources and the management of very large tracts of land by a single entity compared to negotiating access and management actions among diverse landholders.

From an ecological perspective, it is vital to better understand how different agricultural land uses impact on important ecological processes such as water retention and nutrient cycling. Documenting differences in vegetation structure and ecological processes associated with particular production land uses and the predominant native vegetation type(s) is a useful first step to understanding potential interrelationships among land covers and the resources they may provide for species (Table 2). Ecologists also need to pay more attention to documenting the groups of biota or particular taxa that are affected positively or negatively by various land-use types.

From the perspective of orchard managers wishing to improve conservation outcomes, a move away from high intensity, homogeneous, 'industrialised' orchard management to lower intensity, more heterogeneous orchards (e.g. those with living ground cover) can enhance the attractiveness of orchards for native species. The benefits of managing orchards in a more traditional sense for biodiversity (e.g. maintenance of leguminous understorey and litter for nitrogen retention, limiting insecticide use and retaining old-growth trees) have been well recognised in Europe and elsewhere (e.g. Bailey *et al.* 2010; Horak *et al.* 2013).

Key Insights

Production landscapes contain a mosaic of land uses and habitats (e.g. crop margins, roadside vegetation, dams and isolated trees) that provide a variety of features to suit particular fauna species. The key message from our work is that remnant native vegetation and horticultural crops should not be managed in isolation. Simply focusing on native vegetation for improving conservation outcomes for species such as the regent parrot would overlook important information about the potential contribution of almonds to species persistence. Likewise, a sole focus by farmers on intensive production would ignore many potential financial benefits that interactions with insects and native birds can provide. Our research has demonstrated a substantial flow of organisms across these land-cover types; nevertheless, the primary (and likely indispensable) habitat for most species in the region is the remnant native vegetation (Box 1). Just as species adapt to ongoing human land-use change, land managers and researchers also need to respond to changes in agricultural land uses, working in an integrative manner to maximise the benefits of living with nature.

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Supporting Information

Additional Supporting Information may be found in the online version of this article:

Table S1. Bird species recorded using almond plantations over four surveys conducted during the nut growing season (two surveys), almond flowering and postharvest.

Table S2. Potential wild pollinators found in each vegetation type during the 2010 and 2011 almond flowering seasons.