# Interspecific interaction and habitat use by Australian magpies (*Gymnorhina tibicen*) on sheep and beef farms, South Island, New Zealand

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# Executive Summary

Australian magpies (*Gymnorhina tibicen*) were introduced to New Zealand in the 1860s from their native Australia. They are regarded as a threat to native biodiversity due to their conspicuous attacks on native birds and some sheep/beef farmers actively control them by trapping, poisoning or shooting. However there is little evidence that magpies are seriously affecting other birds on New Zealand sheep and beef farms. We conducted distance sampling surveys of bird abundance across 12 'clusters' of sheep and beef farms between 17 November 2004 and 31 January 2005 to test whether magpies affect the abundance, conspicuousness and habitat use of other birds. Clusters were spread between Marlborough and Southland in eastern South Island, New Zealand. Each had a 'conventional' farm (no accreditation scheme), a certified organic farm, and an 'Integrated Management' (IM) farm. The farms within each cluster were within 25 km of each other and approximately matched for altitude, rainfall and soil type.

The study aimed to: (1) determine whether the presence of many magpies interferes with the conspicuousness and therefore the abundance estimations of other species; (2) test whether magpies reduce the abundance or even cause the localized extinction of some other species on farms or alter their habitat use within the farms; (3) advise sheep/beef farmers whether control of magpies is a worthwhile investment for biodiversity conservation on farms; (4) determine whether magpie abundance varies between conventional, organic, or integrated management farms; (5) describe the variation in magpies numbers and their habitat use, and (6) consider whether magpies should be a priority focal species for ongoing ecological monitoring of ARGOS farms.

Data were analysed with the computer software 'Distance™' to estimate abundance for the most common species (ones with more than 20 records for the entire study). The method proved to be relatively precise and was able to provide abundance estimates for 27 species on farms (although individuals of each of these species did not occur on every farm). There were not enough sightings across the farms to calculate abundance estimates for a further 22 species. Abundant and widespread species that do not usually flock together (such as blackbird, chaffinch, house sparrow, skylark and song thrush) had the most precise abundance estimates. There is evidence that detectability of magpies and starlings differs between farms, so our assumption that a single 'global detection function' can be applied across all farms for each species to estimate abundance is violated. Future work will have to either (i) determine a correction factor for adjusting the global detection functions for each farm based on its habitat or landscape features, or (ii) amass at least 60 sightings of each species per farm.

The abundance of magpies varied little between clusters, suggesting that mainly local rather than regional factors affect their numbers. The average abundance of magpies on all farms was estimated to be 0.18 per ha (95% confidence: 0.16-0.21 per ha).

Magpies were present on all of the farms, so there is widespread potential for them to affect other species. We predicted that if magpies are having a significant impact, we should have seen lower abundance or complete absence of some other birds on farms where magpies are present or most abundant. However there was no evidence that magpie abundance was negatively correlated with the abundance of other species. Nor was there any sign that any species was more likely to be completely absent from farms with more magpies. We did find significant differences in habitat use by bellbird, skylark, song thrush and starling on farms with high magpie abundance compared to ones with low magpie abundance. All four species were seen less frequently in open pastures where more magpies were present. Magpies concentrate their feeding in these open pastures, so interference competition may reduce the habitat use of the other species.

Collectively our own results suggest that magpies are only displacing birds on very local areas. However we also found no evidence that high magpie abundance reduced the conspicuousness of birds. This challenges an earlier study that interpreted increased bird

counts following magpie control to simply reflect elevated conspicuousness rather than a real increase in bird abundance. Perhaps a real increase in bird numbers was triggered by magpie control in that previous study after all? A repeat of the experiment using the Distance sampling method is now needed to resolve the issue.

In the meantime we see little reason for farmers to invest time and money in magpie control, at least for reasons of biodiversity conservation. Priority in control effort should be given to controlling potentially more serious predators such as rats and mice, hedgehogs, stoats, ferrets, possums and feral house cats, which have proven negative impacts on native birds in forest ecosystems. Provision of suitable habitat for native and introduced birds is also an immediate priority if bird communities are to be restored in South Island sheep/beef farming landscapes. In the meantime magpie control effort on all participating farms should be monitored.

We found no evidence that magpie abundance differed on average between organic, IM or conventional farms. Imprecision of counts and restriction of the information to a survey of each farm on a single day may have prevented us from detecting a real difference. Also our survey of abundance at the whole-farm scale may not be appropriate for detecting real effects of different farming systems because farm boundaries may not be ecological boundaries for magpies or the other species we investigated. For example, magpies may roost on a farm where management has encouraged the retention and planting of trees, but forage on a neighbouring farm if it contains more food in open paddocks. Breeding magpies are strongly territorial but non breeding groups are semi-nomadic, potentially ranging over several neighbouring properties with different farming systems. With only some of their time spent on any one farm, the impact of specific management actions such as farming system and magpie control may be very real but undetectable by sampling at whole-farm scales.

Repeated surveys of magpies and other birds (including identification of individual magpies) and surveys of available habitat and resources on both the focal ARGOS farm and surrounding properties will eventually help clarify the relationships between farm management, habitat features and magpie abundance and impacts. However an expensive and large scale experiment is needed to understand the impacts properly.

In view of the conflicting and weak inferences about magpie impacts so far and the lack of evidence for magpie abundance being different between farming systems, we do not recommend magpie as a priority focal species for ARGOS research in the meantime. Nevertheless, a watching brief for other research outcomes should be maintained. In the meantime successively improved estimates of magpie abundance should be included as a covariate in future statistical analyses of bird abundance on ARGOS farms in case they are indeed interfering with the bird estimation methods or impacting on the abundance of other valued species.

# Acknowledgements

# 1  Introduction

Australian magpies (*Gymnorhina tibicen*) were introduced to New Zealand in the 1860s from Victoria and Tasmania (Thomson, 1922) to control agricultural invertebrate pests (Heather & Robertson, 2000).  Over 546 were released in Canterbury between 1864 and 1870 (Bull, 1985).  Since this time they have expanded their range considerably (Figure 1) and are now classified as an 'abundant Australian introduction' (Heather & Robertson, 2000).

Magpies are highly social birds (Veltman, 1982; 1989) and can be extremely territorial (Reader's Digest, 1976) and highly aggressive, especially in their breeding season from July to December (Chambers, 1989; Jones & Nealson, 2003; Stevenson, 2005; Morgan, in review).  The clearing of land for agriculture has benefited magpies in terms of food, as they feed mainly on pasture invertebrates.  They will also feed on seeds, carrion, mice, lizards and other birds (Moeed, 1976; Reader's Digest, 1976; Veltman & Hickson, 1989; Whiting, 1996; Heather and Robertson, 2000).

Magpies have acquired a bad reputation both in Australia and New Zealand.  Extravagant claims have been made regarding their impact on other bird species.  For example:

>  "It was like a scene out of Hitchcock's 'The Birds' … They took over the skies and the land.  Overnight the dawn chorus, apart from their own, dried up" (Barrington, 1996).

They have been blamed for attacking birds, dogs, sheep, horses and humans, stealing food and shiny objects, short-circuiting power lines and even starting forest fires (McCaskill, 1945; Moon, 1956; Reader's Digest, 1985; Porter, 1993; Barrington, 1995; Barrington 1996; Cilento & Jones, 1999; Sanders & Maloney, 2002; Warne & Jones, 2003).  Magpies are responsible for more attacks on humans than any other species of wildlife in Australia (Stevenson, 2005). In New Zealand, they are regarded as a threat to native biodiversity due to their conspicuous attacks on native birds, with at least 45 bird species known to be attacked by magpies in New Zealand (Morgan *et al.*, 2005).  Legal protection was removed from magpies in 1951 after complaints that they were driving away native birds and attacking small children (Reader's Digest, 1985).

A recent study by Innes *et al.* (2004) examined the effect of magpies control on other birds in rural areas.  They found that in areas where magpie control was applied, counts of song thrush, myna, starling, blackbird, skylark, and to a lesser extent tui and kererū increased. However, the authors concluded that increased conspicuousness rather than any real increase in abundance was the most likely explanation of higher counts. Birds may sing less when magpies are nearby so as not to draw attention to themselves, or remain under cover. Innes *et al.* (2004) concluded that magpies may displace other species from small areas, but seldom do they kill them and they probably have little impact on their overall populations.

Our study attempts to cross-check Innes *et al.* (2004)'s conclusion by using a different bird abundance estimator to circumvent problems of altered conspicuousness.  The five-minute counts used by Innes *et al.* (2004) may be ineffectual for detecting changes in population abundance (Rexstad, 1994, in Hein, 1997; Blackwell *et al.* 2005a, b).  We used distance sampling because it accounts for differential detectability when estimating the absolute abundance of birds present (Rosenstock *et al.*, 2002; Thompson, 2002). Therefore distance sampling enabled us to estimate changes in conspicuousness in the presence of high compared to low numbers of magpies, as well as potentially factor out its disruptive influence on our abundance estimation.  The Agriculture Research Group on Sustainability (ARGOS) will monitor changes in bird abundance on approximately 100 farms in the coming decades. It is therefore imperative that any impacts of magpies on the monitoring methods are accounted for.  Our first aim was therefore to test whether magpies affect bird monitoring results by altering conspicuousness.

Secondly, we sought to use the more sophisticated distance sampling methods to re-assess whether magpies might indeed be impacting on other birds.  We do this by first examining

whether the abundance and habitat use of other birds correlates with magpie abundance. We predicted that if magpies are significantly impacting, we should see lower abundance of other birds on farms where magpies are relatively more abundant. Magpies may be forcing other birds to use less preferred habitats within the farms, even if they are not affecting abundance at the whole-farm scale (Innes *et al*., 2004). Therefore, we compared the habitat use of bellbird, blackbird, skylark, song thrush and starling on farms with low- and high-magpie abundance. If magpies are impacting we would expect these species to use different, possibly lower quality, habitats on farms with high magpie abundance. Both magpie and skylark are known to preferentially use areas of open pasture for foraging, and skylark use these habitats for nesting, so we would expect skylark to be particularly affected.

Magpies are commonly trapped with the aid of 'call birds', poisoned or shot (Barrington, 1995; Banks Peninsula Conservation Trust, 2003; Environment Bay of Plenty, 2005). All control methods can become costly as ongoing control is needed to keep magpies from reestablishing (Innes *et al.*, 2004). A third aim of this study was to advise farmers on whether magpie control effort is worth their investment of time and resources.

The fourth aim of our study was to describe the variation in abundance and habitat use by magpies. This is a first step in determining the factors affecting magpie populations and thereby their potential impacts on other birds in agricultural landscapes. There are three primary farm management strategies used on sheep/beef farms in New Zealand; organic, Integrated Management (IM) and conventional farms. Organic management strategies claim significant potential to increase broad biodiversity values, including increases in native vegetation and avifauna (Hole *et al.*, 2005). IM farms are rapidly becoming more common and offer an intermediate strategy between organic and conventional farming (Wharfe & Manhire, 2004). It is unclear whether these different farm management strategies have any consistent impacts on magpies or wider avifauna on farms in New Zealand. Also, farms can vary greatly in their habitat composition, heterogeneity and complexity, and the influence of these factors and magpie presence and interactions with other species is unknown. This information is required to enable farmers to make informed decisions for the effective management of biodiversity in agricultural landscapes.

**X = Australian Magpie** *(Gymnorhina tibicen)*
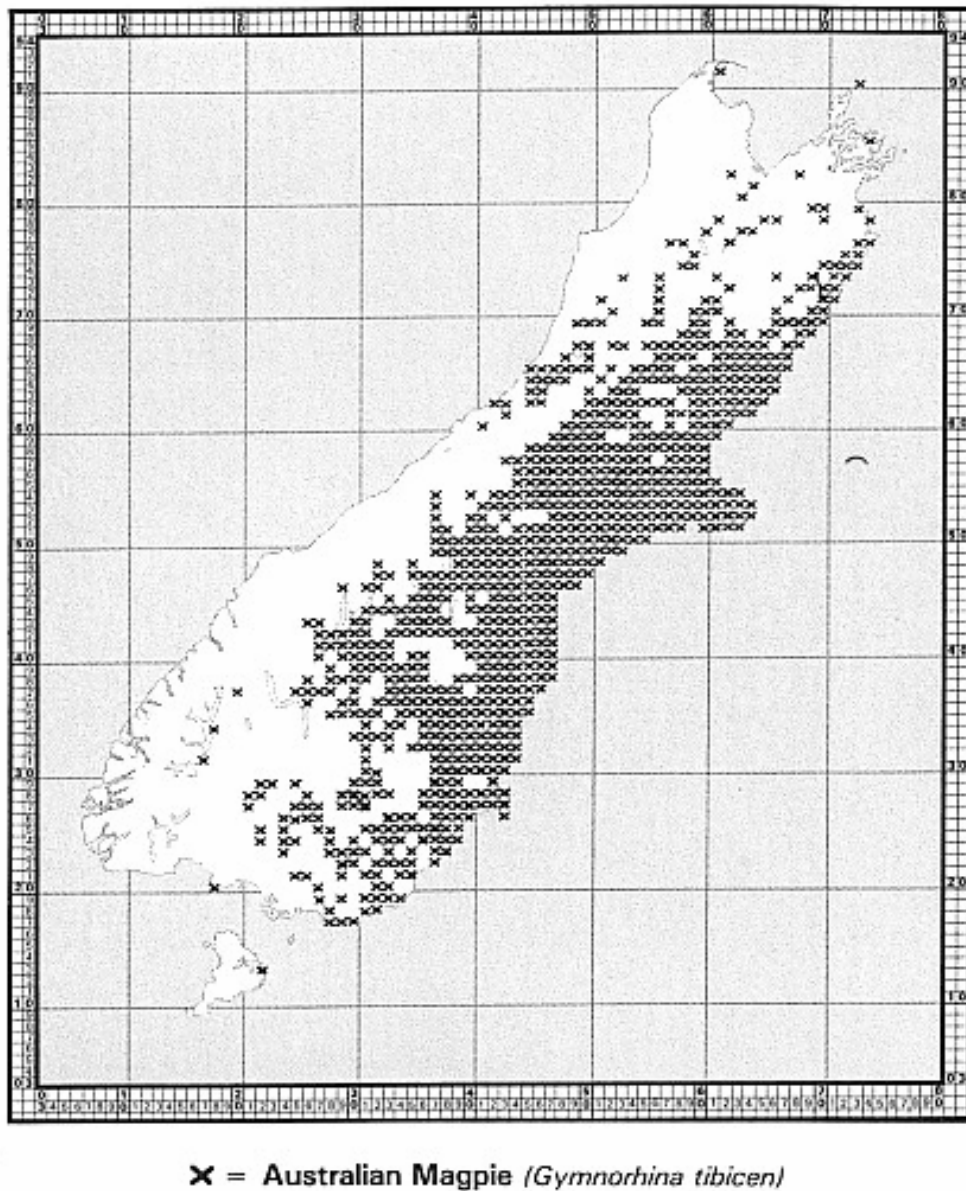
**Figure 1. Australian magpie distribution in the South Island, New Zealand** (from Bull *et al*., 1985). Bull *et al*. (1985) divided the country into 10 km grid squares and collated all records and sightings for each species across the country.  A cross represents presence of magpie recorded at least once somewhere in any one 10 Km grid square.

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# 2 Study areas and methods

## 2.1 Study areas

Twelve clusters of sheep and beef farms were selected from eastern South Island, New Zealand (Figure 2). Each cluster consisted of three farms within 25 km of one another to approximately match them for altitude, rainfall and soil type. Each cluster had a 'Conventional' farm (no accreditation scheme), a certified Organic farm, and an 'Integrated Management' farm[1].
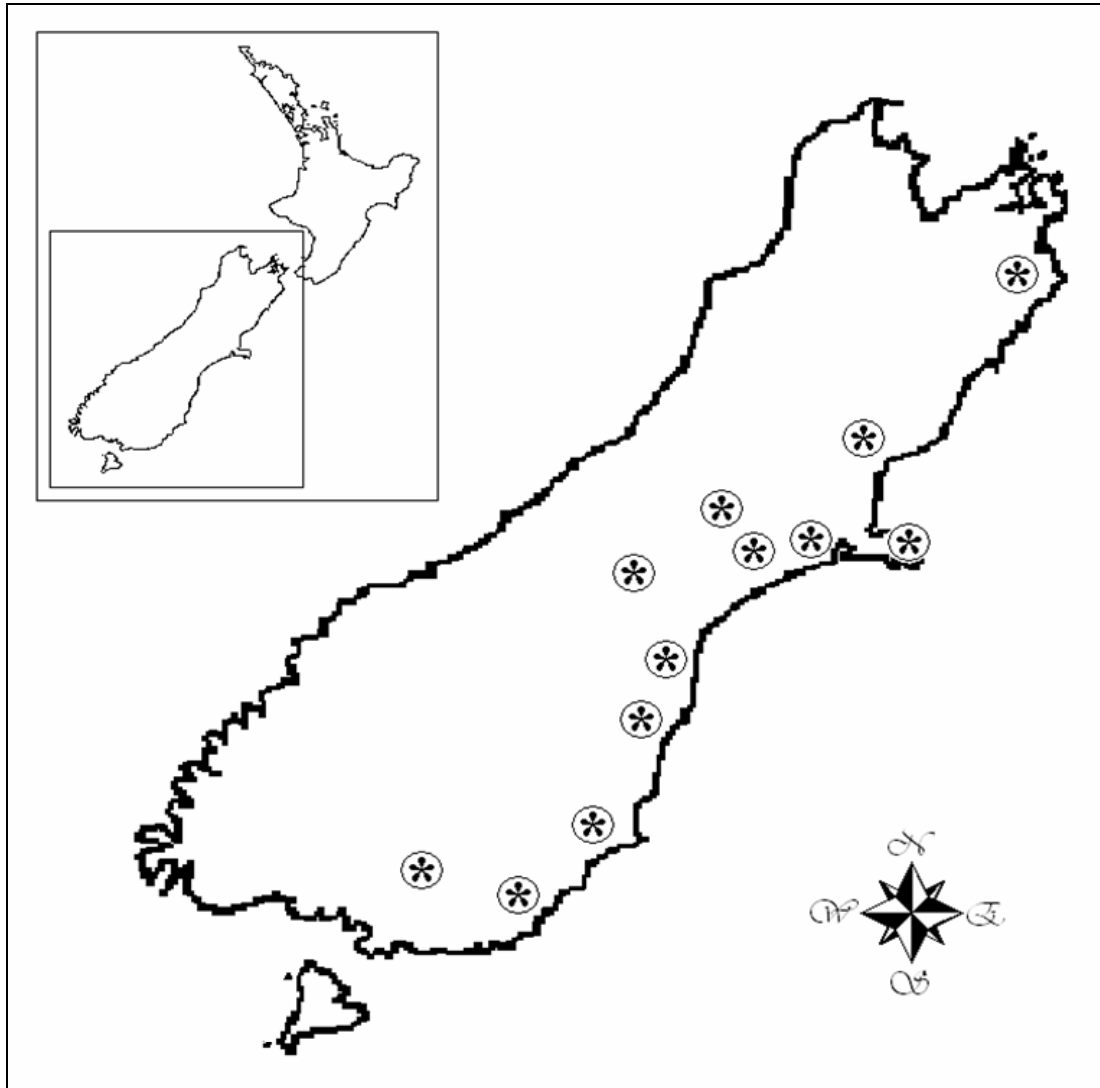


**Figure 2. Approximate locations of study sites, South Island, New Zealand.**

Habitat composition varied widely across all 37 farms, ranging from largely open farms with little woody vegetation (Waimate and Gore), to farms with large extents of exotic vegetation in shelterbelts (Canterbury), to farms with large tracts of native vegetation and high habitat complexity (Banks Peninsula and Owaka).

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[1] With the exception of the Waimate cluster, which had a fourth farm that was in the process of converting to organic production.

## 2.2  Sampling method

Five observers were trained prior to the beginning of the surveys by listening to bird call CDs, and practicing identification of birds amongst urban parks and gardens.  One morning was spent on a farm to become familiarized with the equipment (range finder, binoculars, compass and GPS) and to help standardize the identification between observers.

Starting points of line transects were placed randomly on farm maps, with a minimum of five transects per farm (range 5-11). The starting points were located by observers using a handheld Garmin eTrex Global Positioning System (GPS; Garmin International Inc). Transects ran due south, where possible extending 500m.  Some transects were stopped short of the farm boundaries by 100m to avoid edge effects, and the shortened distance was recorded using GPS.  Altogether there were 333 transects, 67 (20.1%) of which were less than 500m long.  The average length (± standard deviation) of the transects <500m long was 362.7 ± 88.6 m.  Observers moved slowly along the transect, noting down every bird seen or heard.  Also noted was distance to individual bird or centre of flock, the incident angle from the transect line to the bird, along with the habitat the bird was observed in and its behaviour, sex (if possible) and group size.  Temperature and humidity was recorded on each farm at the time of the survey.

An initial pilot run of the survey technique was conducted on the first cluster (Cluster 8; Outram), where one observer was placed on each of the three farms in the cluster on the same morning for three successive days so that all transects were surveyed simultaneously. This approach allowed better control for the influence of variation in daily weather, but it proved to be too time consuming.  For the remaining clusters, all transects on a single farm were surveyed on the same day.

Each transect was surveyed once by one of four observers between the hours of 0800 and 1400 to avoid the peak calling periods at dawn and dusk where conspicuousness and detectability can change rapidly (Dawson & Bull, 1975).  No counts were conducted during rain because it is likely to suppress bird counts more than any other weather condition (Robbins, 1981).  The accepted upper limit of wind speed for satisfactory bird count results is 20kph, so no counts were conducted if wind reached this limit (Robbins, 1981).  Given that accuracy in distance measurement is the foundation of line transect sampling and the key factor in producing reliable abundance estimates, all distances were measured using range finders (Scott *et al.*, 1981; Bibby *et al.*, 2000). Surveying began on November 17th 2004 and was completed on January 31st 2005, which is the summer season in New Zealand.  The total length of transect sampled was 157.4 km.

The same four observers were used for the surveys in 11 of the 12 clusters.  For the final cluster (Cluster 12; Owaka), one observer was replaced with a fifth observer who had recently completed survey's using the same techniques on ARGOS kiwifruit orchards.

More details of the survey protocol are given in Blackwell *et al.* (2005b).

## 2.3  Data entry and analysis

Observers entered their own data into Excel™ spreadsheets, which were then checked for accuracy and combined into one spreadsheet.  Observations lacking species, distance or angle information were discarded, and records for 22 species with less than 20 observations each for all farms combined were also excluded from the analysis because smaller samples become more vulnerable to stochastic factors and may therefore not be representative of the wider population (Barraclough, 2000; Buckland *et al.*, 2001). Altogether 2636 records were excluded, leaving 8086 observations for analysis.

For each of the remaining 27 species, perpendicular distances to each sighting and flock size (if more than one bird was seen) for each farm were imported into the analysis software Distance™ (Distance, 2005).  Distance™ analyses calculate abundance by modeling the probability of detecting animals at different distances from the transect line, using the actual

data from the survey (called the 'detection function'). The technique assumes that all individuals on the transect line will be seen or heard (i.e. that they have a probability of detection of 1.0) and that the chance (probability) of detection decreases as the distance from the line increases. At greater distances, individuals may be obscured by habitat features (long grass, shelterbelts etc.) or their calls may not be heard by the observer. The analysis then uses the detection function and the numbers of animals seen to determine how many individuals were missed, and hence estimates the 'effective strip width' of the detection zone (the distance out from the transect where the same number of birds are missed inside the strip than are detected outside it). The actual abundance of birds present is therefore determined from the total number seen divided by the area within this detection width.

In this analysis, separate detection functions and abundance estimates were calculated for each species. In each case a 'global detection function' (Seddon *et al.*, 2003) was calculated by pooling all records from all farms (which assumes habitat preferences within a species are fairly conservative across farms). In the Distance™ software, the detection function can be generated using different mathematical functions, including the uniform, half-normal, hazard-rate and negative-exponential functions. It can also be fine-tuned to better fit the collected data (using cosine and simple polynomial adjustment factors). The half-normal key function with simple polynomial adjustment factor was recommended by Rosenstock *et al.* (2002) as a good starting model for land birds, but this study found that other combinations generally resulted in a better fit to our data. The accuracy of the estimated abundance can sometimes be improved by truncation (to remove the few records recorded far away from the line that do not add much extra information), while grouping of individual records into 'distance bands' may also improve the model's accuracy (for example, records may be entered as being between 10-15 m from the transect, rather than their exact distance). For each species, various degrees of truncation and data grouping were tested to see if they improved the abundance estimate. The optimum model was selected by comparing the Akaike Information Criteria (AIC) values and chi-squared statistics. The AIC test aims to find the most parsimonious detection function that uses the simplest model (with fewest adjustment factors) to explain most of the variation in the data, while the chi-squared test compares how well the final model reflects the actual data.

The global detection function from the most parsimonious model for each species was then applied to the individual farm counts to calculate abundance estimates for each farm (Appendix 7.2). Farm area was not included in the Distance analysis, so the abundance estimates are expressed as individuals per hectare.

In order to test for effects of magpies on the conspicuousness and abundance of birds, we divided the farms into 'High-magpie' (abundance estimate above the median magpie density) and 'Low-magpie' farms (abundance below the median). We then calculated separate detection functions using distance records from each of the two groups of farms for magpies themselves and for the 5 species considered to be most affected by magpies by Innes *et al.* (2004) and for which we had sufficient sightings (bellbird, starling, skylark, blackbird and song thrush).

Pearsons correlations were performed using Minitab version 14.1 (Minitab Inc, 2003) to determine if magpie abundance was correlated with the abundance of other bird species. For each pair of species, a farm was only included in the analysis if both species were present. When many comparisons are made between inter-related samples it is possible for some significant relationships to turn up simply by chance. For example, if greenfinch and goldfinch abundance correlated we may conclude that there is a positive interaction of these species on each other. However, each species' abundance may be driven by some other factor or group of factors that are independent of one other. Greenfinch may be responding to the amount of woody vegetation on the farms, but goldfinch may be responding to the abundance of thistles and other weeds which just happen to vary in the same way as woody vegetation. Therefore we used Dunn-Sidak corrected significance levels which are a more

conservative test of any association to control for these family-wise Type 1 errors (Quinn & Keough, 2002).

The 37 ARGOS farms vary in their farming system, location, altitude, rainfall, habitat variety and habitat complexity.  It is possible that some regional differences between farms may have important influences on magpie abundance and impacts, which may then mask any impact of the different farming systems on magpies.  This concern affects all other analyses undertaken in the ARGOS project, where comparisons are made between clusters and management systems.  To control for this, a two way ANOVA was performed where the analysis accounts for differences between the clusters to allow a stronger test for any differences due to the farming system (Organic, IM or Conventional).

## 2.4  Habitat use and interactions

The inclusion of habitat information is recommended when censusing biological populations to gain a deeper understanding of the adaptations and behaviour of a species (Rotenberry, 1981; Wiens & Rotenberry, 1981).

The habitat where we detected each individual bird was coded into one of twelve categories that reflected structurally different habitats or vegetation classes (Table 1).

'Crops' were defined as any paddock that had a sprouted or growing crop in it.  These included cereals such as barley, wheat and oats and brassicas such as kale, turnips and swedes.  These paddocks often provide a large food resource for birds (either on the crop itself or invertebrates found among the plants). 'Cliffs' were very steep areas (>45° slope) that had no grazing or cropping on them.  This habitat was uncommon on the ARGOS farms. The 'dense grass' category included pasture paddocks that had been closed up for hay and other areas of long dense or rank grass, such as field margins, riparian strips, or track and road verges.  The 'exotic vegetation' category included small clumps of species such as Monterey pine (*Pinus radiata*), macrocarpa (*Cupressus macrocarpa*), gums (eucalyptus species), poplars (*Populus* spp.) and willows (*Salix* spp.), as well as fruit trees in orchards. These species are planted on farms for shelter, erosion control, or food production.  They provide important roosting and nesting sites for many birds (many male mating songs were heard in them), as well as providing a wide range of food resources. 'Individual trees' were any single isolated native or exotic trees, usually out in the middle of paddocks.  These were often used by birds as vantage points or singing posts from which they could identify prey, competitors and predators.  The 'man-made structure' category included things such as the farm house and buildings, sheds, yards, troughs, fences and irrigation equipment that may be used for roosting or foraging.  Native vegetation included areas of regenerating manuka (*Leptospermum scoparium*), kanuka (*Kunzea ericoides*) or matagouri (*Discaria toumatou*) scrub on hill slopes and in gullies and large blocks of native forest containing species such as rimu (*Dacrydium cupressinum*), totora (*Podocarpus totora*), broadleaf (*Grisilinea littoralis*), manuka and kanuka.  Native vegetation was used for perching and roosting by many species and also provides important habitat and resources for native species on the farms.  The 'open paddock' category included grazed or recently grazed pasture paddocks which were covered in grasses, legumes and broadleaf herbs.  These habitats provided food for many species (grass and weed seeds and insects) as well as nesting sites for species such as skylark.  'Ploughed paddocks' were any recently cultivated paddocks that were still in bare earth, although they may have been planted (in which cases the crop had not yet emerged). They were important as food sources for many species (such as starling, black backed seagull and spur-wing plover) as well as important nesting sites for pied oystercatcher.  The 'road' category included any formed road-way, either sealed or gravel roads along the farm boundary, or well-formed tracks within the farm.  The 'shelterbelt' category included linear plantings of species such as pine, macrocarpa, gums, poplars and willows used for stock shelter.  The final category, 'water feature', included any still or flowing water found on the farm (streams, natural or constructed ponds, and lakes).

The main feature that the bird was most closely associated with was scored on the bird's first sighting. For example, a bird perching on a fence between two open paddocks would be scored as being on the fence, while one flying over the open paddock would have its habitat scored as the paddock. The average habitat use in the twelve categories across all farms was calculated for each species for which we had abundance estimates. Some of the categories had too few records in them to allow statistical analysis, so the results were pooled into six broader categories for species that are known or suspected to interact with magpies (bellbird, blackbird, skylark, song thrush, and starling; Innes *et al.*, 2004). Similar categories were pooled together (Table 2), so that the final six categories used in the analysis were Crop, Shelterbelt/Exotic vegetation, Native vegetation, Open paddock/Dense grass, ploughed paddock, and Other (Cliff, Individual tree, Man-made structures, Roads and Water features).

Use of the six pooled habitat categories was calculated for the five species listed above for 'low-magpie' and 'high-magpie' abundance farms. A chi-square contingency test was performed to see if habitat use was different between low and high magpie abundance farms. The chi-square test compares the observed proportions with those expected if there was no impact of magpies on their distribution (Quinn and Keough, 2002). The same test was also used to compare magpie habitat use on low and high abundance farms, to see whether within-species competition may influence magpie habitat use. As with the tests of correlations between species abundance, Dunn-Sidak corrections were used to control for family-wise Type I errors.

**Table 1 Original habitat categories used to score habitat use during the summer 2004/2005 bird surveys on 37 ARGOS farms**

| Code | Name | Description |
|------|------|-------------|
| **C** | Crop | Sprouted or growing cereal or brassica crop |
| **CF** | Cliff | Any steep (> 45°) slope, generally rocky with sparse vegetation and very little or no grazing or cropping |
| **DG** | Dense grass | Long or rank grass, either in paddocks closed up for hay production, or on road/track or other margins |
| **EV** | Exotic vegetation (forest block, scrub, orchard) | Pine/macrocarpa/eucalypt, as scattered trees, along waterways, or in small plantations |
| **IT** | Individual tree | Single or two-three native or exotic trees in paddock |
| **MS** | Man-made structure (house, farm building, yards, irrigator, power line) | Any man-made physical structure on the farm, including fences |
| **NV** | Native vegetation (bush gully, forest, scrub, tussock) | Native scrub along field/stream margins, gullies, faces, or areas of native forest |
| **OP** | Open paddock | Currently or recently grazed pasture paddocks |
| **PP** | Ploughed paddock | Recently ploughed or planted paddock that was still bare earth |
| **R** | Road (includes farm tracks) | Any formed road-way, either sealed or gravel roads along the farm boundary, or well formed farm tracks |
| **SB** | Shelterbelt | Any linear native or exotic woody-vegetation feature, usually on a paddock boundary, planted for stock shelter and weather protection |
| **WF** | Water feature (pond, wetland, stream) | Any still or flowing water found on the farm; including streams, natural or constructed ponds, and lakes |

**Table 2. Summarized habitat categories used in the analysis of habitat use by blackbirds, skylarks, song thrushes and starlings on low and high magpie abundance farms.**

| Code | Name | Description |
|---|---|---|
| C | Crop | Sprouted or growing cereal or brassica crop |
| SB/EV | Shelter belt/Exotic vegetation | Pine/macrocarpa/eucalypt, as scattered trees, along waterways, linear shelterbelts or small plantations |
| NV | Native vegetation | Native scrub along field/stream margins, gullies, faces, or areas of native forest |
| OP/DG | Open paddock/dense grass | Pasture paddocks, either grazed or closed up for hay production |
| PP | Ploughed paddock | Recently ploughed or planted paddock that was still bare earth |
| Other | All other habitats (Cliff, Individual tree, Man-made structure, Road, Water feature) | Man-made structures includes buildings, yards, troughs, etc. Roads included sealed and unsealed roads and farm tracks |

# 3  Results

## 3.1  Magpie and other species abundance

Forty-nine bird species were recorded by observers over all 37 farms (Appendix 7.1). Of these, 22 species were unsuitable for analysis due to low numbers (<20 observations). These species were as follows: little owl, morepork, pheasant, pipit, shining cuckoo, banded dotterel, black shag, falcon, robin, red billed gull, turkey, cirl bunting, grey duck, kingfisher, pūkeko, black billed gull, rifleman, kererū, California quail, tui, poultry and tomtit. Densities per farm were estimated for the remaining 27 species, most often using the hazard-rate and negative exponential as the optimum model for abundance estimation (Appendix 7.1).

Precision of the abundance estimates, as measured by the coefficient of variation (CV), varied between 4% and 228%. Precision was highest for species such as skylark, which occurred in relatively high numbers and for the most part as single individuals (CV of farm-by-farm estimates = 4.1% to 33.01%). Precision was lower for species with fewer observations, such as white faced heron (CV = 159.95% to 185.7%) and species which occurred in large flocks, such as starling (CV = 10.6% to 200.6%).

The overall average abundance (± standard deviation) of magpies across all farms was 0.19 ± 0.07 birds/ha (CV 38.41%) and the median was 0.17 birds/ha. The densities of magpies across the individual farms are shown in Figure 3.

The average abundance (± standard error) of magpies on Organic, IM and Conventional farms was 0.19 ± 0.02 birds/ha, 0.17 ± 0.02 birds/ha, and 0.19 ± 0.02 birds/ha respectively. These differences are not statistically significant ($F_{2,23} = 0.28$, $P > 0.5$ for farming systems; $F_{11,23} = 0.89$, $P > 0.5$ between clusters). However, it should be noted that the precision of the estimates was low (as indicated by the large 95% confidence limits) and thus the analysis had low power to detect any significant differences.


## 3.2  Is bird conspicuousness reduced by magpies?


Results for separate detection functions modeled from records from high-magpie compared to low-magpie farms are presented in Table 3. The confidence intervals for 'p' (probability of recording a bird in the zone from the transect to the furthest sighting) and 'ESW' (Effective Strip Width) overlapped considerably for blackbird, skylark and song thrush. There was marginal overlap for bellbird, but no overlap for magpie and starling. This suggests that conspicuousness of starlings was significantly <u>higher</u> in the farms we designated to be high-magpie farms, the reverse of what had been predicted (Figure 4).

The result for bellbirds is more equivocal, perhaps partly because there were relatively few sightings overall (n= 106) and they were detected on only 9 of the 37 farms. If any difference occurred, bellbird conspicuousness decreased in the presence of relatively higher magpie abundance (Figure 5), as predicted by Innes *et al.* (2004).
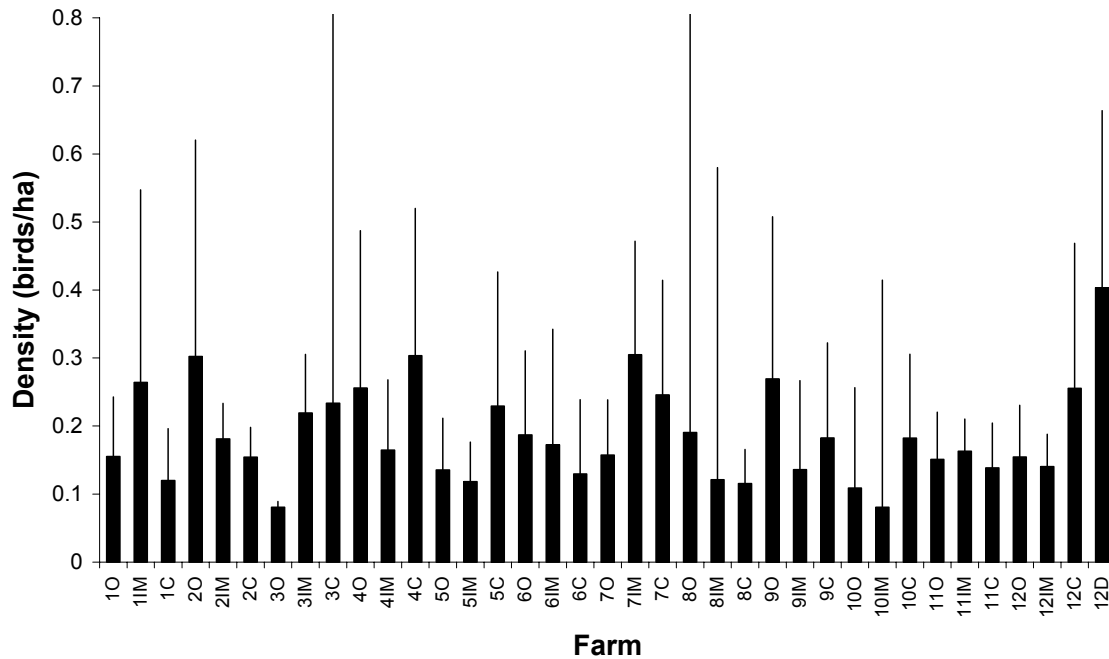
**Figure 3. Abundance of magpies on each of 37 ARGOS farms surveyed in summer 2004/05.** Bars represent the estimated number of birds per hectare using the global detection function for all farms and the error bars represent the upper 95% confidence interval for each estimate. Farming systems are coded as O = Organic, IM = Integrated management and C = conventional. The farm numbers denote the clusters, as follows: 1 = Blenheim, 2 = Amberley 3 = Banks Peninsula, 4 = Leeston, 5 = Methven, 6 = Ashburton, 7 = Fairlie, 8 = Outram, 9 = Owaka, 10 = Gore, 11 = Oamaru, 12 = Waimate. The error bars for farms 3C and 8O have been truncated from values of 0.90 and 1.48 respectively.

Increased conspicuousness of magpies and starlings on high-magpie farms illustrates an underlying problem with our classification of the two groups of farms when using a single underlying detection function (the 'global detection function'; Seddon *et al.* 2003). It is not clear whether some habitat or landscape features that promote magpie and starling conspicuousness have caused the difference, or whether the presence of large numbers of magpies themselves triggers increased conspicuousness of those present. Perhaps increased intraspecific interactions amongst magpies at higher abundance increases their detectability, or spillover into new habitats within farms is forced by higher magpie abundance.

Whatever the reason for changing conspicuousness in magpies between farms, it is clear that some of the farms we have designated as high-magpie abundance may simply be farms where the magpies are more easily detected. Magpie abundance was estimated to be nearly twice as high on high-magpie farms than low–magpie farms using our original designation (Table 4). However, if we recalculate the abundance in the two groups using the different detection functions summarized in Table 3, the average abundance (± standard deviation) in low-magpie farms was 0.17 ± 0.04 birds/ha, and 0.20 ± 0.05 birds/ha in high-magpie farms. The difference approaches statistical significance ($F_{1,35}$ = 3.95, P = 0.06), but the averages now differed by only 15%.

## 3.3  Is bird abundance reduced by magpies?

We conducted a correlation analysis to look for any relationships between magpie abundance and that of other species that magpies may interact with on farmland, and for which we had abundance estimates (Table 5). Using un-corrected significance levels, there were significant positive correlations between magpie abundance and that of chaffinch and house sparrow; i.e., farms with high magpie numbers also had higher chaffinch and house sparrow densities (shown in bold in Table 5; and see Figure 6). However, these correlations were not significant when the more conservative Dunn-Sidak test was used and the result for chaffinch was heavily influenced by a single outlier (Figure 6a). Consequently, there was no evidence of an effect of magpie abundance on any other species abundance ($P>0.05$). There were negative but non significant correlations between magpie abundance and dunnock abundance and between magpie abundance and pied oystercatcher abundance.

**Table 3. Parameters of probability detection functions for magpie, bellbird, blackbird, skylark, song thrush and starling on 'low-magpie' and 'high-magpie' abundance farms.** In the table, p refers to the probability of recording a bird at any given point from the transect line to the furthest sighting in the analysis (denoted by 'W' in Distance™). ESW refers to the 'effective sampling width', which is estimated as p x W. Upper and lower 95% CI's are estimated for p and ESW.

| Species | Abundance class | Detection function | Expansion | p | lower 95% CI | Upper 95% CI | ESW | Lower 95% CI | Upper 95% CI |
|---|---|---|---|---|---|---|---|---|---|
| Magpie | Low-magpie | Negative exponential | Polynomial | 0.22 | 0.19 | 0.25 | 101.13 | 88.08 | 116.13 |
| | High-magpie | Hazard rate | Polynomial | 0.30 | 0.26 | 0.35 | 143.25 | 124.19 | 165.24 |
| Bellbird | Low-magpie | Negative exponential | Polynomial | 0.30 | 0.21 | 0.44 | 42.52 | 29.01 | 62.31 |
| | High-magpie | Negative exponential | Polynomial | 0.18 | 0.14 | 0.24 | 25.57 | 19.29 | 33.88 |
| Blackbird | Low-magpie | Negative exponential | Polynomial | 0.26 | 0.22 | 0.30 | 32.46 | 27.99 | 37.64 |
| | High-magpie | Negative exponential | Polynomial | 0.25 | 0.21 | 0.29 | 30.97 | 26.34 | 36.41 |
| Skylark | Low-magpie | Negative exponential | Polynomial | 0.21 | 0.19 | 0.22 | 51.29 | 47.60 | 55.26 |
| | High-magpie | Negative exponential | Polynomial | 0.19 | 0.18 | 0.21 | 47.61 | 44.14 | 51.36 |
| Song thrush | Low-magpie | Hazard rate | Polynomial | 0.25 | 0.20 | 0.32 | 50.28 | 39.35 | 64.25 |
| | High-magpie | Hazard rate | Polynomial | 0.20 | 0.14 | 0.28 | 39.68 | 28.22 | 55.79 |
| Starling | Low-magpie | Negative exponential | Polynomial | 0.28 | 0.19 | 0.40 | 44.20 | 30.22 | 64.64 |
| | High-magpie | Half normal | Cosine | 0.48 | 0.44 | 0.52 | 76.34 | 69.67 | 83.65 |

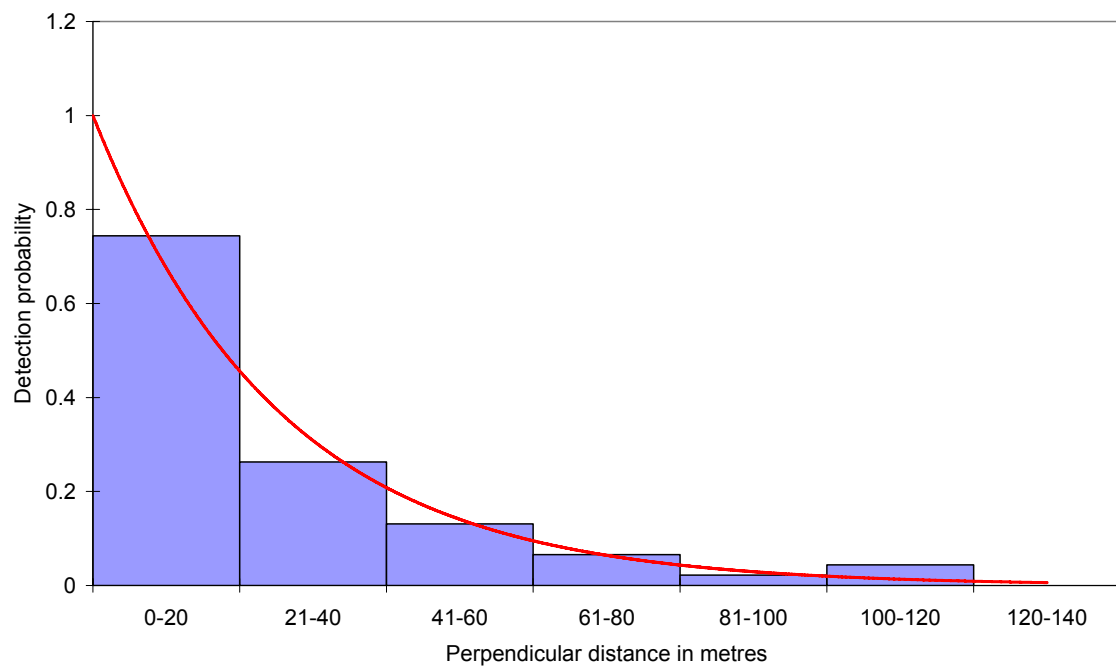a)  Low-magpie abundance farms
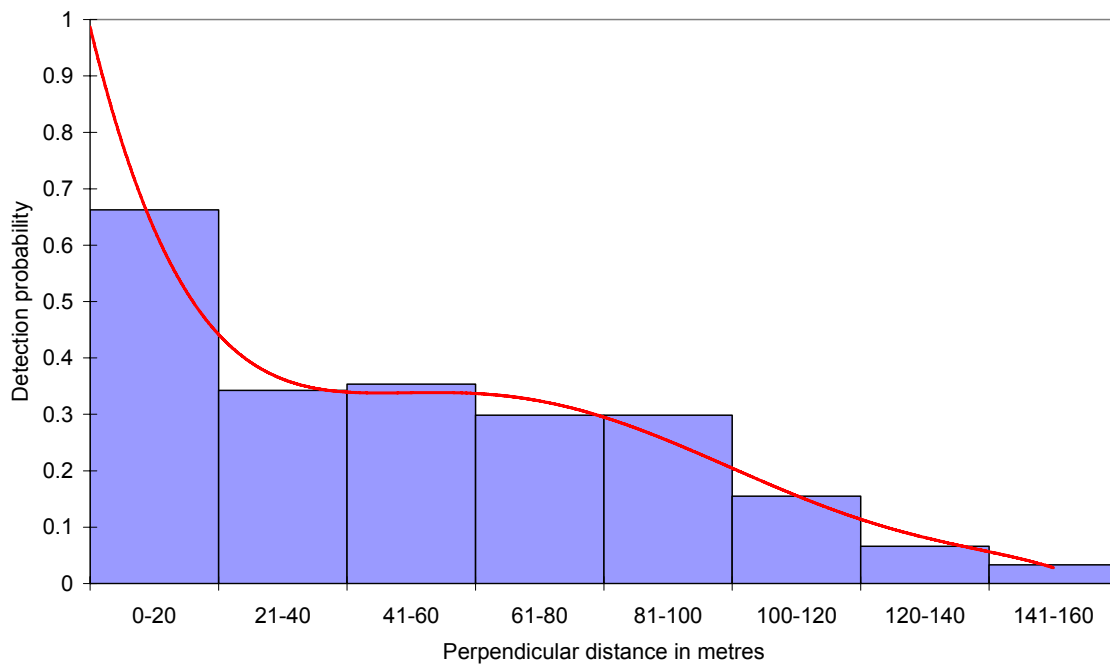


b)  High-magpie abundance farms
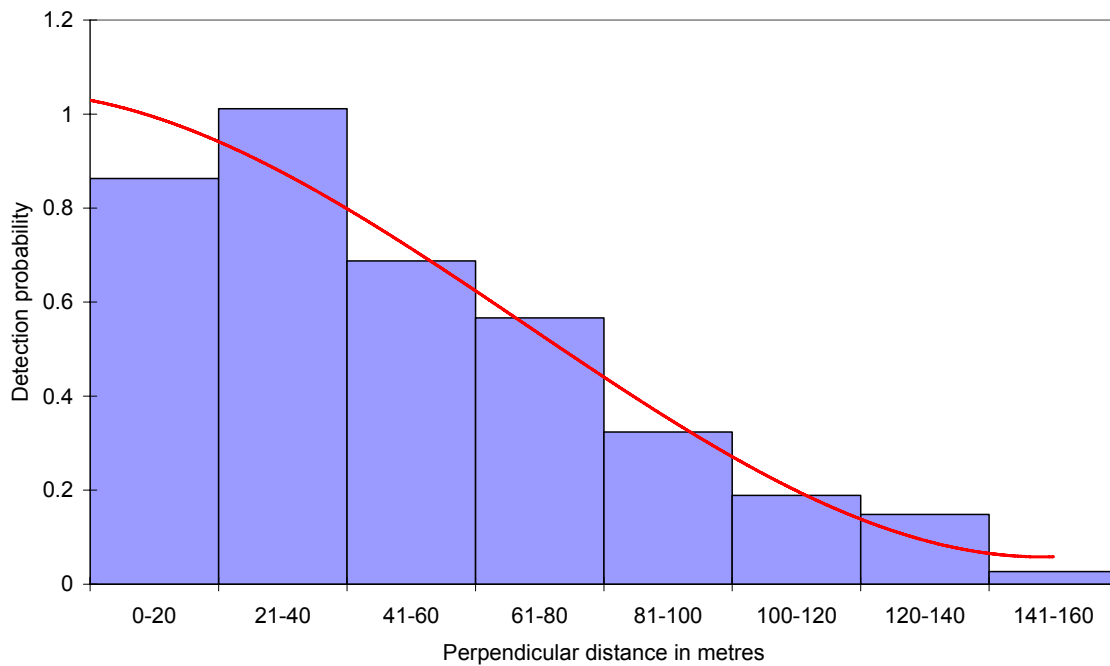


**Figure 4.  Distribution of sightings and fitted probability detection functions for starlings on a) low-magpie and b) high magpie abundance farms**.  Sightings were truncated at 160m and grouped into 8 distance bands for the analysis. For low-magpie farms, the negative exponential detection function with a polynomial expansion gave the best fit to the observed data, while the half-normal detection function with a cosine expansion gave the best fit on high-magpie                                                                                                          farms.

a) Low-magpie abundance farms
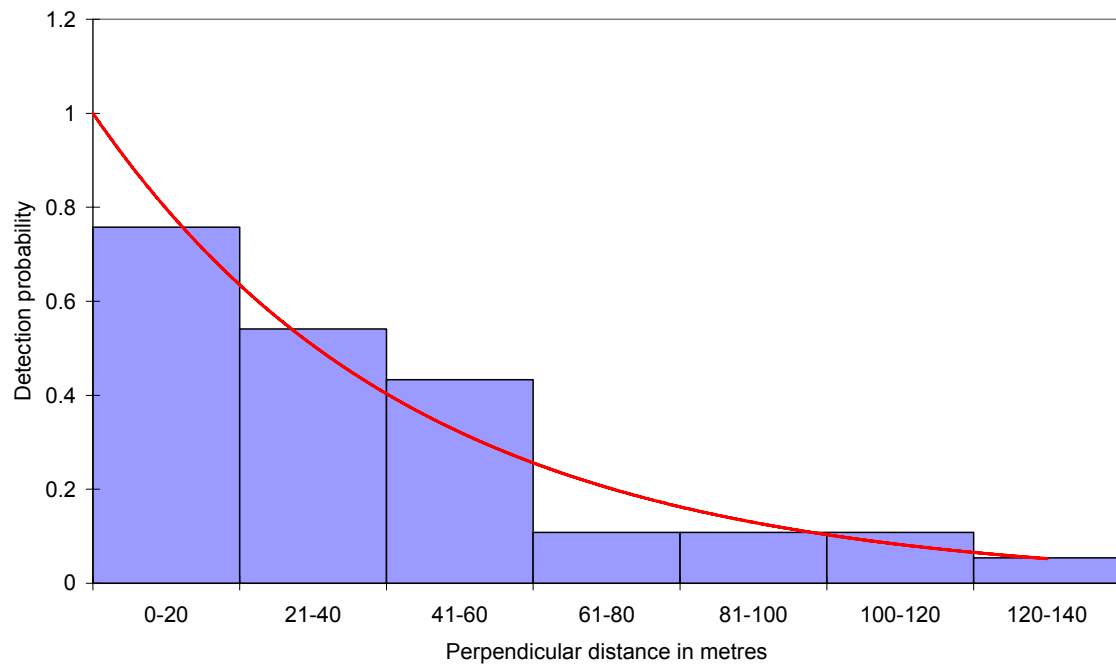


b) High-magpie abundance farms



**Figure 5. Distribution of sightings and fitted probability detection functions for bellbird on a) low-magpie and b) high magpie abundance farms.** Sightings were truncated at 141m and grouped into 8 distance bands for the analysis. For both categories, the negative exponential detection function with a polynomial expansion gave the best fit to the observed data.

**Table 4. The abundance of selected species on farms classified as having low or high magpie abundance.** Farms with magpie abundance lower than the median (middle) value were classified as low abundance, while those with magpie abundance higher than the middle value were classified as high abundance. In the table, n refers to the number of farms in each category on which each species was recorded in the farm surveys, while the mean is the average abundance on those farms and SD refers to the standard deviation, which measures how variable the abundance was in the category. For example, 17 low magpie farms had song thrushes on them, and the average abundance on those farms was 0.37 birds/ha, and the standard deviation was 0.13 birds/ha. The average densities for each species on low and high magpie abundance farms were compared using a one-way analysis of variance, indicated by the F-ratio. Only magpies differed significantly in abundance between low and high abundance magpie farms (in bold).

| Species | Magpie abundance | n | mean | SD | F-ratio | P value |
|---|---|---|---|---|---|---|
| **Magpie** | Low-magpie | 19 | 0.13 | 0.02 | **54.81** | **<0.001** |
| | High-magpie | 18 | 0.24 | 0.06 | | |
| Bellbird | Low-magpie | 5 | 1.38 | 1.25 | 0.69 | 0.43 |
| | High-magpie | 4 | 0.85 | 0.12 | | |
| Blackbird | Low-magpie | 19 | 0.58 | 0.31 | 2.09 | 0.15 |
| | High-magpie | 18 | 0.46 | 0.14 | | |
| Skylark | Low-magpie | 19 | 0.28 | 0.05 | 0.22 | 0.64 |
| | High-magpie | 18 | 0.27 | 0.08 | | |
| Song thrush | Low-magpie | 17 | 0.37 | 0.13 | 0.97 | 0.33 |
| | High-magpie | 18 | 0.43 | 0.22 | | |
| Starling | Low-magpie | 18 | 7.27 | 25.71 | 0.43 | 0.51 |
| | High-magpie | 17 | 3.00 | 7.48 | | |
| Dunnock | Low-magpie | 13 | 2.70 | 3.75 | 0.21 | 0.65 |
| | High-magpie | 13 | 3.63 | 6.31 | | |
| Pied oystercatcher | Low-magpie | 12 | 0.57 | 0.90 | 1.10 | 0.31 |
| | High-magpie | 10 | 0.26 | 0.16 | | |

**Table 5. Pearson correlation coefficients for species found on more than 20 ARGOS farms.** Correlations in bold were significant at the 0.05 significance level, while values with * were significant after Dunn-Sidak correction to control for family-wise type 1 errors.

| | Magpie | Black-bird | Chaf-finch | Dunnock | Gold-finch | Green-finch | Harrier hawk | House sparrow | Pied oyster-catcher | Redpoll | Skylark | Song thrush | Southern black backed gull | Spur winged plover | Starling | Yellow-hammer |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. of farms | 37 | 37 | 37 | 26 | 35 | 35 | 30 | 30 | 22 | 36 | 37 | 35 | 34 | 33 | 35 | 37 |
| Magpie | - | | | | | | | | | | | | | | | |
| Blackbird | -0.08 | - | | | | | | | | | | | | | | |
| Chaffinch | **0.40** | 0.20 | - | | | | | | | | | | | | | |
| Dunnock | -0.12 | 0.14 | 0.13 | - | | | | | | | | | | | | |
| Goldfinch | -0.19 | 0.04 | -0.06 | 0.10 | - | | | | | | | | | | | |
| Greenfinch | 0.33 | -0.05 | 0.12 | -0.02 | 0.18 | - | | | | | | | | | | |
| Harrier hawk | 0.26 | -0.16 | 0.17 | -0.16 | 0.22 | 0.03 | - | | | | | | | | | |
| House sparrow | **0.38** | -0.08 | -0.16 | -0.11 | -0.16 | -0.03 | -0.22 | - | | | | | | | | |
| Pied oyster-catcher | -0.16 | **0.46** | -0.19 | 0.20 | 0.33 | 0.07 | -0.08 | -0.03 | - | | | | | | | |
| Redpoll | -0.07 | -0.08 | -0.05 | -0.10 | **0.62*** | 0.01 | 0.29 | -0.08 | -0.04 | - | | | | | | |
| Skylark | 0.08 | 0.04 | 0.22 | **0.47** | 0.12 | **0.49** | 0.28 | -0.22 | -0.04 | -0.02 | - | | | | | |
| Song thrush | 0.32 | -0.02 | 0.13 | 0.33 | 0.29 | 0.22 | 0.17 | -0.01 | 0.03 | 0.13 | 0.10 | - | | | | |
| Southn bl backed gull | 0.30 | -0.06 | -0.04 | 0.33 | -0.06 | 0.18 | -0.18 | 0.17 | -0.02 | 0.32 | 0.06 | -0.10 | - | | | |
| Spur winged plover | 0.23 | 0.12 | -0.06 | 0.21 | **0.50** | 0.08 | 0.23 | 0.02 | **0.84*** | -0.08 | 0.00 | 0.25 | -0.01 | - | | |
| Starling | -0.05 | **0.36** | -0.11 | 0.16 | 0.37 | 0.22 | 0.07 | -0.05 | **0.97*** | -0.02 | 0.10 | -0.03 | -0.05 | **0.72*** | - | |
| Yellowhammer | 0.03 | -0.19 | 0.16 | **0.42** | -0.05 | -0.06 | 0.04 | 0.01 | 0.01 | -0.13 | -0.06 | 0.10 | 0.01 | 0.08 | -0.01 | - |

**a)**
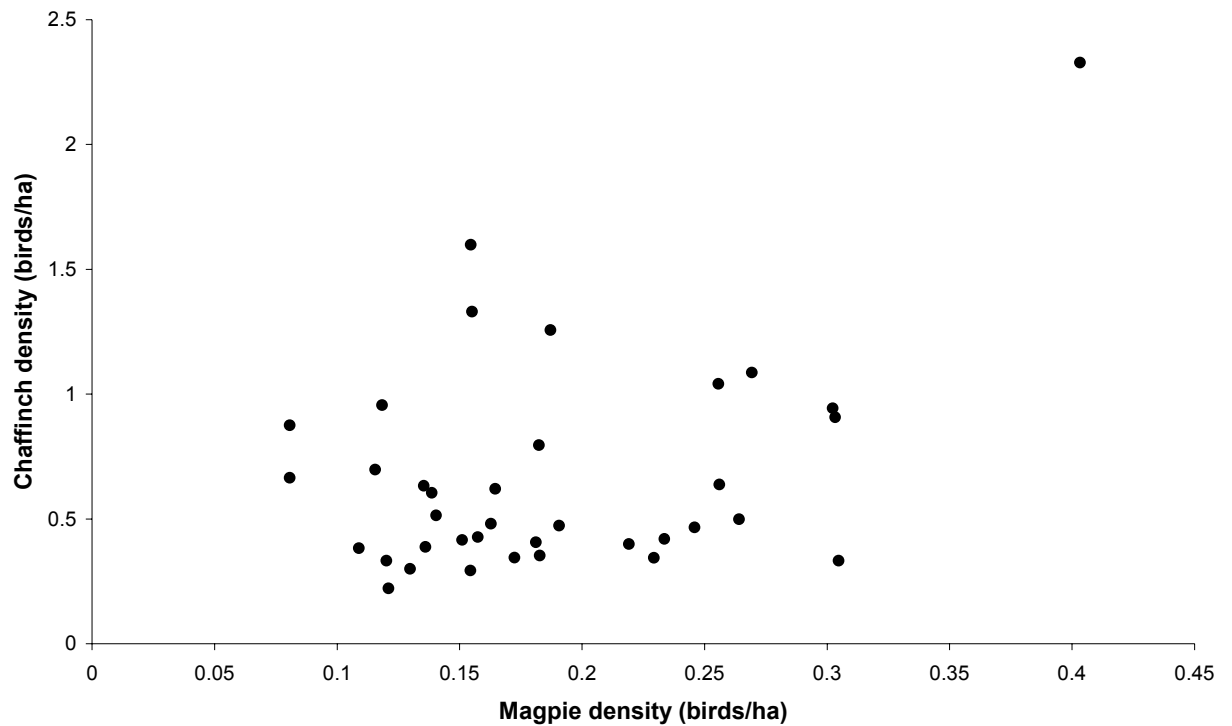
**b)**
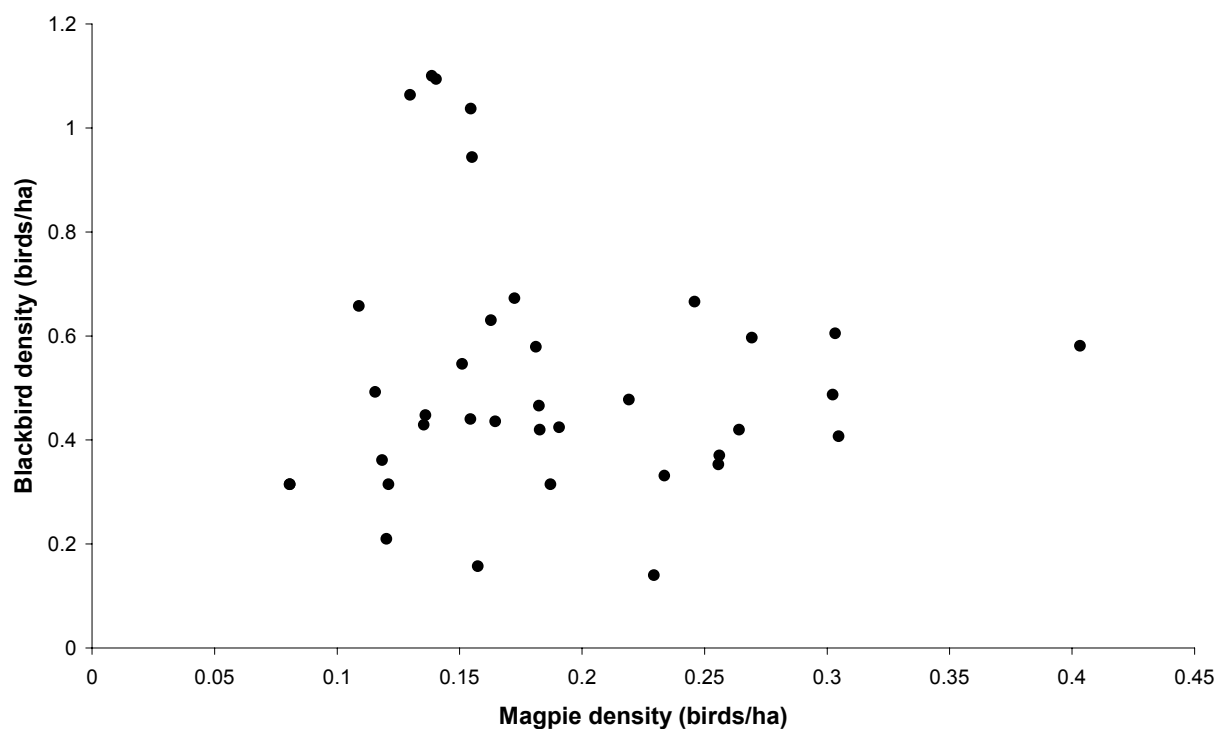
**Figure 6. Scatterplot of the relationship between magpie abundance and a) chaffinch abundance and b) blackbird abundance of the 37 sheep/beef farms in the ARGOS project.** The correlation between magpies and chaffinches was significant using un-corrected significance levels, but was not significant when corrected Dunn-Sidak confidence levels were used. The significant overall relationship is driven primarily by one farm that had very high abundances for

both magpie and chaffinch (farm 12A).  There was no evidence of a significant relationship between magpie and blackbird abundance (4b).

The only relationships between species that were significant using the more conservative Dunn-Sidak test (marked with an asterix in Table 5) were positive correlations between goldfinch and redpoll, between pied oystercatcher and both spur-wing plover and starling, and between spur-wing plover and starling.

The impact of magpies could conceivably be obscured in these analyses if they forced localized extinction of the species. Therefore we tested whether the presence/absence of dunnock, pied oystercatcher and bellbird varied between low-magpie and high-magpie farms. These species were tested because they were the only ones to have been found on fewer than 30 of the 37 farms in our study (Table 4). All species were about equally distributed between high-magpie and low-magpie farms (p>0.10), so there is no evidence for localized exclusion of any species from whole farms in high magpie areas.

## 3.4  Do magpies alter habitat use by other birds?

The average habitat use across the 12 original categories for each species that we had Distance™ abundance estimates for are shown in Figure 7.  Habitat use probably reflects the breeding requirements, size, physiology, and interactions with other bird species and predators.  The species fell into four main categories:
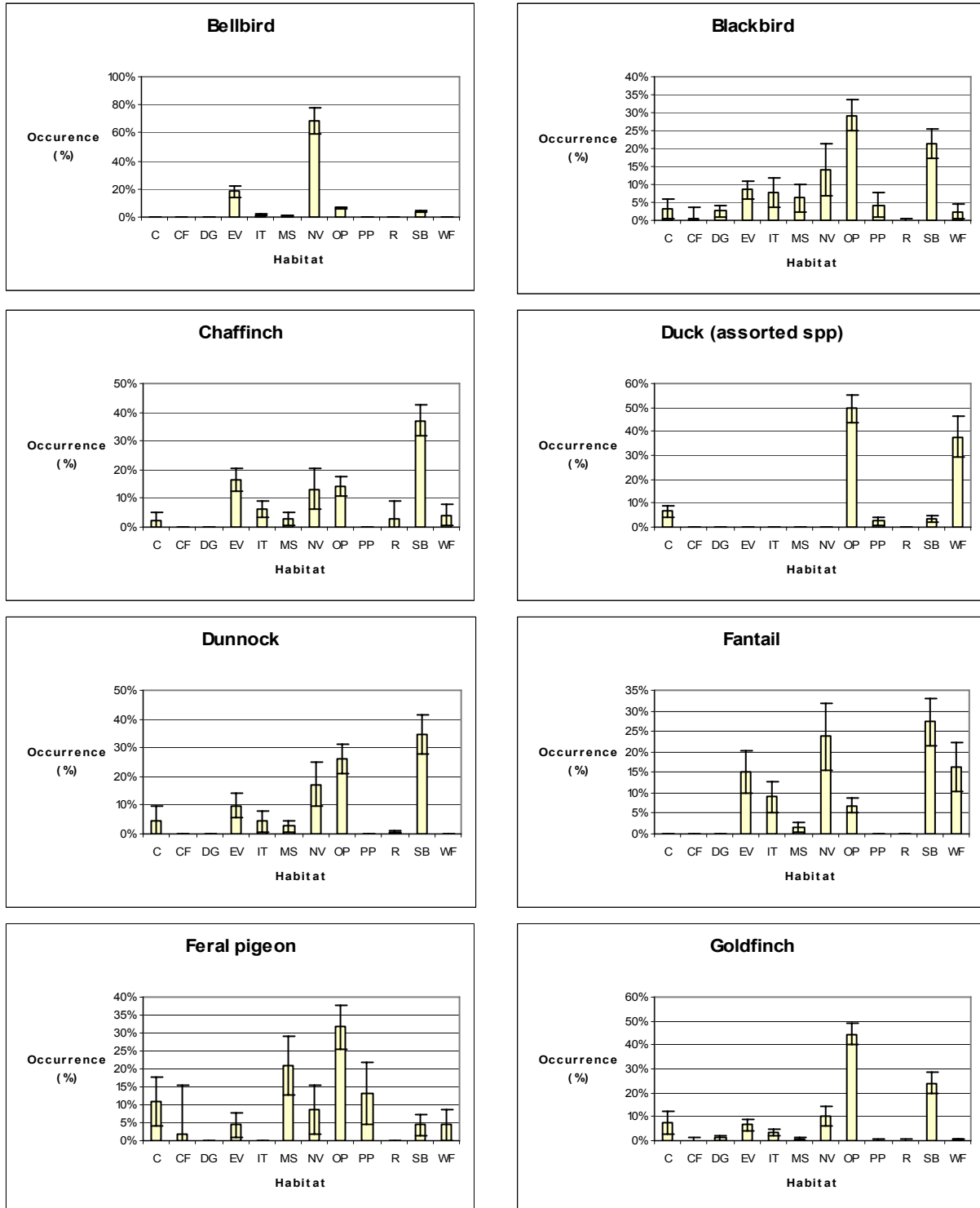1. Generalist woodland species:  These were usually recorded in native or introduced woody vegetation, including individual trees, shelterbelts, plantations, native scrub and bush.  These species were both native and introduced, all of which are known to be forest and woodland species.  Examples include blackbird, chaffinch, fantail, grey warbler, and song thrush.
2. Generalist open country species:  These were primarily associated with open pasture and crop paddocks, although they were sometimes also found in habitats around field margins.  The category included species such as goldfinch, greenfinch, house sparrow, magpie, redpoll and yellowhammer.
3. Specialist forest/woodland species: These were only recorded in closed vegetation, such as native and exotic forest and scrubland. They included bellbird and silvereye (waxeyes).
4. Specialist open country species:  These were only recorded in the fields and paddocks.  They included mallard and paradise shelduck, skylark, southern black-backed seagull, and spur-wing plover.

Using the six combined habitat categories, there were no significant differences in proportional habitat use for magpie on low-magpie or high-magpie farms (Table 6).  Three-quarters of all observations were recorded in woody vegetation (shelterbelts, and pine plantations) or the open pasture category. Magpies were rarely recorded in crops, ploughed paddocks and native vegetation and were uncommon in the 'other' category (buildings, tracks and structures on the farms).  The lack of evidence for a shift in habitat use by magpies between low-magpie and high-magpie farms greatly simplifies the interpretation of our data because it excludes the possibility that the shifts in habitat use observed for other species is driven by spillover of magpies into less preferred habitats on the farm where they are more numerous.
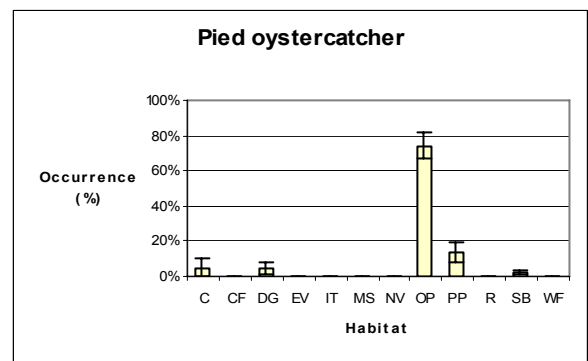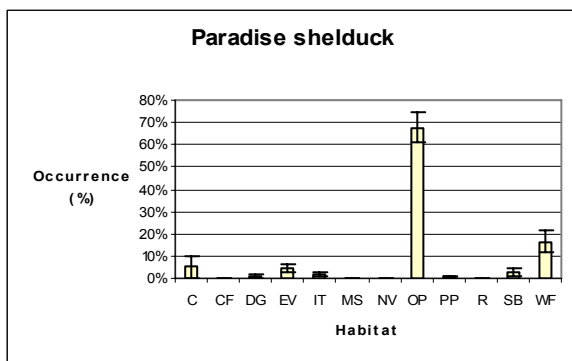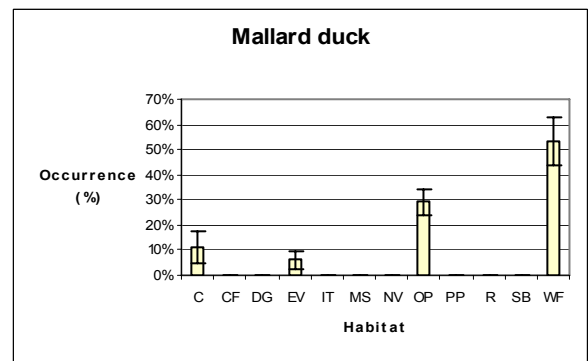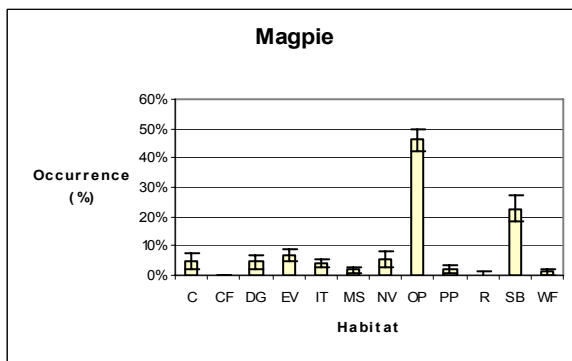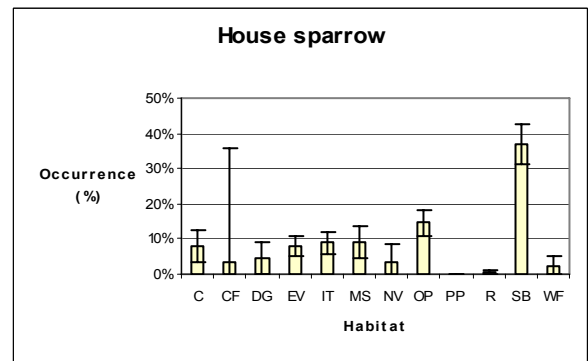
Both blackbird and song thrush had similar overall habitat preferences, with most records coming from the SB/EV, NV and OP/DG categories.  Both skylarks and starlings were more frequently recorded in crops and OP/DG categories.  Skylark, song thrush and starling all occurred more frequently in ploughed paddocks and less frequently in open paddocks and dense grass on high-magpie farms.  Skylark also occurred more frequently in crops on high-magpie farms, while starling occurred less frequently in crops, and more frequently in the 'Other' category on high-magpie abundance farms.

The vast majority of bellbird records were in native vegetation, with a much smaller proportion of records in the SB/EV and OP/DG habitats. The records in open paddocks and dense grass were all of birds flying over this habitat. We confined the analysis of bellbird habitat use to the SB/EV, NV and OP/DG categories due to the smaller number of records for this species. There was significantly more use of shelterbelts and other exotic vegetation and decreased use of open paddocks and dense grass when magpies were more abundant.

**Figure 7. Percent use of different habitats for the twelve original habitat categories (see Section 3.4) for all species with Distance abundance estimates.** Bars are the average proportional use for each category from all farms where each species was found. Habitat codes are as follows: C = Crop, CF = Cliff, DG = Dense grass, EV = Exotic vegetation, IT = Individual tree, MS = Man-made structure, NV = Native vegetation, OP = Open paddock, PP = Ploughed paddock, R = Road, SB = Shelterbelt, and WF = Water feature. For a full description, see Section 3.4 and Table 1.

Greenfinch



Grey warbler



Harrier hawk



House sparrow



Magpie



Mallard duck



Paradise shelduck



Pied oystercatcher

## Pied stilt



## Redpoll



## Silvereye



## Skylark



## Song thrush



## Southern black backed gull



## Spur winged plover



## Starling

Welcome swallow



White faced heron



Yellowhammer
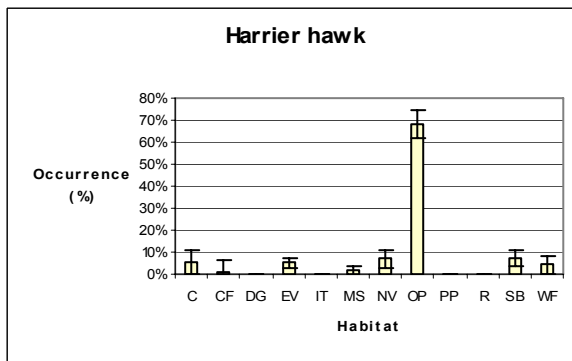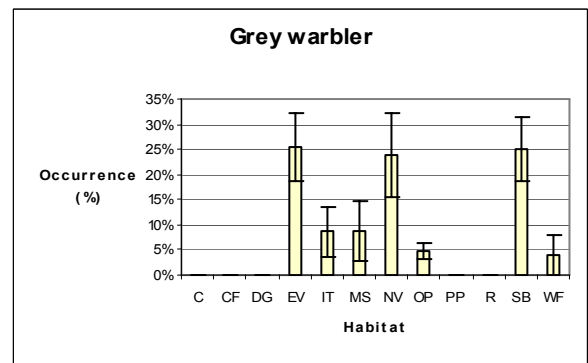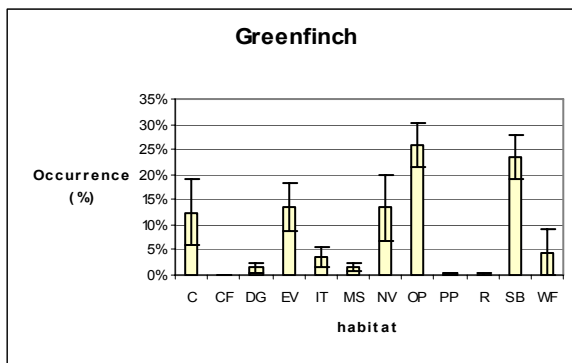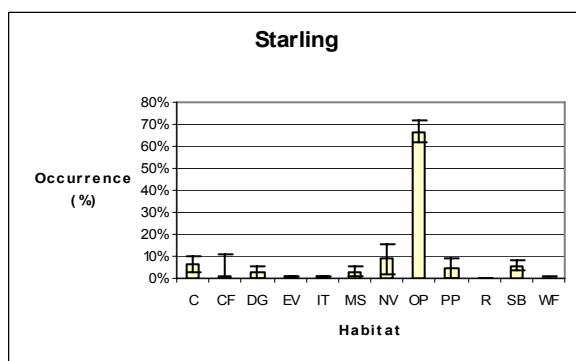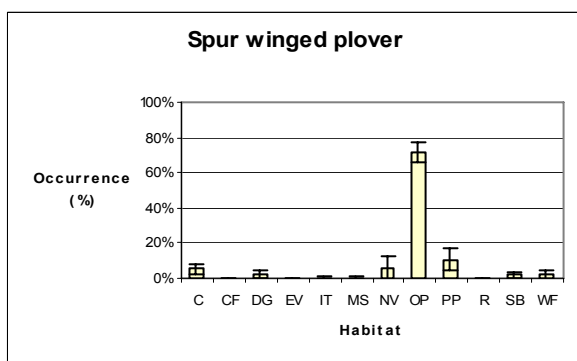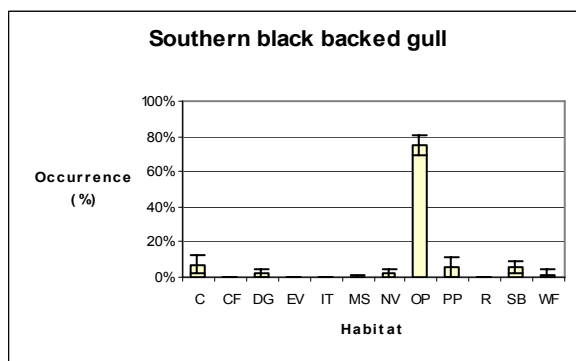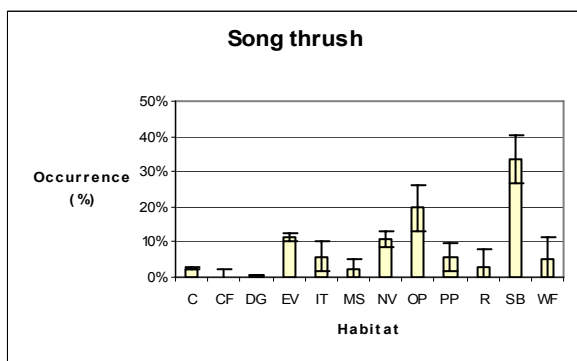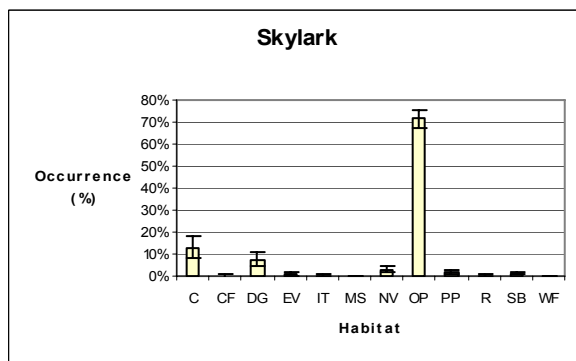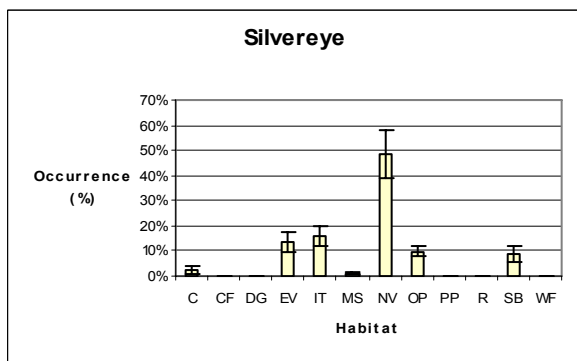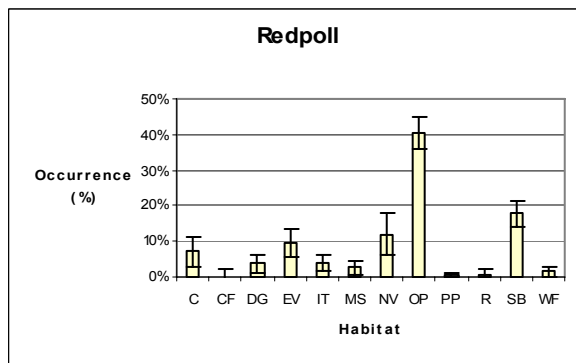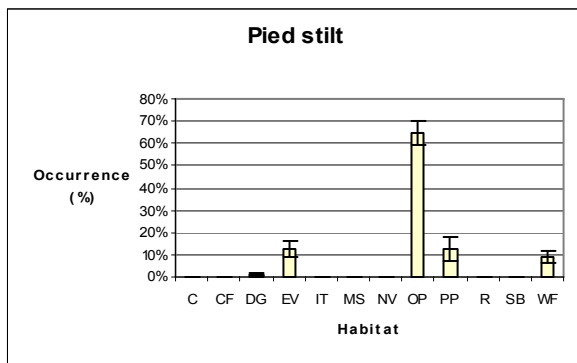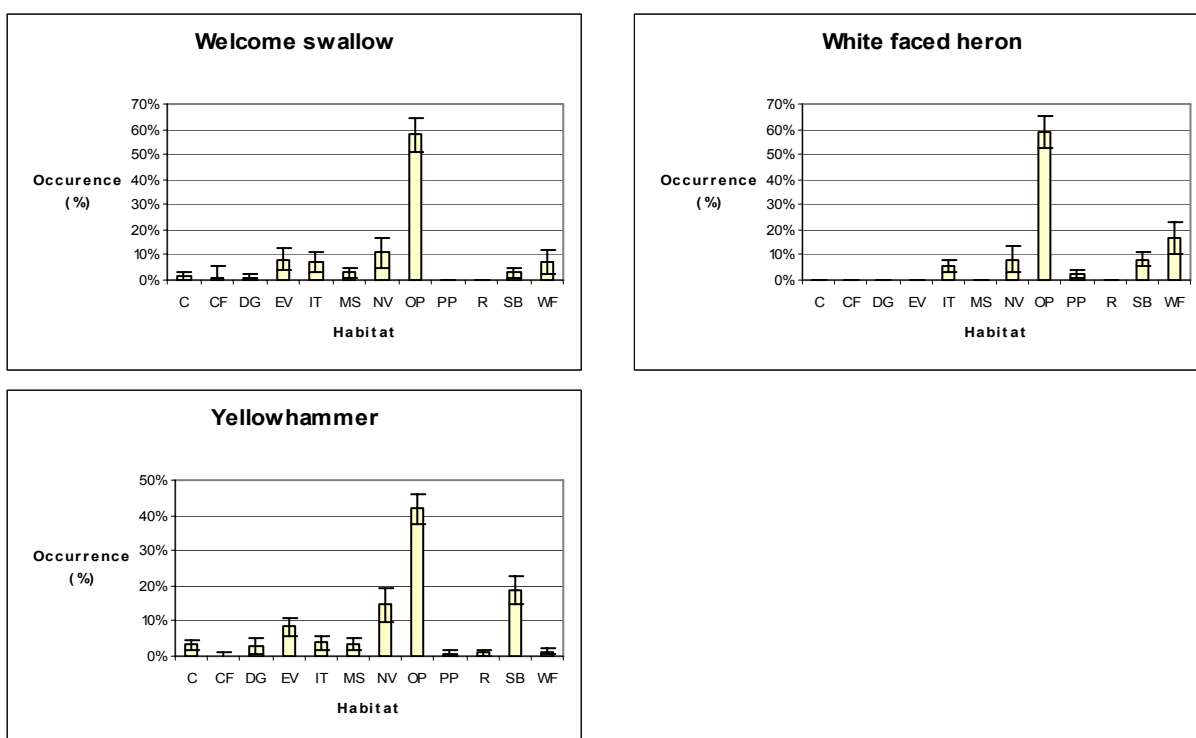
**Table 6. Proportional habitat use in the six composite habitat categories for selected species on low and high magpie abundance farms.** Species were chosen following Innes et al (2004) and differences in habitat use were compared using a chi-square test, which compares the observed proportions to those expected if there was no effect of magpies on habitat use. The habitat codes are as follows: C= crop, SB/EV = shelterbelts and exotic vegetation, NV = native vegetation, OP/DG = open paddocks and dense grass, PP = ploughed paddocks, and Other = farm tracks and structures and water features. Full descriptions of the habitats are given in Section 3.4 and in Tables 1 and 2.

| Species | Abundance category | C | SB/EV | NV | OP/DG | PP | Other | Chi-square | P |
|---------|--------------------|------|-------|-------|-------|-------|-------|------------|-------|
| **Magpie** | Low-magpie | 4.37 | 25.79 | 2.58 | 57.74 | 2.38 | 7.14 | 7.48 | 0.19 |
| | High-magpie | 4.75 | 24.13 | 4.75 | 53.38 | 2.93 | 10.05 | | |
| Blackbird | Low-magpie | 3.03 | 32.32 | 12.88 | 31.31 | 10.86 | 9.60 | 6.90 | 0.22 |
| | High-magpie | 2.56 | 30.35 | 13.10 | 39.30 | 7.35 | 7.35 | | |
| Skylark | Low-magpie | 18.77 | 2.28 | 2.13 | 74.47 | 0.91 | 1.44 | 81.01 | <0.001 |
| | High-magpie | 29.42 | 4.32 | 1.68 | 59.63 | 3.60 | 1.36 | | |
| Song thrush | Low-magpie | 1.85 | 32.87 | 13.43 | 42.13 | 3.70 | 6.02 | 37.75 | <0.001 |
| | High-magpie | 1.51 | 32.66 | 11.06 | 24.12 | 20.60 | 10.05 | | |
| Starling | Low-magpie | 11.59 | 4.59 | 2.17 | 79.86 | 0.05 | 1.74 | 397.55 | <0.001 |
| | High-magpie | 3.52 | 9.45 | 1.84 | 68.14 | 9.50 | 7.55 | | |
| Bellbird | Low-magpie | 0.00 | 6.03 | 81.03 | 10.34 | 0.00 | 2.59 | 7.51 | 0.02 |
| | High-magpie | 0.00 | 10.22 | 78.49 | 8.06 | 0.00 | 3.23 | | |

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# 4  Discussion

## 4.1  Precision of abundance estimates

Precision of abundance estimates calculated by Distance, as measured by the coefficient of variation (CV), ranged from 4% to 228% for individual farms. Only 24% of abundance estimates were below the CV <20% recommended for estimates of abundance (White *et al.*, 1982, in Corn & Conroy, 1998). Of the 706 abundance estimates, half had a precision above 37%. For magpie, the precision of the abundance estimates was moderate, with the CV <20% on 12 of the 37 farms, and <30% on 25 of the farms, although it reached 100% on one farm. This level of precision may not have been high enough to identify some subtle but important trends in the data, such as differences in magpie abundance between farms and management types (Section 4.1). Magpie abundance differed between farms, but the large 95% confidence intervals meant there was not enough power to test if any of these differences were significant. Similarly, our tests for correlations between magpie and other bird abundance will have been weakened by the high CVs evident in individual farm estimates.

The precision of the abundance estimates could be improved by taking repeated surveys of the sampling sites to build up sample sizes to >60 observations, as recommended by Buckland *et al.* (2001). Increasing the number of observations would also diminish other problems, such as data loss resulting from truncation. For example, the optimal model for white faced heron involved truncation at 101m. As a result of this, the abundance of farm 7A became 0, as the only white faced heron recorded on that farm had a perpendicular distance of 196m. However, the species of primary interest in this study (blackbird, skylark, song thrush and starling) generally had CVs below the recommended level of 20%.

Long-term monitoring on ARGOS farms will eventually overcome some of these limitations in precision of bird abundance estimates for each individual property. However, models predicting variation in bird abundance at individual farm levels are unlikely to be strong until there have been three or four repeated surveys there (in 6-8 years). The initial main null hypothesis under test by the programme is that there is no difference in environmental, social and economic outcomes between organic, IM and conventional panels. Once our abundance estimates are averaged for all 12 farms in each panel, the standard error of the mean was 5.5-86.2% of the panel average for the six species being investigated in detail here. Therefore tests of the farming systems null hypothesis will be much more powerful than investigations requiring individual farm estimates of bird abundance, but power will remain low for some species like bellbird.

## 4.2  Accuracy of abundance estimates

Some of the scientific questions raised by the ARGOS agenda can adequately be answered provided the bird abundance estimates are relatively precise, even if not accurate. For example, provided that there is no bias in the estimates, a relative index of abundance would suffice to test most aspects of the ARGOS farming systems hypothesis. However, other more specialised agendas, such as ecological energy budgets for instance, might require both precise and accurate estimates.

There are three critical assumptions of the distance sampling technique that must be met if our abundance estimates are to taken as accurate indicators of actual densities on the ARGOS farms. The assumptions are that (1) all birds on the line are detected; (2) birds are detected prior to evasive movement triggered by the observer; and (3) distances are measured accurately (Rosenstock *et al.*, 2002).

The majority of transects on the farm moved through paddocks for most of their length, although some of these were planted in crops or had dense ungrazed grass. Very few or no birds on the line were missed in ploughed paddocks and grazed pasture, although it is

possible that some were missed in crops or when the transect passed though shelterbelts, native or exotic forest and other woody vegetation, or when a hill or hummock obscured some part of the paddock from the observer. Overall it is unlikely that many birds within 15-20 m of the observer along the transect were missed. Nevertheless, it is possible that some birds that were originally on the transect line at greater distances from the observer would have moved away before they were sighted.

Some birds were not detected until they were flushed by the observer and flew away. This generally only occurred at distances of <20m, and always took the form of rapid, explosive, and highly visible flight (there were no flightless birds on the farms that may have quietly moved away through the vegetation without being detected). Therefore observers were able to fairly accurately determine the original location of the bird before it was disturbed by the observer.

Distance sampling requires that the perpendicular distance of the bird from the transect line can be precisely determined. All observers were equipped with a laser range-finder, accurate to one metre at distances less than 60m. However, there were several factors that affected this accuracy. It could be hard to get an accurate distance reading when birds were observed at large distances (>60 m), or were moving, because they presented a very small target to fix the laser on. If the bird was sighted on the ground, the grass or crop may scatter the laser beam to such an extent that the range-finder could not estimate the distance. In such cases it was often possible to record the distance by sighting on a nearby habitat feature, such as the fence post the bird was perched upon. If the bird was in a shelterbelt or other woody vegetation, the laser may bounce back from the main trunk rather than the exact branch the bird was on. There was error associated with estimating the distance of flying birds, as they are almost impossible to get a direct fix on. Again, it was necessary to use a nearby habitat feature if available, or otherwise to exclude the bird from the analysis. A further potential error was introduced if the bird was not observed perpendicular to the line, but rather at an angle to the transect. In such cases the observers used a compass to determine the angle to the transect line so that the distance to the bird could be converted to a perpendicular distance. There is a risk in such cases that the observer will read the compass inaccurately (particularly if the bird is far away), or that they will round the angle to the nearest 5 or 10°. Consequently, the distance estimates to the birds were not always exact, thereby contributing to inaccuracy in the detection function and hence the abundance estimates. However, individual distances are often pooled in to distance bands (for example, all birds recorded between 10 and 15 metres from the transect) for analysis, and records far from the transect were often discarded to improve the fit of the model (see 'Truncation' in Appendix 7.2).

Overall then, the data collected in our surveys generally met the assumptions of distance sampling. More worryingly, we did find evidence of differential conspicuousness of magpies and starlings in our low-magpie and high-magpie farms (Table 4, Figures 4 & 5). This may relate to habitat or landscape differences between the groups (tall vegetation and hills tend to obscure long-distance vision of the observers; Blackwell *et al.* 2005a,b). Whatever its source, the analysis challenges our assumption that a global detection function applies i.e. that the same species detection function applies for all farms for a given species. Repeated surveys to amass more data will eventually allow us to measure the error associated with this initial simplifying assumption.

The correlation of magpie abundance with the detectability of at least some species suggests that magpies have the potential to disrupt the monitoring methods. This gives further weight to Blackwell *et al.* (2005a)'s recommendation that five-minute bird counting should be avoided. Much more intensive sampling will be needed to further investigate the degree of interference in detectability by magpies and eventually to incorporate different detection functions for each farm to factor out their impact. In the meantime we recommend that magpie abundance is retained as a covariate in all ANOVA or General Linear Modeling of abundance estimates for other species.

## 4.3  Do magpies affect abundance and presence of other birds?

Results from this study showed that magpie abundance did not correlate with the abundance of most other bird species at the whole-farm scale.  There were positive correlations between magpie abundance and that of chaffinch and house sparrow, but these were not significant when more conservative statistical tests were used (Table 5). Average bird abundances for the four species thought to potentially be most affected by magpie were not significantly different between low-magpie and high-magpie farms (Table 4). There was no evidence that differential conspicuousness has confounded this result (Table 3).   Nor was there any suggestion that some species of birds were completely absent on high-magpie versus low-magpie abundance farms.  Collectively these results give no evidence for magpies impacting on population abundance and distribution of other species when measured at a whole-farm level. However, the power of our tests of magpie impacts was severely limited by (a) low precision of abundance estimates at each farm and (b) our need to pool data across all farms for each species (thereby assuming a constant detection function across all farms).   If magpie detection functions had been equivalent between the low-magpie and high-magpie groups of farms, or had we been able to calculate a separate detection function for each farm, we would have achieved much better tests for impacts by ANOVA (Table 4) and correlation (Table 5, Figures 5 & 6). Also, as there was relatively little variation in magpie abundance itself (5-fold from min-max), there was relatively little scope for correlations between magpie and other bird abundance.  The only really satisfactory evaluation of magpie impacts would be by experiments where magpies are controlled and the abundance of other species monitored.

Innes *et al.* (2004) did such an experiment but were not able to determine if the increased counts for blackbird, kererū, myna, skylark, song thrush and starling in areas with magpie control were due to increases in their abundance or in conspicuousness.  It is plausible that birds will forage more widely or spend more time in the open when magpies are scarce – indeed we detected signs of such habitat shifts in our study.  But we found that bellbirds, blackbirds, skylarks and song thrushes were about equally detectable in low-magpie and high-magpie farms. The detection functions for starlings did indeed differ between low- and high-magpie abundance farms, but in the opposite direction predicted by magpie harassment.  Accordingly, our result challenges Innes *et al.*'s (2004) interpretation that their apparent experimental effect was driven by changes in conspicuousness rather than real increases in bird abundance.

## 4.4  Do magpies alter habitat use by other bird species?

Magpies are territorial and aggressive, and frequent tall vantage points from where they can broadcast territorial calls and detect other magpies and potential competitors or prey (Heather and Robertson 2000).  Over 50% of magpie habitat use on all farms was in open paddocks and dense grass, which may reflect preferred foraging sites for invertebrates.  Magpie abundance may be high enough in these habitats on high-magpie farms to cause the shift in skylarks, song thrushes and starlings out of open paddocks into other habitats, particularly ploughed paddocks, which we observed.  Skylarks require grassy pasture in which to nest and forage, while song thrushes and starlings may preferentially forage in these habitats.  Magpies were very rarely recorded in ploughed paddocks, so this habitat may provide an alternative refuge foraging site for skylark, song thrush and starling in the presence of high magpie abundance.

The differences we recorded in bellbird habitat use may also reflect interference competition with magpies, but the lower number of sightings and patchy distribution of bellbirds prevents firm conclusions.  There was little difference in the proportion of bellbird records in native bush on farms with different magpie densities.  This is to be expected, as magpies are known to seldom frequent native bush (Chambers, 1989) and bellbirds are most often found in this habitat type (Heather and Robertson, 2000).  There were fewer records of bellbirds in open paddocks and more in shelterbelts and exotic vegetation where magpies were more

abundant. This may reflect attempts by bellbirds to escape interference from magpies as they crossed open paddocks to reach isolated bush fragments (Innes *et al.*, 2004).

The lack of difference in blackbird habitat use on low and high magpie farms suggests that competition between the species is not driving blackbird population abundance or behaviour.

## 4.5  Is control of magpies needed for biodiversity conservation?

Future surveys of ARGOS and other farmer's investment in magpie control and efficacy of their efforts is recommended.  This preliminary study was motivated in part by two of the participating farmers reporting that they attempt to control them.

Our findings broadly concur with those of Innes *et al.* (2004) and Morgan *et al.* (in review) who also suggest that magpies may displace other birds only on local scales.  Nevertheless, we did find tentative evidence that the habitat use by skylark, song thrush and starling shifted between low-magpie and high-magpie abundance farms.  These changes were predominantly in the direction predicted by magpie harassment, especially avoidance of the open pasture areas.   Our correlative tests had low power to detect impacts on bird abundance or distribution.  Also our distance sampling did not support Innes *et al.* (2004)'s *post hoc* explanation that increased bird counts following magpie control was caused by increased conspicuousness. Collectively these contradictory strands lead us to conclude that putative impacts of magpies on other bird abundance can neither be ruled out nor confirmed from the evidence so far available.  Another experiment in which magpies are removed and more intensive distance sampling of the other birds is still needed to clinch the issue and thereby to assess whether magpie control effort assists bird conservation.  Unfortunately ARGOS does not have sufficient resources to mount such an experiment in the near future.

Until such an experiment is completed, we see little reason for farmers to invest time and money in magpie control, at least for reasons of biodiversity conservation.  Priority in control effort should be given to more serious predators such as rats and mice, stoats, ferrets, possums and feral house cats. There is much more definite evidence that these have negative impacts on native birds and they may also affect beneficial introduced birds (Moller *et al.* 2005).  If  restoration of birds on farms is the aim, provision of suitable habitat or food resources by planting of kowhai, native broom and other food producing plants and potentially also the provision of nest boxes should prove more beneficial and cost effective than magpie control.

## 4.6  Does magpie abundance vary between farming systems?

We found no evidence that farming system affected magpie abundance.  This might be attributed to the imprecision of the abundance estimates and failure to meet the assumption of equal detectability on all farms. However, it might also reflect a mismatch in scale and variety of the agricultural landscape in which magpies are found compared to the nature of our sampling at the whole farm spatial scale.   Farm boundaries may not be ecological boundaries for magpies or the other species we investigated for impacts.  For example, magpies may roost on a farm where management has encouraged the retention and planting of trees, but may forage on a neighbouring farm if it contains greater food resources in open paddocks.  While breeding magpies are strongly territorial, non breeding groups are semi-nomadic (Carrick, 1972 in Morgan *et al.*, in review), so their range could encompass a number of properties with different farming systems.  With only some of their time spent on any one farm, the impact of specific management actions such as farming system and magpie control may be very real but undetectable by sampling at whole-farm scales.

Our distance sampling has so far only been conducted on one morning per farm and therefore only gives a snap-shot of the bird community present at one season.  A low abundance in this first spring/summer survey might represent unsuitable general habitat, unfavorable farm management practices for magpies, recent magpie control, or simply chance (they may have been concentrated on a neighbouring farm at the time of the survey).

Repeated surveys of magpies (including identification of individual birds), accompanied by surveys of available habitat and resources on both the focal ARGOS farm and surrounding properties would be required to clarify the relationships between organic, IM and conventional farm management. Improved habitat measures at a landscape level will eventually be available via remote sensing and GIS (Moller *et al.* 2005) and repeated surveys are planned annually on a subset of 9 or 12 ARGOS farms, and on all 37 ARGOS farms every 3 or 4 years.

In the meantime there is no evidence to reject the null hypothesis that magpie abundance does not vary between organic, IM or conventional farms. Therefore, so far we have no reason to expect that magpie harassment will drive differences in bird abundance between organic, IM or conventional farms.

## 4.7  Conclusions and recommendations

1. ARGOS must use distance sampling methods to monitor bird abundance because this study detected differences in detectability of some species between farms.

2. Global detection functions are unreliable for some species, so different detection functions will be needed for each farm.

3. Investigation of links between detection functions and forthcoming habitat and terrain measures may predict 'correction factors' for detection functions for each farm and species. Otherwise the ARGOS programme must invest in sufficient extra distance sampling to achieve at least 60 observations per species per farm.

4. At current intensity of sampling, around half the species present can be estimated with reasonable precision. Firm prioritization of investigation and analysis around a subset of focal species will be needed.

5. Magpies are ubiquitous and their abundance varies relatively little amongst South Island sheep/beef farms. Their average abundance is around 0.18 birds per hectare (95% c.i. 0.16-0.21 per ha).

6. Magpie abundance should be included as a covariate in all statistical tests of changes in abundance of birds on farms. This is the safest and only practical 'patch' available until more definitive evidence is available to prove or discount that magpies interfere with chosen bird monitoring methods.

7. The abundance and presence/absence of other bird species did not correlate with magpie abundance, but there was evidence of shifts in habitat use in the presence of relatively high magpie abundance (especially avoidance of open paddock areas). However there was no evidence for reduced conspicuousness of other birds in the presence of relatively more magpies, so the increased bird counts following magpie control (Innes *et al.* 2004) may have reflected real changes in abundance rather than just increased conspicuousness. These conflicting inferences mean that another experiment using Distance sampling methods is needed to test whether magpies affect overall abundance of other birds. Until this experiment is completed, magpie impacts on other species can neither be asserted nor ruled out.

8. The value of magpie control for biodiversity conservation is therefore uncertain. Control of the introduced small mammal pests (rodents, mustelids, hedgehogs, possums and feral house cats), and provision of suitable habitats are probably much more likely to help restoration of bird populations on farms than will control of magpies. Current effort by farmers on magpie control should be monitored.

9. There is no evidence that magpie abundance varies between organic, IM or conventional farms. Therefore there is no reason to suspect that magpies will drive differences in the abundance of other birds in these different farming systems.

10. We do not recommend choice of magpie as a priority focal species but urge a watching brief to continually reassess their potential importance in affecting other species and interfering with bird abundance estimation.

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# 6  Appendices

## 6.1  Species list

| Common name(s) | Scientific name | Number of observations |
|---|---|---:|
| Banded dotteral (tuturiwhatu) | *Charadrius binictus* | 2 |
| Bellbird (korimako) | *Anthornis melanura* | 106 |
| Black billed gull | *Larus bulleri* | 7 |
| Black shag (kawau) | *Phalacrocorax carbo* | 3 |
| Blackbird | *Turdus merula* | 456 |
| California quail | *Callipepla californica* | 10 |
| Chaffinch | *Fringilla coelebs* | 364 |
| Cirl bunting | *Emberiza cirlus* | 5 |
| Duck (assorted spp) | | 32 |
| Dunnock | *Prunella modularis* | 86 |
| Falcon (karearea) | *Falco novaeseelandiae* | 3 |
| Fantail (piwakawaka) | *Rhipidura fuliginosa* | 49 |
| Feral pigeon | *Columba livia* | 79 |
| Goldfinch | *Carduelis carduelis* | 598 |
| Greenfinch | *Carduelis chloris* | 544 |
| Grey duck (parera) | *Anas superciliosa* | 6 |
| Grey warbler (riroriro) | *Greygone igata* | 98 |
| Harrier hawk (kahu) | *Circus approximans* | 84 |
| House sparrow | *Passer domesticus* | 448 |
| Kererū | *Hemiphaga novaeseelandiae* | 8 |
| Kingfisher (kotare) | *Halcyon sancta* | 6 |
| Little owl | *Athene noctua* | 1 |
| Magpie | *Gymnorhina tibicen* | 580 |
| Mallard duck | *Anas platyrhynchos* | 38 |
| Morepork (ruru) | *Ninox novaeseelandiae* | 1 |
| Paradise shelduck (putangitangi) | *Tadorna variegata* | 71 |
| Pheasant | *Phasianus colchicus* | 1 |
| Pied oystercatcher (torea) | *Haematopus ostralegus* | 108 |
| Pied stilt (poaka) | *Himantopus himantopus* | 20 |
| Pipit (pihoihoi) | *Anthus novaeseelandiae* | 1 |
| Poultry | *Gallus gallus domesticus* | 15 |
| Pūkeko | *Porphyrio porphyrio* | 6 |
| Red billed gull (tarapunga) | *Larus novaeseelandiae* | 4 |
| Redpoll | *Carduelis flammea* | 773 |
| Rifleman (titipounamu) | *Acanthisitta chloris* | 7 |
| Robin (toutouwai) | *Petroica australis* | 3 |
| Shining cuckoo (pipiwharauroa) | *Chrysococcyx lucidus* | 1 |
| Silvereye (tauhou) | *Zosteropus lateralis* | 81 |
| Skylark | *Alanda arvensis* | 1640 |
| Song thrush | *Turdus philomelos* | 395 |
| Southern black backed gull (karoro) | *Larus dominicanus* | 173 |
| Spur winged plover | *Vanellus miles* | 249 |
| Starling | *Sturnus vulgaris* | 504 |
| Tomtit (ngiru-ngiru) | *Petroica macrocephala* | 15 |
| Tui | *Prosthemadera novaseelandiae* | 11 |
| Turkey | *Meleagris gallopavo* | 4 |
| Welcome swallow | *Hirundo tahitica* | 132 |

| | | | | | |
|---|---|---|---|---|---|
| White faced heron (matuka-moana) | *Ardea novaehollandiae* | | | | 20 |
| Yellowhammer | *Emberiza citrinella* | | | | 728 |

## 6.2 Global detection functions for each species

| Species | Key function | Adjustment factor | Truncation | Interval Number | Chi-p |
|---|---|---|---|---|---|
| Bellbird | Negative exponential | Simple polynomial | 141 | 7 | 0.672 |
| Blackbird | Negative exponential | Simple polynomial | 125 | 6 | 0.501 |
| Chaffinch | Hazard rate | Simple polynomial | 150 | 14 | 0.770 |
| Duck (assorted spp) | Negative exponential | Simple polynomial | none | none | 0.786 |
| Dunnock | Negative exponential | Simple polynomial | 68 | 7 | 0.961 |
| Fantail | Hazard rate | Cosine | none | 10 | 0.881 |
| Feral pigeon | Negative exponential | Simple polynomial | 190 | none | 0.087 |
| Goldfinch | Half normal | Cosine | 190 | 11 | 0.398 |
| Greenfinch | Negative exponential | Simple polynomial | 200 | none | 0.357 |
| Grey warbler | Hazard rate | Cosine | 250 | 10 | 0.859 |
| Harrier hawk | Hazard rate | Simple polynomial | none | none | 0.477 |
| House sparrow | Negative exponential | Simple polynomial | 175 | 8 | 0.316 |
| Magpie | Half normal | Cosine | none | 17 | 0.841 |
| Mallard duck | Negative exponential | Simple polynomial | none | none | 0.206 |
| Paradise shelduck | Negative exponential | Simple polynomial | none | none | 0.960 |
| Pied oystercatcher | Negative exponential | Simple polynomial | 200 | 10 | 0.971 |
| Pied stilt | Half normal | Cosine | 180 | 19 | 0.779 |
| Redpoll | Hazard rate | Simple polynomial | 100 | 10 | 0.940 |
| Silvereye | Hazard rate | Cosine | 80 | 8 | 0.705 |
| Skylark | Half normal | Cosine | 270 | 11 | 0.535 |
| Song thrush | Hazard rate | Cosine | 200 | 8 | 0.755 |
| Southern black backed gull | Negative exponential | Simple polynomial | none | none | 0.846 |
| Spur winged plover | Half normal | Cosine | none | 22 | 0.939 |
| Starling | Uniform | Cosine | 160 | 8 | 0.884 |
| Welcome swallow | Half normal | Cosine | none | 7 | 0.961 |
| White faced heron | Hazard rate | Cosine | 101 | 10 | 0.659 |
| Yellowhammer | Hazard rate | Simple polynomial | 160 | none | 0.477 |