FORUM ARTICLE

The forgotten 60%: bird ecology and management in New Zealand's agricultural landscape

Catriona J. MacLeod[1*], Grant Blackwell[2], Henrik Moller[2], John Innes[3] and Ralph Powlesland[4]
[1]Landcare Research, PO Box 40, Lincoln 7640, New Zealand
[2]Agriculture Research Group on Sustainability, University of Otago, PO Box 56, Dunedin, New Zealand
[3]Landcare Research, Private Bag 3127, Hamilton 3240, New Zealand
[4]Research, Development and Improvement Division, Department of Conservation, PO Box 10 420, Wellington, New Zealand
*Author for correspondence (Email: macleodc@landcareresearch.co.nz)

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Abstract: Production lands make up 58% of Aotearoa New Zealand's landcover and contribute greatly not only to the national economy but also to patterns and trends in native and introduced avian biodiversity. However, unlike in native forest and other indigenous habitats, birds in agro-ecosystems have received little attention to date. We argue that this is due to (1) a research focus on understanding the causes of the dramatic decline of New Zealand's critically endangered, endemic species, (2) an adherence to a 'preservation for intrinsic value' over a 'conservation through sustainable use' paradigm for environmental management, and (3) a historical view of production landscapes as being devoid of endemic and native species and thus of no conservation value. In countering these attitudes, we suggest that the agricultural matrix may contain more native species than many people believe, and that many introduced bird species are key contributors to the social and environmental performance and resilience of these systems. We draw attention to the context, composition, ecology, and status of native and introduced birds in production landscapes in New Zealand, particularly in the face of ongoing agricultural intensification. We first identify the potential roles of local habitat, landscape composition, and introduced predators in shaping farmland bird communities. We then highlight the potential threats and opportunities for birds posed by ongoing intensification, particularly the influences of habitat modification and simplification, increased ecological subsidies through farm inputs, increased stocking rates and yields, and altered predator–prey interactions. We suggest the landscape is the appropriate spatial scale for research and management, and call for an integrated approach to the investigation of farmland birds that combines ecology, sociology, and agro-ecosystems management, and includes farmers, researchers, regulators, and the wider New Zealand public.

Keywords: Canterbury Plains; kererū; predator–prey interactions; sustainable landscapes; tūī

Introduction

Agriculture has played an important historical role in the development of Aotearoa New Zealand's contemporary environment, economy, and society (Pawson & Brooking 2002). Production lands (i.e. land classified as occupied for agricultural use; MacLeod & Moller 2006) currently cover 58% of New Zealand's total land area and agricultural-based products make up about 53% of its merchandise exports (Ballingall & Lattimore 2004; Statistics New Zealand 2004). Agriculture therefore continues to have a significant influence despite a major change in agro-economic policy over the last two decades, aiming to reduce the country's economic dependence on the agricultural sector. At the same time, however, significant changes in land use and management practices have occurred (Parliamentary Commissioner for the Environment (PCE) 2004; MacLeod & Moller 2006). This trend for land-use change is ongoing, but the impacts of these changes on biodiversity and the wider agro-ecosystem are largely unknown (PCE 2004; MacLeod & Moller 2006; Moller et al. 2008).

Consequently, concerns have been raised about the current lack of any national or regional schemes for monitoring reliable indicators of sustainable land use[1] (Meurk & Swaffield 2000; Norton & Miller 2000; Perley et al. 2001; PCE 2004; Moller et al. 2005, 2008; MacLeod & Moller 2006). The Ministry of Agriculture and Forestry (2007) has defined 'sustainable development' as:

> agriculture and forestry delivering optimal socio-economic benefits to New Zealanders in current and future generations through the inter-relationships between people, the biophysical environment and the natural resources people draw from that environment, while maintaining over time the environment's life-sustaining capability and functioning.

Without information on the environmental status and trajectory of New Zealand's agro-ecosystems, it is not possible to know where we are in terms of sustainable agricultural practice, where we are trying to go, or if we have any chance of getting there.

In Europe and North America, the negative impacts of agricultural intensification on bird populations are well documented (e.g. Campbell & Cook 1997; Krebs et al. 1999; Donald et al. 2001; Murphy 2003), and there, birds have been identified as suitable indicators of sustainable land use. However, although agriculture is predominant in New Zealand's landscape, and intensification is a current and ongoing process, we know very little about the status or ecology of its farmland bird populations. The management of bird communities in agro-ecosystems occurs in 'the forgotten 60%' of New Zealand's conservation landscape.

This lack of understanding results from three main causes. First, most recent and current bird research in New Zealand has focused on understanding the causes and mitigating the effects of the dramatic decline of critically endangered, endemic species. The prehuman New Zealand land-breeding avifauna is characterised by a high degree of endemism, flightlessness, and gigantism (Daugherty et al. 1993; Worthy & Holdaway 2002), and evolved in a largely forested environment devoid of mammalian predators (Cooper & Millener 1993; Worthy & Holdaway 2002). Habitat modification and species introductions (specifically rodents, mustelids, and domestic cats and dogs) following human settlement since c. AD 1000 have caused widespread declines and extinctions, with at least 40% of endemic-land-bird species nationally extinct to date (Atkinson & Cameron 1993; Worthy & Holdaway 2002). The endemic avifauna is widely appreciated for its ecological, aesthetic, and intrinsic value, and has been the primary, almost sole, focus of the majority of research and conservation management in New Zealand (Norton 2001).

Second, 'preservation for intrinsic value' has predominated over a 'conservation through sustainable use' paradigm for environmental management in New Zealand (Moller et al. 2008). Several early scientists and naturalists raised concerns over the unique nature and security of many species in the face of human actions (e.g. Buller 1877; Hill & Hill 1987). These calls were combined with early attempts internationally to develop national parks to preserve native landscapes and species (which resulted in the gifting and establishment of Tongariro National Park as the fourth oldest national park in the world), resulting in a preservation model focusing on the protection of 'untouched' wilderness areas and wild species (Catlin 1844; Chapman 1899; Young 2004).

Third, production landscapes have historically been perceived as being devoid of endemic and native species and thus of no conservation value (Norton 2000). The extent of agricultural lands and the efficiency with which we could farm them to supply first the British Empire and then other markets have been a source of national pride and national identity for many generations of New Zealanders (Bell 1996). This efficiency was achieved through the almost complete replacement of native flora and fauna with introduced pastures, crops, trees, and livestock (Holland et al. 2002) and continual technological advancement of breeding, husbandry, and farm management techniques (Brooking et al. 2002). Such landscapes were for agricultural production and nothing else, while the native species and landscapes were believed to be safely contained (and protected) within the conservation estate. In combination, these three factors have resulted in a paucity of interest, concern, and research into birds in agricultural landscapes in New Zealand; a situation that is only just beginning to change.

In our review of the existing literature on bird ecology in New Zealand's agricultural landscape, we found that the research to date has focused on understanding the ecology of bird species that are widely regarded as significant agricultural pests (see Appendix for a summary). The primary motivation for most of this work was, therefore, to inform pest management strategies. Relatively few studies, by comparison, concentrated on the ecology of native species and only one provided comprehensive information on the population dynamics of a native species, the pied oystercatcher (*Haematopus ostralegus*), in the context of agricultural management practices and the wider landscape (Appendix; Sagar & Geddes 1999; Sagar et al. 2000, 2002). We found no studies on the composition of bird communities in the agricultural landscape.

[1] The one current exception is the proposed National Landbird Monitoring Scheme (Spurr & Ralph 2005), sponsored by the Ornithological Society of New Zealand. The scheme is not yet fully developed or implemented, but aims to conduct volunteer-based nationwide surveys of land breeding birds, encompassing all habitats and species.

Thus, the purpose of this forum article is to draw attention to the context, composition, ecology, and status of native and introduced birds in production landscapes in New Zealand, particularly in the face of ongoing agricultural intensification. Given the paucity of current knowledge, the majority of our thesis consists of questions and hypotheses about the potential implications of agricultural practices and intensification for farmland birds. It is not our intention here to provide an exhaustive review of international studies of birds in agricultural landscapes, but rather to refer the reader to excellent reviews such as Chamberlain et al. (2000), Donald et al. (2001), Murphy (2003) and Gregory et al. (2004). We hope this article will promote discussion, comment, research, and ultimately progress towards understanding and managing birds in production landscapes both in New Zealand and in other regions of intensive agriculture.

Trends in agriculture

Over the last 150 years, New Zealand's species-rich lowland ecosystems have been modified by several phases of agricultural development (Ministry for the Environment 1997; Norton & Miller 2000). In the initial colonisation and expansion phases, alluvial floodplain forests, fertile wetlands, and indigenous grassland were replaced with agricultural land, predominantly pastures of introduced grasses and clovers (*Trifolium* spp.) (Molloy 1980; Langer 1990). An early intensification phase began in 1920, whereby productivity increased substantially, facilitated by the application of new soil science, fertilisers, and improvements in plant and animal breeding, while the area of sown pasture remained relatively stable.

This general trend towards more intensive agricultural practices has continued over the last 40 years (MacLeod & Moller 2006), as indicated by (1) increased stocking rates and yields, (2) increased pesticide, nutrient and energy inputs, and (3) conversion to more intensive forms of agriculture (e.g. sheep and beef farms converted into dairying). The agricultural industry has also diversified to include new sectors such as forestry and deer farming. During the 1960s and 1970s, the area of agricultural land (especially sheep farms) expanded rapidly, but then contracted again after a major change in agro-economic policy occurred in the mid-1980s. Over the past decade, the rate of contraction in agricultural land has slowed but the rate of intensification and diversification has accelerated. The trend for intensification of agriculture is predicted to continue for at least another decade (PCE 2004). However, in general, the drivers of historical patterns in land-use change are poorly understood, making it difficult to predict future land use trends (MacLeod & Moller 2006).

Farmland birds

Farmland bird community composition

In general, we know little about the species composition of New Zealand's farmland bird communities or how the composition of these communities varies in space and time (Appendix). Is the widely held perception that native species are rare in the agricultural landscape correct? Or are introduced species simply more conspicuous or abundant than native species? Indeed, some introduced species are so abundant in the agricultural landscape that they are considered significant crop pests (Coleman & Spurr 2001). For example, large flocks of greenfinches (*Carduelis chloris*) and house sparrows (*Passer domesticus*) can destroy radish seed crops (E. Spurr, Landcare Research, unpubl. data) and blackbirds (*Turdus merula*) can cause significant damage to grapes in vineyards (Boyce et al. 1999).

Case study: the Canterbury Plains

A recent study of farmland bird communities on 19 mixed cropping sites in the Canterbury Plains recorded a similar number of native ($n = 16$) and introduced ($n = 17$) species on those sites over a 2-year period (C. MacLeod, Landcare Research, unpubl.). However, estimates of species richness per site were relatively low for native species (breeding season: 1.74 ± 0.23; winter: 3.31 ± 0.23) compared with those for introduced species (breeding season: 11.2 ± 0.36; winter: 9.33 ± 0.35), because native species were more patchily distributed among sites (mean ± SE proportion of sites present per species in the breeding and winter seasons respectively; introduced: 0.79 ± 0.08 and 0.83 ± 0.08; native: 0.35 ± 0.07 and 0.54 ± 0.07). A coarse estimate of species abundance (i.e. number of individuals detected) indicated that, in general, native species were also much less abundant than introduced species. This trend was consistent across seasons, although native species were detected in greater numbers and across a wider range of sites in the winter than in the breeding season. This suggests farmland habitats may provide important food resources for native birds during the winter period. However, it is not known whether the trends detected in this study are representative of a generic trend across different regions and sectors in New Zealand or not.

Origin, perception and value of species

Discussions concerning birds in New Zealand's productive landscapes need to consider both the origin and function (identified contribution to agricultural biodiversity or intrinsic value) of the birds when considering actions for sustainable land management. The short history of human colonisation of New Zealand (~800 years for Polynesian settlers and ~170 years for Europeans; Hogg et al. 2003; Wilmshurst & Higham 2004) and the long prehuman history of isolation mean that people frequently divide habitats and species into aesthetically or intrinsically valued endemic species and introduced species with utility but lower intrinsic value. This valuation of species does not always align along endemic versus introduced status. In a study of farmer attitudes to birds on South Island sheep and beef farms, for example, the species most frequently noted and classified by the farmers fell into three groups (Hunt et al. 2006). Identified species were either iconic native (e.g. fantail *Rhipidura fuliginosa*) or endemic species (e.g. bellbird *Anthornis melanura*, and paradise shelduck *Tadorna variegata*); 'pest' species that caused economic damage (e.g. house sparrow *Passer domesticus*), or were a nuisance to farmers (e.g. magpie *Gymnorhina tibicen* during the nesting season); and culturally valued introduced (e.g. mallard *Anas platyrhynchos*) and native game species (e.g. grey duck *Anas superciliosa*).

Since perceptions of the intrinsic or utility value of bird species vary among farmers and members of the wider New Zealand society (Green et al. 2005; Hunt et al. 2005, 2006), questions need to be asked regarding the focus of bird conservation in farmland systems: Should species be classified according to their origin (e.g. endemic vs self-introduced vs human-introduced species)? Should we only be considering native species for conservation, or are self- and/or human-introduced species a valid focus for attention? Do some introduced species have intrinsic value to members of New Zealand society, or do they hold potential as indicators of sustainable use for market access into the European Union or North America? Do some native species have more intrinsic value to stakeholders than other species? If so, how should these values be used to set management objectives? How do we define whether a bird species has attained pest status or not? Should we be actively managing bird pest populations in wider agricultural landscapes? Who should be responsible for managing or controlling bird pest species? Are we just interested in actions to conserve or control particular species, or are we also interested in enhancing agricultural biodiversity and agro-ecosystem resilience and sustainability?

Factors limiting farmland bird populations

Introduced mammalian predators (e.g. ship rats *Rattus rattus*, brushtail possums *Trichosurus vulpecula* and stoats *Mustela erminea*) have been identified as the main threat to conservation of New Zealand's endangered birds in native forest habitats (e.g. McLennan et al. 1996; Innes et al. 1999, 2004 (unpubl.); Powlesland et al. 2000; Moorhouse et al. 2003). However, the factors limiting populations of both native and introduced bird species in New Zealand's modified landscapes are generally unknown (e.g. MacLeod et al. 2005a,b,c; MacLeod & Till 2007; Moller et al. 2008; Appendix). Thus, selection of suitable bird indicator species for monitoring sustainable land use is limited by our lack of understanding of bird ecology in farmland.

As a consequence, we have several agents potentially affecting birds in farmland areas, and a long list of research questions. What regulates bird populations in New Zealand's production landscapes? Why are introduced bird species so abundant and native species so rare? Is habitat composition or structure/complexity more important than predation in determining bird population sizes and species richness in farmland or does the answer lie in some interaction between the two factors? Is persistence of endemic biota in small isolated reserves within production landscapes compromised or enhanced by current agricultural practices? Can we change land management practices in New Zealand's agricultural landscape so introduced pest bird species are controlled and other bird species can flourish both on farmland and in the few remaining forest, wetland and native grassland reserves within production landscapes? Should conservation management strategies focus on developing land management strategies that enhance only populations of native species or should populations of benign or beneficial introduced species also be targeted? Does the long evolutionary isolation of New Zealand, particularly the absence of mammalian predators and the predominance of forest habitats, mean conservation strategies for endemic species will need to be different from those for valued introduced species, or from endemic species that evolved in the historically rarer more open habitats?

Potential impacts of intensification

In general, little has or is being done to conserve birds in farmland habitats in New Zealand, and there is no general call for these actions from wider society. Some national agencies, such as the Department of Conservation, Queen Elizabeth II National Trust, Landcare Trust, Nga Whenua Rahui, and regional territorial authorities (regional and district councils), encourage local communities to protect and restore existing native habitat patches within the agricultural landscape, and many individual landowners undertake their own conservation actions (Ministry for the Environment 2000). However, the effectiveness of such conservation covenants and restoration projects in maintaining and restoring biodiversity, including birds, within New Zealand's rural landscape is largely unknown. Information from Europe and North America on the impacts of intensification on biodiversity and ecosystem function suggests we should be concerned about similar impacts in New Zealand. Several of the introduced bird species in New Zealand's agricultural landscapes are the same species as those undergoing declines in Europe (e.g. MacLeod et al. 2005a,b,c; MacLeod & Till 2007). It seems likely, at least for introduced bird species, that intensification of agriculture in New Zealand has also had a negative impact on bird populations. Here, we outline some of the potential impacts of agricultural intensification on New Zealand's native and introduced farmland birds, giving examples where research has been conducted, in an attempt to identify the management issues that potentially need to be addressed (Moller et al. 2008).

Degradation and removal of spatial refuges?

Identified trends towards habitat degradation and simplification have the potential to reduce bird diversity and abundance in production landscapes (Sagar et al. 2002; Ewers et al. 2005; MacLeod & Moller 2006; Moller et al. 2008). Degradation of habitat, particularly native and exotic woody vegetation, in farmland is related to reductions in habitat area and the quality of the landscape matrix (i.e. the relative spatial position of patches within the landscape, their structure and floristic composition). Bird species richness and community composition on sheep and beef farms is strongly influenced by habitat composition, extent, and diversity (Blackwell et al. 2005). These general relationships between habitat and bird community composition probably hold true for all arable and grassland farming systems in New Zealand. However, not all habitat management under intensification will necessarily affect bird communities in the same way. For example, habitat simplification resulting from conversion to dairy production may negatively impact some bird species, while riparian planting schemes associated with dairy conversion and diversification into farm forestry within grassland farming operations may provide conservation benefits for bird species. Research into the specific and overall impacts of habitat management on birds in New Zealand's farming systems is urgently required.

Increased farm inputs?

Increasing yields in the cropping and livestock industry over the last 40 years have been associated with significant increases in fertiliser, pesticide, energy, water and foodstock inputs (MacLeod & Moller 2006). However, it is generally not known whether these increases are concentrated in particular land uses or regions. Evidence from a recent study suggests that the effects of alternative management systems, such as organic farming, may be greater in more intensive farming sections (Blackwell et al. 2005). For example, both bird abundance and richness were significantly higher on organic kiwifruit orchards than on standard integrated pest management orchards, but there was no evidence of increased bird species richness or abundance on organic sheep and beef farms with reduced inputs of chemical fertilisers and pesticides compared with conventional sheep and beef farms. It is possible, therefore, that the effects of increased inputs may be greater in arable systems than in grassland farming. Yet, increased pesticide use may also provide benefits for birds by reducing food resources for introduced mammal predators and controlling weed and invertebrate pest populations that otherwise might outcompete native species, which provide important food resources.

Increased stocking rates and yields?

Historical changes in stocking rates and resource extraction rates have differed among the livestock industries in New Zealand (MacLeod & Moller 2006). The relative impact of the different industries on bird populations is unknown, but changes in access to cover and food resources are likely to have occurred. For example, vegetation structure and seed resource availability, which can be altered by changes in stocking rates (Vickery et al. 2001; Wilson et al. 2005), were determinants of winter bird distribution for some introduced species on a mixed cropping farm in Canterbury (MacLeod & Till 2007). Also, increased stocking rates have been facilitated by increased use of supplementary animal feed (MacLeod & Moller 2006), which may help sustain seed-eating bird species.

Predator–prey interactions?

Although predation by introduced small mammals is recognised as the major factor limiting bird populations in New Zealand's native forest habitats (e.g. McLennan et al. 1996; Innes et al. 1999, 2004 (unpubl.); Powlesland et al. 2000; Moorhouse et al. 2003), the relative importance of habitat composition and predation in controlling both introduced and native bird species' populations in the agricultural landscape is yet to be established (Moller et al. 2008). A long-term predator press experiment on simplified and diverse grassland farm landscapes would be valuable to set overall conservation and restoration priorities; i.e. should farmers concentrate most on habitat restoration or on predator control, or are they interdependent?

Spatial scale for management

At what spatial scale is it best to integrate bird management with production in agricultural systems? The lack of research into bird communities on agricultural lands in New Zealand hampers any efforts to prescribe suitable scales of management. However, information on the ecology of endemic and introduced bird species, evidence from studies in Europe and North America, and knowledge from ecological first principles all suggest management actions should be centred at the landscape scale, and aim to integrate actions on private production lands and the public conservation estate (Knight 1999; Norton 2000; Moller et al. 2008). The scale of the landscape depends on the bird species in question, but at population level may be in the order of hundreds of kilometres (combined home ranges of the endemic honey eater tūī *Prosthemadera novaeseelandiae*) to thousands of kilometres for the kererū or native pigeon *Hemiphaga novaeseelandiae* (see below). This approach will include on-farm management actions (e.g. modification of habitats, chemical or food inputs, on-farm pest control) and integration of flows and processes across management and ecological boundaries in the wider landscape.

Case study: tūī and kererū

As an example, tūī and kererū are two iconic endemic species that also play an important ecological role as pollinators (Robertson et al. 1999) and seed dispersers (Clout & Hay 1989). The kererū is gradually declining and the tūī is locally rare where there has been extensive forest clearance and intensification of farming. Both species are mainly resident in primary and secondary native forests, but also occur in urban, farmland, and plantation habitats.

In a recent study of tūī habitat use and landscape ecology in the Waikato region (Innes et al. 2005), observations from landowners showed that tūī are winter visitors to urban and rural areas where they feed mainly on nectar of planted non-native species. Most tūī that were banded and radio-tagged in urban areas within the region during winter flew back to the nearest native forest patches (approximately 7–16 km away) to nest in summer (Innes et al. 2005). Similar results were found in Hawke's Bay in 1984–88 (unpubl. DSIR report) and in Auckland (Bergquist 1985a,b). However, a different pattern of movement was observed for tūī in the Southland region (Powlesland unpubl. data). Tūī nested in woody patches in the urban parks within Invercargill and in winter flew several kilometres to flowering heart-leaved silver gums (*Eucalyptus chordata*) on farmland to feed on nectar. Exotic vegetation associated with urban parks and shelterbelts in farmland, therefore, provide Southland tūī with two important resources, nesting habitat and a winter food source. Regional variation in kererū movement was also detected. Some tagged kererū in Taranaki were relatively sedentary in urban and suburban areas, while others moved extensively (35–100 km) between native forest blocks, particularly during autumn and winter (Powlesland et al. 2007). Like tūī, kererū mainly nest in native forest patches but will also nest in exotic trees in parks and plantations.

Nests of both tūī and kererū species are susceptible to predation from introduced mammalian predators, especially ship rats and brushtail possums. These pests may also be competitors for food resources. Therefore, a management strategy to conserve tūī in arable and grassland landscapes may require on-farm planting of woody species for winter food supply, and control of mammalian predators in public forest reserves during the spring–summer breeding season. Such an approach requires not only coordinated management actions in different locations, but also cooperation between private individuals and regulatory authorities, with corresponding frameworks, financial and social support, and mutual assistance.

Can we identify focal species and research priorities?

Given the long list of questions posed in this article, it would be helpful to conclude by outlining research priorities and management options that provide a pathway towards sustainable agricultural land use in New Zealand. Unfortunately, we feel that the current state of knowledge of farmland birds and perceptions of agricultural landscapes are such that a detailed response of this nature is not yet possible, although we have discussed various pertinent points and issues that inform this debate throughout this article. Before we can identify specific focal or indicator species and processes, we need a national debate and common understanding of the value, role and contribution of agricultural lands to the overall New Zealand landscape.

However, we feel it is possible to identify the crucial change required to the current conservation approach, as well as several key research areas for birds in agricultural landscapes. The most important shift that needs to occur is from the current allocative and preservationist model (with endemic and native species safely contained in reserves and production conducted in modified separate production areas), to a more integrated landscape approach based on conservation through sustainable use. Such a change does not deny the value of natural habitats and endemic species, but rather acknowledges the links between natural and modified habitats and the opportunities and threats these connections present. An integrated landscape, sustainable-use approach also creates room for key ecological flows and functioning and people to be included in our understanding. It is also better suited than the current compartmentalised model to deal with issues such as those surrounding the spatial ecology of tūi and bellbirds, or the selection of the most appropriate indicators of agricultural sustainability.

We are in no way suggesting that endemic species are of no value and should not continue to be the focus of research and conservation management. On the contrary, we feel that a shift to a more landscape-based sustainable use approach will help conserve endemic and native species. An approach that considers the ecological processes and flows that affect species, habitats and landscapes at the appropriate scale is more likely to lead to positive conservation outcomes than one that continues to isolate individual species as the focus of study.

In conjunction with (or irrespective of) this change in approach we can see a number of key research areas that should first occupy our attention. In the absence of extensive empirical data, we posit that the effects of habitat modification, increased farm inputs, increased stocking rates and yields, and altered predator–prey regimes all need further study. The perceptions of farmers and the wider New Zealand society concerning the value and utility of different bird species need to be better understood when planning conservation outcomes. Better estimates of the actual extent and costs of crop and other damage caused by birds perceived by landowners to be pests are also required to inform these perceptions. Finally, any management efforts need to combine actions at the farm scale with an understanding of the landscape-scale processes that affect farmland birds, such as seasonal use of farms and other habitats, cross-boundary flows, and the need for cooperation and coordination of management between private landholders and regulatory authorities.

Conclusions

Pastoral farming has a short history in New Zealand. However, since the early 18th century, the country has experienced large-scale conversion of predominantly forested habitats to arable and grassland farming, with significant intensification since the 1940s. Recently, concerns have been raised about the potential impact of these land use changes on New Zealand's predominantly introduced farmland birds and on the wider faunal communities living in the agro-ecosystems. Calls have been made for the development of avian indicators of agricultural sustainability. However, bird research in New Zealand has focused on understanding the causes of the dramatic decline of its critically endangered, endemic species, with little attention given to production landscapes, which have historically been perceived as being devoid of endemic and native species and thus of no conservation value.

We suggest a change in conservation focus from a compartmentalised, endemic/native species preservation ethic to an integrated landscape, sustainable-use approach is a crucial first step to achieving long-term positive outcomes for birds in agricultural landscapes in New Zealand. In conjunction with this change in emphasis, we suggest research into the specific effects of intensifying agricultural practices and the perceptions and attitudes of farmers and the general public to farmland birds and farmland in general are important first steps to achieving more sustainable agricultural land use.

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Appendix. Summary of previous research on farmland bird species composition, distribution, abundance, ecology and management in New Zealand. Studies relating to particular taxa are listed alphabetically by common name. Species and scientific names are from Heather & Robertson (2000).

Topic	Species	Geographic location	Key results/ issues addressed	Reference
Species composition, distribution and abundance	All species	New Zealand	Distributions of species for 1969-79 and 1999-2004 are presented in two atlases.	Bull et al; Roberston et at. 2007
	Native and introduced species	Native Bush remnants in urban/agricultural landscape, Port Hills, Canterbury	Seasonal variation in species composition and abundance in native bush patches.	Freeman 1999
Ecology and management of pests and introduced species	11 introduced passerines	Mixture of arable and pastoral sites, South Island	All species, except the blackbird, attain higher densities than observed in similar UK farmland habitats.	MacLeod et al. in press
	Introduced passerines	Range of habitats, New Zealand	Compared with the UK, breeding seasons are longer but clutch sizes or volumes and nest survival rates are generally lower.	MacMillan 1985; Evans et al. 2005; Cassey et al. 2005; MacLeod et al. 2005a, b; Flux 2005
	Introduced passerines	Orchards	Organochlorine poisoning likely cause of starling, blackbird and song thrush deaths. High levels of residues in myna eggs and nestlings associated with high levels of residue in soil and invertebrates but not fruit.	Wilson 1980
	Many species	New Zealand	Key pest species, crops most susceptible to damage and bird control methods implemented.	Dawson & Bull 1970; Porter et al. 1994; Coleman & Spurr 2001
	Many species	Apple orchard, Hawke's Bay	Blackbird and starling caused crop damage but silvereye, greenfinch, goldfinch and house sparrow only fed on damaged fruit. Hedge sparrow, song thrush, fantail, chaffinch and magpies only fed on invertebrates or swards.	Baker 1980
	Several passerines	Arable/pasture, Canterbury	Preferred to forage in pasture in winter – related to seed resource abundance and vegetation structure.	MacLeod & Till 2007
	Blackbird *Turdus merula*	Nelson	Role as seed dispersers for both native and introduced plant species.	Williams 2006
	Canada goose *Branta* canadensis	Eastern South Island from Marlborough to Southland	Population trends from aerial counts in high country pasture (increases associated with pasture improvement) and coastal wetlands.	Potts 1984
		Arable/pasture by Lake Grasmere, Canterbury	At Lake Grasmere, fed consistently and extensively over farmland adjacent to lake.	Potts & Andrew 1991
	Eastern rosella *Platycercus eximius*	New Zealand	Wide distribution in the North Island but not the South. Occur in many important forest remnants.	Wright & Clout 2001
	Feral pigeon *Columba livia*	Arable/pasture, Hawke's Bay	Breed year round, but particularly in spring and autumn. Peas and maize stubble were the two main food items. No data on damage or impact of pigeons on crop yields.	Dilks 1975a, b
	Greenfinch *Carduelis chloris*	Orchard and arable/ pasture, Hawke's Bay	Nested in mānuka, kānuka, matagouri, exotic deciduous and coniferous trees: 27% eggs survive to fledging; 30–40% of eggs and chicks lost to predation, mainly by rats. Adult diet January–June: 27% maize, 12% fodder radish, 61% weed seed and few invertebrates. Nestling diet primarily weed seeds.	MacMillan 1981, 1985; McLennan & MacMillan 1985
	House sparrow *Passer domesticus*	Arable/pasture, Hawke's Bay	Grain loss to birds in wheat and barley crops ranged from 1% to 12%. Adult diet January –June: 31% wheat, 23% maize, 47% weed seed and few invertebrates. Nestling diet: initially mainly invertebrates then switch to mostly grain and pulses.	Dawson 1970; MacMillan 1981; MacMillan & Pollock 1985

Topic	Species	Geographic location	Key results/ issues addressed	Reference
Ecology and management of pests and introduced species	11 introduced passerines	Mixture of arable and pastoral sites, South Island	All species, except the blackbird, attain higher densities than observed in similar UK farmland habitats.	MacLeod et al. in press
	Magpie *Gymnorhina tibicen*	Manawatu	Variation in food supply was not a proximate cause of post-natal dispersal in juvenile magpies, and non-territorial magpies were not less successful foragers than territorial birds.	Veltman 1989; Veltman & Hickson 1989
		Pasture in Northland, Bay of Plenty, Wellington, Southland and Waikato	After magpie control, significant but 'unspectacular' increases in bird numbers were recorded for one native and several introduced species. Recommended predator control would be better targeted towards reducing introduced mammals numbers.	Innes et al. 2004 (unpubl. report)
		Orchards and pasture, Waikato	Rarely attack other birds or prey on nests. Main nest predators were harriers (*Circus approximans*), ship rats, and cats.	Morgan et al. 2006a, b
	Paradise shelduck *Tadorna variegata*	High country, Canterbury	Grass, clover and rushes were predominant in diet throughout year. Seasonal intake of *Muehlenbeckia axillaris, Gunnera dentata* and *Cyathodes fraseri* fruits recorded. Other foods included grain, aquatic plants, terrestrial and aquatic invertebrates.	Bisset 1976
		High country and coastal sites, Wanganui	Post-moult dispersal distances were lower at hill country than coastal sites, where hunting pressure was higher. Frequent movement among lakes within the hill country or coastal localities but rare between localities.	Barker 1990
	Pūkeko *Porphyrio porphyrio*	National review	Conflict between conservation and farm management of populations discussed. National historical records show most abundant in farmland with wet areas. Draining wet farmland reduced numbers.	Fordham 1983
		Swamp and pasture, Rotorua, Nelson, Westland, Canterbury	Grasses and sedges predominant diet. Clover (*Trifolium* spp.) leaves, dock and sorrel (*Rumex* spp.) seeds, willow-weed (*Polygonum* spp.) and rush (*Juncus* spp.) seed-heads also eaten. Animal material was sparse but included invertebrates, lizards and birds.	Carroll 1966
		Aquatic habitats and pasture, Manawatu	Flocking peaked in the autumn when more abundant on pasture, near water, than in swamp. Group composition and size and breeding success varied in relation to habitat structure.	Carroll 1969; Craig 1979, 1980
		Swamp and pasture, Otago	Increased nest predation following release of rabbit haemorrhagic disease. Possible reason was a shift in diet of the harrier.	Haselmayer & Jamieson 2001
	Rook *Corvus frugilegus*	New Zealand with particular focus on arable/pasture and orchards, Canterbury and Hawke's Bay	Historical and current data on the distribution, abundance and control of rooks at rookeries and roost sites. Detailed information on breeding biology and success: 10–30% of eggs survive to fledging. Cause of losses generally unknown. Foraged preferentially in cereals, cultivated land and walnut orchards. Invertebrates (*Wiseana* spp., Lumbricidae, *Costelytra zelandica*), meat, nuts, cereals and pulses predominant in diet. Damage pasture to get access to grass grub larvae, but only removing 15–22% of larvae.	Bull 1957; Coleman 1971, 1972; Bull & Porter 1975; Porter 1979, 1987; Purchas 1979, 1980, 1981; McLennan & MacMillan 1983; Langham & Porter 1991; Porter et al. 2008

Topic	Species	Geographic location	Key results/ issues addressed	Reference
Ecology and management of pests and introduced species	11 introduced passerines	Mixture of arable and pastoral sites, South Island	All species, except the blackbird, attain higher densities than observed in similar UK farmland habitats.	MacLeod et al. in press
	Skylark *Alauda arvensis*	Arable/pasture, Canterbury	Densities were highest in lucerne and extensively managed pasture during breeding and winter seasons. Avoided small field and tall field boundary habitats. Susceptible to high levels of nest predation, primarily by hedgehogs (*Erinaceus europeaus*).	Thomsen 2002
	Silvereye *Zosterops lateralis*	Apple orchard, Nelson	Diet included 61 different arthropods belonging to 14 orders. Earthworms, fruit and seeds also eaten.	Moeed 1979
	Songthrush *Turdus philomelos*, blackbird	Dairy pasture and farmhouse gardens, Mangere, Auckland	Both species more abundant, but had lower nest success, in gardens compared with pasture.	Bull 1946
	Starling *Sturnus vulgaris*	Arable/ pasture, New Zealand	Use of artificial nests boxes; temporal and spatial variation in breeding success. Age structure and survival estimates of breeding females. Variation in fledgling survival and recruitment in relation to clutch size and nestling body mass. Preferred to forage in cereal stubbles, tilled fields and well-stocked heavily grazed pasture. Invertebrates, in particular Coleoptera and Lepidoptera, and fruit predominant in diet.	Coleman 1974, 1977; Moeed 1980; Flux & Flux 1981; Thompson & Flux 1991; Bull & Flux 2006
	Sulphur-crested cockatoo *Cacatua galerita*	New Zealand	Distribution is expanding in the North Island but not the South. Authors 'see no biodiversity mandate for controlling cockatoo numbers or spread at present'.	Watts et al. 2000 (unpubl. data)
	Yellowhammer *Emberiza citrinella*	Arable/pasture, Canterbury	Preferentially select hedgerows and/or ditches adjacent to cereal crops for breeding territories. Higher nesting success in these habitats. Relationships between invertebrate food supplies and chick condition and growth investigated.	MacLeod et al. 2005a, b, c
Ecology and management of native species	Australasian harrier *Circus approximans*	Sand dunes, swamp, pine plantations and pasture, Manawatu	Density 1 bird per 50 ha. Nests located in swamp vegetation, but foraged mainly in farmland: 55% of nests produced young; 1.8 young produced per successful nest.	Baker-Gabb 1981
		Pasture, tussock and rank grass, Tekapo, Canterbury, Southland	Mammal carrion and introduced birds predominant in diet, but also fed on large invertebrates. When rabbit numbers were scarce fed on alternative prey, especially skinks.	Carroll 1968; Redhead 1968, 1969; Douglas 1970; Fennell 1980; Pierce & Maloney 1989
	Brown kiwi *Apteryx australis*	Forest patches and adjacent farmland, Northland	Assessed role of introduced mammals in decline of kiwi populations: 94% mortality of juveniles, populations declining at 6% per annum.	McLennan et al. 1996
	Kererū *Hemiphaga novaeseelandiae*	Native forest and farmland, Marlborough	Travelled 2–18 km between native forest areas. In spring, fed on deciduous foliage on neighbouring farmland. Consistent seasonal patterns of movement, but timing varying depending on fruiting phenology and breeding success. Late summer and autumn movements to feed on fruiting miro *Prumnopitys ferruginea*.	Clout et al. 1991
		Farmed landscape, Whangarei	Mean life expectancy was only 1.25 years.	Pierce & Graham 1995
	Kingfisher *Halcyon sancta*	11 districts between Waikato and North Canterbury	Road survey suggested densities decline at higher latitudes. Were concentrated at lower elevations and in open pasture.	Ralph & Ralph 1977

Topic	Species	Geographic location	Key results/ issues addressed	Reference
Ecology and management of native species	11 introduced passerines	Mixture of arable and pastoral sites, South Island	All species, except the blackbird, attain higher densities than observed in similar UK farmland habitats.	MacLeod et al. in press
	NZ falcon *Falco novaeseelandiae*	National survey and focal study in Marlborough	Historical estimates of breeding population size and distribution are reported at the national scale. Decline in breeding numbers 1994–2004 in Marlborough. Habitat change, poisoning and a reduction in mammalian pest numbers are cited as potential causes of decline.	Fox 1977, 1978a, b; Gaze & Hutzler 2004
		Exotic plantation forest, Kaingaroa Forest	Identified 13 introduced and 5 native bird species, 1 mammal and 2 invertebrate species in pellet and prey remains.	Stewart & Hyde 2004
	NZ falcon and Australasian harrier	Range of habitats, New Zealand	Organochlorine residues detected in tissue but no direct evidence of cause of mortality or egg-shell thinning.	Fox & Lock 1978
	NZ pipit *Anthus n. novaeseelandiae*, Chatham Island pipit *A. novaeseelandiae chathamensis*	North Island and Chatham Island	Use of farmland habitat bordering scrub or sand dune habitats for foraging for insects during the post-fledgling phase and in the winter.	Beauchamp 2002, 2007
	Pied oystercatcher *Haematopus ostralegus*	Arable/pasture, Canterbury	Males show stronger fidelity to breeding territories than females. Predicts intensification of agriculture on breeding grounds will reverse observed trend for population increase. Seasonal and annual variation in breeding parameters. Trampling by stock and farming activities main causes of egg loss. Hatch success greater in cultivated than pasture sites. Moved 97–834 km north from breeding sites in farmland to wintering sites in coastal locations around New Zealand. High fidelity to winter sites within and between years.	Sagar & Geddes 1999; Sagar et al. 2000, 2002
	Spur-winged plover *Vanellus miles*	Arable/pasture and surrounding landscape, Southland and Otago	Records of establishment in 1940s–50s. Historical records of subsequent spread and distribution in region and beyond. Majority of nests located in rough and, to a lesser extent, improved pasture: 35% nest losses due to farming or livestock disturbance and 8% to predation.	Sansom 1951; Barlow 1972; Barlow et al. 1972
	Welcome swallow *Hirundo tahitica*	Range of habitats, including farmland – New Zealand, primary focus Northland	Records of establishment and spread since 1958. Anecdotal reports of distribution of nesting sites and flocks in autumn–winter. Frequently associated with buildings and water bodies on farms. Most nests fail at egg stage due to nest collapse/disturbance, predation, desertion or infertility: 48% of eggs survive to fledging.	Edgar 1966; Tunnicliffe 1968
	White-faced heron *Egretta novaehollandiae*	Pasture, Manawatu	Forage in pasture with transitory surface water. Major prey groups were insects, tadpole shrimps, earthworms, tadpoles and frogs. Composition varied in relation to seasonal availability of prey.	Lo 1991