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Native bird abundance after Australian magpie (*Gymnorhina tibicen*) removal from localised areas of high resource availability

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Abstract: Many reports exist of Australian magpies (*Gymnorhina tibicen*) attacking and sometimes killing other birds. One study concluded that magpies had little impact on the abundance of other birds at landscape scales, but another found that birds (mainly exotic species) avoided flying or landing close to them. We assessed whether continuously removing magpies for 6 weeks from localised areas of high resource availability (e.g. bush remnants or private gardens with fruit- or nectar-producing trees) in rural areas increased visitations by native birds compared with similar sites where magpies were not removed. Three count methods were used to estimate bird abundance: five-minute bird counts and 'slow-walk' transects in bush remnants, and five-minute bird counts and 'snapshot' counts in gardens. Generally, the abundance of native birds did not increase in treatment areas after magpie removal. In bush remnants, transect counts were typically better at detecting the presence of most species compared with five-minute bird counts. In gardens, snapshot counts were better at detecting tui (*Prosthemadera novaeseelandiae*) while five-minute bird counts were better at detecting magpies. Despite these differences, the different bird counting methods were generally in agreement and revealed that magpies had little impact on native birds at the scale we examined.

Keywords: bird monitoring; exotic pest; local-scale; removal experiment
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Introduction

Australian magpies (*Gymnorhina tibicen*; 'magpie' hereafter), introduced to New Zealand during the mid-19th century (Thomson 1922), are now widely distributed and particularly abundant in rural habitats (Robertson et al. 2007). They are conspicuous birds that prefer extensive short pasture for foraging and tall trees for nesting (Heather & Robertson 1996). In New Zealand, the magpie is often perceived as a pest species reducing abundance and affecting the distribution of native birds (Barrington 1995, 1996). This perception is likely based on numerous anecdotal and published accounts of magpies chasing, attacking and even killing many bird species (e.g. McCaskill 1945; reviewed by Morgan et al. 2005); however, reasons for these attacks are obscure as magpies seldom prey on other birds (Morgan et al. 2006a,b), and their resource requirements often do not overlap with their target species (Morgan et al. 2005).

Reducing magpie populations on several large (c. 900 ha) rural blocks in New Zealand resulted in significant, but relatively small increases in only one native species (New Zealand pigeon, kererū *Hemiphaga novaeseelandiae*; a comparatively rare species in rural habitats), and five exotic species (Eurasian blackbird *Turdus merula*; common myna *Acridotheres tristis*; Eurasian skylark *Alauda arvensis*; song thrush *Turdus philomelos*; and common starling *Sturnus vulgaris*) over a 3-year period (Innes et al. 2012). Another study reported that rural birds also actively avoided foraging close (<50 m) to magpies relative to adjacent magpie-free areas (Morgan et al. 2006a). These studies suggest that while magpies may not have a major impact on other birds on a large-scale, they may be altering the distribution of these on a local scale.

For exotic passerines, the predominant avian species in New Zealand's rural areas (Blackwell et al. 2005), the potential cost of being displaced by a magpie is likely trivial; their displacement distances are usually short (e.g. 200–700 m; Morgan et al. 2006a) because suitable foraging sites (i.e. pasture) are ubiquitous. In contrast, for native species with specialised dietary requirements, the energetic costs of magpie displacement are potentially large. Tūī (*Prosthemadera novaeseelandiae*) and kererū, for example, forage mainly on nectar- and fruit-bearing plants (Heather & Robertson

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1996) that are usually confined to bush remnants or private gardens. These habitats are intermittently dispersed across the rural landscape, so alternative resources for native birds may be several kilometres away. As tūī and kererū observations are often sporadic, quantifying changes in their numbers or behaviour in relation to magpie presence is difficult (Morgan et al. 2006a; Innes et al. 2012), without a more targeted monitoring approach.

The main aim of this study was to measure the impact magpies have on the abundance of native birds in rural areas where high resource availability exists (e.g. bush remnants or private gardens containing nectar- or fruit-bearing plants). These habitats should attract the greatest number of native birds during times when plants are in bloom or producing fruit (spring to early summer). We predicted that if magpies do have a local-scale impact on the distribution of native birds, visitation rates by native birds during peaks in food availability should be higher at sites where magpies have been removed (quantified by measuring abundance). Such an effect may explain not only anecdotal reports of native birds 'disappearing' from rural gardens after the arrival of magpies (e.g. McCaskill 1945; McIlroy 1968; Barrington 1995), but also why increases in bird abundance were generally not detected during the large-scale magpie removal programme described above (Innes et al. 2012).

A second aim was to compare the performance of different count methods in measuring changes in bird abundance associated with magpie removal. Innes et al. (2012) were able to use five-minute bird counts (5MBCs; Dawson & Bull 1975) to reliably detect changes in bird abundance during their large-scale magpie removal programme as their study was conducted over a relatively long period (4 years) and each study site was large enough (c. 900 ha) to incorporate many counting stations. However, the sites in the current study were comparatively small, which meant that fewer count stations could be established. Furthermore, the study was necessarily conducted over a short time frame (i.e. during peaks in food abundance). Accordingly, 5MBCs may not have been optimal. Therefore, in addition to 5MBCs, we trialled two other count methods that may better detect changes that occur at a local-scale: 'snapshot' counts (see below) and modified 'slow-walk' transects (Lovegrove 1986).

Methods

Our study focused on small bush remnants (n = 16; c. 0.5 – 4 ha) and gardens (n = 6) surrounded by pasture but close to Pirongia Forest Park (Waikato), a podocarp–broadleaved dominated forest (17 000 ha) with large resident populations of many native bird species, including tūī and kererū. Sites (located between 37°50'35.99"S, 175° 7'0.43"E in the north-east and 38° 2'45.22"S, 175° 9'11.61"E in the south-east; a total distance of 23.13 km) were selected by approaching landowners or volunteers responding to a local advertisement. All sites were separated by a minimum distance of 600 m (to reduce the likelihood of the same magpies visiting multiple sites) and had had no magpie trapping conducted for at least 2 years. Bush remnants varied in composition, but generally contained native fruit- and nectar-bearing trees such as tawa (*Beilschmiedia tawa*), kōwhai (*Sophora microphylla*), kahikatea (*Dacrycarpus dacrydioides*), and rewarewa (*Knightia excelsa*). Garden sites contained some of these native trees, but also exotics including Japanese cherry (*Prunus serrulata*), *Banksia* spp., and fruit trees.

Over the study period, a total of nine visits were conducted per site: three in the pre-trapping period (a 3-week period: 21 August – 8 September 2006) and then another three surveys during each of the two trapping periods (two consecutive 3-week blocks; 18 September – 26 October 2006). During each visit bird counts were completed between 0630 and 1530 hours, but most (83%) were completed before 1200 hours. Counts were not conducted if the weather was excessively wet or windy as these conditions have been shown to reduce bird conspicuousness and observer performance (Ratkowsky & Ratkowsky 1979).

A subset of eight bush-remnant and three garden sites were randomly chosen as magpie removal (treatment) sites, while remaining sites were used as controls (no magpie removal; non-treatment sites). Each magpie removal site received 2–4 traps (Larsen traps or commercially available magpie 'trip-traps'), each containing a 'call bird' (see Morgan et al. (2007) for details). Food, water and perches were provided in the traps. Traps were cleared daily within 12 h of sunrise; any caught magpies were humanely killed by a blow to the head with a blunt object.

Bird monitoring

At each site, we monitored the relative abundance of magpies and five focal native bird species (tūī, kererū, New Zealand fantail *Rhipidura fuliginosa*, grey warbler *Gerygone igata*, and New Zealand kingfisher (kotare) *Todiramphus sanctus vagans*) before and during magpie removal. These focal species were selected because they were the most common 'iconic' or high-conservation-value species inhabiting the study region (Barrington 1995, 1996; Morgan et al. 2005).

Five-minute bird counts

Five-minute bird counts were conducted at all sites. The standard 5MBC protocol (Dawson & Bull 1975) was modified to record only magpies and the five focal native species seen or heard within 50 m of the remnant or focal garden tree. Three 5MBCs were conducted during each site visit: before, after and in between the pair of transect or snapshot counts (for remnant and garden sites respectively; see below). At remnant sites, 5MBC stations were located at the beginning and end of each transect, while at the garden sites they were positioned 10–15 m from the focal tree in an inconspicuous place.

Transect counts

Modified 'slow-walk' transects (Lovegrove 1986; 'transects' hereafter) were conducted at remnant sites only (garden sites were too small). At each site, a marked transect was established either through the remnant at its widest point (creating the longest possible route) or, if the remnant was in a gully (with dense undergrowth, or streams and swamps), the transect ran on the pasture adjacent to it, to give the observer a better view. Transects were marked with flagging tape so that the same route could be followed during each visit. Transects varied in length between sites (110–485 m; mean = 251 m ± 28.3 SE).

During each site visit, the observer (DKJM) walked the same transect (at a constant speed of 0.7–0.8 km per hour) in both directions, with at least 7-min intervals between surveys. During the transect walk, all magpies and five native bird species seen or heard within 50 m of the remnant were recorded. For birds flushed along transects adjacent to remnants, the observation was classified according to the bird's initial location. If it was not possible to determine a bird's position relative to the bush remnant during a count and the observer could not ascertain its location afterwards, it was considered >50 m away and excluded from the count. This was mainly a problem for magpies, which often inhabit pasture adjacent to remnants. We treated transect counts as a measure of a species' relative abundance instead of a density estimate. This was because the original 'slow-walk' transect protocol produced an estimate of birds per hectare, while our protocol produced an estimate of a species number per unit area (which was the size of a given remnant). The size of remnants varied considerably between sites and we did not attempt to calculate detection probabilities for this method (MacKenzie & Kendall 2002), making a standardised density estimate difficult to obtain.

'Snapshot' counts

Snapshot counts were conducted only at garden sites. Within each garden site, a high-resource focal tree (usually the largest or most laden nectar- or fruit-bearing tree) was chosen as these generally had the greatest number of native birds present in, or close to it. At least three 50-m lengths radiating out in different directions from the focal tree were marked to help the observer determine bird distance from the tree during counts. Two counts were conducted per site visit and each took 1–2 min to complete, with at least 7-min intervals between counts. The observer walked briskly around the focal tree, following a set route in a roughly circular direction, until the entire area had been searched for birds. Magpies and the five focal native species seen or heard within 50 m of the tree were recorded, with the original position of flushed birds noted. Snapshot counts could potentially provide density estimates for species as the area surveyed was known (0.79 ha); however, we treated data collected from this method as a measure of relative abundance, mainly because no attempt was made to estimate detection probabilities for the other sampling procedures (MacKenzie & Kendall 2002).

Data analysis

Because bird counts within a given site visit were all conducted over a relatively short time frame, differences in bird numbers across those counts were more likely due to inconspicuousness than the absence of those individuals. Thus, for each site visit and survey method (three 5MBCs and two transect or snapshot counts), we calculated the maximum number of birds observed for each species.

The response of birds to magpie removal was measured using (1) 5MBC data and (2) an amalgamation of the transect and snapshot count data. In all cases, counts were analysed using a generalised linear model specifying a Poisson error structure, with a log-link function (where the count variance is proportional to their mean). The latter was equivalent to the biological assumption that controlling magpies would increase a species' abundance by the same proportion at each site, and variance proportional to the mean would follow from a random distribution of birds. The average maximum species count for each stage of the experiment (pre-trapping, trapping block 1, and trapping block 2) at each site was used in the analysis. For 5MBCs, log(pre-magpie trapping count + 0.5) was included as a covariate to adjust the post-treatment count for initial site differences so the two were proportional. To facilitate an amalgamation of the transect and snapshot count data, the ratio of the post-treatment count to pre-treatment count at each site was modelled by adding a log(pre-treatment count + 0.5) covariate with a coefficient of 1.0.

To compare the performance of 5MBCs to the other count methods, we calculated the number of times that each species was recorded during counts using one method but not the other, and vice versa, during all site visits. We then assessed whether a given species was over- or under-represented in 5MBCs relative to the matched alternative survey methods (transect or snapshot counts) by calculating, for each count method and species, the proportion of the total number of birds of all species recorded per site visit. Wilcoxon signed-rank tests (Sokal & Rohlf 1995) were then used to determine if proportionally more of one species was recorded using 5MBCs or transect counts (for remnant sites), or 5MBCs and snapshot counts (for garden sites). Here, we assumed that the probability of detecting a species using different methods at the same site should not vary across treatment and non-treatment sites, so data from all sites were pooled to give 144 and 54 paired comparisons for remnant and garden sites respectively. Resampling sites introduces a lack of independence across samples (Dobkin & Rich 1998). However, our objective was to evaluate the performance of different count methods when conducted concurrently; therefore, by conducting dependent comparisons, only data collected from a given site during the same visit were compared together. On occasions when no birds were detected during one of the count methods during a visit, that visit was dropped from the analysis as the proportional composition of each species could not be calculated. This criterion was employed once for bush remnant sites (when the 5MBC did not detect birds) and on seven occasions for garden sites (on three occasions no birds were detected during snapshot counts, on two occasions during 5MBCs, and on two occasions no birds were detected during either count method).

S-Plus® 6.1 for Windows®, 2001 (Insightful Corporation, Seattle, WA, USA) was used to conduct the general linear model analyses, while *STATISTICA* 9.1 (StatSoft Inc, Tulsa, OK, USA) was used to compare the performance of the 5MBC method to the alternative count methods.

Results

Response of magpie and other birds to magpie trapping

Most (122 of 174; 70.1%) magpies were trapped during the first 3-week trapping block. Over the two trapping blocks, an average of 15.8 (±3.14; range 5–40) magpies were removed from each treatment site, with a significant reduction in magpie numbers recorded during counts at those sites (Table 1, Appendices 1 & 2). However, a remnant magpie population was always present at treatment sites throughout the entire trapping blocks (Appendices 1 & 2).

Removing magpies from treatment sites had little effect on counts of the other birds that were monitored (Table 1); however, tūī marginally increased at magpie removal sites during the first trapping block when compared with non-treatment sites (Table 1, Appendices 1 & 2). This was most likely because very high tūī numbers (means of 11.0 ± 2.1 and 9.3 ± 2.2 for snapshot and 5MBCs, respectively) were counted at one non-treatment site in response to several prolifically flowering Japanese cherry trees during the pre-trapping period. The numbers of flowers from the trees at that site declined towards the end of the pre-trapping period, and were minimal during both trapping blocks; accordingly, a reduction in the numbers of tūī counted

Table 1. Results from a general linear model that tested for the mean change in bird counts in magpie removal sites (T) over non-treatment sites (NT) in relation to pre-treatment bird abundance using: (a) 'transect' and 'snapshot' counting methods, and (b) five-minute bird counts. '% change' = the mean ± SE ratio of treatment to non-treatment as a percentage; therefore, values > 100% indicate an increase in bird abundance in treatment (magpie removal) sites cf. non-treatment (no magpie removal) sites. 'Threshold%' = the ratio of treatment to non-treatment (as a percentage) that would have resulted in a significant species increase.

		(a) Change in T/NT ratio post-treatment				(b) Change in T/NT ratio post-treatment			
Species	Trapping block (TB)	% change	Threshold %	*P* value	Trend	% change	Threshold %	*P* value	Trend
Tūī	TB 1	258 ± 69	237	0.04	Increase	234 ± 66	241	0.06	Marginal increase
	TB 2	91 ± 69	455	0.90		47 ± 40	328	0.21	
	All average	146 ± 65	308	0.51		94 ± 42	249	0.89	
Kererū	TB 1	137 ± 52	251	0.50		101 ± 85	585	0.99	
	TB 2	131 ± 53	261	0.58		126 ± 64	331	0.70	
	All average	134 ± 42	215	0.45		111 ± 60	326	0.86	
Magpie	TB 1	40 ± 16	167	<0.01	Decrease	71 ± 24	183	0.27	
	TB 2	32 ± 13	157	<0.01	Decrease	39 ± 21	194	0.01	Decrease
	All average	35 ± 11	146	<0.01	Decrease	52 ± 19	174	0.03	Decrease
Fantail	TB 1	83 ± 16	144	0.33		87 ± 15	141	0.44	
	TB 2	112 ± 12	127	0.35		123 ± 13	128	0.11	
	All average	97 ± 12	129	0.82		103 ± 13	131	0.81	
Grey warbler	TB 1	101 ± 15	138	0.97		118 ± 22	153	0.44	
	TB 2	108 ± 14	132	0.59		124 ± 21	149	0.30	
	All average	104 ± 14	133	0.77		121 ± 18	141	0.28	
Kingfisher	TB 1	88 ± 29	193	0.69		76 ± 26	185	0.37	
	TB 2	103 ± 32	195	0.92		122 ± 31	180	0.51	
	All average	95 ± 29	188	0.87		97 ± 24	168	0.90	

was then observed (mean < 1 per snapshot or 5MBC). If this site was omitted, then the change in tūī numbers during counts was very similar between treatment and non-treatment sites over the period of the experiment.

Comparisons between count methods

Changes in the abundance of the bird species monitored in response to magpie removal were very similar regardless of the count method used (Table 1). The only deviation from this trend was observed for magpies, which were recorded as significantly decreasing using the snapshot and transect count methods but not the 5MBCs during the first trapping block; however, similar treatment to non-treatment ratios were observed for this species regardless of the count method for the second trapping block and on average (Table 1).

5MBCs and transect counts

The transect count method generally had a greater probability of detecting the six species monitored, particularly kererū and magpie, as these species were detected in transect counts but not 5MBCs in 26 and 28 of the 144 paired comparisons respectively (Table 2 (a)). In comparison, kererū and tūī were only recorded during 5MBCs and not transect counts in 9 and 10 of these paired comparisons respectively (Table 2 (a)). Despite these apparent differences in the detection of birds, the mean proportion of each species detected using the two count methods was very similar (Table 3); while kererū made up a significantly greater proportion of the birds recorded during transect counts, it was only by a small margin (Table 3).

5MBCs and snapshot counts

During bird counts conducted at garden sites, snapshot counts were better at detecting tūī while 5MBCs were better at detecting magpies (Table 2 (b)). These trends were also reflected in the analysis of the paired comparisons across the six garden sites; tūī made up a higher proportion of snapshot counts compared with 5MBCs while the same was true for magpies in the 5MBCs (Table 4). The detection rates and mean proportions of the other four species using these two count methods were similar (Tables 2 (b) & 4).

Discussion

Response of native birds to magpie population reduction

Significant reductions of magpie numbers around bush remnants and private gardens generally failed to increase the abundance of native birds in those areas. This supports findings from a large-scale magpie removal operation, where the only native species to increase after 3 years of magpie removal were kererū by a small amount (Innes et al. 2012). Our current findings differ from those we reported earlier (Morgan et al. 2006a; see also Borowske et al. 2012), where we found that birds largely avoided landing or flying <50 m from territorial

Table 2. Number of times a species was detected during (a) transect and five-minute bird counts (5MBCs) conducted consecutively during visits to 16 bush remnants (n = 144 paired transect and 5MBC comparisons), and (b) snapshot and 5MBCs conducted consecutively during visits to six garden sites (n = 54 paired snapshot and 5MBC comparisons).

	Tūī	Kererū	Magpie	Fantail	Grey warbler	Kingfisher
(a) Bush remnant sites						
Times detected during transect but not 5MBC	15	26	28	3	11	13
Times detected during 5MBC but not transect counts	11	9	10	3	2	4
Detected or not detected during both transect and 5MBCs	118	109	106	138	131	127
(b) Garden sites						
Times detected during snapshot but not 5MBCs	9	0	2	4	3	2
Times detected during 5MBCs but not snapshot counts	0	2	14	6	4	3
Detected or not detected during both snapshot and 5MBCs	45	52	38	44	47	49

Table 3. Mean percent ± SE of counts made up by individuals of each species counted during five-minute bird counts (5MBCs) and transect counts at bush remnant sites (n = 16). P values < 0.05 indicate significant differences between count methods, using Wilcoxon signed-rank tests.

	5MBC (%)	Transect count (%)	P value
Tūī	9.34 ± 1.19	7.33 ± 0.84	0.14
Kererū	4.04 ± 0.70	5.82 ± 0.81	0.03
Magpie	18.86 ± 1.39	19.52 ± 1.15	0.61
Fantail	32.29 ± 1.30	30.92 ± 1.28	0.24
Grey warbler	22.78 ± 1.10	23.24 ± 0.92	0.64
Kingfisher	12.69 ± 1.10	13.17 ± 0.97	0.44

Table 4. Mean percent ± SE of counts made up by individuals each species counted during five-minute bird counts (5MBCs) and snapshot counts at garden sites (n = 6). P values < 0.05 indicate significant differences between count methods, using Wilcoxon signed-rank tests.

	5MBC (%)	Snapshot count (%)	P value
Tūī	28.07 ± 4.78	37.63 ± 4.99	<0.01
Kererū	0.47 ± 0.47	0	n/a*
Magpie	21.36 ± 3.89	13.65 ± 3.87	0.03
Fantail	30.27 ± 3.68	29.76 ± 4.01	0.83
Grey warbler	16.04 ± 2.68	16.30 ± 2.69	0.93
Kingfisher	3.79 ± 1.28	2.66 ± 1.09	0.61

*Not enough data to conduct statistical analyses.

magpies. In Morgan et al. (2006a), however, most of the birds counted were exotic passerines. Native birds, such as kererū and tūī, were poorly represented. Finally, our findings also failed to support anecdotal reports that suggest magpies 'drive everything else before them' (Barrington 1995), and the prediction that the removal of magpies would promote native bird communities in localised areas (Barrington 1996).

Although trapping significantly reduced the magpie populations at our removal sites (Table 1), eradication never occurred and a residual magpie population remained at treatment sites (see Appendices 1 & 2). Reducing pest populations to below threshold abundances has been shown to be important for recovering threatened species. In one study, populations of ship rats and brushtail possums (*Trichosurus vulpecula*) needed to be reduced to very small numbers before nesting rates of North Island kōkako (*Callaeas cinerea wilsoni*) increased (Innes et al. 1999). It is thus possible that magpies, even at very low numbers in an area, may still have serious impacts on other birds. Accordingly, more research is needed to determine if reducing magpie populations to even lower numbers would increase visitation rates by native birds.

It is also possible that the length of our trapping period (6 weeks) was not sufficient for native birds to alter their routines and subsequently visit sites where magpie numbers had been reduced. Our experiment took place during the Austral spring to take advantage of seasonal food sources in bush remnants and private gardens, and the increased visitation rates by birds that exploit these resources before they return to larger forest blocks to breed (Heather & Robertson 1996). We assumed that, unlike territorial magpies, some of the native birds monitored would range over relatively large areas (e.g. tūī; Innes et al. 2005), where they might encounter both our magpie removal and non-removal sites, opting to make more visits to areas with lower magpie numbers. Such an effect could ultimately occur, but may take longer than 6 weeks to be realised. For example, if native birds had encountered aggressive magpies in a given magpie removal area in the past, it may take a long time for them to detect the reduced risk of visiting such sites. Although further research is needed to investigate this hypothesis, we doubt that extending the trapping period would have drastically increased native bird abundance at the removal sites; by the time the experiment finished (October), birds such as tūī and kererū were returning to the forest to breed (Heather & Robertson 1996). Tūī and kererū are relatively long-lived species (Heather & Robertson 1996) and may avoid certain sites over many years if they had been attacked there by a magpie in the past. Therefore, removal of magpies at treatment sites for a number of years may be required before increased visitation rates by native birds are observed.

Individuals of the same species can respond to the same stimuli in markedly different ways. These variations in behaviour have been interpreted as different 'personality' types (Sih et al. 2004; Bell 2007). Research focusing on agonistic behaviour by magpies towards humans has shown that only a small portion of magpie pairs (c. 9%) will actually attack people, and then only under highly specific circumstances (Jones 2002). Individual variation in the rate of aggression by magpies towards other birds, however, is generally poorly understood (but see Morgan et al. 2006a). Accordingly, if this type of behaviour is also only displayed by a very small proportion of magpies, our sample size may have been too small to appropriately represent highly aggressive birds. In any case, current results suggest that anecdotal reports of magpies attacking other birds are 'sensational' events and not common (Morgan et al. 2005, 2006a). Therefore, it may be better to remove magpies from an area only if they are seen frequently attacking other birds, because 'passive' resident magpie pairs that do not attack other birds would exclude any potentially aggressive colonising pairs because magpies defend territories year-round (Brown & Veltman 1987).

Native bird visitation rates to bush remnants and private gardens may be independent of magpie presence, and more closely correlated with the quantity or quality of resources available at a given site, which were not quantified in our study. This was highlighted by the extraordinarily high numbers of tūī recorded at a non-treatment site during the pre-trapping period when several Japanese cherry trees were in full bloom. Tūī numbers then declined considerably at this site as the trees stopped flowering despite no manipulation to the magpie population (see Results). Bush remnants or gardens with the highest resource availability should have the greatest visitation rates by native birds. Therefore, if increased visitations to bush remnants and private gardens by native birds are desired, the resource potential of the site should be increased by planting more fruit- and nectar-bearing trees, rather than by magpie control.

Comparisons between different bird counting methods

Transect counts were marginally better than 5MBCs at detecting most species in bush remnants (Table 2 (a)). However, tūī were detected more often using snapshot counts, and magpies using 5MBCs, at garden sites (Table 2 (b)). Despite these discrepancies, and fundamental differences in how count protocols were executed, the results of the 5MBCs and combined snapshot/transect analyses led to similar conclusions regarding changes in each species' abundance over the duration of the experiment (Table 1). Accordingly, we do not believe that any one of the count methods was vastly superior in the context in which they were applied in this study, and advise managers to choose the most appropriate protocol that suits the question, the target species, and the habitat type in which their study will be conducted.

The 5MBC method is often criticised because the assumption is made that the population index is proportional to the actual number of birds in a given area (Anderson 2001). However, few studies have directly compared 5MBCs with other survey methods. An exception to this is the study by Dawson and Bull (1975), who compared 5MBCs with 'walking counts' (where an observer walked a transect counting every bird seen or heard). In that study, species' relative abundance was lower in 5MBCs compared with walking counts, yet the ranking order of the species were similar between different count methods (Dawson & Bull 1975). This finding is similar to other studies that have compared point-counts (similar to 5MBCs; Ralph et al. 1995) with other transect count protocols (Verner & Ritter 1985; Wilson et al. 2000; but see Dobkin & Rich 1998). Nevertheless, 5MBCs have been shown to detect changes in bird abundance following management events (e.g. mammalian pest control operations) and positively correlate with changes in other population demographic parameters (e.g. increased nest survival; Innes et al. 2004). Therefore, we suggest that wildlife managers need to decide whether they require accurate population density estimates or simply a tool to detect changes in relative abundance when monitoring birds. If the latter, the 5MBC method, designed and executed properly, is an appropriate option.

It is highly likely that detection probability for any given method will vary between the habitats in which they are conducted and the species that inhabit those areas (Greene & Pryde 2012). For example, transects were generally better than point-counts for detecting Nearctic–Neotropical migrants in hardwood and cottonwood (*Populus deltoids*) plantations (Wilson et al. 2000), while point-counts were better at detecting several passerine species in oak–pine-dominated woodlands (Verner & Ritter 1985). Using a variety of different counting methods may be the most appropriate way of conducting bird surveys where the objective of the study is to count a suite of species, and we encourage researchers to consider using multiple count methods when designing future studies. For example, most birds recorded during 5MBCs are heard rather than seen (Dawson & Bull 1975), which makes less vocal species, such as kererū, potentially difficult to detect and consequently under-represented if only this count method is used. Including another count method, such as transects, may improve detection rates as the observer would be more likely to visually encounter cryptic species. In addition, visually identifying birds may help an observer more accurately determine the number of individuals in bird flocks, which is difficult to achieve if only acoustic cues are used. Furthermore, conducting additional bird counting methods may not significantly add to the amount of time that an observer would need to spend on site. 5MBC stations need to be located some distance apart (Dawson & Bull 1975); transects could be conducted between these sites. Alternatively, if multiple 5MBCs are being conducted at a station another survey method, such as a snapshot count, could be done in the interval between 5MBCs. The possible cost to an observer having to spend slightly longer at a site would be offset by the potential increase in accuracy and detection rates.

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