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Magpie interactions with other birds in New Zealand: results from a literature review and public survey

DAI MORGAN
Department of Biological Sciences, University of Waikato, Private Bag 3105, New Zealand
dm30@waikato.ac.nz

JOSEPH R. WAAS
Department of Biological Sciences, University of Waikato, Private Bag 3105, New Zealand

JOHN INNES
Landcare Research, Private Bag 3127, Hamilton, New Zealand

Abstract Accounts of magpie *Gymnorhina tibicen* attacks on birds in New Zealand were collated from literature and a survey of the public, and then summarised to identify the frequency and characteristics of reported attacks on different species. Magpies were reported attacking 45 bird species. Species commonly found in rural habitats (e.g., harrier hawk *Circus approximans*, blackbird *Turdus merula*) where magpies are abundant were attacked most; however, a directly proportional relationship between species abundance in rural habitats and reported attack frequency did not occur. Species consuming similar foods to magpie tended to be attacked more often, probably because these foods are more abundant in rural areas. Attacks on smaller birds (e.g., grey warbler *Gerygone igata*) regularly (66%) resulted in death, but deaths declined as victim weight increased. Non-contact attacks were most common for the largest species (e.g., kereru *Hemiphaga novaeseelandiae*). Non-contact and non-lethal contact attacks occurred throughout the year while attacks resulting in death occurred mainly during the magpie's breeding season (July to November). This study indicates that magpies can attack a wide range of species but fails to determine why (no one explanation satisfies all cases). Limitations of the dataset and future research to control these are discussed.

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INTRODUCTION

The Australian magpie (*Gymnorhina tibicen*) was introduced to the Auckland, Wellington, Canterbury, and Otago regions of New Zealand during the 1860s and 70s in an attempt to help control pest invertebrates in pasture (Oliver 1930; McIlroy 1968). Since then, magpie populations have gradually increased and magpies are now widely distributed throughout North and South Islands up to low alpine levels, with their highest concentrations being in rural areas (Heather & Robertson 1996).

Public perception of magpies is often negative as they are undeniably aggressive and many anecdotal reports of attacks on other animals exist (McCaskill 1945; McIlroy 1968; Paton 1977; Ashton 1986; Barrington 1995, 1996; Cilento & Jones 1999). The possibility that magpies have negative impacts on the abundance and distribution of other birds, especially native New Zealand birds, is of particular concern (Barrington 1995,1996). However, during one study of magpie involving over 2000 hours of observations, only one avian predation event was observed (a magpie killed a goldfinch *Carduelis carduelis* chick; Barrington 1995). Furthermore, aggressive behaviour by magpies may, at least in some cases, promote bird abundance; for example, magpies have been observed harassing predators such as harrier hawks (*Circus approximans*).

Alone, these reports confirm that magpies interact with other species, but they fail to address important issues such as their impact on bird populations. If, however, many anecdotal reports are collated, it becomes possible to identify characteristics of the species targeted most frequently, the context of the attacks, and perhaps, even the reason for the attacks.

Some clues as to why magpies attack other species are available from studies conducted in Australia, where attacks on humans have become such a problem in cities that rangers are often employed to deal specifically with troublesome magpies (Jones & Thomas, 1999). For example, attacks by male birds on humans increase during the breeding period (Jones *et al.* 1980; Jones & Thomas 1999) when increased levels of hormones like testosterone may lower their tolerance to other animals (Jones *et al.* 1980). However, in another

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Australian study, Carrick (1972) found that while territorial behaviour peaked during breeding, magpies defended territories rigorously all year round and that defensive behaviour was not explained wholly by gonadal state as caponised males still actively defended territories. Warne (2001) found that testosterone levels of male magpies aggressive towards humans were not different from those in magpies that did not attack humans. Attacks by female magpies on conspecifics and other animals have also been frequently observed (Veltman 1984; Jones 2002; pers. obs.). Thus, levels of aggression are not solely regulated by changes in gonadal state associated with breeding and territorial defence, leaving the mechanisms of interspecific aggression obscure.

The aim of our paper is to collate reported accounts of magpies attacking other birds from: (a) New Zealand publications and (b) a survey of the general public. These accounts are pooled and analysed to identify: (1) which species of bird were most commonly attacked, (2) whether overlap in diet or habitat requirements (foraging/nest location) might explain the frequency of magpie attacks, (3) if magpies alter attack intensity depending on the size of the victim to minimise their own risk of injury, (4) if the most attacked species are in greater numbers in rural areas (where magpies are most commonly found), and (5) if attacks in New Zealand are more frequent during certain times of the year. We used this information to develop specific testable hypotheses to explain why magpies attack other species of birds in New Zealand.

METHODS

Data collection

Using the keywords "magpie", "black-backed magpie", "white-backed magpie", "Cracticidae" and "Gymnorhina" in the NZ Superindex database (www.knowledge-basket.co.nz/superindex/welcome.html), a search of published accounts of magpies attacking other animals was conducted (1945-2001). The NZ Superindex was used because it is the only database to index the journal of the New Zealand Ornithological Society, *Notornis*, and its predecessor *New Zealand Bird Notes*, as well as other New Zealand based ecological journals (e.g., *New Zealand Journal of Ecology*, *New Zealand Journal of Zoology*). Popular articles, books, theses, Classified Summarised Notes (*Notornis*) and media reports were also consulted. Requests for published accounts of magpies attacking other birds can be made by contacting the first-named author.

The public was also invited to submit their personal observations of magpies attacking other birds. Requests for information (see below) were made through the magazine of the Ornithological Society of New Zealand (*Southern Bird* September 2001), the annual newsletter updating the national magpie control programme (*Quardle Oodle Ardle* October 2001), Radio Pacific (16 February 2002), and major New Zealand newspapers including *The Dominion* (9 February 2002), *Otago Daily Times* (11 February 2002), *The Press* (12 February 2002), and *Waikato Times* (5 March 2002). Information requested from the public included (i) where and when the interaction took place, (ii) the species that were involved, and (iii) what actually happened during the attack. We considered attacks involving magpies that occurred long-ago to be as relevant as attacks that occurred recently; therefore, no limit on the date of interactions was set.

Data management

The relevant information (i.e. i-iii above) was entered into a database for both literature and public sources. Birds were ordered from most- to least-attacked and grouped into three "attack classes" according to the number of times the species was reported as being attacked by magpies (attack class 1 = ≥5 reports, attack class 2 = 2-4 reports, attack class 3 = 1 report). We also classified each report into one of three attack categories: non-contact, non-fatal contact, or kill. Non-contact attacks included magpies swooping at or chasing other birds without touching them. Non-fatal contact attacks included all interactions where physical contact occurred at least once during the encounter but did not result in the death of the target bird. All interactions where the loss of life was confirmed as the result of a magpie attack were classed as kills, including those where magpies were observed eating adult birds or chicks or preying on eggs.

In some instances, the reports sent to us did not include all the information we required. In these cases, we wrote back to the respondent. If the respondent could not provide the missing information (e.g., when an attack occurred), we entered missing values for that part of the analysis. Some published accounts also had information missing. In most of these cases it was not possible to write back to the author due to the age of the report; however, whenever possible attempts were made to gain the required data. Several reports were of magpies carrying away live adults or chicks but it was not possible to establish the final fate of the prey, or observers attempted to stop the magpie from killing the bird. In these instances, we assumed that the victim was killed by the magpie but formed no conclusions on whether consumption of the victim then occurred. Therefore, the proportion of prey listed as "consumed" may be under-estimated in our analysis.

We compared the number of reports for each attack type (non-contact, non-fatal contact, and

kill) for each species between literature (n = 97) and public responses (n = 98) to determine if there were differences in the types of species reported between the two information sources. The only significant difference between the two sources was for non-fatal contact attacks (Wilcoxon's signed ranks test, Z = -2.76, P = 0.006; the public reported less non-fatal contact attacks), however, because there were no significant differences between the other two attack types (Z = -0.47, P = 0.64 [non-contact], Z = -1.53, P = 0.13 [kill]), or when attack types were combined (Z = -1.56, P = 0.12), we pooled all reports for analysis.

To examine "time of year" effects, magpie interactions were each assigned to a month of the year (when known; n = 33). When only the season was known, or the attack was reported to have occurred during the magpie breeding season (n = 12), the middle month for that season was assigned (January, April, July, and September for summer, autumn, winter and spring, respectively; September for magpie breeding season). When a species was reported as being attacked frequently, and at all times of the year (n = 11), an interaction was entered for each month. Likewise, when a species was reported as being attacked many times across the magpie breeding season (July to November; Heather & Robertson 1996) (n = 2), an interaction was recorded for each month during this period.

In some instances, the specific name of a bird was not known (e.g., observers only reported "duck" or "finch"). If, when re-contacted, the respondent could not give a species name, their observation was dropped from the analysis.

Ecological parameters

To investigate whether there were relationships between life history characteristics of the victims and the frequency, or type, of attack, the habitat preference, abundance in rural habitat, dietary preference, weight class and nesting preferences of attacked bird species were examined.

Habitat

We defined 'habitat' as the resources and conditions present in an area that produce occupancy by a species (Hall *et al.* 1997). Habitat types (rural, urban, coastal, native forest, exotic forest, forest edge and alpine; see Appendix 1) were defined broadly as the inclusion of too many categories prevented us from being able to identify general trends in the data set. While some of these categories were labelled on the basis of vegetation associations (e.g., native forest), vegetation type was not the only criterion for defining habitat because areas such as 'urban' or 'rural' often have a range of vegetation associations within them (Hall *et al.* 1997). Each species reported as being attacked by magpies was assigned a value from 0-3 depending on how commonly it occurred in each habitat type (see Appendix 1). No standardised system of quantifying the relative abundance of New Zealand bird species in different habitats currently exists. Therefore, we allocated values by using information on distribution and habitat for each species from contemporary ornithological texts (Marchant & Higgins 1990, 1993; Heather & Robertson 1996; Higgins & Davies 1996; Higgins 1999; Higgins *et al.* 2001). To determine if there was an association between habitat and attack frequency, victim preference within each habitat type was compared with the number of reports of them being attacked by magpies.

Bird occurrence in rural environments

Species occurrence at five-minute bird count sites in rural areas (where magpies occur most commonly) was derived from data supplied courtesy of Auckland Regional Council (ARC), Environment Bay of Plenty (BOP), Environment Waikato (EW), Wellington Regional Council (WRC) and Environment Southland (ES). These Councils participated in a trial co-ordinated by Manaaki Whenua Landcare Research to examine the effect of magpie control on other bird species (Innes *et al.* 2004).

Five-minute bird counts (following Dawson & Bull 1975) were conducted in areas where magpies were common and not controlled (Circle L [ARC], Matahi [BOP], Mangatautari [EW], Waiorongomai [WRC], and Warwick Downs [ES]; Fig. 1) by Landcare Research trained observers. Sample blocks were approximately 900 ha and 35-36 count sites were located in each. Six counts took place at each count site during December 1999 and January 2000, and during November and December 2000. The number of times that each species was observed (seen or heard) in each block was totalled and divided by the number of count stations for that site to provide a mean occurrence/five-minute count. The mean across-block occurrence of each species was then calculated.

We then averaged the mean occurrence of species at count sites for species in each of the three attack classes to determine if victims in attack class 1 (most attacked) were counted more often compared to victims in attack classes 2 or 3 (moderately or least attacked). We also used the five-minute count data to determine if there was a positive correlation between the frequency that victims were attacked and their mean occurrence at count sites.

Diet

Thirteen food categories were used to characterise the diet of all birds attacked by magpies (see Appendix 2). A ranking value (0-3) was assigned to each food type for each bird to characterise

how important that component of the diet was to that species (see Appendix 2). Each rank was derived by interpreting information on the attacked species' diet from contemporary ornithological texts (Marchant & Higgins 1990, 1993; Heather & Robertson 1996; Higgins & Davies 1996; Higgins 1999; Higgins *et al.* 2001). We then compared diet preference with attack frequency to determine if species with particular food preferences were attacked more often, or if the most attacked species had dietary overlap with magpies.

Bird weights
Species were grouped into one of four weight categories (see Appendix 3) in order to determine whether a species' mean weight influenced the number and severity of attacks. Information relating to the mean weight of each species was obtained from Heather & Robertson (1996). We then determined whether the frequency, or the type, of attack (i.e., non-contact, non-fatal contact, kill) differed across the four weight categories.

Nest Type
In order to determine whether birds using magpie-like nesting sites were attacked more often, each species' nesting preference was assigned to one of six categories: above ground in open, above ground in tree hole (or cavity), ground nest in open area, ground nest in wetland, ground nest in burrow (or under cover), or varied nesting habits. All information regarding nest location was sourced from Heather & Robertson (1996). Two species were excluded from this analysis because they normally breed in captivity (canary *Serinus canaria*) or outside New Zealand (cattle egret *Bubulcus ibis*). We then compared nesting preference with attack frequency to determine if species with nesting preferences similar to magpie were attacked more often.

Analysis
The total number of attack reports per species, and species abundance in rural habitats (sighting/five-minute count), were square root transformed as a variance stabilising technique so that standard regression methods could be used.

Linear regressions on the transformed data were used to correlate the number of reported attacks on each species with their habitat and dietary preferences. Only species recorded during the five-minute counts were included in the analysis of attack frequency with respect to occurrence (n = 30). Data from harrier hawks were analysed separately as attacks on this species were much higher than other species, skewing the data set for each measured parameter.

We used a Kruskal-Wallis H test to detect differences in species occurrence from the five-minute counts in rural areas across the three attack classes. When a significant difference ($P < 0.05$) was identified, post-hoc multiple comparisons were conducted to investigate where the main differences occurred (*sensu* Siegel & Castellan 1988).

RESULTS

Magpies were observed to attack harrier hawks 2.6 times more frequently than the next most attacked species (Table 1). All birds that were reported as being attacked by magpies are listed in Table 1 (arranged from species attacked most to those least attacked).

Attack rates with respect to habitat preference
Species that were common or abundant (habitat rank 2 or 3) in rural areas (Appendix 1) were attacked more often than species that were rarely (habitat rank 0 or 1) found in these areas ($r^2 = 0.23$, $df = 43$, $P = 0.001$). All of the species (12/12) attacked most often (attack class 1; Table 1) and 94% (16/17) of species that were attacked at intermediate rates (attack class 2; Table 1) were commonly found or abundant in rural habitats (Fig. 2). Only 38% (6/16) of species attacked at low rates (attack class 3; Table 1) were common or abundant in rural habitats (Fig. 2).

Species commonly found (habitat rank of 2) on forest edges may also have been attacked more often than those rarely found near forest edges (habitat rank of 0 or 1) ($r^2 = 0.11$, $df = 43$, $P = 0.03$, Fig. 2).

Species that were ranked as common or abundant in the other five habitat types were not attacked at higher rates than species that were ranked as rarely occurring there.

Attack rates with respect to occurrence in rural areas
Species occurrence at five-minute count sites varied significantly across the three attack classes ($H = 17.00$, $df = 2$, $P < 0.05$). On average, individuals of species in attack classes 1 and 2 were counted 0.22 (± 0.08 *se*) and 0.27 (± 0.08 *se*) times/five-minute count, a difference that was not statistically significant according to the post hoc comparisons. Birds in attack class 3, however, were only counted 0.03 (± 0.01 *se*) times/five-minute count, a value that was significantly lower than that for attack classes 1 and 2.

Attacks on species in attack class 1 made up 58% of the total reports on all species, however, species from this attack class only made up 35% of birds counted during five-minute bird counts, a variance that was significantly different ($\chi^2 = 16.01$, $df = 1$, $P < 0.05$; Fig. 3). The percentage of total attacks on species in attack class 2 was 32% while these species made up 60% of birds counted in five-minute bird counts, also significantly different ($\chi^2 = 13.07$, $df = 1$,

Table 1 Species attacked by magpies according to literature and a public survey, including the total number of reports per species, attack class (i.e., attack class 1 = ≥5 reports, attack class 2 = 2-4 reports per species, and attack class 3 = 1 report), type of attack (non-contact, non-fatal contact or kill), and the mean frequency at which each species was counted in five-minute bird counts at five locations throughout New Zealand

	Total	Attack class	Attack type			Species occurrence at five-minute count stations
			Non-contact	Non-fatal contact	Kill	
harrier hawk *Circus approximans*	37	1	30	6	1	0.07
blackbird *Turdus merula*	15	1	7	2	6	0.56
song thrush *Turdus philomelos*	14	1	5	3	6	0.48
kereru *Hemiphaga novaeseelandiae*	11	1	8	1	2	0.04
house sparrow *Passer domesticus*	11	1	2	3	6	0.84
white-faced heron *Ardea novaehollandiae*	9	1	4	2	3	0.01
bellbird *Anthornis melanura*	6	1	3	1	2	0.03
skylark *Alanda arvensis*	6	1	1	1	4	0.51
chicken *Gallus gallus domesticus*	5	1	3	1	1	0
kingfisher *Halcyon sancta*	5	1	2	0	3	0.09
pipit *Anthus novaeseelandiae*	5	1	2	1	2	0
tui *Prosthemadera novaseelandiae*	5	1	2	1	2	0.05
black-backed gull *Larus dominicanus*	4	2	2	1	1	0.01
goldfinch *Carduelis carduelis*	4	2	0	1	3	0.83
pheasant *Phasianus colchicus*	4	2	0	1	3	0.03
pukeko *Porphyrio porphyrio*	4	2	2	2	0	0.02
rock pigeon *Columba livia*	4	2	2	2	0	0.01
silvereye *Zosteropus lateralis*	4	2	0	0	4	0.41
starling *Sturnus vulgaris*	4	2	3	0	1	1.03
paradise shelduck *Tadorna variegata*	3	2	2	1	0	0.13
spur-winged plover *Vanellus miles*	3	2	1	1	1	0.09
black shag *Phalacrocorax carbo*	2	2	1	1	0	0
chaffinch *Fringilla coelebs*	2	2	0	1	1	0.6
fantail *Rhipidura fuliginosa*	2	2	0	0	2	0.27
little owl *Athene noctua*	2	2	1	1	0	0
grey warbler *Greygone igata*	2	2	0	0	2	0.36
mallard *Anas platyrhynchos*	2	2	0	1	1	0.01
morepork *Ninox novaeseelandiae*	2	2	1	1	0	0
yellowhammer *Emberiza citrinella*	2	2	0	0	2	0.74
banded dotterel *Charadrius bicinctus*	1	3	0	0	1	0
black-fronted tern *Sterna albostriata*	1	3	0	0	1	0.01
canary *Serinus canaria*	1	3	0	0	1	0
cattle egret *Bubulcus ibis*	1	3	1	0	0	0
Indian myna *Acridothesres tristis*	1	3	1	0	0	0.25
kaka *Nestor meridionalis*	1	3	0	1	0	0
kea *Nestor notabilis*	1	3	1	0	0	0
kokako *Callaeas cinerea*	1	3	1	0	0	0
long-tailed cuckoo *Eudynamys taitensis*	1	3	1	0	0	0
New Zealand dotterel *Charadrius obscurus aquilonius*	1	3	1	0	0	0
New Zealand falcon *Falco novaeseelandiae*	1	3	1	0	0	0
California quail *Callipepla californica*	1	3	0	0	1	0
red-billed gull *Larus novaeseelandiae*	1	3	0	1	0	0
eastern rosella *Platycercus eximius*	1	3	1	0	0	0.16
spotted turtle-dove *Streptopelia chinensis*	1	3	0	0	1	0
tomtit *Petroica macrocephala*	1	3	0	0	1	0

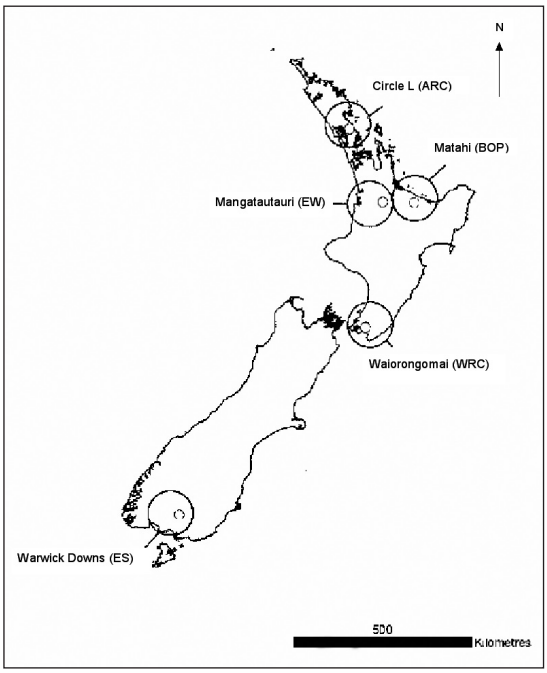

Figure 1 Locations of five-minute count blocks monitored by Regional Councils in New Zealand.

$P < 0.05$; Fig. 3). There was no significant difference between the percentages of total attacks on species in attack class 3 (10%) and the proportion they made up of birds counted during five-minute counts (5%) ($\chi^2 = 3.68$, $df = 1$, $P > 0.05$; Fig. 3). Therefore, species in attack class 1 were reported as being attacked at rates higher than their occurrence would suggest, while species in attack class 2 were attacked at lower rates.

Attack rates with respect to dietary preference

Nine of 12 species (75%) in attack class 1 and 59% of species in attack class 2 commonly or mostly consumed open or pasture invertebrates (Fig. 4). Only 19% (3/16) of species in attack class 3 commonly or mostly consumed this food type (Fig. 4). Species that commonly or mostly consumed pasture invertebrates in their diet (diet rank 2 or 3), were attacked more often than species that rarely or never consumed this food type (diet rank of 0 or 1) ($r^2 = 0.12$, $df = 43$, $P = 0.02$). When only the species that were common or abundant (habitat score of 2 or 3) in rural, forest edge and urban areas ($n = 38$) were included this difference was not apparent ($r^2 = 0.06$, $df = 37$, $P = 0.13$).

No other significant correlations could be identified between reported attack frequency of species and the other food types.

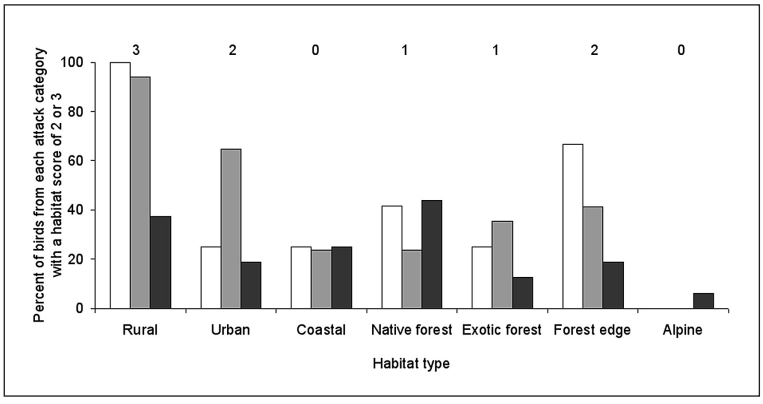

Figure 2 The proportion of species from each attack type that are common or abundant (habitat score of 2 or 3) in each habitat type (numbers above bars represent magpie habitat rank from Appendix 1; open bars denote species in attack class 1, grey bars denote species in attack class 2, black bars denote species in attack class 3).

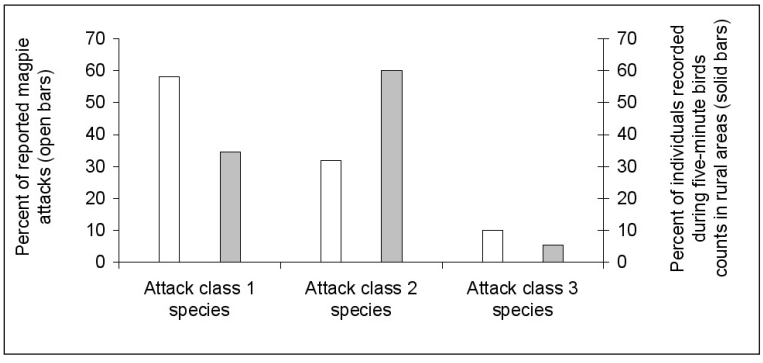

Figure 3 The percentage of birds from each attack class that were counted in five-minute bird counts in rural areas (solid bars) and the percentage of total attacks on birds in each attack class (open bars).

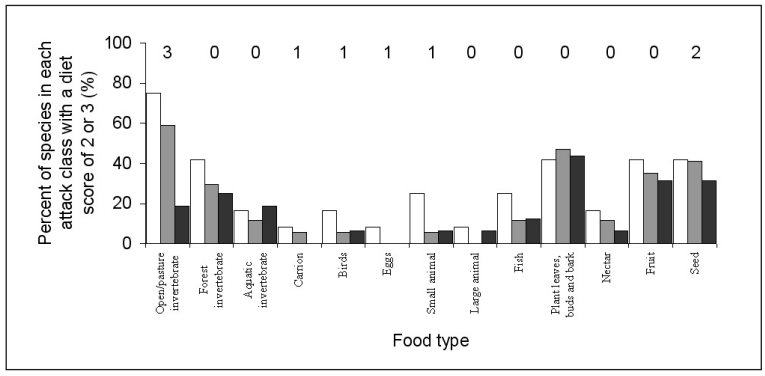

Figure 4 The proportion of the species from each attack category that have each food type as a common or main component (diet score of 2 or 3) of their diet (numbers above bars represent magpie diet rank from Appendix 2; open bars denote species in attack class 1, grey bars denote species in attack class 2, black bars denote species in attack class 3).

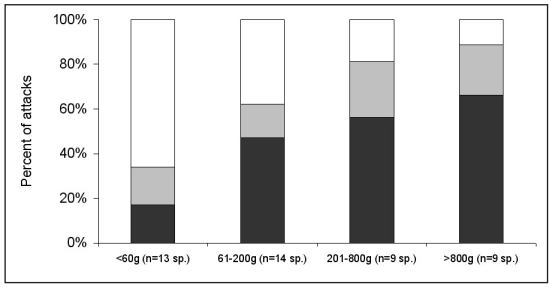

Figure 5 The proportion of different types of attacks (black bars denote non-contact, grey bars denote non-fatal contact, open bars denote kill) by magpie on birds in four different weight categories.

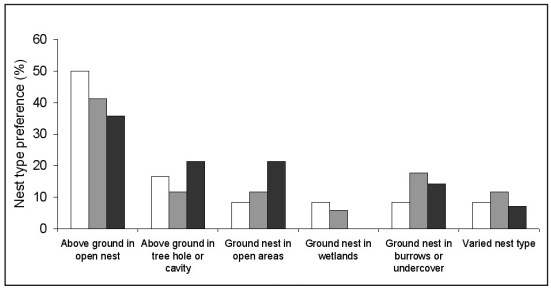

Figure 6 The proportion of birds from each attack category that have a specific type of nest (open bars denote species in attack class 1, grey bars denote species in attack class 2, black bars denote species in attack class 3).

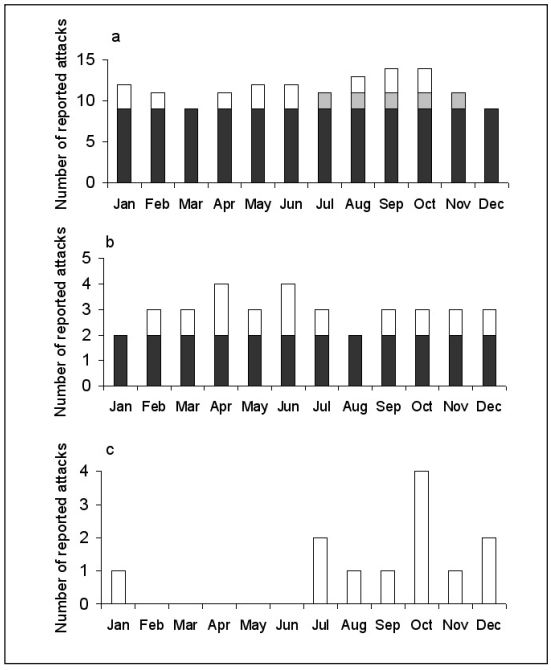

Figure 7 Number of (a) non-contact, (b) non-fatal contact, and (c) kill attacks per month for all attacked species (open bars denote attacks when month was known, grey bars denote attacks reported occurring frequently throughout the magpie breeding season, black bars denote attacks reported as occurring frequently throughout the year).

Effect of weight

The probability of death when magpies attacked a species was associated with the victim's weight. An encounter between magpies and a bird in the lightest weight class (<60g) was more likely to result in death (66% of reports for this weight class) compared to non-contact (17% of reports) or non-fatal contact (17% of reports) (Fig. 5). While the total proportion of non-fatal contact attacks was relatively constant over all weight categories (approximately 12-20%), kills significantly decreased and non-contact attacks significantly increased as the weight of the victim increased ($\chi^2 = 85.76$, $df = 6$, $P < 0.001$) (Fig. 5).

Nest location

Half (6/12) of the species that were attacked the most built open nests above the ground as magpies do (attack class 1), compared to 41% (7/17) and 36% (5/14) of species in the intermediate and least attacked classes, respectively (Fig. 6).

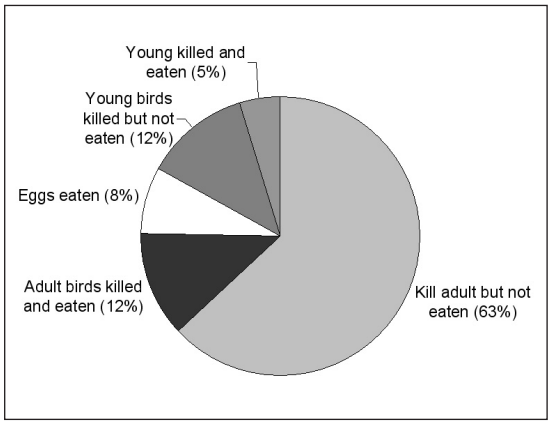

Figure 8 Fates of birds killed by magpies (n = 65).

Timing of attacks

Non-contact and non-fatal contact attacks occurred evenly across the year (Fig. 7). However, reported killings where dates were given (n = 12) occurred mainly during the magpie breeding season (July to November; Heather & Robertson 1996; Fig. 7). Also reported were accounts of eggs or young birds being killed by magpies but no date given (n = 11). Although the month of these incidents could not be extrapolated from the available information, it is likely that most of these attacks occurred during the magpie breeding season.

Consumption of victims by magpie

Magpies were observed preying on eggs on five occasions (8% of kill attacks; Fig. 8). Only a small proportion of attacks where victims were killed (17%) resulted in consumption of adult or young birds by magpies. Most birds that died as a result of being attacked (75%) were subsequently abandoned by the magpie.

Place of attack

The majority of attacks (83%) were witnessed in rural areas (when the place was given; n = 87) with the rest of the interactions occurring in urban areas (9%), at forest edges or clearings surrounded by bush (7%), and coastal sites (1%).

Non-avian targets

Although not specifically investigated in the current study, we obtained a number of reports from the public and from the literature involving magpies harassing species other than birds, including sheep (*Ovis aries*), dogs (*Canis familiaris*), cats (*Felis catus*), hedgehogs (*Erinaceus europaeus*), horses (*Equus* spp.), possums (*Trichosurus vulpecula*), rabbits (*Oryctolagus cuniculus*), humans and inanimate objects such as automobiles and model aeroplanes.

DISCUSSION

Magpies were reported attacking 45 bird species, although one (harrier hawk) was attacked considerably more often than any other. The list of attacked species is virtually a complete list of New Zealand's rural birds, and the species missing (e.g., redpoll (*Carduelis flammea*), greenfinch (*C. chloris*), hedge sparrow (*Prunella modularis*), little shag (*Phalacrocorax melanoleucos*), little black shag (*P. sulcirostris*), tend to be less known to the general public, and so may be less likely to be reported. Perhaps the only well-known absentee is turkey (*Meleagris gallopavo*). The large range of sizes (7-1700 g), preferred habitats (coastal to alpine) and guilds (including aerial insectivores, nectarivores and piscivores) of the targeted birds, combined with the known non-avian targets of magpies (including horses and model aeroplanes), confirm that magpies have a generalised attack regime, at least occasionally attacking many objects that move in the rural landscape.

Limitations of the dataset and analysis

Our collation of published and reported eye-witness accounts of magpie attacks, while describing the span of magpie behaviours, is limited as a database for quantitative exploration because of the unstructured way that observations were obtained.

Possible biases exist in whether an interaction between a bird and a magpie will firstly be observed, and secondly reported. Birds that are highly likely to be observed are probably those that are conspicuous, large, abundant, widespread, or common around farmhouses and other places where observers spend most time. Harriers were reported to be attacked nearly three times as often as the next most reported species (blackbird (*Turdus merula*) and song thrush (*T. philomelos*)), perhaps because they are large and conspicuous and would easily be seen from large distances or moving vehicles. Birds more likely to be reported may include easily recognised or highly valued species. People may be more inclined to report attacks on uncommon native birds such as kereru (*Hemiphaga novaeseelandiae*) and tui (*Prosthemadera novaseelandiae*) because they care for these species and hope that their report will trigger some conservation action. Finally, this study cannot determine what proportion of passing birds are attacked by magpies.

These biases can be overcome only by planning more scientifically structured observations in which trained observers undertake prolonged observations at a site where magpies and other species are common and are likely to interact. We undertook such observations for a year (October 2002-October 2003) at a field site in the western Waikato. We also

examined whether only territorial magpies attacked other species, which would suggest that attacks are linked with territorial defence in some way and will report on this research separately.

The largest response to the public surveys we describe here came from the Wairarapa, Wellington, Canterbury, and Otago regions of New Zealand, south of approximately 45° S. It is possible that some birds locally common or abundant north of 45° S (e.g., Indian myna *Acridothesres tristis*, eastern rosella *Platycercus eximius*, turkey; Heather & Robertson, 1996) are under-represented in the results.

Attributes of attacked bird species

Species with similar habitat preferences to magpies (i.e., predominantly rural birds) were reported to be attacked more frequently than birds typical of other habitats. This is unsurprising, because the majority of reported attacks were witnessed in rural habitats (*cf.* urban, coastal etc.) where magpies themselves are most abundant. Also, magpies would encounter more such birds because those birds are more abundant than others in rural areas. The mean counts of commonly attacked birds (attack classes 1 or 2; ≥ 2 reported attacks) in rural five-minute counts were significantly higher than for rarely attacked species (attack class 3; 1 reported attack). However, within attack classes 1 and 2, there was no evidence that magpies attacked the most abundant species most often (Table 1). Of the 12 most-attacked species (attack class 1; ≥ 5 reported attacks), only the house sparrow (*Passer domesticus*) was among the five most abundant species according to Regional Council counts (Table 1), while the most counted species (starling) was reported as attacked only four times.

After harriers, the most attacked species were middle-sized omnivores or insectivores e.g., blackbird, song thrush, house sparrow, skylark (*Alauda arvensis*), pipit (*Anthus novaeseelandiae*), kingfisher (*Halcyon sancta*), native frugivores and honeyeaters e.g., kereru, tui, bellbird (*Anthornis melanura*), a large insectivore and piscivore (white-faced heron), and a large omnivore (chicken *Gallus gallus domesticus*). Most of these species (and most attacked species overall) have at least some invertebrate intake at some time of the year, and so may be regarded by magpies as competitors for food. The two most attacked passerines (blackbird and song thrush) eat many pasture invertebrates, as magpies do. Magpies are also opportunistic feeders and will consume many other types of food ranging from carrion, eggs, juvenile and adult birds, mice, lizards, frogs, seeds and grass (Vestjens & Carrick 1974; Moeed 1976; Sanders & Maloney 2002), but usually only to supplement their diet when invertebrates are less abundant (Vestjens & Carrick 1974). Therefore, because magpies do occasionally consume these items nearly all birds in rural areas may be regarded as potential competitors. However, aggression towards such a wide array of species is rare as inter-specific aggression is usually between species with very similar resource requirements (Newton 1998). This is because the costs (energetic and risk of injury) of attacking another species are often very high but the benefit (exclusive use of a resource) is also high and generally results in fitness gains for the victor (Nuechterlein & Storer 1985; Newton 1998). The generalised attack pattern including birds that are not major food competitors would suggest that magpies are not highly focused on the main food competitors. Most targeted species (excluding harrier hawks) pose little threat of injury to magpies. Therefore, any benefit, regardless of the size, would be obtained virtually risk free by the attacking magpie and would incur only an energetic cost.

Magpie chasing versus magpie killing

Most (66%) of the birds in the smallest weight-class (< 60 g) attacked by magpies were killed, whereas the proportion of non-contact attacks reported increased significantly as the weight of the victim increased. If smaller birds died more often due to frailty alone (rather than magpies attacking small birds more fiercely), we would expect to see the proportions of non-contact attacks similar for all weight classes; however, this did not occur (Fig. 5). There were more reported non-contact attacks on heavier birds, suggesting that magpies perceived larger birds to be riskier to attack.

Beneficial effects of magpies

While magpie aggression has been thought to have detrimental impacts on the abundance and distribution of some birds (e.g., Barrington 1995, 1996), such aggression may occasionally benefit other birds. For example, some respondents from the survey, and McIlroy (1968), suggested that magpies harassing harriers, a major avian predator (Heather & Robertson 1996), may promote the abundance of some species. Tryjanowski (2001) found that some rural bird species nest closer to raven (*Corvus corax*) roosts because they are known to chase away predators. It is possible that rural birds in New Zealand may gain from associations with magpies as well; the associated cost of occasional attacks by magpies may be out-weighed by the benefits of increased nesting success.

Why magpies attack other birds, mammals, and moving objects

Several non-exclusive hypotheses about why magpies attack birds and other objects can be explored using the results of this analysis:

1. Magpie eggs, chicks or adults are directly threatened by other birds, mammals and objects. This is true only for harriers and falcons, and to a lesser extent for kingfishers and moreporks, and arguably for humans who may shoot magpies. The high rate of magpie attacks on harriers may be substantially due to this threat, since harriers are a major predator at bird nests in rural areas (Morgan *et al. in prep.*), making them a direct threat to breeding magpies. However, the vast majority of reported attacks were against birds that do not threaten magpies, and the attacks occurred year-round, not just when magpies were nesting.
2. Magpies are themselves predators which kill and eat other birds. This is generally untrue. Although magpies occasionally ate small birds, most attacks occurred against birds and mammals which were far too large for them to eat, and two-thirds of adult birds killed by magpies were not eaten; even most young birds that were killed were not eaten (Fig. 8). Magpies did not even come into contact with the birds they chased in about half of the reported attacks (Table 1, Fig. 5), so predation was an unlikely intention.
3. Magpies are defending their invertebrate food supply or their nest site by driving food or nest site competitors away. This may be true as many attacked species are insectivores or seed-eaters and/or nest in open nests in trees. Also, magpies are opportunistic feeders and consume many other types of food when invertebrates are less abundant making nearly all birds potential competitors, if only in a small capacity.
4. Magpies attack others as a consequence of intra-specific territorial behaviour. Nearly all attacks where the victim was killed were observed during the magpie breeding season (July-November). Australian research has shown that magpies become more aggressive during the breeding season (Jones *et al.* 1980; Jones & Thomas 1999). Increased aggression during the breeding season is linked with hormone changes, especially in testosterone which is usually at its highest just prior to egg laying (Wingfield *et al.* 2001). Testosterone levels in magpies in Australia have been shown to increase from relatively low levels prior to breeding to a peak during the egg-laying period and then a decline during chick-rearing (Schmidt *et al.* 1991). Hormonal changes associated with territory defence against other magpie may explain the increased intensity in attacks during this period (Schmidt *et al.* 1991), but not *why* attacks occurred on other species. Also, magpies were observed attacking (non-contact/non-fatal contact) other birds equally at all times of the year (Fig. 7). Furthermore, Australian research has shown that magpies with artificially lowered or naturally lower testosterone levels display similar levels of aggression as those with normal or high concentrations of the hormone (Carrick 1963; Warne 2001).
5. Magpies may chase other birds to signal their "quality" to conspecifics. Inter-specific attacks not intended to kill avian prey may be performed to show mates or potential mates that they are willing to undertake risky behaviour in the future (e.g., warding off predatory species). Therefore, attacks may signal to potential mates that the actor has attributes of a successful breeder; alternatively, conspecific subordinates or neighbours may recognise the actor as a worthy adversary (Arnold 2000). Chasing other birds may also provide the actor with a net energy gain, especially for territorial holders, as the flying time would also double as a signal to neighbouring magpies that the territory is occupied, and the occupants alert.
6. Magpies attack other species because they have evolved in an environment that rewards such behaviour. This may be true as prior to European colonisation of Australia, suitable magpie habitat was limited and a greater proportion of closed woodland and forest existed (Taylor 1997). Therefore, it is likely that magpies evolved in a more competitive environment (both within and across species), and unlike New Zealand, Australia has many native species of predatory hawks, kites, eagles (family: Accipitridae), owls (family: Strigidae), and falcons (family: Falconidae) that prey on birds such as magpies and their eggs and chicks (Hill 1967; Blakers *et al.* 1984). Furthermore, other Artamidae species such as butcherbirds and currawongs, as well as ravens and crows (family: Corvidae) have diet and nesting overlap with magpies and are all noted for being aggressive (Hill 1967; Blakers *et al.* 1984). Clearly, being aggressive would have been an advantage for magpies in an environment with many avian predators and where food and nest sites were limited. In New Zealand where food and nest sites do not appear to be in short supply and there are comparatively few avian predators, being aggressive towards other species would not be as beneficial. Magpies, however, have only been in New Zealand around 120 years and the high rates of aggression may occur simply because they evolved in an Australian environment that rewarded such behaviour.

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Appendices

Appendix 1 Abundance of all birds reported as being attacked by magpies in various habitats. Species are ordered from most to least attacked. Magpies are also listed at bottom of table. (Key: 3 = where largest numbers are found, 2 = commonly found, 1 = reported as occurring, but not common, 0 = very rarely or never found here; rural = developed farmland/hedgerows/wetlands/small settlements, urban = cities/city parks/ towns, coastal = beaches/estuary, native forest = predominantly native forest, exotic forest = predominantly exotic forest, forest edge = edge of forests or small patches of bush/trees [i.e. remnants], alpine = above the tree line).

Habitat type	Rural	Urban	Coastal	Native forest	Exotic forest	Forest edge	Alpine
harrier hawk *Circus approximans*	3	1	0	1	1	2	0
blackbird *Turdus merula*	3	3	0	2	2	2	0
song thrush *Turdus philomelos*	3	3	0	1	2	2	0
kereru *Hemiphaga novaeseelandiae*	2	0	0	3	1	2	0
house sparrow *Passer domesticus*	3	3	1	1	1	2	0
white-faced heron *Ardea novaehollandiae*	3	1	2	0	0	0	0
bellbird *Anthornis melanura*	2	1	1	3	1	2	0
skylark *Alanda arvensis*	3	1	0	0	0	1	0
chicken *Gallus gallus domesticus*	3	0	0	0	0	0	0
kingfisher *Halcyon sancta*	3	1	2	2	2	2	0
pipit *Anthus novaeseelandiae*	3	1	2	0	0	1	1
tui *Prosthemadera novaseelandiae*	2	1	1	3	1	2	0
black-backed gull *Larus dominicanus*	2	1	3	0	0	0	0
goldfinch *Carduelis carduelis*	3	3	0	0	0	2	0
pheasant *Phasianus colchicus*	3	0	0	0	2	1	0
pukeko *Porphyrio porphyrio*	3	2	1	0	0	1	0
rock pigeon *Columba livia*	1	3	1	0	0	0	0
silvereye *Zosteropus lateralis*	2	3	0	3	3	2	0
starling *Sturnus vulgaris*	3	2	1	1	1	2	0
paradise shelduck *Tadorna variegata*	3	0	1	0	0	0	0
spur-winged plover *Vanellus miles*	3	2	2	1	1	1	0
black shag *Phalacrocorax carbo*	2	1	3	0	0	0	0
chaffinch *Fringilla coelebs*	3	2	0	1	2	1	0
fantail *Rhipidura fuliginosa*	2	2	0	3	2	2	0
little owl *Athene noctua*	3	2	0	0	0	2	0
grey warbler *Greygone igata*	2	1	0	3	2	2	0
mallard *Anas platyrhynchos*	3	3	2	0	0	1	0
morepork *Ninox novaeseelandiae*	2	1	0	3	3	2	0
yellowhammer *Emberiza citrinella*	3	2	0	0	0	1	0
banded dotterel *Charadrius bicinctus*	2	0	3	0	0	0	0
black-fronted tern *Sterna albostriata*	1	0	3	0	0	0	0
canary *Serinus canaria*	0	0	0	0	0	0	0
cattle egret *Bubulcus ibis*	3	0	1	0	0	0	0
Indian myna *Acridothesres tristis*	3	3	1	1	1	1	0
kaka *Nestor meridionalis*	0	0	0	3	1	1	0
kea *Nestor notabilis*	0	0	0	3	0	1	3
kokako *Callaeas cinerea*	0	0	0	3	0	1	0
long-tailed cuckoo *Eudynamys taitensis*	0	0	0	3	1	1	0
New Zealand dotterel *Charadrius obscurus aquilonius*	0	0	3	0	0	0	0
New Zealand falcon *Falco novaeseelandiae*	1	1	1	3	1	2	1
California quail *Callipepla californica*	3	0	0	0	2	1	0
red-billed gull *Larus novaeseelandiae*	2	2	3	0	0	0	0
eastern rosella *Platycercus eximius*	3	1	0	2	2	2	0
spotted turtle-dove *Streptopelia chinensis*	1	3	0	0	0	0	0
tomtit *Petroica macrocephala*	1	1	0	3	1	2	0
magpie *Gymnorhina tibicen*	3	2	0	1	1	2	0

Appendix 2 Diet of birds reported as being attacked by magpies. Species are ordered from most to least attacked. Magpies are also listed at the bottom of table. (Key: 3 = main component of diet, 2 = commonly consumed, 1 = known to consume, but not common, 0 = not known to consume; "aquatic invertebrates" includes both freshwater and marine invertebrates, "small mammal and reptile" include mammals and reptiles ≤2kg, "large mammal" includes mammals >2kg).

Food type	Open/pasture invertebrate	Forest invertebrate	Aquatic invertebrate	Carrion	Birds	Eggs	Small mammal and reptile	Large mammal	Fish	Plant leaves, buds, bark	Fruit	Nectar	Seeds
harrier hawk *Circus approximans*	2	0	0	2	3	2	3	3	2	0	0	0	0
blackbird *Turdus merula*	3	2	0	0	0	0	0	0	0	3	3	0	3
song thrush *Turdus philomelos*	3	2	0	0	0	0	0	0	0	3	3	0	3
kereru *Hemiphaga novaeseelandiae*	2	0	0	0	0	0	0	0	0	1	1	1	3
house sparrow *Passer domesticus*	0	0	0	0	0	0	0	0	0	2	3	0	0
white-faced heron *Ardea novaehollandiae*	3	0	3	0	0	0	2	0	2	0	0	0	0
bellbird *Anthornis melanura*	0	2	0	0	0	0	0	0	0	2	2	3	0
skylark *Alanda arvensis*	2	0	0	0	0	0	0	0	0	0	0	0	3
chicken *Gallus gallus domesticus*	2	0	0	0	0	0	0	0	0	1	0	0	3
kingfisher *Halcyon sancta*	3	3	2	0	2	0	2	0	2	0	0	0	0
pipit *Anthus novaeseelandiae*	3	0	0	0	0	0	0	0	0	0	0	0	1
tui *Prosthemadera novaseelandiae*	0	2	0	0	0	0	0	0	0	2	2	3	0
black-backed gull *Larus dominicanus*	2	0	2	2	0	0	0	1	2	0	0	0	0
goldfinch *Carduelis carduelis*	2	0	0	0	0	0	0	0	0	0	0	0	3
pheasant *Phasianus colchicus*	2	0	0	0	0	0	0	0	0	3	2	0	2
pukeko *Porphyrio porphyrio*	2	0	1	0	1	1	1	0	1	3	1	0	1
rock pigeon *Columba livia*	0	0	0	0	0	0	0	0	0	1	0	0	3
silvereye *Zosteropus lateralis*	0	3	0	0	0	0	0	0	0	2	3	3	0
starling *Sturnus vulgaris*	3	0	0	0	0	0	0	0	0	3	3	2	0
paradise shelduck *Tadorna variegata*	1	0	1	0	0	0	0	0	0	3	1	0	2
spur-winged plover *Vanellus miles*	3	0	1	0	0	0	1	0	0	1	0	0	1
black shag *Phalacrocorax carbo*	0	0	0	0	0	0	0	0	3	0	0	0	0
chaffinch *Fringilla coelebs*	2	2	0	0	0	0	0	0	0	3	2	0	3
fantail *Rhipidura fuliginosa*	1	3	0	0	0	0	0	0	0	2	2	0	0
little owl *Athene noctua*	3	0	0	0	1	0	1	1	0	0	0	0	0
grey warbler *Greygone igata*	0	3	0	0	0	0	0	0	0	1	1	0	0
mallard *Anas platyrhynchos*	2	0	2	0	0	0	0	0	0	3	3	0	3
morepork *Ninox novaeseelandiae*	1	3	0	0	2	0	2	0	0	0	0	0	0
yellowhammer *Emberiza citrinella*	2	0	0	0	0	0	0	0	0	0	0	0	3
banded dotterel *Charadrius bicinctus*	2	0	3	0	0	0	0	0	0	0	1	0	0
black-fronted tern *Sterna albostriata*	1	0	3	0	0	0	0	0	2	0	0	0	0
canary *Serinus canaria*	0	0	0	0	0	0	0	0	0	0	0	0	3
cattle egret *Bubulcus ibis*	3	0	0	0	0	0	1	0	0	0	0	0	0
Indian myna *Acridothesres tristis*	3	0	0	0	1	1	1	0	0	3	3	0	0
kaka *Nestor meridionalis*	0	3	0	0	0	0	0	0	0	2	3	3	3
kea *Nestor notabilis*	0	0	0	1	0	0	0	0	0	3	3	0	2
kokako *Callaeas cinerea*	0	2	0	0	0	0	0	0	0	3	3	0	0
long-tailed cuckoo *Eudynamys taitensis*	0	3	0	0	1	1	1	0	0	0	0	1	0
New Zealand dotterel *Charadrius obscurus aquilonius*	0	0	3	0	0	0	0	0	1	0	0	0	0
New Zealand falcon *Falco novaeseelandiae*	0	0	0	0	3	0	3	3	0	0	0	0	0
California quail *Callipepla californica*	1	0	0	0	0	0	0	0	0	2	0	0	3
red-billed gull *Larus novaeseelandiae*	1	0	0	1	0	1	0	0	3	0	0	0	0
eastern rosella *Platycercus eximius*	1	0	0	0	0	0	0	0	0	3	3	0	3
spotted turtle-dove *Streptopelia chinensis*	1	0	0	0	0	0	0	0	0	0	0	0	0
tomtit *Petroica macrocephala*	0	3	0	0	0	0	0	0	0	2	0	0	0
magpie *Gymnorhina tibicen*	3	0	0	1	1	1	1	0	0	0	0	0	2

Appendix 3 Weight categories of all birds reported as being attacked by magpies.

<60g	60-200g	201-800g	>800g
banded dotterel *Charadrius bicinctus*	blackbird *Turdus merula*	cattle egret *Bubulcus ibis*	black shag *Phalacrocorax carbo*
bellbird *Anthornis melanura*	black-fronted tern *Sterna albostriata*	kaka *Nestor meridionalis*	black-backed gull *Larus dominicanus*
canary *Serinus canaria*	California quail *Callipepla californica*	kereru *Hemiphaga novaeseelandiae*	chicken *Gallus gallus domesticus*
chaffinch *Fringilla coelebs*	eastern rosella *Platycercus eximius*	kokako *Callaeas cinerea*	harrier hawk *Circus approximans*
fantail *Rhipidura fuliginosa*	Indian myna *Acridotheres tristis*	New Zealand falcon *Falco novaeseelandiae*	kea *Nestor notabilis*
goldfinch *Carduelis carduelis*	kingfisher *Halcyon sancta*	red-billed gull *Larus novaeseelandiae*	mallard *Anas platyrhynchos*
grey warbler *Gerygone igata*	little owl *Athene noctua*	rock pigeon *Columba livia*	paradise shelduck *Tadorna variegata*
house sparrow *Passer domesticus*	long-tailed cuckoo *Eudynamys taitensis*	spur-winged plover *Vanellus miles*	phesant *Phasianus colchicus*
pipit *Anthus novaeseelandiae*	morepork *Ninox novaeseelandiae*	white-faced heron *Ardea novaehollandiae*	pukeko *Porphyrio porphyrio*
silvereye *Zosterops lateralis*	New Zealand dotterel *Charadrius obscurus aquilonius*		
skylark *Alauda arvensis*	song thrush *Turdus philomelos*		
tomtit *Petroica macrocephala*	spotted turtle-dove *Streptopelia chinensis*		
yellowhammer *Emberiza citrinella*	starling *Sturnus vulgaris*		
	tui *Prosthemadera novaseelandiae*		