Birds as indicators of agroecosystem resilience and sentinels of market accreditation: A case study of New Zealand South Island sheep/beef farms

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Summary

New Zealand is unique among industrialized countries in that, in the absence of farming subsidies, farm management is governed largely by consumers in Europe, the United States and Japan, where the majority of agricultural products are exported. The neoliberal context in which New Zealand agriculture is presently situated may provide the most likely vehicle through which biodiversity care on production lands may be introduced. As consumers in key niche markets abroad express increased preference for "green" commodities produced using sustainable and biodiversity-friendly farming practices, New Zealand farmers may be required to alter their farm management to include provisions for biodiversity care, or risk losing access to international markets. There is presenty a great need to identify ecologically relevant indicators of farm environment health and biodiversity that are simultaneously able to guide farm management and resonate with farmers and consumers alike.

Chapter 1 describes a conceptual model that proposes the establishment of a 'Market Flagship Species,' an innovative surrogate based on ecological and social science research that signals biodiversity-friendly farming practice. Using birds as proxies for wider agroecosystem diversity as well as farmer attitudes and actions toward biodiversity on their farms, Chapters 3-6 take a transdisciplinary approach in testing the efficacy of the model to select appropriate Market Flagship Species.

A principal aim of the ecological component of this study was to examine the role of woody vegetation or 'refuge' habitat patches embedded within the production land matrix of sheep/beef farms in supporting bird diversity. Accordingly, bird community composition was measured by conducting five-minute point counts exclusively within woody vegetation patches on 12 South Island sheep/beef farms ranging in geographic distribution from Banks Peninsula (Canterbury) to the Catlins (Southland). 9,050 birds were recorded during 1,086 point counts conducted within 246 different patches over the course of 8 field circuits conducted between 2007-2010.

Data were collected according to distance sampling methods, but the extrapolation of diversity estimates within individual patches presented a unique methodological problem: Namely, what is the best method to mitigate bias associated with data collected within a series of discrete patches of varying sizes? Chapter 2 describes a methodology for generating unbiased indices of bird species richness based on the exclusion of data beyond a radial truncation distance of 10m. With an assumed detection probability of 1 within a

10m radius, densities of 12 common species occurring within two key habitats were generated. 10m truncation densities closely corresponded to densities generated using distance methods. Although the developed method reduces available data for analysis, it largely mitigates bias associated with detection while ensuring that sampling effort within small versus large patches remains equivalent. This method was therefore used to establish a dataset upon which analyses of Chapters 3 and 4 were derived.

Based on the truncated 10m dataset, Chapter 3 uses general linear models (GLMs) to identify associations between species richness of native and introduced bird species and specific woody vegetation habitat paramaters, such as predominant vegetation species, patch area and patch shape complexity. Models indicated native species richness was strongly associated with native tree habitat and patch area ($p<0.001$). By contrast, introduced species richness was seemingly emblematic of the generalist ecology that characterizes many introduced species and not significantly associated with any measured habitat parameters.

Chapter 4 considers emergent ecological themes from Chapter 3 with regard to individual species. Specifically, the analyses of Chapter 3 are complemented by measuring an index of bird abundance, rather than species richness, for 12 candidate indicator species representing six native and six introdcued species. Candidate species were chosen based on their potential utility to serve as ecological indicators and accommodate social elements of the Market Flagship Species model. Non-parametric analyses indicated strong area and habitat effects for the Bellbird *Anthornis melanura*, Fantial *Rhipdura fuliginosa*, Grey Warbler *Gerygone igata* and Rifleman *Acanthisitta chloris*($p<0.002$), intimating a native species preference for large, native tree habitat patches. The introduced Blackbird *Turdus merula*, Chaffinch *Fringilla fringilla*, Goldfinch *Carduelis carduelia* and Yellowhammer *Emberiza citrinell* similarly showed significant area and habitat effects ($p<0.005$), though to a lesser degree than native species. These findings support that relationships between native species richness, patch area and habitat type may also be evident at the individual species level. Based on findings of this Chapter, the Bellbird, Grey Warbler, Yellowhammer and Goldfinch were nominated as themost likely candidate species to thread through the Market Flaghsip Model.

Chapter 5 supplements ecological data with social science research that describes farmer attitudes and actions toward birds on their farms. Quantitative analysis was performed on Likert responses of sheep/beef farmers to questions regarding farmer perceptions of birds as providers of ecosystem services, pest species, and possible

indicators of farm environment health. This chapter identifies a population of farmers who, irrespective of management system, acknowledge the importance of birds, and by association, biodiversity in supporting farm production. Further, these farmers express a willingness to support bird diversity both independently and in conjunction with audit systems, pointing to their value as a potential demographic with which to trial biodiversity-based market audit systems.

Finally, in Chapter 6, the findings of all previous chapters are considered as they pertain to the Market Flagship Species model. Of the original 12 candidate indicator species, four (Bellbird, Grey Warbler, Goldfinch, Yellowhammer) were threaded through the Market Flagship Species model. Given this final subset, the Bellbird was the sole species that adequately met all social and ecological criteria, and in doing so demonstrated the efficacy of the Market Flagship Species model in selecting an appropriate ecological and social indicator. While the Market Flagship Species model and sampling methods outlined were based on data from New Zealand's sheep/beef sector, they are equally applicable to any number of pastoral and arable crop sectors, and of great potential value in guiding biodiversity-friendly farming practices in Europe, Australia, the U.S. and Canada, where market institutions remain a strong impetus behind sustainable farm management practices.

Author's Note

Although this thesis contains introduction and conclusion chapters, all chapters of this thesis were structured as stand-alone papers to be submitted for publication in refereed journals, once examiners comments have been received and incorporated. Whenever possible, other chapters within this thesis were cross-referenced. However, there is a certain amount of repetition that is unavoidable between chapters, particularly with regard to introduction and methods section, where different aspects of the same field study, social context of research and important ecological paradigms are discussed.

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Chapter 1: Market Flagship Species for biodiversity care on farms: A conceptual model

Abstract

Following the removal of agricultural subsidies in the mid-1980's environmental regulation of New Zealand's production lands has been largely governed by neoliberal audit systems. Consumer demands for sustainable and biodiversity-friendly farming practices are presently the most practical way to influence environmental management of New Zealand's agroecosystems. Accordingly, there is a critical need to identify meaningful biodiversity indicators for New Zealand's production lands. While the temptation to select charismatic species of intrinsic value to customers is great, selection of indicator species must first and foremost be ecologically relevant and able to direct biodiversity management at the farm scale. This paper proposes the establishment of a "Market Flagship Species" indicator, a novel agroecosystem surrogate that is derived from both ecological data describing associations with wider agroecosystem health and biodiversity, and social science research of farmer perceptions of indicator species. While this represents an essential first step in the development of audit systems structured around ecologically and culturally relevant criteria for New Zealand, the conceptual framework developed has a more general utility in countries like Australia, Canada and U.S., where market institutions are charged with delivering sustainability to broadly unregulated production landscapes.

Key words: Audit system, surrogate species, indicator, agroecosystem, flagship species

Introduction

Agricultural intensification and biodiversity conservation on production lands

Agricultural intensification, defined by the Food and Agriculture Organization (FAO) of the U.N. as "an increase in agricultural production per unit of inputs (which may be labor, land, time, fertilizer, seed, feed or cash)," largely stems from the critical need to expand food supply, particularly to accommodate rapid population growth (FAO 2008). The ecological subsidies that characterize intensification in effect force land to produce beyond its inherent capacity. Moreover, the application of such inputs is often directed toward increasing yields of monoculture crops and pasture grasses while controlling "pest" or "weed species" (Marshall et al. 2003). This process homogenizes the landscape and makes it inhospitable to an array of non-production species. Over the last two decades, concerns have arisen over the long-term sustainability of these production systems as well as the wider environmental consequences affecting biota and ecological processes beyond the farm (Matson et al. 1997, Stoate et al. 2001, Donald et al. 2002, Stoate et al. 2009)

Agroecosystems are reliant on essential ecosystem services, such as nutrient cycling, pollination and pest control, provided by non-production biodiversity (Matson et al. 1997). Accordingly, a number of recent efforts to increase farmland sustainability have been structured around efforts to retain or enhance the diversity and abundance of non-production species on production lands (Donald et al. 2002, Benton et al. 2003, Bracken and Bolger 2006, Kleijn et al. 2006). Rather than relying upon a baseline suite of species to supply ecosystem services, it is posited that agroecosystems benefit from broad scale increases in biodiversity, where a number of species may perform similar or overlapping ecological functions (Walker 1995, Fischer et al. 2006, Darnhofer et al. 2010*a*). These redundancies may reduce reliance on external inputs to maintain production, and augment a system's resilience, or capacity to recover from perturbation and transition to new states if environmental conditions change (Walker 1995).

While the impact of agricultural intensification on biodiversity within production landscapes has been extensively studied in Europe and North America (Donald et al. 2002, Báldi et al. 2005, Tscharntke et al. 2005, Butler et al. 2007), little such research has been conducted in New Zealand. Only 18% of New Zealand private lands below 500m are currently part of the public conservation estate, with most of the remainder used in agriculture and forestry production (Norton 2000). The warm, fertile conditions that make lowlands ideal for these means of production similarly enable them to support high levels

of biodiversity. Production lands undoubtedly benefit from the diversity and abundance of species present on them. Reflexively, conservation of non-production species has much to gain by the inclusion of production lands into biodiversity monitoring plans and conservation efforts, which have heretofore largely neglected these potentially critical systems (Norton 2000, MacLeod et al. 2008). In recent years, studies examining the sustainability of New Zealand's farming systems has been undertaken by the Agriculture Research Group on Sustainability (ARGOS, http://www.argos.org.nz), a transdisciplinary team of researchers that draw from the fields of ecology, sociology and economics in comparing whole-farm sustainability across a number of sectors (kiwifruit, dairy, high country and sheep/beef) and management approaches. The ultimate goal of ARGOS research is to assist landholders in increasing farm sustainability and resilience. Associated research places emphasis on transdisciplinarity and addressing pertinent ecological questions at the farm level and is framed around the 'farming systems null hypothesis': that conventional, organic, and Integrated Management (IM) farming will have the same environmental, economic and social outcomes.

Neoliberalism and conservation of biodiversity within agroecosystems

Within the European Union, biodiversity conservation in agricultural systems is chiefly supported by Agrienvironment Schemes (AES), which offer farmers financial compensation for participating in management practices that encourage biodiversity on their farms (Ovenden et al. 1998, Kleijn et al. 2006, Ottvall and Smith 2006). New Zealand, by contrast, is unique among industrialized countries in that the majority of agricultural subsidies were removed in the early 1980's. There is currently neither formal government support of biodiversity conservation on production lands, nor a strong regulatory framework to force biodiversity care. In the absence of government funding, the environmental regulation of New Zealand agriculture is, to a large extent, governed by consumer- and industry-driven initiatives that are often manifest in neoliberal audit systems (Campbell 2005, Campbell et al. 2006). Neoliberalism is characterized by free market systems, government deregulation and placing responsibility of management on the individual. Consumer demands for sustainable and biodiversity-friendly farming practices are therefore the only practical way to influence environmental management of New Zealand's agroecosystems (Campbell 2005, Campbell et al. 2006, Campbell and Le Heron 2007).

Currently, over 80% of New Zealand agricultural output is exported to Europe, the United States and Japan (Smith and Montgomery 2003; Statistics New Zealand 2006).

Within these markets, an increasing demand for agricultural commodities that are produced using environmentally sustainable practices and respectful of biodiversity of non-production species has led to the creation of several private-sector audit systems that place emphasis on sustainability and biodiversity conservation. For example, Global Good Agricultural Practice includes provisions to minimize the detrimental impact of farming operations (GlobalG.A.P. 2010). The Linking Environment and Farming marque scheme further places emphasis on biodiversity conservation through the inclusion of a whole farm conservation plan, provisions for wildlife habitat retention and a biodiversity management component (LEAF 2010). Already exports from New Zealand's fresh produce sector must be accredited by GlobalG.A.P., with other sectors likely to follow suit. As consumers within high value niche export markets exhibit continued preference for commodities produced using environmentally sustainable practices, there is a great need to identify species that may serve as meaningful indicators of farm environment health and wider biodiversity that could be incorporated into schemes that 'eco-verify' sustainability and incentivize consumer choice and land care by farmers.

Situating indicators within a social context

Indicator species are organisms whose presence, population density, dispersion or reproductive success are used to inform indices of attributes too difficult, inconvenient or expensive to measure for other species or environmental conditions (Landress 1988). Indicator species may serve as surrogates for environmental health, population trends of prey species, or wider diversity of sympatric species (Caro and O'Doherty 1999). While the selection of indicator species is typically largely contingent upon the degree to which indicators effectively represent environment health or wider biodiversity, the personal and professional goals of stakeholders and the value systems in which they are rooted warrants consideration (Halberg 1999, Duelli and Obrist 2003, Maegli et al. 2007). Farmer economic motivations to increase farmland sustainability and enhance biodiversity are often accompanied by intrinsic values of conservation, a sense of serving as a custodians of the land and a sense of pride in participating in on-farm conservation efforts (Morris and Potter 1995, Wossink and Van Wenum 2003, Smallshire et al. 2004, Sutherland 2004, Berentsen et al. 2007, Dutton et al. 2008, Ahnstrom et al. 2009). These attributes underscore the need to identify indicator species that are selected not solely using ecological criteria, but according to their cultural relevance and efficacy in reflecting farmers' actions and guiding farmers' future actions (Halberg 1999). Optimal choice of

such indicators therefore needs to be relevant for New Zealand farmers and wider society, while still resonating with sustainability goals of overseas consumers.

Often species that are indicative of environmental health or system biodiversity are either not familiar to or not considered endearing by the public, and consequently of limited value in rallying conservation support (Caro and O'Dougherty 1999). The term "flagship species" refers to charismatic species that are often used to anchor environmental campaigns due to their ability to elicit support and sympathy from the public (Western 1987, Dietz 1994, Caro and O'Dougherty 1999, Bowen-Jones and Entwistle 2002). Though flagship species need not necessarily indicate wider diversity or environment health, conservation of their habitat may confer protection to other less charismatic species with similar habitat requirements (Simberloff 1998). When searching for surrogates within an agroecosystem context, there is a simultaneous need for the identification of species that indicate both environmental health and biodiversity and possess sufficient intrinsic value to effect consumer support and serve as cues to farmers in directing biodiversity conservation actions on their lands. This paper proposes formal delineation of a "Market Flagship Species" indicator, a novel agroecosystem surrogate that is derived from both ecological data describing associations with wider agroecosystem health and biodiversity, and social science research on farmer and consumer perceptions of indicator species. Spefically, a Market Flagship Species is a dual-purpose surrogate that is simultaneously able to meet the ecological criteria of a successful indicator (Landress 1988, Figure 1) and possesses sufficient resonance with stakeholders and consumers to serve as a flagship. Here in Chapter 1, a formal examination of the key criteria for its design (based on international ecological and food systems literature) is presented. Subsequent chapters then develop a specific case for optimum choice of a Market Flagship Species to guide sustainable food and fibre production on New Zealand sheep-beef farms. This thesis concludes (Chapter 6) by revisiting the conceptual model and nominating future research priorities to perfect the New Zealand example.

A New Zealand Sheep-beef Market Flagship Species as a case study

The neoliberal system in which New Zealand agriculture is situated provides a unique and especially valuable opportunity with which to develop a Market Flagship Species. While New Zealand's fresh produce sectors have been subject to private sector audit systems for a number of years, the sheep/beef sector is a relatively new entrant into the process (Wharfe and Manhire 2004), and presently the majority of attention is directed

toward animal welfare practices (Campbell et al. 1997, Haggerty et al. 2009). Although sheep/beef farmers are seemingly accepting of the impending influence of audit compliance, a chief complaint is that such systems are often misinformed ventures by external bureaucrats that often lack a tangible reward in the form of price premiums for certified products (Rosin et al. 2007). The inclusion of farmers in the development of indicator-based biodiversity accreditation schemes may serve the dual function of mitigating this frustration and providing internally relevant criteria upon which to base associated audit systems. Put simply: if farmers trust and see biodiversity indicators as locally relevant, their inclusion in market audit schemes will build commitment to participation and sustainability; if the choice is not valued by the farmers' themselves, inclusion of biodiversity indicators will erode support for the audits by encouraging cynicism and resistance. While establishment of a Market Flagship Species is a valuable first step in the development of audit systems structured around ecologically and culturally grounded criteria within New Zealand, the conceptual framework developed has a more general utility in countries like Australia, Canada and U.S., where market institutions are charged with delivering sustainability to broadly unregulated production landscapes.

Developing a conceptual model for market flagship species

Establishing a sound ecological basis

Although the identification of an effective Market Flagship Species is contingent upon both ecological and social criteria, the selection process should utilize a a hierarchical approach (Figure 1). Because the purpose of the entire configuration is to attach human values to tangible indicators of agroecosystem environment health or biodiversity of non-production species, ecological data should assume initial priority over social data within the hierarchy. For this reason, ecological design issues are dealt with first.

The selection hierarchy for ecological criteria is centred around the fulfilment of a set of common "rule of thumb" conditions. First and foremost, an appropriate indicator must have a quantifiable association with the environmental or species population attributes it purports to represent (Duelli and Obrist 1998). Depending on the goals of the audit system, these may include measures of richness, abundance, whether a species population is self-sustaining within a given system and a species' association with habitat extent and complexity. Second, species should neither be extremely rare, nor ubiquitous and thus able to act as cues in the event of disturbance (Favreau et al. 2006). Finally, specialists are typically more effective than generalists as indicators, as their feeding

ecology or reliance up on specific habitat characteristics makes them more sensitive to changes in the environment (Favreau et al. 2006). This step is based on the concept that agricultural landscapes are frequently characterized by habitat homogeneity, which in turn may restrict the number of specialist speces able to successfully forage and breed (Newton 2004, Wilson et al. 2005). Emphasis here should be placed on the notion that while this is the norm, the argument can be made that the absence of generalist species within the system might aptly signal broad scale ecological change or disturbance, and that these species may still represent useful indicators (Roth and Weber 2008). The trade-off between the use of a generalist in the absence of a specialist might be that changes in the environment are not detected until a particular threshold is reached, and more intensive and expensive management action is required. In sum, the selection of a specialist species is often preferred, but the association between a specialist and the specific habitat it is indicating should be unambiguous and robust. Linkages between the indicator and what it indicates ideally apply everywhere and remain intact even over long time periods and through major land use transitions.

Irrespective of whether a candidate species is a specialist or generalist, it must be non-migratory and a year-round resident of the agroecosystem of concern. If a given species is present on the farm for temporally-explicit periods, such as breeding or winter feeding, changes in presence and abundance of that species may reflect changes in the state of systems extraneous to the farm, rather than changes in management or ecological disturbance on the farm itself (Atkinson et al. 2002). The spatial scale of influence of key ecological processes affecting the flagship indicator should roughly match the scale of the whole farm, which is seen as the key site of action to promote resilience and sustainability in agricultural land use (Darnhofer et al. 2010*b*).

If all ecological criteria are satisfied, consideration should be given to the ease with which a candidate species can be monitored and the feasibility of collecting relevant data. Data regarding candidate species presence should be inexpensive to collect and easy to audit (Bibby 1999, Halberg et al. 2005).

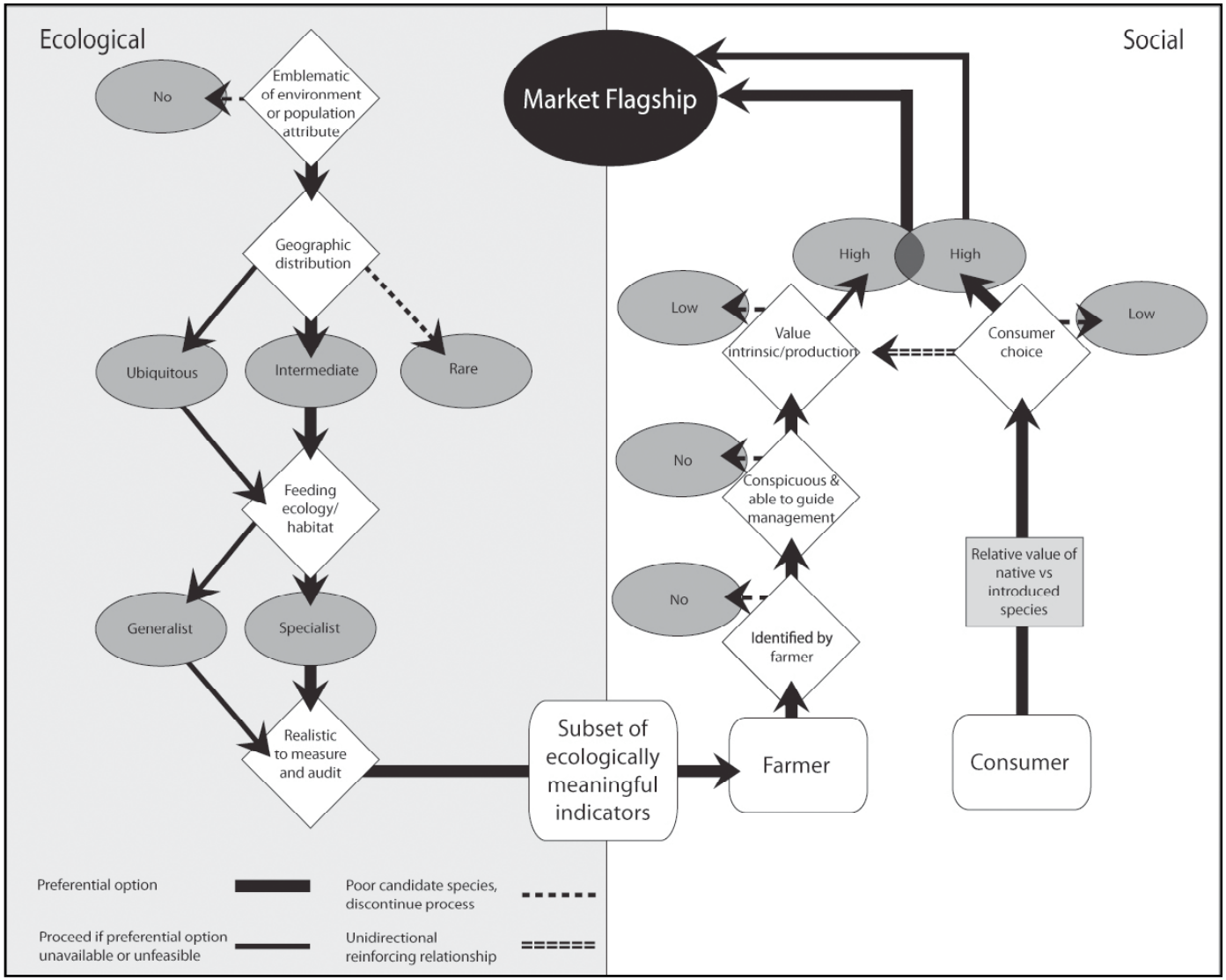


Figure 1.1 Proposed model for selection of a market flagship species and the social and ecological contexts in which criteria are nested.

Using ecology to direct social research

Once one or more candidate species have been nominated using ecological criteria, progression into the social sphere begins with farmers' ability to identify candidate species on their farms. This then flows on to species conspicuousness and ability of a species to guide farm management (Halberg 1999). The latter step is of particular importance with regard to stakeholder involvement, as farmers will eventually have to commit to management plans and targets, and may be required to collect relevant data (Bibby 1999). Within pastoral agroecosystems, the majority of bird species frequently encountered are those that are either open land specialists or generalists that thrive in disturbed environments. The primary goal of the model is to identify a proxy for heath of non-production components of the land matrix, so it becomes important at this step to ensure candidate species occur in areas that are readily accessible to the farmer. This may periodically, but not always, rule out the use of strictly 'interior species' (i.e. a species that remains out of view within farm forest patches). Alternatively, species that tend to avoid edges, but have distinct calls may be used, providing the farmer is able to identify the call. In fact, selecting an indicator with a loud or distinct call may assist ease of monitoring, as it is often difficult to properly discern between a number of species, particularly small passerines, either at a distance or within vegetation patches (dos Anjos 2007). Choosing a medium density species may also facilitate informal monitoring of relative abundance by farmers – if a species were hyper-abundant and highly aggregated (e.g. in flocks) if becomes difficult even for an astute observer to monitor changes in overall population size.

The final stage, and one of paramount importance, is the assessment of value placed on candidate species by both farmers and consumers. By definition, a traditional flagship species is a single charismatic species that is capable of eliciting sympathy and conservation (Caro and O'Doherty 1999). This sentiment should similarly be reflected in the selection of a market flagship species. As the majority of New Zealand agricultural commodities are purchased by consumers in overseas markets, a critical but still unknown factor is the relative value overseas consumers place on native versus introduced species as indicators of farm environment health. New Zealand agroecosystems support healthy populations of a number of farmland bird species associated with historic declines in their European home ranges (Chamberlain et al. 2000, MacLeod et al. 2005*a* and *b*). These species may thus prove highly meaningful as indicators to consumers in key European markets. Conversely, attaching a New Zealand native species to a labelling scheme may reinforce the "clean green" image many overseas consumers have of New Zealand, and

serve as an equally compelling motivation to purchase a certified product. Because consumer preference for sustainable and biodiversity-friendly commodities is ultimately the key impetus behind the establishment of Market Flagship Species-based audit systems, the value of candidate species to the consumers will probably dominate the relative value placed on potential species by New Zealand farmers. Herein lies the most likely source of tension between social components of the model. Preferably, an indicator will possess utility in guiding management at the farm scale in addition to being valued by the consumer. The inherent plasticity in such value systems merits attention. For example, species presumably of little initial value to farmers may become more highly regarded if their presence commands price premiums for consumers. Though principally a product of the neoliberal environment in which such audit systems dictate farm environment management, priority of consumer value systems should not negate the importance of the production and cultural value famers place on non-production species on their lands. Economic motivations for engaging in efforts to conserve non-production species are often accompanied by intrinsic values of conservation, a sense of serving as custodians of the land and a sense of pride in participating in on-farm conservation efforts (Morris and Potter 1995, Wossink and Van Wenum 2003, Smallshire et al. 2004, Sutherland 2004, Berentsen et al. 2007, Dutton et al. 2008, Ahnstrom et al. 2009). Involving farmers in the selection of an indicator through gauging their attitudes and actions toward particular candidate species may instil a sense of pride and stewardship, and by association facilitate compliance with audit standards. In general, participation of local resource users in monitoring environmental health and resource use is fundamentally important in changing their environmental subjectivity/orientation (Agrawal 2005). Developing flagship species and monitoring methods that are applied and trusted by farmers is therefore likely to be key to long-term utility and collaboration that makes market quality assurance audit schemes succeed and trigger real change in both environmental and social resilience. It is therefore imperative that effort be taken to find a balance between farmer and consumer components of the model in identifying a species that is informative both at the farm level and to consumers abroad.

Choice of birds as candidate flagship species

Birds are ideal species with which ecological measures of diversity and abundance may be effectively complemented by social data describing farmer attitudes and actions toward non-production species. Birds tend to be high up in food chains and are highly visible on the landscape, making them both representative of lower trophic taxa and

amenable to field data collection (Hutto 1998, Gregory and Strien 2010). Their conspicuousness similarly means farmers are typically more aware of birds as providers of ecosystem services as well as pest species relative to other taxa (Hutto 1998, Herzon and Mikk 2007). Further, birds are often used as indicator or flagship species due to their frequent association with high intrinsic value (Caro and O'Dogherty 1999). New Zealand agroecosystems are characterized by largely introduced arable crops and grasses as well as a suite of introduced invertebrate and bird species (Norton and Miller 2000). While several native bird species are regarded as iconic and associated with high cultural value (Department of Conservation and Ministry for the Environment 2000, hereafter DoC and MfE 2000), the cultural and ecolgoical contribution of introduced species to socio-ecological farming systems of New Zealand's production lands cannot be neglected (Macleod et al. 2008). Many introduced bird species suffering population declines abroad presently thrive on New Zealand sheep/beef farms (Macleod et al. 2005*a* and *b*; MacLeod et al. 2008; MacLeod et al. 2009). These species have potential to serve the combined role of indicating ecological health within New Zealand and signaling biodiversity friendly farming practices to consumers in export markets.

Testing the utility of the market flagship model

In the following chapters, birds are used as focal taxa in testing the efficacy of first ecological, then social criteria in informing the proposed Market Flagship Species conceptual model as it pertains to the South Island sheep/beef sector. Research is considered within the framework of the 'ARGOS null hypothesis' which posits that the ecological, social and economic outcomes of organic, Integrated Management and conventional farming are the same. Within certain sectors, such as kiwifruit, there is a distinct delineation between organic and IM standards. However, all research within the sheep/beef sector should be approached with the caveat that IM in this sector follows a more fluid and somewhat varied protocol where a wider range of chemicals can be applied, and inputs are minmised by a variety of strategies (Wharfe and Manhire 2004). Given this, IM management of sheep/beef farms represents something of a spectrum encompassing the effictively conventional to the effectively organic, and any conclusions regarding panel effects should be interpeted with caution.

In general, conservation biology has proceeded on a normative claim that increased biodiversity is a positive thing that confers adaptability and systems resilience. This research described in this thesis was conducted under the axiomatic assumption that

greater bird diversity is representative of greater diversity of invertebrates and plant food sources (Furness et al. 1993, Huttto 1998, Gregory and van Strien 2010), and that systems with high levels of biodiversity are more resilient (Tilman et al. 1996, Peterson et al. 1998, Tilman 1999, Elmqvist et al. 2003, Tscharntke 2005, Darnhofer et al. 2010). Only recently has research begun to address the specific benefits of ecosystem services performed by a diversity of species within a system (Luck et al. 2003, Luck et al. 2009), particularly with regard to birds (Whelan et al. 2008, Sekercioglu, 2010). Presently, ARGOS has yet to investigate how specific ecosystem services equate to economic gains at the farm level, though there is a call for such research. A central objective of this thesis is to generate and synthesize findings that may better inform and guide subsequent studies and methods. Taking into account the aforementioned assumptions, the main steps in testing and developing the conceptual model for a market flagship species are:

1). Development of a robust methodology to measure bird abundance and diversity in full range of habitat types, patch sizes and configurations commonly present on South Island sheep-beef farms (Chapter 2)

2). The identification of associations between richness of native and introduced bird species and characteristics of unmodified habitat patches such as dominant vegetation type, patch size and patch shape complexity (Chapter 3).

3). The proposal of an initial set of native and introduced candidate species, and description of quantifiable relationships between each species, habitat metrics and wider species richness. Findings are discussed as they pertain to ecological strata of the market flagship model (Chapter 4).

4). The examination of farmers' attitudes and actions toward birds using Likert-based survey responses of sheep/beef farmers to specific questions regarding the perceived role of native and introduced birds birds as supplies of agro-ecosystem services, possible pest species, and willingness to participate in a market accreditation scheme that uses birds as indicator species. Survey data are accompanied by commentary from sit-down interviews in which farmers were asked to elaborate on their perceptions of birds (Chapter 5).

5. The description of farmers' ability to recognize different bird species on their farms, with particular emphasis on recognition and perceptions of candidate market flagship species. Farmer attitudes and actions toward birds are further discussed with regard to the intrinsic and production value placed on birds, the role of birds as suppliers of ecosystem services, the utility of birds as indicators of healthy, robust

agroecosystems, enablers and constraints to supporting birds, and the plain practicalities of monitoring the abundance of candidate market flagship species. Finally all findings are synthesized into a transdisciplinary analysis of candidate indicator species using the outlined conceptual framework (Chapter 6).

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Chapter 2: A method for the elimination of bias in estimating bird community structure within small habitat fragments

Abstract

Based on data collected during five-minute point counts of bird species within woody vegetation patches on sheep/beef farms, South Island, New Zealand, the distance detection function was used to derive a method of truncating counts of birds detected close to the observer to estimate their relative abundance in small habitat patches. This method trades off loss of information by truncation of bird sightings at successively larger distances from the observer to reduce sampling bias. Truncation of counts to a core-truncation-radious of 10m around the observer gave similar absolute density estimates as distance methods for six native and six introduced bird species. Distance analysis showed that introduced species were in general more conspicuous than native species, and that all species had an effective detection radius (EDR) of 20-30m. 10m truncation allowed retention of 20% of the initial dataset, but excluded only 20% of all sampled patches. Use of counts very close to the observer reduces detectability biases for species and habitat comparisons, gives more robust measures of community structure, allows inclusion of very small habitat fragments into the analysis and provides a relative abundance measure for infrequently encounterd species. Despite correspondence with distance density estimates, counts are still best treated as relative indices rather than absolute density estimates. The described research suggests much of the international literature using counts and distance sampling estimation methods to claim increased diversity and abundance of birds in larger habitat patches may be unreliable

Key words: distance analysis, five-minute point count, farmland bird, sampling bias

Introduction

Distance analysis

Point counts are frequently used to generate abundance estimates for bird species. A key drawback to this methodology is that it often does not account for detection bias, which may vary greatly according to a number of factors such as observer, individual species behaviour, habitat type, vegetation density and season (Norvell et al. 2003, Dos Anjos 2007, Johnson 2008). Increasingly, distance sampling theory and analysis (Buckland et al. 2001, 2004) is used to eliminate detection bias by describing a detection function for each species and habitat type or landscape. The detection function describes the probability of detecting a bird present at successively larger distances from the observer. If detection differs by habitat type (for example, because of effects of vegetation thickness on detectability), the measure of differential detectability is incorporated to convert the number of detections to an unbiased estimate of absolute density (birds/ha).

The basic assumptions behind distance sampling are that 1) all animals at zero distance from the observer are detected, 2) detectability declines monotonically with distance, 3) animals do not move in response to the observer before they are detected and 4) measurements of distance from the observer to the animal are accurate (Buckland et al. 1993, 2001, 2004). A fifth and usually unstated assumption was encountered when counting birds in New Zealand sheep/beef farmland woody habitat patches, such as forest remnants and farm shelterbelts: that sufficient habitat is present around the observer for counts at successive distances to decay away fully and thereby reliably reveal the detection function. In many cases, the woody vegetation patches on sheep/beef farms are each so small that the habitat itself runs out well before the probability of detecting a bird at increasing distance from the observer is extinguished. A standard distance sampling analysis approach would therefore seriously distort the density calculations. The main objective of this thesis was to identify associations between species richness and habitat metrics, such as patch size and patch shape complexity within continuous vegetation, in order to advise farmers on how to restore bird abundance and diversity. To accomplish this, a method was needed to describe community composition with minimal detection and sampling bias between different patches and habitat types, some of which were very small. The study goals therefore precipitated a major conceptual problem about how to estimate a detection function from counts pooled from several small, medium and large patch sizes,

rather than the typical circumstance of pooling all bird detections in a global landscape study.

This chapter first describes the conceptual problem in more detail, then proposes a range of potential solutions. A modified estimation methodology is described that uses short radial truncation distances to simultaneously mitigate sampling and detection biases so that relatively unbiased comparisons of relative abundance and diversity in different habitats and patch sizes can follow. The new method is tested by comparing density estimates with classical distance estimates for six native and six introduced bird species in mixed native and exotic forest patches on New Zealand South Island sheep/beef farms. Finally, a modified estimation methodology is described that uses short radial truncation distances to simultaneously mitigate sampling and detection biases so that unbiased comparisons of relative abundance and diversity in different habitats and patch sizes can follow (Chapters 3 and 4).

Methods

Study questions and data collection

Bird surveys were conducted within woody habitat patches on 12 South Island, New Zealand sheep/beef farms over the course of 8 field circuits from 2007-2009 (Meadows 2010). Five-minute point counts were conducted according to the general methods of Dawson and Bull (1975), but incorporated distance sampling field methods by measuring the radial distance and angle from the observer to each recorded bird. On each farm, five-minute count locations were generated using Hawth's Analysis Tools for ArcMap v.9.2 (Beyer 2004, ESRI 2006), which generated 15 random sample points within vector polygons representing shelterbelts and woody patches of each farm's boundary for every survey circuit. To account for spatial representation of varying patch sizes across the landscape, points were generated such that more counts occurred within large vegetation patches than small patches. All survey points were at least 100m apart to avoid double-counting.

Observers waited for two minutes upon reaching each sample point before starting the five-minute count in order to ensure that any species that may have been disturbed would have returned to the site and recommenced movement or singing. The following data were recorded for all birds detected within a five minute period: species, individual or group, number of individuals (cluster/flock size), detection cue (seen, heard or both), behaviour and location (distance and angle to observer using a range finder (Bushnell

Yardage Pro®, Bushnell Performance Optics, Overland Park, Kansas). The peak calling periods at dawn and dusk, when conspicuousness and detectability can change rapidly (Dawson and Bull 1975), were avoided.

Each habitat polygon was assigned one of 7 habitat types: mixed native trees, mixed native and exotic trees, Manuka/Kanuka trees, exotic conifer trees, shrubland, exotic conifer shelterbelt, mixed tree shelterbelt. As the fundamental ecological question centred around species presence within woody vegetation, a habitat boundary truncation rule was applied: First, radial distance and angle information were used to generate a GIS map of bird sightings across the landscape for all farms. All sightings located outside of vegetation patches (usually open paddock) were eliminated. Second, to ensure sightings within polygons were representative of bird presence within a given habitat and not error around coordinate estimation by GPS units, observer-reported habitat was compared to habitat type information for each polygon. Recorded habitat information tightly corresponded to that of ArcMap, and only a few points were eliminated based on disparities between habitat data.

Generating a detection function using distance theory

When using distance sampling in conjunction with point counts, observers record the distance from a randomly placed point to an animal detected within a conceptual truncation radius *w* (Figure 1). Not all animals within distance *w* will be detected, but a fundamental assumption is that all animals at zero distance are detected, or failing that, that the proportion of detections at zero distance is known. The distribution of the observed distances is used to estimate a detection function *g(r)* that describes the probability of detecting a bird at radial distance *r*, where $g(0) = 1$ (Buckland et al. 1993, 2001, 2004). If the assumptions hold, this function allows the estimation of the average probability *P* of detecting a bird given that is within radius *w* around the point. Animal density can then be estimated as:

$$D = n/(P*a)$$

where *n* is the number of animals detected and *a* is the size of the region covered (the total number of survey points multiplied by πw^2). A related and useful metric associated with the distance analysis is the "Effective Strip Width" (for counts along transects), or "Effective Detection Radius" (for point counts like those employed in this study). The Effective Detection Radius (EDR) is the distance beyond which as many extra birds are

actually detected as were present but not detected inside the radius (Figure 1). The area of a circle with a radius of EDR is therefore equivalent to the area where all birds have been censused (i.e. probability of detection is 1).

It is recommended that in order to reliably estimate detection function and density, a minimum of a total of 60–80 sightings from 10–20 replicate transects is needed within a study area (Buckland, 2001, Mazerolle et al., 2007). To maximize model fit for point count data, it is further recommended (Buckland, 2001) that data are 'right truncated' beyond the radial distance ('right-truncation-distance') *w* at which the probability of detection in the initial model < 0.10 (Figure 2.1).

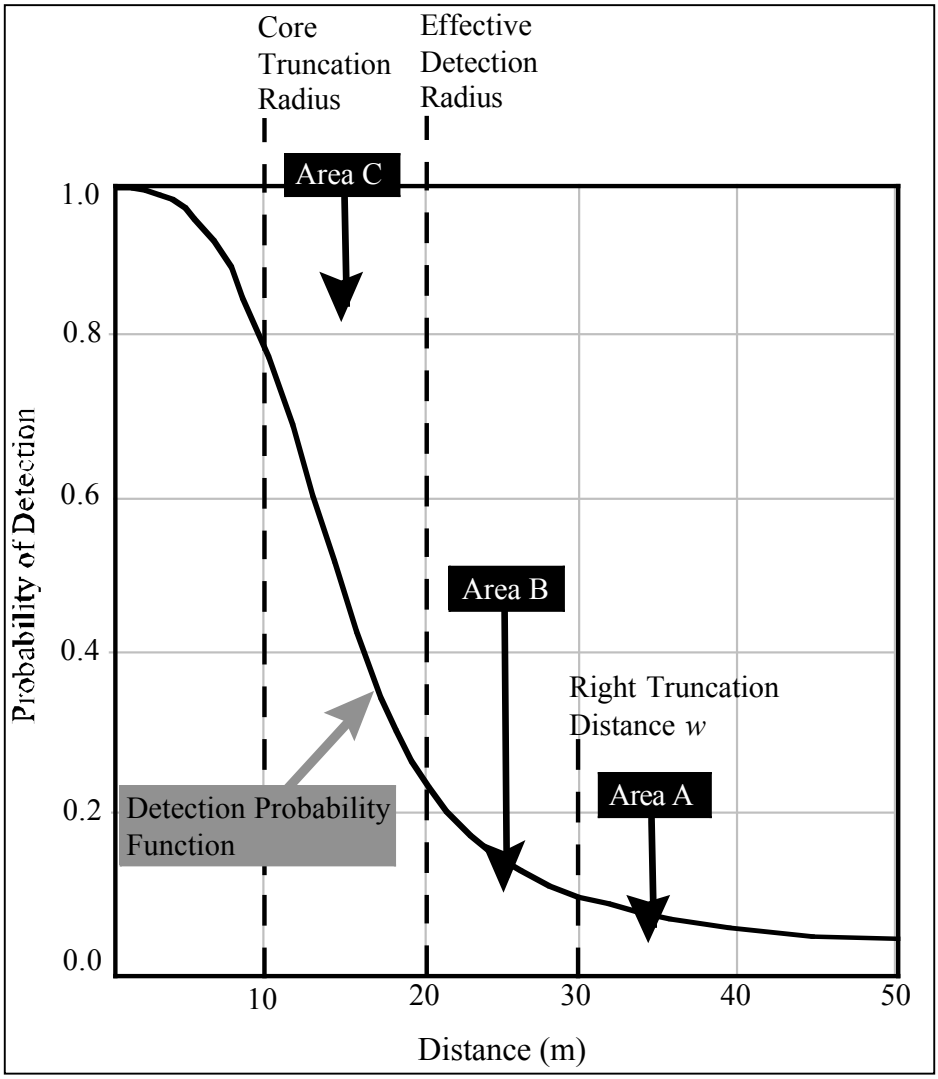


Figure 2.1 Underlying model behind distance estimation. All data in Area A are eliminated to help modelling the detection function within radius *w*. The Effective Detection Radius is estimated so that the same number of birds are missed within the EDR as are detected outside it *i.e.* Area B (below the detection function line and between 20 and 30 m) and Area C (above the detection function but within the EDR) will therefore have the same size. This study proposes the instigation of a 'core-truncation-radius' at 10m within which nearly all birds will be detected.

Limitations of distance sampling for estimates in small habitat patches

Distance density estimates are mostly used to estimate species densities at a landscape scale, with little focus on delineating differences in size and type of discrete habitat patches within the land matrix. While habitat may be included as a covariate in fitting a detection function, there is no clear established methodology for looking at patch-level differences in density estimates. A fundamental and usually unstated assumption of distance modelling is that a continuous sampling domain is available, with birds present all the way out and well beyond the right truncation distance. If so, the rate of fall of the detection probability function at increasing distance from the observer is driven entirely by the conspicuousness of the birds and the observer's ability to detect the birds in such a habitat type. However, if the radius of some of the patches sampled for distance estimation is less than right-truncation-distance, part of the decrease in the number of birds detected is also driven by the distribution of patch sizes in the landscape. Any density estimates generated using a common detection function from all bird counts pooled from several patches will therefore be distorted. The degree of distortion will depend on the proportion of the overall habitat sampled that is made up of small patches with a radius less than the EDR. Most seriously, the abundance and diversity of birds in very small habitat patches would be underestimated compared to in larger patches where the radius of the patch is greater than distance *w*.

Unbiased estimation at the individual patch level

There appear to be at least three interrelated ways to estimate patch level bird abundance and diversity by performing distance analysis.

1) Treat each individual patch as a separate study area and generate patch by patch detection probability functions and then density estimates for each focal species.

2) Generate a global detection function based only on data from relatively large patches (where the radius of the patch exceeds the right-truncation-distance) of a given habitat type and exclude sample points close to the habitat patch edges. Normally the habitat type influence on the detection probability function would be calculated by 'post-stratification' within Program Distance software (Buckland et al. 1993, 2001, 2004). If it can be reliably assumed that the detection probability function applies equally well to small and large patch sizes of a given habitat type, two general approaches to generate patch-level density estimates for all patch sizes then become:

(a) divide the total number of birds detected in each count by a modified and aggregated estimate of the probability of detection for the patch as a whole. This 'patch probability of detection' will depend on patch size and can be found by integrating the area under the distance probability detection function for successively larger patch radii (r) and dividing it by the area of a circle of radius *r*.

(b) truncate the data to only admit detections very close to the observer into the analysis. For example, if a 10m 'core-truncation-radius' is used (Figure 1), birds more than 10 m from the observer are eliminated from consideration. The global detection function generated from large continuous habitat patches is nearly equal to 1 at these short truncation distances, so it can be assumed that nearly all the birds present in the inner circle (10 m radius) around the observer are detected. There will be virtually no scope for detection bias from habitat type or patch size effects at such short distances from the observer. Nevertheless, data from very small habitat patches which have a radius less than the core-truncation-radius distance must be further delineated and treated separately: ie. either such patches

(i) should be eliminated from the analysis altogether, or

(ii) the physical area of these small patches must be calculated and divided into the total count to estimate absolute abundance for the patch.

Approach followed in this study

The present research recorded a total of 33 different species in the 7 described main habitats. There were very few patches for which distance sampling recommendations regarding sightings and replicate transects could be sufficiently met. Even when pooling across patches of similar habitat types, there were still insufficient sightings in one or more habitats to meet recommendations for generating a global detection function. This totally precluded the use of approach '1' above and forced use of approach '2' by calculating a global detection function from data pooled only from the relatively large patches (ie. where the radius of the patch was greater than *w*).

Approach '2a' was also judged impractical because (1) integration of global detection functions for individual species (each including, mean and upper and lower confidence intervals to account for uncertainty) would have been complex; and (2) patches

are irregular shapes, so assuming that they are circular to generate a patch probability of detection from an assumed radius could have introduced several errors.

This left approach '2b' as the remaining practical alternative to generate patch-level estimates of bird abundance and community composition. Eliminating all data beyond the core-truncation-radius removes detection bias from raw counts. However such a truncation also results in a loss of potentially valuable ecological information. If severe, this could undermine statistical power for hypothesis testing. The initial line of inquiry therefore focused on the optimum choice of the core-truncation-radius to trade-off reduction in potential bias against loss of sampling information: setting the truncation distance too far out introduces potential habitat and patch size biases; setting it too close to the observer forces elimination of more data than necessary in order to make unbiased comparisons.

Results

Point counts

Altogether 9,050 birds were detected at 1,086 points distributed between 246 habitat patches over the two year study. There were sufficient data to generate distance sampling estimates using the 2 (b) (ii) approach for 6 native species (Bellbird *Anthornis melanura*, Fantail *Rhipidura rhipidura*, Grey Warbler *Gerygone igata*, Rifleman *Acanthisitta chloris*, Silvereye *Zosterops lateralis*, Tomtit *Petroica macrocephala*) and 6 introduced species (Blackbird *Turdus merula*, Chaffinch *Fringilla fringilla*, Goldfinch *Carduelis carduelis*, Redpoll *Carduelis flammea*, Starling *Sturnus vulgaris*, Yellowhammer *Emberiza citrinella*). These were chosen candidate indicator species selected for a separate component of the described research (Chapters 3 and 4**).**

Distance analysis within large patches

The detection function was generated within the two main habitat types, each of which included adequate recorded sightings to meet distance sampling assumptions for most species. Detection functions were based on data only from patches with an average radius >30m. A global detection function was generated for each species, then post-stratified by habitat type.

Cursory preliminary distance analysis using a truncation probability of detection of 0.10 pointed to a right truncation distance of 30m. This corresponded very well to right-truncation-distances selected by MacLeod et al. (2011) and Weller et al. (2011) for farm

landscape level distance models. All subsequent distance analyses and associated detection probability functions and EDRs were therefore generated from a pooled sample of counts taken only from patches with a radius ≥ 30m of continuous habitat (assuming the area of the patch was a circle). After the removal of patches with < 30m radii, a number of smaller habitats, such as mixed tree stands and plantation conifer blocks contained insufficient sightings for reliable habitat-level estimates, so detection functions could only be described for two prominent habitat types that were present on the majority of study farms (mixed native and exotic trees and mixed native trees). Best fits were found using half-normal and hazard function cosine relationships after right-truncation at 20-30m where the detection probability reached 0.10 (Table 2.1). Whether a species was first seen or heard, observer and season were covariates that were of greatest utility in fitting detection functions (Table 2.1).

The shape of detection functions varied considerably between species. Starlings were the most detectable (conspicuous), Fantails the least, and Bellbirds exemplified medium detectability (Figure 2.2, Table 2.1). Generally, the introduced species were more conspicuous than native species i.e. their EDRs were much higher and detection probability started to inflect downwards around 10m or more from the observer. By contrast, average detection probability had already fallen to 0.3 to 0.7 for the native species at 10m from the observer (Figures 2.2b and c, Chapters 3 and 4).

Core truncation to create an unbiased index of abundance

A truncation at a core radius of 10m resulted in retention of only ≈ 20% of the original bird detections, but only exclued sampling from 48 of 246 (20%) of the available patches of all habitat types. However, shelterbelts are generally smaller than bush and scrub patches, so counts at 13 (42%) of 31 shelterbelts were eliminated when using a 10m truncation distance. Choosing a truncation distance of more than 10m from the observer would have started to seriously impair overall average detectability, especially of the native species (Table 2.1, Figures 2.2b and c). The higher the proportion of birds missed, the more scope there is for habitat and observer influences on detectability. Therefore 10m truncation distance was fixed for all point counts as a practical compromise and optimum trade-off between overall loss of information (birds detected ≥ 11m from the observer), retaining ability to sample small woody vegetation patches (especially of particular types like shelterbelts), and minimising bias by keeping detection probability close to 1.

Table 2.1 Model selection for each of 12 candidate species for 2 predominant habitat types, including detection function, truncation distance and covariates for the best-fit mode. A maximum of two covariates were selected.

Species	Detection function (expansion)	Right Truncation (m)	Covariates	EDR Mixed Native and Exotic (m)	EDR Mixed Native (m)	Probability of detection at 10m
Native						
Bellbird	Half-normal (Cosine)	30	None	14.06	15.43	0.6
Fantail	Half-normal (Cosine)	20	None	9.26	9.63	0.3
Grey Warbler	Half-normal (Cosine)	30	Observer	16.3	16.3	0.75
Rifleman	Half-normal (Cosine)	20	None	11.94	11.94	0.55
Silvereye	Hazard-rate (Cosine)	30	Seen/Heard	16.09	16.45	0.9
Tomtit	Hazard-rate (Cosine)	20	Seen/Heard, Season	11.42	11.42	0.5
Introduced						
Blackbird	Hazard-rate (Cosine)	30	Observer	17.34	17.54	0.8
Chaffinch	Hazard-rate (Cosine)	25	None	17.19	17.19	1
Goldfinch	Hazard-rate (Cosine)	30	Seen/Heard	19.06	19.06	1
Redpoll	Hazard-rate (Cosine)	25	Seen/Heard	17.47	17.47	1
Starling	Half-normal (Cosine)	30	Seen/Heard	18.77	19.21	1
Yellowhammer	Hazard-rate (Cosine)	30	Seen/Heard	17.69	17.86	0.9

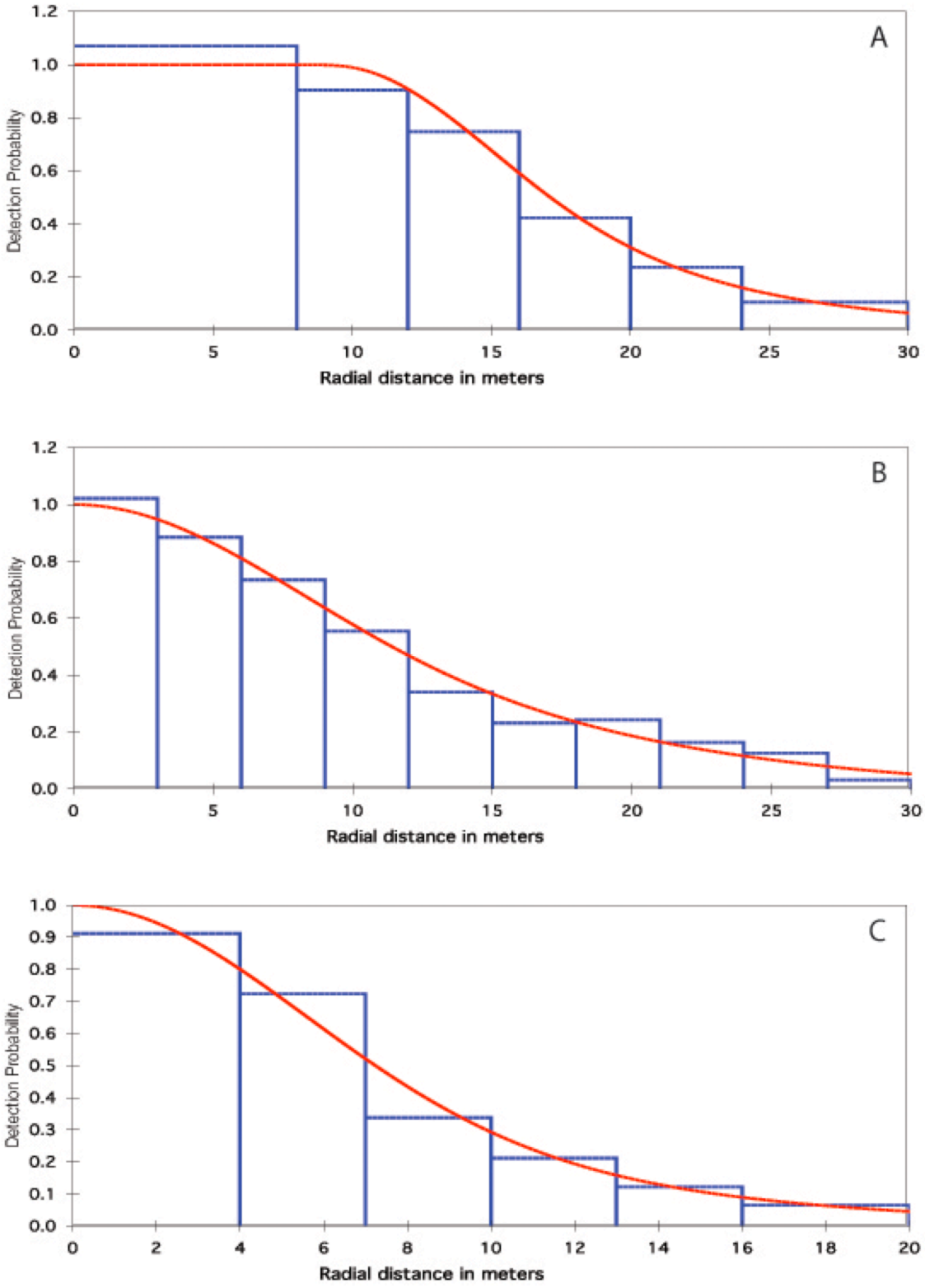


Figure 2.2 Estimated detection function pooled over the two main habitat types for (a) Starling, (b) Bellbird, and (c) Fantail. The histogram shows the number of detections in 3 bands out from the observer and the line is fitted by Program Distance from data pooled from large (radius ≥30 m) patches using a 20-30m right-truncation-distance (as in Table 2.1)

Comparison of absolute density from distance sampling and point counts

Next, the expectation that counts truncated at 10m would not be seriously biased was tested by checking that their density estimates (birds detected within a circle of 10m radius) were approximately equal to those generated for large patches in each of the two main habitat types. The distance estimate was calculated by dividing the number of birds detected out to the right truncation distance (20-30m depending on bird species) by a circle of radius EDR estimated for that species (Table 2.1). As detection probability within the 10m inner core around the observer is assummed to be close to 1, the density determined from dividing the count by an area of a circle of radius 10m (314 m^2) should be similar to that generated from EDR.

There was a reasonably close correspondence between the average absolute density estimated from counts (10m truncation) and the density estimated from distance sampling (using EDRs) for each species (Figure 2.3). The largest discrepancy between the two estimates was for the Fantail, the species with lowest conspicuousness. Otherwise, most of the estimates fell on or just above the line of parity, exactly as predicted if probability of detection has already begun to dip before 10m distance from the observer is passed. Only Silvereye estimates lie to the right of the line of parity in Figure 2.3. Some scatter around the line of parity is expected because of chance influences of how many birds in the patch occurred during the 5 minute count within the inner 10m core around the observer compared to how many occurred in the wider zone out to the right truncation distance. With such a short period of observation and continuous movement of the birds, it is expected that the proportion of the birds in the two zones would fluctuate a lot between 5 minute monitoring periods. As the inner core (10m radius) is generally a third the size of the area censused by distance models (a circle of radius EDR, ≈ 20-30 m, Table 1), the variance in the 10m count is likely to be higher than for the distance estimate for that same point. Also, disturbance by the observer may trigger a net movement out of the inner 10m radius core so that more birds are detected using the wider EDR method from Distance (Table 2.1).

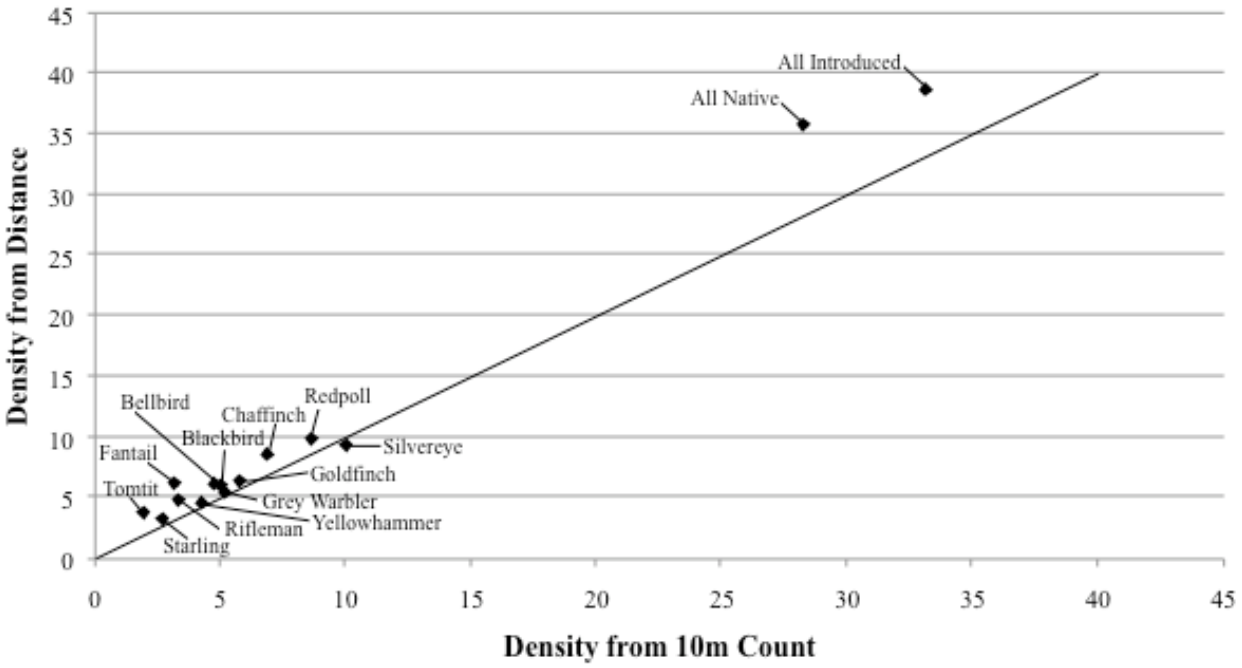


Figure 3. Comparison of the average density calculated from 10m truncated bird counts (x-axis) and the predicted density from distance methodology (y-axis). The line shows parity (i.e. equivalent density estimates from the two methods). The combined density of all six native species and all six introduced species are shown at the top right

Discussion

Distance model building

In accordance with the method presented here, MacLeod et al. **(**2011) and Weller et al. **(**2011) analysed much larger datasets and similarly found a 20-30m right truncation was most appropriate and that whether a bird was first seen or heard often improved model fit (Table 1). However, a fundamental point of the proposed method is that detection functions were only able to be fitted for 12 species within two key habitats in order to meet recommendations for detection and replication of the modelling. This emphasizes the limitations of distance sampling in describing bird community composition in fragmented habitat mosaics, especially when the key ecological processes to be researched require unbiased estimates or indices of bird abundance at the individual patch level, as opposed to the landscape level.

Another problem in estimating density within individual patch sizes arises from an 'edge sampling bias'. Estimation by distance analysis will underestimate density when many sampling points fall near the edge of habitat patches. A segment of the standard detection circle (out to the right-truncation-distance *w*) that lies outside the patch cannot easily be excluded from the detection function without reducing the sampling area by the

proportion of a full circle that falls outside the patch. When sampling points are randomly assigned, as in the present study, the probability of a point falling near the edge of a small patch is very much greater in small patches than for large patches. The resulting effect will be serious under-estimation of bird density when using distance methods in smaller patches. Using counts with a very short truncation distance therefore also helps the robustness of the bird abundance estimation by being relatively unaffected by this edge sampling bias compared to much greater distortions likely from Distance estimation. While methods exist to account for the presence of excluded or uncovered portions in the surveyed area (Buckland et al. 2001), they are computationally difficult, and normally would require the use of an accurate GIS map. The strength of this edge bias has generally not been quantified in other studies using distance analysis. This study therefore asserts that near-truncation counts are likely to be relatively unbiased compared to full distance sampling estimates in fragmented habitat mosaics.

Choice of core-truncation-radius

A single truncation distance of 10m was chosen for all species. This resulted in differences in correspondence of the counts compared to distance estimates between species (eg. Starlings vs. Fantail in Figure 3). Other studies, especially those focussing on a few species, may benefit from species specific truncation distances. However using a single distance keeps the method simple, facilitates field recording, and will allow a direct correspondence between measures of bird density and habitat quality (all of which can be conducted within the same 10m radius of the observation point). Also, keeping the truncation distance as long as possible maximises the information gathered and might minimise the disturbance effects of the observer. There are several examples in the distance estimation literature where attraction or repulsion of the birds from the immediate vicinity of the observer can distort density estimation (Gutzwiller and Marcum 1997; Buckland et al. 2001, 2004; Diefenbach et al. 2003).

The traditional five-minute bird count method normally excludes all birds detected more than 200m from the observer (Dawson and Bull 1975). This study using distance methods underscores how these extreme distance for truncation has the potential to very seriously bias five-minute bird counts for inter-species comparisons. Similarly, strong biases would be expected between five-minute bird counts in open habitats compared to relatively closed ones like bush and scrub where line of sight is rapidly occluded by woody vegetation. Indeed, the main conclusion of the present study is that truncation distance

must be very short (in the order of 10m) to minimise bias when using raw counts to compare the abundance of different species, or of the same species in different habitats.

Truncation does not remove bias altogether

Counts truncated at 10m still failed to detect some birds (Figures 2.2 and 2.3). Rather than regard 10m counts as measures of absolute density (birds/ha), it is more prudent to assume that counts within the core-truncation-radius are only correlated with absolute density, and thus should be regarded as a relative index of abundance (Caughley 1977). Native species density will be particularly underestimated by the core count method compared to introduced species, at least when a 10m core truncation radius is used. However, by minimising area C in Figure 1, little scope remains for differential bias between very different habitat types and species, so diversity indices and relative abundance can be investigated with less risk of detectability having confounded conclusions.

A large gain for this study was realised by being able to estimate relative abundance from core counts even for the infrequently encountered species. Data constraints made it impossible to estimate density by distance methods for 65% of the 17 native species and 31% of the 16 introduced species recorded, whereas relative indices were available from all and from small habitat patches provided it is assumed that the detection functions of all the species are very similar close in to the observer. However, it is important to note that the two methods were compared at the exact same locations within a very restricted set of conditions (only two habitat types and only in large patches ≥30m). Although the EDRs for the two types of forest were remarkably similar (Table 2.1), application of the method to much smaller habitat patches and different habitat types might introduce more error from the 10m truncation counts as estimates of absolute density. For example, if smaller habitat patches have more undergrowth because of increased light penetration, perhaps the detectability function estimated within large patches of the same broad habitat type will no longer be accurate. Similarly, detectability of birds in close scrubby habitats may be so different from that in the mature tree habitats used here for calibrating and cross-checking the truncated count technique, that even a severe 10m truncation may lead to some birds in scrub not being detected.

Until a larger sample of sightings in alternative habitats can be gathered to build comparative distance samples that actually measure the detectability differences in these very different types of habitat, it is recommend that the 10m truncated counts are treated only as relative indices of abundance. Presently, they should only be used for cautious

comparisons of relative abundance between different habitat types. Truncation will have reduced potential bias, albeit not totally eliminated it.

Extending the duration of counts

Severe truncation of bird observations to include only those close to the observer minimises bias, but it also causes loss of data. For some agendas, such as calculating species diversity indices, many of the core counts will be difficult to analyses statistically because many are zeros (Chapters 3 and 4). Further study is recommended to test the utility of extending the count duration well beyond the 5 minute protocol commonly used in New Zealand. This may increase the diversity of species detections, but also might introduce new problems of double-counting of the same individual birds.

Bias in previous studies

Much of the international literature using counts and distance sampling estimation methods concludes that diversity and abundance of birds increases in larger habitat patches (Uezu et al. 2005, Davis et al. 2006, Marsden et al. 2006, Mitchell et al. 2006). If so, ecological restoration should prioritise creation of fewer but larger patches over many small ones for a given diversion of landuse from production to conservation goals (Diamond 1976, Brotons et al. 2003, Donald and Evans 2006). It is of concern that some of these conclusions may be unreliable because of underestimation of abundance and diversity of birds in small habitat patches. In general, more critical evaluation of the influence of scale of habitat patches on density estimation is urged, regardless of which method is deployed. The now traditional use of five-minute bird counts in habitat fragments in New Zealand is potentially misleading.

Conclusion

Though a somewhat rudimentary approach, the truncation of sightings to a close distance to the observer ensures that nearly all present species and individuals are recorded, and thus serves as a relatively unbiased and locally comprehensive index. Further, it provides abundance indices for all present species in the majority of sampled habitat patches and allows a more comprehensive description of community composition than is possible with distance. Loss of data from exclusion of detections greater than a core-truncation-radius could undermine statistical power for testing hypotheses about habitat and farming effects on avian diversity and abundance, but at least any differences

detected can now be more reliably interpreted as being real ecological patterns rather than artifacts of differential detectability.

Chapter 3: Bird community composition associations with woody vegetation on New Zealand South Island sheep/beef farms

Abstract

Bird species richness within woody vegetation patches of sheep/beef farms on New Zealand's South Island was examined with regard to habitat size and complexity. General linear models were used to predict richness of native and introduced bird species using patch characters such as area, shape complexity and vegetation composition as predictive variables. The model that best predicted native species richness explained 62% of variance, compared to 5% for the introduced species model. Native species richness was strongly associated with area ($p<0.001$) and habitat, with highest native species richness associated with mixed native tree ($p=0.017$) and Manuka/Kanuka tree ($p<0.001$) habitats. Native species richness was also negatively associated with the Integrated Management (IM) farming system ($p=0.03$). By contrast, Introduced species richness was positively associated with IM farming ($p=0.007$), and significantly associated with Manuka/Kanuka and exotic conifer tree habitat. These findings indicate native species are greatly reliant on the presence of native tree species within the agricultural land matrix, and further suggest efforts to increase native species richness within pastoral systems should direct focus toward protection and enhancement of large, native tree habitats.

Key words: Agroecosystem, biodiversity, farmland birds, species richness, New Zealand

Introduction

Biodiversity provides ecosystem services essential to commodity production, such as nitrogen fixation, decomposition, pollination and pest control (Matson et al.1997). Redundancies in species and processes within an agroecosystem may enhance a system's, resilience, or capacity to recover from perturbation and transition to new states (Fischer et al. 2006, Darnhofer et al. 2010). Systems with greater biodiversity and resilience are potentially less reliant on external inputs that maintain production (Milestad and Darnhofer 2003).

Birds are often high in the food chains of agroecosystems. Changes in richness and abundance of bird species and communities may thusly indicate cascading changes across several trophic levels (Furness et al. 1993, Krebs et al. 1999). Declines in farmland birds in Europe and North America over the latter part of the 20th century have been largely attributed to agricultural intensification, or the process by which an increase in the output of agricultural commodities is driven by the increase of input of subsidies such as labour, fertilizer or seed (Chamberlain et al. 2000, Donald et al. 2001. Newton 2004, Ghilain and Belisle 2008, FAO 2008). More specifically, these declines are correlated with homogenization of habitat, which likely reduces the diversity and abundance of bird species able to successfully forage and breed on production lands (Newton 2004, Wilson et al. 2005). Intensive farming need not invariably imply all potential bird habitat within an agroecosystem is homogoneous or that intensification itself must reduce biodiversity (Moller et al. 2008*a*, Meadows et al. 2008, Weller et al. 2008). For example, recent evidence suggests farmland bird diversity is best explained by a combination of the extent and complexity of habitat and management system (Freemark and Kirk 2001, Hole et al. 2005, Smith et. al. 2010). Maintaining agricultural intensification while securing biodiversity in production landscapes therefore depends on detailed knowledge of the influences of 'refuge habitats' within the farmland matrix to guide targeted farm management, habitat restoration, choice of woody vegetation planting and shelterbelt maintenance.

Agricultural production comprises a significant portion of the New Zealand economy, with agricultural-based products representing 53% of merchandise exports (Ballingall and Lattimore, 2004, Statistics New Zealand, 2006). Over the last 40 years, New Zealand agriculture has been characterized by intensification in the form of increasing stock rates and use of pesticides and fertilizers. The rate of intensification may still be accelerating, raising concerns about the present and future sustainability of New

Zealand production (PCE 2004, MacLeod and Moller 2006). Presently, nearly all but 18% of New Zealand private land below 500 metres is used in agriculture and forestry production (Norton 2000). The warm, fertile conditions that make lowlands ideal for these means of production similarly enable them to potentially support high levels of biodiversity. As a result, the New Zealand government has deemed biodiversity conservation on private lands a conservation imperative (Doc and MfE 2000). This goal, seemingly at odds with the existing system of intensive production, would require an integrated landscape approach based on conservation through sustainable use (MacLeod et al. 2008).

In order to best inform a move toward biodiversity conservation through sustainable use on production lands, baseline levels of biodiversity must be measured and associations between biodiversity and factors such as habitat and management system must be identified. While recent research has begun to establish surveys of bird diversity and associations between bird diversity and management system on New Zealand sheep/beef farms, the structure of the landscape often results in the majority of bird counts occurring in open-paddocks (Blackwell et al. 2005, MacLeod et al. in review, Weller et al. in review). Forest and scrub patches embedded within the production land matrix are critical in supporting birds and other farmland biodiversity (Fuller et al. 2001, Marshall 2005, Blackwell et al. 2008, Lee et al. 2008, Moller et al. 2008*a* and *b*, Whittigham et al. 2009). A detailed understanding of the link between bird diversity and community composition and the nature, stature and management of woody vegetation patches within farms may be of great importance in guiding farm management.

There are clear signs of rapid removal of farm shelterbelts in southern pastoral landscapes of New Zealand (Lee et al. 2008), while woody vegetation is simultaneously being added in riparian zones to protect stream health. Although there are no published accounts of the relative frequency, physical dimensions and vegetation composition of woody vegetation within New Zealand farms, it is obvious through casual observation that introduced woody species, especially fast growing conifers (pines, macrocarpa) and several Australian eucalypt species often predominate. Prolonged geographic isolation and consequent co-evolution of New Zealand's native biota suggests that native bird species may be closely associated with native woody vegetation communities, whereas most of the species introduced in the past two centuries exhibit no strong association with any particular vegetation type. (Freeman 1999, Williams 1973, Blackwell et. al 2005). However, the distribution, abundance and diversity of native and introduced bird species

amongst relatively small and highly modified patches of native and introduced woody vegetation within pastoral farms has not yet been investigated in detail. Biogeographical studies have emphasised that the arrangement of a given vegetation type might also greatly influence its ability to support biodiversity. For example, larger patches often support higher abundance and diversity of birds (MacArthur and Wilson 1967, Diamond 1976, Forman 1995, Brotons et al. 2003, Uezu et al. 2005), and smaller patches that are 'connected' to larger patches by ecological corridors may contribute more to maintaining biodiversity (Diamond 1978, Forman 1995).

There is an urgent need to investigate the specific role these woody vegetation patches play in supporting bird diversity, and by proxy, biodiversity on New Zealand pastoral landscapes. This chapter describes bird species diversity and abundance within unmodified habitat patches on South Island sheep/beef farms. Specific emphasis is placed on the degree to which habitat characteristics, such as patch size, patch shape complexity and dominant vegetation type are associated with bird diversity. Bird species/habitat associations are compared across conventional, Integrated Management (IM) and certified organic management systems. By identifying key habitat factors within the land matrix associated with higher levels of bird diversity, this research endeavors to provide a foundation of ecological knowledge upon which sustainable use and biodiversity-friendly management practices can be based. A secondary aim is to facilitate the nomination of a 'Market Flagship Species' for promoting biodiversity care and monitoring longer-term changes in biodiversity on farms (Chapter 1). More simply and immediately, the descriptive studies presented in this chapter are first steps in testing and refining a methodology for monitoring biodiversity in future. Chapter 4 (following) takes a single species and comparative abundance approach to complement the community composition emphasis presented here.

Methods

Overall study design

This study was conducted within the Agriculture Research Group on Sustainability (ARGOS, http://www.argos.org.nz). ARGOS seeks to identify pathways to sustainability in New Zealand farming systems through the comparison of social, economic and environmental factors. ARGOS conducts ongoing research in multiple farm sectors that differ and geographic location and management system. A key focus is the collection of longitudinal data within all disciplines that will allow for temporal comparisons of social,

economic and environmental states, particularly with regard to disturbance and changes in farm management practices. Research was confined to the sheep/beef sector, which is located predominantly on the South Island. ARGOS farms are matched according to a cluster design, with each cluster comprised three farms of like elevation, climate and soil type, and representing each of three different management types, or "panels": conventional, IM and certified organic. Organic farms follow strict protocols laid down by Bio-Gro or CertNZ that use no artificial fertilisers or pesticides. IM follows a somewhat more varied protocol where a wider range of chemicals can be applied, but inputs are minimised by a variety of strategies (Wharfe and Manhire, 2004). Through this quasii-experimental design, a key focus of ARGOS is to test the null hypothesis that there are no differences in environmental, social and economic outcomes between organic, integrated and conventional farming. Accordingly, the presented research seeks identify differences in bird abundance and diversity between panels.

Study areas

Research was conducted on four clusters of South Island sheep/beef farms. Clusters were located near Outram, Oamaru, the Catlins and on the Banks Peninsula and each contained one conventional, IM and organic farm (Figure 3.1.) These particular clusters were chosen because the proximity of farms to one another within each cluster allowed for efficient repeated surveys in all areas, and their spatial distribution across the South Island provided a wide variety of landscape types.

Average farm size was ~520ha, with Outram farms being the largest and Oamaru farms the smallest. Landscape differed between clusters, with Banks Peninsula farms tending to have steeper slopes and Outram farms, located on the Central Otago plateau, tending to have a flatter topography with more open spaces. Catlins farms contained the largest native forest blocks.

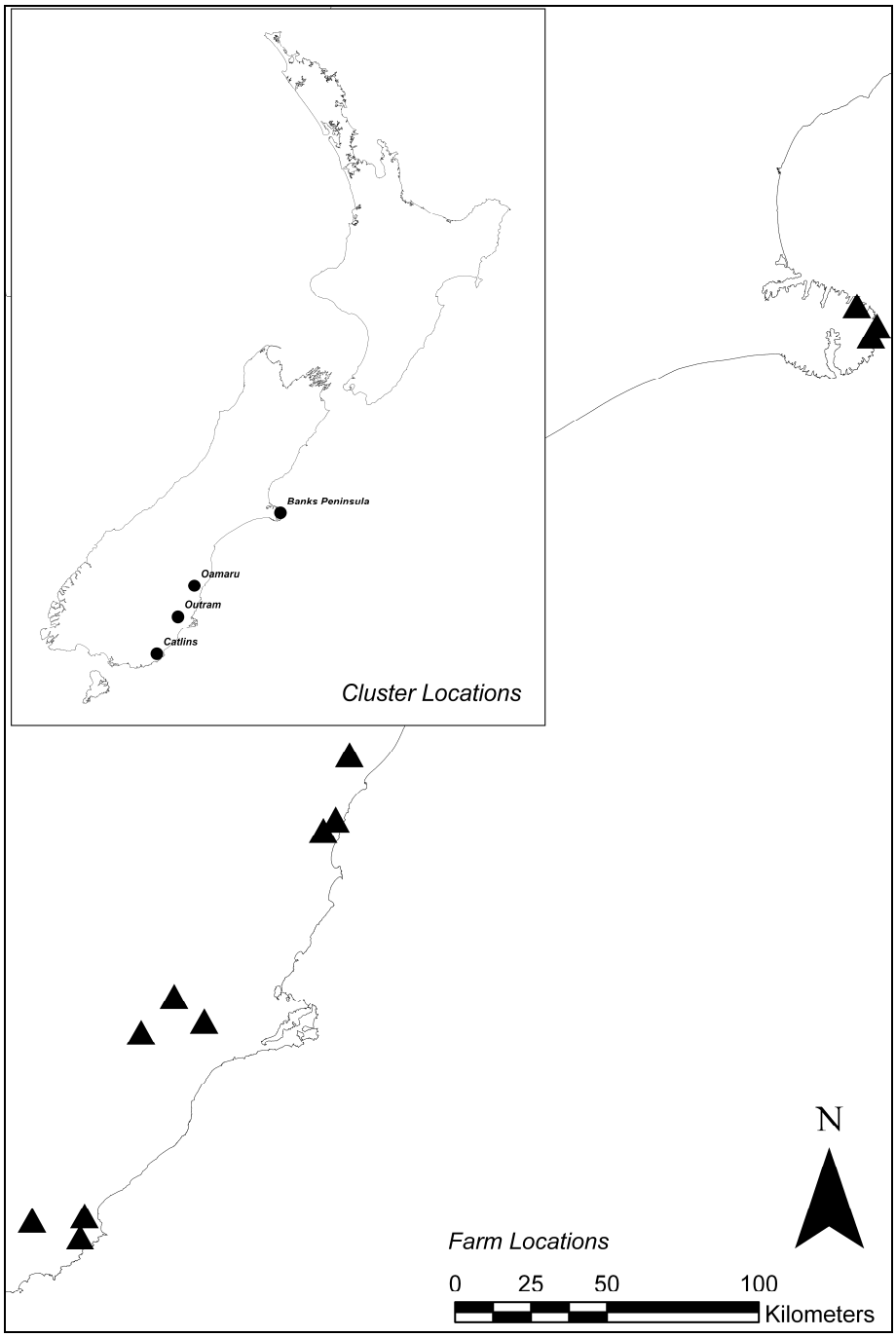


Figure 3.1 Map of the South Island of New Zealand showing cluster locations in Banks Peninsula, Oamaru, Outram and Catlins and individual sheep/beef farm locations within each cluster.

Measures of habitat size and complexity

Because the focus of this study centres on woody components of the land matrix, habitats were grouped into 7 different types based on predominant woody vegetation species (Table 3.1) Patch Analyst software (Rempel and Carr 2008) was used in conjunction with ArcMap (ESRI 2006) to create maps of habitat type and generate habitat metrics describing size and shape complexity of patches (Table 3.1). These metrics included patch area, perimeter, area-perimeter ratio, shape index and fractal dimension.

The latter two measures describe shape complexity. Briefly, the shape index measures complexity of patch shape compared to a standard shape (in this case, a circle) of the same size. Shape index values are 1.0 for a circular patch and increase with patch complexity. Fractal dimension is widely used in wildlife ecology to describe the complexity of patch shapes within a landscape (Virkkala 1993, Brennan and Schnell 2005, Guldemond and van Aarde 2010). For simple Euclidean shapes, such as circles and rectangles, fractal dimension = 1.0. As the shape increases in complexity, fractal dimension approaches 2.0.

Table 3.1 Habitat type, predominant woody vegetation species, and mean (range) for: area, perimeter, perimetar-area ratio, shape index and fractal dimension metrics.

Habitat type	Dominant Species	Area (Ha)	Perimeter (m)	Perimeter area ratio	Shape index	Fractal dimension
Mixed native trees	Broadleaf (*Griselinia littoralis*, Mapau (*Myrsine australis)* Mahoe (*Melicytus ramiflorus*), *Pittosporum spp,* Tree fuchsia (*Fuchsia excorticata*), Five-finger (*Pseudopanax arboreus*), Pepper tree (*Pseudowintera axillaris*)	29.52 (0.07-61.42)	4817.55 (144-10,126.86)	0.03 (0.01-0.21)	2.61 (1.11-4.41)	1.37 (1.23-1.61)
Mixed native and exotic trees	Exotic deciduous trees, exotic Eucalypts (*Eucalyptus spp.)*, native Manuka (*Leptospermum scoparium*), native Kanuka (*Kunzea ericoides*), Pepper tree, Tree fuchsia	10.78 (0.02-51.78)	2591.92 (72.13-10,475.47)	0.05 (0.02-0.33)	2.26 (1.15-6.93)	1.39 (1.25-1.61)
Manuka/Kanuka trees	Manuka/Kanuka monoculture	11.52 (0.43-25.96)	5030.19 (251.12-11,65.38)	0.05 (0.02-0.09)	3.78 (1.07-6.40)	1.41 (1.29-1.51)
Shrubland/small trees	Exotic gorse (*Ulex europeaus*), exotic broom (*Cytisus scoparius*), native Matagouri (*Discaria toumatou*), Manuka/Kanuka scrub	12.40 (0.02-17.64)	4503.11 (65.96-6686.05)	0.04 (0.01-0.27)	3.41 (1.07-4.49)	1.41 (1.23-1.52)
Exotic conifer trees	Mainly plantation blocks of *Pinus radiata*	5.68 (0.03-17.67)	1203.62 (77.23-2439.73)	0.04 (0.01-0.23)	1.59 (1.09-2.97)	1.34 (1.26-1.55)
Mixed tree shelterbelt	Mainly exotic Eucalypt species; some exotic deciduous species	0.38 (0.06-1.46)	487.55 (119.67-972.06)	0.18 (0.06-0.33)	2.45 (1.32-4.60)	1.54 (1.40-1.71)
Exotic conifer shelterbelt	Mainly *Pinus radiata*	0.41 (0.024-1.54)	984.74 (69.80-2433.24)	0.26 (0.10-0.34)	4.13 (1.26-6.51)	1.66 (1.46-1.70)

Bird survey methods

Eight field circuits, during which researchers attempted to conduct five-minute bird counts on each research farm, were conducted between August 2007 and April 2009. Across all years, circuits were post-stratified into winter, spring and summer months (Table 3.2). A greater number of circuits were conducted during summer due to the wider availability of field assistants during these months and because inclement weather disrupts the efficacy of standard bird monitoring (MacLeod et al., in review, Weller et al. in review). Effort was made to visit all farms during each circuit, but inclement weather and on-farm activities, such as lambing, occasionally prevented farm visits. Surveys were conducted during 0700 and 1500 hours by one or more trained observers. During each circuit, modified five-minute point counts were conducted on all surveyed farms. The five-minute count procedure generally followed that prescribed by Dawson and Bull (1975), but also included measurement of the angle and distance of all detected birds from each survey point to enable distance analysis (Chapter 2). On each farm, five-minute count locations were generated using Hawth's Analysis Tools for ArcMap v.9.2 (Beyer 2004), which generated 15 random sample points within vector polygons representing shelterbelts and unmodified patches of each farm's boundary for every survey circuit. To account for spatial representation of varying patch sizes across the landscape, points were generated such that more counts occurred within large vegetation patches than small patches. All survey points were at least 100m apart to avoid double-counting. An example of the choice of bird sampling points is given in Figure 3.2. When pooled across circuits, point counts were relatively homogenous in spatial distribution and conducted within the majority of woody vegetation patches and habitat types for all farms.

Table 3.2 Temporal spacing of field circuits across seasons and years

Year	Season	Month	Circuit
2007	Winter	August	1
	Spring	September	
		October	2
		November	
	Summer	December	3
2008		January	
		February	4
	Autumn	March	
		April	
		May	
	Winter	June	
		July	
		August	5
	Spring	September	
		October	6
		November	
	Summer	December	7
2009		January	
		February	8

Field data were collected to accommodate subsequent estimates of bird abundance and density using distance sampling methods. A Garmin eTrex hand-held GPS unit was used to navigate to each survey point. Observers waited for two minutes upon reaching each sample point before starting the five-minute count in order to ensure that any species that may have been disturbed would have returned to the site and recommenced movement or singing. All birds seen or heard within a five minute period were recorded for each survey point. For each independent sighting of an individual bird or group of birds, the observer recorded the detection cue (seen, heard or both), the number of individuals (or cluster size when a flock was present) and the behaviour and location of the birds (or cluster for flocks). Observers also recorded the angle of the bird from the observer and the radial distance to the location where the bird was first located using a range finder (Bushnell Yardage Pro®, Bushnell Performance Optics, Overland Park, Kansas). For birds that were heard singing or calling (but not seen) within a clearly defined habitat feature, the distance to that feature was measured. No distance measures were recorded when the observer was uncertain about the location of the bird(s). Observers also identified those individuals that were only observed flying overhead (and not associated with any specific

habitat feature at the study site). The distance and angle information was used to calculate the location of the bird on the landscape relative to the survey point.

On all sites, the current ambient temperature, average wind speed (km/hr) and relative humidity were recorded using a Kestral 4000 portable weather meter (Nielsen-Kellerman, PA). The relative cloud cover (on a six-point scale where 0 = no cloud and 5 = complete cloud cover) and weather conditions (fine, overcast, raining) were recorded. The peak calling periods at dawn and dusk, when conspicuousness and detectability can change rapidly (Dawson and Bull 1975), were avoided. Within each sampled patch, predominant plant species were recorded.

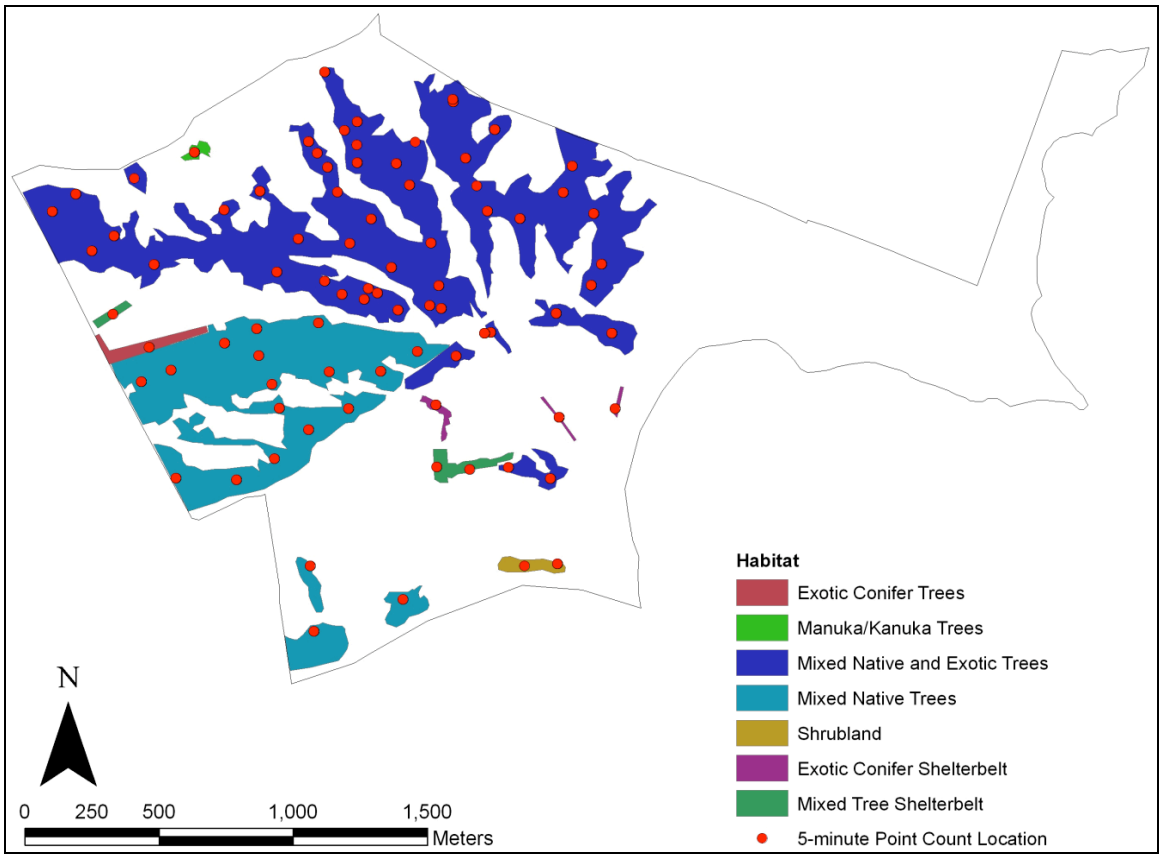


Figure 3.2 Example of point count locations and habitat coverage for a single Banks Peninsula farm pooled across sampling circuits.

Statistical analysis and accounting for bird detection bias

Data were entered into excel and the location of each observed bird on the landscape was calculated using radial distance and angle from the observer. Bird locations were plotted on farm maps using ArcMap. Because the focus of this study centres on woody components of the land matrix, data were post-stratified to include only sightings within such habitats.

Distance analysis estimates the absolute density of a given species using observer counts along a transect line or point count. Specifically, distance accounts for variation in

observer detection, with particular emphasis on the decreasing probability of detection with increasing distance between the observer and species of interest in the field (Buckland et al. 1993, 2001, 2004). Although distance techniques were used for data collection, there were insufficient sightings for most species within each habitat type to generate reliable species densities in the Program Distance™. Also, an unstated assumption of a continuous sampling domain (here a continuous vegetation type or 'patch/polygon') to generate a 'distance detection function' is violated in this study of birds within many small patches (Chapter 2). Consequently, full distance estimates could not be used to estimate bird diversity within a patch. To account for detection bias, statistical analysis was performed on data from sightings truncated to a radial distance of 10m of the observer, and assumed all birds within this distance were recorded (Chapter 2).

Statistical analysis of habitat /diversity associations

Bird community structure within each habitat patch was examined using species richness estimates as well as the 'geometric mean of relative abundance' as a diversity estimate (GMRA, see Buckland et al. 2005 for details). The GMRA was used to estimate diversity, as it is more robust than conventional diversity measurements, such as the Shannon index or Simpson's index (Buckland et al. 2005). This is because it averages relative abundance of species within a community on a log scale, and so it largely ameliorates conflicts arising in other indices when the presence of rare but increasing species result in poor precision (Buckland et al. 2005, Gregory and van Strien 2010). A second benefit of using the geometric mean is that it can be integrated across time series to describe temporal changes in composite bird communities (Buckland et al. 2005, Gregory and van Strien 2010). This is of particular relevance in the broader context of the ARGOS longitudinal study, of which this research is a component.

Exploratory statistical analysis sought to build residual maximum likelihood (REML) models to predict species diversity (species richness, GMRA) measured at each point from season, habitat, farming panel and patch descriptors (area, shape, fractal dimension and perimeter/area ratio). The 'random model' formulations within the Genstat (Release 9.1 for PC) routines were used to remove any effects of cluster and to account for lack of independence of multiple sampling within each Farm and habitat Polygon. This nested structure (cluster>farm>patch) is logical because (a) regional variation (cluster) is considered a nuisance variable that potentially blunts the power of the models to detect main effects; (b) because whole farm management may affect birdlife in all patches on a particular farm; and (c) the aspect, location and vegetation composition of a particular

patch is hypothesised to have a dominating influence on bird abundance and diversity. Patches were sampled from 1 to 40 times ($\bar{x} = 3.6$), so blocking counts for each patch was particularly important for removing pseudo-replication.

Inspection of residuals generated from a large number of exploratory REML models demonstrated broad scale failure to meet the models' assumptions. No transformations of either response or predictor variables could be found to generate satisfactory model residuals, mainly because of (i) the preponderance of zeros (absence of a given bird species in a particular bird count); (ii) a skew in the number detected when they were present (often because of the arrival of large flocks); and (iii) the unbalanced nature of the data sets once random selections of sampling points was post-stratified by habitat, patch and season.

Accordingly a more complicated and somewhat less elegant analysis path was required:

1. Seasonal and habitat effects were tested by analyses of individual point samples using a two-step process like that suggested by Fletcher et al. (2005) for skewed data with too many zeros i.e. first analyses predict the probability of at least one bird being present using logistic regression; the second phase of analyses uses normal regression to test for differences in the number of birds present (given that at least one was detected). Logistic regressions were constructed within Genstats' GLM routines to predict the presence/absence of any native or introduced species.
2. Where satisfactory residuals and realistic predicted means could still not be generated for the above two-stage process on individual point samples, one of the following analysis pathways were taken:
    a. smaller habitat categories were eliminated (shelterbelts) to concentrate on data from larger habitats (mixed native trees, manuka/kanuka trees, shrubland, exotic conifer trees and mixed exotic trees)
    b. Average counts and diversity scores were calculated for each Polygon and then statistical models generated using the average datum for each polygon. It is important to note that the diversity scores and bird counts were averaged for each count in a given patch, rather than averaging all the counts and then calculating a diversity score from the average species profiles (the latter approach would have artificially inflated diversity scores simply from a larger number of counts being conducted in that patch). Averaging per patch cannot account for seasonal

variation, and so would have added some unexplained variance to statistical testing and thereby reduced statistical power to detect main effects. However it eliminated pseudo-replication at the patch level and simplified the statistical models to better meet assumptions. The number of counts within a particular polygon was entered into the 'weights' function within general linear model of Genstat to give relatively more importance to those average bird counts from patches where more point counts of birds had been performed.

c. described median scores for each of the potential predictors were treated individually and test for differences using non-parametric tests (Kruskal-Wallis, Spearman's rank correlation coefficient). To account for statistical noise caused by potentially confounding variables and the likelihood of Type I errors from multiple testing, predictors were treated as significant only when the null hypothesis was rejected at the $p < 0.01$ level in all these univariate tests.

Results

Pooling across farms and field circuits, a total of 21 native and 16 introduced bird species were recorded (Table 3.3). The 10m truncation required for unbiased analysis (see Chapter 2) resulted in the retention of 11 native and 15 introduced species (Table 3.3). The Redpoll *Carduelis flammea*, Chaffinch *Fringilla fringilla* and Goldfinch *Cardeulis carduelia* were the most frequently-recorded birds of either native or introduced species. Typically open-paddock, wetland or nocuturnal species, such as the Spur-winged Plover *Anellus miles novaehollandiae*, Australasian Harrier *Circus approximans*, New Zealand Falcon *Falco novaeseelandiae*, White-faced Heron *Egretta novaehollandiae*, Pukeko *Porphyrio porphyrio melanotus*, Mallard *Anas platyrhynchos* and Little Owl *Athene noctua* were rarely recorded. Of the native species, the Silvereye *Zosterops lateralis* was most common, followed by the Grey Warbler *Gerygone igata* and Bellbird *Anthornis melanura*. Of natives that typically occur within vegetation patches, the Shining Cuckoo *Chrysococcyx lucidus*, Tui *Prosthemadera novaeseelandiae* and New Zealand Pigeon *Hemiphaga novaeseelandiae* were rarest. Though more common than many natives, the Greenfinch *Carduelis chloris* and House Sparrow *Passer domesticus* were the two most infrequently-recorded introduced passerines.

Table 3.3 All bird species recorded on 12 sheep/beef study farms, South Island, New Zealand over the course of 8 field circuits conducted from 2007-2009 (X = species retained in data set after 10m truncation; † = species presence recorded, but not formally counted due to behavioural [e.g. flying over habitat] or habitat [e.g. present in surrounding paddock] exclusion).

Species	Scientific name	Recorded within 10m truncation	Total Count	Frequency (%)
Native				
Spur-winged Plover	*anellus miles novaehollandiae*		1	<0.001
White-faced heron	*Egretta novaehollandiae*		1	<0.001
Pukeko	*Porphyrio porphyrio melanotus*		2	0.001
New Zealand falcon	*Falco novaeseelandiae*		3	0.001
Shining cuckoo	*Chrysococcyx lucidus*		3	0.001
Australasian harrier	*Circus approximans*		5	0.002
Tui	*Prosthemadera novaeseelandiae*	X	24	0.012
Pipit	*Anthus novaeseelandiae*	X	27	0.013
Brown creeper	*Mohoua novaeseelandiae*	X	35	0.017
New Zealand pigeon	*Hemiphaga novaeseelandiae*	X	38	0.018
Welcome Swallow	*Hirundo tahitica neoxena*	X	43	0.021
Tomtit	*Petroica macrocephala*	X	102	0.049
Fantail	*Rhipidura rhipidura*	X	140	0.068
Rifleman	*Acanthisitta chloris*	X	171	0.083
Bellbird	*Anthornis melanura*	X	360	0.174
Grey Warbler	*Gerygone igata*	X	448	0.217
Silvereye	*Zosterops lateralis*	X	661	0.320
Black-backed gull	*Larus dominicanus*		†	
Oystercatcher	*Haematopus unicolor*		†	
Paradise duck	*Tadorna variegata*		†	
Red-billed gull	*Larus scopulinus*		†	
Native Total			**2064**	
Introduced				
Mallard	*anas platyrhynchos*	X	1	<0.001
Little owl	*Athene noctua*		2	<0.001
California quail	*Callipepla californica*	X	8	0.001
Skylark	*Alauda arvensis*	X	10	0.001
Rock pigeon	*Columba livia*	X	44	0.006
Magpie	*Gymnorhina tibicen*	X	128	0.018
House sparrow	*Passer domesticus*	X	163	0.023
Dunnock	*Prunella modularis*	X	234	0.033
Greenfinch	*Cardeulis chloris*	X	288	0.041
Song thrush	*Turdus philomelos*	X	330	0.047
Starling	*Sturnus vulgaris*	X	496	0.071
Yellowhammer	*Emberiza citrinell*	X	721	0.103
Blackbird	*Turdus merula*	X	749	0.107
Goldfinch	*Cardeulis carduelia*	X	1053	0.151
Chaffinch	*Fringilla fringilla*	X	1124	0.161
Redpoll	*Carduelis flammea*	X	1635	0.234
Introduced Total			**6986**	

Geometric mean diversity indicies

Irrespective of data transformation, models using the GMRA for native, introduced and combined species as response variables produced poor residuals and identified no significant habitat, panel, cluster or farm predictors. The simpler measure of species richness was therefore favoured to describe bird community structure. Kruskal-Wallis tests did identify significant habitat ($p<0.001$) and farm ($p=0.002$) effects for combined native and introduced species GMRA (Table 3.4). Similarly, significant habitat ($p<0.001$), farm ($p=0.002$) and area ($p<0.001$) effects were identified for native species GMRA (Table 3.4).

Table 3.4 Non-parametric Kruskal-Wallis and Spearman's correlation coefficient analysis for native, introduced, and combined-species richenss and geometric mean of relative abundance (GMRA). Tests were conducted on average count differences per point sample, but averaged for each vegetation patch. Emboldened cases show statistical significance at the $p<0.01$ level, the revised threshold chosen to minimise Type I errors and confounded effects

	Mean combined species richness	**Mean native species richness**	**Mean introduced species richness**	**Mean combined GMRA**	**Mean native species GMRA**	**Mean introduced species GMRA**
Kruskal-Wallis						
Habitat	**0.001**	**<0.001**	0.035	**<0.001**	**<0.001**	0.077
Panel	0.495	0.417	0.238	0.845	0.269	0.391
Cluster	0.015	0.031	0.021	**0.01**	0.032	0.063
Farm	**0.004**	0.031	0.015	**0.002**	**0.002**	0.012
Spearman's correlation coefficient						
Area	**0.005**	**<0.001**	0.714	0.660	**<0.001**	0.637
Spearman's correlation coefficient						
Mixed native trees	0.232	0.06	0.839	0.954	0.304	0.7
Mixed native and exotic trees	0.935	**<.001**	0.051	0.144	**<0.001**	0.021
Manuka/Kanuka trees	0.917	0.254	0.176	0.38	0.114	0.792
Exotic conifer trees	0.466	**0.001**	0.448	0.585	**<0.001**	0.392
Shrubland	0.362	0.679	0.43	0.048	0.587	0.05
Exotic conifer shelterbelt	0.211	*	0.211	0.322	*	0.322
Mixed tree shelterbelt	0.736	0.12	0.938	0.709	0.12	0.709

Native species richness

Species/habitat associations were predicted by GLMs using each native and introduced species richness as response variables. A square root transformation of native species richness and removal of two outliers was needed to meet the assumption of homoscedasticity. Initial models overestimated species richness in smaller shelterbelt habitats, so these were removed from subsequent models. The inclusion of habitat x area interaction effects only increased R^2 by 1% and forced elimination of several outliers, so only main effects were included in the final model.

The addition of shape index, perimeter-area ratio and fractal dimension terms to both native and introduced species models increased heteroscedasticity of residuals while slightly decreasing variance explained by the models, suggesting these variables had no power to predict either native or introduced species richness once patch area had been incorporated into the model (Table 3.5). The shape dimensions were therefore eliminated from the final model to predict mean species richness for each habitat at the median patch size across all habitat patches (Figure 3.3).

The native species richness model that best accounted for variance ($R^2 = 0.63$) indicated a significant habitat effect, evidenced by strong positive associations between native species richness and mixed native tree and Manuka/Kanuka habitats (Figure 3.3, Table 3.5). The model also indicated a significant positive relationship between native species richness and patch area, as well as a significant cluster effect that was explained by a negative association with the Outram cluster (Table 3.5, Figure 3.5). Modelled predictions for species richness within each habitat type were similar to mean observed values. Comparison of the observed mean species richness in the two shelterbelt habitat types with the model's predicted species richness elsewhere suggests that shelterbelts are obviously depauperate in native species compared to any habitat patches that had some component of native vegetation (Figure 3.3). Indeed, within the 10m truncated data set, no native species were among the 33 recorded bird sightings in 11 purely exotic conifer shelterbelt habitats and only two native species were among the 16 sightings recorded in six mixed tree shelterbelts (Chapter 2, Table 2.1).

Table 3.5 Explanatory variables in the GLM for native bird species richness on 12 sheep and beef farms, South Island, New Zealand († = Parameter not retained in final model presented in Figure 3.3). Exotic conifer trees and the Banks were reference factors for habitat and cluster comparisons. Emboldened cases indicate significance at $p<0.05$

Parameter	Estimate	S.E.	p
Habitat			
Mixed native trees	0.256	0.107	**0.017**
Mixed native and exotic trees	0.127	0.095	0.181
Manuka/Kanuka trees	0.409	0.119	**<0.001**
Exotic conifer trees	0.048	0.095	0.616
Shrubland	-0.091	0.109	0.405
Mixed tree shelterbelt	0.086	0.148	0.560
Patch Metric			
Log Area	0.110	0.011	**<0.001**
Perimeter-area ratio†	0.079	0.351	0.823
Shape index†	-0.002	0.016	0.883
Fractal dimension†	0.042	0.278	0.880
Panel			
IM	-0.091	0.042	**0.03**
Organic	0.024	0.042	0.567
Cluster			
Catlins	0.066	0.047	0.167
Oamaru	-0.066	0.058	0.254
Outram	-0.232	0.057	**<0.001**

Native species richness increased with increasing area of patch (Figure 3.5, Table 3.5). The model predicts a 75% increase in native species richness in patches spanning the full patch size range (0.02 – 16.42 Ha, Table 3.1). The GLM model's conclusions are corroborated by non-parametric correlations between native species richness and patch size when each habitat type is considered separately (Table 3.4).There was 51-76% lower native species richness at the Outram cluster relative to the other three clusters (Table 3.5, Figure 3.7). There was markedly lower native species richness in IM farms (Figure 3.8), but no evidence for a difference in species richness between conventional and organic farms (Table 3.5).

Temporal pulses in bird abundance are expected because of restricted breeding seasons in temperate ecosystems of New Zealand. As the abundance of the birds will affect the probability of detecting at least one of that species, seasonal changes in species richness would be expected. Unfortunately heteroscedasticity of residuals prevented testing for seasonal effects in a main model while simultaneously accounting for habitat, area and cluster effects. As a result, average species richness was calculated for each habitat polygon in a given season and Wilcoxin matched-pairs tests were to compare

spring vs winter and summer vs winter species richness in the same patches. There was no evidence for seasonal effects ($p>0.229$).

Results for all non-parametric Kruskal-Wallis tests are given in Table 3.4 to cross-check the above inferences from the more complex GLMs. Native species richness GLM tests for significant effects partly corresponded with with Kruskal-Wallis tests which indicated a strong habitat ($p<0.001$) and farm ($p=0.004$) effects and weakly implied a non-significant cluster effect ($p=0.015$, Table 3.4). Spearmann's tests of native species richness versus patch area suggested significant positive associations with increasing patch size of mixed native and exotic tree habitat ($p<0.001$) and exotic conifer tree habitat ($p=0.001$). Weak evidence of a mixed native tree habitat effect was found ($p=0.06$). The disparity between Spearman's tests and GLM analysis in this regard likely describes a gradual increase size of native habitat patches.

Introduced species richness

Log_e transformation of the introduced species richness term sufficiently increased homoscedasticity of residuals. Again the inclusion of patch shape descriptors did not improve model fits (Table 3.6), and so these were eliminated from all subsequent models. The model that best explained introduced species richness accounted for far less variance than that of the native model and indicated slight negative associations between introduced species richness and area and mixed native and exotic tree habitats ($R^2 = 0.05$ compared to 0.57 for native species, Table 3.6, Figure 3.4). As with native species richness, the model predicted means of introduced species richness within each habitat type that were similar to corresponding raw mean observed richness. Overall species richness was higher for introduced species compared to native species and much less variable between habitat types (Figures 3.3-3.4). The model indicated a significant habitat effect, with positive associations with Manuka/Kanuka and exotic conifer tree habitats (Table 3.6). Otherwise, species richness exhibited little variation between different habitat types (Figure 3.4). As with native species richness, there was no sign of variation in introduced species richness between clusters (Table 3.6, Figure 3.7). There was also a significant panel effect, with introduced species richness positively associated with IM farms. Unlike native species richness, introduced species richness did not change significantly with patch area ($p=0.793$, Figure 3.6),

Kruskal-Wallis tests revealed no siginficant relationships between introduced species richnes and habitat ($p=0.035$), panel ($p=0.238$), cluster ($p=0.021$) or farm ($p=0.015$, Table 3.4). In contrast to GLM predictions, Spearman's test of introduced species richness of

pooled habitats versus habitat area indicated no significant area effect. Wilcoxin matched-pairs tests gave no evidence for seasonal differences in introduced species richness ($p>0.207$)

Table 3.1 Explanatory variables in the GLM for introduced bird species richness on 12 sheep and beef farms, South Island, New Zealand. Key is as for Figure 3.4.

Parameter	Estimate	S.E.	p
Habitat			
Mixed native trees	0.166	0.113	0.144
Mixed native and exotic trees	0.175	0.100	0.083
Manuka/Kanuka trees	0.352	0.127	**0.003**
Exotic conifer trees	0.221	0.101	**0.030**
Shrubland	0.175	0.116	0.133
Mixed tree shelterbelt	0.041	0.158	0.793
Patch Metric			
Log Area	-0.006	0.013	0.793
Perimeter-area ratio†	-0.340	1.370	0.806
Shape index†	-0.004	0.062	0.950
Fractal dimension†	1.170	1.090	0.283
Panel			
IM	0.119	0.044	**0.007**
Organic	0.012	0.045	0.795
Cluster			
Catlins	0.056	0.050	0.265
Oamaru	-0.002	0.060	0.977
Outram	0.031	0.060	0.607

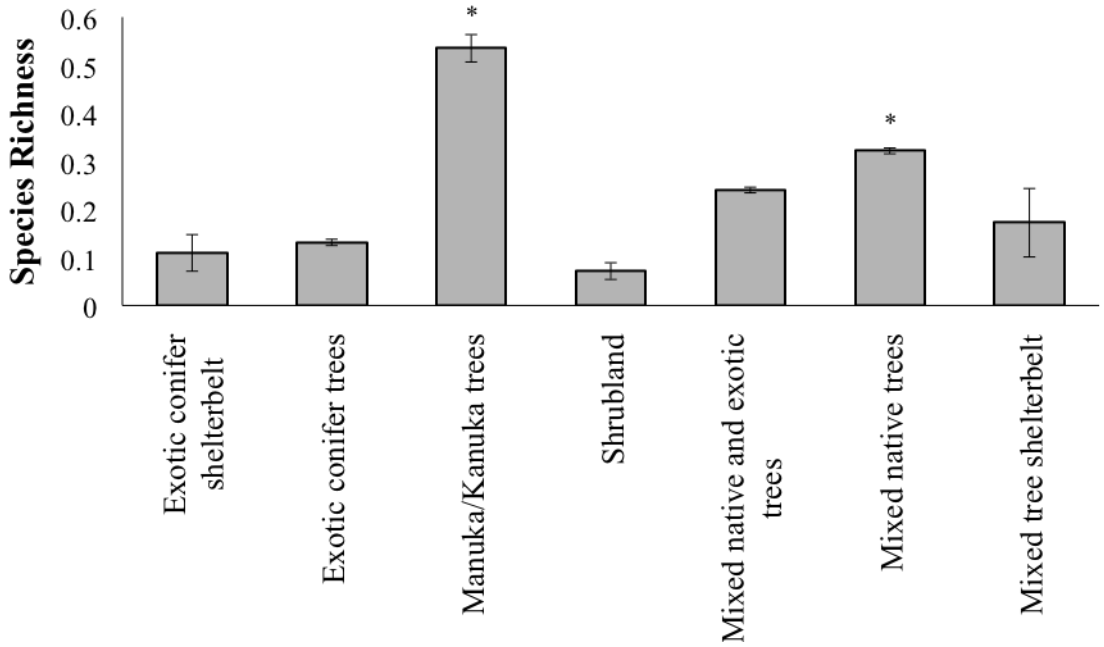


Figure 3.3 GLM predicted mean native species richness and standard errors for median patch size of each habitat type. Both shelterbelt habitats were excluded from modeling analyses. No native species were recorded within exotic conifer shelterbelts (* = $p<0.05$).

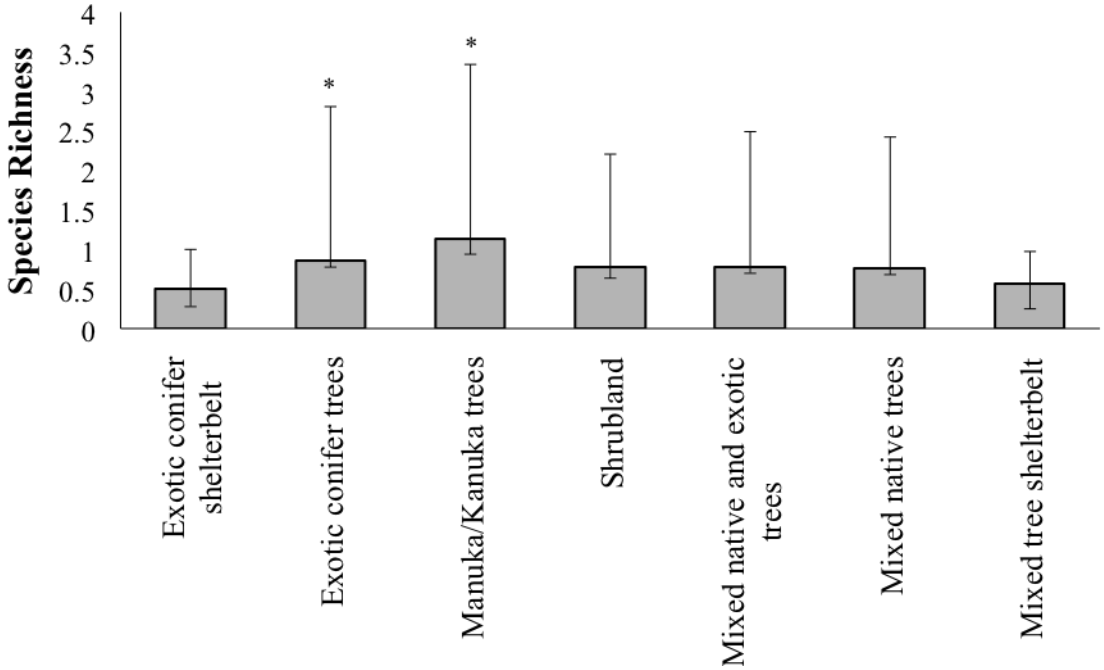


Figure 3.4 GLM predicted mean introduced species richness and standard errors for median patch size of each habitat type. Both shelterbelt habitats were excluded from modeling analysis and presented as observed means (*=$p<0.05$).

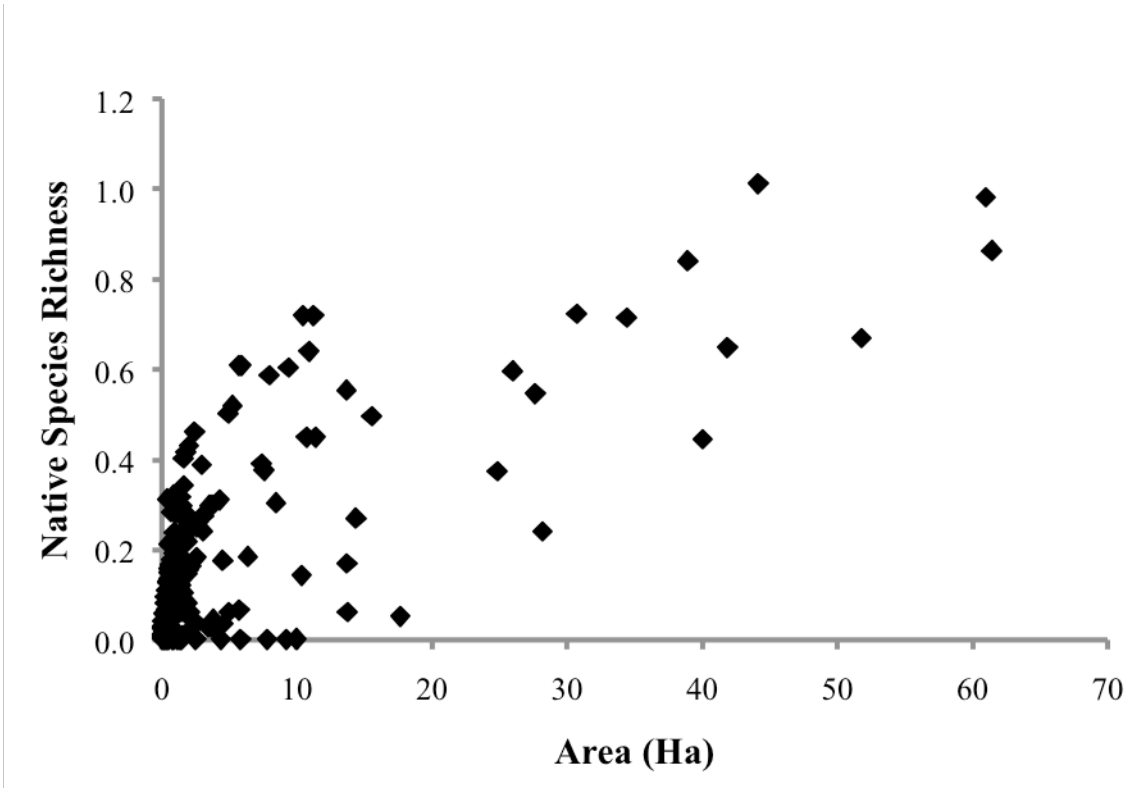


Figure 3.5 Scatterplot of native species richness versus main effect log area from the GLM ($p<0.001$, full-model $R^2 = 0.62$).

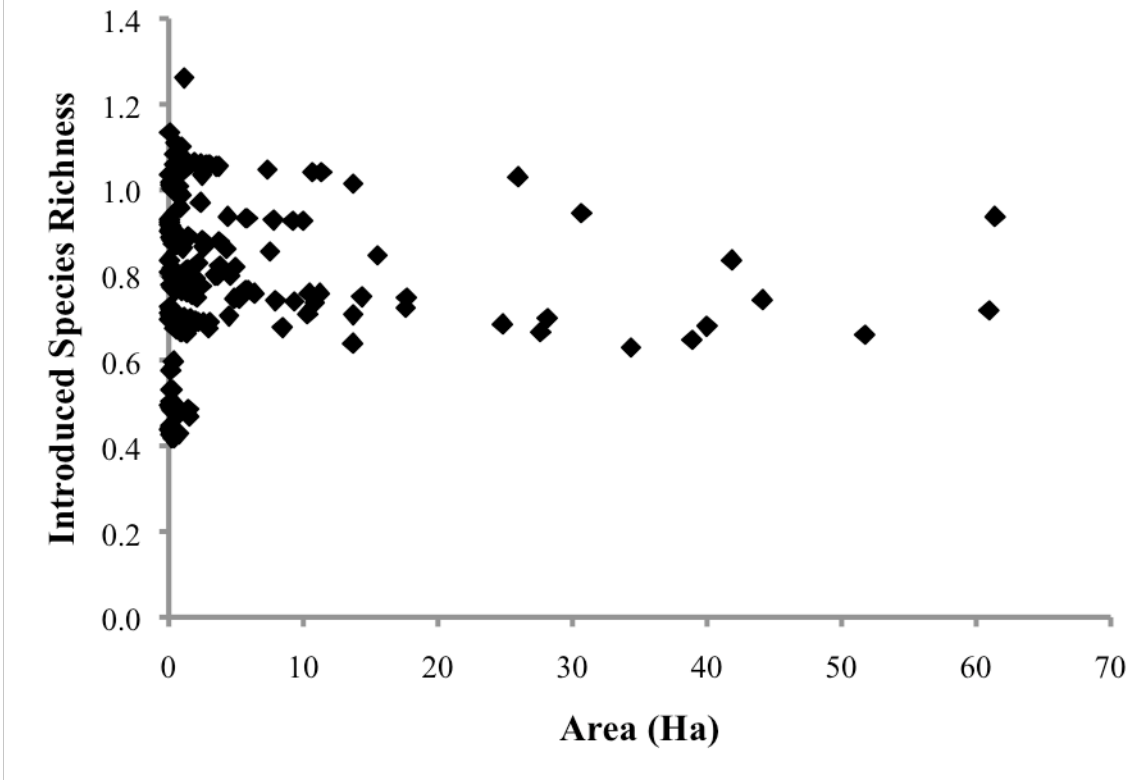


Figure 3.6 Scatterplot of introduced species richness versus main effect log area from the GLM ($p<0.001$, full-model $R^2 = 0.05$).

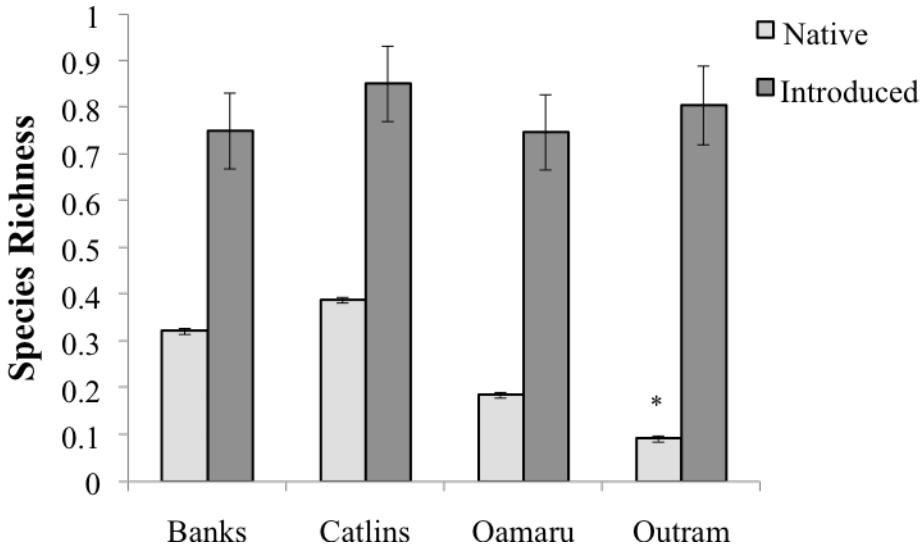


Figure 3.7 GLM predicted mean native and introduced species richness and standard errors for median patch size within each cluster, pooled across habitat types (* = $p<0.05$)

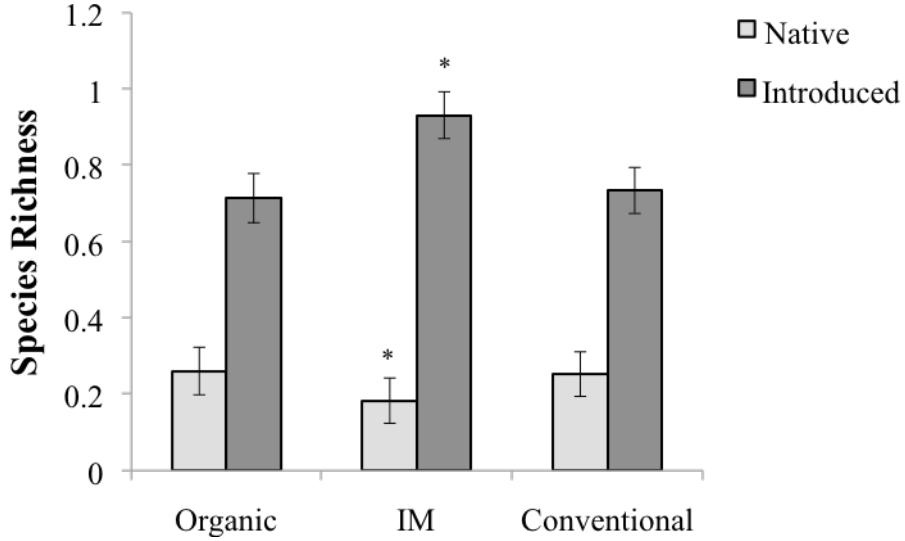


Figure 3.8 GLM predicted mean native and introduced species richness and standard errors for median patch size within each management panel, pooled across habitat types (* = $p<0.05$)

Discussion

Habitat influences on species richness

Native species richness was strongly predicted by Manuka/Kanuka and mixed native tree native habitat. The presence of native vegetation is likely the single-most effectual predictor of native species presence. Regardless of patch size, additional research within New Zealand intimates a similar relationship between native species richness and diversity and the presence of native vegetation habitats (Clout and Gaze 1984, Day 1995, Blackwell

et al. 2005, Deconchat et al. 2009). Introduced species richness was similarly associated with Manuka/Kanuka habitat as well as exotic conifer habitat. Research within the historic home ranges of several introduced species suggests that, while a number of species may be farmland generalsts, many are greatly reliant on landscape heterogeneity and the presence of woody vegetation on production lands (Whittingham et al. 2001, Woodhouse et al. 2005, Buckingham et al. 2006, Whittingham et al. 2009). Measures of introduced species richness from the present study were higher than those of native species for the majority of habitats. The abundance of several introduced species on New Zealand production lands is highly anomalous relative to that of each species' native range (MacLeod et al. 2009). Specifically, observed mean densities of several introduced species on New Zealand agricultural lands are more than 20 times greater than densities predicted for farmland in the U.K. (MacLeod et al. 2009). Whether or not the prevalance of introduced species on New Zealand production lands negatively affects native species via interspecific competition for food resources or nesting sites is an issue of great concern, and one that demands immediate attention. While prior studies have described the ecology of individual native and introduced species occurring on New Zealand farmland (Coleman 2010, Green et al. 2005, MacLeod et al. 2005*a* and *b*), there is a pressing need for studies examining interactions between the two.

Patch size and shape associations

Equilibrium theory and the species-area relationship of island biogeography predict that large, circular-shaped habitats will be associated with higher levels of diversity than smaller, irregular-shaped and discontinuous habitat patches (MacArthur and Wilson 1967, Diamond 1976). Though a number of studies seemingly support the species-area relationship within fragmented agricultural landscapes (Opdam et al. 1985, Helzer and Jelinski 1999, Chamberlain et al. 2001, Conover et al. 2009), the dearth of demographic information for many recorded species may lead to tenuous assertions regarding relationships between species richness and increased patch area (Conover et al. 2009). While the often described area effect is similarly consistent with findings of the present study concerning native species richnesss, it is necessary to remain vigilant of drawing spurious conclusions with regard to systems where metapopulation dynamics and flows across agricultural landscape mosaics are largely unknown . Quality of the surrounding matrix may mitigate negative area effects characteristically associated with fragmentation (Green et al. 1994, Brotons et al. 2003, Whittingham et al. 2009), and potentially obfuscate species-area relationships (Ewers et al. 2005, Davis et al. 2006). Bird surveys for the

present research were conducted at the farm level, but according to a clustered structure designed to factor out potential regional nuisance variables. Some cluster effects were detectable (there were fewer introduced species in the Outram area after estimating the effects of habitat type and patch size). However, limited data were available for habitat composition of adjacent farms and land matrices, thus making integration of spatial habitat analysis at a fully landscape scale logistically impracticable. Within New Zealand agroecosystems, the surrounding land matrix may be crucial in determining native species richness within fragmented habitat patches, as evidenced by greater native species richness within patches in close proximity to native forest habitats (Deconchat et al. 2009).

No measures of patch perimeter or shape complexity were found to be significant predictors of native or introduced species richness after patch area was incorporated into models. Shape metrics, such as patch perimeter-area ratio, may poorly predict the presence of specialist bird species (Caprio et al. 2009). As the majority of native species recorded on sheep/beef farms surveyed for this study appear to be native habitat specialists (Figure 3.3), the lack of association between these species and measures of patch shape complexity is unsurprising.

In comparison to native species richness, introduced species richness exhibited a more tenuous relationship to patch area, which was intimated by non-parametric analysis, but not supported by the GLM. Several introduced species, such as the Chaffinch, Dunnock, Goldfinch and Yellowhammer typically thrive in open-paddock and arable crop environments, providing some hedgerow habitat is available (Green et al. 1994, Whittingham et al. 2001, Fuller et al. 2001, MacLeod et al. 2004, Woodhouse et al. 2005). These species may be unlikely to exhibit any quantifiable relationship to patch area because their primary requirements from woody vegetation relate to platform and cover for nesting and perhaps territorial display and defence. The weaker area effects for introduced species may be emblematic of generalist habitat preferences, broad feeding and nesting niches and consequent exploitation of much of the available area on a farm. Wider empirical evidence and invasion theory both predict that highly successful cosmopolitan species, like several of the open farmland birds studied here, will share these characteristics of adaptability, ubiquity and comparative immunity to biotic resistance (especially predation and competition) to establishing new populations (Begon et al. 2006).

Although many introduced generalist species have been positively linked to woodland edge in their home ranges (Whittingham et al. 2009), no associations between perimeter or shape complexity and introduced species richness were identified in the

present study. The sampling of points exclusively within patch interior, omission of shelterbelt habitats with insufficient area, and severe truncation of the count data to avoid detectability bias (see Chapter 2) might all have combined to muddle or remove any perimeter or patch shape complexity effects. Studies placing a greater emphasis on the role of ecotones and edge effects within agroecosystems might better address this problem by deliberately conducting five-minute point counts along the periphery of vegetation patches and adjacent to shelterbelts, which might better facilitate the identification of any potential shape or edge effects.

Effects of farming systems on species richness

Though not corroborated by non-parametric analysis, the native species richness GLM suggested a significant panel effect, evidenced by significantly lower species richness for IM farms than either conventional or organic. Conversely, the introduced species GLM implied a significant panel effect that predicted higher species richness for IM farms compared to conventional and organic. When considered concurrently, the contrary effect of panel on native and introduced species richness is perplexing. International research widely indicates that organic farming systems are associated with higher species richness than extensively manged systems that rely on consistent application of ecological subsidies, such as pesticides and fertilizers (Freemark and Kirk 2001, Hole et al. 2005, Genghini et al. 2006, Smith et al. 2010). Indeed, ARGOS research on kiwifruit orchards has further supported this assertion (Maegli et al. 2007). Although previous research has not sought to decouple introduced and native species richness in comparative analyis of farming systems, prior studies would predict a similar general trend in associations between intensively-managed lands and both native and introduced species richness. Native species were primarily confined to large patches of native vegetation (Table 3.3, Figure 3.3), whereas introduced species were present throughout the farm and would expectedly be subject to impacts of changed fertilizer and chemical use. For New Zealand pastoral farming systems, IM farming is not bound to any rigid structure and thus represents more of a continuum of intensification than a discrete system in which type and application of ecological subsidies are clearly defined. IM farms may therefore differ widely with regard to the degree of intensification, with some farms effectively adhering to organic farming methods and others favoring a conventional approach. Given this spectrum and the small sample size of the described research (n = 12 total farms, 4 IM farms), any inferences regarding panel effects on either native or introduced species richness, particularly in relation to IM farming, should be drawn with caution. Based on

data from the 12 farms on which bird data were collected, there is little support to either reject or fail to reject the ARGOS farming systems null hypothesis. The null hypothesis appears to hold for soil quality indicators (Carey et al. 2010), and subtle, but nevertheless statistically significant, shifts in community-level biodiversity and foodweb structures have been detected within streams running through ARGOS organic, IM and conventional dairy farms (Magbuani et al 2010). This suggests at least some biophysical and chemical flows between adjoining habitats are possible. However, the degree to which ecosystem processes within woody vegetation are copuled with pasture ecosystems and how these relationships influence bird diversity remains unclear.

Choice of market flagship species for monitoring

Chapter 3 has has demonstrated that native and introduced bird communities may greatly differ in their utilization of woody vegetation patches embedded within pastoral systems. Rather than applying a brodbrush management approach, the results presented in Chapter 3 suggest that conservation of bird species on New Zealand's production lands will require a directed approach that is mindful of the often-differing habitat requirements of native specialist and introduced generalist species. In Chapter 4, These themes are considered in greater detail with regard to individual species. A guiding aim is to elucidate whether the described species richness/habitat associations are evident at the individual species level.

Chapter 4: In search of surrogates: Identifying indicators of habitat quality and biodiversity on New Zealand South Island sheep/beef Farms

Abstract

The present study describes associations between habitat characteristics and six native and six introduced canddiate indicator bird species on New Zealand South Island sheep/beef farms. Presence or absence of candidate indicators was examined with regard to characteristics of individual woody vegetation patches within the agricultural land matrix using logistic general linear mixed models and non-parametric analysis. Non-parametric Spearman's tests indicated strong area and habitat effects for the Bellbird *Anthornis melanura*, Fantial *Rhipdura fulignosa*, Grey Warbler *Gerygone igata* and Rifleman *Acanthisitta chloris*, intimating a native preference for large, native habitat patches ($p<0.01$). The introduced Blackbird *Turduc merula*, Chaffinch *Fringilla fringilla* and Goldfinch *Cardeulis carduelia* similarly showed significant native habitat associations ($p<0.001$) and the Blackbird, Chaffinch, Goldfinch and Yellowhammer *Emberiza citrinell* showed significant area associations ($p<0.01$). These findings support that relationships between native and introduced species richness, patch area and habitat type may also be evident at the individual species level.

Keywords: Indicator species, agroecosystem, New Zealand, farmland birds

Introduction

The term "surrogate species" may encompass a number of definitions, but most often refers to indicator, flagship or umbrella species (Caro and O'Doherty 1999, Favreau et al. 2006). Landres (1988) defined an indicator species as "an organism whose characteristics (e.g., presence or absence, population density, dispersion, reproductive success) are used as an index of attributes too difficult, inconvenient, or expensive to measure for other species or environmental conditions of interest." Caro and O'Doherty (1999) further refined this definition, detailing that indicator species may serve as surrogates for one or more of the following: the environmental health of a region; population trends of prey species; or wider diversity of sympatric species. Umbrella and flagship species may not directly signal changes in environment or ecosystem processes, but can act as surrogates by conferring protection on other species via efforts to conserve their habitat (Favreau et al. 2006). Specifically, umbrella species require a large home range that includes that of a myriad of other species (Wilcox 1984). Flagship species serve as rallying points for conservation associated with the high intrinsic value placed on them by people (Dietz 1994, Bowen-Jones 2002). Chapter 1 proposed an additional 'Market Flagship Species' concept that seeks surrogate species that simultaneously indicate biodiversity-friendly farm practices while incentivizing farmers and consumers to transition to more resilient and sustainable agriculture.

Given the broad nature of surrogate approaches, much scepticism has been expressed over the past two decades regarding their ability to capture or describe critical components of the ecosystems they purport to represent. Many concerns centre on the extrapolation of one species' habitat requirements to those of sympatric species (Landres et al. 1988, Niemi et al. 1997, Simberloff 1998, Andelman and Fagan 2000, Seddon and Leecy 2008). For example, the selection of indicators of habitat health might overlook or neglect the degree to which non-indicator species' populations are limited by factors such as predation, climate and migration (Landres et al. 1988). Nevertheless, the dilemma remains: financial and labour costs usually prevent detailed and comprehensive monitoring of biota across all trophic levels of an ecosystem (Favreau et al. 2006).

Provided that monitoring of surrogate species is interpreted with its limitations, it has particular value in guiding conservation of biodiversity on production lands (Lambeck 1997, Duelli and Olbrist 1998, Duelli and Olbrist 2003, Noe et al. 2005, Favreau et al. 2006, Moonen and Barberi 2008). Within agroecosystems biodiversity provides essential ecosystem services such as decomposition, pollination and pest control (Matson et al.

1997). Biodiverse ecosystems are more likely to contain species that perform similar or overlapping ecological functions (Walker 1995, Fischer et al. 2006, Darnhofer et al. 2010). These redundancies create systems that are more resilient, or better able to recover from perturbation and transition to new states if environmental conditions change (Walker 1995). As the ability of land to produce agricultural products is greatly dependent on services rendered by biodiversity, the monitoring and conservation of non-production species and associated ecological processes within agroecosystems is essential in maintaining and promoting farm health (Alteri 1999, Bullock et al. 2001, Fischer et al. 2006).

Following the arrival of European settlers, New Zealand's historically species-rich lowland ecosystems underwent extensive modification to accommodate agricultural production (MfE 1997, Norton and Miller 2000, PCE 2004). Pastures principally composed of introduced grasses and clover that provide grazing for livestock now characterize these areas. Agricultural development was also accompanied by the introduction of a suite of European invertebrate, mammal and bird species, resulting in production systems reliant largely on services provided by introduced flora and fauna (Norton and Miller 2000). Consequently, within New Zealand's highly-modified agroecosystems, the selection of surrogates for any number of factors must take into consideration the ecological contributions of introduced species. This, however, does not negate the value of native species to serve as surrogates within agroecosystems. Although New Zealand production lands are largely characterized by introduced species, several native species persist in unmodified scrub and remnant forest patches (Norton and Miller 2000, Blackwell et al. 2005). Beyond contributing to overall ecosystem health, several native species are associated with high intrinsic value (DoC and MfE 2000). Presently, all but 18% of New Zealand private land below 500 meters is used in agriculture and forestry production (Norton 2000). Accordingly efforts to protect and conserve native species should direct focus toward these areas. Native surrogates may be of further utility through their potential to serve as flagship species through which awareness and support for conservation efforts on agricultural lands can be fostered

An essential first step in selecting surrogate species on production lands is delineating exactly what species or processes the surrogates will be acting as proxies for. Within an agricultural context, surrogate approaches typically hinge on identification of indicator species that are representative of wider diversity or habitat quality and respond to environmental perturbation (Chapter 1, Duelli and Obrist 1998, Butler et al. 2007, Gregory

and Strien 2010). Birds occur high in food chains, are sensitive to environmental change and are highly visible on the landscape. Additionally, data on multiple species can sometimes be collected simultaneously using a single, simple survey method, allowing for the calculation of both community and single-species diversity indicators (Hutto 1998, Gregory and Strien 2010). However, design of bird monitoring methods and sampling regimes can also sometimes be fine-tuned for particular focal species to minimise errors and uncertainty around abundance estimates (MacLeod et al. in review, Weller et al. in review), so there may still be added value from identifying a particular surrogate bird species.

In the U.S. and Europe, several biodiversity monitoring schemes that use birds as indicators of environmental health and biodiversity are currently in place (Bibby 1999, Chase et al. 2000, Gregory et al. 2004, Butler et al. 2009). These biodiversity monitoring systems are chiefly government-funded and designed to maintain production and farmer livelihood, while mitigating detrimental environmental impacts of agricultural practices. In recent years, consumer demands for agricultural products that are produced using environmentally sustainable practices and respectful of biodiversity of non-production species have led to the creation of several private-sector audit systems that place emphasis on sustainability and biodiversity conservation. For example, Global Good Agricultural Practice (GlobalG.A.P.) includes provisions to minimize the detrimental impact of farming operations (GlobalG.A.P. 2010). The Linking Environment and Farming (LEAF) marque scheme further places emphasis on biodiversity conservation through the inclusion of a whole farm conservation plan, provisions for wildlife habitat retention and a biodiversity management component (LEAF 2010).

Over 80% of New Zealand agricultural output is exported, with primary markets in the European Union, United States, and Japan (Smith and Montgomery 2003; Statistics New Zealand 2006). In the absence of government subsidization of conservation-orientated and sustainability-driven farming programs, sustainable farming practices and enhancement of biodiversity on production lands within New Zealand have been largely driven by international private sector auditing systems (Campbell et al. 2006). Access of New Zealand fresh produce to European markets, for example, is often contingent on compliance with GlobalGAP. As concern regarding food safety and sustainable farming practices continues to grow overseas, New Zealand products within all farming sectors are likely to incur increased pressure to adhere to standards set by international markets. The extensive modification of the New Zealand landscape over the last century to

accommodate agricultural production created systems dominated by introduced production and non-production flora and fauna. Ironically, many bird species that are native to Europe and declining there flourish in New Zealand (MacLeod et al. 2005*a* and *b*, MacLeod et al. 2008, MacLeod et al. 2009). These species may therefore signal sustainable agricultural practice for European market access. As prospective biodiversity-based accreditation schemes and audit systems are likely to be structured around species of intrinsic worth to consumers abroad, there is great need to identify meaningful indicator species that are of value to consumers in overseas markets and selected using ecologically relevant criteria. Introduced bird species are obvious candidates to act as indicators for such schemes.

With the aim of selecting species indicative of agroecosystem resilience and health derived from ecologically relevant criteria (Chapter 1), Chapter 3 identified associations between habitat metrics and species richness of native and introduced birds on New sheep/beef farms. In accordance with the rationale outlined in Chapter 1 and carried through Chapter 3, the present chapter is structured around the assumption that systems with greater species diversity are better able to recover from perturbation, and thus more resilient. In this vein, the present chapter pursues habitat, farm practice (Organic, IM and Conventional) and seasonal predictors of the abundance of six native and six introduced candidate indicator species that have potential to serve as Market Flagship Species. The principal objective is the identification of species that exhibit quantifiable relationships to concurrent richness estimates (Chapter 3). Failing the identification of a direct association, the present research seeks to identify species associated with habitat attributes that are characteristic of patches with high species richness. By focusing on a handful of candidate species, emphasis is placed on the selection of single-species, rather than community-level indicators of bird diversity. The reasoning behind this approach is that individual species will be easier to identify and monitor, and therefore possess greater potential to serve as management tools in subsequent monitoring and accreditation schemes. This chapter complements the analyses of Chapter 3 by measuring an index of bird abundance, rather than species richness. Whereas Chapter 3 mainly focused on the presence or absence of native and introduced species groups, here the abundance attained when a given species is present is also investigated.

Methods

Study area and data collection

Details regarding study areas and collection of data are described in full in Chapters 2 and 3.

Candidate species selection

The present study elected to examine the potential for the following native species to serve as indicators of agroecosystem health and resilience: Bellbird *Anthornis melanura*, Fantail *Rhipdura rhipdura*, Grey Warbler *Gerygone igata*, Rifleman *Acanthisitta chloris*, Silvereye *Zosterops lateralis* and Tomtit *Petroica macrocephala*. These species were chosen using the "rule of thumb" criteria described in Chapter 1 as well as for their collective representation of a range of dietary preferencs and primary habitat requirements (Table 4.1). The selection of European candidate species was slighly more challenging, as the majority of European bird species found on New Zealand production lands tend to be generalists with catholic habitat requirements (Robertson et al. 2007). The following species were chosen based on their varying feeding ecology and potential to serve as indicators for habitats ranging from woodland to farmland according to the British Government's Department for Environmental Food and Rural Affairs Quality of Life Indicators Index: Blackbird *Turduc merula*, Chaffinch *Fringilla fringilla*, Goldfinch *Cardeulis carduelia*, Redpoll *Carduelis flammea*, Starling *Sturnus vulgaris* and Yellowhammer *Emberiza citrinell* DEFRA 2002, Table 4.1).

Table 4.1 Native and introduced candidate species, diet, primary habitat, New Zealand geographic distribution and DEFRA indiator category. DEFRA (2002), Heather and Robertson (2005), Robertson et al. (2007)

Species	Diet	Primary Habitat	Status in New Zealand	DEFRA Indicator
Native				
Bellbird	Invertebrates, fruit, nectar	Native forest	Common	-
Fantail	Invertebrates	Native and exotic forest, scrub	Abundant	-
Grey Warbler	Invertebrates	Native forest, scrub	Abundant	-
Rifleman	Invertebrates	Native forest, scrub	Locally common	-
Silvereye	Invertebrates, Fruit, nectar	Native and exotic forest, scrub	Abundant	-
Tomtit	Invertebrates	Native forest, scrub	Common	-
Introduced				
Blackbird	Invertebrates, fruit	Deciduous forest, garden	Abundant	Woodland generalist
Chaffinch	Seeds, invertebrates	Open forest garden, farmland	Abundant	Woodland generalist
Goldfinch	Seeds, invertebrates	Open forest, garden	Abundant	Farmland specialist
Redpoll	Seeds, invertebrates	Forest, scrub	Common	Woodland specialist
Starling	Invertebrates, fruit, seeds	Open forest, open rural, open urban	Abundant	Farmland Specialist
Yellowhammer	Seeds, invertebrates	Lowland arable and mixed farmland	Common	Farmland specialist

Statistical analysis

All statistical analyses were conduced on a 10m truncated data set of bird sightings recorded during five-minute point counts (see Chapters 2 and 3) of either binary candidate indicator species presence/absence values or mean number of indicator species recorded within each patch. Preliminary statistical analysis sought to build REML and GLM models on individual bird count data for individual species. Just as for species richness models (Chapter 3), heteroscedasticity of residuals prevented simultaneous examination of main habitat, panel and seasonal effects for individual species. This forced reduction of the analysis to logistic (binomial distribution) models to predict presence or absence of candidate indicators measured within each bird count from farming panel, season, habitat type and patch size. These were constructed within the GLM routine of REML within

Genstat (Version 9.1) using the same rationale and nested design (cluster>farm>panel) described for Chapter 3 to remove pseudo-replication. Models were run with and without shelterbelt habitats as explanatory variables. Binomial models generally failed to achieve convergence or predict approximate observed raw means if the candidate species was recorded in <10% of counts. Even when the fixed models were reduced as much as possible (i.e. inclusion or exclusion of a habitat x season interaction term and removal of smaller shelterbelt habitats), models were either unstable or failed, and showed low correspondence between predicted and observed mean values for presence/absence within different habitat types. Robust logistic models accounting for habitat, log patch area, season and panel effects were all that could be retained. Model convergence and correspondence with predicted and observed means was achieved for 'any native species', 'any introduced species', Blackbird, Chaffinch, Silvereye, and Yellowhammer.

Non-parametric tests were used to examine relationships between candidate indicator species and habitat type, patch size, season and panel. Although the non-parametric tests do not assume a normal distribution, the measures must be independent of each other. Accordingly, the mean count of each bird species per five-minute point count within each patch (all seasons combined) were calculated. Kruskal-Wallis tests were then performed on patch averages so that each patch entered the analysis only once. A separate search for seasonal effects for each species was also performed using Wilcoxon matched pairs tests of the average count in a given patch for each season.

Relationships between the count of individual candidate species and patch size were tested by calculating Spearman's correlation analysis for each habitat type combined and separately. Univariate non-parametric analyses required testing a large number of single variables against one another. In order to reduce the probability of Type I errors and to minimize the potential for accepting effects caused by confounding variables, the philosophical decision was made to designate a significance level of $p<0.01$.

Results

GLM models to predict combined effects on bird counts

Full binomial REML models predicting presence/absence from habitat, patch size and patch shape variables (shape index, fractal dimension, perimeter-area ratio), season and farming panel (organic, IM, conventional) could be successfully constructed for eight species, each of which had an overall average probability of occurrence in a count of >0.1 (Table A1 in Appendix 1). Excluding a weak association between Blackbird presence and

shape index ($p = 0.029$, Table A1 in Appendix 1), full models found no evidence that patch dimensions and shape helped predict species abundance once patch size had been included. The exception may be a Type I error (many tests have been constructed) and the general lack of predictive power for individual species (here) and for overall species richness (Chapter 3). Therefore, patch shape descriptors were excluded from analysis and the models were reduced to include habitat, $\log_e$area, panel and season.

Habitat predicted the presence of any native native species within a patch ($p < 0.001$, Table 4.2). Predicted means showed correspondence with observed means and were highest for mixed native tree and Manuka/Kanuka tree habitats (Table A1 in Appendix 1). Introduced species models similarly indicated the presence of any introduced species was predicted by habitat ($p<0.001$, Table 4.2). Predicted means corresponded to observed means, with highest predicted mean values for shelterbelts, Manuka/Kanuka trees and shrubland. Predicted mean occurrences for any introduced species were higher than those for any native for all habitat types. Habitat was a significant predictor of Yellowhammer presence, which had highest predicted means in Manuka/Kanuka and shrubland habitats (Table A1 in Appendix 1, Figure 4.1). Season was not significant for either pooled native or introduced species, though it was a significant predictor for the presence of Blackbirds ($p<0.006$).

Native species presence and relative abundance within different habitat types

The Silvereye was the most ubiquotous recorded native species, whereas the Rifleman and Tomtit were the rarest; the Bellbird, Fantail and Grey Warbler were relatively intermediate in distribution (Figure 4.1). For the Bellbird, Silvereye and Tomtit, mean presence within a patch of a given habitat type was highest for mixed native trees (Figure 4.1). By contrast, highest means for the Grey Warbler and Rifleman were in Manuka/Kanuka trees, a habitat absent of Bellbird observations. The highest observed habitat mean for the Fantail was for mixed tree shelterbelts; only the Bellbird and Fantail were recorded within this habitat type (Figure 4.1). No native candidate species were observed in exotic conifer shelterbelts.

Table 4.2 Explanatory variables in the REMLs for presence/absence of any native species, any introduced species and individual candidate indicator species. Models depicted are only those for which model convergence was achieved and observed and predicted means were similar. Emboldened cases indicate significance at the $p<0.05$ level.

Parameter	Any native	Any intro	Blackbird	Chaffinch	Silvereye	Yellowhammer
Habitat	**<0.001**	**0.001**	0.451	0.118	0.118	**0.04**
Log_earea	**0.014**	**0.004**	0.912	0.574	0.91	0.166
Season	0.557	0.29	**0.006**	0.438	0.744	0.124
Panel	0.055	0.052	0.667	0.224	0.152	0.855

Kruskal-Wallis tests identified a greater number of associations between individual native species and habitat, with significant habitat effects for Bellbird, Grey Warbler, Rifleman and Tomtit presence ($p < 0.007$), and non-significant a trend toward a habitat effect for Silvereye presence ($p<0.01$, Figure 4.1, Table 4.3). Cluster was found to be significant for the Bellbird and Fantail ($p<0.001$, Figure 4.3, Table 4.3). Farm was also significant for the Fantail ($p<0.001$, Table 4.3). Area was significant for all native candidate species ($p<0.001$, Table 4.2). There was no significant panel effect for any native candidate species (Figure 4.4). Spearman's correlation coefficient analyses suggested strong habitat associations for a number of native species. The Bellbird Fantail, Grey Warbler, Rifleman and Tomtit showed strong positive associations with mixed native tree habitats ($p<0.01$, Figure 4.1, Table 4.2). Wilcoxon matched pairs tests suggested Rifleman counts were highest in summer ($p<0.001$), but pointed to no seasonal differences in counts for any other native species.

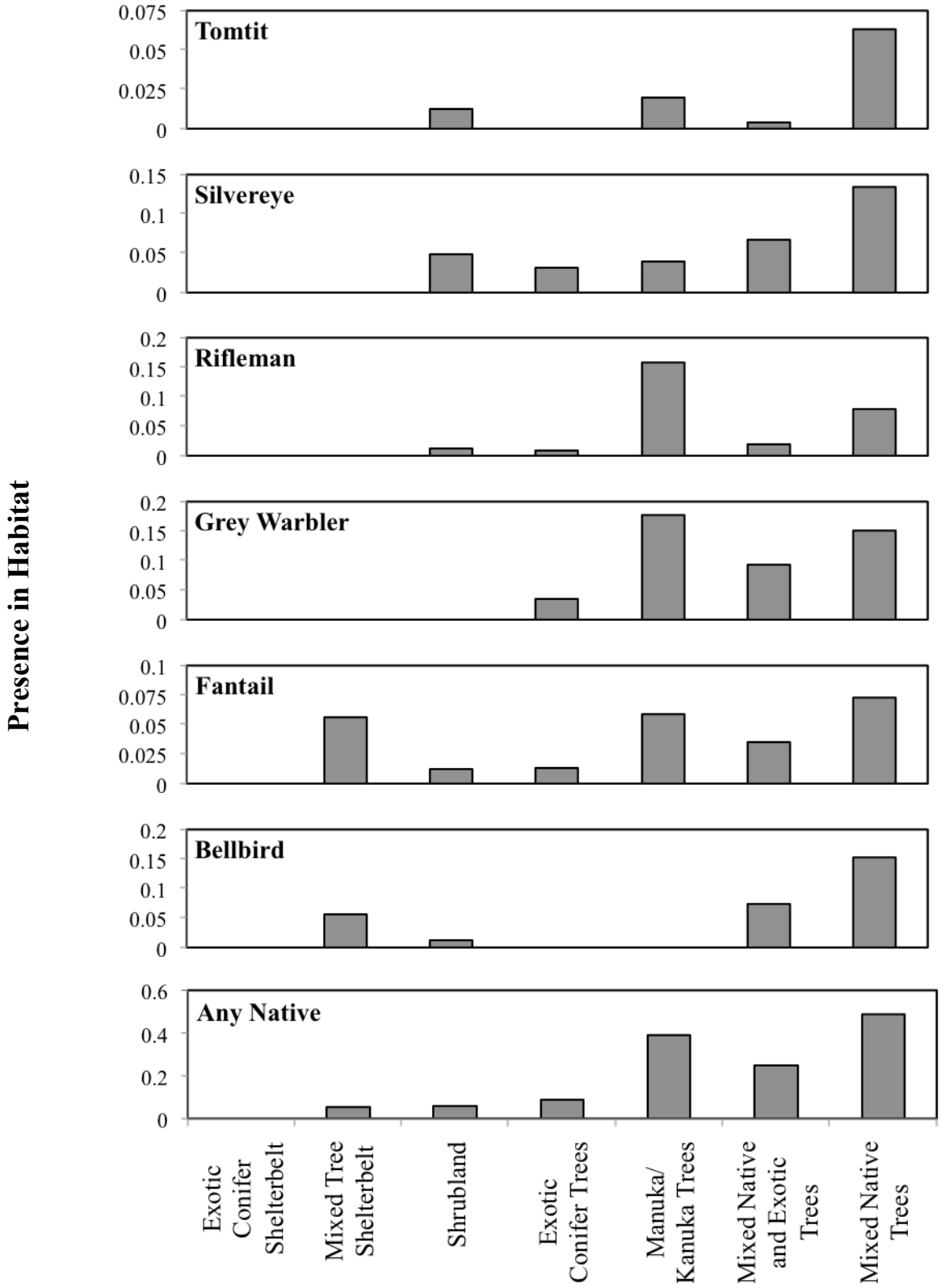


Figure 4.1 Native candidate species presence expressed as mean proportion of total batches of each habitat type each species was recorded

Table 4. 3 Kruskal-Wallis significance levels (p<0.01) of median native candidate species counts by habitat, panel, cluster, farm and Spearman's test significance levels for correlation between mean species count per patch versus patch area. Emboldened cases show statistical significance at the P<0.01 level, the revised threshold chosen to minimise Type I errors and confounded effects.

	Bellbird	Fantail	Grey Warbler	Rifleman	Silvereye	Tomtit
Kruskal-Wallis						
Habitat	**<0.001**	0.135	**<0.001**	**0.005**	0.01	**0.007**
Panel	0.27	0.789	0.395	0.036	0.056	0.685
Cluster	**<0.001**	**<0.001**	0.207	0.017	0.783	0.011
Farm	0.024	**<0.001**	0.053	0.022	0.307	0.214
Spearman's correlation of bird count versus patch size for all habitats combined						
Area	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**
Spearman's correlation of bird count versus patch size for separate habitats						
Mixed native trees	**0.004**	**<0.001**	**<0.001**	**0.002**	0.038	**0.003**
Mixed native and exotic trees	**<0.001**	**0.004**	**<0.001**	**0.001**	0.045	0.185
Manuka/Kanuka trees	*	0.889	0.563	0.812	0.343	0.432
Exotic conifer trees	*	0.035	0.169	0.802	0.012	*
Shrubland	0.605	0.918	*	0.605	0.319	0.605
Exotic conifer shelterbelt	*	*	*	*	*	*
Mixed tree shelterbelt	0.12	0.12	*	*	*	*

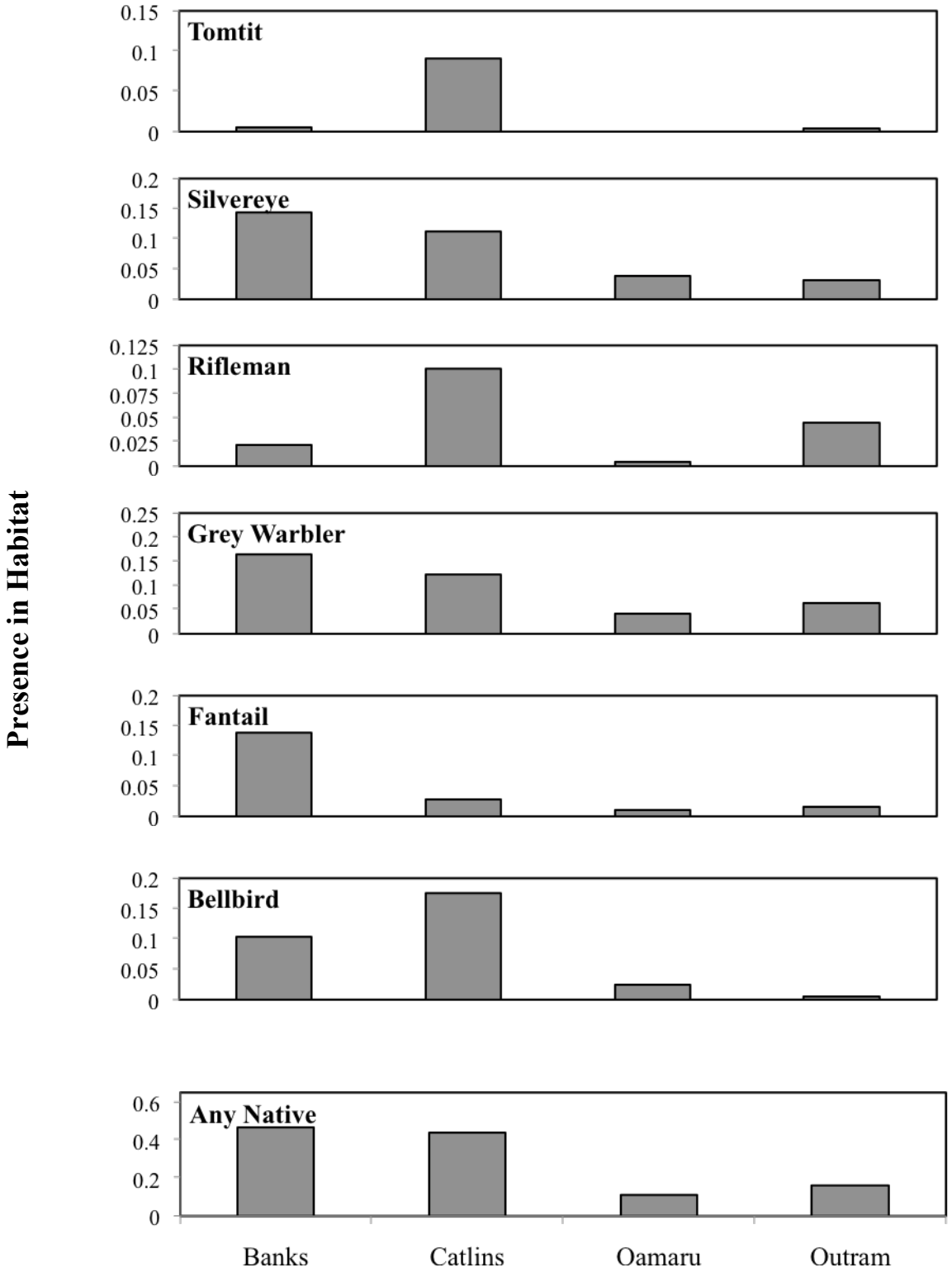


Figure 4.2 Native candidate species presence as mean proportion of total patches pooled across habitat types for each farm cluster.

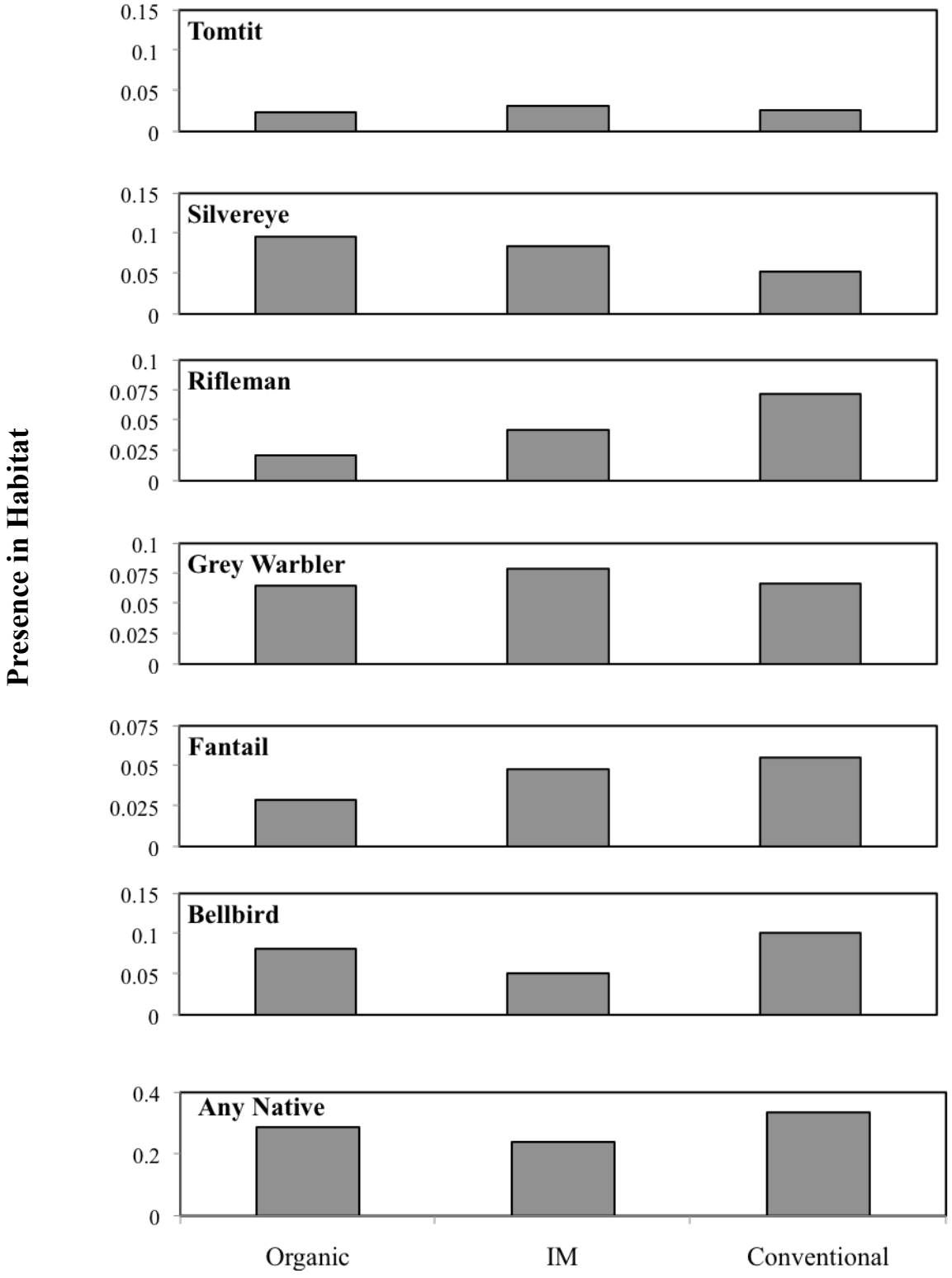


Figure 4.3 Native candidate species presence as mean proportion of total patches pooled across habitat types for each management panel.

Introduced species presence and relative abundance within different habitat types

Most introduced candidate species were recorded within all habitat types, with the exception of the Redpoll and Goldfinch, which were not recorded within mixed tree shelterbelts (Figure 4.2). The Chaffinch and Blackbird exhibited the most even distribution among habitats, though Blackbirds were relatively uncommon in exotic conifer shelterbelts. Relative to native candidate species, introduced species were far more common across habitat types (Figure 4.3 cf. 4.1).

Far fewer associations between presence/absence of individual species and habitat characters were evident in introduced species Kruskal-Wallis analysis. The Goldfinch was the only species significantly associated with habitat; Spearmann's correlation analysis suggested a strong relationship between Goldfinch presence and native tree habitat (Figure 4.2, Table 4.4). Significant cluster and farm effects were identified for the Goldfinch and Redpoll (Figure 4.5, Table 4.4). The Blackbird, Chaffinch, Goldfinch and Yellowhammer all exhibited significant area effects ($p<0.002$, Table 4.4). Individual habitat analysis identified a significant positive relationship between mixed native tree habitat and Blackbird, Chaffinch and Goldfinch presence ($p<0.004$, Table 4.4). The Yellowhammer showed a significant relationship to both mixed native and exotic tree, Manuka/Kanuka and shrubland habitats ($p<0.008$).

Wilcoxin matched pairs tests for introduced species indicated seasonal differences in recorded presence for a number of species: Goldfinch presence was significantly different between summer and winter ($p<0.002$), Redpoll presence in summer was significantly different from both spring ($p<0.001$) and winter ($p<0.001$). Finally Yellowhammer presence was found to significantly differ between summer and spring ($p<0.001$).

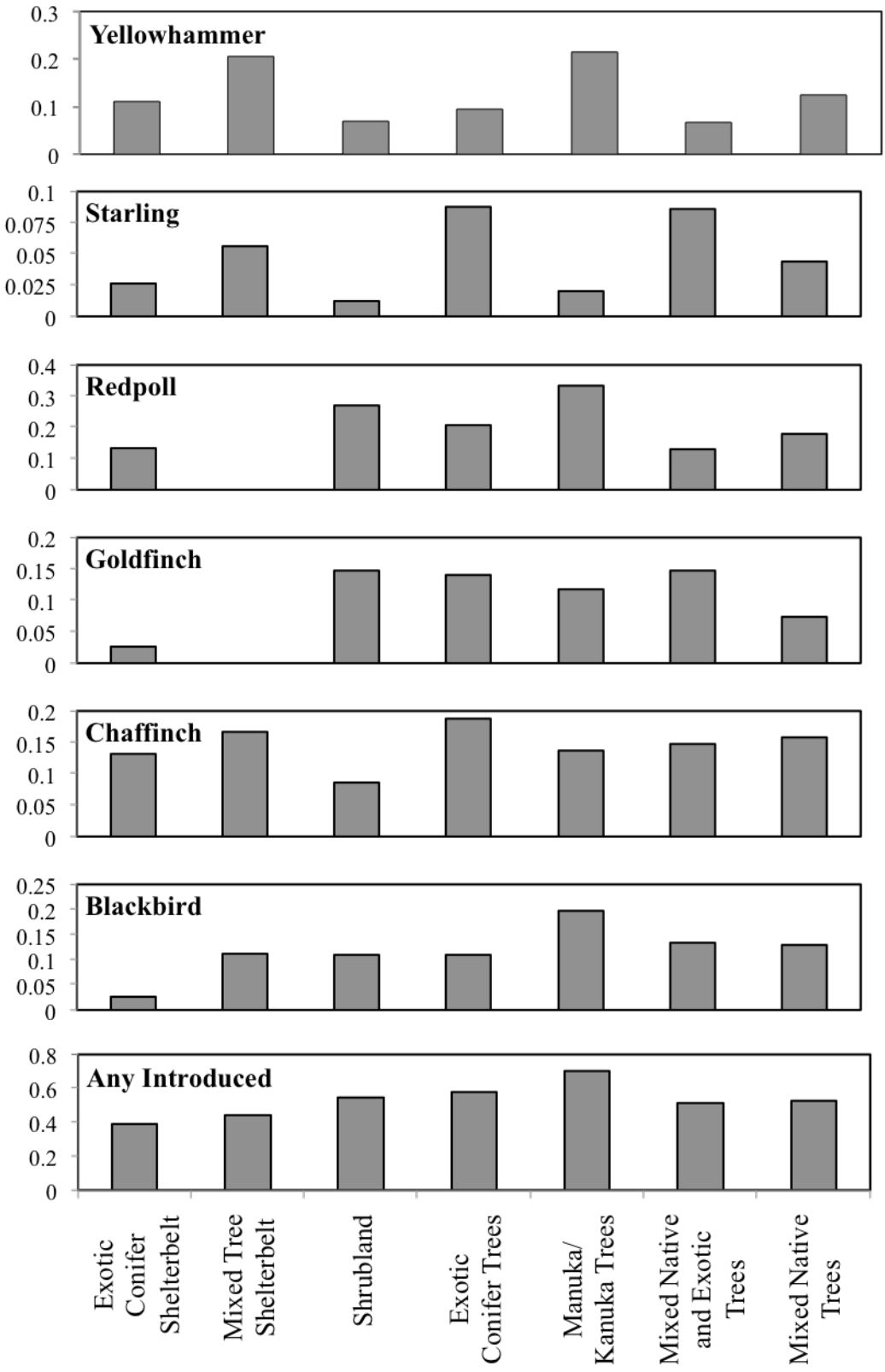


Figure 4.4 Introduced candidate species presence expressed as mean proportion of total patches of each habitat type each species was recorded in.

Table 4. 4 Kruskal-Wallis significance levels (p<0.01) of median introduced candidate species counts by habitat, panel, cluster, farm and Spearman's test significance levels for correlation between mean introduced species count per patch versus patch area. Emboldened cases show statistical significance at the P<0.01 level, the revised threshold chosen to minimise Type I errors and confounded effects.

	Blackbird	**Chaffinch**	**Goldfinch**	**Redpoll**	**Starling**	**Yellowhammer**
Kruskal-Wallis						
Habitat	0.102	0.815	**0.002**	0.017	0.077	0.067
Panel	0.348	0.124	0.028	0.037	0.507	0.267
Cluster	0.081	0.376	**<0.001**	**0.002**	0.023	0.096
Farm	0.023	0.149	**<0.001**	**0.001**	0.071	0.218
Spearman's correlation of bird count versus patch size for all habitats combined						
Area	**0.002**	**0.002**	**<0.001**	0.01	0.036	**<0.001**
Spearman's correlation of bird count versus patch size for separate habitats						
Mixed native trees	**<0.001**	**<0.001**	**0.004**	0.161	0.067	0.07
Mixed native and exotic trees	0.977	0.269	0.55	0.334	0.357	**0.008**
Manuka/ Kanuka trees	0.059	0.913	0.818	0.319	0.697	**0.006**
Exotic conifer trees	0.992	0.133	0.401	0.275	0.311	0.034
Shrubland	1	0.265	0.061	0.555	0.757	**0.002**
Exotic conifer shelterbelt	0.558	0.318	0.145	0.36	0.145	0.45
Mixed tree shelterbelt	0.962	0.389	*	*	0.517	0.243

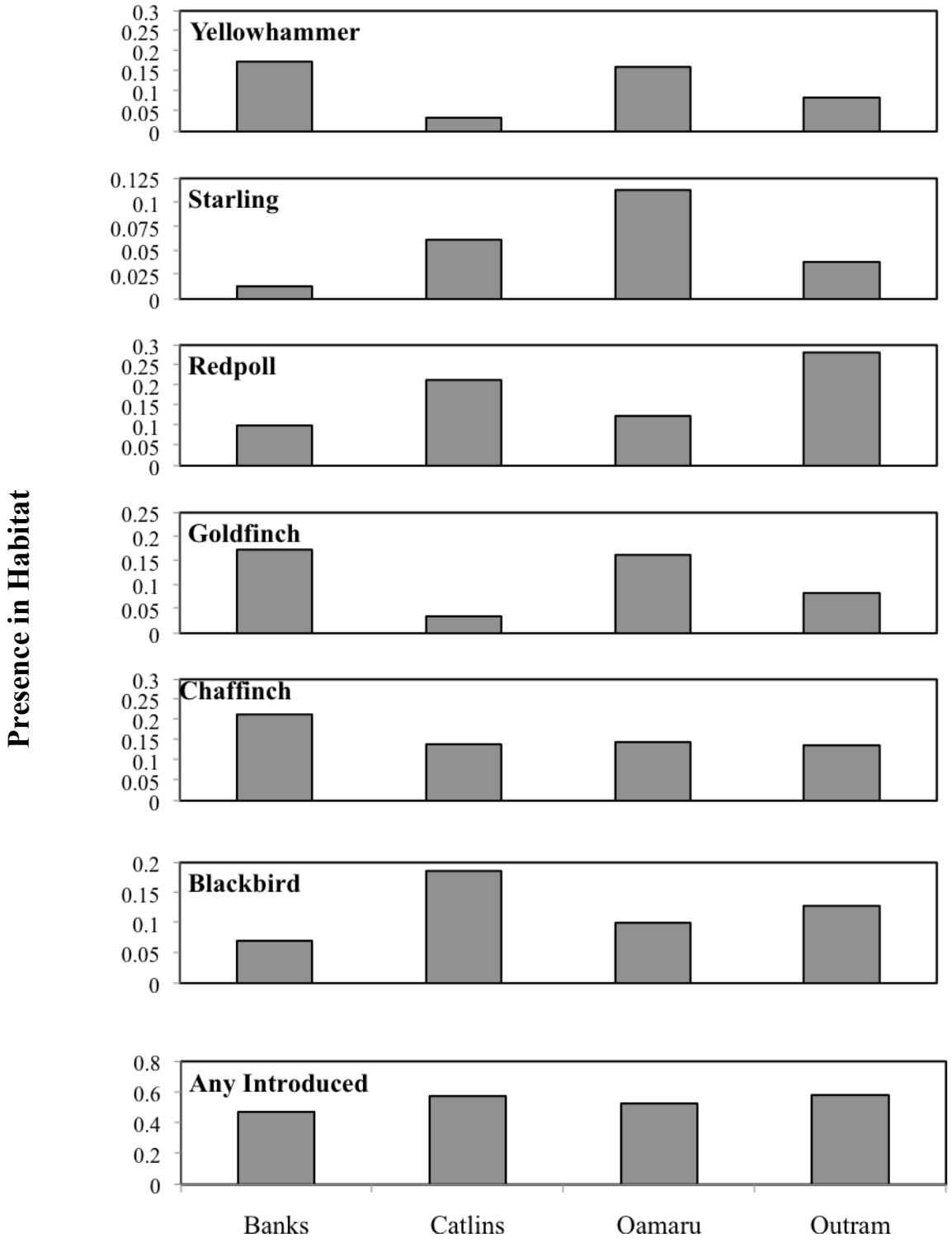


Figure 4.5 Introduced candidate species presence as mean proportion of total patches pooled across habitat types for each farm cluster

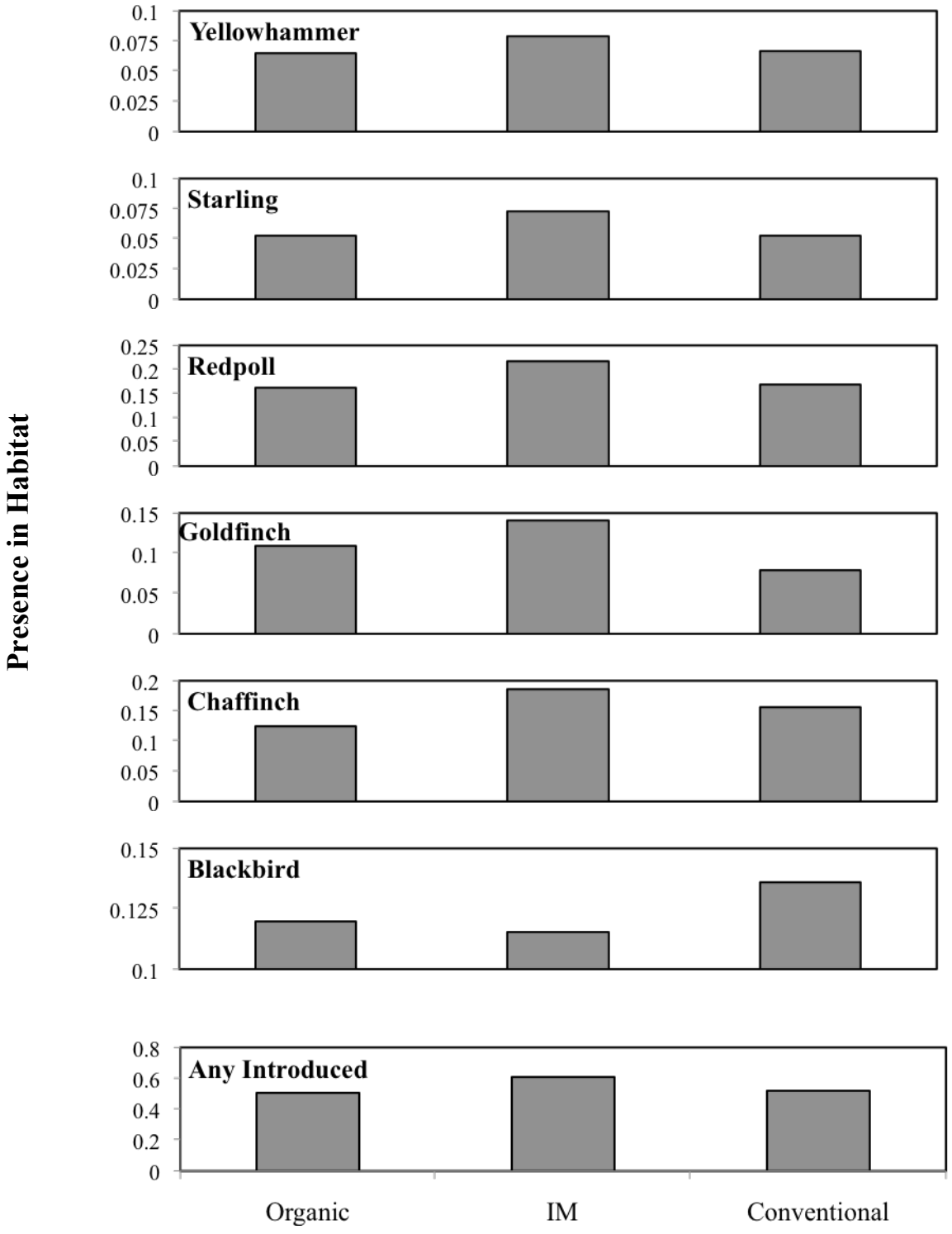


Figure 4.6 Introduced candidate species presence as mean proportion of total patches pooled across habitat types for each management panel.

Discussion

Trends in individual species distribution and abundance

GLMs and non-parametric tests of individual native and introduced candidate indicator species confirm the findings of concurrent analysis of native and introduced spcies richness (Chapter 3): the presence of native species is, in large part, predicted by large, native tree habitats. While the findings of Chapter 3 suggest introduced species are ubiquotous in distribution and exhibit no strong associations with patch size or habitat type, the research presented here suggests that the Blackbird, Chaffinch and Goldfinch may also exhibit preference for native habitat.

In accordance with species richness analysis, the present study identified strong assocations between native species presence and habitat, which were predominantly evident in positve relationships between median native species counts and mixed native tree and mixed native and exotic tree habitats. Again, a strong area effect was observed for all native species and all introduced species, with the exception of the Redpoll and Starling. In conjunction with species richness models (Chapter 3), individual species analysis points to a legitimate area effect that is unlikely the mere product of confounding variables, such as inter-farm differences or the external land matrix. For members of the honeyeater guild, namely the Bellbird and Tui, and frugivores, such as the New Zealand Pigeon, larger native habitats may provide a greater supply of native flower and fruit food resources, which increase richness and abundance of these species (Warburton et al. 1992, O'Donnell and Dilks 1994). The prevalance of native flowers and fruit-bearing plants, however, does not explain increased richness of insectivores and non-native generalists. Large native forest patches visited for this study were often located on steep slopes or rugged terrain that in many instances prohibited plowing or grazing of livestock (pers. obs.). Removal of land from agricultral production promotes regeneration of field margins and forest undergrowth, which leads to increased diversity and abundance of invertebrate prey species available to birds (Knopp et al. 2006, Marshall 2005, Marshall et al. 2006, Conover et al. 2009). While native species clearly exhibit preference for native vegetation, the spatial disconnect between many native tree habitats and farm-level production activities, such as grazing, planting or fertilizing, may be a key determinant in a habiat's ability to support a greater number and wider variety of bird species (Woodhouse et al. 2005, Marshall 2005, Haslem and Bennet 2008, Conover et al. 2009). This most probably also explains the prevalence of Blackbirds, Chaffinches and Goldfinches in native habitat.

A number of introduced species, many of which are considered farmland specialists in their native ranges (DEFRA 2010), were prevalent in all surveyed habitats. The historic association of these species with production lands is reflected in their superior ability ot exploit smaller, non-native habitats compared to native species. While there was some evidence of a panel effect for native and introduced species richness (Chapter 3), panel was found not to be a significant predictor of the presence of any individual species in this study. Habitat type and area appear to be far more critical in determining bird species presence and relative abundance than management system.

Native species as indicators

The Tomtit and Rifleman were fairly uncommon and tended to be restricted to native habitats. The monitoring of rare species can be intensive in terms of both time and labor, and therefore these species may not be viable indicators for schemes that require regular counts to meet sampling targets. Conversely, the catholic distribution of the Silvereye among different habitat types described in this and other research (Moffat and Minot 1994, Day, 1995, Deconchat et al. 2009**)** may detract from their ability to respond to environmental change and serve as valuable indicators.

Insectivores may prove meaningful indicators of environment health and wider biodiversity, as their richness and abundance is often reflective of richness and abundance of invertebrate species (Sotherton and Self 2000, Benton et al. 2002, Iwata et al. 2003) . The Fantail is a native obligate insectivore, and as such, a species with great potential utility as an indicator. However, though not evident in the present study, Fantail abundance within production landscapes can exhibit a high degree of seasonal variation (Coleman 2010), and their use as a surrogate species would necessitate a more comprehensive understanding of metapopulation dynamics and specific use of different habitats within the production land matrx. Median counts of Grey Warblers, another native insectivore, showed significant habitat effects, with strong assocaitions between Grey Warbler counts and mixed native tree and mixed native and exotic tree habitats. This is consistent with prior studies, which have similarly indicated strong associations between Grey Warbler abundance and native plant species (Warburton et al. 1992, Elliott et al. 2010). Although Grey Warblers were absent from shelterbelt and shrubland habitats within study farms, other research suggests they frequently occur in modified environments, particularly when some native habitat is available (Day 1995). No significant seasonal effects were evident for Grey Warbler presence described in this study. This may be of crucial importance, as a

key attribute for a successful indicator is the temporal consistency of monitoring (Bibby 1999, Halberg et al. 2005).

The Bellbird has more specialized habitat requirements than the two insectivores, and expectedly showed strong a strong preference for mixed native tree and mixed native and exotic tree habitats. These findings are supported by previous work linking Bellbird presence to native habitat (Freeman 1999, Deconchat et al. 2009). Though fruit and nectar is an important component of Bellbird diet, Bellbirds utilize a much wider range of plants than other honeyeaters and frugivores, and rely greatly upon insects for sustenance (O'Donnell and Dilks 1994). The specialist ecology of the Bellbird may make it more sensitive to environmental change than either the Fantail or Grey Warbler, while its ability to incorporate a wider variety of food sources into its diet may enable it to be sufficiently common for monitoring.

Introduced species as indicators

The identification of potential introduced indicator species somewhat problematic. The Goldfiinch, Starling and Yellowhammer all exhibited significant seasonal differences in counts. While this does not negate their potential utility as indicator taxa, more needs to be known about the demographics of all three species, particularly with regard to habitat fidelity and reproduction. All three species were associated with significantly higher abundances in summer relative to other months. This trend may be indicative of a "birth pulse," (Caughley 1967) in which a prevalence of juveniles following hatching temporarily inflates local population size. Alternatively, if any of the three species is utilizing habitat extraneous to the farm for either foraging or reproduction for a substantial portion of the year, any population changes may not necessarily be indicative of processes occurring on the farm.

The Goldfinch is considered a farmland specialist throughout its historic range and characteristically thrives in arable crop and open wooded environments (DEFRA 2002). However, the present research identified a strong association between Goldfinch presence and mixed native tree habitat. As this habitat is characterized by dense vegetation and canopy cover, the degree to which Goldfinches use it, particularly with regard to provision of food resources, warrants attention. That Goldfinches tend to rely on the presence of seed-bearing plants for sustenance suggests there may be little interspecific competiition with native species. Therefore, the Goldfinch may be beneficial in serving as a complementary, rather than conflicting, indicator to a native surrogate species.

Kruskal-Wallis tests pointed to a significant area effect, as well as significant relationships between median Yellowhammer counts and mixed native tree, Manuka/Kanuka and Shrubland habitats. As with the Goldfinch, within its European range, the Yellowhammer is considered a farmland specialist (DEFRA 2002), yet it demonstrates a strong preference for a range of native New Zealand habitats. Though associated with historic population declines in Europe, the Yellowhammer presently flourishes wihtin New Zealand agroecosystems, and seemingly incurs little regulation in the form of predation, parasitism or interspecific competition (MacLeod et al. 2005*a* and *b*). Yellowhammer populations are presently monitored within the U.K. as part of the Wild Bird Indicator program (DEFRA 2002). Parallel monitoring of this species within New Zealand may provide valuable insight into differences between New Zealand and British farming practices at an ecological level. While the potential for Yellowhammers to adequately indicate habitat quality or farm environment health remains to be seen, when monitored in conjunction with programs abroad, they may be immensely informative in reflexively directing conservation within New Zealand and the U.K.

Managment and conservation implications

The selection of an appropriate indicator is contingent upon a species first and foremost having a quantifiable association with either wider diversity or an environmental attirubte of concern (Duelli and Obrist 1998). When searching for indicators of agroecosystem environment health, given this criterion is met, a species must: be sufficiently common to be of relevance across a broad geographic scale; exhibit a temporally consistent pattern of occurrence; be a habitat specialist or possess a feeding ecology that is disrupted by enviornmental change; and be realistic to measure or audit (Chapter 1). Truncation of all sightings to a 10m radius, coupled with the large number of zero values resulting from one or more species being absent from a patch, meant complex models describing associations between individual species presence and species richness were unable to meet key assumptions. Consequently, the present study was unable to identify direct associations between the presence and abundance of any individual species and wider species richness. This forced exploration of the secondary objective – the identification of species whose presence and abundance is associated with similar habitat attributes that characterize high species richness. In addition to exhibiting similar habitat associations as species richness measures, of the native candidate species evaluated in the present study, the Bellbird and Grey Warbler and Fantail most aptly fit the remaining Market Flagship criteria

The inconsistency with which Fantails are able to be monitoried in a production context (Coleman 2010), coupled with the relative rarity with which they were encountered during five-minute point counts (Chapter 3) may represent warning flags that signal this species' potential unsuitability to serve as an indicator. In order to succintly demonstrate the value of the Market Flagship model to select ecologically-relevant indicators, the Bellbird and Grey Warbler are accordingly given preference over the Fantail and nominated as the two 'best-case' native species to test the conceptual model hierarchy.

Again, the nomination of an introduced indicator species is slightly more convoluted. Goldfinch and Yellowhammer abundance was significantly related to area and native tree habitat. In addition to serving as indicators of diversity, associations with native habitat suggest that efforts to protect these two species might confer protection upon sympatric natives. For this reason, these two species are proposed as the most ideal candidates from within the inroduced set with which to examine the Market Flagship Model. . It should be emphasized that these four species are principially nominated to examine the utility of the Market Flagship model, and only represent potential Market Flagship species within the context of the South Island sheep/beef farms suveyed in the present study. While Grey Warblers are present throughout New Zeland, Bellbirds are rare or absent from many agricultural systems on the North Island. Attempts to identify indicators within these systems should conduct similar bird counts and propose a list of candidate indicator species emblematic of the unique geography and ecology of those locales.

Chapter 5 (following) ventures into the social realm in quantifying farmer attitudes and actions toward bird diversity on their farms. The research presented here is revisited in Chapter 6, which combines both ecological and social data into a transdisciplinary endeavour to identify a Market Flagship Species.

Chapter 5: Can birds inform resilient farming and environmental care in market accreditation systems? Perspectives of New Zealand Sheep/Beef farmers

Abstract

In this research birds are used as a proxy for wider agroecosystem biodiversity to examine attitudes and actions of New Zealand sheep/beef farmers toward biodiversity. Farmer interviews were complemented by analysis of a national farmer survey. Survey questions focused on (i) birds as emblematic of system resilience, (ii) birds as providers of ecosystem services, (iii) farmers' responsibility to encourage birds on their farms and (iv) farmers' willingness to participate in market accreditation systems that use birds as indicators of biodiversity. Analysis of survey responses links the presence of non-production species as environmental performance indicators, connection to the local area and management system to positive attitudes toward birds. Birds were recognized as components of a larger, complex system and their presence as evidence of a healthy, robust farm environment. Willingness to shoulder responsibility for encouraging birds was linked to the financial constraints of doing so. Market accreditation systems were suggested as the most likely mechanism through which biodiversity conservation measures could be introduced. It is posited that involving farmers in the establishment of such a scheme may create a system in which farmers have a vested interest and foster positive attitudes toward biodiversity conservation on production lands.

Key words: agroecosystem, audit, farmers' attitudes, farmland birds, New Zealand, resilience

Introduction

Agricultural intensification, the process by which an increase in the output of agricultural commodities is driven by increasing the input of subsidies such as labor, fertilizer or feed (FAO 2008), resulted in a number of negative ecological consequences during the latter part of the 20th century. Intensification-linked soil erosion, loss of woody vegetation, homogenization of grasslands and associated declines in the diversity of flora and fauna on production lands prompted calls for greater sustainability in farming practices in many industrialized countries (PCE 2004, Millenium Assessment 2005). This concern contributed to the development of both governmental agri-environment schemes and voluntary private-sector auditing programs structured around sustainable farming practices (EU 2005, Albersmeier 2009). At the crux of many such initiatives is the assertion that biodiversity plays an integral function in maintaining agroecosystem health. Biodiversity provides ecosystem services essential to commodity production, such as nitrogen fixation, decomposition, pollination, and pest control (Matson et al. 1997, Altieri 1999), and contributes to an agroecosystem's resilience, or capacity to absorb and recover from perturbation (Duelli and Obrist 2003, Fischer et al. 2006), and adaption to more sustainable states when social-environmental conditions change (Darnhofer et al. 2010).

Within Europe, agri-environment schemes are designed to maintain production and farmer livelihood while mitigating the negative environmental impacts of agricultural practices, and to alter the structure of the production land matrix such that it becomes amenable to supporting greater biodiversity (EU 2005). While private-sector bodies tend to maintain a focus on food quality and safety, systems like Global Good Agricultural Practice (GlobalGAP) include provisions to minimize the detrimental impact of farming operations. The Linking Environment and Farming (LEAF) Marque scheme, in particular, places greater emphasis on biodiversity conservation through the inclusion of a whole farm conservation plan, provisions for wildlife habitat retention and a biodiversity management component.

Over 80% of New Zealand agricultural output is exported, with primary markets in the European Union, United States, and Japan (Smith and Montgomery 2003, Statistics New Zealand 2006). In the absence of government subsidization of conservation-orientated and sustainability-driven farming programs, sustainable farming practices and enhancement of biodiversity on production lands within New Zealand have been largely driven by international private sector auditing systems (Campbell et al. 2006). Access of

New Zealand fresh produce to European markets, for example, is often contingent on compliance with GlobalGAP. As concern regarding food safety and sustainable farming practices continues to grow overseas, New Zealand products within all farming sectors are likely to incur increased pressure to adhere to standards set by international markets.

Prospective biodiversity-based audit systems are likely to be in part structured around species that are both meaningful to consumers in markets abroad and indicative of wider diversity. A number of introduced bird species characterized by population declines on farmland in Europe are seemingly thriving in New Zealand agroecosystems (MacLeod et al. 2005*a* and *b*, MacLeod et al. 2008, MacLeod et al. 2009). These species may therefore signal sustainable agricultural practice for European market access. Extraneous to mandates set by consumers abroad, there exists a powerful connection between several indigenous species and New Zealand cultural identity (DOC and MFE 2000). In particular, a number of endemic bird species, such as the Tui (Prosthemadera novaeseelandiae) , New Zealand Fantail (*Rhipidura fuliginosa*) and Wood Pigeon (*Hemiphaga novaeseelandiae*), are associated with high intrinsic value and regarded as cultural icons by many New Zealanders. The conversion of New Zealand's lowlands to agriculture and forestry constricted the historic distribution of a suite of native species, and at present much of the 82% of New Zealand's lowlands not part of the public conservation estate are utilized in agriculture and forestry production (MFE, Norton and Miller 2000). In recent years, however, the nurturing of New Zealand's unique indigenous biota on private and agricultural lands has been deemed a conservation imperative by the New Zealand government (DOC and MFE 2000, Perley et al. 2003).

Given increasing international moves toward biodiversity-friendly agricultural practices and the national aspiration to cultivate indigenous biota on public lands, the implementation of some form of biodiversity management by New Zealand farmers is likely inevitable. However, a critical first step in assessing the potential for adoption of and compliance with biodiversity-centered national conservation strategies and international audit systems is establishing a dialogue between farmers, researchers and policy makers, with the aim of elucidating how farmers perceive biodiversity as a component of their farm operations (Norton and Miller 2000, Jackson and Jackson 2002, Blesh 2006). Previous work within New Zealand and abroad has examined the degree to which farmer attitudes affect land management with regard to the farm environment as a whole, as well as specific detrimental environmental events (e.g. soil erosion, pollution, loss of vegetation, Buttel 1981, Beedell and Rehman 1999, Fairweather and Campbell

2003). Farmers' perceptions of biodiversity and how they situate it within the wider context of land management, has remained largely unstudied.

The concept of biodiversity itself is seemingly broad or intangible to many non-scientists (Elder et al. 1998, Fischer and Young 2007). Consequently, rather than questioning farmers about an abstract and complex system of interrelated species and processes, this research used surrogate species or group of species familiar to farmers to gauge perceptions of and behaviors toward biodiversity. Birds are frequently used as proxies for wider diversity, as they are often relatively high in the agroecosystem food chain and frequently require a number of specific habitat characteristics to persist within a given area. Accordingly, their presence is often emblematic of a multitude of species lower on the food chain (Hutto 1998, Bibby 1999, Chambers 2008). Compared to other taxa, birds are also often highly visible on the landscape. In conjunction with their suitability as surrogates for biodiversity, the conspicuous nature of birds on the landscape and social value attached to them makes them ideal models with which to examine farmer attitudes and actions toward biodiversity on production lands (Moller et al. 2005).

This chapter presents findings of research into farmers' attitudes and actions toward biodiversity within New Zealand's sheep/beef sector. Using birds as surrogates for wider agroecosystem biodiversity, it examines the relative influence of factors such as the perceived importance of non-productive plant and animal species on the farm in signaling environmental performance, financial costs of biodiversity enhancement, customer requirements and farm management system on farmer behaviors toward biodiversity as it pertains to the farm operation. It further seeks to identify whether there exist particular social or economic predictors of "biodiversity friendly" farming practices. These findings are interpreted as they relate to developing pathways to biodiversity conservation strategies on New Zealand's agricultural lands

Methods

This project was conducted within the broader research of the Agricultural Research Group on Sustainability (ARGOS, www.argos.org.nz). ARGOS seeks to identify pathways to sustainability in a number of New Zealand farming sectors through the comparison of social, economic and environmental factors across conventional, 'Integrated Management' (IM) and organic management systems. Organic farms follow strict protocols laid down by Bio-Gro or CertNZ that use no artificial fertilizers or pesticides. IM follows a somewhat more varied protocol where a wider range of chemicals can be applied

but inputs are minimized by a variety of strategies (Wharfe and Manhire, 2004). The sheep/beef sector is represented by twelve clusters of farms spanning the South Island of New Zealand, with each cluster containing a single conventional, IM and organic farm (Carey et al. subm.). At present, auditing of IM practices within the sheep/beef sector centre chiefly around documenting animal welfare practices and agricultural inputs, with no specific stipulations as to application rates. Consequently, there is a great degree of overlap between conventional and IM management practices.

National survey using Likert responses in a questionnaire

As an integral element of the project, questions examining farmer attitudes and actions toward birds and biodiversity on their lands were included in a national farmer survey (See Fairweather et al. 2009*a* for specifics regarding development of the survey instrument, Farmer and orchardist survey in Appendix 2), and provided an instrument through which quantitative analyses of behaviors could be assessed. The national survey of farmers was part of ongoing research within the social objective of ARGOS examining general farmer attitudes and practices with regard to sustainability, and was the second such survey, the first being conducted in 2005 (Fairweather et al. 2007). Briefly, the survey included registered organic, IM and conventional farmers. A simple random sample of farms in each of the sheep/beef, dairy and horticultural sectors was purchased from AssureQuality (formerly AgriQuality). Each separate sector sample included 666 farms, and each farm was sent a questionaire by post in August 2008. This study analyzed only data from the sheep/beef sector. The response rate and effective sample size for the sheep/beef sector were 23.6 percent and 145 farmers, respectively. The questionaire was comprised of multiple sections, several of which focused on farmers' attitudes to performance indicators pertaining to financial, production, environmental and social aspects of the farm; other sections examined management strategy, connections to community and the local region, a broad suite of farming factors including customer requirements and satisfaction, emissions trading, bird diversity and farm management and background information, which included data such as farm size, farmer age and level of debt (Farmer and orchardist survey in Appendix 2). Most questions used a seven-point Likert scale ranging from the negative (e.g., very unimportant, strongly disagree, strong intention not to use) to the positive (very important, strongly agree, strong intention to use) with the midpoint (4) being neutral (neither unimportant nor important, neither disagree nor agree, no intention either way). The researchers involved in the present study were not involved in the design of the questionaire. Rather, a number of questions pertaining to

farmers' attitudes and actions toward birds were submitted to researchers within the ARGOS social objective and subsequently incorporated into the wider questionaire as a subsection. All statistical analyses described here use only responses to bird questions as response variables and responses to questions from other sections within the survey as explanatory variables.

Qualitative interviews

Semi-structured interviews were conducted with twelve sheep/beef farmers on whose farms bird surveys had been conducted for a parallel study. To accommodate logistical and financial limitations, interviews were conducted with all sheep/beef farmers of only four of twelve ARGOS sheep/beef clusters. All twelve farmers interviewed similarly participated in the national survey used to generate ordered logistic models. During interviews, farmers were asked to discuss the contribution of birds to the functioning of the agroecosystem, and whether or not farms that have a greater number of birds are better able to cope with environmental and economic stressors. Farmers were questioned regarding the extent to which farming conventionally, organically, or according to integrated management principles affected the presence and abundance of both native and introduced bird species on their farms. Finally, they were asked about willingness to participate in potential bird- or biodiversity-derived market accreditation schemes, and to identify other possible mechanisms through which bird conservation on production lands could be introduced. Recordings were transcribed and coded for concepts using NVivo software. Due to the extensive array of potential explanatory variables, not all variables found to be significant predictors in ordered logistic models were discussed in farmer interviews. Interviews focused primarily on the broad concepts of birds as proxies for ecosystem health and resilience, providers of ecosystem services and potential species around which to devise biodiversity-dependent market accreditation schemes.

Statistical Analysis

Ordered logistic regression was performed using Stata software (StataCorp 2009) on survey data. Rather than identifying overall trends in the data, ordered logistic models identify positive responses to the bird variables, thereby describing subsets of individuals within the New Zealand sheep/beef sector who most frequently engage in biodiversity friendly farming practices or are most amenable to adopting biodiversity conservation measures. The analysis of sheep/beef farmers' orientations to bird diversity, and by association, biodiversity, is based on their responses to the four sentinel questions

involving birds as indicators of ecological resilience, ecosystem services, perceived responsibility to encourage biodiversity and willingness to adopt bird-derived market accreditation schemes (Table 5.1). Each sentinel question was asked separately for native and introduced bird species on their farm. Responses to questions within other sections of the survey and background information data were used as explanatory variables.

Ordered models are of particular value in analyzing Likert data, as response categories are treated as ordered, rather than interval data, consequently, any two measure variables can be compared in terms of the order relation (UCLA: Academic Technology Services 2010). Models were generated using the omodel command in Stata (Wolfe 1997), which performs a likelihood-ratio test of the proportional odds assumption across response categories. Models were rejected for failure to meet this assumption at $p < 0.05$. Coefficients produced by ordered logistic regression describe the increase in log odds of an explanatory variable being in a higher response category, given all other variables in the model are held constant. As these terms are often cumbersome to interpret, coefficients were exponentiated to generate odds ratios, which were in turn used to derive percent change in odds terms. The percent change in odds describes the percent change in odds of an explanatory variable being in a higher response variable category for every one unit increase in the response variable, as that variable moves toward the next higher category (Long and Freese 2006). In any instances where two or more models fitted the same data, the "best" model was selected based on Akaike's Information Criterion (AIC) values (Burnham and Anderson 1998).

Table 5.1 Mean responses of ARGOS (n = 12) and all sheep/beef farmers (n = 150) to eight bird-related sentinel survey questions

Sentinel statement	Native birds				Introduced birds			
	All sheep/beef		ARGOS		All Sheep/beef		ARGOS	
	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.
Farms that have more *native/introduced* birds are also more likely to cope with drought and climate stresses	3.36	0.15	3.07	0.34	3.10	0.16	3.13	0.35
Native/introduced birds provide important services on my farm (pollination, pest control, or nutrient cycling)	4.66	0.14	4.87	0.40	4.24	0.16	4.80	0.42
It is not my responsibility to encourage *native/introduced* birds on my farm	2.67	0.15	2.80	0.47	3.11	0.17	2.93	0.45
I would be interested in participating in a market accreditation scheme in the form of a "bird tick" that certifies my production as *native/introduced* bird friendly	3.84	0.18	3.33	0.61	3.38	0.18	3.25	0.58

Results

ARGOS farmers' responses for all bird-related questions were not significantly different from those of all sheep/beef farmers ($p > 0.05$, Table 5.1). This suggests responses of ARGOS farmers are representative of sentiments within the wider sheep/beef farming population, and that interviews likely reveal attitudes emblematic of New Zealand sheep/beef farmers, in general. Significant explanatory variables and their positive or negative association with response variables are given for all models in Appendix 2, Table 1. AIC selected models for the four sentinel questions contained a total of 18 explanatory variables. While a number of potential explanatory variables independently had significant statistical relationships with response variables, many were either non-significant when included within models or resulted in models which violated the proportional odds assumption. These included variables measuring the importance placed on both soil and livestock health in assessing environmental performance of the farm and agreement with statements such as *"No potentially productive land is going to waste," and "My farm is contributing to the local community."*

Resilience

Model selection indicated that farmers who agreed with the statement "*Farms that have more native birds are also more likely to cope with drought and climate stress*," tended to place less importance on minimum weeds as indicators of production; placed greater importance on the presence of productive and non-productive species on the farm; placed less importance on the use of pesticides as indicators of environmental performance; tended to be more amenable to experimentation with farm management; were more likely retain unused resources for future use; were more likely to disagree with the notion that New Zealand farmers contribute to and should take responsibility for climate change; and tended to own smaller farms ($n = 118$, LR $\chi^2 = 56.62$, $p < 0.000$, Table 5.2). The same statement regarding introduced bird species generated a model containing fewer predictive variables, which similarly included the retention of unused resources and disagreement with farmer contribution to climate change as significant. However, in contrast to the native species model, farmers who agreed with the introduced species statement tended to place importance on pesticide use as an indicator of environmental performance ($n = 115$, LR $\chi^2 = 20.82$, $p < 0.000$, Table 5.2).

Table 5.2 Farms that have more *native/introduced* birds are also more likely to cope with drought and climate stresses

NATIVE						
Explanatory Variable	**Coef.**	**S.E.**	**p**	**% Change in Odds**	**95% C.I.**	
Production Indicators						
(Very Unimportant → Very Important)						
Minimum weeds	-0.297	0.136	0.029	-28.4	-0.564	-0.031
Environmental Performance Indicators						
(Very Unimportant → Very Important)						
The presence of both productive and non-productive species on the farm	0.438	0.120	0.000	56.5	0.202	0.374
Pesticide use	-0.226	0.082	0.006	-17.9	-0.387	-0.064
Approach to Management						
(Never Consider/Implement →Always Consider/Implement)						
I adopt proven practices rather than do my own experimentation	-0.409	0.156	0.009	-33.7	-0.715	-0.103
I keep unused resources in case they are needed in the future	0.251	0.100	0.012	28.9	0.055	0.448
Emissions Trading						
(Very Strongly Agree → Very Strongly Disagree)						
New Zealand farmers contribute to climate change and should take responsibility for reducing emissions	-0.313	0.103	0.002	-28.9	-0.516	-0.110
Background Information						
Farm Size (ha)	-0.469	0.179	0.009	-39.1	-0.819	-0.119

INTRODUCED						
Environmental Performance Indicators						
(Very Unimportant → Very Important)						
Pesticide use	0.200	0.092	0.004	24.4	-0.372	-0.070
Approach to Management						
(Never Consider/Implement → Always Consider/Implement)						
I keep unused resources in case they are needed in the future	0.227	0.097	0.019	24.3	0.038	0.417
Emissions Trading						
(Very Strongly Agree → Very Strongly Disagree)						
New Zealand farmers contribute to climate change and should take responsibility for reducing emissions	-0.221	0.077	0.004	-20.0	-0.372	-0.070

Matching the ordered logistic model, interviewed farmers similarly placed value on the presence of biodiversity in general, and birds in particular, as an integral component of the agroecosystem. As one farmer put it:

> *Obviously the biodiversity, bugs and flies and all the rest of it, they're a significant part of that set-up. I'd be saying that our microbiology is dead and stuffed without the birds there. They're certainly an important part of the ecology of the place.*

Some farmers acknowledged the use of pesticides as not particularly important in determining farm environmental performance, and further elaborated on the detrimental impact of pesticide use on farmland biodiversity:

> *I think if you're using chemicals, you're probably killing off the food chain. All the insects and critters that they eat, if they're killed off because of chemical drift, that's the habitat, isn't it?*

The only non-negative comment made by a farmer regarding pesticide use intimated frustration at the inability to utilize pesticide as a management tool due to a meat packing company imposing restrictions on its use:

> *Certain weeds, like the likes of gorse, have to be controlled. The meat packers say you're not allowed to spray your gorse. But what do you do? Which is the lesser of two evils? I don't know.*

Ecosystem Services

Farmers who agreed with the statement *"Native birds provide important services on my farm,"* also tended to place importance on the number of native and introduced plant species; placed less importance on pesticide use; were more likely to monitor changes in plants, animals and insects on the farm; and were more likely to be organic, as opposed to conventional or integrated management ($n = 105$, LR $\chi^2 = 43.02$, $p < 0.000$, Table 5.3). Concerning introduced birds, farmers again were more likely to attach greater importance to the number of native plant species; placed less importance to pesticide use; and were more likely to regard the farm as important in developing a connection to the local area ($n = 115$, LR $\chi^2 = 32.23$, $p < 0.000$, Table 5.3).

Table 5.3 *Native/introduced* birds provide important services on my farm (pollination, pest control, nutrient cycling)

NATIVE						
Explanatory Variable	**Coef.**	**S.E.**	**p**	**% Change in Odds**	**95% C.I.**	
Panel						
Conventional	-1.155	0.508	0.002	-51.0	-2.547	-0.557
Integrated Management	-1.050	0.530	0.048	-38.4	-2.089	-0.012
Environmental Performance Indicators						
(Very Unimportant → Very Important)						
The number of plant species, native and other	0.436	0.131	0.001	99.5	0.180	0.692
Pesticide use	-0.255	0.096	0.001	-35.6	-0.445	-0.070
Approach to Management						
(Never Consider/Implement → Always Consider/Implement)						
I pay close attention to changes in plants/animals/insects on my farm	0.386	0.175	0.028	42.1	0.042	0.730
INTRODUCED						
Environmental Performance Indicators						
(Very Unimportant → Very Important)						
The number of plant species, native and other	0.441	0.121	0.000	55.5	0.204	0.678
Pesticide use	-0.242	0.077	0.002	-21.5	-0.394	-0.090
Social Performance Indicators						
(Very Unimportant → Very Important)						
My farming helps me to develop a connection to the place where it is located	0.348	0.120	0.004	41.7	0.113	0.584

Interviewed farmers similarly acknowledged birds as providing ecosystem services on the farm, particularly with regard to control of insect pests. The concept of birds as a necessary component of a larger natural system was described:

> *If you've got birds, it's part of the whole food chain. They eat bugs. They've all got their little thing that they'll chase around…even the odd starlings, when you get grass grub, they'll just work a paddock. I'm a big fan of having the old birds.*

> *I suppose they [birds] keep our insects in balance…Everything goes together, doesn't it? An indication that nature's in balance.*

When considering whether organic farms would likely have a greater number of bird species, and therefore reap greater benefit from their presence, conventional and integrated management farmers tended not to volunteer commentary, while organic farmer responses were mixed:

> *It would be interesting to see if there are actually more birds on organic. I suspect probably not…I suppose there would be more insects. So, yeah, maybe for certain kinds of bird, there's a few more on an organic farm.*

> *I'd be disappointed if they [organic farms] haven't [more birds]. If so, what were we doing wrong? I would think that there should be more birds on an organic farm. It just seems logical.*

However, irrespective of management system, some farmers suggested that the extent and diversity of vegetation played a greater role in determining whether a farm could support a high diversity and abundance of birds than management system alone:

> *I think we're seeing more [birds] because our bush is better…It's much greener, a much fuller green. So, it must have an affect on the life of the creatures living in it.* (Conventional farmer)

> *I'd think it's more the habitat that's around the place. You know, like if I'm in the middle of Canterbury plains with no bush, I'm going to get less birds than you get here.* (Organic farmer)

> *I think organic people tend to have more trees, which encourages birds more…And a bigger variety, which suits more variety of birds, anyway.* (Organic farmer)

As indicated by the introduced species model, interviewed farmers conveyed not only a desire for their farms to connect them to the local area, but further elaborated on the degree to which succession strengthens and maintains not only a connection to the local area, but is crucial in sustaining the ecological integrity of the farm:

It's probably the farmers who have had farms in their families for a long time that are the ones who have perhaps a better feel for the land. Whereas someone who's just bought a farm and run it for capital gain, they're not going to worry a hoot about what's on the land.

Most farmers farm with – hope is not the right word – but with the hope that the farm will continue in the family…And unfortunately we're seeing more corporate farms in this country…They don't think "Well, my grandkids will…" It's just a different psyche to the land, so they don't tend to be caretakers. They tend to be business people.

Responsibility to Encourage Birds

Farmers who agreed with the statement, *"It is not my responsibility as a landowner to encourage native birds on my farm,"* tended to place less importance on each of the following; the monitoring of financial performance of the farm; the level of biodiversity on the farm; and farm environmental health ($n = 82$, LR $\chi^2 = 53.29$, $p < 0.000$, Table 5.4). Farmers who indicated it was not their responsibility to encourage introduced birds tended to disagree with the notion that farm management affects the environment in the region where the farm is located, were less likely to have a strong attachment to the local community, and less likely to attach importance to the number of trees and plant species as an environmental indicator ($n = 137$, LR $\chi^2 = 26.93$, $p < 0.000$, Table 5.4)

Table 5.4 It is not my responsibility as a landowner to encourage *native/introduced* birds on my farm

NATIVE						
Explanatory Variable	**Coef.**	**S.E.**	**p**	**% Change in Odds**	**95% C.I.**	
Financial Indicators						
(Very Unimportant → Very Important)						
I don't monitor financial performance because it just follows on from physical management	0.292	0.117	0.013	78.9	0.063	0.522
Environmental Performance Indicators						
(Very Unimportant → Very Important)						
The level of biodiversity (the number and type of productive and unproductive species) on my farm	-0.649	0.187	0.001	-57.5	-1.015	-0.283
Other farming factors						
(Very Unimportant → Very Important)						
Farm environment health	-0.616	0.187	0.001	-51.6	-1.015	-0.283
INTRODUCED						
Environmental Performance Indicators						
(Very Unimportant → Very Important)						
The number of plant or tree species, native and other	-0.337	0.109	0.002	-29.7	-0.551	-0.123
Connections						
(Very Strongly Agree → Very Strongly Disagree)						
My farm management affects the environment in the region where my property is located	-0.264	0.103	0.010	-21.0	-0.517	-0.063
Community Participation						
(*Very Negative Connection → Very Positive Connection*)						
What is your level of attachment towards the area where you live?	-0.255	0.134	0.056	-23.3	-0.517	0.007

The aforementioned native species model was the only model for which a financial indicator, "I don't monitor financial performance because it just follows on from physical management" (Table 5.4), was a significant predictor of the response statement. Within interviews, when asked whether farmers have a responsibility to encourage birds on their land, a number of farmers expressed reluctance, citing the financial cost of implementing conservation measures:

Ah, yeah, I do. I think most farmers do. I think we would do a lot more if we had more money. Money is definitely the limiting factor. You know what I mean?

I think most farmers do [have a responsibility to encourage birds on their land], to a degree. You know, it's a balance…Looking after the farm would probably come first, but it does fit into the equation here.

The bottom line in this question is that it costs farmers. It's costing somebody money. So the absolute litmus test of your question is, "Why do farmers have to bear the cost?"

Um, probably not. No. I guess it's something I haven't thought about either, to be honest. I mean, I certainly enjoy seeing the native birds around that I do see, but at the end of the day, we've got to make a living.

Those who without reservation agreed with the statement tended to regard themselves as stewards of the land, and responsible for ensuring the persistence of biota on it:

Yeah, I think so [farmers have a responsibility to conserve birds on their land]. Custodians of the land. That sort of thing.

Well, we're only caretakers, aren't we?...And if we're only caretakers, we could do more. Boy, you could get yourself into some arguments, 'cause a lot of the farmers really don't think any more than the next financial year. You know, they want to pay the bills this year, but if you can't think five years plus, you can't really think conservation, can you?

I think they [farmers] definitely have a responsibility to protect. They're in a system, and if you wipe it out, you don't always know what you've wiped out…It may not seem to be very significant, but there will be an effect if you don't protect them.

As previously stated, the level of attachment of farmers to their particular farms and the regions in which they are located was often accompanied by both an assumed sense of serving as a custodian of the land and the desire to bestow the farm on successive generations. These attitudes further support the introduced species model's prediction that

farmers who have a low level of attachment to their local communities and do not see their farming operation as impacting the local environment are less likely to feel a responsibility to enhance bird diversity on their farms.

Market Accreditation

Finally, farmers who agreed with the statement, "I would be interested in participating in a market accreditation scheme in the form of a "bird tick" that certifies my production as bird friendly," placed importance on the number of native plant or tree species; placed importance on customer requirements; and agreed with the assertion that New Zealand farmers should assume responsibility for reducing greenhouse gas emissions (n = 140, LR χ^2 =, p <, Table 5.5). When responding to the same statement concerning introduced birds, farmers who expressed agreement placed importance on the presence of both native and introduced plant species and were more likely to be organic (n = 121, LR χ^2 = 24.21, p < 0.000, Table 5.5).

Table 5.5 I would be interested in participating in a market accreditation scheme in the form of a "bird tick" that certifies my production as *native/introduced* bird friendly

NATIVE						
Explanatory Variable	**Coef.**	**S.E.**	**p**	**% Change in Odds**	**95% C.I.**	
Environmental Performance Indicators						
(Very Unimportant → Very Important)						
The number of native plant or tree species	0.511	0.109	0.000	66.7	0.297	0.724
Other farming factors						
(Very Unimportant → Very Important)						
Customer requirements	0.413	0.136	0.002	51.2	0.147	0.679
Emissions Trading						
(Very Strongly Agree → Very Strongly Disagree)						
New Zealand farmers contribute to climate change and should take responsibility for reducing emissions	0.246	0.077	0.002	27.8	0.094	0.397
INTRODUCED						
Panel						
Conventional				-1.276	0.392	0.001
Integrated Management				-1.019	0.449	0.023
Environmental Performance Indicators						
(Very Unimportant → Very Important)						
The number of plant or tree species, native and other	0.423	0.127	0.001	48.6	0.174	0.672

Though management system was a significant predictor of interest in adopting an introduced bird friendly market accreditation scheme within the ordered logistic model, interviewed farmers neither placed greater value on native species, nor consistently differed in their general line of commentary across management system. Interest in participating in bird or biodiversity-friendly market accreditation schemes varied between interviewed farmers, with several farmers indicating the demands of consumers and overseas markets were the most likely mechanism to implement the eventual adoption of such schemes:

> *The perceptions of city people is frustrating. They think it's just one giant farm park and they demand and expect this that, and all the rest of it, and are oblivious to what it takes to get it to that state and keep it at that state and still make a dollar…I'm not saying that's the reality of it, but the way it is and what it takes to be there, I guess. They expect it all to be a given, and when you reach that threshold, then they expect a whole lot more.*

> *It's [accreditation schemes] driven by the consumerist management. I think they're New Zealand farmers' motivation to get their act up.*

One organic farmer additionally emphasized how the marriage of consumer requirements abroad and sustainable farming practices leads to greater protection of several components of the farm environment:

> *We are aiming at providing a story on our environment, our sustainability, our organic status…it's like a bottle of French wine. It goes with the story… And that is commercial, but it's also protecting the environment. It has to be a complete package: Animal welfare, environment, maintaining high quality water, a nice place to live and work. It's a complete package. Lots of bird life. And these people will buy that meat. They'll take it home and have a party, and they'll talk about how this lamb was raised and can see the sea and can hear the birds. Makes it taste better, doesn't it? Even if it's only mind over matter! It tastes better!*

As was the case with the model predicting the recognition of birds as supplying ecosystem services, the presence of plant species as an indicator of environmental performance was a significant predictor of willingness to adopt a bird-friendly auditing

scheme. The importance of plants in both models, coupled with the farmer interview data given in support of the ecosystem services model further emphasizes the importance of habitat not only as a critical part of the agroecosystem, but likely a necessary component of any potential conservation or accreditation scheme.

Discussion

Exploration of the relative influence that international private-sector accreditation systems; public pressure to foster biodiversity on production lands; and personal valuation of biodiversity exert on farmers' land management practices is especially important for understanding the most effective means of devising biodiversity conservation strategies for New Zealand's agricultural land. Removal of subsidies and absence of regulation since the 1984 'neo-liberal reforms' has accelerated intensification (MacLeod and Moller 2007), with potential, though largely unproven, impacts on biodiversity (Moller et al. 2008*a*). The sheep/beef sector provides a particularly interesting case with which to examine farmer behaviors toward biodiversity. Relative to their fresh produce counterparts, sheep/beef farms are less likely to incur financial loss through damage to or consumption of crops by wildlife. Further, sheep/beef farmers often leave shelterbelts and 'bush' (forest) patches on their properties to provide cover during lambing and calving as well as in times of inclement weather. Consequently, this sector may be best suited to adopt initial biodiversity conservation measures.

Existing literature suggests species non-essential for production are often considered by farmers predominantly in terms of aesthetic value, rather than for the ecosystem services they render (Okey 1996). A deficiency in biodiversity-related knowledge is considered to be the primary cause of poor farm environmental management (Swift et al. 2004). Within the context of the agroecosystem, this lack of ecological understanding can detract from overall system resilience (Folke et al. 2005). In contrast, the present study indicates that many New Zealand sheep/beef farmers have a complex consideration for non-productive components of the agroecosystem. Both quantitative and qualitative analyses suggest that farmers recognize birds as components of a larger, complex system and regard the presence of birds as evidence of a healthy, robust farm environment. In accordance with Folke et al. (2005) and Milestad and Darnhoffer (2003), This awareness of the abundance or dearth of birds on the landscape may further contribute to the overall resilience of the social-ecological system by serving as feedback mechanism that signals the need for redirection of or changes in farm management practices.

For farmers who regard birds as emblematic of agroecosystem resilience, the anticipation of and preparation for perturbation is exemplified by a greater willingness to experiment and the retention of unused resources for future use. Such foresight and intentionality reveals a plasticity in human behavior that allows for fluctuations in both the ecology and economics of the farm system (Holling 2001). In conjunction with the aforementioned subjectivities regarding biodiversity, in general, and bird diversity, in particular, this study identifies a subset of New Zealand sheep/beef farmers who are seemingly cognizant of the relationship between biodiversity and ecological processes on the farm, and possess a capacity to anticipate and accommodate agroecosystem disturbance within their management practices.

When examining farmer recognition of birds as suppliers of ecosystem services, both the native and introduced bird models included the presence of a greater number of plant species and lack of pesticide use as predictors of a farm's environmental performance. The model for native birds also included organic participation as a significant factor enhancing perceived importance of birds. While interviewed farmers primarily attributed a farm's lack or abundance of birdlife to the extent and complexity of vegetation, and expressed a general understanding that pesticide use detrimentally affects biodiversity, these attitudes neither differed with regard to native species nor consistently fell within the bounds of a specific management system. The presence of nearly identical explanatory variables within models, coupled with varied responses in interviews, suggests a degree of attitudinal overlap between farmers of different management systems. This is consistent with prior research, which indicates that proenvironmental orientations of New Zealand farmers cannot be explained exclusively by management system (Fairweather 1999, Fairweather et al. 2009*b*). Organic farmers may express a degree of ambivalence toward the characteristic "green" organic philosophy, pointing to premiums as key motivators for their choice of management practice (Fairweather 1999). Their conventional counterparts, by contrast, may regard such alternative management systems as fundamental in maintaining the environmental health and sustainability of New Zealand's production systems (Fairweather et al. 2009*b*).

The willingness of a farmer to assume responsibility for encouraging birds on their farm was linked to the financial cost of implementing requisite measures in both survey models and interviews. Irrespective of management system, sector or geographic location, the financial and labor costs of nurturing and protecting non-production species within agroecosystems are repeatedly cited as the predominant barriers to farmers implementing

conservation measures on their lands (McCann et al. 1997, Siebert 2006, Berentsen et al. 2007, Ahnstrom et al. 2009). A respect and understanding of non-production species and processes may be overshadowed by an obligation to ensure a farm remains economically viable (McCann et al. 1997). Even within European countries that offer financial support through AES, participation in biodiversity conservation schemes is often contingent upon associated management practices falling in line with the financial and economic interests of the farm (Siebert 2006, Berentsen et al. 2007, Ahnstrom et al. 2009).

Interviewed farmers who unequivocally agreed farmers should shoulder responsibility in nurturing bird diversity on their farms tended to place themselves in the roles of custodians of the land. Research abroad indicates stewardship can be instilled through participation in AES (Ahnstrom et al. 2009), and that farmers are more willing to engage in such schemes if conservation actions compliment their personal stewardship philosophy (Dutton 2008). Given the dearth of AES or government financial support for biodiversity enhancement, New Zealand farmers rely entirely on their personal sense of stewardship in managing biodiversity on their farms, and currently incur the costs associated with any conservation actions. The adoption of such measures may be inevitable, as participation in accreditation schemes becomes increasingly compulsory for farmers to maintain access to overseas markets where consumers demand products originate from environmentally friendly production regimes (Campbell et al. 2006) The findings of this study support that New Zealand sheep/beef farmers are highly sensitive to the demands of consumers, and further indicate that most farmers readily recognize the demands of international markets and associated audit systems as the key drivers through which biodiversity conservation can and will be enacted.

A pertinent question is whether the adoption of biodiversity-friendly accreditation schemes, beyond providing incentive to encourage good management practice, will provide a vehicle through which a sense of stewardship may grow. Much of the international literature describing farmer perceptions and behaviors with regard to biodiversity often does so as they pertain to the potential adoption and eventual implementation of AES (Kleijn and Sutherland 2003, Herzon and Mikk 2007, Ahnstrom et al. 2008). In Europe and North America, positive shifts in conservation-oriented attitudes of farmers have been attributed to AES participation (Wilson and Hart 2002, Robinson 2006, Dutton et al. 2008). However, a number of studies have shown that AES over-regulation of farming is often met with a sense of distrust and apprehension that restrictions will compromise farmers' sense of independence in managing their lands;

consequently, it is often difficult to recruit farmers into conservation programs (Ahnstrom et al. 2008, Brooke et al. 2003). The same sense of apprehension and curtailment can be evident in response to audit systems as well. Within New Zealand's dairy sector, for example, farmers acknowledge that mandatory fencing of streams stipulated by the primary dairy processing company has improved water quality, but express frustration that their autonomy has been compromised (Rosin 2008). Conversely, audit systems and associated biodiversity benefits may also be acclaimed by farmers, as exemplified by the development of the KiwiGreen™ system in the New Zealand kiwifruit sector (Campbell et al. 1997, Rosin 2008, Darnhofer et al. 2010). The success behind KiwiGreen™ has been partly attributed to its domestic origin and formulation at a time when the viability of the sector was threatened (Rosin et al. 2007, Rosin 2008). The degree to which similar systems would be embraced by the sheep/beef sector remains unclear. Interviews from this study and prior research suggest sheep/beef farmers are characterized by a strong, independent nature (Hunt et al. 2006). However, relative to dairy farmers, many sheep/beef farmers are presently finding themselves in dire financial straits (Ministry of Agriulture and Forestry 2010). Price premiums associated with products originating from biodiversity-friendly audit systems may serve as positive feedbacks and, as with the kiwifruit sector, instill a sense of satisfaction and stewardship.

While there was substantial overlap between native and introduced species explanatory variables for multiple models, the recurrence of variables emphasizing connection to the land and local region within introduced species models warrants consideration. When discussing relationships between their farming and the local region, interviewed farmers stressed the importance of succession in establishing and maintaining a custodial connection to the farm, intimating that it fosters a better feel for their land and the surrounding area. This may be indicative that farmers who situate their farming practices within a greater spatial and temporal context are similarly inclined to accommodate the presence and ecological contributions of introduced species in their farming philosophy. MacLeod et al. (2008) stressed that conservation of biodiversity on New Zealand's production lands must by necessity deviate from the traditional, compartmentalized endemic preservationist approach toward one that acknowledges the utility of introduced species in agroecosystems. Many introduced bird species suffering population declines abroad presently thrive on New Zealand sheep/beef farms (Macleod et al. 2005*a* and *b*, MacLeod et al. 2008, MacLeod et al. 2009). These species therefore have potential to serve the dual roles of indicators of ecological health within New Zealand and

relevant indicators of biodiversity friendly farm practices to consumers in export markets. Intensification of New Zealand agriculture, however, is accelerating (PCE 2003, Macleod and Moller 2006) and may threaten both native and introduced biodiversity (Moller et al. 2008*b*, Meadows et al. 2008).

The present study identifies a group of farmers who, irrespective of management system, acknowledge the importance of birds, and by association, biodiversity in supporting farm production. They express a willingness to support bird diversity both independently and in conjunction with audit systems. It may therefore be prudent for any biodiversity-inclusive accreditation schemes to first consider this demographic as a means to trial initial audits and rely partly on participating farmers to disseminate outcomes to their neighbors and communities. Involving farmers in the establishment of such a system may serve to assuage fears of constraints on their autonomy, create a system in which farmers have a vested interest, and, by association, foster positive attitudes toward biodiversity conservation on production lands.

Preceding chapters first identified ecological associations between species richness and individual habitat parameters (Chapter 3), then examined whether similar habitat associations were retained at the species level and thus able to proximally indicate diversity (Chapter 4). The present chapter points to the need to involve stakeholders in any emergent biodiversity-friendly audit systems, and underscores the need to maintain a transdisciplinary approach in the selection of indicator species. The final chapter relies on both disciplines to direct the selection of a Market Flagship Species.

Chapter 6: Science and farmers' perceptions for selecting indicators for biodiversity restoration on New Zealand sheep/beef farms

Abstract

South Island, New Zealand sheep/beef farmers were interviewed regarding their ability to recognize different birds on the production landscape and the degree to which birds serve as environmental cues in guiding land management decisions. Birds were discussed in terms of provision of essential agroecosystem services, status as both pest and charismatic species and value in signaling biodiversity-friendly farming via a market accreditation scheme. Farmers expressed universal fondness for native species and relative ambivalence toward most introduced species. These findings were paired with prior social science and ecological research to inform the nomination of Market Flagship Species. Based on interview findings and ecological rationale, the Bellbird is proposed as the most suitable Market Flagship Species. Introduced passerines, such as the Yellowhammer and Goldfinch may represent suitable introduced Market Flagship Species, but more information regarding the ecology and metapopulation dynamics of these species needs to be known before any formal inclusion in a market accreditation system should be advised.

Key words: Farmer attitudes, indicator species, agroecology, flagship species

Introduction

In the absence of direct financial support from the government, the environmental regulation of New Zealand agriculture is, to a large extent, governed by consumer- and industry-driven initiatives that often manifest in neoliberal audit systems (Campbell 2005, Campbell et al. 2006). 'Green' accreditation schemes and associated audit systems stemming from consumer demands for sustainable and biodiversity-friendly farming practices are seemingly the most practical way to influence environmental management of New Zealand's agroecosystems (Campbell 2005, Campbell et al. 2006, Campbell and Le Heron 2007). Economic motivations for farmer participation in schemes that offer financial compensation or price premiums for engaging in sustainable and biodiversity-friendly farming practices are often complimented by intrinsic values of conservation, a sense of serving as custodians of the land and a sense of pride in participating in on-farm conservation efforts (Morris and Potter 1995, Wossink and van Wenum 2003, Smallshire et al. 2004, Sutherland 2004, Berentsen et al. 2007, Dutton et al. 2008, Ahnstrom et al. 2009).

Irrespective of the vehicle through which biodiversity conservation is introduced to farm management practice, the identification of meaningful biodiversity indicators is essential in monitoring farm progress. The role of non-production species as indicators of ecological resilience and agricultural sustainability is well established for the production lands of Europe (Duelli and Obrist 1998, Noe et al. 2005, Butler et al. 2009, Gregory and van Strein 2010). A number of motivations may inform selection of indicator species, such as concern for conservation of rare or endangered species, the desire to enhance ecological resilience and the desire to promote biological control of pest species (Chapter 4, Duelli and Obrist 2003). While the selection of indicator species is therefore largely contingent upon the degree to which indicators effectively represent wider diversity, the personal and professional goals of stakeholders and the value systems in which they are rooted warrant consideration (Chapter 1, Halberg 1999, Duelli and Obrist 2003, Maegli et al. 2007).

Farmland sustainability requires an integrated approach involving the disciplines of ecology, sociology and agroecosystems (MacLeod et al. 2008). It is imperative that efforts to select appropriate indicators of agroecosystem health and biodiversity seek to strike a balance between both scientific and human components of socio-ecological farm systems (Chapter 1). Chapter 1 introduced the concept of a Market Flagship Species, an agroecosystem surrogate that is derived from both ecological data describing associations

with wider agroecosystem health and biodiversity, and social research on farmer perceptions of indicator species. The Market Flagship Species conceptual model was used to guide the investigation of associations between native and introduced species richness and habitat type, extent and complexity (Chapter 3). These findings were then related to similar analyses describing associations between the same habitat metrics and the presence or absence of six native and six introduced candidate indicator species (Chapter 4). Chapter 5 began to address the social structure of the Market Flagship model by identifying trends in farmer attitudes and actions toward birds with regard to birds' provision of essential ecosystem services, birds' ability to signal farm environment health, and willingness to participate in a bird-related market accreditation scheme.

This chapter completes exploration of the social structure of the Market Flagship Species model as it pertains to the farmer realm. This is accomplished through a qualitative approach that describes New Zealand sheep/beef farmers' recognition of native and introduced species that occur on their farms and farmer perceptions of the social, ecological and economic costs and benefits to the presence of various bird species on their farms.

The discussion of this chapter first revisits the ecological predictions presented in Chapters 3 and 4, and establishes linkages to results from this chapter and Chapter 5. Findings from all chapters are then integrated into a final analysis that threads a subset of 'best-case' Market Flagship Species (Bellbird *Anthornis melanura* , Grey Warbler *Gerygone igata*, Goldfinch *Carduelis carduelis*, Yellowhammer *Emberiza citrinell*) through the conceptual model described in Chapter 1. Finally, synthesized findings are discussed in relation to the establishment of accreditation schemes based on Market Flagship Species. Particular emphasis is placed on management actions that may be undertaken to enhance abundance of Market Flagship Species and ultimately inform audits of associated accreditation schemes. Taken in its entirety, this thesis demonstrates a clear and effective method to guide the development of audit systems structured around ecologically and culturally relevant criteria. Though discussed within the context of the New Zealand sheep/beef sector, the described model is equally applicable to countries like Australia, the U.S. and Canada, where market institutions are key drivers behind measures to enhance agricultural sustainability.

Methods

Birds as surrogates for biodiversity and human attitudes

Based on the rationale described in Chapter 1 and Chapters 3-5, birds were used as proxies for wider agroecosystem diversity in semi-structured sit-down interviews with farmers from the 12 ARGOS-participating farms on which fieldwork was conducted (Chapters 3 and 4). Interviews were conducted in accordance with previous ARGOS social research methods by an interviewer experienced in qualitative methods (Chapter 5, Hunt et al. 2006). Briefly, in conjunction with the bird survey field circuit conducted in February 2008, interviews were conducted with individuals and couples that either owned or were responsible for farm management of each study farm. During interviews, farmers were shown colour plates of 40 native and introduced bird species that might occur on their farms (Table 6.1). No information regarding species name, distribution or whether a species was native or introduced was given. Farmers were asked to identify as many species as possible, whether identified species were native or introduced, and which species occurred on their farms. Following the species identification exercise, farmers were asked to discuss their perceptions of birds as components of the agroecosystem with regard to contributions to the farm operation, intrinsic value, and as pests. Finally, farmers were asked to discuss willingness and current efforts to enhance bird diversity on their farms as well as potential avenues through which bird diversity could be enhanced, with particular emphasis of the potential efficacy of market accreditation schemes and audit systems.

Interviews were transcribed and coded using NVivo software (QSR International 2010). During the coding process, blocks of text were coded according to emergent themes in the data. Codes were often constructed in a hierarchical fashion using a tree node structure. For example, blocks referencing positive or negative comments regarding either native or introduced species were coded under a general "attitude toward birds" node, followed by subsequent "native," "introduced," and specific species branches. Often the text query function was used to perform key word searches that informed coding of text blocks for primary concepts of interest. The text associated with a given code was not necessarily found only at the point where the question was asked in the interview. Rather, responses to relevant questions may have arisen in comments throughout the interview. Following the coding exercise, the text that had been assigned to a particular code was printed out, read through and put through another categorization process.

Table 6.1 Identification of native and introduced bird species by farmers pooled across farms, recorded presence of each species during 5-minute point count surveys on each farm and percent difference between farmer-reported values and field measurements.* Denotes a candidate indicator species. Emboldened cases indicate species identified by all interviewed farmers.

Species	Native/ Introduced	Proportion of farmers identifying species presence	Proportion of farms species recorded on	% Difference
Mallard Duck	Introduced	0.83	0.08	-0.75
White-faced Heron	Native	0.75	0.08	-0.67
Little Owl	Introduced	0.75	0.17	-0.58
Pukeko	Native	0.58	0.08	-0.50
New Zealand Falcon	Native	0.50	0.08	-0.42
California Quail	Introduced	0.50	0.08	-0.42
Morepork	Native	0.33	0.00	-0.33
Canada Goose	Introduced	0.33	0.00	-0.33
Shining Cuckoo	Native	0.33	0.08	-0.25
Welcome Swallow	Native	0.75	0.50	-0.25
Pied Stilt	Native	0.25	0.08	-0.17
Tui	Native	0.58	0.42	-0.17
Bellbird*	**Native**	**1.00**	**1.00**	**0.00**
Wood Pigeon	**Native**	**0.75**	**0.75**	**0.00**
Paradise Shelduck	Native	0.83	0.92	0.08
Rock Pigeon	Introduced	0.83	0.92	0.08
White Heron	Native	0.08	0.17	0.08
Oystercatcher	Native	0.75	0.83	0.08
Spur-Winged Plover	Native	0.92	1.00	0.08
Blackbird*	Introduced	0.92	1.00	0.08
Magpie	Introduced	0.92	1.00	0.08
Starling*	Introduced	0.92	1.00	0.08
Australasian Harrier	Native	0.83	1.00	0.17
Black-backed Gull	Native	0.83	1.00	0.17
Fantail*	Native	0.75	0.92	0.17
Goldfinch*	Introduced	0.83	1.00	0.17
House Sparrow	Introduced	0.83	1.00	0.17
Song Thrush	Introduced	0.83	1.00	0.17
Silvereye*	Native	0.75	1.00	0.25
Tomtit*	Native	0.25	0.50	0.25
Redpoll*	Introduced	0.67	1.00	0.33
Skylark	Introduced	0.67	1.00	0.33
Yellowhammer*	Introduced	0.67	1.00	0.33
Greenfinch	Introduced	0.58	1.00	0.42
Brown Creeper	Native	0.08	0.50	0.42
Red-billed Gull	Native	0.50	1.00	0.50
Rifleman*	Native	0.25	0.75	0.50
Chaffinch*	Introduced	0.50	1.00	0.50
Grey Warbler*	Introduced	0.42	1.00	0.58
Dunnock	Introduced	0.42	1.00	0.58

The matrix coding query function was used to tabulate the frequency with which farmers identified different bird species at both the farm and panel level. Due to the small sample size from which interview data were generated (n=12), statistical analyses examining differences in attitudes and actions toward birds between farms and panels was not feasible. Instead, farmer attitudes and actions toward birds and avenues through which bird diversity might be enhanced on their farms were compared using descriptive statistics and cross-tabulation tables. Associated research examining farmers' perceptions of birds using a Likert-based questionnaire suggests sociodemographic factors do not predict New Zealand sheep/beef farmers' attitudes and actions regarding bird conservation on their lands, nor do they predict farmers' willingness to participate in potential biodiversity-based market accreditation schemes (see Chapter 3 for more detail). As ARGOS farmers interviewed for the present study similarly completed the questionnaire, interview coding as not structured with regard to any socioeconomic data. Ecological data from parallel research (see Chapters 1 and 2) were paired with interview findings to identify areas of overlap and disparity between scientific measures of diversity and self-reported diversity from farmers.

Results

Farmer recognition of bird species

Because interview data were represented by 12 farms, representing four conventional, four IM and four organic farms, sample sizes were too low to make firm inferences with regard to panel. Consequently, interpretaton of results with regard to panel effects should remain cautious.

Of the 12 candidate indicator species, the Bellbird, Blackbird *Turdus merula* and Starling *Sturnus vulgaris* were the most recognized species when pooling across panels (Table 6.2). Overall, introduced species were more frequently recognized than native species. The Bellbird was the only species identified by all interviewed farmers; The Dunnock *Prunella modularis* was the least-reported introduced species and the Rifleman was the least-reported native species. The Bellbird and New Zealand Pigeon *Hemiphaga novaeseelandiae spadicea* were the only species for which the proportion of farms identifying the species as present were equivalent to field measures of species presence. The largest discrepancies between farmer-reported presence and field measurements chiefly fit within four distinct categories: 1) Primarily open-paddock or wetland species (e.g. Mallard *Anasplatyrhynchos*, Pukeko *Porphyrio porphyrio melanotus*, White-faced

Heron *Egretta novaehollandiae* 2) Nocturnal species (Morepork *Ninox novaeseelandiae novaesellandiae* and Little Owl *Athene noctua*), 3) Locally uncommon native species (e.g. Shining Cuckoo *Chrysococcyx lucidus lucidus* and Tui *Prosthemadera novaeseelandiae novaeseelandiae*) and 4) Small, often drab passerines (e.g. Grey Warbler, Chaffinch *Fringilla coelebs*). The latter category was the only for which field measurements of birds were greater than self-reported farmer data. Of the 17 introduced and 23 native bird species presented to farmers on color plates, farmers typically identified a greater proportion of introduced species than native, irrespective of panel (Table 6.2). Mean proportion of native and introduced species recognized by organic and conventional farmers was higher than that of IM farmers. Again, caution should be used in interpreting this trend as the sample size greatly limits explanatory power.

Table 6.2 Proportion of native and introduced bird species recognized from colour plates by ARGOS farmers from organic, IM and conventional management systems (panels).

	Native			**Introduced**		
Panel	**Min**	**Mean**	**Max**	**Min**	**Mean**	**Max**
Organic	0.39	0.63	0.78	0.65	0.78	0.88
IM	0.35	0.48	0.61	0.47	0.59	0.82
Conventional	0.52	0.60	0.65	0.53	0.75	0.94

Benefits to birds on farm

The aesthetic value associated with native species and the function of birds as sentinels of overall agroecosystem health were cited as the most beneficial aspects to the presence of birds on farms (Table 6.3). Control of invertebrate pest species by birds was also referenced by most farmers as an advantage to farmland bird presence. The aesthetic value placed on introduced bird species was referenced in interviews, but by less than half of farmers (Table 6.3). Within interviews there was an evident dichotomy between how farmers perceived and valued native and introduced species. Native species, such as Bellbirds and Tuis were regarded as highly charismatic and discussed nearly entirely in terms of intrinsic value:

> *When we have Tuis and Bellbirds…everyone will stop and watch them. I'm thinking I have no idea of whether they're beneficial or anything, but they're just eye-catching and the appeal of watching this little bird going about its business is really special.*

By contrast, introduced species, like the Starling were valued predominantly in terms of provision of ecosystem services that directly benefited farm production:

> *The Starling. We have lots and lots of those in big, big flocks. Down in this laneway, we've got quite a few nesting boxes for them. They're treated very much as a friendly animal as far as your grass grubs and those sorts of things go.*

> *There's a rookery of Starlings that nest over in the blue gums up there. And they obviously clean up all the grass grubs. There's huge flocks of them you see swarming around the place. And obviously I'd think we'd get a fringe benefit off it – eating the grubs closest to where they roost.*

Personal efforts undertaken to encourage birds on farms most often included fencing off of bush and planting of native trees, though several farmers also engaged in some form of control of mammalian predators (Table 6.3)

Table 6.3 Tabulation of farmer comments regarding beneficial aspects of bird presence on farms and actions taken to encourage birds. Results are shown as number of farmers within each panel expressing each attitude or action.

	Organic	**IM**	**Conventional**	**Pooled**
Benefits to birds on farm				
Aesthetic value of native species	3	3	4	10
Indicators of agroecosystem health	3	4	3	10
Pest control	3	3	2	8
Aesthetic value of introduced species	1	2	2	5
Ecotourism	2	0	1	3
Pollination	1	1	1	3
Actions to encourage birds on farm				
Fencing off bush	4	1	4	9
Planting native trees	2	2	3	7
Predator control	2	2	1	5
Making farm compliant with market accreditation standards	2	0	2	4
Supplementary feeding	2	0	2	4
Planting shelterbelts and other non-native vegetation	1	2	0	3
Placing land in conservation covenant	1	0	1	2
Installing nesting boxes	0	1	0	1
Protecting nesting sites	0	1	0	1

Drawbacks to birds on farm

Damaging or killing livestock and dirtying farm buildings and machinery were the most cited negative activities associated with bird presence on farms (Table 6.4). Farmers were most likely to shoot birds perceived as pest species relative to other methods of control (Table 6.4).

Table 6.4 Tabulation of farmer comments regarding negative aspects of bird presence on farms and actions taken to control or discourage birds. Results are shown as number of farmers within each panel expressing each attitude or action.

	Organic	IM	Conventional	Pooled
Drawbacks to birds on farm				
Damage or kill livestock	3	4	1	8
Make buildings and machinery dirty	2	4	2	8
Chase or bully other birds	2	1	2	5
Consume crops or animal feed	1	3	1	5
Chase/attack people	1	1	1	3
Damage or eat fruit in garden	1	1	1	3
Spread disease	1	0	1	2
Actions to control or discourage birds				
Shooting	2	1	2	5
Trapping	1	2	0	3
Poisoning	0	0	2	2
Breaking Eggs	0	1	0	1

Although several farmers pointed to damage incurred by birds, particularly in terms of crop loss, this sentiment was often tempered by an understanding that damage was relatively small and often temporally limited:

> *But for me, growing crop, you actually be surprised at how much they peel off. But it's a small price to pay. They get it pretty tough the rest of the year, but they certainly get their tonnage. Especially next to plantations or anything… You've still got to have them. You can't just have your cropping season and say, "Right-o birds, bugger off now."*

The Starling, a species revered by some farmers for its role in controlling pest invertebrates was considered a nuisance that dirtied farm structures and machinery by other farmers:

They [Starlings] are a bloody nuisance. They're actually quite dangerous because they do nest in the trucks and the motor heats and we have to leave the bonnets up so they don't nest in there.

I don't like Starlings. They're a big nuisance. They nest in the tractors and can cause fires and that. They get into the buildings. They're the next on the hit list after Magpies, I'd say.

Farmers' perception of self as land steward and avenues to bird conservation

Whilst organic farmers referenced the importance of serving as custodians of the land, and conventional farmers pointed to succession and the importance of preserving areas of native bush associated with spiritual significance, no IM farmers commented on their role as stewards or custodians of their land (Table 6.5). Particular affinity was expressed for areas of native bush patches:

It really is special. I mean, it is gorgeous to walk through. It's nice having that big, traditional, original bush.

We muster through about a half dozen times a year, so we get down through the bush …I'll just make an excuse to sit down there for 10 minutes. It's always great for the fantails. I'll often take the kids or other families down, because it's just a special place. It's one of the few places left in New Zealand where you have podocarp right there on the cliff edge. And that's treated as a special place.

Irrespective of panel, most farmers agreed that they do have a responsibility to encourage birds on their farms, although several expressed reservation that farmers should not shoulder sole responsibility for all New Zealanders (Table 6.5). Financial constraint was the principal hindrance to farmers encouraging bird diversity on their farms (Table 6.5). When asked to elaborate on this concept, most farmers expressed a strong desire to engage in bird-friendly management, but emphasized that the economics of farm operations were a powerful limiting factor:

I think most farmers do [have a responsibility to encourage birds], to a degree. You know, it's a balance. Not absolutely carte blanche, I think. The economy – looking after the farm would probably come first, but it does fit into the equation there.

So when you're saying there's a responsibility – 'cause one of my catch cries is that conservation costs money – we can have native birds and listen to them and have the bush back. That's costing someone some dough. Whether they're fencing off bush or keeping possums out of it. But when there's a responsibility for looking after birds, your Forest and Bird and DoC are going to be in there smiling and saying, "Yes, it's a great idea," but when it's a farm which is not doing very well financially, and that's right across the board, and then you're lumbering on a responsibility for looking after birds. Well, hang on a minute there, guys. We've got to meet somewhere on this.

It's expenditure above normal expenditure. You know, if you're making – if you're doing quite well and you've got money to spend, it's the sort of thing you'd do. Just for the sake of protecting the birds, I think that would be an expense you didn't need. If times were more economic, I think you'd be more likely to do that.

Attitudes regarding environmentally- and biodiversity-based market accreditation systems varied, though most farmers expressed the main impetus behind such systems was a consumer desire for farm products produced via environmentally sustainable means (Table 6.5). :

We are aiming at providing a story on our environment, our sustainability, our organic status. All those things, so that when people go to Whole Foods in America and buy our lamb, it's like a bottle of French wine. It goes with the story. And the story is just about as much as the photographs of the family; photographs of the livestock; photographs of the sea, of the bush. And that is commercial, but it's also protecting the environment, isn't it?

New Zealand's marketing of its produced overseas is like that – you see clean, green images, which is a good marketing ploy. They do want to know that the farms are – that the animals are grass-fed in a nice environment.

Table 6.5 Tabulation of farmer comments regarding perceived responsibility to act as stewards for their farms, encourage birds, constraints to encouraging birds and perceptions of environmentally- or biodiversity-driven market accreditation schemes. Results are shown as number of farmers within each panel expressing each attitude or action.

	Organic	IM	Conventional	Pooled
Role as land steward				
Succession - Farm environment must be cared for future generations	1	0	2	3
Farmers should be custodians of the land	2	0	0	2
Preserving native bush equates to preserving special/spiritual place	0	0	2	2
Responsibility to encourage birds				
Farmers absolutely have a responsibility to encourage birds on their farms	2	1	2	5
Farmers should encourage birds on their farms, but should not bear the cost for all New Zealand	0	2	2	4
Farmers have no responsibility to encourage birds on their farms	1	1	0	2
Constraints to encouraging birds				
Lack of funds	3	3	3	9
Reliance on pesticides and chemicals for production	2	3	2	7
Lack of education of bird ecology and life history	2	3	0	5
Cannot use land for production or other development	0	1	1	2
Perceptions of environmentally- and biodiversity-based market accreditation systems				
Driven by consumers concerned with sustainability and healthy farm environments	4	2	1	7
Driven by consumers concerned with food safety and quality	2	0	1	3
Driven by consumers concerned with animal welfare	1	0	1	2
Accreditation systems are a tool for excluding New Zealand farmers from key export markets	0	2	0	2
Do not think consumers would pay premium for bird friendly product	0	0	1	1

Discussion

Meeting ecological criteria of the Market Flagship Species Model

(1) Quantifiable linkages to character being indicated

The first and most important criterion for selection of a Market Flagship Species is that it must exhibit a quantifiable relationship to the habitat or species population character it purports to represent (Chapter 1). Rather than seeking a direct correlation between the presence of a given candidate indicator species and overall species richness, the research described in the preceding chapters followed a two-pronged comparative approach that simultaneously predicted (i) associations between native and introduced species richness and habitat characters (Chapter 3) and (ii) associations between the same habitat characters and the presence or absence individual native and introduced candidate indicator species (Chapter 4). Native species richness was found to be positively associated with patch area and native tree habitat (Chapter 3). This finding was also evident at the single-species level for the Bellbird and Grey Warbler (Chapter 4). Based on their ability to meet the crucial first ecological criterion, the Bellbird and Grey Warbler are appropriate sub-candidates with which to examine the efficacy of the Market Flagship Species model.

The identification of introduced species to thread through the model framework, however, is less straightforward. No significant relationships were identified between introduced species richness and habitat type or habitat size and shape metrics (Chapter 3). Of the six candidate species, a few were significantly associated with any habitat parameters: Yellowhammer presence was positively related to area and mixed native tree habitat, Manuka/Kanuka habitat and shrubland; and Goldfinch presence was similarly characterized by significant area and native habitat relationships (Chapter 4). The Goldfinch and Yellowhammer thus present themselves as the best introduced candidate species with which to gauge the effectiveness of the model.

(2) Abundance and geographic distribution

The second level within the Market Flagship Species hierarchy most importantly discourages the adoption of rare species indicators, as these species may be difficult to monitor and of no explanatory power within areas extraneous to their established geographic ranges (Bibby 1999, Favreau et al. 2006**)**. Although it is specified that species that are common or of intermediate geographic distribution should be given preference over species that are abundant and ubiquitous, it should be noted that this level represents the most malleable of ecological criteria and should serve as a guide, rather than a hard and

fast rule for the acceptance or rejection of a candidate species. Although both the Bellbird and Grey Warbler are considered abundant throughout New Zealand, both are less common than most sympatric introduced species (Robertson et al. 2007). Further, their tight association with native habitat, and by proxy, potential to serve as indices of native species richness (Chapters 3 and 4) far outweighs value associated with more restricted distributions.

Both the Yellowhammer and Goldfinch are considered abundant species throughout New Zealand. Indeed, this is the case for the majority of introduced species recorded on study farms (Robertson et al. 2007), and likely to hold true for the selection of many introduced candidate species. Following the same logic described for the Bellbird and Grey Warbler, the Yellowhammer and Goldfinch should proceed through the model hierarchy.

(3) Habitat/feeding ecology specialization

The last purely ecological criterion proposed for selection of a Market Flagship Species states that species that have a unique feeding ecology or are regarded as habitat specialists should be chosen over generalist species. The crux of this criterion is that specialist species will be more likely to respond to changes in the environment, which may affect populations directly through removal of breeding habitat or plant food resources, or indirectly, through decreases in abundance of prey species (Newton 2004, Wilson et al. 2005, Favreau et al. 2006**).** Both the Bellbird and Grey Warbler aptly fit this rule. The Grey Warbler is insectivorous, and as such its abundance may be reflective of richness and abundance of invertebrate species (Sotherton and Self 2000, Benton et al. 2002, Iwata et al. 2003). Bellbirds are omnivorous, but as members of the honeyeater guild, are often reliant upon the presence of native flowers and fruit species in their diet (Warburton et al. 1992). As with the previous tier, there is a degree of flexibility with regard to this criterion, and the lack of a specialist candidate species should not rule out the progression of a generalist through the hierarchy.

Both the Goldfinch and Yellowhammer are generalist foragers, as are most introduced species found on New Zealand production lands. Though not ideal, there is insufficient cause to preclude the progression of either species through the hierarchy.

(4) Realistic to measure and audit

All of the aforementioned ecological descriptors are of little use if candidate species are unable to be easily and economically measured and audited. Regardless of agreement with described ecological criteria, nocturnal or cryptic species, or species within

inaccessible habitats would be too difficult and inconvenient to monitor on a regular basis (Bibby 1999). Both the Bellbird and Grey Warbler produce loud and distinct calls that would serve to facilitate, rather than hinder, monitoring efforts. However, although not explicitly cryptic, the small size and drab appearance of the Grey Warbler may make it more difficult to identify in the field, and thus potentially problematic to audit. Even when taking this into account, previous ecological criteria suggest that both the Bellbird and Grey Warbler have sufficient ecological backing to progress into the social strata of the model.

The Yellowhammer and Goldfinch similarly exhibit neither behavioral traits nor habitat associations that would preclude progression through the social hierarchy of the model.

Meeting social criteria of the Market Flagship Species Model

(1) Identified by farmer and (2) able to guide management

While the first two tiers within the social component of the Market Flagship Species model are seemingly self-evident, it is of great importance that farmers are able to identify candidate species on their farms. The ability to identify indicator species is of particular relevance for any systems that would require farmers to commit to management plans and targets and contribute to monitoring efforts (Bibby 1999). Farmers interviewed for the present study identified a greater proportion of introduced species compared to native species. Although organic farmers identified more species than either IM or conventional farmers, the difference between the three panels was slight. Using a survey study instrument, Jacobson et al. (2003) found the majority of surveyed vegetable and row crop farmers in Florida, U.S.A. reported recognizing most birds on their farms, but that organic farmers reported having more species on their farms than conventional farmers. Because these numbers were self-reported, however, it is unclear whether discrepancies between panels was a function of true differences in bird diversity between panels, a greater understanding of non-production ecology on behalf of organic farmers, or an interaction of the two. Farmers interviewed for the present research were asked to identify birds from color plates that included the majority of common and rare species potentially occurring on sheep/beef farms. Presenting interviewed farmers with identical information, rather than relying upon each individual to independently recall and report the exact number of species occurring on their farms, likely alleviated bias associated with self-reporting of species presence.

The disparity in the proportion of introduced and native species identified by farmers may reflect the frequency with which farmers encounter species from each group during daily farm operations. No concrete associations between introduced species richness and habitat were identified for the 12 farms upon which all ecological and sociological analyses of the present research were based (Chapters 3 and 4). This suggests many introduced species are ubiquitous in distribution and likely to be observed by farmers conducting daily farming activities. By contrast, native species were strongly associated with large, native habitat patches (Chapters 3 and 4). These areas are, for the most part, exempt from production and thus species residing primarily within them are less likely to be encountered (Chapters 3 and 4).

Although interviewed farmers tended to recognize a greater number of introduced species than native bird species on their farms, the Bellbird was the most widely recognized species. Additionally, the Bellbird was the only candidate indicator of either native or introduced sets identified by all farmers. Despite the fact that Grey Warblers were recorded on all surveyed farms (Chapters 3 and 4), less than half of interviewed farmers were able to identify the Grey Warbler from color plates. Based on farmer perceptions, the advancement of the Bellbird through the Market Flagship Species model is strongly supported. Rather than abandon the Grey Warbler as a candidate species, it should perhaps be retained as an alternate, should the Bellbird fail to meet a key social criterion.

Most interviewed farmers identified both the Yellowhammer and Goldfinch from color plates, though the Goldfinch was more widely recognized. Both species are characterized by bright plumage and often occur within open paddocks (Blackwell et al. 2005, MacLeod et al. 2005*b*, Gregory and Van Strien 2010). This conspicuousness and presence within components of the agricultural matrix directly associated with production may imbue both species with great potential to guide management.

(3) Intrinsic/production value of candidate species

The final step within the farmer hierarchy of the model emphasizes the importance of the value farmers place on species occurring on their lands, may be of understated importance. Results presented in this chapter and Chapter 5 identify a dichotomy between how farmers regard native and introduced species on their farms. Farmer attitudes toward native species were almost exclusively positive, with the majority of volunteered commentary centering on the intrinsic and aesthetic value of native species. Introduced species, by contrast, were often discussed as they pertained to day-to-day

management of the farm operation. If a species was perceived to supply an agroecosystem service, such as control of invertebrate pest species, it was regarded fondly. Conversely, if a species was perceived to cause damage to farm structures or machinery, it was perceived negatively. In the case of the Starling, both attitudes applied. Emergent audit systems must be mindful of the dichotomy in farmer attitudes regarding native and introduced species. Selection of contentious species, such as the Starling, may be met with skepticism by farmers and undermine audit-based efforts to encourage biodiversity-friendly farming practices.

Many interviewed farmers expressed an affinity for the Bellbird and included it among self-reported lists of charismatic species. However, no commentary was volunteered with to the Grey Warbler, providing further evidence that it may be a poor candidate to serve as a Market Flagship Species. Of the initial six proposed native candidate indicator species, the Bellbird is the singular species that adequately meets all social and ecological criteria investigated over the course of the preceding five chapters: it shows a strong association with native habitat, which in turn is associated with high native species richness; it is sufficiently abundant to be a relevant indicator throughout a broad geographic range; it possesses a unique feeding ecology that may make it more sensitive to environmental change than generalist species; it possesses a loud, unique call that makes it easy to identify on the landscape and subsequently audit; and it is readily identified by farmers who almost universally associate it with high intrinsic value.

Interviewed farmers offered neither positive nor negative commentary with regard to either the Yellowhammer or Goldfinch. Should these species be given serious consideration to serve as indicators, market-based or otherwise, this relationship would require further investigation. Additionally, support from ecological components of the hierarchy for both species is tenuous, and further research that directs specific focus toward each species' utilization of various components of the agriculture land matrix is needed before either can progress safely through the social structure.

Consumer choice

The research presented in this and preceding chapters was confined to analysis at the farm scale, and included no formal analysis of consumer perceptions of indicator species, either within New Zealand or abroad. This points to a large and extremely important research gap. The described research has demonstrated the navigation of both native and introduced species through the Market Flagship Species hierarchy with respect to all ecological criteria and all criteria nested within the farmer hierarchy of the model.

Consumer preference will serve as the ultimate litmus test of the efficacy of a Market Flagship Species to signal biodiversity care, and reflexively influence the value farmers place on any such species (Chapter 1). Accordingly, there is a critical need for research examining consumer valuation of potential Market Flagship Species. Whether consumers in key niche markets abroad exhibit preference for products tied to native versus introduced species indicators is a key unknown. While the inclusion of introduced species in accreditation schemes may resonate with consumers abroad, attaching a native New Zealand species to such schemes may reinforce New Zealand's 'clean green' image and serve as an equally-compelling motivation to purchase a certified product. While there are presently accreditation schemes in place overseas that signal environment and wildlife care (GlobalG.A.P. 2010, L.E.A.F. 2010), corresponding systems within New Zealand are predominantly nascent. Recent trials of a 'green tick' label that certified agricultural products as originating from environmentally sustainable practices suggest that, like their European counterparts, consumers in New Zealand and Australia often opt to purchase certified sustainable products in preference to others, provided that the products are well-labeled and marketed (Harris 2007). The role of specifically native species to signal biodiversity care within these markets also warrants further study.

Conservation and management implications

Market Flagship Species are of little actual value unless they are attached to accreditation schemes that promote positive changes in management of non-production species at the farm scale. When considered in conjunction with a possible area effect, the patent positive relationship between native species richness and native vegetation suggests that the most obvious route to encourage native biodiversity on New Zealand sheep/beef farms would be to plant or protect large areas of native bush. The findings presented in Chapter 3 indicate that small slivers of native vegetation are not nearly as effective in supporting native species as are large patches. Moreover, these findings intimate that the highly visible woody shelterbelts predominating in most South Island sheep/beef farms are virtually useless for supporting native birds, even though other studies have underscored their potential value for native invertebrates and ecosystem services in adjacent paddocks (McLachlan and Wratten 2003, Fukuda et al. in review). Given that socio-economic factors invariably dominate farm ecological management, the implementation of such strategies may be unfeasible, in many, if not the majority of instances. It appears that for native species, conventional efforts to enhance species richness by enhancing the margins of shelterbelts and gullies with woody vegetation may be insufficient to effect positive bird

community changes. As the surrounding land matrix greatly influences native species richness within production landscapes, future focus should perhaps be placed on the relationship between individual farm patches and the wider landscape. There is currently a pressing need for more research investigating the metapopulation dynamics of native bird species within agroecosystems, particularly with regard to reproduction and movement between farm patches and adjacent native forest habitats that may be in public ownership.

If recreating large native patches of woody vegetation within farms is generally unfeasible, the alternatives for protecting and restoring native biota in production landscapes will depend on instigation of a range of strategies for much more active management of biodiversity in other ways. Enrichment planting within existing shelterbelts and riparian zones are potential examples. Control of mammalian predators could serve to increase native species abundance through increased brood survival and decreased adult mortality, but the efficacy of investments in predator control to increase avian biodiversity and abundance on production landscapes in New Zealand remains largely unstudied (Moller et al. 2008*b*, Weller in press).

Conversely, introduced species may greatly benefit from the enhancement of field margins and shelterbelts, as supported by equivalent efforts in Great Britain. (Woodhouse et al. 2005, Marshall et al. 2005, 2006). The hint of a possible panel effect for introduced species richness implies that introduced species might be less responsive than native species to the application of chemicals and fertilizers and better able to exploit food resources in habitat patches bordering pastures where chemicals and fertilizers are applied. While introduced species richness may not be indicative of habitat suitability for native species, panel differences in introduced species richness may highlight the efficacy of introduced species to serve as indicators of agroecosystem health and sustainability. This potential relationship warrants further attention. Specifically, introduced species richness should be measured with simultaneous consideration of efforts to enhance field margins bounding habitat patches and chemical and fertilizer use on the surrounding matrix. These species may be of further value in monitoring schemes because their seeming lack of preference for specific habitat types and presence along habitat edges makes them amenable to data collection and monitoring.

Social considerations

(1) Economic constraint and perceptions of market accreditation systems

Several interviewed farmers indicated that while they would like to take action to conserve biodiversity on their lands, the financial cost associated with conservation

measures prohibited them from doing so. Sheep/beef farmers have indicated that they could be willing to incorporate audit standards into their management if doing so commands a premium price for their farm products (Rosin et al. 2007). Interviewed farmers were acutely aware of increasing consumer demand for products deemed environmentally sustainable, and acknowledged market accreditation as a likely driver behind future conservation actions on their lands. Involvement of farmers in the development of these systems is of great importance, as mandatory environmental initiatives imposed by processors or external bodies can lead farmers to feel their autonomy in managing their lands has been compromised (Ahnstrom et al. 2008, Rosin 2008). Accordingly, willingness of farmers to adopt conservation strategies is often related to their degree of involvement in development of management initiatives, and greatest success is achieved when local knowledge claims are accommodated and used to inform practice (Harrison and Burgess 2000, Ahnstrom et al. 2008, Defrancesco et al. 2008, Dutton et al. 2008, Greiner et al. 2009). Additionally, the involvement of stakeholders in the development of conservation protocols can serve to reinforce a sense of stewardship in farmers and instill a sense of personal gratification and accomplishment (Wilson and Hart 2001, Ryan et al. 2003, Smalshire et al. 2004).

(2) Farmers as land stewards and self-motivated conservation measures

The reliance of farmers' livelihood upon the continued ability of their land to produce has resulted in their recurrent characterization as individuals who, by necessity, have a deep understanding and appreciation of their land and the natural cycles and ecological process upon which production depends (Sullivan et al. 1996, McCann et al. 1997). This close association with the land, particularly over successive generations, can instill a sense of stewardship (Westmacot 1983, Sullivan et al. 1996, Ahnstrom et al. 2008). However, the objectives of production and stewardship or conservation are often at odds with one another, and production always takes priority over efforts to conserve or protect non-production flora and fauna (Curtis and DeLacy 1998, Ahnstrom et al. 2009, Greiner et al. 2009). Buttel (1981) argued that agroecosystem environmentalism was not a singular construct with a uniformity of antecedents. This theme has persisted over the last three decades, with correlates of farmer proenvironmental attitudes and behaviors pointing to a myriad of geographic and socioeconomic predictors (Sullivan et al. 1996, McCann et al. 1997, Ahnstrom et al. 2008). Within New Zealand, there appear to be few specific correlates to or qualitative predictors of proenvironmental attitudes in farmers (Fairweather and Campbell 2003, Hunt et al. 2006, Fairweather et al. 2009*b*), although recent research

has pointed to a pro-environmental orientation among a sect New Zealand sheep/beef farmers (Fairweather et al. 2009*b*). This orientation, supported by the findings of this chapter and Chapter 5, points to a population of individuals amenable to the adoption of biodiversity-dependent accreditation schemes. Fairweather et al. (2009*b*) posited that proenvironmental attitudes of New Zealand sheep/beef farmers was linked to their greater exposure to existing best-practice audit systems. This specific demographic may therefore point to the best sector with which to trial and ultimately establish a biodiversity-based accreditation scheme.

If the goal of enhancing biodiversity of non-production species within New Zealand's agricultural landscapes is to be realized, an integrated approach that involves the disciplines of ecology, sociology and economics is required. All research must remain mindful of the farm as a socio-ecological entity. The current lack of transdisciplinarity in addressing pertinent questions regarding agricultural sustainability and care of species and ecological processes not directly related to production is troubling. While efforts to direct farm management in the absence of ecological data are ill-advised and disquieting, so too are attempts at ecological research in a social vacuum. Though of great scientific value, ecological research within agroecosystems is of limited practical utility unless it is able to guide farm management toward a more sustainable end. The research detailed over the previous six chapters represents a rare attempt to pair ecological and sociological research in addressing a question that is likely to be of increasing importance as New Zealand farmers experience continued pressure from overseas markets to adhere to sustainability standards set by consumers. The described research was conducted within New Zealand's sheep/beef sector. However, the Market Flagship Species model and sampling methods developed may be broadly applied to any number of sectors, and guide development off market-based biodiversity-friendly farming systems within Europe, the U.S. and Australia

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Appendix

Table A1 Explanatory variables, significance levels for full binomial models using presence/absence of any native species, any introduced species, and individual candidate indicator species as response variables. Predicted means (for median patch size) are for reduced binomial models, which excluded patch complexity terms (shape index, fractal dimension, perimeter area ratio). Individual species models depicted are only those for which convergence was achieved and predicted means were similar to observed means. Emboldened cases show statistical significance at the $p<0.05$ level.

Parameter	Any native	Any intro	Blackbird	Chaffinch	Silvereye	Yellowhammer
Habitat	**<0.001**	**0.005**	0.457	0.119	0.075	0.055
Log_earea	**0.015**	**0.008**	0.894	0.581	0.594	0.149
Season	0.56	0.324	**0.006**	0.441	0.849	0.133
Panel	0.054	0.054	0.651	0.225	**0.039**	0.874
Shape index	0.838	0.494	**0.029**	0.955	0.191	0.171
Fractal dimension	0.809	0.277	0.832	0.883	0.19	0.253
Panel	0.612	0.183	0.279	0.82	0.787	0.959
			Predicted means (reduced model)			
Habitat						
Mixed native trees	0.582	0.723	0.157	0.195	0.168	0.071
Mixed native and exotic trees	0.392	0.782	0.255	0.249	0.061	0.066
Manuka/Kanuka trees	0.568	0.921	0.226	0.178	0.104	0.187
Exotic conifer trees	0.255	0.876	0.189	0.312	0.048	0.105
Shrubland	0.199	0.938	0.172	0.155	0.085	0.196
Season						
Winter	0.433	0.828	0.239	0.184	0.094	0.101
Spring	0.35	0.888	0.225	0.248	0.089	0.093
Summer	0.38	0.877	0.14	0.21	0.076	0.157
Panel						
Organic	0.436	0.836	0.182	0.175	0.144	0.113
IM	0.27	0.911	0.185	0.241	0.075	0.126
Conventional	0.469	0.841	0.228	0.227	0.057	0.104

Appendix 2

Farmer and orchardist survey



New Zealand Farmer and Orchardist Attitude and Opinion Survey:

Change in primary production

Winter, 2008

General instructions:

- Please tick the box or put the number for your best answer in the box provided. In some cases we ask you to write your answer.
- Most of the questions use a seven-point scale. The mid point of the scale (4) represents neutral or neither/nor.
- Please return the questionnaire to John Fairweather, AERU, PO Box 84, Lincoln University, Lincoln, 7647 using the Freepost envelope provided.

A. Farm or Orchard Management System

1. Overall, how would you classify the management system used on your farm or orchard? (Please put the number in the box):

(1) **Conventional management.** (Does not use modifications to conventional practice, nor is certified as organic, but can still aspire to best practice)

(2) **Modified conventional management.** (Integrated Management). (Accepts some constraints on inputs in order to improve environmental outcomes and to better meet market demand. These systems are also called Environmental Management Systems, usually have their own name, e.g., KiwiGreen, and are not necessarily called integrated management. We do not mean integrating your farm production practices or types of land use.)

(3) **Organic management**. (Registered or certified as officially organic or in transition to organic) ☐

(4) **Other**, please specify _____

2. Assume you continue in farming: within the next ten years, how strong is your intention to use **each** of the following:
(Please rate each management system using the following range.)

Very strong intention not to use	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Very strong intention to use**

Conventional management	
Modified conventional management	
Organic management (registered)	
Organic methods (not registered)	
Genetically modified plants or animals, if they become available	

B. Indicators

1. What is the importance to you of **each** of the following measures when you are considering the **annual financial** performance of your farm/orchard?

Very Unimportant	1	2	3	4	5	6	7	Very Important

Gross income	
Working expenses	
Change in bank balance over the year	
Actual income versus budget income	
Cash surplus/deficit (income minus all cash expenses; the cash available for tax, drawings and reinvestment)	
Net profit/loss (income minus all cash expenses and depreciation; the taxable component of income)	
Changes in equity	
The ratio of working expenses to gross income	
Return on capital	
Money is available to cover cash needs	
I don't monitor financial performance because it just follows on from physical management	
Other, please specify _____	

2. What is the importance to you of **each** of the following measures when you are considering the **production** performance of your farm/orchard?

Very Unimportant	1	2	3	4	5	6	7	Very Important

The health of stock and/or plants	
Yields per hectare compared to other similar farmers/orchardists	
The presence of a neat and tidy landscape	
Minimum weeds	
Volume of production is at a maximum	
Quality of production is at a maximum	
The farm/orchard has a good mixture of productive uses/activities	
No potentially productive land is going to waste	
Reducing carbon emissions	
Other, please specify _____	

3. What is the importance to you of **each** of the following measures when you are considering the **environmental** performance of your farm/orchard?

Very Unimportant	1	2	3	4	5	6	7	Very Important

Please use 0 for not applicable

Soil fertility levels	
Soil biological activity	
Soil health	
The health of livestock and/or plants	
The level of biodiversity (the number and type of productive and unproductive species) on my farm/orchard	
The number of native bird species	
The number of all bird species, native and other	
The number of native plant or tree species	
The number of plant or tree species, native and other	
Water quality in nearby streams and waterways	
The presence of both productive and non-productive species flourishing on the farm/orchard	
Water budgeting	
Nutrient budgeting	
Pesticide use	
Energy use	
The amount of carbon stored (sequestered)	
A tidy, well maintained farm/orchard	
Other, please specify _____	

4. What is the importance to you of **each** of the following measures when you are considering the **social** performance of your farm/orchard?

Very Unimportant	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Very Important**

Please use 0 for not applicable

The children are involved in the farm or orchard	
I have enough time to participate in community activities	
I have enough time to devote to family and friends	
I have enough time to participate in activities and recreation off farm	
My farming/orcharding helps me to develop a connection to the place where it is located	
Members of my farm/orchard family will be able to find employment in this area	
My farming/orcharding is able to contribute to local traditions, festivals or customs	
My farm or orchard is contributing to the local community	
My neighbours approve of my farming/orcharding practices	
My farming/orcharding helps to create an attractive place to live	
My neighbours consider me to be a good farmer/orchardist	
My family has a good reputation in the local community	
Farm/orchard workers are treated well	
There is scope for farm succession	
Other, please specify _____	

C. Your approach to management

1. How often do you consider or implement **each** of the following strategies:

Never	1	2	3	4	5	6	7	Always

I adopt proven practices rather than do my own experiments	
I pay close attention to changes in plants /animals/insects on my farm	
I pay close attention to money in the bank and good financial returns from each part of my business	
I pay close attention to what is going on in NZ and in the world	
I focus on a limited number of income sources	
I keep unused resources (e.g., buildings, machines) in case they are needed in the future	
I seldom deviate from established farm plans	
I learn new things by talking with a wide variety of people	

2. How different will your farm or orchard be in ten years from now compared to the present time?

Exactly the same	1	2	3	4	5	6	7	Very different

D. Connections

1. How much do you agree or disagree with **each** of the following relationships?

Very Strongly Disagree	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Very Strongly Agree**
My farm/orchard and my management of it are closely related to the wellbeing of **myself and my family**								
My farm/orchard and my management of it are closely related to the wellbeing of **the local community**								
My farm/orchard and my management of it are closely related to the wellbeing of **the nation and the world**								

2. How much do you agree or disagree with **each** of the following statements?

Very Strongly Disagree	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Very Strongly Agree**
My farm/orchard management affects the environment **primarily within the productive areas of the property**								
My farm/orchard management affects the environment **in the region where my property is located**								
My farm/orchard management affects the environment **on a global scale**								

E. Community participation

1. How involved are you and/or your family in **each** of the following?

Little or no Involvement	1	2	3	4	5	6	7	Heavily Involved

Voting in national elections	
Voting in local body elections	
Submitting comments on local government plans and policy	
School or educational groups e.g., PTA, school committees	
Church groups and/or care agencies	
Sports/athletic/recreational groups	
Civic organisations (e.g., Rotary, Lions)	
Festivals, shows (e.g., A&P)	
Fire service, ambulance, search and rescue	
Providing cash financial support to community activities	
Hospital/medical organisations/trusts	
Other, please specify _____	

2. What is your level of attachment towards the area where you live?

Very Negative Connection	1	2	3	4	5	6	7	Very Positive Connection	

F. Farming factors

1. How important or unimportant to you is **each** of the following?

Very Unimportant	1	2	3	4	5	6	7	Very Important

Customer requirements	
Customer satisfaction	
Family needs	
Farm environment as a place to live	
Farm environmental health	
Future generations/succession	
Off-farm product quality	
Personal satisfaction	
Stream health	
Please tick this box if your farm/orchard does not have streams	

G. Emissions trading

1. How much do you agree or disagree with **each** of the following views about responsibility for reducing greenhouse gas emissions?

Very Strongly disagree	1	2	3	4	5	6	7	Very Strongly agree

New Zealand farmers contribute to climate change and should take responsibility for reducing emissions	
New Zealand farmers should take responsibility only to the same extent as farmers elsewhere	
Within New Zealand, farmers are being asked to assume more than their fair share of responsibility for emissions	
Technological solutions are needed to decrease agricultural greenhouse gas emissions	
Higher market returns will balance the costs of reduction efforts	

H. Bird Diversity and Farm Management

1. How much do you agree or disagree with **each** of the following statements about the diversity **and** abundance of birds, native **and** introduced?

Very Strongly Disagree	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Very Strongly Agree**

	Native birds	**Introduced Birds**
I would not like more birds on my farm		
Farms that have more birds are also more likely to cope with drought and climate stresses		
Birds provide important services on my farm (pollination, pest control, or nutrient cycling)		
It is not my responsibility as a landowner to encourage birds on my farm		
I would be interested in participating in a market accreditation scheme in the form of a "bird tick" that certifies my production as bird friendly		
Some birds cause damage to my farm operation		

If birds are causing damage, please describe how:

_____

_____

2. Do you actively encourage birds on your farm or orchard?

(1) Yes (2) No (3) Unsure

If yes, how do you do this? _____

_____

I. Trees and shrubs

1. How important or unimportant to you is **each** of the following benefits from planting native and exotic trees and shrubs on your farm (not your garden)?

Very Unimportant	1	2	3	4	5	6	7	Very Important

	Native Trees/ shrubs	Exotic Trees/ shrubs
Generating carbon credits		
Increasing native bird diversity and abundance		
Increasing insect diversity and abundance		
Enhancing stream health by planting along riparian zones		
Enhancing shelter for stock or fruit		
Managing erosion		
Making my farm/orchard look attractive		
Providing fodder for stock		
Providing logs/timber		

2. In the last year, approximately how many trees/shrubs have you planted and how many have you removed? Please break into those below 3m and those 3m or taller at maturity, and exclude garden plantings.

	Native below 3m	Native 3m or taller	Exotic below 3m	Exotic 3m or taller
Number planted				
Number removed				
Number which replaced those removed in last 5 years				

J. Background information

1. What is the size of your farm or orchard?

Total hectares: ☐

Effective hectares: ☐

2. What is your predominant farming activity?

(1) Dairy
(2) Sheep/beef/deer
(3) Specialist livestock
(4) Arable or cropping
(5) Horticulture
If kiwifruit, please tick this box ☐
(6) Other please specify, _____

3. For farmers with livestock, we want to calculate your total number of stock units as at June 2008. Please fill out the following table:

Sheep	Number	Cows	Number
Ewes		Max. cows milked	
Hoggets (ewe or wether)		Total milk solids (Kg)	
Other			
		Deer	
Beef		Rising 1 yr hinds	
Rising 1 yr heifers		Rising 2 yr hinds	
Rising 2 yr heifers		M/A hinds	
M/A cows		Rising 1 yr stags	
Rising 1 yr steers/bulls		Rising 2 yr stags and older	
Rising 2 yr steers and older			
Rising 2 yr and older bulls			

4. In which province is your farm located: _____

5. So that we can gauge the size of your farming operation, what was the annual gross revenue (approximate figures) from your farm for the:

2006-07 financial year? Approximate figures only: ☐

2007-08 financial year? Approximate figures only: ☐

6. What is your level of debt at present (approximate)?

(1) Debt is over 80% of equity
(2) Debt is between 60-80% of equity
(3) Debt is between 40-60% of equity
(4) Debt is between 20-40% of equity
(5) Debt is between 0-20% of equity
(6) My farm is debt free
(7) Don't know

☐

7. How satisfied are you with your current level of economic viability?

Very Unsatisfied	1	2	3	4	5	6	7	Very Satisfied

☐

8. For how many years have you managed, owned or been associated with your current farm or orchard? ☐

9. For how many years have you been farming or orcharding? ☐

10. For how many years in the future do you expect to be in farming/orcharding? ☐

11. In ten years time do you think you will still be living in your present community?

(1) Yes (2) No (3) Unsure

12. Are you the:

(1) Farmer (2) Spouse or partner of farmer

13. Please provide the year you were born.

14. Are you: (1) Male (2) Female

15. What is your highest level of education completed?

(1) Attended secondary school

(2) Trade technical qualification or similar

(3) Undergraduate diploma or certificate

(4) University degree

16. What type of farm do you have?

(1) Full-time farm

(2) Part-time farm

(3) Lifestyle or hobby farm

(1) Corporate farm

(2) Family farm

Thank you for giving your valuable time.

Please return the completed questionnaire in the freepost envelope.

Table A2 Explanatory variables for all ordinal logistic models predicting responses to eight sentinel questions. + indicates positive association that is statistically significant ($p<0.05$); - indicates negative association that is statistically significant ($p<0.05$).

	Resilience		Ecosystem Services		Responsibility to encourage		Market accreditation	
	Farms that have more birds are also more likely to cope with drought and climate stresses		Birds provide important services on my farm (pollination, pest control, or nutrient cycling)		It is not my responsibility to encourage birds on my farm		I would be interested in participating in a market accreditation scheme in the form of a "bird tick" that certifies my production as bird friendly	
	Native	Introduced	Native	Introduced	Native	Introduced	Native	Introduced
Background Information								
Farm size	-							
Management System								
IM and conventional vs organic			-					-
Financial Indicators								
I don't monitor performance because it follows on from physical management					+			
What is the importance of the following measure when you are considering the production performance of your farm?								
Minimum Weeds	-							

Table A2 (continued)

	Resilience		**Ecosystem Services**		**Responsibility to encourage**		**Market accreditation**	
	Farms that have more birds are also more likely to cope with drought and climate stresses		Birds provide important services on my farm (pollination, pest control, or nutrient cycling)		It is not my responsibility to encourage birds on my farm		I would be interested in participating in a market accreditation scheme in the form of a "bird tick" that certifies my production as bird friendly	
	Native	Introduced	Native	Introduced	Native	Introduced	Native	Introduced
What is the importance of the following measures when you are considering the environmental performance of your farm?								
The level of biodiversity								
The number of native plant or tree species							+	
The number of plant species, native or other			+	+		-		+
The presence of both productive and non-productive species flourishing on the farm/orchard	+				-			
Pesticide use	-	+	-	-				
What is the importance to you of the following measures when you are considering the social performance of your farm								
my farming helps me to develop a connection to the place where it is located				+				

Table A2 (continued)

	Resilience		**Ecosystem Services**		**Responsibility to encourage**		**Market accreditation**	
	Farms that have more birds are also more likely to cope with drought and climate stresses		Birds provide important services on my farm (pollination, pest control, or nutrient cycling)		It is not my responsibility to encourage birds on my farm		I would be interested in participating in a market accreditation scheme in the form of a "bird tick" that certifies my production as bird friendly	
	Native	Introduced	Native	Introduced	Native	Introduced	Native	Introduced
How often do you consider each of the following strategies?								
I adopt proven practices rather than do my own experiments	-							
I pay close attention to plants/animals/insects on my farm			+					
I keep unused resources in case they are needed in the future	+	+						
How much do you agree with the following relationship?								
My farm management affects the environment in the region where my farm is located						-		
Community Participation								
What is the level of attachment towards the area where you live?						-		